MSCBOT-603

M.Sc. III Semester

PLANT RESOURCE UTILIZATION AND CONSERVATION

DEPARTMENT OF BOTANY
SCHOOL OF SCIENCES
UTTARAKHAND OPEN UNIVERSITY

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1.1 OBJECTIVES

This unit will help you to understand the origin, introduction and domestication of cultivated plants. This unit also describes in detail that how an individual plant species introduce to new region and acclimatized. The main objectives of this unit are:

- To know about the domestication and introduction of plants.
- To know the origin of cultivated plants
- To know about Vavilov's centers of origin

1.2 INTRODUCTION

The food is an essential requirement of human beings. The prehistoric humans primarily got their food from the wild edible plants but since the time passed, they started to cultivate the wild plants. The traditions of those prehistoric humans take very prominent part in the origin of cultivation of plants. The domestication of plants is the starting step in the direction of a full-fledged agricultural economy. A plant is refers to as domestic when its natural characteristics got improved too much therefore it is hard to grow and reproduce those plant without human participation. It is thought the domestication is the co-evolutionary outcome of the symbiotic relationship between humans and the plants because plants and human behaviours evolve to suit one another. The humans started harvesting of plants selectively based on some precise characteristics of plants like taste, size, colour and many more. They stored and utilize the seeds of those specific plants for further cultivation.

It is believed that most of the plant were cultivated first during historical times and consequently have exceptionally poor evidence. The paleontological data is entirely unavailable for cultivated plants and archaeological information is fragmented and very poor. In the beginning of 19^{th} century the origin of majority of the cultivated plants were unknown. No species was common to the tropical regions of the two hemispheres before cultivation. In brief, the original distribution of the cultivate species were very much uneven. There was no proper proportion in the number of plants cultivate and their needs for human.

Some ancient Roman and Greek naturalists like Theophrastus, Elder, and Galen Pliny laid down systematic groundwork of wild plant domestication. Alexander von Humboldt also considered the origin of useful plants is a big secret as well. Finally, Darwin's evolutionary theory recommended that origin of cultivated plants take place through natural selection and repetitive hybridization.

So, in this chapter we will discuss about the domestication and introduction of plants, origin of cultivated plants in detail.

1.3 INTRODUCTION AND DOMESTICATION OF PLANTS

What is introduction and domestication of plants?

The human beings received their nutrition from others (plants and animals), therefore, they are called heteroptops in nutrition. The present day humans are evolved from herbivorous ancestors but in a while about two million years ago (viz., early Palaeolithic man), they started using hunting through weapons made by stone. Later on they began to eat roots, tubers and fruits of wild plants too. Much later, man started cultivating plants and raising animals and started a settled life. Initially their establishments have been primarily located in the river valleys and plains near river banks where plenty of water and fertile soil was accessible. By getting all these favorable conditions, it was easy to cultivate crops, resulted plentiful crop production and they became self-sufficient.

It is believe that agriculture have been originated somewhere in the well irrigated highlands of the Indus, Euphrates and Nile and Tigris rivers nearly 7000-13000 years ago. A few other prehistoric sites like Tehuacan valley in modern Mexico and banks of Yellow river in modern China are also the evidences of ancient agricultural activities. Apart from this, the agriculture has begun separately in various parts of the world. So, do you ever think that how a regional cultivated crop becomes cosmopolitan in its distribution? It could become possible only due to the “plant introduction” of a particular region to the other region. Let’s make it easy to understand this concept with this example. The cultivation is called deliberately growing a plant. Foremost, those individual plants were brought into cultivation that grow fast and produce crop rapidly within a season which include the present day cereals. Cereals were originally weeds that grew in mountain areas of Asia, Africa, Europe, North and South America but now they are being cultivated in all other parts of the world due to the plant introduction. So, the plant introduction is a progression of introducing plants (a genotype or a group of genotypes) from their own environment to a new environment. This process may include new varieties of crop or the wild relatives of crop species or totally a new crop species for the area. Introduction may be classified into two categories:

(a) Primary Introduction: When the introduced variety is well suitable to new environment afterward it released, devoid of any modification of genotype for commercial production is called primary introduction. Some examples of primary introduction are; dwarf wheat varieties like Lerma roja, Sonora-64, and dwarf rice varieties like ‘IR-8’ and Taichung Native 1.

(b) Secondary Introduction: When the introduced variety is subjected to the selection or used in hybridization programme with local varieties having some new characters to obtain the superior varieties called secondary introduction. For example, the varieties like ‘Kalyan Sona’ and Sonalika of wheat have been selected from material introduced from CIMMYT, Mexico.

The progression of plant introduction is the thriving observance of two imperative aspects, viz.

(i) Domestication: It is a method of bringing of wild plants under cultivation by making them appropriately modified for new environment. In other words, we can say that it is the practice in which wild species have been evolved into crop plants using artificial selection of some characters. The plant domestication involves an early hybridization event followed by selective breeding. With the help of this technique now the cultivars are able to cultivate plant based on some selectively and specific characteristics like taste of the fruits, size of the flowers, colour of the flowers and fruits and so on. The domestication of plants is the starting step in the direction of a full-fledged agricultural economy.

Domestication is the reflection of co-evolution where both the components (plants and humans) developing a symbiotic relationship because human and plant behavior evolve to suit one another. The process of domestication of wild edibles and introduction of plants has been going on since the prehistorical time. Some important crops of human use and their domestication information are given below (Table 1.1):

Table 1.1: List of domestication of some important plants

Domestication time	Plant name	Domesticated at
9000 BC	Fig tree	Near East
	Rice	East Asia
8500 BC	Barley, Einkorn wheat, Emmer wheat	Near East
	Chick pea	Anatolia
8000 BC	Bottle gourd	Asia
	Potato	Andes mountain
	Squash	Central America
7000 BC	Maize	Central America
6000 BC	Broomcorn millet	East Asia
	Bread wheat	Near East
	Cassava	South America
5000 BC	Avacado	Central America
	Cotton	Southwest Asia
4000 BC	Chilli Peppers	South America
	Water melon, Olives	Near East
	Cotton	Peru
3500 BC	Pomegranate	Iran
	Hemp	East Asia
3000 BC	Cotton	Meso America
	Cocoa	South America

	Squash	North America
2600 BC	Sunflower	Central America
2500 BC	Sweet potato	Peru
2400 BC	March Elder	North America
2000 BC	Sorghum	Africa
	Sunflower	North America
1800 BC	Pearl millet	Africa
1600 BC	Chocolate	Mexico
1500 BC	Chenopodium	North America
1st century BC	Egg Plant	Asia
14th century AD	Vanilla	Central America

(ii) Acclimatization: When an improved variety from distant or neighbouring area is introduced at a new area, normally it fails to express its phenotypic expression in the same manner as its native place. But later on, the growth of new plant variety accelerates and furnishes optimal phenotypic characters. In other words, now the variety becomes acclimatized to their new environment. Sometimes, the performance of a variety improves with a number of generations grown when introduce to a new environment. So, acclimatization is the capability of a plant variety to become adapted to a new edaphic and climatic condition. The process of acclimatization leads to increase the frequency of most adapted genotypes which depends on three factors:

(a) Breeding system: Breeding systems referring in plants is simply called as "Who mates with whom". It is an essential aspect which determines the homozygosity, patterns of genetic diversity and genome evolution in plants. It can divide into two types; (i) *Pure breeding:* Breeding between pure breeds where the ancestors of both mating type have been members of a recognized breed and (ii) *Cross breeding:* Breeding where status of only one parent is known or breeding between two different breeds, varieties, or populations.

(b) Genetic variation: Genetic variation or diversity is called as the diversity exists within different genotypes of the same species. It is required in natural selection where the organisms with environmentally preferred traits are improved which are very much competent to adapt the environmental conditions and transfer their genes to next progeny.

(c) Duration of the crop: The time duration from establishment to harvesting a crop is known as duration of the crop. Its timing may differ a little depending on the growing circumstances especially water availability and solar radiation.

1.3.1 Purpose of Plant Introduction and Domestication

(i) For germplasm conservation: The dissemination of high yielding varieties is one of the many reasons of a threat to old varieties to abolish from an area. Here, germplasm collection as well as conservation helps to maintain the pure line, cultivars, mutants, clones etc from as many sources as possible.

(ii) Use in agriculture, forestry and industry: New varieties of plants or crops which are high quality and better production introduced from various places for use as fiber, food, medicinal, timber etc as well as the breeding material for hybridisation work.

(ii) For aesthetic interest: Various ornamental plants are introduced for beautification and for aesthetic value.

(iv) For studying origin and distribution: The distribution of crop plants and their various forms in different parts of the world gives an idea of their origin and evolution.

1.3.2 Procedure of Plant Introduction

Plant introduction procedure consists of following steps:

(i) Ways of Procurement of Plants or Germplasm: Commandeer for introduction of new varieties crop or plant should be submitted to National Bureau of Plant Genetic Resources (NBPGR) within the country or to International Bureau of Plant Genetic Resources (IBPGR). One may get the plant specimen on an exchange basis from friendly countries either directly or through Food and Agriculture Organization (FAO) or the specimen can also be purchased or obtained as free gift from individuals or organizations.

(ii) Packaging and Dispatch: Any part of the plant which is utilized for the propagation of that species is called a propagule. Based upon the type of propagule, it gets cleaned from other weed-seeds and contaminants and treated with fungicides, packed carefully and dispatched so that it can reach the intention in viable condition. The propagule may be tubers, bulbs, buds, seeds, seedlings, root cuttings, suckers, stolons runners etc depending upon the plant species.

(iii) Entry and Plant Quarantine: On receiving of the specimen the entry inventory, examination and checking is done by the nation for other contaminants and the presence of diseases, nematodes, insect etc. The specimen first treated with fungicides, nematicides, insecticides, and then released to the user. The general purpose of all this ‘regulatory and quarantine’ procedures is to prevent diseases and pests from entering into the country as well as to check spreading further.

(iv) Cataloguing: Subsequent to quarantine, the introduced specimen is given a number concerning place of origin, variety, species, and the data are recorded. The plant materials are classified into three groups:

1. Exotic collection – prefix ‘EC’
2. Indigenous collection – designated as TC’
3. Indigenous wild collection – marked as TW’.

(v) Evaluation: To evaluate the potential of new introductions, their performance at different substations are evaluated as well as resistance to diseases and pests are evaluated under different environments.

(vi) Multiplication and Distribution: The capable newly introduced species is propagated and then released as varieties after required examinations.

1.3.3 Agencies associated to Plant Introduction in India

The central plant introduction agency in India is National Bureau of Plant Genetic Resources (NBPGR), which has its headquarters at New Delhi, but has substations for testing the plant materials. NBPGR has the gene bank for long term storage and future use; it helps to assess the introduced plant material, coordinates the work of other agencies and imparts training in plant collection, introduction and maintenance in India. The Substations under NBPGR are:

(i) Shimla: It represents the temperate zone of approx. 2300 m above sea level, place for germplasm collection in northern hills, station for acclimatization of material introduced from temperate zone and high altitude.

(ii) Jodhpur: Exclusively meant for exploring and acclimatizing plant material for arid zone, this is under Central Arid Zone Research Institute.

(iii) Amravati: This substation carries out acclimatization and multiplication of introduced material for central zone of India.

(iv) Kanya Kumari: It represents the tropical zone situated at South India.

(v) Shillong: This centre has been created for collection of germplasm from North-East India.

Other agencies engaged for this purpose are:

(i) Forest Research Institute (FRI): It situated at Dehradun, Uttarakhand**.** The plant introduction organization set up at the institute at looks after introduction, acclimatization, conservation and testing of forest trees.

(ii) Botanical Survey of India (BSI): It is located in Kolkata, West Bangal. This body is meant for introduction of medicinal plants and also plants for botanical importance.

(iii) Different **Central Research Institutes** as well as **Agricultural Universities** play the role for collection, introduction and maintenance of germplasm of crop plants.

1.3.4 Merits and Demerits of Plant Introduction:

(A) Merits:

i. Introduction provides completely new crop plants to a place.
ii. Better yielding varieties may be originated directly or after selection or hybridisation.
iii. Introduction is the most economical and quick method of crop improvement when introduced material can be used directly.
iv. Germplasm collection, maintenance and protection of genetic variability are possible through the ways of introduction and exploration.

v. Introduction of some varieties to newer areas may protect them from some diseases.

(B) Demerits:

i. **Some disadvantages or demerits coupled with plant introduction are prologue of some transmissible diseases, pests and weeds.**

ii. Some weeds like *Lantana*, *Argemone*, *Eichhornia*, etc have also been introduced from other countries with the introduction of crop plants.

iii. Some diseases like flat smut of wheat, late blight of potato, coffee rust, bunchy top of banana etc are have been introduced in India along with introduction of plant materials.

iv. Many insect pests like potato tuber moth, woolly aphis of apple, fluted scale of citrus were introduced in India along with plant introduction.

However, in most of the cases, the introduction of diseases, pests, insect and weeds occurred during a phase when quarantine was almost non-existent.

1.3.5 Achievements of Plant Introduction

The course of introduction from the ancient times assists the entire world to achieve newer crop species to new places as well as the new varieties of crop plants. Some important achievements are:

(A) New Crop Species: A number of crops have been introduced in India from outside which ar not native of India. Many cereal, fruit, oil yielding and many more economical utilized crops like maize, potato, groundnut, chillies, tea, coffee, rubber, guava, grape, pineapple etc are now cultivated in India only by introduction of all these species to India. Many ornamentals plants like Gulmohor, Phlox, Salvia, Aster are also introduced to India.

(B) New Crop Varieties:

(a) Selection of desirable varieties: A lot of varieties have been developed after selecting from introduced varieties. E.g., Sonalika and Kafyan Sona were selected after introduction of Mexican varieties.

(b) Direct multiplication and released as new varieties: The very useful and high yield dwarf varieties of rice (e.g., TN-1, IR-8) and wheat (e.g., Sonora 64, Lerma Rojo) are introduced in India. There are many more examples of direct release of varieties in other crop plants like soya-bean, oat, tomato, onion, cauliflower etc.

(c) Introduced varieties as donor in hybridization programme: Sometimes the introduced varieties have better-quality in comparison to the already existing varieties. This may be used as donor for disease, pest and stress resistance for plant type and quality characters in hybridization. In case of rice, the dwarfing gene from TN-1 or IR-8 have been used for developing, other dwarf rice varieties in rice. All the sugarcane varieties have been derived from introduced noble cane variety of *Saccharum officinarum*.

(d) Mutation breeding: Sometime**,** if the introduced variety is lacking a few characters but is agronomically superior may be treated with mutagen to resolve the deficiency or incompetency. For example, a wheat variety Sonora-64 introduced with red colour grains did not take too much attention of the farmers; therefore, the new mutagenic variety produced called Sharbati Sonora with amber colour grains by the Gamma- ray treatment by M.S. Swaminathan.

1.4 AGRICULTURAL ORIGINS

Evidence for plant cultivation and domestication comes from a variety of sources including:

- Carbonized remains formed by high temperature 'baking' under low oxygen.
- Parched plant remains produced under extreme dry conditions.
- Impregnations of metal oxides.
- Fecal remains.
- Mineralization where cell cavities are replaced by minerals such as silica (phytoliths).
- Impressions pressed into pottery and bricks.
- Plant material sunk in peat bogs or mud under anaerobic conditions.

In these deposits, domestication is considered to be signified by substantial increases in the size of seeds, dramatic reductions in seed or fruit coat thickness and the apparent loss of dispersal organs**.** These confirmations are often complemented by the human artifacts which offer traces about diet, such as grinding wheels and sickles. Soil from prehistoric settlements is sometimes passed through screens to obtain small objects, but this technique often allows valuable material such as seeds to be lost.

The transformation of human from hunter to farmer is a gradual process which took thousands of years. The early documentation of this has been recorded in the excavations in the Tehuacán Valley of Mexico where excavates 12 sites and uncovered 12,000 years of agricultural history in the area. Primarily, humans who got their food from small animals and wild plants now collect plant products in a set round of annual activities. About 9000 years ago, it became more difficult and humans began to relocate more of their energy to collections of wild plant like avocados, chili, peppers squash etc. They dispersed into small forage groups during the unfavorable seasons while came together during the abundant season. They tried to begin the produced wild plants through the periodic farming, however, the effort was negligible. Over the next 5000 years, the humans of the Tehuacán Valley slowly enhanced the utilization of the cultivated vegetation, such that, by 7000 BP, about 10% of their diet came from cultivated plants. They were outside the native areas of domestication, but by this time a large group of potentially introduced crops were growing, including maize, amaranth, beans, squash, and peppers. As the time precede, humans continued to put more and more effort in cultivation. Around 3000 BP, a large proportion of their diet came from cultivated sources. They also cultivated the cotton plants. In animal kingdom the records indicated that the dog has domesticated about 5000 years ago and Turkeys about 2000 years ago. Parallel verification of evolutions from hunters to farmers can be established at copious places across the Near East. One such site is Jericho in the Jordan Valley, where a continuous record of 9000 years of habitation was left as people built new mud huts on top of others as they deteriorated over time. In the earliest period, the settlement consisted of Natufians, who were primarily hunters of gazelles and foxes and who tended a few cereals but had no domestic animals. About 9000 years ago, they began to raise cereals in earnest, and there is the first confirmation that sheep and goats were being domesticated. A similar long-term record of successive settlement is recorded at Catalhöyük, Turkey, where people were initially foragers who raised a few cereals on the side, but by 10,000 BP had domesticated cattle and were large-scale farmers.

Agriculture arose about 12,000 years ago separately at many locations across the world. Vavilov (1926, 1949–1950) initially recognized 8 centres of domestication, mainly based upon the outlines of crop diversity. These were customized by Harlan in 1967 that are based on the native range of crop progenitors along with the combination of many archaeological confirmations. Harlan identified 3 comparatively small geographical areas, which are called centres, and another three rather diffuse regions, which are called noncentres (Fig 1.1). According to him these centres were most likely self-governing but the non-centres may have had few contacts with neighboring ones. The three centres were the: (i) Near East (parts of Jordan, Turkey, Syria, Iraq and Iran), (ii) Mesoamerica (Central America & Mexico) and (iii) North China. He considered Africa, South-East Asia and South America to be non-centres. Recently, eastern North America has also been added as a centre of crop origin.

Fig. 1.1: Earliest places where agriculture began; A1- Near East centre; A2- African non-centre; B1- North Chinese centre; B2- South East Asian and south Pacific non-centre; C1-Mesoamerican centre; C2-South American non- centre; D-Eastern North American centre (Figure modified from Harlan, 1967)

The sufficient evidences have specified that human started farming in the hills above the Tigris river on the western edge (now Iran). A lot of primeval agricultural places have been positioned in this region. Among the first crops domesticated in this region were einkorn and emmer wheat, pea, lentil chickpea, barley and flax. Sheep and goats were the first domesticants animal.

Agriculture began at the early age in the forest margins of Ethiopia, West Africa, and along a transcontinental band through the savannah as well. Ethiopia has provided the most primitive confirmation (6th millennium BP) of African farming but the other origins are most likely just as old. People in the Sahel domesticated pearl millet, sorghum, guinea-fowl and African rice. West Africans were cultivated cowpea, African yams, and the oil-palm. Ethiopians domesticated finger millet, coffee and teff. Data on China and Asia are still rising, but they were evidently primitive regions of animal and plant domestication. The Wei and Yellow river basins in the north China and the Yangtze valley in the south China also illustrate proof of agriculture about 8000 BP. They started domestication of plants like rice millets; soybean etc and pigs as animal were the early Chinese domesticants. South-East Asia is the biggest dilemma due to its humid and hot weather surroundings lead to rapid degradation of food resources, however, there is evidence that farming was practiced by 8000 to 10,000 BP in New Guinea and Thailand. Sugar cane and banana were first domesticated in South-East Asia.

Louis Pierre de Candolle, a Swiss botanist, worked on phytogeography and published his work in 1883 entitled "Origin of cultivated plants" which sustains the available prehistoric literatures and ancient ethnological studies. His work documented the history of 247 species of cultivate plants and consists the ancestral forms of regions of domestication. According to de Candolle, cultivated plants have originated for a while in the distant past from wild ancestors in relatively restricted areas of the world. Further, he also recommended that each crop had a single region of origin. Based on his work, he recognized following classes of economic plants:

Classes	**Cultivated plants**
Class 1: Old world plants that have been cultivated for over 4,000 years	*Pyrus malus, Solanum melongenum, Setaria italic, Panicum miliaceum, Pennisetum typhoideum, Oryza sativa, Sorghum vulgare, Triticum vulgare* etc.
Class 2: Old world plants that have been cultivated for over 2,000 years	*Beta vulgaris, Avena sativa, Papaver somniferum Secale cereal, Saccharum officinarum, Juglans regia* etc.
Class 3: Old world plants that have been cultivated for less than 2,000 years	*Fagopyrum esculentum, Coffea arabica, Abelmoschus esculentus, Petroselinum crispum, Pastinaca sativa* etc.
Class 4: New world plants that have been cultivated for more than 2,000 years	*Theobroma cacao, Phaseolus vulgaris, Zea mays Ipomea batatas, Nicotiana tabacum* etc.
Class 5: New world plants that have been cultivated before the time of Columbus	*Persea americana, Gossypium sp., Psidium guajava Ananas comosus, Solanum tuberosum, Vanilla planifolia* etc.
Class 6:	*Rubus biflorus, Cinchona sp., Prunus domestica,*

New world plants that have been cultivated since the time of Columbus	*Hevea brasiliensis, Fragaria vesca* etc.

Agricultural probably began independently in the New World, 1000–2000 years later than in the Old World. There was a comparatively dense Mesoamerican centre expanding from Honduras to Mexico City, while South American produce emerged in a wide region covering most of coastal and central South America. Coastal Peru is often called as a central point of early South American agriculture, but the data are somewhat prejudiced, since the majority archaeological research has been achieved on dry coastal regions where plant material is readily preserved. Three ecological/geographical regions of domestication have been proposed:

(i) An Andean high elevation complex

(ii) A lowland complex

(iii) An Andean mid-elevation complex

The centre in eastern North America spanned the area between the Appalachian Mountains and the western borders of Missouri and Arkansas. A diverse group of crops and animals were initially cultivated and domesticated in the America. Potatoes, quinoa and several other tuber crops were domesticated in the Andean high-elevation complex. Groundnut, amaranth, bean, coca, etc were part of the Andean mid-elevation complex. Avocados, chilli, cotton, peppers, manioc, pawpaw, squash, pineapple, sweet potato and yams were domesticated in the tropical lowlands of Central and South America. In recent times, fruit phytoliths (silica deposits) have been recovered from domesticated *Cucurbita* in early Holocene archaeological sites in south-western Ecuador (12,000–10,000 BP). The starch grains of yam, manioc and arrowroot have been found on ancient plant milling stones from the Panamanian tropical forest (7000–5000 BP), supporting the independent emergence of plant domestication in the lowland neotropical forest. Species of avocado, amaranth, beans, cotton, chenopod, chilli peppers, pumpkin and squash were domesticated independently in Mesoamerica, along with maize. Turkeys were the first animals domesticated in Mexico, while llamas and guinea pigs were the first animals tamed in South America. Sunflower, goosefoot, sump weed and squash originated in North Americans.

1.5 ORIGIN OF CULTIVATED PLANTS-VAVILOV'S CENTRES OF ORIGIN

Agriculture is the oldest occupation of the human's oldest occupation and probably began when they discovered that certain seeds when spilled on disturbed ground grew in some mysterious way into new plants. It now appears certain that early domestications were made more or less alongside and independently on the lower slopes of the Zagros Mountains, the 'fertile crescent' of the Tigris and Eupharates valleys in northern Iraq (Old World), and in the Tehuacán Valley of Mexico (New World). Ancient arrangement was astonishingly copious in both these regions. The initial confirmation of authentically cultivated forms so far discovered, dates from about 7000

BC in both the hemispheres. Every necessary plant species which we worth nowadays is a living compliment to our primitive ancestors who, discovered the virtues of certain plants, long before the dawn of recorded history, chosen the most valuable wild species and intensely altered them. Many of them have been changed so much that their wild ancestors cannot be traced with conviction. Indeed, early humans were a plant breeder, devoid of any sufficient acquaintance of genetics, and exhibited a notable knowledge in domesticating plants and preparing them for food. For the invention of numerous of those economic plants, their relocations from one continent to another and information of their properties and cultivation, we are indebted to the scholars of antiquity, the ancient conquerors, the medieval trade 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 revisit, brought home for transplantation anything they found fit. Even though human domesticated plants at very first but he did not document them critically for a long time however some irregular plant sketches were made by the Palaeolithic man. The actual establishment of the systematic 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 subsequently 14 centuries, in botany as in other sciences, roughly nothing was proficient. The previous attempts of Aristotle and Theophrastus were considered thus accomplished and reliable that there was little besides to study and surely not anything for questioning. However, the revival of information in the 'Renaissance' had a enormous impact on agriculture. One of the old perspectives regarding the origin of cultivated plants postulated that these are the gift to humans by the God. In addition, there was a faith that the procedure of cultivation itself enhanced the genetics of plants. However, men perplexed these submissions by the end of the 18 century.

Alexander von Humboldt in 1807 proclaimed that 'we know nothing of the original source of our most useful plants; their origin is an impenetrable secret'. These domesticated plants were arise by the intense 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.

Nikolai Ivanovich Vavilov

A Russian scientist, Nikolai Ivanovich Vavilov was a pioneer worker in the field of plant introduction and exploration. He was recognized for the gene centre concept of cultivated plants and their wild progenitors. Under his novel guidance, one of the greatest investigators in crop geography and genetics, widespread collections of these plants and their wild relatives were made by sending expeditions all over the world. His deductions were foundation on a selection of facts, obtained from the sources diverse from those of his predecessors, such as morphology, cytology, genetics anatomy distribution and reaction to disease. Vavilov maintain the record of the varied forms of the most significant cultivated plants and their allocation over a range of parts of the earth. He perceived that the allocation of plants was not uniformly distributed. In few limited areas, an extensive range of genetic inconsistency was encountered. For example, South America for potato and Ethiopia for wheat. Over fifty per cent of the diversity found in the world was present in these regions. There are a few such regions and mostly they are small areas restricted to the mountains or foothills of the subtropics and tropics. Vavilov called these regions with the greatest wealth of forms, 'gene or diversity centres' and further suggested that these are the regions of origin as well as dispersion. From these centres, the species have migrated in different directions in the course of which many recessive mutants arose. All discrepancy from the cultivated type to a entirely wild species were to be seen in these centres. In the case of potato, a investigate for its prime centre of origin, the Andes of South America, exposed all degrees of variation from a tuber forming cultivated type to the wild non-tuber forming types. These centres were characterized by the presence of dominant genes. It emerged that the heart of these gene centres was distinguish by the preponderance of the dominant genes and towards the peripheral regions these genes were replaced by recessive alleles increasingly. A Vavilov Center (of Diversity) is a region of the world first specify by Nikolai Vavilov to be an original center for the domestication of plants. For crop plants, Nikolai Vavilov identified various numbers of centers. It was only 3 in 1924 which increased by 8 in 1935 and reduced to seven again in 1940.

Vavilov's scheme as updated by Schery and Janick

Vavilov centers are those centers which maintain the high diversity of crop and their wild relatives can be found which are representing the natural relatives of domesticated crop plants. Later in 1935 Vavilov divided the centers into 12, giving the following list:

1. Chinese center
2. Indian center
   (a) *The main centre* Assam and Burma (now called Myanmar)
   (b) *The Indo-Malayan centre* includes Indochina and the Malay Archipelago
3. Indo-Malayan center
4. Central Asiatic center
5. Persian center
6. Mediterranean center
7. Abyssinian center
8. South American center
   (a) The Peruvian-Ecuadorean-Bolivian centre
   (b) The Chiloe centre
   (c) The Brazilian-Paraguayan centre
9. Central American center
10. Chilean center
11. Brazilian-Paraguayan center

12. North American center

Table 1.2: Cultivated plants of eight world centers of origin (Source: Schery 1951 and Janick 2002)

Center	Plants
(1) South Mexican and Central American Center: Southern sections of Mexico, Guatemala, H onduras and Costa Rica.	• *Grains and Legumes:* maize, common bean, lima bean, tepary bean, jack bean, grain amaranth • *Melon Plants:* malabar gourd, winter pumpkin, chayote • *Fiber Plants:* upland cotton, bourbon cotton, henequen (sisal) • Miscellaneous: sweet potato, pepper, papaya, guava, cashew, chochenial, arrowroot, wild black cherry, cherry tomato, cacao.
(2) South American Center includes 62 plants listed; three subcenters	*2) Peruvian, Ecuadorean, Bolivian Center:* • Root Tubers: Andean potato, Other endemic cultivated potato species. Fourteen or more species with chromosome numbers varying from 24 to 60, Edible nasturtium • *Grains and Legumes:* starchy maize, lima bean, common bean • *Root Tubers:* edible canna, potato • *Vegetable Crops:* pepino, tomato, ground, pumpkin, pepper, cherry • *Fiber Plants:* Egyptian cotton • *Fruit and Miscellaneous:* cocoa, passion flower, guava, tobacco, coca, heilborn, quinine tree, cherimoya, *2A) Chiloé Center* (Archipelago near the coast of southern Chile) Common potato (48 chromosomes), Chilean strawberry *2B) Brazilian-Paraguayan Center* manioc, peanut, rubber tree, pineapple, Brazil nut, cashew, Erva-mate, purple granadilla.
(3) Mediterranean Center: Includes all of Southern Europe and Northern Africa bordering the Mediterranean Sea. Listed 84 plants	• *Cereals and Legumes:* durum wheat, emmer, Polish wheat, spelt, Mediterranean oats, sand oats, canarygrass, grass pea, pea, lupine • *Forage Plants:* Egyptian clover, serradella, white clover, crimson clover • *Oil and Fiber Plants*: flax, rape, black mustard, olive • *Vegetables*: cabbage, turnip, lettuce, asparagus, celery, chicory, pa rsnip, rhubarb, garden beet • *Ethereal Oil and Spice plants*: caraway, anise, peppermint, sage, hop thyme
(4) Middle East: Includes interior of Asia Minor, all of Transcaucasia, Iran,	• *Grains and Legumes:* einkorn wheat, durum wheat, poulard wheat, common wheat, oriental wheat, Persian wheat, two-row barley, rye, Mediterranean oats, common oats, lentil, lupine • *Forage Plants:* alfalfa, Persian clover, fenugreek, vetch, hairy vetch

and the highlands of Turkmenistan. Listed 83 species	• *Fruits:* fig, pomegranate, apple, pear, quince, cherry, hawthorn.
(5) Abyssinian Center: Includes Ethiopia, Eritre, and part of Somalia. 38 species listed; rich in wheat and barley.	• *Grains and Legumes:* Abyssinian hard wheat, poulard wheat, emmer, Polish wheat, barley, grain sorghum, pearl millet, African millet, cowpea, flax, teff • *Miscellaneous:* sesame, castor, bean, garden, okra, myrrh, coffee, indigo cress, enset.
(6) Central Asiatic Center: Includes Northwest India (Punjab, Northwest Frontier Provinces and Kashmir), Afghanistan, T adjikistan, Uzbekistan, and western Tian-Shan. 43 plants	• *Grains and Legumes:* common wheat, club wheat, shot, peas, lentil wheat, horsebean, chickpea, mung, mustard bean, flax, sesame • *Fiber Plants:* hemp, cotton • *Vegetables:* onion, garlic, spinach, carrot • *Fruits:* pistachio, pear, almond, grape, apple.
(7) Indian Center	Two sub-centers: *Indo-Burma:* Main Center (India): Includes Assam, Bangladesh and Burma, but not Northwest India, Punjab, nor Northwest Frontier Provinces, reported 117 plants • *Cereals and Legumes:* chickpea, pigeon pea, urd bean, mung bean, rice bean, cowpea, • *Vegetables and Tubers:* eggplant, cucumber, radish, taro, yam • *Fruits:* mango, tangerine, citron, tamarind • *Sugar, Oil, and Fibre Plants:* sugar cane, cotton, coconut, palm, sesame, safflower, tree, oriental cotton, jute, crotalaria, kenaf • *Spices, Stimulants, Dyes, and Miscellaneous:* indigo, hemp, black pepper, gum, sandal wood, cinnamon tree, croton, bamboo, turmeric, *7A) Siam-Malaya-Java:* statt Indo-Malayan Center: Includes Indo-China and the Malay Archipelago, 55 plants • *Cereals and Legumes:* Job's tears, velvet bean • *Fruits:* pummelo, banana, breadfruit, mangosteen • *Oil, Sugar, Spice, and Fibre Plants:* candlenut, coconut palm, sugarcane, clove, nutmeg, black pepper, manila hemp.
(8) Chinese Center: A total of 136 endemic	• *Cereals and Legumes*: rice, broomcorn millet, Italian millet, Japanese barnyard millet, sorghum, buckwheat, hull-less barley, soybean, Adzuki bean, velvet bean

plants are listed in the largest independent center	• *Roots, Tubers, and Vegetables:* Chinese yam, radish, Chinese cabbage, onion, cucumber • *Fruits and Nuts:* pear, litchi, orange, peach, cherry, Chinese apple, apricot, , walnut, , • *Sugar, Drug, and Fibre Plants:* sugar cane, opium poppy, ginseng camphor, hemp.

These areas of diversity constitute only a small proportion (two to three per cent) of the total land surface of the earth and are geographically distinct, being isolated by deserts or mountain ranges. Eighty-five per cent of the 640 species listed by Vavilov originated in the Old World (Asia, Europe and Africa), and the remainder are of the New World (the Americans).

All the centres of diversity are situated in the mountainous regions of the tropical zones of the Old and New Worlds. The wide temperature fluctuations and the strong ultraviolet radiations in these areas are the grounds of the origin of such a multitude of forms. The extraordinary diversity of the climate of all mountains, especially the tropical ones, makes it easier for the newly originated mutants to find a suitable environment than it would be in a region with a more uniform climate.

Vavilov further distinguished between primary and secondary or ‘accumulation’ gene centres. He suggested that the process of domestication from the native wild relatives began in the primary gene centre, and these are characterised by the dominant genes. As the cultivated plants later migrated to another gene centre, they were subjected to the same natural force that again led to a considerable increase in the diversity of the cultivated plants that came into this region. In this way, a new or secondary gene centre was developed from the cultivated plants in question. This gene centre was significantly characterised by a diversity of recessive characters and was also devoid of wild relatives. The Abyssinian centre was extraordinarily rich in the varieties of wheat, barley, pea, flax and lentil, but there are none of the wild relatives that are found in the Middle East, many thousands of kilometers from Ethiopia. Thus, in the primary gene centre the diversity was a consequence of ancient cultivation. The longer a given biological entity occupied a particular region, the larger would be the number of variables it would exhibit (Willis’ age-and area hypothesis, 1922). In contrast, the reasons for the diversity in the secondary gene centre were ecological diversity, farming practice, human migration patterns (attraction of different tribes to different races of a crop) and the internal biological dynamics of hybridisation, segregation and selection.

Even within a basic centre of biodiversity, there are very tiny areas of varietal richness, which Vavilov called as ‘agro-ecological groups’. This idea was expected by Harlan was used the term ‘microcentre’- a region that may contain an astonishing variation of one or more crops.
According to Vavilov, many of our most important cultivated plants had a multiple rather than a single origin as suggested by de Candolle. These primary crops were domesticated directly from the wild plants, example of which are wheat, barley, rice, soybean, flax, cotton, maize and

potato. Vavilov pointed out that there were at least two distinct centres of distribution for wheat; soft wheat originated in the Southeast Asia, whereas the hard wheat came from the Mediterranean region. Likewise, barley was domesticated in the Southwest Asia, North Africa and Southeast Asia.

On the other hand, secondary crops, such as rye, oats, etc. originated as weeds growing with the primary crops. As the primary crops were taken to areas with harsher climatic conditions and poorer soils, the percentage of weeds increased since they were better adapted to such conditions. Hence, finally the weeds became the crop, and the crop became the weed.

1.6 SUMMARY

The broad objective of the present unit is to know about the domestication and introduction of plant species and their origin. The history of human evolution is very old where the prehistoric human primarily got their food from the wild edible plants but as the time passed, they started to cultivate the wild plants. Therefore, the traditions of those prehistoric humans take very prominent part in the origin of cultivation of plants. It is believed that most of the plant were cultivated first during historical times. However the paleontological data is entirely unavailable for cultivated plants and archaeological information is fragmented and very poor.

The efforts of some ancient Roman and Greek naturalists like Theophrastus, Elder, and Galen Pliny laid down systematic groundwork of wild plant domestication. Alexander von Humboldt also considered the origin of useful plants is a big secret as well. Finally, Darwin's evolutionary theory recommended that origin of cultivated plants take place through natural selection and repetitive hybridization.

If we talk about the agriculture it is believed that agriculture have been originated somewhere in the well irrigated highlands of the Indus, Euphrates and Nile and Tigris rivers nearly 7000-13000 years ago. A few places of other prehistoric sites like Tehuacan valley in modern Mexico and banks of Yellow river in modern China are also the evidence of ancient agricultural activities.

Do you ever think that how a regional cultivated crop becomes cosmopolitan in their distribution? It could become possible only due to the "plant introduction" and domestication of a particular region to the other region. The plant introduction is a progression of introducing plants (a genotype or a group of genotypes) from their own environment to a new environment. This process may include new varieties of crop or the wild relatives of crop species or totally a new crop species for the area. Introduction may be classified into two categories: (i). Primary introduction: When the introduced variety is well suitable to new environment afterward it released devoid of any modification of genotype for commercial production. (ii). **Secondary introduction:** When the introduced variety is subjected to the selection or used in hybridization programme with local varieties having some new characters to obtain the superior varieties called secondary introduction.

The plant domestication is a method of bringing of wild plants under cultivation by making them appropriately modified for new environment. Domestication is the reflection of co-evolution where both the components (plants and humans) developing a symbiotic relationship because human and plant behaviours evolve to suit one another. Some main purposes of plant domestication are germplasm conservation, enhancement in agriculture, forestry and industry, aesthetic interest etc. The major agencies which are associated to plant Introduction in India are National Bureau of Plant Genetic Resources (NBPGR), Forest Research Institute (FRI), Botanical Survey of India (BSI) etc.

Agriculture is the oldest occupation of the human's oldest occupation. A Russian scientist, Nikolai Ivanovich Vavilov was a pioneer worker in the field of plant introduction and exploration. Vavilov proposed some centers of origin of cultivated plant which are known as Vavilov's centers of origin. These are those centers which maintain the high diversity of crop and their wild relatives. According to Vavilov, many of our most important cultivated plants had a multiple rather than a single origin as suggested by de Candolle. These primary crops were domesticated directly from the wild plants, for example wheat, barley, rice, soybean, flax, cotton, maize, potato etc.

1.7 GLOSSARY

Prehistoric time: the vast period of time before written records or human documentation, includes the Neolithic Revolution, Neanderthals and Denisovans, Stonehenge, the Ice Age and more.

Wild relative crop: wild plant species that are genetically related to cultivated crops.

Domestication: the process of taming an animal or plant and keeping it as a pet or on a farm or cultivation.

Evolution: the development of plants, animals, etc. over many thousands of years from simple early forms to more advanced ones

Co-evolution: the influence of closely associated species on each other in their evolution.

Symbiosis: It is a type of a close and long-term biological interaction between two different biological organisms.

Archaeology or archeology: It is the study of human activity through the recovery and analysis of material culture.

Plant Hybridization: It is the process of crossing two genetically different individuals to result in a third individual with a different, often preferred, set of traits.

Cultivation: It is called deliberately growing a plant.

Plant introduction: It is a progression of introducing plants (a genotype or a group of genotypes) from their own environment to a new environment.

Acclimatization: It is the capability of a plant variety to become adapted to a new edaphic and climatic condition.

Breeding systems: It referring in plants is simple called as "Who mates with whom"

Pure breed: Breeding between pure breed where the ancestors on both mating type have been members of a recognized breed.

Cross breed: Breeding where status of only one parent is known or breeding between two different breeds, varieties, or populations.

Genetic variation or diversity: It is called as the diversity exists within different genotypes of the same species.

Crop duration: The time duration from establishment to harvesting a crop is known as duration of the crop.

Germplasm: It is living tissue from which new plants can be grown. It can be a seed or another plant part – a leaf, a piece of stem, pollen or even just a few cells etc.

Conservation: It is the moral philosophy and conservation movement focused on protecting species from extinction, maintaining and restoring habitats, enhancing ecosystem services, and protecting biological diversity.

Aesthetic value: It is the emotional or spiritual value attributed to a work of art or nature because of its beauty or other factors associated with aesthetic preference.

Plant variety: It represents a more precisely defined group of plants, selected from within a species, with a common set of characteristics.

Propagules: a vegetative structure that can become detached from a plant and give rise to a new plant, e.g. a bud, sucker, or spore.

Plant quarantine: It is a technique for ensuring disease- and pest-free plants, whereby a plant is isolated while tests are performed to detect the presence of a problem.

Phytogeography or botanical geography: It is the branch of biogeography that is concerned with the geographic distribution of plant species and their influence on the earth's surface.

Vavilov center: A center of origin is a geographical area where a group of organisms, either domesticated or wild, first.

Biodiversity: developed its distinctive properties. They are also considered centers of diversity.
Biodiversity is the biological variety and variability of life on Earth. Biodiversity is a measure of variation at the genetic, species, and ecosystem level.

1.8 SELF ASSESSMENT QUESTIONS

1.8.1 Multiple Choice Questions:

1. Centres of early civilization were in:

(a) Tropical plains (b) River valleys
(c) Temperate plains (d) Hills

2. The earliest place where agriculture and civilisation are believed to have started

(a) Nile (b) Northern plains of India
(c) China River valley (d) All of the above

3. Ethiopia is the original home of
(a) Coffee (b) Maize
(c) Rice (d) Cabbage

4. Cabbage originated in:
(a) Mexico and Central America (b) Peruvian Andes
(c) Mediterranean (d) South West Asia

5. Maize evolved in
(a) Brazil (b) Mexico and Central America
(c) U.S.A. (d) Asia Minor and Afghanistan

6. The centre of origin of Almond and Apple is
(a) South-West Asia (b) South-East Asia
(c) China (d) Asia Minor and Afghanistan

7. The original home of Rice is
(a) South-West Asia (b) South-East Asia
(c) Mediterranean (d) China

8. Peruvian Andes are believed to be centre of origin of
(a) Tomato (b) Potato
(c) Tomato and Potato (d) Tomato, Potato and Chillies

9. The origin of Sunflower is believed to be in
(a) Mexico and Brazil (b) Brazil
(c) U.S.A. (d) Peruvian Andes

10. South-East Asia is thought to be centre for the origin of
(a) Rice (b) Rice and Sugarcane
(c) Rice, Sugarcane and Mango (d) Rice, Sugarcane, Mango and Banana

1.8.2 Fill in the blanks:

1. The famous cultivated plant which developed in China is _______
2. The birthplace of Hevea/Para Rubber is _______
3. The centre of origin of Wheat is _______
4. Gene banks comprise _______

5. Dwarf wheats were developed by the scientist _______

6. The dwarf varieties brought from Mexico into India were _______and _______

7. IR.-36 was developed through breeding of _______ and _______

8. Cereals belong to family _______

9. Major crops of the world belong to family _______

10. Triticale is a man-made cereal which has been developed through hybridisation between _______ and _______

1.8.3 True and False:

1. Rice is the principal cereal of Tropical region.
2. The plants introduced from Old World to New World is maize.
3. Food grains which provide the most important staple food to man are Legumes.
4. Rice is the good source of carbohydrate.
5. Cereals are biennials crop.
6. Botanical name of Rice is *Pennisetum typhoides.*
7. Sharbati Sonora and Sonalika are the Improved Wheat varieties.
8. Paddy is Rice grain with husk.
9. Polished rice is the best form of rice.
10. *Triticum monococcum* is the common bread wheat.

Answer Key:

1.8.1: 1(c); 2(d); 3(a); 4(c); 5(b); 6(d); 7(b); 8(d); 9(c); 10(d).

1.8.2: 1. Tea; 2. Brazil; 3. South-West Asia; 4. Seed banks, orchards, tissue culture and cryopreservation; 5. Borlaug; 6. Sonora-64, Lerma Rojo-64; 7. Thirteen Rice varieties, *Oryza nivara; 8.* Gramineae; 9. Gramineae; 10. Wheat, Rye

1.8.3: 1. True; 2. False; 3. False; 4. True; 5. False; 6. False; 7. True; 8. True; 9. False; 10. False

1.9 REFERENCES

- https://www.studyandscore.com/studymaterial-detail/Alphonse-de-Candolle-Origin-of-cultivate-plants-Classes-of-economic-plants-Regions-of-first-origin
- https://www.studyandscore.com/studymaterial-detail/origin-and-introduction-of-plants-domestication-of-plants-basis-of-plant-domestication
- Janick J (2002) History of Horticulture, Purdue University,
- Schery R. W. Adapted from Vavilov (1951) by, Plants for Man, Prentice Hall, Englewood Cliffs, NJ, 1972

1.10 SUGGESTED READINGS

- Janick J (2002) History of Horticulture, Purdue University,
- Schery R. W. Adapted from Vavilov (1951) by, Plants for Man, Prentice Hall, Englewood Cliffs, NJ, 1972

1.11 TERMINAL QUESTIONS

1.11.1 Short answer type questions:

1. What do you under by introduction of plant species?
2. Describe the primary and secondary introduction in brief.
3. What do you know about the domestication of plant?
4. What is acclimatization of a species?
5. Highlight the main purposes of plant introduction and domestication.

1.11.2 Long answer type questions:

1. Write in detail note on procedure and agencies associate of plant introduction in India.
2. Discuss the merits and demerits of plant introduction.
3. Highlight some achievements of plant introduction in detail.
4. Discuss the origin of agriculture in detail.
5. What do you understand by the Vavilov's centres of origin?

UNIT-2 FOOD SPECIES, FRUITS AND NUTS

Contents

2.1 OBJECTIVES

After reading this unit the students will be able to known about the;

- Major food species of the world.
- Origin, cultivation, food value and production of the cereals.
- Origin, cultivation, food value and production of the pulses.
- Food value and uses of millets.
- Major vegetable, fruit and nut species and its nutrient values and uses.

2.2 INTRODUCTION

Food plant species may be defined as those plant species or plant organs that can be included in human meal or a part of it. Human meals can be chiefly divided into three categories breakfast, lunch and dinner. These three meals are mainly consists either of plant products (cereals, vegetables, legumes, fruits and nuts) or products of animals (meat, cheese, butter, curd, yoghurt, milk, eggs etc.).

As the title of the block "**Plant resources of food value**" asks to mention about the plant species which can be used as food, so here in this unit we are going to study only about the plant products which make our meals.

As we look at the major classification of plant products used as food it appears that only higher plants made their way to our dining table but this is not the complete truth. Human also use various lower plants in their diet. Among these lower plants **macro-fungi** such as mushrooms, morels, truffles and puffballs contribute the major portion; **Algae** such as sea grapes (*Caulerpa lentillifera*), Nori or purple laver (*Porphyra* spp.), Aonori or green laver (*Monostroma* spp. and *Enteromorpha* spp.), Kombu or haidai (*Laminaria japonica*), Wakame, quandai-cai (*Undaria pinnatifida*), Hiziki (*Hizikia fusiforme*), Mozuku (*Cladosiphon okamuranus*), Dulse (*Palmaria palmata*), Irish moss or carrageenan moss (*Chondrus crispus*), Winged kelp (*Alaria esculenta*), Ogo, ogonori or sea moss (*Gracilaria* spp.), *Callophyllis variegata*, *Spirulina*, *Chlorella*, *Gelidium corneum*, *Gracilaria lichenoides* and *Eucheuma spinosum* are the second largest contributor, and only a single species i.e. *Matteuccia struthiopteris* of **Ferns** made to the contributor list. Some species of lichens contribute in making spices.

Very few species of **Gymnosperms** provide some nuts to eat such as the Mexican pinon (*Pinus cembroides*), the Colorado pinion (*P. edulis*), the Italian stone pine (*P. pinea*), and the Chinese nut pine (*P. koraiensis*), Chilgoza Pine (*Pinus girardianana*) and Sago from some cycads e.g. *Cycas revoluta*.

Angiosperms are the most dominating plant group in obtaining food products. The main reason why these plants are so much in demand as food products because these species contain all the necessary and sufficient nutrients like carbohydrates, fats, proteins, vitamins and minerals. A major portion of the global supply of food products is obtained from rice, wheat, maize, sugar cane, potato and beans etc. Some beans and vegetables such as mustard, groundnut, soyabean, sunflower, linseed, olive and castor oil are widely used in the food industry.

Almost all the vegetables provide vitamins and mineral salts that are essential for human health. The lack of these vegetables from the diet results in vitamin deficiency and consequently causes some diseases such as beriberi, scurvy and pellagra from the lack of vitamin B (thiamine), vitamin C and vitamin B6 (niacin), respectively.

As we saw in the above paragraphs, with the help of some examples, plants constitute a large proportion of human diet. A huge section of all the edible plant species can be categorized into three broad categories such as cereals, vegetables and legumes. We will study these three categories in details further in this chapter.

2.3 FOOD SPECIES

2.3.1 Cereals

The term 'cereals' is derived from a Greek festival 'Cerealia' which is celebrated in ancient Rome to honor the goddess Ceres who is the goddess of agriculture, grain crops, fertility, and motherly relationships. In this festival Romans used to offer grains such as wheat and barley to the goddess Ceres.

Cereals are the important component of human diet. True cereals belong to the family Poaceae also known as grass family (Fig 3.1). On the other hand there are some other crops which are used to make flour but these species do not belong to the family Poaceae. These plants are called as pseudocereals for example buckwheat (*Fagopyrum esculentum*), quinoa (*Chenopodium quinoa*), *Amaranthus* spp. etc.

Cereals have a significant role in the evolution of Human civilizations. No civilization can ever be imagined without a stable supply of food and the agricultural revolution was the answer to the mentioned problem. Cereals were the first plants ever to be domesticated and cultivated in agricultural lands. Roughly every civilization, whether it is Ancient Egypt, Greece, Inca, Indus valley, Mayan, Mesopotamian and Roman was based on one or another species of the cereals.

Now the question arises why the cereals have so much significance as food plant species. The cereals belong to the grass family and grasses have adapted themselves in growing almost on every possible habitat; cereals give very high yield per unit area; in comparison to the products of other plant species cereal grains are very compact and dry, this feature of cereals make them the perfect food species for handling, transporting and storing without the fear of spoilage; apart from all the above mentioned reasons the cereal grains have great nutritive value, as they contain a higher percentage of carbohydrates than any other food plant, sufficient protein (7-10 per cent), fats, vitamins and minerals. The general characteristics of cereals are following:

Habit: Generally herbaceous annuals, few are perennial.
Stem: Cylindrical, often erect, generally hollow (except at the nodes), have intercalary meristem. Primary, secondary and tertiary or even quaternary tillers may arise from the subterranean nodes of the primary, secondary and tertiary stems, respectively and this gives the plant a tufted appearance.
Leaves: Alternate with parallel venation, having two distinct parts (leaf sheath and lamina). A ligule (membranous outgrowth) is also found at the junction of the leaf sheath and lamina.
Inflorescence: Spike of spikelets (wheat, barley and rye) or panicle of spikelets (oats, rice and sorghum).
Stamen: Usually three, sometimes six.
Gynoecium: Single with two feathery stigmas.
Flower: Chasmogamous and adapted for wind pollination.
Fruit: One-seeded indehiscent fruit, or caryopsis, in which the pericarp is completely fused with the seed-coat.

The most commonly used cereals are wheat, rice, corn, barley and oats. Some important millets are Finger millet (ragi), Foxtail millet, Barnyard millet and pearl millet. A study conducted in 2013 suggests that a large percentage of the world's population manages to survive chiefly on wheat, rice or maize (Graph 1). China (552,430,540 tones) is the world's largest producer of cereals, followed by United States (436,553,678 tones) and India (293,940,000 tones). Some most common species of cereals and millets are being described here in details.

(A) Wheat

Botanical Name: *Triticum* spp.

Characteristic Features: Annual grass, comprising various wild (weeds) and cultivated species. Cultivated wheat (*T. aestivum*) grows to a height of 2-4 ft. Inflorescence terminal spike or head consisting of 15-20 spikelets borne on a zigzag axis. Individual spikelets sessile, solitary, consist of 1-5 flowers each. Mature grain consists of the embryo (6 per cent), a starchy endosperm (82 to 86 per cent), the nitrogenous aleurone layer (3 to 4 percent), and the husk or bran (8 to 9 per cent). Husk or bran is made up of the remains of the nucellus, the integuments of the seed coat, and the ovary walls or pericarp.

Origin: On the basis of the number of chromosomes present in their reproductive cells, all the wheat species can be classified into three categories namely diploid, tetraploid and hexaploid wheat. Originally all the wheat varieties were considered to be diploid but in time, unknowingly, human provided them a chance to get naturally hybridized and after that their chromosomes doubled and gave rise to the modern day tetrapliod and hexaploid wheat varieties.

Production: According to a datum published in 2012 wheat has a total production of about 670.8 million metric tons and it is the third most produced cereal after maize and rice. The top producer of wheat is China (120 million tons) followed by India (94.8 MT).
India produces 86 per cent common bread wheat (*T. aestivum*), 13 per cent durum wheat (*T. durum*) and the remaining 01 per cent is emmer wheat (*T. dicoccum*).

Types: On the basis of the growing season of wheat all the varieties of wheat can be categorized in to two main groups: *Spring and winter wheat*.

Spring wheat: Short growing season (almost 100 days), no need of very low temperatures in the early phases of growth, sown in March-May, harvested in the late summer from August to September.

Winter wheat: Long duration, require relatively low temperatures during the early phases of growth, sown in October-November and reaches maturity in the early summer of the next year, that is, May to July. On the basis of the chemical composition of the grain wheat can be divided into two broad groups: *Soft and hard wheat.*

Soft wheat: Pale, possess a white starchy interior, lower in gluten content and make a weak flour suitable for making cakes, crackers, cookies, pastries and household flour.

Hard wheat: Dark and vitreous show no white starchy area, higher in gluten content and make strong flour, a property desirable for bread making (leavened loaf).

On the basis of official grain standards in the United States, wheat is categorized into seven grades: (1) hard-red spring, (2) durum, (3) hard-red winter, (4) soft-red winter, (5) white wheat, (6) red durum and (7) mixed wheat.

Cultivation Method: The wheat seeds must be sown in about 4 to 5 cm inside the soil. Always put the seeds in rows and maintain a spacing of 20-22.5 cm between the rows. Planting or sowing the seeds in the right time is also important as delayed sowing can cause a gradual decline in the production.

Season: Wheat is a Rabi crop that is grown in the winter season. Sowing of wheat takes place in October to December and harvesting is done during the months of February and May. The wheat crop needs cool winters and hot summers, which is why the fertile plains of the Indo-Gangetic region are the most conducive for growing it.

Soil: Wheat grows best in a well-drained loamy soil. The term “loam” is textural and reflects the particle size distribution of the soil and the relative quantities of the sand, silt and clay size fractions.

Harvesting: The crop is harvested when it is ripe and the straw has turned golden yellow and brittle. At this stage, the moisture content of the grains is nearly 14 per cent. Wheat is sown in

October and harvested in May-June. The crop remains dormant in the cold months of November to March and starts growing as the temperature rises in April.

Uses: Wheat is the important source of carbohydrates to human. Wheat flour has good baking qualities and be used in various forms. In India almost 85-90 per cent of wheat is used to make *roties*. The soft wheat flour is mainly used in making cakes, biscuits, pastries etc. and hard wheat flour is used in bread making. Flour from Durum wheat is used in making macaroni, spaghetti, semolina, vermicelli, noodles.

Wheat is also used in industrial preparations such as starch, gluten, distilled spirits, malt etc. Wheat starch is preferred by many laundries for use in finishing clothes. Gluten is used for the production of monosodium glutamate, a product that intensifies the flavour of food.

Wheat bran is rich in proteins and vitamins and is a valued livestock feed. It is employed in the human diet not only for its nutritional quantities but for its role as ‘roughage’, indigestible material, which stimulates intestinal peristalsis and adds bulk to the waste mass. Wheat straw is used as livestock feedstuff, animal bedding and compost. Some wheat straw is used for making corrugated paper, as well as high-quality insulated building board.

(B) Rice

Botanical Name: *Oryza sativa*

Characteristic Features: The rice plant is a semiaquatic, free tillering annual grass with a cylindrical jointed stem (culm), about 50-150 cm tall. The internodes are shortest at the base, becoming progressively longer. Above each node, there is a pronounced thickening ‘pulvinus’ with an intercalary meristem. Generally, it has a shallow root system further depends on the type of the soil and the water availability. The first leaf at the base of the main culm and each tiller is rudimentary, consisting of a bladeless ‘prophyllum’. Leaves are arranged in alternate manner on the stem in two levels – one at each node, each consisting of leaf sheath, leaf blade, ligule and auricles, the former encircling the whole or part of the internode. At the junction of the leaf sheath and leaf blade, there is a triangular membranous, usually colourless ligule that tends to split with age and is flanked on either side by a small sickle-like appendage, fringed with long hairs (auricles). The leaf blade is long, narrow, 30–50 cm or more in length and 1-2 cm broad and somewhat pubescent having spiny hairs on the margins. The lamina of the uppermost leaf below the panicle (‘flag’ or ‘boot’) is wider and shorter than the other.

The rice inflorescence is a loose terminal panicle. The spikelets are usually borne singly, but clustered forms with 2-7 spikelets together. The flower is usually self pollinated and is surrounded by lemma and palea that make up the hull or husk and remains attached to the grains in threshing. The lemma is tough, papery and may be fully awned, partially awned or awnless, while the palea is somewhat smaller and sometimes awned. Enclosed within the lemma and palea are two broad, thick, fleshy lodicules, six stamens in two alternating whorls and a pistil with two plumose stigmas on two styles.

Origin: It has the origin in Southeastern Asia, but in time it has spread to every warm region of the world. The Chinese were the first to cultivate rice, and their records go back for 4000 years. Rice was introduced into India before the time of the Greeks, and very early reached Syria and Northern Africa. The first rice was grown in Europe in 1468 in Italy. The first rice in America was grown in South Carolina in 1694 from seed brought from Madagascar.

Production: The global production of rice in 2012 was around 719 million tons. Out of that, 152.6 million tons (around 35 per cent) were produced in India. European countries like Italy and Spain also produced small quantities of rice but Asian continent alone accounts for more than 90 per cent of the world's production.

Cultivation: The rice crop is grown over an extremely wide range of climatic conditions. Rice production requires; relatively high temperature; ample amount of water; close textured or relatively impervious subsoil to prevent excessive loss of water by seepage and good drainage system to allow the field to dry at the time of harvesting. Different varieties of rice vary in their season of growth, maturation period and suitability to varying conditions of soils, temperature, rainfall, altitude and adaptability to such special environments such as flooded land, alkalinity and acidity of soil and depth of standing water.

Flooded fields are a prime requirement for rice production. Rice can be grown on different soil types but it prefers the heavy alluvial soils. Acidic soil pH is good for rice cultivation. Best conditions for rice to grow are high temperature (21 to 35 °C) and humidity.

Harvesting: The right time to harvest the crop is when the panicles become yellowish in color and turned downward. Pre-mature and delayed harvesting are the reasons for lowering the yield.

Uses: Rice is the vital part of the diet in Southeast Asia. About 90 per cent of rice is eaten as plain boiled rice with cooked pulses, curd, vegetables, fish or meat. The other Indian rice preparations are *kheer*, *firni* and *pulao.* In South India, fermented preparations such as *dosa*, *idli* and *uppma* are prepared. Rice flour is used in confectionery, ice creams, puddings and pastry. Rice starch, has broad industrial potential in the cosmetic industry, as a thickener in calico printing, in the finishing of textiles and for making dextrins, glucose and adhesives. Alcoholic beverages such as 'sake' in Japan and 'wang-tsin' in China are made from rice through fungal fermentation.

Fig. 2.1: Some important cereal, pulse and millet crop of human food

The rice husk is of little value as an animal feed because of its high silicon content. Hulls are used as a fuel, as bedding for poultry and for packing and insulation. Ash from the burnt rice hulls is used as a filler in concrete and bricks, and as a source of sodium silicate in making soaps, polishes and other cleaning agents. The bran and rice polish, by-products of the rice milling industry, are valued as a stock feed. Rice bran oil (RBO) is used for edible purposes.

In China and Japan, a very fine type of paper is manufactured from the rice straw. The straw is also used for feeding cattle, as soil mulch, fertiliser and for the manufacture of strawboards. It is also employed for thatching, making hats, mats, sacks, ropes and baskets. Rice has played an important part in many ancient customs and religious and magical rituals in the East and is still associated with several ceremonies.

(C) Maize

Botanical Name: *Zea mays*

Characteristic features: Maize is a tall annual grass (3 to 15 ft). The jointed stem is solid and contains a considerable amount of sugar when young. The leaves are large and narrow, with wavy margins. Extensive fibrous root system, aerial prop roots are usually formed at the base of the stem. Two kinds of flowers are produced. The tassel, at the top of the stem, bears the staminate flowers, while the cob or ear with the pistillate flowers is produced lower down on the stalk and so is protected by the leaves. Each ovary has a long silky style, the corn silk. The ovaries, and consequently the mature grains, are produced in rows on the cob. The cob is surrounded by a husk composed of leafy bracts. The grains consist of the hull, protein, endosperm and embryo. Two kinds of endosperm are usually present: a hard, horny yellow endosperm and a soft white starchy endosperm.

History and Origin: Maize is supposed to have originated in Guatemala and Southern Mexico. All the principal types of maize we know today were already in existence in the pre-Columbian times.

Production: The global production of maize is 872 million tons and out of that United States alone produced 273.8 million tons. The other major maize producers in the order of ranking are China 208.2 Mt, Brazil 71.2 Mt, Mexico 22 Mt, Argentina 21.2 Mt and India 21 Mt.

Types: There is no knowledge about the wild species of *Zea* in the present. On the basis of nature of endosperm and shape of the grain maize can be broadly categorized into the following:

Pod Maize (*Zea tunicata*):

1. Each grain is covered with a husk.
2. The plant is very leafy and the tassels are very heavy.
3. Has no commercial value because of the presence of the individual husks.

Pop Maize (*Zea everta*):

1. Grains are usually elongate and oval, small in size, very hard and flinty with a tough hull.
2. The endosperm is mostly hard and glossy.

3. Dry grains explode (expansion of endosperm) with a popping sound
4. Two kinds of popcorn occur: *rice popcorn* (pointed and imbricated grains) and *pearl popcorn* (rounded and very compact grains).
5. Has little commercial production.

Flint Maize (*Zea indumta*):

1. Hard endosperm present outside the embryo and white endosperm as a protective layer.
2. Height ranges from 5-9 ft
3. The ears are two in number, long and cylindrical, have 8-16 rows of grains of different in color.
4. Matures early.

Dent Maize (*Zea indentata*):

1. This is the largest species, with a height ranging from 8-15 ft.
2. Only one ear is produced in a plant. The ears are large
3. Grains are deep wedge-shaped and commonly yellow or white in color.
4. Due to its massive yield it is chiefly grown in the Corn producing areas.
5. It is the main source of fodder and commercial grain.

Soft Maize (*Zea amylacea*):

1. The hard endosperm is entirely lacking.
2. The morphology of grains is similar to flint maize, but the size varies.
3. It is not grown on a commercial scale in the United States.

Sweet Maize *(Zea saccharata)*:

1. The entire endosperm is translucent and the starch is almost changed to sugar.
2. The grains are broad and wedge-shaped with a characteristically wrinkled surface. The grain is used in the unripe state.
3. It is adapted to the colder areas.

Cultivation: Alluvium soil with high organic and nitrogen content is best suited for the production of maize. Average temperature ranging from 66-75 °F is the best for its cultivation. For the optimum growth of the plant proper sunlight and 20-in. annual rainfall are the two essential factors.

Uses: The whole plant including the grain is the chief source of livestock feed. The grain is very nutritious, with a high percentage of easily digested carbohydrates, fats, and proteins and very few harmful substances. The heavy use of maize is in the US pork industry which uses about 40 per cent of the total production. Because of the absence of gluten it cannot be baked as bread. Cornmeal is often baked in cakes, such as johnny cakes, ash cakes, hoe cakes, corn pone, and the Mexican tortillas. Corn is also used in producing cornstarch, corn syrup, corn sugar, corn oil, dextrins and industrial alcohol. Various types of alcoholic beverages are made from the grain. The stock fibers are used for making paper and yarn, cigarette papers are made from inner husks and the cobs are used for fuel and as a source of charcoal. As a result of recent chemical investigations the stalks, cobs, and other waste from maize bid fair to become important sources of valuable solvents, explosives, and even a gas that can be used for home consumption.

2.3.2 Pulses

Pulses are the chief source of protein to the vegetarian population. Protein is present in the large proportion then carbohydrates and fats. All the pulses belong to the family Leguminosae (Fabaceae). The characteristic feature of this family is the presence of a special kind of fruit, a legume, which is a pod that opens along two sutures when the seeds are ripe. Out of the 11,000 known species of legumes, majority of them have industrial, medicinal, or nutritive value. Legume seeds have low water content and impermeable seed coats which facilitate their storage for long duration. Because of the rich energy content legumes are particularly used in cold weather or by those who take part in rigorous physical work. The immature fruits also serve as a vegetable. Legumes are also used as field and forage crops. When plowed under they are an excellent fertilizer and greatly increase the nitrogenous content of the soil.

Classification: All the species of pulses (Fig 2.1) belong to the family Fabaceae. The tabular representation (Table 2.1) of the different groups of pulses is mentioned below:

Table 2.1: Different groups of most common pulses

Family	Tribe	Genera
Fabaceae	Vicieae	Lentil (*Less esculenta*), Pea (*Pisum sativum*), Chick pea (*Cicer arientum*), Grass pea or Khesari dhal (*Lathyrus sativus*) and Broad or Horse bean (*Vicia faba*)
	Hedysareae	Groundnut (*Arachis hypogaea*)
	Phaseoleae	Soya bean (*Glycine max*), Lablab bean (*Lablab purpureus*), Common beans (*Phaseolus* spp.), Cowpeas (*Vigna unguiculata*), Pigeon pea (*Cajanus cajan*), Horse gram (*Dolichos uniflorus*) and Ground beans (*Voandzeia subterranea*) and minor pulses such as Sword and Jack beans (*Canavalia* spp.)
	Galegeae (Indigofereae)	Cluster bean or Guar (*Cyamopsis tetragonoloba*)

Origin: According to the Chinese literature, the soya bean was cultivated between 3000 and 2000 BC. Legumes also featured in the cropping systems of the early Egyptian dynasties. Pea and lentils were present at various archaeological sites such as Hacilar, Beidha and Jarmo, dating as far back as 7500 to 6500 BC (Helbaek 1966). *Pisum*, *Vicia* and Lens were found at Neolithic sites in Greece (Renfrew 1966). The evidences suggest the domestication of common bean back in 4975 BC in the Tehuacan Valley in Mexico. Fragments of lima bean (*Phaseolus lunatus*) or common bean have been reported in dried human excreta (desiccated faeces or coprolites) in coastal Peru, dating back to 3000 BC. According to Kaplan et al. (1973) the common bean and the lima bean were present in the inter-montane Peruvian Valley, dating to about 6000 BC.

Nutrition: Pulses contain, almost 2-3 times more protein (about 30 % of its dry weight) than cereals, up to 60 % carbohydrates and 1-2 % fat except soya bean having up to 20 % fat. They also have niacin, thiamine, carotene, riboflavin and ascorbic acid. Pulses are rich in calcium and iron. Sprouted legume seeds are a great source of vitamin C.

Production: Pulses are chiefly cultivated in the tropical and subtropical regions of the world. India is the world's largest producer as well as the biggest consumer of legumes. Pulses cover 28170000 ha land area and according to a data published in 2013, produces about 18311200 tones which is about 25 % of the total global production. In India, the top three pulse growing states are Madhya Pradesh, Uttar Pradesh and Rajasthan. Globally, the top three producers are Canada, Myanmar and China.

Uses: Pulses are consumed in different forms e.g. whole or de-husked splits (daal), fried or puffed grain products, fermented preparations, germinated seeds and flour. In India, more than 75 per cent of pulses are consumed as daal (dehusked splits). Sprouted pulse grains are a good source of vitamin C. List of some pulse crops used as food is given in the Table 2.2.
Legumes are also used as fodder because they are rich in proteins and minerals. Some examples of fodder legumes are Alfalfa or Lucerne (*Medicago sativa*), Clovers (*Trifolium* spp.), White clover (*Trifolium repens*), *Acaciella angustissima*, *Leucaena leucocephala*, *Indigofera spicata*, *Acacia aneura*, *A. albida*, *Albizia canescens*, *A. lebbeck*, *Cassia sturtii*, *Brosimum alicastrum* and *Prosopis tamarugo*. List of some fodder legumes is given in Table 2.3.
Legumes are the best manures because they biologically fix atmospheric nitrogen with the help of *Rhizobium* bacteria which lives in their root nodules. Table 2.4 showing List of some common legume species used as manure. After harvesting the crop the remaining green plant is tilled back in to the soil which improves soil fertility, moisture content and nutrient retention. Some commonly used pulses are described in brief.

(A) Pea

The common pea *(Pisum sativum)* is a annual, glaucocus, tendril-bearing, climber with white or coloured flowers and pendulous pods. It is native of Southern Europe and has been cultivated since before the beginning of the Christian era. In India, the pea is grown during winter season in the plains while during summer season in the hills. The global production of pea was 9.8 million tons. Canada (2.8 MT), Russia (1.6 MT), and China (1.1 MT) were the top three roducer of pea globally. India comes at fourth number with the production of 0.62 MT.
There are two type Field Pea and garden pea. Field pea (*P. sativum* ssp. *arvense*) have stipulate with a red spot, pink or purple flower, small pod, small seeds, angular, brownish or grey in colour. It is usuall grown in the fields for the dried seeds and sometime for the forage. Garden Pea (*P. sativum* ssp. *hortense*) have stipulate without a red spot, white flower, large pod, seeds

are large, bluish green in colour, round/smoot/ wrinkled in shaped, rich in sugar. It is more robust but less hardy and is usually grown for green pea.

(B) Chick Pea

The chick pea *(Cicer arietinum)* is a native of Southern Europe, where it is still extensively grown. It is also an important food plant in many parts of Asia, Africa, and Central America. The plant is a branching, bushy annual, which matures in 90 days. It is well adapted to arid and semiarid regions. The chick pea is one of the best legumes for human consumption as the seeds are very nutritious. The sparse foliage is poisonous so the plant cannot be used for forage. The green pods are sometimes eaten, and the seeds are used as a substitute for and as an adulterant of coffee.

(C) Bean

On the basis of origin the bean can be grouped into two broad category: American (New world) and Asiatic (Old world). The new world species had large, flattened pods, large seeds and white to purple flower e.g., common bean, kidney bean or haricot bean (*Phaseolus vulgaris*), lima, butter or sieve bean (*P. lunatus*), tepary bean (*P. acutifolius*) and the scarlet runner bean (*P. coccineus*). The old world species have yellow flowers, cylindrical pods with breaks, seeds are smaller. Some important species of old words are golden gram, green gram or mung (*P. aureus*), black gram (*P. mungo*), adzuki bean (*P. angularis*), rice bean (*P. calcaratus*) and mat bean (*P. aconitifolius*). Beans can also be categorized in two major group: **Dry bean** are eaten either fresh or dried. The top three producers of the dry beans were Myammar (3.8 million tons), India (3.6 million tons) and Brazil (2.9 million tons). In **green beans** the pods and matured seeds are eaten as vegetable. Top producers of green beans are China (16.2 million tons), Indonesia (0.87 million tons) and India (0.62 million tons).

(D) Cowpea

The cowpea *(Vigna sinensis)* in spite of its name is more closely related to the beans than to the peas. It is a vigorous bushy or trailing summer annual, with curious, cylindrical, pendant pods. The plant grows indefinitely as long as the environmental conditions are favorable. The cowpea is a native of Southeastern Asia. The chief value of cow pea is as a forage crop, as a cover crop to prevent erosion, and as a green manure. The cowpea is an important crop in China, India, and the southern United States, where it is increasing in prominence.

(E) Soyabean

The soyabean *(Glycine soja)* is a small, bushy, erect or prostrate annual plant. The soybean is a native of Southeastern Asia, where over 1000 varieties are grown. Manchuria leading in commercial production followed by Korea, Japan, and the Dutch East Indies. It is easily the most important legume in the Far East, where soybeans are used everywhere in the daily diet of the natives to supplement rice. Soybean sauce, made from cooked beans, roasted wheat flour, salt, and ferment, is widely used. The flour, with a low carbohydrate and high protein content, is an excellent food for diabetics. Soybean milk, extracted from the seed, is used in cooking and is recommended for infants and invalids. Soybean oil, an important drying oil.

(F) Peanut

The peanut *(Arachis hypogaea)* is a true legume rather than a nut, for the shuck is merely a shell like pod. The plant is a bushy or creeping annual with the peculiar habit of ripening its fruit underground. As many as 20 kinds of peanuts are grown, differing in habit and the size of the pod. Peanuts require ample warm sunshine and a moderate rainfall. The nuts or seeds are used for roasting or salting, in candy, and for the preparation of peanut butter. Peanuts are a very nutritious food. One lb. yields 2700 cal., whereas 1 lb. of beef furnishes only 900 cal. Peanut oil, is also important food oil.

(G) Lentil

The lentil *(Lens esculenta)* is one of the most ancient of food plants and also one of the most nutritious. It is a native of Southwestern Asia, and was early introduced into Greece and Egypt. The plant is a slender, tufted, much-branched annual with tendrils. The pods are short and broad, with small lens-shaped seeds. The seeds are widely used, chiefly in soups. They are more digestible than meat and are used instead of meat in many Catholic countries during Lent. The plants are somewhat used for fodder.

(H) Cajan Pea

The cajan pea or pigeon pea (*Cajanus cajan*) is one of the most promising legumes at the present time. It was first domesticated in Asia or Africa and is now widely cultivated in the tropics, particularly in the East Indies, India, and the West Indies, where over 30 kinds are grown. The plant is an erect shrub. Both the immature and ripe seeds have been used for human and animal food since earliest time. In recent years the plant has been developed as a forage crop and rivals alfalfa in importance. It is drought resistant, grows well in any soil, matures rapidly, and in many other ways is highly desirable. Livestock and poultry are particularly fond of it.

Table 2.2: List of some pulse crops used as food

S. No	English name	Common Indian name	Botanical name	Centre of Origin
1	Pea	Matar	*Pisum sativum*	Central to Western Asia
2	Chickpea, Gram, Bengal gram, Garbanzos	Arhar	*Cicer arietinum*	Southwest Asia
3	Cluster Bean	Guar ki phalli	*Cyamopsis tetragonoloba*	India
4	Grass pea, Chickling Vetch or Pea, Lathyrus Pea	Khesari dhal	*Lathyrus sativus*	Southern Europe and Western Asia
5	Bean	Moth	*Phaseolus aconitifolius*	India
6	Common bean, French bean, Kidney bean, Haricot beans	Rajma	*Phaseolus vulgaris*	America
7	Black gram, Woolly pyrol	Urd	*Phaseolus mungo*	India
8	Cowpeas	Lubia	*Vigna unguiculata*	Central Africa
9	Winged bean, Princess bean, Goa bean, Asparagus pea, Manila bean	Chaukoni bean	*Psophocarpus tetragonolobus*	Papua New Guinea
10	Lima beans	Sem, Lobia	*Phaseolus lunatus*	Central and South America
11	Scarlet runner beans		*Phaseolus multijlorus*	South America
12	Green gram, Golden gram	Moong	*Phaseolus aureus*	India
13	Cowpea		*Vigna sinensis*	Southeastern Asia
14	Soybean	Soya bean	*Glycine max*	Southeastern Asia
15	Broad bean, Windsor, horse, or Scotch bean		*Vicia faba*	Algeria or Southwestern Asia
16	Peanut	Mungfali	*Arachis hypogaea*	Brazil
17	Lentil	Masoor, Malka	*Lens esculenta*	Southwestern Asia
18	Cajan pea, Pigeon pea, Congo pea or Red gram	Arhar	*Cajanus cajan*	Africa
19	Lablab or bonavist bean	Sem	*Dolichos lablab*	Asia

Table 2.3: List of some fodder legumes

S. No.	English name	Botanical name
1	Horse beans or Jack beans	*Canavalia ensiformis*
2	Velvet bean	*Stizolobium deeringianum*
3	Kudzu bean	*Pueraria thunbergiana*
4	Kidney Vetch	*Anthyllis vulneraria*
5	Crown Vetch	*Coronilla varia*
6	Lucerne, Alfalfa	*Medicago sativa*
7	Black Medic, Yellow Trefoil	*Medicago lupulina*
8	White Sweet Clover	*Melilotus albus*
9	Yellow Sweet Clover	*Melilotus officinalis*
10	Sainfoin	*Onobrychis vicifolia*
11	French Serradella	*Ornithopus sativus*
12	Red Clover	*Trifolium pretense*
13	Persian Clover (shaftal)	*Trifolium resupinatum*
14	White Clover	*Trifolium repens*
15	Strawberry Clover	*Trifolium fragiferum*
16	Egyptian Clover or Berseem	*Trifolium alexandrinum*
17	Alsike Clover	*Trifolium hybridum*
18	Crimson Clover	*Trifolium incarnatum*
19	Subterranean Clover	*Trifolium subterraneum*
21	Yellow Sulking Clover	*Trifolium dubium*
22	Broad Bean	*Vicia faba*
23	Bitter Vetch	*Vicia ervilia*
24	Spring Vetch or Common Vetch	*Vicia sativa*
25	Purple Vetch	*Vicia atropurpurea*
26	Hungarian Vetch	*Vicia pannonika*
27	Hairy Vetch	*Vicia villosa*
28	White Lupin	*Lupinus albus*
29	Yellow Lupin	*Lupinus luteus*
30	Blue Lupin	*Lupinus angustifolius*
31	Cowpea (Lobia)	*Vigna unguiculata*
32	Fenugreek (Methi)	*Trigonella foenum-graecum*
33	Butterfly Pea	*Centrosema plumeieri*
34	Sesban	*Sesbania sesban*
35	Florida Beggerweed	*Desmodium tortuosum*
36	Hetero Desmodium	*Desmodium heterophyllum*

37	White Popinac	*Leucaena leucocephala*
38	Velvet Bean, Bengal Bean	*Mucuna deeringiana*
39	Indigo	*Indigoferra arrecta*, *Indigoferra paucifolia*
40	Macroptilium, Purple Bean	*Macroptilium atropurpureum, Macroptilium geophilum*
41	Kudzu Vine	*Pueraria lobata*
42	Tropical Kudzu	*Pueraria phaseoloides*
43	Brazilian Lucerne, Stylo	*Stylosanthes guianensis*
44	Cluster Bean (guar)	*Cyamopsis tetragonoloba*
45	Sunhemp	*Crotolaria juncea*
46	Pillipesara	*Phaseolus trilobus*
47	Mat or Moth Bean	*Phaseolus aconitifolius*
48	Indian Clover or Senji	*Melilotus parviflora*

Table 2.4: List of some legume species used as manure

S. No.	English name	Botanical name
1	Dhaincha	*Sesbania* speciosa, Sesbania *bispinosa*
2	Sunhemp	*Crotalaria juncea*
3	Wild Indigo or Purple Indigo	*Tephosia purpurea*, *Tephosia noctiflora*
4	Bengal Indigo, Common Indigo	*Indigofera tinctoria*
5	Pillipesara	*Phaeseolus trilobatus*
6	Cluster Bean or Guar	*Cyamopsis tetragonoloba*
7	Spotted Gliricidia or Madre tree	*Ipomoea carnea*
8	Tanner’s Cassia	*Cassia auriculata*
9	White Gold Mohur	*Delonix elata*
10	Karanj or Indian Beech	*Pongamia pinnata*
11	Portia Tree or Indian Tulip Tree	*Thespesia populnea*
12	Neem Tree or Margosa Tree	*Azadirachta indica*
13	Horse Tamarind	*Leucaena leucocephalum*
14	Morinda	*Morinda tinctoria*
15	Indian Ash Tree	*Lannea coromandelica*
16	Giant Sunhemp	*Crotolaria mucronata*
17	Negundo or Chinese Chaste Tree	*Vitex negundo*
18	Agati Sesbania	*Sesbania grandiflora*

2.3.3 Millets

Millets are a group of highly variable small-seeded grasses, widely grown around the world as crops or grains for fodder and human food. Millets are important crops in the semiarid tropics of Asia and Africa (especially in India, Mali, Nigeria, and Niger), with 97% of millet production in developing countries. The crop is favored due to its productivity and short growing season under dry, high-temperature conditions. Millets are indigenous to many parts of the world. The most widely grown millet is pearl millet, which is an important crop in India and parts of Africa. Finger millet, proso millet, and foxtail millet are also important crop species. Millets may have been consumed by humans for about 7,000 years and potentially had "a pivotal role in the rise of multi-crop agriculture and settled farming societies.

(A) Pearl Millet (Bajra)

Botanical Name: *Pennisetum typhoides*

It is a tall plant (6-15 ft.), with 3-8 compact cylindrical spikes that bear white grains. It is grown in India, Egypt, and Africa in rainy-season. It is an important food source for the lower classes, and especially used in cold weather because of its heating qualities. The flour is very nutritious and used for making bread or cake. It has an enormous yield of forage, which is succulent when young, and it can be cut several times in a season.

(B) Finger Millet (Rahi, Madua)

Botanical Name: *Elusine corocana*

It is a tall plant with tufted stems, each with 4-6 spikes. It is grown from Dutch Malaya to Northern Africa. It is a very high yielding crop, needs no added fertilizers to the soil. It is one of the major crops in India, particularly during the rainy season, and is an important food. The grain is free from insects and can be stored for a long time. Its flour is used for puddings and cakes, and grain is used to make a local fermented beverage.

(C) Barnyard Millet/ Himalayan Millet (Madira)

Botanical Name: *Echinochloa frumentacea*

It is herbaceous annual with spares tillers, height 60-120 cm, roots fibrous and shallow, stem slender, leaves flat, glabrous or slightly hairy, inflorescence panicle with densely crowded unawned spikelets, fruit caryopsis, color of the grain is generally yellow or white. It is a very drought resistant plant but generally grown as a rainfed crop. Its grains are used in making pudding (kheer), sometimes in making beer and also as feed for cage birds. The straw of Himalayan millet is used as fodder for cattle.

Grains are the very important component of the human diet as well as for the animal as the fodder. Table 2.5 showing some of the major grain crops of the world, their centre of origin and their uses in daily life. Some most commonly used vegetables are discuss in brief.

Table 2.5: Some of the major grain crops of the world

S. No.	English name	Common Indian name	Botanical name	Family	Type of fruit	Centre of Origin
1	Common Wheat	Gehun	*Triticum aestivum* subsp. *aestivum*	Poaceae	Caryopsis	Western Asia
	Food Value: Produced in majority worldwide (95%), usually high in gluten and consumed as grounding flour in bakeries.					
2	Club Wheat		*T. aestivum* subsp. *compactum*	Poaceae	Caryopsis	Syria
	Food Value: Similar enough to common wheat, grown in Pacific northwest. Alternative of common wheat.					
3	Durum wheat (Semolina)	Rava/sooji	*T. durum*	Poaceae	Caryopsis	Central Europe
	Food Value: Used to produce dry pasta, making Upma, and couscous. Gluten is relatively less than other wheat species.					
4	Spelt/hulled/dinkel wheat	-	*T. spelta*	Poaceae	Caryopsis	Transcaucasia (North east of Black-Sea)
	Food Value: Important source of carbohydrates, protein, and fiber. Lesser gluten than common wheat.					
5	Emmer/Awned wheat	Khapali Gehun	*T. dicoccon*	Poaceae	Caryopsis	Old Mesopotamia
	Food Value: Used in bakeries. Popular as *farro* food in Italy. Grown in Deccan's of India for its possible value for Diabetics.					
6	Wild Emmer	-	*T. dicoccoides*	Poaceae	Caryopsis	Middle-East (Modern day Israel to Iran)
	Food Value: Popular human food, rich in nutrients and used as fodder also.					
7	Polish Wheat	-	*T. polonicum*	Poaceae	Caryopsis	Mediterranean region
	Food Value: High in Gluten and used to make Macaroni.					
8	Persian Wheat	-	*T. carthlicum*	Poaceae	Caryopsis	Iran
	Food Value: Usually ground into flour and used as cereal. Not suitable for bakeries.					
9	Macha Wheat	-	*T. aestivum* subsp. *macha*	Poaceae	Caryopsis	Caucasus region (Georgia)
	Food Value: Rich in protein. Suitable for bread making.					
10	Vavilov Wheat	-	*T. aestivum* subsp. *vavilovi*	Poaceae	Caryopsis	Southwest Asia
	Food Value:					

11	Shot Wheat	Indian dwarf wheat	*T. aestivum* subsp. *sphacrococcum*	Poaceae	Caryopsis	Indian subcontinent
	Food Value: Relatively high in protein content than common wheat.					
12	Oriental Wheat	Kamut	*T. turanicum*	Poaceae	Caryopsis	Iran and Afghanistan
	Food Value: Same as common wheat.					
13	Timopheevi Wheat	-	*T. timopheevii*	Poaceae	Caryopsis	South eastern turkey
	Food Value:					
14	Einkorn/little spelt	Dalia	*T. monococcum*	Poaceae	Caryopsis	Hills of Antolia and Balkans and turkey
	Food Value: Rich in fiber and proteins, low gluten. Used in making bulgur.					
15	Wild Einkorn	-	*T. boeotictim*	Poaceae	Caryopsis	Syria
	Food Value:					
16	Maize	Makka	*Zea mays*	Poaceae	Caryopsis	Mexico
	Food Value: Consumed as most apt human food. Such as: sweet corn, toasted corn, dried corn. Corn flakes are a common breakfast cereal in most parts of the world especially North America.					
17	Rice	Chawal	*Oryza sativa*	Poaceae	Caryopsis	India or China
	Food Value: Rice is a very important staple food for a large segment of the world population.					
18	Barley	Jau	*Hordeum vulgare*	Poaceae	Caryopsis	Western Asia
	Food Value: Source of dietary fiber and minerals. Used in making bears.					
19	Oat	Jai	*Avena sativa*	Poaceae	Caryopsis	Middle East
	Food Value: Rich in antioxidants. Contains powerful soluble fiber called beta glucan.					
20	Sorghum/broom cron	Jowar/durra	*Sorghum vulgare*	Poaceae	Caryopsis	East Africa
	Food Value: Consumed as flatbreads/rotis. Enriched with iron, protein, fiber. This can help reduce cholesterol.					
21	Pearl millet	Bajra	*Pennisetum typhoides*	Poaceae	Caryopsis	Northern- central sahel in West Africa
	Food Value: Iron content 8 times higher than rice. Rich in fiber so that can help attain weight loss.					
22	Finger millet	Ragi, Madua	*Eleusine coracana*	Poaceae	Caryopsis	Highlands of east Africa

	Food Value: This gluten free millet is good for brain development in growing kids. Ragi is a powerhouse of nutrition.					
23	Proso or Common millet	-	*Panicum miliaceum*	Poaceae	Caryopsis	China
	Food Value: It is low glycemic index has made it a fad among weight watchers. It is a common bird feed also.					
24	Foxtail millet	Thinai/kangani	*Setaria italic*	Poaceae	Caryopsis	China
	Food Value: Good for immunity. Available in form of Semolina and rice flour.					
25	Teff	-	*Eragrostis tef*	Poaceae	Caryopsis	Ethiopia
	Food Value: Teff provides two third portion of daily protein intake around African continent.					
26	White fonio	-	*Digitaria exilis*	Poaceae	Caryopsis	West Africa
	Food Value: Gluten free and high in dietary fiber. Seeds are used in making of porridge and couscous.					
27	Black fonio	-	*Digitaria iburua*	Poaceae	Caryopsis	West Africa
	Food Value: Rich in fibers.					
28	Guinea millet	-	*Brachiaria deflexa*	Poaceae	Caryopsis	Guinea (West Africa)
	Food Value: World's most obscurely cultivated crop. High in fiber and minerals.					
29	Himalayan millet	Jhangora/madira	*Echinochloa frumentacea*	Poaceae	Caryopsis	Central Asia
	Food Value: High fiber content, which can help in losing weight. Good replacement of rice. Good for healthy bones.					
30	Little millet	Kutki/shavan saamai	*Panicum sumatrense*	Poaceae	Caryopsis	Temaprate zones of Asia
	Food Value: Packed with a goodness of vitamin B and minerals. High content of fiber. Help in weight loss.					
31	Kodo millet/cow grass/Indian crown grass	Varagu/kodra	*Paspalum scrobiculatum*	Poaceae	Caryopsis	Tropical Africa
	Food Value: Easy to digest and rich in photochemicals and antioxidants.					
32	Job's tears	Samkru/Ranmaka/gurlu	*Coix lachryma-jobi*	Poaceae	Caryopsis	Southeast Asia
	Food Value: High in carbohydrates, protein, mineral ions and fibers. Low in fat.					

2.3.4 Vegetables

The dictionary meaning of the term vegetable is edible seeds, roots, stems, leaves, bulbs, tubers or non-sweet fruits of any of numerous herbaceous plant. Vegetables are a vital part of the human diet worldwide especially in the tropical areas. They are the main source of essential vitamins and minerals. Vegetables are significant because they grow rapidly and produce a maximum quantity of food for the area planted.

The food value of vegetables, especially leafy and fruit vegetables is low because of the presence of large amount of water. Root crops, however, contain large amounts of carbohydrates but are poor in proteins and oils, and rank next to cereals as a source of a carbohydrate food. Grain legumes differ from other vegetables owing to the large amount of proteins they contain and are familiarly known as 'poor man's meat'. Soya bean is a valuable article of human diet, being rich sources of oil as well as proteins.

Carotene, a precursor of vitamin A, is abundant in several vegetables, such as carrots, sweet potatoes, spinach, lettuce, amaranths, kale, turnip greens, muskmelon and watermelon. It is also found in raw tomatoes, cabbage and green peppers. Vitamin C is abundant in many vegetables, such as broccoli, lettuce, tomatoes, peppers, potatoes, cabbage, cucumber, bitter gourd and onion, especially when they are uncooked. Thiamine, niacin and riboflavin occur in succulent vegetables and legumes. Green vegetables have vitamin E and the quantity of vitamin E in leafy vegetables increases with their greenness.

Potato, sweet potato and onion contain phosphorus; Spinach, beans, lettuce, onions, tomatoes and head cabbage, cauliflower and broccoli contain Calcium; Soya bean, spinach, peas, chillies, radish, garlic, beans and tomato have iron; Onion, okra and asparagus contain iodine; legumes contain more iron, calcium and potassium salts.

Classification of Vegetables: On the basis of part of the plant used as vegetable they can be classified as root crops, leafy vegetables and fruit vegetables (Table 2.6).

Table 2.6: Classification of the vegetables according to their parts uses

S. No.	Part of the plant used	Name of the vegetable
1	Bracts and thickened receptacle	Globe artichoke
2	Buds	Brussels sprouts
3	Bulbs	Onion and garlic
4	Corm	Taro
5	Flower stalk and buds	Broccoli and cauliflower
6	Leafstalk or petiole	Celery, rhubarb and Swiss chard
7	Leaves	Spinach, lettuce, cabbage, parsley and chive
8	Mature fruits	Tomato and pepper
9	Petals	*Yucca* and pumpkins

10	Root	Radish, carrot, turnip, sweet potato, cassava and beet root
11	Seeds	Beans, pea and lentil
12	Stem tubers	Potato and yams
13	Stems	Kohlrabi, asparagus and bamboo
14	Young fruits	Eggplant, cucumber and sweet corn

(A) Potato

Botanical Name: *Solanum tuberosum*

Characteristic Features: It is an erect, branching, more or less spreading annual from 2-3 ft. in height. It has pinnately compound leaves, fine fibrous roots, and numerous rhizomes which are swollen at the tip to form the familiar tubers. The flowers are white, yellow, or purple, with a tubular corolla, while the fruit is a small brownish-green or purple inedible berry.

History and Origin: It is a native American species and was cultivated from Chili to New Granada at the time the Spanish explorers reached this continent. The potato was introduced into Europe soon after 1580 by the Spaniards, and by the end of the seventeenth century it had spread all over Europe and the British Isles. The potato was first introduced into New England by Irish immigrants in 1719.

Cultivation: Potatoes are adapted to many soils and many climates. They are grown all world over except in 1ow tropical regions. They are hardy and mature rapidly. The optimum temperature for potato cultivation ranges between 40-50 °F and optimum soil is a rich light soil. Potatoes are usually propagated vegetatively by means of tubers, or parts of tubers, the so-called seed potatoes. Pieces of the tubers are cut at right angles to the main axis so as to remove the inhibiting effect of the terminal bud. The tubers have a rest period of several weeks.

Production: Potatoes are grown more universally than any other crop. Around 9 per cent of the global potato production is grown in Europe. The commercial production of potatoes is being done in Long Island, New York, southern New Jersey, Pennsylvania, and the eastern shore of Maryland. Other important states are Minnesota, New York, Michigan, Wisconsin, Pennsylvania, and Idaho.

Uses: Potato is eaten as boiled, steamed, fried, baked or roasted. Potato chips are a world famous snack. Various culture media for the growth of microorganisms are made of potato. Numerous commercial products namely starch, alcohols, glucose, lactic acid, etc. are also made from potato. Fermented cooked potatoes are also used in making Vodka.

(B) Onion

Botanical Name: *Allium cepa*

Characteristics Features: Onion is a biennial crop; root shallow and fibrous; leaf consists of a sheathing leaf base and a hollow, linear, cylindrical or flattened blade and ligule; bulb consists of a short, plate-like stem surrounded by a number of concentric layers of fleshy leaf bases. The outer leaf bases are thin, fibrous and dry, forming a protective covering or 'tunic' around the inner fleshy ones, which are laden with food. The innermost leaves also have thickened leaf bases but with an aborted lamina. Intact onions are odourless, the odour comes after cutting or because of some injury to the bulb when organic sulphur compounds (mostly n-propyl disulphide) get released.

Origin: Onion is believed to have originated from the eastern Mediterranean region, including Iran, Pakistan and the mountainous countries to the North. No wild varieties are known. Pictures carved on Egyptian monuments prove that onions were cultivated in Egypt at least 4800 years ago.

Cultivation: It is grown in the colder parts of temperate regions. It grows best on sandy or silt loam soil with a pH ranging 5.8-6.5. A comparatively high temperature is needed for bulb formation.

Uses: Onion is used in culinary practices in various ways. Bulbs (immature and mature) are eaten raw as a salad. Onions are extensively used for flavoring soups, ketchups, canned meat products, sausages, sauces, stews, curries and a great variety of other savoury dishes.

(C) Tomato

Botanical Name: *Lycopersicon esculentum*

Characteristics Features: It is a branched and short-lived perennial plant but from agricultural point of view it is considered as annual. Branching is monopodial at the base of the stem and sympodial towards the apex. Small glandular hairs cover the stem, petiole and peduncle. Imparipinnate compound leaves spirally arranged with lobed margins. The ovary is 6-20 chambered because of the false septa. Fruits are berries. The red color of tomato fruit is because of the presence of two pigments carotene and lycopersicin (lycopene).

History and Origin: It is a native of Peru and Ecuador. In pre-Columbian times tomato spread to Mexico and after that from Mexico to Europe in 1523 and from there to across the Pacific into South East Asia. Initially, it was grown mainly as an ornamental crop and called as 'object of affection'. Before the 19^{th} century Italy was the only tomato consuming nation after the second half of the nineteenth century tomatoes were started being cultivated widely.

Production: Worldwide production of tomatoes was around 162.7 million tons in 2012. Three greatest producers are China about 50.5 MT, India (17.5 MT) and US (13.2 MT). Some other producing nations were Turkey, Egypt, Iran, Italy, Spain, Brazil, and Mexico.

Cultivation: The seeds are first sown in a nursery and then transplanted into the field. The plants are sensitive to frost. Tomatoes can be grown anywhere globally and except colder regions, in colder areas tomatoes are grown in glasshouses.

Uses: It is widely used as salads and in making of tomato soups, pickles (green tomatoes), ketchups, sauces and other products. Its seeds are used in making semi-drying oil which is used as a salad oil and also in the manufacture of margarine and soap. The residual mass or "press" cake' is employed as stock feed and fertilizer.

2.4 FRUITS

Before the Humans started agriculture they were partly dependent on fruits. At that time fruits were, and still are, the easily available source of minerals, organic acids, vitamins, pigments and tannins. Fruits have high water content but they are low in proteins and fats.

Classification of fruits: The classification of fruits has been performed on numerous criteria but these two criteria are the most common, which are being mentioned below:

1) Number of ovaries involved in fruit formation
2) Climatic adaptability

1) Number of ovaries involved in fruit formation: According to this criterion fruits can be categorized into three groups:

a) **Simple fruits:** This class of fruits is derived from a single ovary of one flower.
b) **Aggregate fruits:** This class of fruits is derived from numerous ovaries of the same flower. The individual ripened ovaries may form a drupe (e.g. blackberries, raspberries) or an achene (e.g. buttercups) etc.
c) **Multiple fruits:** This class of fruits is derived from the ripened ovaries of several flowers crowded on the same inflorescence.

2) Climatic adaptability: According to this criterion fruits can be categorized into three groups:

a) Temperate: These fruits are deciduous and require a period of cold.
b) Subtropical: They are either deciduous or evergreen, and are usually able to withstand a light frost.

c) **Tropical:** These are evergreen and extremely sensitive to low temperatures.

In 2012 it was reported that China is the leading country (139,680,899 tones) in the production of fruit crops, followed by India (71,072,580 tones) and Brazil (38,368,678 tones). Some most common and frequently consumed fruits are being mentioned in detail below. However, a comprehensive list of some of the major fruit crops of the world is given in Table 2.7.

Table 2.7: Some of the major fruit crops of the world

S. No.	English name	Common Indian name	Botanical name	Family	Types of fruit	Centre of Origin	Edible Part
1	Grapes	Angoor	*Vitis vinifera*	Vitaceae	Berry	West Asia	Fruit wall/Pericarp and Placenta
	Food Value: Eaten fresh as table grapes. Used for making wine, jam, juice and jelly. Good source of fibers and mineral ions.						
2	Banana	Kela	*Musa paradisiaca*	Musaceae	Berry	Southeast Asia	Mesocarp and endocarp
	Food Value: Cholesterol and fat free. Rich in mineral ion and dietary fiber.						
3	Orange	Malta	*Citrus sinensis*	Rutaceae	Hesperdium	Southeast Asia, China	Mesocarp or pulp
	Food Value: Eaten fresh as raw fruit. Great source of vitamin C.						
4	Mandarin orange	Narangi	*Citrus reticulata*	Rutaceae	Hesperdium	Southeast Asia, China	Mesocarp or pulp
	Food Value: Eaten fresh as raw fruit.						
6	Apple	Seb	*Malus domestica*	Rosaceae	Pome	Central Asia	Hypanthium layer
	Food Value: High in fiber and vitamin C. Rich in antioxidant.						
7	Mango	Aam	*Mangifera indica*	Anacardiaceae	Drupe	East Asia	Mesocarp
	Food Value: King of fruits. Very high in carbohydrates and all Vitamins.						
8	Olive	Jaitoon	*Olea europaea*	Oleaceae	Berry	Mediterranean basin	Fleshy mesocarp
	Food Value: High in good fat. Rich in antioxidant.						
9	Pear	Nashpati	*Pyrus communis*	Rosaceae	Pome	Central Asia	Flashy thalamus
	Food Value: Contain high amount of water. Decent amount if vitamins and minerals.						
10	Peach	Aaru	*Prunus persica*	Rosaceae	Drupe	China	Fleshy exterior and mesocarp
	Food Value: Rich in antioxidants. Improves digestion and heart's health.						
11	Plum and prune	Pulam	*Prunus domestica*	Rosaceae	Drupe	Europe	Pericarp and fleshy

							mesocarp
	Food Value: Rich in polyphenols and help protect against bone loss.						
12	Pineapple	Ananas	*Ananas comosus*	Bromeliaceae	Sorosis	Brazil	Exterior rachis, bracts, Rind (core)
	Food Value: Improves digestion and helps in making bones strong.						
13	Lemon	Nimboo	*Citrus limon*	Rutaceae	Hesperdium	Southeast Asia, China	Mesocarp or pulp
	Food Value: High concentration of citric acid.						
14	Lime	Chota Nimbu	*Citrus aurantifolia*	Rutaceae	Hesperdium	Southeast Asia, China	Mesocarp or pulp
	Food Value: Used as flavoring agent in various drinks.						
15	Grapefruit	Chakotra	*Citrus paradisi*	Rutaceae	Hesperdium	South Asia	Mesocarp or pulp
	Food Value: Rich in polyphenols, flavanoids and vitamin C.						
16	Pummelo	Chakotra	*Citrus grandis*	Rutaceae	Hesperdium	South Asia	Mesocarp or pulp
	Food Value: Good source of flavanoids.						
17	Dates	Khajoor	*Pheonix dactylifera*	Arecaceae	Drupe	Southern Mediterranean basin	Mesocarp
	Food Value: High content of carbohydrates.						
18	Cherry (Sweet)	-	*Prunus avium*	Rosaceae	Drupe	Central Europe and West Asia	Mesocarp
	Food Value: Good source of vitamin A and C.						
19	Cherry (Sour)	-	*Prunus cerasus*	Rosaceae	Drupe	West Asia	Mesocarp
	Food Value: Slightly better nutritional profile than sweet one.						
20	Cacao	-	*Theobroma cacao*	Sterculiaceae	Berry	Amazon Basin (South America)	Dried pulp or mesocarp

	Food Value: Contains fibers, protein, and healthy fats. Rich in mineral ions.						
21	Strawberry	-	*Fragaria* spp.	Rosaceae	Etaerio of Achene	America	Fleshy receptacle
	Food Value: Source of vitamin C. Helps in weight management and maintaining healthy skin.						
22	Apricot	Khubani	*Prunus armeniaca*	Rosaceae	Drupe	Central and East Asia	Pericarp and fleshy mesocarp
	Food Value: Good source of vitamin A and C.						
23	Passion fruit	-	*Passiflora edulis*	Passifloraceae	Pepo	Brazil	Endocarp and partially mesocarp
	Food Value: Rich in vitamin A, B, C. Reduces anxiety and stress. Contains iron, antioxidants, and fibers.						
24	Raspberry	Hisaalu	*Rubus ellipticus*	Rosaceae	Etaerio of berries	Europe, America	Complete fruit
	Food Value: Rich in antioxidants. Good for bones.						
25	Cranberry	-	*Vaccinium macrocarpon*	Ericaceae	Berry	Eastern United States	Pericarp and placenta
	Food Value: High in fiber, prevents tooth decay and treats urinary tract infections.						
26	Sapodila or sapota	Chiku	*Achras sapota* L.	Sapotaceae	Berry	Tropical America	Mesocarp
	Food Value: Storehouse of vitamin A, C, E. Great for skin health and have amazing moisturizing properties.						
27	Cherimoya	Hanumanphal	*Annona cherimola*	Annonaceae	Aggregation of berries	Andes of Peru and Ecuador	Mesocarp
	Food Value: Sweet, juicy and very fragrant. Used in making of ice cream and custard. Rich in potassium and magnesium so that it can help to reduce blood pressure.						
28	Sweetsop, Sugar apple	Sharifa/ sitaphal	*Annona squamosa*	Annonaceae	Aggregation of berries	South America and West Indies	Mesocarp
	Food Value: Contain anti-oxidant. Rich source of Vitamin A and C.						
29	Breadfruit	-	*Artocarpus altilis*	Moraceae	Multiple	East Indies	Pulpy mesocarp

					fruit		
	Food Value: It can be dried, and ground into flour for later use. Seeds are edible after cooking. Used in arthritis, asthma, and back pain.						
30	Jackfruit	Kathal	*Artocarpus heterophyllus*	Moraceae	Sorosis	Malaya	Bract, perianth, and seeds.
	Food Value: High in carbohydrates and other mineral ions. Low in fat.						
31	Papaya	Papita	*Carica papaya*	Caricaceae	Berry	West Indies or Mexico	Mesocarp
	Food Value: Low in sugars and rich in vitamin C.						
32	Watermelon	Hadwana tarbooz	*Citrullus lanatus*	Cucurbitaceae	Berry (Pepo)	Tropical Africa	Inner pericarp and mesocarp fused with endocarp.
	Food Value: Water content is 91.5%. Helps in retaining hydration.						
33	Muskmelon	Kharbuza	*Cucumis melo*	Cucurbitaceae	Pepo	India	Mesocarp
	Food Value: Good source of potassium especially.						
34	Fig	Anjeer	*Ficus carica*	Moraceae	Syconus	West Asia	Flashy receptacle
	Food Value: Lowers cholesterol and control blood sugar level. Good source of calcium so that can ward of osteoporosis.						
35	Mangosteen	Mangustan	*Garcinia mangostana*	Clausiaceae	Berry	Malaya	Mesocarp
	Food Value: Rich in antioxidants. Support blood sugar control.						
36	Phalsa	Phalsa	*Grewia asiatica*	Tiliaceae	Drupe	India	
	Food Value: One can consume phalsa by blending them with sugar and lime.						
37	Litchi	Litchi	*Litchi chinensis*	Sapindaceae	Berry	China	Aril
	Food Value: Rich in vitamin c and carbohydrates. Consumed raw or in form of juice.						
38	Mullberry	Shahtoot	*Morus alba*	Moraceae	Sorosis	China	
	Food Value: Rich in vitamins. Low level of fat and carbohydrates. Help to reduce blood sugar level.						
39	Avocado	-	*Persea americana* Mill.	Lauraceae	Berry	Mexico or South	Fleshy inner pericarp and mesocarp.

						America	
	Food Value: Contains low carbohydrates and high in good fat. Avocado oil is highly conducive.						
40	Guava	Amrood	*Psidium guajava*	Myrtaceae	Berry	Tropical America	Pericarp and placenta
	Food Value: Rich in vitamin C.						
41	Pomegranate	Annar	*Punica granatum*	Punicaceae	Balausta berry	Iran	Seeds
	Food Value: High in fiber, vitamins and minerals.						
42	Jambolan	Jamun	*Syzygium cumini*	Myrtaceae	Berry	East Indies	Pericarp and mesocarp
	Food Value: Incredible source of vitamin B and C. Good for stomach.						
43	Jujube	Ber	*Zizyphus mauritiana*	Rhamnaceae	Drupe	China	Peicarp and mesocarp
	Food Value: Anti bacterial and anti inflammatory. Contraceptive properties.						
44	Kiwifruit	-	*Actinidia delicious*	Actinidiaceae	Berry	China	Inner pericarp, mesocarp, and endocarp along with seeds.
	Food Value: Kiwi fruit is rich in fiber so can help in better digestion. Rich in vitamin C, E and K.						
45	Coconut	Nariyal	*Cocus nucifera*	Arecaceae	Drupe	Southeast Asia	Seed and endosperm
	Food Value: Coconut flesh is high in vitamins and rich in fibers. Coconut water consumption is also conducive.						
46	Aegle	Bel	*Aegle marmelos*	Rutaceae	Amphisarca	Indian subcontinent	Inner pericarp and fleshy placenta
	Food Value: Consumed raw and by making juice. Beneficial in diabetes and high cholesterol.						

(A) Apple

Botanical Name: *Malus domestica*

Characteristics Features: It is a low spreading and long-lived tree; leaves simple, dull green; flowers in terminal umbel like cymes, usually borne on spurs. Flowers have five sepals, five petals, numerous stamens arranged in three whorls and a pentacarpellary, five-styled inferior ovary. Tree possesses pale green foliage and pinkish-white bloom. The fruit is a pome and also a false fruit.

Apples are classified on the basis of their time of maturation (summer, winter or autumn), color, size and flavour, etc. into four broad categories like cooking apples, eating apples, cider apples and drying apples.

History and Origin: Apple is believed to have originated in the Caucasus Mountains of western Asia. Remains of apple fruits and seeds have been found in the ruins of prehistoric lake dwellings in Switzerland. Neolithic finds in central Europe include the remains of sliced dry apples, indicating that even then they were used as dried fruits or stored for the winter.

Cultivation: It is a cold season crop. It requires an annual rainfall of 60-75 cm and temperature ranging between -2 to 6°C for 2-3 months. Apples grow best on fertile, well-aerated moist soil with lime in traces. In orchards apples are propagated by grafting or clonally propagated.

Production: Washington, New York, Pennsylvania, California, Virginia, Michigan, Ohio, and Oregon lead in production in the order named. Canada is also a large producer.
In 1935, 168,465,000 bu. were grown in the United States, about half of which were consumed locally.

Uses: It is mostly consumed as fresh fruit but also used in processed form such as apple butter, jelly, canned apple sauce and apple juice (sweet cider). Sweet cider can be further fermented with controlled bacterial inoculation to an alcoholic product (hard cider) or into acetic acid (vinegar). The byproduct of cider press (apple pomace) is a commercial source of pectin, which is used in the preparation of jellies, jams and marmalades. *Murabba* (an Indian preserved food) is also made from apple and considered as a stimulant for the heart. Apple is the only fruit with a world famous saying that ‘an apple a day keeps the doctor away’.

(B) Banana

Botanical Name: *Musa paradisiaca*

Characteristics Features: It is herbaceous plant however it has treelike appearance. The stem is composed of the sheathing spiral leaf bases. Leaves are about 4 ft. in length and 1 ft. in width, with a prominent midrib. Inflorescence consists of clustered flowers which are nearly surrounded by large, fleshy, reddish, spathelike scales, which drop off as the fruits mature. These drooping inflorescences develop into the familiar "bunches" of bananas. The fruit is a modified berry and lacks seeds. After one harvest the tree is cut down, and suckers develop from the rhizome, which give rise to new plants. Banana trees have very rapid growth and are very high yielding depending on the locality and other climatic factors.

History and Origin: Banana is originated in the humid tropical regions of South East Asia. It spread across the islands of the South Pacific at a very early date. According to the Arab legends, banana plant is the tree of paradise. The impact of the legend reflects in the naming of the fruit as *Musa paradisiaca.* Banana was first referred in ancient Hindu writings and epics dating as far back as 500 BC.

Production: About 101.9 million tons of banana were produced worldwide, and India's contribution was about 24.8 million tons, followed by China (10.8 MT), the Philippines (9.2 MT) and Ecuador (7.0 MT) – all together producing almost 50 per cent of the world total. The other major producing countries, in the order of importance, were Brazil (6.9 MT), Indonesia (6.1 MT), Angola (2.9 MT), Guatemala (2.7 MT) and Tanzania (2.5 MT).

Cultivation: It can be grown in almost all warm regions of the globe however the ideal conditions for cultivation is tropical lowlands. It grows best in rich alluvial soil with a pH ranging between 4.5-7.5. For banana cultivation 100-250 cm rainfall and 27^0C average temperature is best amd the plantation should be protected against heavy winds.

Uses: Ripe banana is the best and instant source of energy and contains various mineral salts, vitamins and a high percentage of carbohydrates with a little oil and protein. It is consumed as raw fruit and various products are made from it such as banana purée and banana chips and banana figs. Banana on fermentation gives alcohol and vinegar. In some regions of southeastern Asia, the male buds, after removal of the fibrous outer bracts, are eaten as a boiled vegetable. Even the inner core of the pseudostem is cooked as a curry in the banana growing areas. Ingestion of banana peel or smoking dried peel is reported to induce hallucinations. These effects are known to be caused by 5-hydroxytryptamine (5-HT).

(C) Mango

Botanical Name: *Mangifera indica*

Characteristics Features: Mango is an evergreen plant with a height of about 90 ft. It has large panicles of small pink colored flowers. The fruit is a fleshy drupe with a thick yellowish-red skin and a large seed. The fruit comes in various size, shape, and quality. The pulp of the fruit is orange or yellow in color, and in ripened state it has a rich, luscious, aromatic flavor with a perfect blending of sweetness and acidity. Unripe fruits are fibrous and very acidic in nature.

History and Origin: It is the native of South East Asia and has been cultivated in India for more than 4000 years. It holds an important place in Hindu mythology, religion, ritual and customs. Garlands of mango leaves are tied on doors as decoration in almost all Hindu festivals. By 10^{th} century AD Persians brought mango into East Africa from South East Asia. Around 1700 Portuguese brought it to Brazil and Tropical Africa from India and then from Brazil to West Indies and from there to Mexico in 1800s.

Production: In 2011, India was reported the largest producer of mangoes with a production of 15.2 million tons, followed by China (4.3 million tons), Thailand (2.6 MT), Indonesia (2.1 MT), Pakistan (1.88 MT), Mexico (1.82 MT), Brazil (1.2 MT). The top mango exporting nations were Mexico, Philippines, Pakistan, Brazil, and India. The biggest importer was America with 43 per cent, followed by China with 10 per cent of global production.

Cultivation: Mangoes are cultivated allover India except the colder areas. It grows best in well-drained soils with a pH 5.5 - 6.0. The optimum average temperature for mango cultivation is 24-27 °C and an annual rainfall of 75-190 cm is required.

Uses: The ripe mangoes are consumed as dessert fruit and also used to make jams, jellies and squash. Mangoes are also used in making pickles, *chutneys*, *aam panna*, *aam papad* and *amchur*. Even the kernel inside the stone is roasted, powdered and then cooked into gruel.

2.5 NUTS

In terms of botany, nut is a one-seeded, indehiscent dry fruit with a hard or stony pericarp (shell), (e.g. Hazelnut, filberts, sweet chestnut and acorn) but most commercial nuts such as coconut, almond, walnut etc. and some seeds such as Brazil nut, Pine nuts do not come under this definition. Nuts are rich in oils and fats and contain moderate amounts of carbohydrates and proteins. They are a good source of vitamins and minerals. Nuts are eaten raw, roasted or salted.

Most of the nuts are now totally cultivated, but some, such as Brazil nut and pine nuts are still collected from stands rather than from well-tended orchards. Almost all nuts are dicotyledonous trees or shrubs (except coconut). Nuts can be handled and stored easily for a long period (because of the lack of water) but cannot be harvested by machine.

The global production of nuts in 2012 was around 14 366 641 tonnes. The top three producers of nuts were China (3625750 tones), US (1547470 t) and Vietnam (1196550 t). The three common nuts are mentioned below in detail:

(A) Almond

Botanical Name: *Prunus dulcis*

Characteristic Features: Trees are small; leaves alternate, oblong, lanceolate and serrate; fruit green drupe, 3-6 cm long, consisting of exocarp, mesocarp and endocarp; seeds flattened ovoid or ellipsoidal; seed coat brownish.

History and Origin: It is originated in Near East and from there spread to Europe. After that it was introduced into California (US), South Australia and South Africa.

Cultivation: Almond tree requires subtropical, warm and dry weather. It needs more than or equal to 60 cm for a good production. It can be grown from seeds or by budding. In seven years it starts producing fruits but reaches its full production at the age of ten years.

Production: In 2012 the global production of almonds was reported 19, 34,817 tons, the highest contributor was US (720000 t), Spain (215100 t) and Australia (142680 t). The other small producers were Syria, Turkey, Tunisia, Afghanistan, China, Algeria, Libya, Greece etc.

Uses: There are two main varieties of almonds, the bitter almond (*Prunus dulcis* var. *amara*) and the sweet almond (*P. dulcis* var. *dulcis*). The bitter almond contains a poisonous glycoside, amygdalin. During the oil extraction process the poisonous substance is eliminated and now the oil can be used for flavouring and preparing lotions or other skin care products. The sweet almonds are consumed raw and roasted, used in making *namkeen* and *kheer*.

(B) Cashew

Botanical Name: *Anacardium occidentale*

Characteristic Features: Tree small, evergreen; trunk twisted, knotted; leaves alternate, simple, leathery, oval, rounded; flowers in clusters on lax terminal panicles at the end of the branches; fruit consists of a soft, shiny, pear shaped, swollen, juicy basal portion or hypocarp, commonly known as a cashew apple. At the top of the apple a kidney-shaped, single-seeded nut with a hard, grey-green pericarp is found. Seeds are exalbuminous with a reddish brown testa, two large white cotyledons and a small embryo. The raw nuts are inedible because the shell of the nut contains bitter juice that causes severe irritation of the skin, resulting in painful blisters and hence the seeds must be cooked or roasted to drive off the volatile oil before it is opened or shelled.

History and Origin: The word ‘cashew’ is based on the Portuguese name ‘caju’, which was derived from the native name ‘acanju’. It is a native of tropical America, from Mexico to Peru and Brazil, and also of the West Indies. The Portuguese introduced it into India from Brazil in the 1600 to control soil erosion on the coasts.

Production: In 2012 the global production was reported around 4 million tons. The top three contributors were Vietnam (1190900 tons), Nigeria (836500 t) and India (680000 t). Some other producers of cashew are Ghana, Thialand, Kenya, Malaysia, Sri Lanka, Maxico etc.

Cultivation: It grows under a variety of climatic and soil conditions. It is hardy and drought-resistant, well adapted to poor soils and dry sandy areas that are not suited to other crops. It can be cultivated up to 1220 m. Propagation is mainly done with the help of seeds, but can also be performed by budding and other vegetative methods. It starts giving fruits in three years, but starts giving maximum production at the age of 10.

Uses: The kerenels are eaten raw as well as fried and sometimes salted. The cashew apple is used in making a fermented alcoholic beverage ‘caju wine’ and jams. The phenolic nutshell oil is widely used as a medicine, an irritant, a wood protectant, a source of resin and as a waterproofing agent. The young leaves of cashew are used in flavoring and medicine. A yellow gum obtained as an exudate is used mainly as an adhesive. The sap from the bark provides an indelible ink.

(C) Walnut

Botanical Name: *Juglans* spp.

Characteristics Features: Tree tall; leaves alternate, imparipinnate, composed of 5 to 11 (rarely 13) subsessile, elliptic to oblong-lanceolate entire leaflets; flowers small, yellowish green, male flowers occur in long pendulous catkins and females in 1-3 flowered terminal catkins; fruit drupe with a smooth fleshy green husk, representing the exocarp and mesocarp, endocarp hard, woody, wrinkled and two-valved; seed, edible non-endospermic, consists mainly of two large cotyledons with numerous invaginations and convolutions. The testa in the fresh nuts has an unpleasant bitter taste but can be peeled off. The seed coats, however, lose their bitter taste on drying.

History and Origin: Various varieties of walnut are present but the most popular is Persian or English walnut (*Juglans regia* L.), which is a native of Persia and now also cultivated in throughout southern Europe, China, some parts of Asia and United States. Two other varieties of walnut namely the black walnut (*J. nigra* L.) and the butternut or white walnut (*J. cinerea* L.) are commonly planted for its hard wood and nuts respectively.

Cultivation: They grow best in the moderate western climates. They are grown as ornamental as well as commercially useful plants.

Production: In 2012 the total global production of walnuts is 3.4 million tons. The top three producers are China (1700000 tons), Iran (450000 t) and US (425820 t). The other walnut producing countries were the Ukraine, India, Chile, France, Romania, Greece, Egypt, Belarus, Germany, Serbia, Afghanistan, Poland, Czech Republic and Pakistan.

Uses: Its kernels are eaten during winters entirely as a dessert nut. It is commonly used in confectionery, ice creams, in preparing of an Indian sweet *kaju katli*. Walnut oil is used for edible purposes, and also for making printing inks, artist's oil colours, varnishes and soaps. The tree bark, known as *dundasa* in India, is used by women for cleaning their teeth or for chewing to redden the lips. Walnut timber is used for furniture, carving and making butts of guns and cabinets of the highest quality. The young green whole fruits, gathered before the nut hardens, are pickled in vinegar.

2.6 SUMMARY

Plants have been the most important part of the human life since the beginning of the human life on this planet. Plants are being used in various forms by human population such as fruits, vegetables, cereals and millets etc. Plants provide almost all the necessary and sufficient nourishment to the body such as vitamins, minerals, carbohydrates and proteins. After the agricultural revolution humans started relying on plants for their nutritional needs and that continues till now with a touch of genetic engineering and molecular biology to increase the production of crops for meeting the needs of rising number of population.

Cereals are the important component of human diet. Cereals were the first plants ever to be domesticated and cultivated in agricultural lands. Roughly every civilization, whether it is Ancient Egypt, Greece, Inca, Indus valley, Mayan, Mesopotamian and Roman was based on one or another species of the cereals. True cereals belong to the family Poaceae also known as grass family. The most commonly used cereals are wheat, rice, corn, barley and oats. On the other hand there are some other crops which are used to make flour but these species do not belong to the family Poaceae. These plants are called as pseudocereals for example buckwheat (*Fagopyrum esculentum*), quinoa (*Chenopodium quinoa*), *Amaranthus* spp. etc. The cereal grains are very nutritious, with a high percentage of easily digested carbohydrates, fats, and proteins. They are chief ingredient of cake, pastries, bread and beverages. Wheat flour has good baking qualities and be used in various forms. Rice flour is used in confectionery, ice creams, puddings and pastry. Rice starch has broad industrial potential in the cosmetic industry, as a thickener in calico printing, in the finishing of textiles and for making dextrins, glucose and adhesives. Alcoholic beverages such as ‘sake’ in Japan and ‘wang-tsin’ in China are made from rice through fungal fermentation. About 90 per cent of rice is eaten as plain boiled rice with cooked pulses, curd, vegetables, fish or meat.

Pulses are the chief source of protein to the vegetarian population. Protein is present in the large proportion then carbohydrates and fats. All the pulses belong to the family Leguminosae (Fabaceae). The characteristic feature of this family is the presence of a special kind of fruit, a legume, which is a pod that opens along two sutures when the seeds are ripe. Out of the 11,000 known species of legumes, majority of them have industrial, medicinal, or nutritive value. Pulses contain niacin, thiamine, carotene, riboflavin and ascorbic acid. Pulses are rich in calcium and iron. Pulses are consumed in different forms e.g. whole or de-husked splits (daal), fried or puffed grain products, fermented preparations, germinated seeds and flour. In India, more than 75 per cent of pulses are consumed as daal (dehusked splits). Legumes are also used as fodder.

Millets are also a good source of nutrients in human diet. The flour obtained from millets are very nutritious and used for making bread, cake, puddings and fermented beverage. Millets also used as the feed for birds.

The vegetable is edible seeds, roots, stems, leaves, bulbs, tubers or non-sweet fruits of any of numerous herbaceous plants. Vegetables are a vital part of the human diet worldwide especially in the tropical areas. They are the main source of essential vitamins and minerals. Vegetables are significant because they grow rapidly and produce a maximum quantity of food for the area planted. On the basis of part of the plant used as vegetable they can be classified as root crops, leafy vegetables and fruit vegetables.

The fruits are the easily available source of minerals, organic acids, vitamins, pigments and tannins. Fruits have high water content but they are low in proteins and fats. The classification of fruits can be done according to the (i). Number of ovaries involved in fruit formation and (ii). Climatic adaptation.

The nut is a one-seeded, indehiscent dry fruit with a hard or stony pericarp (shell), (e.g. Hazelnut, filberts, sweet chestnut and acorn) but most commercial nuts such as coconut, almond, walnut etc. and some seeds such as Brazil nut, Pine nuts do not come under this definition. Nuts are rich in oils and fats and contain moderate amounts of carbohydrates and proteins. They are a good source of vitamins and minerals.

2.7 GLOSSARY

Alluvial soil: Alluvium is loose, unconsolidated soil or sediment that has been eroded, reshaped by water in some form, and redeposited in a non-marine setting.
Berry: Fleshy fruit without a stone produced from a single flower containing one ovary.
Carbohydrates: A carbohydrate is a biomolecule consisting of carbon, hydrogen and oxygen atoms, usually with a hydrogen–oxygen atom ratio of 2:1.
Caryopsis: a dry one-seeded fruit in which the ovary wall is united with the seed coat, typical of grasses and cereals.
Culm: A culm is the aerial stem of a grass or sedge.
Endocarp: The innermost layer of the pericarp which surrounds a seed in a fruit.
Exocarp: The outer layer of the pericarp of a fruit.
Loam soil: Loam is soil composed mostly of sand, silt, and a smaller amount of clay.
Pericarp: The part of a fruit formed from the wall of the ripened ovary.
Pome: A pome is an accessory fruit composed of one or more carpels surrounded by accessory tissue.
Pseudocereals: A pseudocereal is one of any non-grasses that are used in much the same way as cereals.
Spikelets: The basic unit of a grass flower, consisting of two glumes or outer bracts at the base and one or more florets above.

2.8 REFERENCES

- archive.india.gov.in
- Hill Albert F. (1937) Economic Botany. Mcgraw-Hill Publications.
- http://agritech.tnau.ac.in/agriculture/millets_kudiraivali.html
- http://www.fao.org/3/W1808E/w1808e0k.htm
- http://www.fao.org/3/y4765e/y4765e0b.htm

- https://hort.purdue.edu/newcrop/Crops/Wheat.html
- Kochhar S. (2016) Economic Botany: A Comprehensive Study. Cambridge University Press. doi:10.1017/9781316286098.003
- krishijagran.com
- www.cerealsdb.uk.net
- https://www.google.com
- Shutterstock.com

2.9 SUGGESTED READINGS

- Kochhar S. (2016) Economic Botany: A Comprehensive Study. Cambridge University Press. doi:10.1017/9781316286098.003
- Hill Albert F. (1937) Economic Botany. Mcgraw-Hill Publications.

2.10 SELF ASSESSMENT QUESTIONS

2.10.1 Multiple choice type questions

1. Major food crops of the world belongs to the family:

(a) Gramineae (b) Cruciferae
(c) Leguminosae (d) Solanaceae

2. Cereals belong to family:

(a) Gramineae (b) Cruciferae
(c) Solanaceae (d) Leguminosae

3. Major cereals are:

(a) Millets, Wheat and Rice (b) Rice, Wheat and Maize
(c) Barley, Rye and Maize (d) Rye, Barley and Wheat

4. The centre of origin of wheat is:

(a) Mexico (b) South-East Asia
(c) South-West Asia (d) Asia Minor and Afghanistan

5. Rice is a crop of:

(a) Clayey loam soils (b) Wet areas
(c) Irrigated areas (d) All the above

6. Maize evolved in:

(a) Mexico and Central America (b) Asia Minor and Afghanistan
(c) U.S.A. (d) Brazil

7. The most common cereal millet crop grown in arid climate is:
(a) Sorghum (b) Maize
(c) Pearl millet (d) Paddy

8. Which vegetable has long storage life?
(a) Spinach (b) Tomato
(c) Onion (d) Brinjal

9. The fruit of banana is botanically a-
(a) Pepo (b) Berry
(c) Pome (d) Drupe

10. Which of the following is the edible part of Litchi:
(a) Pericarp (b) Kernal
(c) Fleshy aril (d) Thalamus

11. A fruit is:
(a) Ripened ovule enclosing one or more seeds
(b) Ripened ovary enclosing one or more seeds
(c) Ripened endosperm enclosing one or more seeds
(d) Ripened nucellus enclosing one or more seeds

12. The edible fleshy part of mango is called:
(a) Percarp b) Mesocarp
(c) Endocarp d) Epicarp

13. The water of coconut is:
(a) Liquid mesocarp (b) Liquid endocarp
(c) Degenerated liquid endosperm (d) Liquid nucellus

14. Almond belongs to family:
(a) Musaceae (b) Rosaceae
(c) Annonaceae (d) Moraceae

2.10.2 Fill in the blanks:

1- Mushrooms, morels, truffles and puffballs grouped under………
2- *Spirulina*, *Chlorella* are grouped under …………………

3- Chilgoza is obtained from …………
4- Sago is obtained from ………………………..
5- The term 'cereals' is derived from a ……………………… Cerealia.
6-Buckwheat (*Fagopyrum esculentum*), quinoa (*Chenopodium quinoa*), *Amaranthus* spp are grouped under …………
7-On the basis of the number of chromosomes present in their reproductive cells, all the wheat species can be classified ………, ……… and …..
8- The ………….. were the first to cultivate rice.
9-Pulses are the chief source of …………… to the vegetarian population.
10- ………….. are the excellent fertilizer and greatly increase the nitrogenous content of the soil.

2.10.3 True and false:

1-Angiosperms are the most dominating plant group in obtaining food products.
2-Wheat, rice and soybean grouped under cereal crops.
3-Pseudocereals belong to family Poaceae.
4- The first cultivated cereal was wheat.
5-Legumes are also used as field and forage crops.
6-All the species of pulses not belong to the family Fabaceae
7-The vegetable is edible seeds, roots, stems, leaves, bulbs, tubers or non-sweet fruits of any of numerous herbaceous plant
8-Carotene, a precursor of vitamin A, is abundant in carrots.
9-Thiamine, niacin and riboflavin is not occur in succulent vegetables and legumes.
10-Subtropical fruits are either deciduous or evergreen, and are usually able to withstand a light frost.

Answer Key:

2.10.1: 1-(a), 2-(a), 3-(b), 4-(c), 5-(d), 6-(a), 7-(c), 8-(c), 9-(b), 10-(c), 11-(b), 12-(b), 13-(c), 14-(b)

2.10.2: 1. Micro-fungi, 2. Algae, 3. *Pinus girardianana*, 4. *Cycas revolute*, 5. Greek festival, 6- Pseudocereals, 7. diploid, tetraploid and hexaploid, 8. Chinese, 9. Protein, 10. Legumes

2.10.3: 1- True, 2- False, 3-False, 4- True, 5- True, 6-False, 7- True, 8- True, 9- False, 10- True

2.11 TERMINAL QUESTIONS

2.11.1 Short answer type questions:

1-Explain the differences between cereals and millets?
2-What is a true fruit?
3- Mention the differences between true and pseudo fruits?

4 -Explain the various types of maize?

5- Name five common fruits of India?

2.11.2 Long answer type questions:

1- Write in detail about three major cereals and millets?

2- Write in detail about three major fruit and nut crops?

UNIT-3 EDIBLE OILS, SPICES AND CONDIMENTS

Contents

3.1 OBJECTIVES

After studding of this unit, you will be able to understand the characteristics of edible oil, spices and condiment yielding plants in special reference to-

- General account on Edible oil
- Types of edible oils.
- Botanical characteristics of commonly used Edible oil yielding plants and their uses.
- Botanical characteristics of some important Spices and Condiments yielding plants with their uses.

3.2 INTRODUCTION

Besides food and fiber, the edible oils, spices and condiments played have an important role in all the ancient civilizations. Edible oils, spices and condiments have been considered as essential ingredients in the culinary art for flavouring foods. Edible oils and fats contain important and essential nutrients to mankind, and enhance the taste and flavour of food. Majority of edible oil are originated from plant crops. Spices and condiments are plant products or their mixture, used for seasoning, enhance flavour, imparting aroma and colour in food. Our country, India is blessed with varied agro-climatic and cultivate majority of the edible oils and spices.

3.3 EDIBLE OILS

Edible oils are most often plant based oils. The vegetable oils and fats are considered as an important part of human food and used as cooking medium. The major proportion of edible is derived from seeds of plants i.e., mustard, groundnut, sunflower, soyabean, linseed, palm, ricebran, coconut etc. There are many types of edible oils, and their consumption depends on consumer preference and availability. Edible oil is extracted by pressing and solvent extraction method. The obtained crude oil then refined, bleached and deodorized to remove pigments and non-triglyceride material. Edible oil is liquid at room temperature and contains high amount of unsaturated fatty acids. Vanaspati is refined hydrogenated vegetable oil and solid at room temperature, as during hydrogenation, the fatty acids get saturated.

Fat have many important functions in our body-

- Fat is a major source of energy (provide 9 calories energy per gram of fat combustion) and nutrients, and help to keep body warm and maintain body temperature.
- Fats help in absorption of minerals and fat-soluble vitamins (vit. A, D, E and K) from food materials, boosts the immune system and help to the cells and organs for their proper functioning.
- Fats help to supports balanced hormones production that helps the body to work properly.

- Fat is also critical to building cell membranes, the important lining of each cell which promotes homeostasis and protects the cell.

Chemically, the plant derived edible oils have along hydrocarbon chains with a terminal carboxylic acid group. The carboxyl group makes the oil edible, and provides a site for enzymes to the breakdown of chain in a process called beta-oxidation. The length or number of hydrocarbon chains define whether the oil is saturated or unsaturated in cis or trans confirmation, which determine how easily it metabolized and become healthy or unhealthy as part of our diet.

Edible oils categorized into three categories-
Saturated oils are saturated fatty acids and have only single bond between their carbon atoms, and solid at room temperature. Saturated fats tend to have higher melting point than corresponding unsaturated fats and considered relatively unhealthy.

Monounsaturated oils are fatty acids have one double bond and liquid at room temperature but begin solidify in the refrigerator. e.g. Olive oil, Coconut oil

Polyunsaturated oils are fatty acids have two or more double bond and liquid at room temperature or when chilled. e.g. sunflower oil, walnut oil.

On the basis of ability of oil to absorb oxygen, vegetative oils are classified into following categories-

I- ***Drying oil-*** These oils readily form a dry thin elastic or solid film after a period of exposure to air. These oils are rich in unsaturated fatty acids, especially linotic and linolenic acid. Drying oil hardens through polymerization and have a high iodine number (>130). Drying oils are a key component of oil paints and varnish industries. e.g. Linseed oil, Tung oil etc.

II- ***Semi-Drying oil*** **–** Semi-drying oils absorb atmospheric oxygen slowly and produce a soft film even after a long exposure. These are fairly rich in linoleic and saturated acids but do not contain linolenic acid. Oils with an iodine number ranges between100-130 are considered non-drying oils. e.g., Cotton seed oil, Sunflower oil, Corn oil etc.

III- ***Non-drying oil***–Non-drying oils do not absorb atmospheric oxygen and fairly rich in saturated acids and oleic acids. These oils does not harden and unable to forming elastic films even after long exposure to atmospheric oxygen. Oils with an iodine number less than 100 are considered non-drying oils. e.g., Groundnut oil, Olive oil etc.

IV- ***Vegetable fats*** – These fats are rich in saturated fatty acids and semi-solid at ordinary temperature. Vegetable fats having a low iodine number (8-50) in comparison to drying, semi-drying and non-drying oils. e.g., Coconut oil, Cocoa butter, Palm oil etc.

Extraction of Vegetable Oil

Oil and fats are deposited in seeds as reserve food and within other cells of plant tissue. The seed coat is usually remover before oil extraction, with the help of specially decorticating machines.

The separated seed kernel is reduced to a paste. The oil from plants can be extracted in several ways including mechanical expression and solvent extraction.

(a) Mechanical expression: Mechanical expression involves mechanical pressure to the oil seeds or oil bearing tissue, to squeeze out the fat. The mechanical pressure is applied through either by hydraulic pressing or screw pressing. The expression may be of cold or hot type. The cold expression involves mere pressing of the kernel without steam, whereas in case of hot expression precooking of kernel usually done with steam, to facilitate oil flow. The oil is than passed through filter presses to refine oil.

(b) Solvent extraction: The Solvent extraction is done by using many solvent including benzene, gasoline, petroleum ether, chlorinated hydrocarbons etc. The plant tissues containing fatty oil are feed from extracting by distillation processes using solvent. The produced oil is subjected to refining process to remove the impurities. The solvent extraction is often practiced on the press cake to extract the oil left. The Solvent extraction method can extracted even low proportion or content of oil form the oil bearing tissues.

Some of the important cultivated and commercially known vegetative oils commonly used as edible oil are described as follows-

3.3.1. Soyabean Oil

Botanical name	:	*Glycine max* (L.) Merr.
Family	:	Papilionaceae
Eng. Name	:	Soyabean
Hindi name	:	Bhat

Botanical characteristics: Soyabean is one of the oldest crop and largest oil seed crop; contribute 22% of total fat production in the world. The soyabean is an erect, herbaceous, annual, leguminous and fast growing plant. The soyabean plant is usually an erect bush with woody stem and grows upto 1m height. Roots bear nodules resulting from *Bradyrhizobium japonicum* infection. The leaves are trifoliate, alternately arranged and leaflets are oval to lanceolate. The fruit are pods and with 2-4 seeds per pod, containing yellow, round seeds with a helum colour. Soyabean oil is low in saturated fats without any trans-fat and contains high amount of poly & mono-saturated fats.

Uses: Soyabean oil is the most widely used edible oil. Soyabean oil has good emulsifying ability and also used in mayonnaise, salad dressing and baked goods. Syabean oil is the principal source of omega-3 fatty acids and commercial source of Vit. E, has an array of incredible health benefits. Soyabean oil are abundant in ‘good’ unsaturated omega-3 and omega-6 fatty acids, it slow down LDL (low density lipoprotein- deposited & clog blood vessels and interface with blood circulation leading to heart attacks or strokes) accumulation and reduce the risk of hypertension and heart diseases. Soyabean oil is rich in Vit. E and K, also have antioxidant and anti-inflammatory properties, boosts bone health and vision. Soyabean oil is used in the manufacturing of candles, varnishes, paints, soap and rubber substitutes.

3.3.2. Sunflower Oil

Botanical name	:	*Helianthus annuus* L.
Family	:	Compositae (Asteraceae)
Eng. Name	:	Sunflower
Hindi name	:	Surajmukhi

Botanical characteristics: Sunflower is an important source of edible oil and oil content ranges between 46-52%, and has non-cholesterol and anti-cholesterol properties. Sunflower is a large annual herb, has an erect rough hairy stem, grow upto 3m in height. The leaves are broad, coarsely toothed and alternate. The inflorescence of sunflower is capitulum or pseudanthium or composite. The center of the flower of the head is made up of disk flowers, surrounded by ray flowers. The disk flowers mature into fruit. Sunflower oil consists of low saturated oil and high amount of vit. E. sunflower oil are two types- Linoleic i.e., common cooking oil with low level of trans fat (11% saturated fatty acids, 20% monosaturated fatty acids and 69% polyunsaturated fatty acids) and Oleic (12% saturated fatty acids, 84% monosaturated fatty acids and 4% polyunsaturated fatty acids).

Uses: The Sunflower oil is used for cooking purposes at low to extremely high temperature. It is a good source of Vitamin A, B and E. Unrefined Sunflower oil is a traditional salad dressing. Sunflower oil is also use as biodiesel. Sunflower oil is directly applied to the skin for joint pain, dry skin and arthritis as massage oil. Sunflower oil does not raise total cholesterol and LDL cholesterol in blood and used by heart patients.

3.3.3. Rice-bran Oil

Botanical name	:	*Oryzae sativa* Linn.
Family	:	Poaceae
Eng. Name	:	Rice-bran Oil
Hindi name	:	Rice-bran Oil

Botanical characteristics: Rice-bran oil is extracted from the paddy husk i.e., hard outer brown layer of rice, called chaff.The term bran includes pericarp, seed coat, nucellus and aleurone layer of seed with some part of endosperm. When paddy is milled, the germ and bran layer separate from the endosperm and result in the milling residue which is commonly called Bran. Rice-bran oil is, therefore, a byproduct of rice milling. Rice-bran with about 15-30% lipids is a good source of protein, minerals, vitamins etc. Rice is an annual plant, growing 1-1.5 m in height. The leaves are long, slender, flattened, 30-50 cm in length and 2-2.5 cm broad. The flowers are arranged in a branched arching to pendulous inflorescence. The seed is a grain, known as caryopsis. Rice-bran oil is distinctive for antioxidant γ-oryzanol (2%of crude oil content). Rice-bran oil has nearly 25% saturated fats (chiefly contain 21.5% Palmitic acid) and75% unsaturated fatty acids with an even balanced of monounsaturated (38% oleic acid) and polyunsaturated fatty acids (34.4% linoleic acid& 2.2% α-linolenic acid). In recent years, the oil has gained worldwide attention due to the presence of several health beneficial components such as oryzanol and other high-value compounds including tocotrienols and squalene.

Uses: The Rice-bran oil is used for cooking purposes at low to extremely high temperature. The Rice-bran oil help to lower cholesterol, promote weight loss, boost the immune system and improve skin health. Rice-bran oil reduces LDL and can help to reduce condition like atherosclerosis and subsequent afflictions like heart attacks and strokes. Rice-bran oil is hypoallergic in nature and can also prevent hypersensitivity to other unusual allergies. Rice-bran oil is rich source of antioxidants, vitamin E and oryzanol, which reduces changes of developing of cancer. Due to the presence of vitamin E rice-bran oil help to protect and improve skin health.

3.3.4. Peanut Oil

Botanical name	:	*Arachis hypogaea* Linn.
Family	:	Fabaceae
Eng. Name	:	Groundnut, Peanut
Hindi name	:	Mungphali

Botanical characteristics: Groundnut is a low growing annual herb with cylindrical or angular, rough hairy stem, grow0.3-0.6m in height. The leaves are quadrifolate with two pairs of leaflet on a slender, grooved petiole and flowers are borne in the axils of leaves. The fruit is an elongated, oblong pod containing 2-4 seeds. Groundnut grows in warm region of tropical and sub-tropical regions, and prefers well drained sandy loam soil. Groundnut oil contains 17% saturated fatty acids, 46% monosaturated fatty acids and 32% polyunsaturated fatty acids.

Uses: Groundnut oil is used for cooking purposes and in making margarine. The oil is rich in phosphorus and Vitamins (thiamine, riboflavin and niacin). Groundnut oil is high in monosaturated fat and low in saturate fat, and help to prevent heart disease and lower cholesterol. It is used for the preparation of 'vegetable ghee' by hydrogenation. Groundnut oil is directly applied to the skin for arthritis, joint pain, dry skin and scalp crusting. The oil is medicinally used as laxative, emollient and in ointments.

3.3.5. Mustard Oil

Botanical name	:	*Brassica compestris* L.
Family	:	Cruciferae (Brassicaceae)
Eng. Name	:	Mustard, Yellow sarson
Hindi name	:	Sarson

The genus *Brassica* includes various species and many of them are used as oil resources. Some of the important species of *Brassica*, extensively used for oil extraction are-

B. juncea L. (Lahi)

B. campestris var. *sarson* (Pili sarson)
B. campestris var.*dichotoma* (Bhuri sarson)
B. campestris var. *toria* (Lahi)
B. napus (Kali sarson)

Botanical characteristics: Three species of *B. campestris* var. *sarson*, *dichotoma* and *toria* are collectively called as rape, and *B. juncea* is known as mustard. Sarson oil is a popular vegetable oil, cooking medium and obtained from seeds of mustard. Mustard plant is an annual herb, slender, erect, branched and attains a height upto 1.5 m. The leaves are lyrate, lobed and arranged alternately and inflorescence is corymbrose racemes. The fruit is a siliqua with small, spherical and yellow or brown seeds on maturity. The seeds have marked reticulation on their surface, and contain 20% protein and 30-45% oil. The characteristic pungency and flavor of mustard oil is due to allyl-iso-thiocyanate. Mustard oil has about 60% monosaturated fatty acids (42% erucic acid & 12% oleic acid), 21% polyunsaturated fats and 12 % saturated fats. Erucic acid is the main fatty acid of mustard with other fatty acids.

Uses: Mustard oil is prominent edible oil and used for food, pickle and snacks preparation, but also widely used for other therapeutic uses. Mustard oil act as appetizer and is a very strong stimulants. It can stimulate digestion by the production of bile and gastric juice from liver and spleen. Mustard oil used for massaging and stimulate circulation very effectively. Mustard oil due to presence of fatty acids i.e., linoleic acid & oleic acid, makes an effective hair vitaliser and also enhance blood circulation of scalp. The lower grade oil is used in soap industry and also used as lubricant of machineries. Mustard oil also used as an ingredient in many Ayurvedic medicated oils for liniment preparation and massage to strengthen nervous system.

3.3.6. Corn Oil

Botanical name	:	*Zea mays* L.
Family	:	Gramineae (Poaceae)
Eng. Name	:	Corn
Hindi name	:	Makai

Botanical characteristics: Maize is annual, herbaceous, attaining a height upto 3 m, stem unbranched and differentiated into nodes and internodes. Leaves are long and grow from node and leaf size upto 4 feet in length and 4 inch in width. The maize plant is monoecious, and the male inflorescence (tassel) found at the apex of stem while the female inflorescence commonly called husk is tightly enveloped by several layers of ear leaves. The fruit is the corn kernel and called caryopsis. Corn oil is extracted from seeds obtained from ears. Maize plant is cold intolerant and most sensitive to drought and prefer well drained, fertile, heavy loamy soil and humus rich soil.

Uses: The refined Corn oil is mainly use in cooking and bakeries. Corn oil can help to control inflammation and excess cholesterol due to low amount of saturated fats. Corn oil is a key component of some margarines or flavouring agent. Corn oil is also used in soap, skin care and low grade paint industries.

3.3.7. Coconut Oil

Botanical name	:	*Cocos nucifera* L.
Family	:	Palmaceae (Arecaceae)
Eng. Name	:	Coconut
Hindi name	:	Nariyal

Botanical characteristics: The coconut palm is important oil yielding plant and obtained from the kernel of its fruit. It is a perennial tall plant growing upto 30 m in height, and bearing a cluster of 4-6 m in long pinnately compound leaves at the apex. Coconut fruit is a fibrous drupe fruit with a tough, greenish exocarp, a brown coloured fibrous mesocarp and the kernel- a fairly thick coating of white milky flesh. The coconut palm prefers shoreline area with abundant sunlight and regular rainfall with humid climate, and thrives on sandy soil. It has tolerance to salinity. Coconut oil has about 82 % saturated fatty acids, 6% monosaturated fatty acids and 1-2% polyunsaturated fats. Lauric acid (44-50%) is the main constituent of coconut oil.

Uses: The refined Coconut oil is used in form of edible oil culinary purposes. Higher content of saturated fats in coconut oil provide incredible benefits if taken in limited quantity and it also lead to healing capabilities. Coconut oil is use as a feedstock for biodiesel. Coconut oil is being rich source of myristate acid and is a good binder and emollient for cosmetics. Coconut oil is used in cosmetic and soap preparations. Coconut oil is the directly applicable and easily available remedy for any kind of skin infection due to its anti-fungal and anti-bacterial property, and used in cracked heal, shedding skin, diaper rashes, skin and hair massage.

3.3.8. Palm Oil

Botanical name	:	*Elaeis guineensis* Jacq.
Family	:	Palmaceae (Arecaceae)
Eng. Name	:	Oilpalm
Hindi name	:	Palm

Botanical characteristics: The oil palm is perennial, tall, monoceious plants grow upto 20 m in height, and leaves are pinnate and 3-5m long. The fruit is a large plum, oval drupe, reddish, grows in large branches with a single seed. The fruit is made up of an oily pericarp or fleshy outer layer and a seed. The mesocarp of fruit *i.e.,* fiberous pulp of the drupe, is the source of palm oil. Palm oil has about 49% saturated fatty acids, 37% monosaturated fatty acids and 9% polyunsaturated fatty acids and contain large amount of –carotene.

Uses: Palm oil is used as cooking oil. Palm oil is rich source of vit. E. It is also used in the manufacturing of margarine, non-dairy creams and ice-creams. Palm oil used in the manufacture of lubricants, candles, soaps and detergents. Palm oil used in pharmaceutical, cosmetics and personal care.

3.4 SPICES AND CONDIMENTS

India is known as 'Land of Spices' from since time immemorial land has a diverse variety of spice. Spices are often dried natural plant products derived from different parts of plants viz. bark, leave, rhizome, stigma, seeds etc. and used whole or crushed, used in minute quantity during food preparation to enhance flavour, colour or aroma. Spices cannot be classes as food, for they contain of little value. Spices give an agreeable flavour and aroma to food. The value of spices and condiments is due to the presence of the essential oils, and occasionally due to other aromatic principles. The aromatic value is due to presence of essential oil in spices. The medicinal value of spices is not so great as was thought during the middle ages, but a considerable number of them are still official drugs. Spices stimulate the appetite and increase the secretion and flow of gastric juice. In addition, spices have antimicrobial and antioxidant properties. Spices are also used in cosmetic, beverages, pharmaceutical, perfumery products and preservation of food. Spices are mainly used for-

- To enhance colour (e.g. Turmeric) and flavour (*e.g*., Cinnamon, ginger)
- Used as preservative agent to enhance the life of food.
- Many of the Spices are known for their antioxidant and antimicrobial compound, and well known for home remedies and Ayurvedic medicine to cure different diseases.

Condiments are dishes seasoning ingredients *i.e.,* including spices, sauces, mixture of spices or salt pepper that mainly added to food immediately prior to serve or before consumption, to contribute specific flavour or enhance flavour. Condiments are used to enhance colour and flavour e.g.- Barbecue sauce, soy sauce, ketchup, mustard, chili sauce, garlic sauce, tomato catchup.

The classification of spices is difficult and no sharp differentiation between the various groups, because all the plant products contain essential oils. Spices are hard and hardened parts of plants, usually used in pulverized state. Whereas Condiments are spices or other flavouring substances that have a sharp taste and usually added after cooking. Savory seeds are small fruits or seeds that are used whole. Essences are aqueous or alcoholic extractions of the essential oils. In order to difficulty of distinguishing between spices, condiments and other flavouring materials, it seems best to consider on morphological basis (nature of plant part utilized). On the basis of the plant part, from which spicesand condimentsare derived, Spices and Condiments are categories as follows –

Dried fruit or seeds- Fennel, mustard, nutmeg, black pepper
Arils- mace (part of nutmeg plant)

Barks- cinnamon and cassia
Stigma- saffron
Roots and rhizomes- turmeric, ginger
Resins- asafoetida

Some of the important plants, which plant parts commonly used as spices and condiments, are described under this section with plant description and their uses.

3.4.1- Spices and condiments obtained from roots

3.4.1.1. Asafoetida

Botanical name	:	*Ferula asafetida* L.
Family	:	Umbelliferae (Apiaceae)
Eng. Name	:	Asafoetida
Hindi name	:	Hing
Parts used	:	root

Botanical characteristics: Asafoetida is the dried latex or oleo gum resin exuded from the tap root of many species of *Ferula* plants. The roots are carrot shaped, massive, thick, and pulpy, 5-6 inches in diameter, with a circular mass of 10-15 inch long leaves with characteristics umble inflorescence. The fruits are oval in shape, flat, thin, reddish brown in colour. *Ferula asafetida* is a perennial herbaceous herb of family Umbelliferae. Asafoetida plant can grow to 1.5-2 m in height. The leaves .*Ferula* plant can grow in all types of soil but prefer well drained moist soil. Asafoetida contains about 40-60% resin, 25% gum and 10% of volatile essential oil with other compounds. Asafoetida resin mainly contains the esters of ferula acid.

Uses: Asafoetida, is also known as **devil's dung**, has a powerful pungent odour and a bitter taste, due to the presence of sulphur compounds in it. Hing is a spice used as a digestive aid, in food as a condiment and in pickles. The gum resin is antispasmodic, carminative, expectorant, laxative and sedative. Asafoetida also thins the blood and lower blood pressure. Asafoetida is uses in traditional medicine as antimicrobial, and used for treatment of respiratory disorder i.e., whooping cough, bronchitis and asthma. In Ayurveda, asafetida considered for treatment of *vata* and *kapha dosha*, and relieves flatulence and colic pain.

3.4.2- Spices and condiments obtained from underground stem

3.4.2.1. Ginger

Botanical name	:	*Zingiber officinale* L.
Family	:	Zingiberaceae
Eng. Name	:	Ginger
Hindi name	:	Adrak
Parts used	:	rhizome

Botanical characteristics: Ginger is underground stem or rhizome of annual herbaceous aromatic plant. Ginger is a slender, 30-50 cm tall pseudo stem with palmately branched rhizome bearing leafy shoots, used as raw or processed and valued as spice. Ginger grows on a wide range of soil and prefers laterite loam soil with well distributed rain fall during growing season.

Uses: Ginger is used in culinary and pickle preparations. Dried ginger is used for flavouring of foods and preparations of extracts i.e., ginger oil. Ginger is also used for flavouring confectionary, brewages, soft drinks, liquors, tea etc. Ginger is widely used in pharmaceutical, ayurvedic and unani drug preparations as well as traditional remedies.

3.4.2.2. Turmeric

Botanical name	:	*Curcuma domestica*syn.*Curcumalonga*L.
Family	:	Zingiberaceae
Eng. Name	:	Turmeric
Hindi name	:	Haldi
Parts used	:	rhizome

Botanical characteristics: Turmeric plant is a herbaceous perennial, 0.5-1m high, a short pseudo stem formed by leave sheath and 7-12 tufted alternate leaves, arranged in two rows. The inflorescence is a central spike of 10-15 cm length with 25-30 flowers. Turmeric is the boiled, cleaned, dried and polished rhizomes of the plants. Turmeric is a tropical cultivated crop grown in warm and moist regions and prefers well drained fertile loam and alluvial soils.

Uses: Turmeric is a key ingredient and specifically valued for its flavour, colour and aroma. Turmeric is used to flavour and colour the food stuffs. Turmeric used as a powder of dried rhizomes to impart golden yellow colour and preferred as an essential gradient of curry powder.

3.4.2.3. Allium

Botanical name	:	*Allium cepa* L.
Family	:	Liliaceae
Eng. Name	:	Allium
Hindi name	:	Piyaz
Parts used	:	bulbs/rhizome

Botanical characteristics: Onion is an herbaceous, herb, biennial plant but usually treated as an annual because harvested in its first growing season, and cultivated for its edible bulb. The plant is attain a height upto 0.5m with stem having a flattened disc at the base and tubular leaves form a pseudo stem where their sheaths overlap. The leaves are erect or oblique and 4-8 per plant. The bulb is oval to spherical in shape and made up of several layers, each corresponding to a leaf. Onion prefers well drained, organic matter rich, clay or silt loam soil.

Uses: Onion is spicy, pungent and lachrymatory and chopped onion used as an ingredient in various dishes. The stem and leaves are eaten and can also put to culinary uses. Onion can be used by baking, boiled, grilled, fried, roasted or eaten raw in salads. Onion is the basic of most sauces and gravies.

3.4.2.4. Garlic

Botanical name	:	*Allium sativum* L.
Family	:	Liliaceae
Eng. Name	:	Garlic
Hindi name	:	Lahsun
Parts used	:	bulbs/rhizome

Botanical characteristics: Garlic is a herbaceous, annual, bulbous plant grow upto 0.5m in height with short, woody central stem or a softer pseudostem made up of overlapping leaf sheath and possess long and blade like leaves. The compound bulb of Garlic consists of several bulblets or cloves. Garlic can grow in different types of soil, however well drained, organic rich, sandy, silt and clay loamy soil are recommended for cultivation.

Uses: Garlic is widely used as a spice or condiments in form of fresh garlic, garlic powder and garlic oil, and known for its pungent, aroma and spicy flavour. The green part of garlic is also edible and often chopped and stir-fried or cooked in soups. Garlic is also used in different kinds of breads, usually in medium of butter.

3.4.3- Spices and condiments obtained from bark and leaves

3.4.3.1. Cinnamon

Botanical name	:	*Cinnamomum tamula* Nees. & Eberm.
Family	:	Lauraceae
Eng. Name	:	Cinnamon
Hindi name	:	Tejpat, Dalchini
Parts used	:	Bark, Leaves

Botanical characteristics: Cinnamon is an evergreen tree attains a height of 6-12 m and having 12-15 cm long and highly aromatic leaves. The bark of Cinnamon has a sweet and agreeable taste. The bark, its powder and leaves are used as spices and removed periodically. Cinnamon is a hardy plant can grow under wide range of climatic conditions and soil; prefer well drained sandy loam soil with rich humus.

Uses: Cinnamon is aromatic, astringent, stimulant and carminative. It possesses the property of checking nausea and act as an anti-emetic. The powerded cinnamon used for flavouring cakes, sweets, candy, chocolate, curry powder, perfumes etc. the leaf oil is also use for preparation of low grade soaps, toothpaste, face creams and hair oils.

3.4.3.2. Curry leaf

Botanical name	:	*Murraya koenigii* (L.) Sprengel
Family	:	Rutaceae
Eng. Name	:	Curry Leaf
Hindi name	:	Barsanga, Mitta Neem
Parts used	:	Leaves

Botanical characteristics: Curry leaf is a spicy leafy vegetable, deciduous herb or a small perennial tree, and having aromatic properties. The plant is a deciduous shrub or a small tree grow 1-6 m in height, with ovale, lanceolate, imparipinnate leaves and white coloured, terminal corymbose flower. It is hardy and temperature tolerant plant, and can grow in different types of soils with proper drainage while prefers red sandy loam soil for better growth.

Uses: Curry leaf is a slightly pungent, bitter and feebly acidic taste, and leaf retain their flavour ever after drying. Curry leaf used in culinary preparations, to enhance the flavour and taste of food. Curry leaf is used as a natural flavouring agent to corries, chutneys, sambar etc. the leaves, bark and roots of curry leaf plant indigenously used as a tonic, syrup, stimulant and carminative in medicine.

3.4.4- Spices and condiments obtained from flower and its parts

3.4.4.1. Clove

Botanical name	:	*Syzygium aromaticum* (L.) Merr. & Perry
Family	:	Myrtaceae
Eng. Name	:	Clove
Hindi name	:	Laung
Parts used	:	flower bud

Botanical characteristics: Clove is an important tree spices and the fully grown, unopened and dried flower bud of *Syzygium aromaticum* used as spices. The Clove is 7-15m tall, evergreen tree with simple, exstipulate, and glabrous leaves. The inflorescence is shortly pedunculate and carries 3-50 flowers. The fruit is usually a single seeded drupe, but sometimes also contain two seeds. Cloves, the unopened buds, are produced on the terminal shoots of the twig. Clove plants grow well warm and humid climate, and prefers humus rich loam, black and laterite well drained soil.

Uses: Clove is valued as a spice and for its essential oil. The clove is majorly used in flavouring domestic culinary, gravies, ketchup, spice mixtures, pickles, sauces, deserts, confectionery, puddings etc. The clove and its oil used as a constituent of medicines, tonics, syrups, ointments etc., and used for cure of different diseases viz., as appetizing, galacto-purifier, diuretic, carminative etc. The clove oil, because of antiseptic property of eugenol (principal constituent of clove oil), is an ingredient in chewing gums, toothpaste, mouth fresheners and mouthwash.

3.4.4.2. Saffron

Botanical name	:	*Crocus sativus* L.
Family	:	Iridaceae
Eng. Name	:	Saffron
Hindi name	:	Kesar
Parts used	:	Stigma

Botanical characteristics: Saffron is the dried tri-lobed stigmas and world's most expensive spices, obtained from flower of *Crocus*. Saffron is a small bulbose, 15-20 cm in height, perennial, with an underground corm and the flowers are large, blue or vilot coloured and arising directly from corms. The flowers have tri-lobed orange coloured stigma used as spice and is the part of commerce. Crocin is the chief colouring while sarranal is the main flavouring agent. Saffron can grow well drained sandy to clay loam, and tolerate frost and snowfall.

Uses: Saffron is used for medicinal, flavouring and colouring purposes. Saffron is an important ingradient of Ayurvedic and Unani medicine. Saffron is popularly known as stimulant, used in urinary, digestive and uterine trouble.

3.4.4.3. Coriander

Botanical name	:	*Coriandrum sativum* Linn.
Family	:	Umbelliferae/Apiaceae
Eng. Name	:	Corainder
Hindi name	:	Dhaniya
Parts used	:	fruit and leaves

Botanical characteristics: Coriander plant is an annual herd, attain a height 30-80 cm, with conspicuously enlarge nodes and hollow internodes. The leaves are pinnately compound with umbel inflorescence. The fruit is a schizocarp, globular to oval, yellow in colour, size about 2-4mm and having aromatic properties. Coriander prefers humus rich, well drained loamy soil with high water holding capacity.

Uses: Coriander is an important aromatic crop, and both the leaves and fruit used as spices and flavouring agent. The leaves of coriander are rich sources of Vitamin C and A. The fruit and powder of dried fruit of coriander used an important ingredient of curry powder, sausages and pickle spices. Coriander fruit is diuretic, antispasmodic and stimulant. The young plant is used in the preparation of sauces, soups, chutneys, bakery, beverages products and curries for flavouring.

3.4.5- Spices and condiments obtained from fruits

3.4.5.1. Black pepper

Botanical name	:	*Piper nigrum* L.
Family	:	Piperaceae
Eng. Name	:	Black Pepper
Hindi name	:	Kali Mirch
Parts used	:	Mature fruit

Botanical characteristics: Black Pepper is the most important, popular and widely used spice of world, and known as 'king of spices' and native to Western Ghats of South India. Black Pepper plant is a perennial woody climber evergreen plant, growing to a height of 5-9 m in length and the vines branches form the nodes. The black pepper leaves are simple, round or obtuse, alternate, smooth, lanceolate and varied in leave shape. The inflorescence is spike type, 3-15 cm long with 60-150 minute white to yellow flowers, and the fruit is a one seeded berry, sessile, globose to oval in size and matured within 6 months. Black Pepper is a crop of humid tropics with adequate rainfall and humidity, avoid sun-scorching (planting towards the eastern slopes) and prefer well drained humus rich laterite or alluvial soil.

Uses: Black Pepper has extensive culinary used for flavouring and preserving preserved food, and medicinal value. Black Pepper used in medicine *i.e.*, as a carminative and febrifuge, for digestion and common cold cure for home remedies. The alkaloid piperine is major constituent responsible for bitter taste of black pepper and the other pungent alkaloids are chovicine and peiperidine.

3.4.5.2. Red pepper (Red chillies)

Botanical name	:	*Capsicum annuum* L.
Family	:	Solanaceae
Eng. Name	:	Chillies
Hindi name	:	Lal Mirchi
Parts used	:	green or ripe dried pod (fruit)

Botanical characteristics: Chili is an annual sub-shrub or perennial shrub; attain a height upto 1m. The flowers of *Capsicum* are borne singly and fruit usually pendent which provide red peppers, cayenne, paprika, and chillies and sweet pepper (bell pepper) a wild from with large inflated fruits. Red chilli is the dried ripe fruit of *Capsicum* and grinded to powder, which is famous due to its pungency, taste and flavour and extensively used as curried dishes and seasonings of dishes.

Uses: Capsicum a tonic and carminative action, helps in digestion and it develops blood and is a very rich source of Vitamin C, which helps in developing immune system. Capsicum used in medicine as a counter irritant in lumbago, neuralgia and rheumatic disorder.

3.4.5.3. Allspice

Botanical name	:	*Pimento dioica* (L.) Merr.
Family	:	Myrtaceae
Eng. Name	:	Allspice, Pimento, Jamaica Pepper
Hindi name	:	Gandamenasu
Parts used	:	Mature fruit

Botanical characteristics: Allspice is an aromatic spice, in form of berries and peppery in taste. Allspice used both in whole and ground form and commercially known as 'pimento'. The Allspice is evergreen dioecious tree attain a height upto 10 m. with small, white colour and peculiar aromatic flowers. The fruit has two kidney shaped seeds and grow in cluster, and ready to harvest when they are green, matured but in unripening state. The plant grows in all types of soil with proper drainage but prefers humus rich laterite soil.

Uses: The pimento berries and its oil are used as a condiment and flavouring ingredient in ketchup, sauces, pickles, soups, gravies, pudding, preservatives etc. Allspice is used as flavouring agent for liquor, pharmaceutical, perfumery and soap industry. Pimento is used in digestive trouble, diarrhea and flatulence as well as an adjuvant to tonics and puratives.

3.4.5.4. Cumin

Botanical name	:	*Cuminum cyminum* L.
Family	:	Apiaceae/Umbelliferae
Eng. Name	:	Cumin
Hindi name	:	Jeera
Parts used	:	Ripe fruit

Botanical characteristics: The ripe fruit of Cumin is one of old spices. Cumin is an annual, slender, small herb; grow upto 50 cm in height with branched, angular stem bearing 2-3 linear leaves. The inflorescence is compound umbel with white coloured flowers. The commonly known cumin is schizocarpic fruit contains single fruit. Cumin grow I tropical and sub-tropical climate, and flourish well in mild cold climate. It grows in all types of soils, and prefers humus rich, sandy loam or loamy soil.

Uses: Cumin is known for its aromatic order due to the presence aromatic alcohol- 'Cuminol', and a spicy bitter taste. Cumin is an essential ingredient of all spices and curry powder to various dishes. Cumin used for enhance the flavour of soups, pastries, pickles, cheese, and for seasoning of bakery products. Cumin seeds are Ayurvedic medicines as stimulant and carminative.

3.4.5.5. Nutmeg

Botanical name	:	*Myristica fragrans*L.
Family	:	Myristicaceae
Eng. Name	:	Nutmeg
Hindi name	:	Jaiphal
Parts used	:	seed and aril

Botanical characteristics: Nutmeg is an evergreen tree10-20 m tall with dense foliage and the leaves are oblong to oval in shape. The inflorescence is cymes with a number of small, pale yellow and bell shaped flower. The fruit is fleshy and globous in shape, containing single brown seed with a brittle shell over by fragile and aromatic aril (reticulate membrane) known as mace. Nutmeg grows on humus rich loamy soils of river bank or hill valleys. Nutmeg yields two types of spices viz. one is Nutmeg it's the kernel which is hard and brown enclosed in thin brittle shell; second is the mace obtained from aril.

Uses: Mace is used as spice and flavouring agent for culinary dishes. The fresh husk of ripe fruit can be used for jelly making. The nutmeg medicinally acts as a stimulant, astringent and carminative. The nutmeg oil used in flavouring bakery items, toothpaste and chewing gums.

3.4.5.6. Small Cardamom

Botanical name	:	*Elettaria cardamomum* Maton
Family	:	Zingiberaceae
Eng. Name	:	Small Cardamom, Malabar Cardamom
Hindi name	:	Choti Elachi
Parts used	:	Fruit (dried capsule)

Botanical characteristics: The Small Cardamom, popularly known as "Queens of Spices", is indigenous to evergreen rainforest of Western Ghats of southern India. Small Cardamoma tall growing perennial, herbaceous, shade loving plant with branched subterranean rhizomes. The leaves are 35 cm long and 10 cm wide, linear, lanceolatein shape with short petioles. The inflorescence is racemose type arise from the underground rhizome and the fruit is a trilocular and globose capsule borne on panicles at the base of the plants and contains 15-20 seeds. The green cardamoms grow well in well drained, organic rich, loamy laterite soils with high and well distributed rainfall.

Uses: Green Cardamomis used in spices and for flavouring purposes. Green Cardamom has a unique intensely aromatic aroma and fragrance, and used for flavouring different drinks, brewages and food. Cineole is the main constituent, responsible for camphoraceous odour.

3.4.5.7. Fenugreek

Botanical name	:	*Trigonella foemum-graecum*L.

Family	:	Fabaceae
Eng. Name	:	Fenugreek
Hindi name	:	Methe, Methi
Parts used	:	seeds

Botanical characteristics: Fenugreek is cultivated as a leafy vegetable, and used as spices and condiment. Fenugreek is an annual herb, grow 30-90 cm in height, and has pinnately trifoliate, light green leaves. The plant produces 8-12 cm long, slender pods, contains 10-20 small, hard, oblong and yellow colour seeds. The dried seeds are bitter in taste and possess a distinct flavour. Fenugreek is fairly frost tolerant plant grow in the tropics and temperate regions and can be cultivated in all types of well drained and humus rich soils.

Uses: The green and dry leaves of *Trigonella* sps. are used as herb and vegetable, while seeds are used as spices, and added nutritive values. The dried leaves of Fenugreek are commercially used as Kasuri Methi. Fenugreek seeds are an important ingredient for curisines, vegetable dishes, while grinded seeds are used for pickles preparation.

3.4.5.8. Vanilla

Botanical name	:	*Vanilla fragrans* syn. *V. planifiolia* Andrews
Family	:	Orchidaceae
Eng. Name	:	Vanilla
Hindi name	:	Vanilla
Parts used	:	fruit/beans/pods

Botanical characteristics: Vanilla is a spicy orchid, and the dried or cured pods are used commercially. Vanilla is cultivated for its fruit- pods, has a sweet scent due to aromatic compound known as Vanillin and used to flavour different products. *V. planifiolia* is a herbaceous, fleshy, perennial vine, climbing upto 10-15 m by means of adventurous roots up onto trees or other support. The stem is monopodial, simple or branch, long, cylindrical, brittle with 5-15 cm long internodes, while leaves are upto 20 cm long, fleshy, subsessile and alternate, oblong-elliptic to lanceolate. The inflorescence is axillary, racemose and borne towards the top of vine with waxy, fragrant and pale-greenish flowers. The fruit is pendulous, narrowly cylindrical in shape, obscurely three-aged 10-15 cm long capsule, known as ‘bean’, with very minute seeds.Vanilla prefers humid and moisture climate and well drained humus rich loamy soil with gentle slopes.

Uses: Vanilla is used to flavour to confectionary items, ice cream, chocolate, beverages, cake, liquoretc. Vanilla is also used in perfumery and pharmaceutical industries *i.e.*, to flavours tonic, syrup, tablet etc.

3.6 SUMMARY

Edible oil containing fats and oil are recognized as a source of essential nutrients and energy in human diets. Edible oil is mainly derived from plant products, and known as vegetable oil. India having a wide range of oilseeds crops grow in different agro-climate zones. Groundnut, mustard, soyabean, sunflower, safflower and linseed are the major traditionally cultivated oilseeds. Coconut is important among the plantation crops, while rice bran oil and cotton seed oil are popular among the non-conventional oil crops. Vegetable oils are a group of fats, extracted from seeds, nuts, cereal grains and fruits. Vegetable oils are mainly triacylglycerols (92-98%), polar lipids (phospholipids and galactolipids), monoacylglycerols, diacylglycerols with minor amount of free fatty acids. Some oil are refined before use to remove undesirable materials i.e. phospholipids, monoacylglycerols, diacylglycerols, free acids, colour, pigment, trace materials etc. During the refining process, minor valuable component i.e. antioxidant, vitamins such as carotenes, tocopherols etc. may also remove. The demand for vegetable oil increased rapidly in past decade due to higher consumption for edible oil and increasing for industrial uses including biodiesel. Nowadays there is a clear shift from a traditionally healthy high fiber, low fat diet to a mechanized lifestyle with high fat and calorie dense, which is specifically high in trans fats. The increased amount of trans fats are responsible to cause many diseases i.e., heart disease, certain types of cancers, asthma, allergies etc. However, excessive consumption of fats increase LDL cholesterol in blood, and a major cause of cardiovascular diseases. The consumption of edible oil after repeated frying resulted change in physical and chemical properties of oil and responsible for adverse health concern.

Spices and condiments are vegetable product or mixtures, free from extraneous material, added to foods as whole spices, as ground spices, as essential oil, as oleoresins or as prepared and filtered vinegar infusion, added flavour, taste and aroma. Spices are used for colourent, preservative, beverages, liquors, perfumery and cosmetic industries. In India, 55-60 spices crop grow or cultivated out of the 109 spices recognised by International Organisation for Standardization (ISO) of World. Besides adding flavour and aroma, spices can be used for pharmacological and health promoting product. The active components in the spices are phthalides, flavonoids, monoterpenes, triterpenoids, polyacetylenes, phenolic acid and serols, and they are used for promoting health wellness through antioxidant, antidiabetic, anti-hypercholesterolemic, antiinflammatory, antimicrobial and anticancer properties of active components. Majority of the spices have antimicrobial properties. Gingerol present in ginger is an intestinal stimulant and promoter of bioactivity of drugs. Spices are natural antioxidant and play an important role in defence against cardiovascular disease, certain epithicial cancer, arthristis and asthma. Phenolic compound such as flavonoids (black pepper & thyme) might be help to prevent against cardiovascular and intestinal cancer diseases. Capsaicin in chilli pepper is used as a counter irritant. Garlic, onion and fenugreek are used to lower cholesterol level.

3.7 GLOSSARY

Absolute: An ethanol extract of a concrete or a resinoid which generally contains the odoriferous components together with very small proportion of colouring matter and is free from any solvent used in the process.

Absolute Oils: Refers to the steam volatile part of an absolute.

Antioxidant: A substance that prevents oxidation or an agent that slows the formation of lipid peroxides and free radical oxygen forms, preventing the rancidity of oils or blocking from peroxides to the mitochondria of cells or cell membranes.

Antiphlegistic: A drug containing cure against inflammation.

Antispasmodic: A drug which counteracts spasmodic disorders.

Aromatic: A drug which is fragrant, spicy and mildly stimulant.

Bronchitis: Inflammation of the mucus membranes on the bronchi, usually caused by an infection, sometimes by allergies or chemical irritations.

Colic: pain in abdomen due to spasmodic contraction.

Distillation: A process of evaporation and recondensation used for purifying liquids.

Essential oil: Essential oil is a volatile perfumery material extracted from a single source of vegetation origin by a process such as hydrodistillation, steam distillation, dry distillation or expression.

Expression: The process of extracting essential oil under pressure.

Extract: The concentrated solution obtained by treating natural perfumery material with a solvent which is subsequently evaporated.

Extraction: The process of extracting essential oil under pressure.

Flavour: Flavour refers to the characteristics quality of a material as affects the taste.

Iodine value: Iodine number of a fat or oil is a measure of its degree of unsaturation and declared as the number of iodine in grams taken up by 100 gms of fat or oil for saturation. For a saturated acid glyceride, the iodine value is zero.

Nacrotic: A drug which induces deep sleep.

Perfume: A suitably blended composition of various materials of natural origin or synthetic to give rise or impart a desired odour effect.

Perfumery compound: A concentrated base which is further diluted with or without toning.

Resin: Solid or semisolid translucent exudation from trees or plants.

Rheumatism: A conditions in which pain feels in the muscle, joints and certain tissue.

Spice or Herb oleoresin: A solvent extraction of dried spice or herb which is virtually free from the extracting solvent. It is used as a replacement of ground spices and spices tinctures.

Steam Distillation:

Tannins: A group of simple and complex phenol, polyphenol, and flavonoid compounds, bound with starches, and often so amorphous that they are classified as tannins.

3.8 SELF ASSESSMENT QUESTION

3.8.1 Indicate whether the following statements are True or False:

1. Coconut oil is a vegetable fat.
2. Edible oil containing high amount of trans fats, are beneficial for human health.
3. Palm oil is considered as non-drying oil.
4. Sunflower oil contains high amount of saturated fats in comparison to unsaturated fats.
5. Vegetative ghee is manufactured by hydrogenation.
6. Saturated fatty acids contain double bond in their hydrocarbon chain.
7. Linseed oil is a drying oil.
8. Cardamom is known as 'Queen of spices'.
9. Savoury seeds are highly aromatic fruit belonging to family Apiaceae.
10. Black pepper is known as king of Indian spices.

3.8.2 Multiple Choice Questions:

1. Which of the following is an example of fats?
(a) Vegetative Ghee **(b)** Coconut oil
(c) Soyabean oil **(d)** Groundnut oil

2. Growth habit of black pepper is
(a) Small bushy plant **(b)** study erect plant
(c) Climbing evergreen plant **(d)** none of the above

3. Indian Institute of spice research is located at
(a) Calicut **(b)** Hyderabad
(c) New Delhi **(d)** Lucknow

4. The biting taste of black pepper is due to the presence of alkaloid
(a) Piperine **(b)** Chovicine
(c) Peiperidine **(d)** All of these

5. Cinnamon belongs to family
(a) Anacardiaceae **(b)** Poaceae
(c) Rosaceae **(d)** Lauraceae

3.8.3 Fill in the blanks:

1. Mustard oil is obtained from ....
2. Vanilla is obtained from ....
3. Cinnamon of commerce is obtained from the bark of ....

4. Asfortida is a gum resin obtained from ....
5. Saffron is the dried stigma of ....
6. Black pepper (*Piper nigrum*) belong to family ....
7. Cinnamon belongs to family………………………..
8. They yellow pigment present in the rhizome of turmeric is..............................
9. Clove of commerce are dried unopen floral buds of ....

Answer keys:

3.8.1: 1-True, 2-False, 3-False, 4-False, 5-True, 6-False, 7-True, 8-True, 9-True, 10-True

3.8.2: 1-(a), 2-(c), 3-(a), 4-(d), 5-(d)

3.8.3: 1-seeds, 2-Fruit, 3- *Cinnamomum zeylanicum,* 4-root, 5- *Corcos sativus,* 6- Piperaceae, 7- Myrataceae, 8- Curcumin, 9- *Synzium aromaticum*

3.9 REFERENCES

- Ankri, S. and Mirelman, D. (1999). Antimicrobia properties of Allicin from Garlic. Microbes. Infest. 2:125-129.
- Arvind, Talukder, S., Kandeepan, G. and Shukla, V. (2016). Indian Spices: Taste of Foods. *Beverage and Food World* 43(1): 46-49.
- Chadha, K.L. and Retrinam, P. (2010). Plantation and Spices Crops, In. *Advances in Horticulture*, Mahotra Publ. House, New Delhi, India. pp. 293-345.
- Farroqui, A.A. and Sreeramu, B.S. (2005). Cultivation of Medicinal and Aromatic crops, University Press Ind. Ltd., Hyderabad.
- Hamm, W., Hamilton, R.J. and Calliauw, G. (2013). Edible Oil Processing (IInd Ed.) Willey-Blackwell, UK. pp. 340.
- Nayik, G.A., Majid, I., Gull, A. and Muzaffar, K. (2015). Rice bran oil, the future edible oil of India: A mini review. Rice res.: *Open Access* 3(4):1-3.
- Peter, K.V. (2001). Handbook of herbs and spices. Woodhead Publishig Ltd., Cambridge, England. pp. 332.
- Sanjay, M.R., Arpitha, G.R., Naik, L., Gopalakrishna, K. and Yogesha, B. (2016). Application of Natural fibers and its composites: An overview. *Natural Resources* 7:108-114.
- Savita, D.P., Suvarna, C.V., Kanchanashri, B. and Niveditha, S.B. (2017). Pharmaceutical Perspectives of Spices and Condiments as alternative antimicrobial remedy. 22(4): 1002-1010.

3.10 SUGGESTED READINGS

- Pandey, B.P. (2011).Economic Botany. S. Chand Pub., New Delhi. pp. 680.
- Verma, V. (2009). Textbook of Economic Botany. Ane Books Pvt. Ltd. pp. 352.
- Singh, V., Pandey, P.C. and Jain, D.K. (2014). Economic Botany. Rastogi Pub., Meerut. pp. 204

3.11 TERMINAL QUESTIONS

3.11.1: Short answer type Questions

1- Write a short note on Saffron.

2- Discuss in short about the extraction of vegetable oil.

3- Write about the uses of Nutmeg.

4-What are spices? Discuss about any one spices.

3.11.2: Long answer type Questions

1. What are edible oils? Write a brief account on with botanical description and uses of important edible oil yielding plants in India?
2. Describe any five edible oil yielding plants with botanical description and their uses.
3. Describe botanical description and their uses of any four edible oil yielding plants under drying oil.
4. Write a detailed account/an essay on Spices and Condiments.
5. Write short notes on any four of the following.

(a) Plam oil (b) Mustard oil (c) Soyabean oil

(d) Coconut oil (e) sunflower oil

BLOCK-2 PLANT RESOURCES: DIVERSE VALUE

UNIT-4 MEDICINAL AND AROMATIC PLANTS

Contents

4.1 OBJECTIVES

After going through this unit, you should be able to:

- define the medicinal and aromatic plants;
- outline the importance of medicinal plants;
- identify the sources of availability of these groups of plants;
- explain the importance of conservation of medicinal and aromatic plants and
- differentiate between medicinal and aromatic plants of India.

4.2 INTRODUCTION

Medicinal and aromatic plants play an important role in the life of the people. In Indian traditions, all the plants on this earth are considered as medicinal *[Jivak* in Astanga *Hriday* (Sutra: 9-10)]. No exact definition of Medicinal plant is possible.

However, the medicinal plants could be defined in the simplest way as the plants which are used in official and various traditional systems of medicines throughout the world. Alternatively, the medicinal plants are those that provide people with medicines- to prevent disease, maintain health or cure ailments. In one form or another, they benefit virtually everyone on the earth.

Aromatic plants are a special class of plants used for their aroma and flavour. Many of them are exclusively used also for medicinal purposes in aromatherapy as well as in various systems of medicine. Similarly, a number of medicinal plants also produce essential oils as well as being used for perfumery e.g. valerian (*Valeriana jatamansi*), tulsi (*Ocimum sanctum*) etc. In this chapter, we shall deal these special classes of plants together as medicinal and aromatic plants (MAPs).

India has one of the richest, oldest and most diverse cultural traditions associated with the use of medicinal plants. Plants and plant based products have been used traditionally in India from the time immemorial. Different references of the healing power of plants are depicted in Rig -Veda (4000-1500 B .C.), Atharvaveda (1500 B.C.), Upanishada (1000 B.C.) and Mahabharata and Puranas (700-400 B.C.). Charaka Samhita and Susruta Samhita- the two important compendia on medicinal plants were also published between 1000 and 600 B.C. The invasion of Greeks and Muslims had a considerable influence on the use of plant based medicines. The rise of Buddhism also gave an impetus to the study of herbal medicines in ancient India. At present, many systems of medicines such as Ayurveda, Siddha, Unani, Homeopathy, Tibetian, tribal medicines, folk medicines, etc. constituting the Indian systems of medicines (ISM) are practiced in India.

Medicinal plants as a group comprise of about 8000 species. About 50 per cent of all the higher flowering plant species in India are considered as medicinal plants. Medicinal plants are used by majority of rural population in self help mode for their primary health care requirements. In recent years, demand for herbal medicines and cosmetic products is increasing globally. It has created a quantum jump in volume of plant material traded within and outside the countries.

Various plant parts like roots, bark, wood, stem and the whole plant in case of herbs are used for preparation of various medicines and related products. As a result, destruction harvesting is followed in many species by uprooting plants. Overharvesting of some species may threaten their survival in the nature.

4.3 DISTRIBUTION OF MEDICINAL AND AROMATIC PLANTS

About 70 per cent of India's MAPs are found in natural habitat of tropical forests of Western and Eastern Ghats, the Vindhyas, Chotta Nagpur plateau, Aravalis and the Himalayas. A large percentage of known MAP occurs in the dry and moist deciduous vegetation area compared to evergreen and temperate regions. Habit-wise classification shows that about 33 per cent are trees, 32 per cent herbs, 20 per cent shrubs, 12 per cent creepers and 3 per cent others.

4.4 CULTIVATION

Cultivation of MAPs is different than that of other agricultural crops. These plants are grown for secondary metabolites. Secondary metabolites are responsible for the therapeutic or aromatic properties of the crops. Alkaloids, steroids and essential oils are some of the examples of secondary metabolites. As MAPs are used for preparation of medicines, even a small quantity of pesticides or heavy metal is harmful. Therefore, the World Health Organization (WHO) has recommended development of Good Agricultural Practices (GAP) for MAPs to guarantee quality of raw drug and to facilitate the standardization of quality of ISM drugs for acceptance to science led world. A large number of laboratories in State Agricultural Universities, Indian Council of Agricultural Research (ICAR) and Council of Scientific and Industrial Research (CSIR) are engaged in developing GAP for MAPs. However, the cultivation is not gaining due momentum in the country due to prevailing unorganized marketing arrangements.

4.5 SUSTAINABLE COLLECTION

Medicinal plants come under the group of Non- Timber Forest Products (NTFP). Collection of NTFP, which includes about 90 per cent of the traded medicinal plants, is also associated with the livelihood of tribal and communities in and around the forests of India. Since the prices paid by the traders often are very low, collectors or gatherers usually over-harvest or over-extracts to generate more income. Several MAP species have fallen in endangered, threatened and vulnerable categories due to indiscriminate harvesting and also absence of sustainable collection or harvesting methodology.

General strategies and basic methods for small- and-large-scale collection of fresh medicinal plant materials should follow the Good Collection Practices (GCP). GCP Medicinal and Aromatic Plants Planning and Management of Horticulture Crops should, ensure the long term survival of wild populations and their associated habitats. Management plans for collection should provide a framework for setting sustainable harvest levels. It must describe appropriate collection practices that are suitable for each medicinal plant species and plant part used (roots, leaves, fruits, etc.). Collection of medicinal plants raises a number of complex environmental and social issues that must be addressed locally on a case-by-case basis. It is recognized that these issues vary widely from region to region and cannot be fully covered by these guidelines.

4.6 CONSERVATION

Conservation of MAP is necessary for the posterity of the future generation. Following two methods of conservation are in practice.

***1. In-situ* conservation:** It means conservation of plants within their natural habitats. Forest departments play an important role in in-situ conservation of medicinal plants. Reserve forests, sanctuaries, biospheres are some important examples of in situ conservation.

***2. Ex-situ* conservation:** It means conservation of plants away from their natural habitats. Some of the examples are herbal garden, seed gene bank, cryopreservation, botanical gardens, etc. Cultivation of medicinal plants also reduces the stress of collection pressure on their natural habitats and is considered as an effort of ex situ conservation.

4.7 IMPORTANT MEDICINAL AND AROMATIC PLANTS

4.7.1 Medicinal Plants

1- Isabgol *(Plantago ovata* Forsk.)

The species belongs to the family Plantaginaceae. Seed coat is known as isabgol husk under trade. The swelling property of the seed coat or husk after absorption of water is the cause of its use as a famous medicine against constipation and gastrointestinal irritations. In addition, it is used in food industries for the preparation of ice creams, candy, etc. India is the leader in Isabgol production and largest exporter of husk. Country earns on an average Rs. 200 crores annually from its export.

It is a cultivated species of North Gujarat, adjoining Rajasthan and Madhya Pradesh over an area of about 1,00,000 ha. A number of high yielding varieties are available in the crop for cultivation. It is an annual herb grown during the rabi season. Seeds are sown in the middle of November. About 3-4 irrigations are given. Nutrient requirement of the crop is very low (30 Kg N and 25 kg P/ha). Crop matures in the last week of March and harvested plants are threshed with tractor. Seed coat (husk) is removed by specially fabricated machines. Average seed yield of the crop is about 10-15 quintal (q) per ha.

2-Senna *(Cassia angustifolia* Vahl)

Senna belongs to family Caesalpinaceae. It is a native to Yemen and parts of Pakistan. Dried young leaves, flowers and 3-5 days old pods are used as source of raw drug. It contains

sennosides which is responsible for the purgative action. In European countries, it is used as herbal tea. In world market, there are two sources of senna raw drug, one is *Tinnevelly Senna*, which has gone from India and the other is *Alexandrian senna* that has gone from Arabian Countries. The former species is *Cassia angustifolia* and the latter is *Cassia acutifolia*.
In India, the species is cultivated both as irrigated and rainfed crops in Tamil Nadu, Rajasthan and Gujarat. Seeds are used for propagation. Sowing is done in September/ October in Tamil Nadu and in June- July in Western India. Fertilizer requirement is N: P: K @ 80:50:50 which may vary depending upon the soil fertility level. Crop is ready for harvest after about 130- 150 days. The harvested leaves and pods are dried under shade for about 3-5 days. Leaf yield is about 15-20 q/ha and pod yield is about 7-10 q/ha.

3-Aloe *(Aloe barbadensis* Mill)

Aloe- a member of the family Liliaceae is indigenous to African countries and naturalized in India. The plant is perennial herb with fleshy leaves and condensed stem. Flowering occurs in winter and the inflorescence stack is about 90-150 cm long with orange coloured flowers. Leaves contain gel (polysaccharides) and leaf exudates contain aloins which are commercially useful. Gel has a cooling and moisturizing action and hence used in cosmetic industries and the leaf exudates contains aloins and aloe emodine which are used as pain killer and purgative.

The crop is under cultivation in Gujarat, Rajasthan, Madhya Pradesh and Uttar Pradesh. Raw material is collected both from wild and cultivation for the industry. Suckers are used for propagation. It is planted at a distance of 75x 75 cm in the rainy season. Irrigation is given at one month interval depending upon the climate conditions. About 15 months old plants are ready for harvesting. Leaves are harvested and the oozing out exudates are used for aloe in extraction and gel scraped out from the leaves are used for cosmetic purposes. Average yield of fresh leaves of about 20 tonne (t)/ha and dry exudates of 50 kg/ ha is obtained.

4-Ashwagandha *(Withania somnifera* Dunal)

It is traditionally cultivated in Madhya Pradesh near Mandsaur and Neemach. However, its cultivation has been extended to most of the states now because of availability of new high yielding and high quality varieties (Jwahar Ashwagandha 20 & J.A. 134). Seeds are sown at a rate of about 12 kg per hectare after the withdrawal of monsoon. Crop is irrigated at depending upon the availability of soil moisture. Two- weeding followed hoeing are done at 45 days intervals. The crop is ready for harvest about seven months after of sowing. Plants are uprooted and roots are cut, cleaned and dried. Average dry root yield of the crop is about 800-1000 kg per hectare.

5- Safed musli *(Chlorophytum borivilianum* Santapu& Fern.)

Safed musli belongs to family Liliaceae. There are a number of Chlorophytum species which are known under the trade 'safed musli' of which *C. borivilianum* is the commercially utilized species. The plant is a perennial herb with condensed stem disc and a whirl of sessile leaves.

Fasciculated roots contain saponins and are medicinally important. It is used as a general tonic and is a well known aphrodisiac. The species is naturally distributed in the forest areas of Maharashtra, MP, Rajasthan and Gujarat. Raw drug is collected both from wild as well as from cultivation. Unorganized collection of the species from the natural habitat has result in endangered species status.

The plant is propagated by the stem disc with the attached fleshy roots as well as by seeds. The crop is planted at the onset of monsoon at a spacing of 35 x 15 cm. The planting is done on ridges or in raised beds. After the withdrawal of monsoon, regular irrigation is done at 20 days interval depending upon the soil moisture level. Weeding and earthing up operations are done at one month intervals. The crop is ready for harvest when the aerial portions completely dry up. The fleshy roots are harvested, peeled and shade dried and used as raw drug. An average of 2 *t/* ha of dry fleshy roots are harvested.

6- Guggal *(Commiphora wightii* (Arn.) Bhandari =*Commiphora mukul* Hook ex Stock)

Guggal is a member of family Burseraceae. It is a perennial shrub or small size tree of about 5 m height. It is a slow growing plant with crooked and knotty branches ending in sharp spines. The species contains male, female and hermaphrodite plants in the population. Propagation is done by seed as well as stem cuttings. The oleogum- resin of guggal is known to be highly effective in the treatment of obesity, arthritis and several other diseases in Indian system of medicine. The species is included in the Red data book (IUCN) as over exploited species in the country. Africa and Asia are the centers of origin of *Commiphora* spp. In India, Guggal is distributed in dry areas Gujarat, Rajasthan and Madhya Pradesh. Guggal gum usually called in trade is a mixture of 61 per cent resins and 29.3 per cent gum, in addition to 6.1 percent water, 0.6 per cent volatile oil and 3.2 per cent foreign matter. Guggulosterol and guggulosterone are the important active ingredients of the gum resin. The plant is propagated by rooted stem cuttings as by true seeds. It is normally not under regular cultivation and grown as hedge plants. A five year old plant is ready for Guggal gum extraction. Lateral incisions are made on the stem at bark-depth and allowed the resinous gum to ooze out and collected. An average of about 250- 300 gram (g) per plant of gum is harvested at a time.

7- Tinospora *(Tinospora cordifolia* Miers ex Hook f. and Thorns.)

Tinospora is a member of family Menispermaceae. It is a deciduous perennial climber and is distributed throughout tropical India. The species produces a lot of aerial roots. It is propagated by stem cuttings as well as by seeds. The stem and leaves are medicinally used as raw drug. Tinospora stem is a common constituent of a number of ayurvedic vital tonics for the treatment of general debility, dyspepsia, fevers and urinary diseases. Starch is present in the stem along with alkaloids main characteristic.

Leaf also contains a number of alkaloids. Leaf is used for the treatment of gout, jaundice and rheumatism. Raw drug is mainly obtained from the wild habitats of the species.

The plant is not under regular cultivation and is grown as a climber on trees in the wild. One year old plants are ready for use as raw drug. The stem is collected from the wild and dried and used for starch extraction. However, it can be propagated by seeds as well as by stem cuttings.

8- Shatavary *(Asparagus racemosus* WilId.)

It is a member of Liliacaeae family. Shatavary is a perennial spiny climber and is distributed throughout tropical and subtropical India. Cladodes are in tufts of 2-6 and leaves are reduced to spines. Fasciculated roots are medicinally important. It contains saponins and is used for the treatment of dysentery, tumours, rheumatism and kidney and liver disorders. Powdered roots are a common ingredient of a number of vital tonics, which are believed to cure sexual weaknesses, leucorrhoea and increase lactation in feeding mothers.

Seeds are used for propagation. Planting is done in the rainy season. Seedlings are planted at a spacing of 90 cm. Regular irrigation; weeding and hoeing at an interval of one month are done for better crop growth. Crop is ready for harvest after about 18-24 months. Fleshy roots are harvested, peeled and shade dried and used for the drug preparations. Yield varies from the crop age and an average of about 10-15 *t/* ha fresh root is obtained if harvested in the second year.

9-Brahmi *(Bacopa monnieri(* L.) Pennel)

It is a member of family Scrophularaceae. Brahmi is a creeping, branched succulent perennial herb distributed in wet and marshy lands throughout India. It is propagated from stem cuttings. The whole herb is the source of the ayurvedic drug 'Brahmi'. It is used in improving memory and intelligence and also in the treatment of dermatosis, anaemia, diabetics and insanity. Bacoposide is considered as the major active ingredient in this plant.

Raw drug is mainly collected from the wild. It can be cultivated as a perennial crop. Plant cuttings are used for propagation and are planted at a spacing of 40 x 40 cm. Planting is done coinciding with monsoon and 10-15 t/ ha FYM is applied at the time of land preparation. During dry periods, irrigation is given at weekly intervals. First harvesting is done in the month of October/ November. The herbage portion including stem and leaves are harvested and shade dried and used for drug preparations. Annual dry herbage yield of about 100 q/ ha is obtained.

10- Mandookaparni *(Centella asiatica* L.)

Mandookaparni is a member of family Umbelliferae and is a prostrate slightly aromatic, perennial herb commonly found as a weed in crop fields. The species is widely distributed in India. It is propagated both by stolons as well as by seeds. It is used for the treatment of leprosy, skin diseases and for improving memory. It is also used against cholera, ulcers, bronchitis, leucorrhoea and kidney troubles. Asiaticoside, indocentelloside, thankuniside are the major glycosides responsible for the medicinal properties.

The plant can be cultivated by using runner stocks. Humus rich soil and partial shade are suitable for cultivation. Field is made weed free at the initial stages. Irrigation is given in biweekly intervals. Herbage can be harvested from six month onwards. The harvested herbage is shade dried or used afresh for raw drug purposes.

11-Kalmegh *(Andrographis paniculata* Nees)

Kalmegh about 30-100 cm tall is a branched annual herb of family Acanthaceae the species is distributed in India, Sri Lanka, Bangladesh and Malaysia. In India, it is found in the plains of Himachal Pradesh to Assam and Mizoram and also in Peninsular India. The whole herb is medicinally useful. Andrographolide is the active component having the therapeutic action. The herb is used for treating diabetics, bronchitis, pile, jaundice and fever. It is considered as a blood purifier and used for the treatment of skin diseases.

It is cultivated as kharif season crop in Gujarat, Uttar Pradesh, West Bengal, Madhya Pradesh, Orissa, Andhra Pradesh and Tamil Nadu. Seeds are sown in the nursery in May and seedlings are transplanted at the onset of rain. Seedlings are planted at a row spacing of 30 cm and plant spacing of 15 cm. Irrigation, weeding and hoeing are done once in a month. The crop is ready for harvest in the month of October-November after about 120 days of growth. The plants are cut above the ground level and shade dried and used as raw drug. Average dry herbage yield of the crop is about 2.5 t/ha.

12- Chirayita *(Swertia chirayita* (Roxb.ex Flem.) Karst.)

The plant belongs to family Gentianaceae. It is an erect annual herb which is distributed in temperate Himalayas from Kashmir to Bhutan. The plant is propagated by seeds. It grows well in moist, temperate forests of Himachal Pradesh. Dried herbage portion is used as raw drug. Flowering occurs in July to October and the raw drug is collected when the capsules are fully formed. The drug is extremely bitter in taste. Chirayita is also known as brown or white chirayita to distinguish it from 'green chirayita' which is the dried herbage of *Andrographis paniculata*. The bitter tonic made from the few drug improve bile secretion and used for the treatment of bronchial asthma, liver disorders, and anaemia. The active ingredient of the raw drug includes ophelic acid, glucosides, etc.

Cultivation has been initiated in the species. It requires cold temperate climate. Nursery raised seedlings are used for propagation. Planting is done in the rainy season. Regular weeding and hoeing are done in one month intervals. Irrigation is required during dry periods at one month intervals. Six to eight month old plants are ready for harvesting. The herbage is harvested and shade dried and used for the medicinal preparation.

13- Kauch *(Mucuna pruriens* Bak.)

The species is a pubescent annual climber. The fruit (pod) is covered densely with stinging hairs. It is distributed almost throughout India and also cultivated in limited areas. The seeds are used to treat, Parkinson disease, sexual disorders, cholera, urinary troubles and liver and gall bladder diseases. L-dopa present in the seeds is the active ingredient responsible for therapeutic action. Seeds are used for propagation and sowing is done at the onset of monsoon at a spacing of 60x60 cm. Land preparation is made with the addition of FYM at 10 q/ ha. Since it is a climber, support is required and irrigation is given during the dry season at 30 days intervals. Flowering starts after 40 days of growth and pods picking is done 3-4 times per season. An average of 35 q/ ha seeds are harvested.

14-Indian Gentian *(Gentiana kurroo* Royle)

The plant is a small perennial herb of family Gentianaceae and is a native of North- Western Himalaya. The dried rhizome and roots are known under the trade name 'Indian Gentian' and is used as a bitter tonic. Gentiopicrin and tannins are present in the raw drug. Rhizome is used as a gastric stimulant and improves appetite. The raw drug is mainly collected from the wild. It is also used for the treatment of fever, abdominal pains and for the purification of blood.

It is propagated by seeds as well as rhizomes. The species is not yet in regular cultivation. However, efforts are made under the All India Coordinated Research Project on Medicinal Plants for its successful cultivation in Himachal Pradesh.

15-Indian valerian *(Valeriana jatamansi* DC)

The species belongs to family Valerianaceae and is a perennial herb of about 45 cm height and rootstock including rhizome is thick, nodular and aromatic. The species is distributed in the Himalayan region. Roots of the species are useful in diseases related to eye, blood, liver and spleen. Leaves are used for the treatment of headache. Roots are also used in aromatic industry. Raw drug is collected mainly from the wild since cultivation is not yet popularized.

Since it is a temperate plant, it requires cold weather for proper growth. FYM is added at the rate of 15-20 t/ha at the time land preparation. It is propagated by the root stocks or seedlings. Planting is done either after autumn or in summer. Row spacing of 30 cm and plant spacing of 40 cm is maintained. The crop requires 2- 3 irrigations during dry periods. Weeding and hoeing are done at monthly intervals. A two year old crop yields about 2.5 t/ ha. The harvested rhizomes and roots are shade dried and used for medicinal and aromatic purposes.

16-Bankakri *(Podophyllum hexandrm* Royle= *P. emodi)*

The plant is an erect, succulent herb with creeping perennial rhizome bearing numerous roots belongs to the family Berberidaceae. The species is distributed in the inner ranges of Himalayas from Kashmir to Sikkim at an altitude of 3000- 4200 m. The rhizome and the root constitute the raw drug source of resin, podophyllin or podophyllin resin. Podophyllotoxin is the active ingredient of podophyllin. The raw drug is used for the treatment of ulcers, cuts and wounds. It is a purgative and is used in curing skin diseases and tumor growth. Podophyllin has acquired special attention during recent time due to its action against cancers. The raw drug is collected mainly from the wild since the cultivation has not gained omentum. The underground rhizome remains dormant during winter.

Seeds and rhizome are used for the propagation. The species grows well in temperate climate at about 2500-4000 m. Rhizome cuttings are planted in May to July at 30 x 15 cm spacing. Seeds are sown in rainy season. FYM is applied at the rate of about 20-25 t/ha at the time of land preparation. The crop is irrigated during the dry period. Hoeing and weeding are done at monthly intervals. Two to four years old crop is ready for harvest and an average yield of about 3 tonne dried rhizome and root is obtained. However, commercial cultivation has not yet been popular.

17- Madhunasini *(Gymnema sylvestris* Retz.)

The plant is a member of family Asclepiadaceae.1t is a woody climber distributed in hill regions of Bihar, Orissa, Madhya Pradesh and southern parts of India. The leaves when chewed temporarily cease one's ability to sense sweet taste. The species have gained importance, as it is used to cure diabeties. Leaves are used for the treatment of diabeties. Gymnemic acid present in the leaves is believed to reduce blood glucose level. Leaves and roots are also used to treat headache, polyuria, leprosy, wounds and prurutis. The raw drug is mainly collected from the wild.

Cultivation can be done by rooted stem cuttings. At the time of land preparation, FYM is applied in the pits at 5 kg/ pit. Pits are made at a distance of 1 m. Plantation raised using supports. Weeding and hoeing are done at one month interval. Irrigation is given at 20 days interval during the dry periods. It is a perennial crop and leaf picking can be started from one year old plantation.

18-Atis *(Aconitum heterophyllum* Wall.ex Royle)

It is a perennial herb of family Ranunculaceae with fleshy roots commonly distributed in Himalayan ranges. Roots are used for medicinal purposes. It is used in diarrhoea, dysentery and gastric pain. It is used as a bitter tonic to combat debility after malaria and other fevers. It is also used against hysteria, dyspepsia, vomiting and cough. Wild habitats are the sole source of the raw drug since the plant is not in cultivation. Price of the raw drug is also very high (about Rs 2000 per kg) since the collection from the wild is also very difficult due to the inaccessibility of the wild habitats. Alkaloids (Heterophyllisine, atidine and atisine) present in the rhizome are the active ingredients.

The crop requires cool climate and 'organic rich soil’ for cultivation. It can be propagated by seeds, tubers or stem cuttings. Planting is done in the monsoon. In dry periods, irrigation is given at one month interval. Regular weeding and hoeing are also done. The crop is ready for harvest after about 5-6 years. An average yield of about 6 q/ ha is obtained per crop.

19- Behda *(Terminalia bellerica* (Gaertn.) **Roxb.)**

Behda is a member of family Combretaceae and is a deciduous tree that grows upto 40 m height. The species is distributed throughout the greater part of India in plains and lower hills. In India, it is mostly distributed in humid areas. The fruit of the species is commercially known as myrobalan or belliric myrobalan and is medicinally important. It is anti-cancerous and used against heart diseases, anaemia and rheumatism. Beta sitosterol, gallic acid and bellericanin are the major active ingredients of the raw drug.

The species is propagated by seeds. The species is not under regular cultivation and the raw drug is mainly collected from the forests. The dried fruits are used for different drug preparations.

20- Harde *(Terminalia chebula* Retz.)

Harde belongs to family Combretaceae and is a about 15-24 m tall tree distributed throughout the greater part of India. In combination with Emblic myrobalan (*Emblica officianalis*) and belliric myrobalan (*Terminalia bellirica*), under the formulation 'Triphala' (three fruit), *T.chebula* is used extensively in a number of ailments. The main purgative ingredient of thriphala is harde and the purgative ingredient is in the pericarp of the fruit, which is a glycoside similar to sennoside A of Senna (*Cassia angustifolia*). Chebulin, chebulinic acid, tannic acid and behinic acid are the major active ingredients of the raw drug.

The species is not under regular cultivation and forests are the main sources of raw drug collection. The collected fruits are dried and used for the preparation of various drugs.

21- Amla *(Emblica officinalis* Gaertn. = *Phyllanthus emblica* L.)

It is a member of family Euphorbiceae. The plant is a small to medium sized deciduous tree. The species is a native of India, Sri Lanka, China and Indonesia. In India, the plant is found wild as well as in organized cultivation. Flowers are unisexual. Flowering mostly occurs during March to June and fruits ripen in the coming winter. The fruit commonly known as amla or emblic myrobalan is a highly reputed drug of Indian Systems of Medicines. It is one of the richest source of vitamin C. The fruits are used for the treatment of vomiting, biliousness, urinary discharges, constipation, leprosy, piles and diseases related to eyes. Triphala, an ayurvedic formulation includes amla as one of the three constituents.

Grafted or budded plants are used for cultivation. A good number of high yielding varieties are available. Pits are made ready for planting in the month of May/ June at a distance of about 4.5x 4.5 m. About 15 kg FYM per pit is added along with one kg of super phosphate. Planting is done in the rainy season and irrigation at 15 days interval is required in the initial years in the dry months. The plant is manured every year with 1 kg each of urea and super phosphate and 1.5 kg of Muriate of Potash (MOP) in two equal splits. The plant bears fruits after about 5 years. An average yield of about 20-25 t/ ha is obtained.

22-Long pepper *(Piper longum* L.)

Long pepper is a member of family Piperaceae and is a slender aromatic perennial herb distributed in Central Himalayas, Assam, Khasi hills, Bengal, Western Ghats and Andaman and Nicobar Islands. Ripened green fruits and roots are used as the raw drug. India imports a large quantity of raw drug from Malaysia and Singapore. The fruits are used as spice also. It has a pepper like taste. Piperine and piplartine are the two important alkaloids responsible for the therapeutic action. In addition, the raw drug also contains a number of essential oils.

Raw drug is collected both from the wild and cultivated areas: The crop is under cultivation in parts of Maharashtra, Kerala, Assam and Tamil Nadu. Stem cuttings are used for the propagation of the species. At the time of land preparation, FYM is applied at 20 t/ ha. Planting is done in pits 3x 2.5 m spacing. It is a perennial crop and each year of the crop, manuring has to be done. Irrigation is done in the drier months and in the first year regular weeding and hoeing are required at one month interval. From 8th months onwards fruits are ready for harvesting and in the third or fourth year entire plants are uprooted and thicker stem parts and roots are also harvested. The harvested products are sun-dried and used. An average of about 22q of dried fruits and 500 kg of roots are obtained per crop.

23-Bala *(Sida cordifolia)*

Bala is an annual herb of family Malvaceae. There are four different varieties viz. bala, atibala, nagabala and mahabala of which bala is most widely used. *Sida cordifolia* is considered as the source of raw drug bala in north India while in south India *Sida rhombifolia* is accepted as the source of the raw drug. All the Sida species are widely distributed as a weed in the tropical and subtropical regions of India. Cultivation in limited scale has been initiated in the species in some parts of India. The root of the species is used as the raw drug for the treatment rheumatism. It imparts strength to the body and is useful in the treatment of facial paralysis, general debility, sciatica, headache, uterine disorders, etc.

Commercial cultivation has yet to gain momentum. The plants can be grown by seeds. Seeds usually germinate in the rainy season and usually come as natural in the uncultivated areas.

24-Vasaka (*Adhatoda vasica* Nees= *A. zeylanica* Medic.)

It is an evergreen, perennial shrub of family Acanthaceae and grows well in waste lands and also used as a hedge plant. The species is a source of a well-known raw drug 'vasaka' which is mainly used for the treatment of bronchitis, asthma, cold, cough and whooping cough. Fresh or dried leaves are used mainly as the raw drug. It is used in the form of fresh juice, decoction, infusion or powder. The leaf juice is also used to cure dysentery, diarrhoea and glandular tumour. A number of alkaloids are present in the raw drug of which vascine and vasicinone are important. It is not commercially cultivated, however, in south India it is grown as hedge. The plants can be grown by stem cuttings. Leaves are collected and shade dried and sold in the local market.

25- Asoka *(Saraca asoca* (Roxb.) De Wilde)

It is a medium size, evergreen tree. Flowers are orange- yellow with bronze coloured tender shoots. It is distributed throughout India particularly in humid areas. The plant is considered as sacred tree of Hindus and Buddhists. Asoka bark is widely used in Indian medicines for the treatment of uterine disorders. Flowers are also used for the treatment of bleeding piles and skin diseases. The activity of the drug is due to the presence of steroidal component and calcium salt. Bark also contains tannins. It is propagated by seeds and is also cultivated as an ornamental plant. The increased demand of the raw drug in recent years has caused overexploitation of the species in wild habitats. It is one of the flagship species identified by National Medicinal Plant Board and targeted for wide scale cultivation in south India. Commercial cultivation is rare. Seedlings are used for planting and are planted at a distance of *4x4* m spacing. 2 kg FYM per pit is applied and planting is done at the onset of monsoon.

26- Sarpagandha (*Rauvolfia serpentina* (L.) Benth.ex. Kurz.)

Sarpagandha is a perennial under-shrub belongs to family Apocynaceae, distributed throughout India. The species attain a height of about 75-100 cm with inflorescence arranged in cymes with deep red flowers. Roots contain alkaloids (reserpine, desrpidine and reseinarnine) which a sedative and used to control high blood pressure. It is also used for the treatment of insomnia, asthma and acute stomachache. Government of India has prohibited its collection from the wild due to ruthless collection of the species from its wild habitats. .

The crop is, under cultivation and propagated mainly by seeds. Tropical humid climate' is better for a better crop growth. Seedlings are transplanted during the rainy season 45x30 cm at spacing. At the time land preparation, *'l-0tJ* ha FYM is applied. During dry period, irrigation is given at 20-30 days intervals. Two to three weeding are required in the first year along with two hoeings. The crop is ready for harvesting after about 18 months. An average dry root yields 20-25 q/ha. The harvested roots are cleaned and cut into small pieces, dried and stored.

27- Periwinkle *(Catharanthus roseus* (L) GDon).

Periwinkle is an erect annual or perennial herb of family Apocynaceae. The plant bears white or pink flowers. It flowers throughout the year with profuse flowering mainly during rainy season. It is a native of Madagascar and brought to cultivation in a number the tropical countries including India during eighteenth century. All parts of the plant, especially roots contain alkaloids. Leaves are used to treat menorrhagia and the plants are also used to treat diabeties in Ayurveda. However, the alkaloids vincristine and vinblastine present mainly in the roots of the plant is used to treat a various types of cancers including leukaemia in modem medical systems. The plant is mainly cultivated for its alkaloids and sometimes as an ornamental plant.

The major cultivation areas are Tamil Nadu, West Bengal, Assam and Karnataka. It is propagated mainly through seeds. Seeds are sown directly or seedlings are raised in nursery and transplanted in the field. An average spacing of about 45x15 cm is maintained. Irrigation is given during the drier period at one month interval. The crop is harvested after about 6-8 months. An average yield of about 65 kg *root*/ ha and 1200 kg/ha foliage is obtained.

28- Bhui amla *(Phyllanthus amarus* Schuin. & Thom.)

It is a small herb of about 60 cm height. The species is distributed throughout India and grows as weed in the cultivated lands. The whole herb is used for the medicinal purposes. It is bitter in taste and is used mainly for the treatment of jaundice. It is also used in dyspepsia, diarrhoea and dysentery. The herbage portion contains the bitter phyllanthin which is responsible for the therapeutic action.

The species is not under regular cultivation and the raw drug mainly grows as wild. However, the plant can be propagated by direct sowing to the field. Field is prepared by adding 15-20t/ ha FYM and seeds are sown in lines at 30 cm apart. The plant can be raised as a rainfed crop. Five months old plants are harvested and dried and used as raw drug.

29- Tulsi *(Ocimum sanctum L.)*

It is an erect highly branched aromatic perennial herb of family Lamiaceae. Two plant types are commonly available; one is with green leaves and the other purple leaves. It is also under cultivation throughout India. Leaves, flowers and occasionally the whole plant are medicinally used to treat heart diseases, leucoderma, asthma, bronchitis and fever. The leaves and tender parts of the shoots are economically important and the essential oils obtained have immense value in aroma industry. The chemical constituents of the essential oils are monoterpenes, sesquiterpines and phenols with their alcohols, esters, aldehydes, etc. Propagation is mainly done both by seeds and seedlings.

Seedlings are used for cultivation. Nursery has to be raised in the first week of April and transplanting will be at 4-5 leaf stage of the seedling at the onset of monsoon. A basal application of 15,t/ha FYM is applied. Seedling will be transplanted at a spacing of 60 x 60 cm. A total of 12·015, irrigations are required per year.

First harvest is.done at the full bloom stage of the plant after that at two months interval. The crop can be cut ar15-20 cm above the ground. Generally, bright sunny days are preferred for harvesting and iris advisable not to harvest the material if there was rain on the previous day. Freshly harvested material is distilled for oil extraction. An average fresh herbage yield of 30t/ha and 40 kg oil per ha are obtained.

9.7.2 Aromatic Plants

1- Muskdana *(Abemoschus moscatus* Medic.)

The plant belongs to family Malvaceae. It is an erect perennial herb with fruits similar to lady finger but smaller in size. It is distributed throughout peninsular India and Himalayan foot hills. The plant is in cultivated in limited areas of Maharashtra, Madhya Pradesh and Uttar Pradesh. Seeds are used commercially both in medicine as well as perfumery. Seeds are musk scented and are used to flavour food and as a substitute of musk. It is used to treat intestinal problems, stomatitis and heart diseases. In Unani, it is also used to treat dyspepsia, urinary discharges, gonorrhoea, leucoderma and itching.

Seeds are used for the propagation of the crop. FYM is applied at the time of land preparation at the rate of 20-25 tonne/ ha. Seeds are sown at a distance of 100 x 60 cm during monsoon NPK. Fertilizer is applied at the rate of 150: 25: 25. Two-weedings followed by hoeing are done at 30 days interval. After the rainy season, irrigation is given at 20 days interval of which irrigations at flowering and seed formation stages are crucial. Harvesting starts after about 150 days of crop growth the matured dried fruits are harvested and seeds are threshed out of the fruits. The seeds are shade dried and used for oil extraction. Seed yield of the crop is about 15q/ha.

2-Lemongrass *(Cymhopogon jlexuosus* Nees ex. Steud Wats.)

The plant belongs to family Poaceae. There are three species of lemongrass such as Cymbopogonie., *C.flexuosus, C.citratus* and *C. pendulus,* commonly grown in India. The odour of the oil extracted from the leaves are lemon scented and hence the name 'lemongrass'. *C.*

flexuosus and *C. citratus* are under cultivation. The species are about 2 m long perennial grass with profuse tillering habit. *C. flexuosus* (East Indian lemongrass or true lemongrass) is more preferred by the industry due its superior oil quality. Lemongrass is distributed commonly in tropical and subtropical Asia, Africa and America. *C. flexuosusis* present in wild state in Western Ghats, Sikkim and Arunachal Pradesh. Citral extracted from the oil is of commercially importance. The oil is used in flavouring and medicinal industry and also for production of Vitamin A and synthetic violets. India is one of the major suppliers of lemongrass oil in the world market. A large number of high yielding varieties are available for cultivation.

Traditionally, it is grown in the areas receiving well-distributed high rainfall. Commercial cultivation of the species is spread to Kerala, Assam, Maharashtra, Uttar Pradesh and Gujarat. C. pendulus is distributed naturally in West Bengal, Sikkim, Assam and Madhya Pradesh and cultivated in parts of Jammu. The crop can be planted after winter (February-March) or during rainy season (June-July). The crop is propagated through seed or slips. In north-eastern hilly regions, close planting (30 x 30 cm) is done while wide spacing (45 x 60 cm) is practiced in the northern plains. In general, 100 kg nitrogen, 30 kg phosphorous and 40 kg potash are applied for 1 ha land. It is generally grown as rainfed crop and no irrigation is required in the areas receiving well-distributed rainfall. However, 2-3 irrigations during hot summer months and one irrigation after each harvest are applied to get higher yield. One or two times weeding after planting and one more weeding within 30 days after first harvest are recommended. Under good rainfall areas, first harvesting can be done at 3-4 months after transplanting. Thereafter, the crop can be harvested at a regular interval of 55-60 days. A total of 2- 3 harvests in the first year and 3-4 in subsequent years are possible. Oil in the herbage is distilled by hydro-distillation. Fresh herbage yield of 25-40 tonnes per ha area is obtained per year. An oil yield of 80-100 kg per ha is expected.

3- Palmarosa *(Cymhopogon martini* Stapf. Var. Motia)

Palmarosa or Rosha grass is a tall perennial herb of family Poaceae. It is distributed in most parts of subtropical India. Distillation of herbs with the flowering parts yields sweet scented oil which is rich in geraniol. The oil has high demand in perfumery, soap, cosmetics and blending tobacco products industries. The species is under cultivation in central, western and southern states of India.

Areas where moist and warm climate persists throughout the year are favorable for its cultivation. The plantation cart is raised by directly broadcasting of seed in row at a seed rate of 8 to 10 kg/ha after the land is saturated with two or three monsoon showers. The nursery raised seedlings are planted during monsoon season from late June to mid August (depending upon the locality) at a spacing of 45 x 30 cm and 60 x 60 cm. The irrigation requirement is about 16-18 light irrigations during a period of 15-18 months where the average annual rainfall is 55-60 cm. Two weeding –cum-hoeing operations are recommended; the first at 40 days after transplantation and a second 30 to 40 days after first weeding. It is harvested when it is of about 4 months age and in full bloom stage. Generally, two cuttings made during first year planting. From second year onwards, three cuttings are possible. Palmarosa plantations remain productive for about 4 years. An oil yield of about 220-250 kg per hectare may be obtained from second year onwards.

4- Geranium *(Pelargonium graveolens* L. Herit.)

The geranium of trade is the common name given to a number of species Pelar gonium species .of family Pelargoniaceae. The major species that is cultivated for the commercial geranium oil is *P. graveolens* L'Herit. The crop is grown as rainfed crop in hilly areas and as irrigated crop in plains. There are two types of *P. graveolens* i.e., Algerian or Tunisian and Bourbon or Reunion. The former is with dark pink flowers, not suitable for wet conditions and cultivated in higher elevations and the latter is with light pink flowers, suitable for wet conditions and cultivated in plains. Egyptian type is another strain identified for cultivation in plains, which is rich in geraniol and resistant to wilt compared to Bourbon. The plant is bushy in nature growing to a height of 1 m. Stem is cylindrical, green when young and turned to brown when matured. Flowering is more profuse in higher altitudes. Rose scented essential oil, extracted from its leaves and tender shoots are commercially important. The crop is propagated by stem cuttings and root suckers. Geranium oil contains 60- 70 per cent alcohols like, citronellol, geraniol; 20-30 per cent esters like, geranyl tiglata, geranyl acetate, citronellyl acetate and the rest aldehydes and ketones, etc.

The crop is grown as rainfed in hilly areas and as irrigated in plains. Nursery developed rooted stem cuttings are used for sowing. Generally, the crop grows well intemperate, subtropical and tropical climates. The field is prepared by adding FYM at *15t*/ ha. Planting is done on the ridges at a spacing of 60x 60 cm. A light irrigation is given immediately after transplanting. Application of NPK at 120: 30: 60 kg per hectare is applied. Under irrigated condition, the crop is irrigated daily for 3-4 days immediately after transplanting, subsequently on alternate days for 10-15 days interval and there after twice in a week. The crop is kept weed free by regular weeding for the first 1-2 months and thereafter at about 45 days interval. After each harvest, hoeing is done followed by irrigation. The crop becomes ready for harvest four months after transplanting. The crop is perennial and a total of three harvests per year is obtained for about 3-4 years. The harvested fresh herbage is distilled by steam distillation. An average fresh herbage yield of about 30 t / ha and 25-30 kg oil per year is obtained.

5- Patchouli *(Pogostemon patchouli* Pellet. = *P.cablin* Benth.)

The plant is a perennial erect or ascending herb of family Lamiaceae. Commercial cultivation in India was first attempted by Tata Oil Mills in 1942. Oil distilled from shade dried leaves is used in perfumery to give a solid foundation and lasting character of other fragrances since it has a fixative property to prevent the rapid evaporation of perfumes. The oil is generally blended with other essential oils like geranium oil or clove oil before use. The oil is also used in major food products as a flavouring agent. Currently, India is producing only a part of its annual requirement and about 20 tonnes of patchouli oil is importing to meet the requirements. It is propagated by shoot tip cuttings. Common strains available for cultivation are Singapore, Johore, Indonesian, Java and Malaysian strains.

Patchouli is propagated through rooted cuttings. However, tissue cultured plants are also available for cultivation. Patchouli grows at its best in hot and humid climate with even distribution of rainfall. This is a shade loving plant and hence partial shade will enhance the crop growth. July-March with assured irrigation is recommended. Once planted, the plants can provide economic yield up to three years. Since the herbage is harvested at three to four times a year, to maintain a good crop stand the recommended dose of 150: 100: 100 kg of NPK per ha is applied in four splits. The crop is irrigated at 3-4 days interval immediately after planting and 10-12 days afterwards. In summer months frequent irrigation may be given depending upon the soil water availability. The crop requires weeding at early stages of its growth. The plots should be kept weed free during the first 2 to 3 months. During the hoeing operations, care should be taken to avoid the damage to roots. A good crop may yield 3 to 5 tonnes per hectare per year dry herbage and about 60-100 kg oil per hectare. The harvested shoots are shade dried and used for oil distillation.

6. Mint *(Mentha arvensis* L.)

Mentha or mints includes a number of aromatic perennial herbs such as *Mentha arvensis* var. piperascense (Japanese mint), *M. piperita* (Peppermint), *M. spicata* (Spearmint) and *M. citrata* (bergot mint) of family Lamiaceae, common cultivated species of Mentha. Japanese mint has high percentage of menthol and is used in cold and cough drops, mouth washes, cosmetics, tobacco flavouring. Pepper mint oil is carminative, antiseptic and gastro-stimulant properties and used in confectionaries, alcoholic drinks, dental creams and mouth washes. Spear mint oil is rich in carvone and has digestive and gastro-stimulant properties; it is used in confectionary, chewing gum and tooth pastes. Bergamot mint oil is rich in linalyl acetate and linalool and mainly used in cosmetic industry. Mints were first introduced to India in 1952 by the Regional Research Laboratory, Jammu. The herbage of the plants is economically useful which yields essential oils. The chief chemical constituents of the essential oils are menthol, carvone, linalyl acetate and linalool and are in great demand in pharmaceutical, food flavour, cosmetics, beverages and related industries. A number of high yielding varieties are now available for cultivation.

At present, the crop is mainly cultivated in Tarai regions, Indo-Gangetic plains, Punjab and in north western India. At the time of land preparation 25-30/t/ha FYM is added. An optimum fertilizer requirement of 150:50:50 kg of NPK per ha is applied. Weeding and hoeing are done at 40 days intervals. During dry periods, irrigation is given at every 15 days interval. First harvesting is done at 110 days of maturity and after that at about 90 days interval. An average of about 30 t/ha of fresh herbage and about 150 kg/ ha oil are obtained from *M. arvensis.*

7. Rose *(Rosa damascena* Mill.)

Rose has a reputed position because of its colour, fragrance and economic benefits. It is a perennial hardy shrub of about 2.5 to 3 m height. Half opened flowers have more fragrance and oil yield than the fully opened flowers. In India about 1500 to 2000 hectares of land is under rose cultivation which is mainly located in Uttar Pradesh. Other commercially important Roses are *R. centifolia* L., and *R. bourboniana* Desp. (Edward Rose). Different perfumery products obtained from rose are rose attar, Gulkhand, Gul-roghan, Punkhuri and Otto rose. Propagation of roses is mainly done by stem cuttings.

Rooted cuttings are used for cultivation. FYM is applied at 30tJ ha at the time of land preparation and planting is done at a spacing of l x l m. About 10-12 irrigation are required per year. A fertilizer requirement of 200:50:25 kg of NPK per ha is applied. Pruning is important for good yield and first pruning is done at a height of 50 cm from the ground level after two years of crop growth in the month of December. After each pruning, irrigation, weeding and hoeing are essential. In the month of January and February, at least three weeding and hoeing are done. The main flowering season is March to April. Flowers which started opening are harvested before sun rise by hand picking. The harvested flowers should be distilled immediately. An average of about 30 q/ha flower is obtained ill an year after third year of plantation:

8. Jasmine *(Jasminum sambac* L.)

It is a more or less scandent shrub with highly fragrant flowers. It is commonly known as French Jasmine. The species is originated in Indo-Burman region in the foothills of Hirnalayas. Other important species of the genus are *J. grandiflorum*, *J. auriculatum* and *J. odorotissimum.* The essential oils obtained from the flowers are used in perfumery and are export oriented also. Plant starts blooming in the first year of planting and full yield will be in the third year and the crop sustains up to 15 years. Good varieties for higher production are available in south India.

In India, organized cultivation of the species was started in Tamil Nadu. Plant is propagated by stern cuttings. Once planted, a well maintained crop continues for about 15 years. Planting is done at a distance of 2 x 1.8 m. Fertilizer application of 100: 150: 100 g, NPK per plant is optimum for a good yield. Weeding is done every month and pruning is done in December at 90 cm from the base level. After each pruning, irrigation, weeding and hoeing are done. The fully mature floral buds are harvested between 3.00 AM and 8.00 AM and allow for opening and immediately used for oil extraction. An average flower yield of 5q/ ha in the first year, *5t1* ha in the second year and 10 t/ha from third year onwards is obtained. Yield of Jasmine concrete is 25-30 kg/ha depending upon the variety.

9. Vetiver *(Vetiveria zizanioides* (L.) Nash.)

It is a tall perennial grass of about 1.5 to 2.0 m height. In India, it is widely seen in wet and damp places; however, it tolerates extreme conditions. The species is used against soil erosion because of its roots' soil binding property. The aromatic roots are traditionally used for making mats, fans, door-screens which produce fragrance imparting a cooling effect during extreme summer when sprinkled with water. The roots on distillation produce volatile oils, which are used in perfumery, cosmetics and toiletries and also as a fixative for blending of other delicate fragrances. It is also medicinal and used against flatulence and colic pains. Sugandha and Nilambore are the two high yielding varieties available for cultivation.

Commercial cultivation is mainly confined to the southern states of India. The crop is raised by root slips. FYM is applied at the time of land preparation at 15t/ha. Planting is done in the rainy season at a spacing of 60 x 25 cm. First weeding cum hoeing is done after 30 days of planting. Two more intercultural operations are done during the initial stages of crop growth. A maximum of eight irrigations are given for the total crop growth period of 15-18 months. A light irrigation is given for the easier uprooting of the plants. The aerial portions are cut off from the ground level and the root stocks are dug up, cleaned, roots are separated our, shade dried and used for oil distillation. An average of 2-3 t/ha of root yield is obtained.

4.8 PROCESSING

4.8.1 Medicinal Plants

Appropriate measures of primary processing are dependent on types of material. These processes should be carried out in conformity with national or regional quality standard norms.

Drying

Medicinal plants can be dried in a number of ways such as in the open air under shade, wire screened rooms, by direct sunlight, drying ovens or rooms, solar drier, indirect fire, microwave, infrared device, etc. depending upon material and requirement.

Specific processing

Some medicinal plants require specific processing such as peeling of roots or rhizomes, boiling in water, steaming, soaking, pickling, distillation, fumigation, roasting, natural fermentation, treatment with lime and chopping.

4.8.2 Aromatic Plants

Hydro-distillation

There are three basic types of essential oil hydro-distillation. The first is the simple and ancient method of water distillation which is least economical. Second is the water and steam distillation which utilizes both water and steam. Plant material is placed within the steel chamber in a grill that separated them from water below. The steam produced by heating the water only comes in contact with the material. This is the best type for leafy herbal material.

Third type is the steam distillation which is the most cost effective hydro-distillation and has the highest rate and production capacity. Plant material is placed in a chamber. Steam is generated in a boiler and pumped into the chamber having plant material. The steam separates the volatile oils from the plant cells when the boiling point is reached.

In all these processes, condensation of the extracted volatiles oil in gaseous form is passed through a condenser which is cooled by running cool water.

Solvent extraction

This method is used where total extractions are need e.g. oleoresins extraction of ginger, cardamom, pepper etc. and concentrates and absolutes of jasmine, rose, etc. After extractions the solvents are totally removed.

4.9 SUMMARY

Medicinal and aromatic plants are very important natural resources. They not only provide cure of several diseases of human being and also provide livelihood to a large number of forest dwellers. Medicinal and Aromatic plants are of different types such as trees, shrubs, herbs, creepers, etc. A large number of MAP species are harvested from forests and therefore, their conservation by *in situ* and *ex situ* methods is an important concern. Good Agricultural Practices (GAP) need to be followed to ensure medicines and ISM drugs prepared from MAPs free of pesticides and heavy metals.

4.10 GLOSSARY

Aromatic Plants: Refer to a special class of plants used for their aroma and flavour.
***Ex-situ* Conservation:** Refers to conservation of plants away from their natural habitats.
Good Agricultural: Guarantee quality of raw drug and to facilitate
Practices (GAP) for MAP: the standardization of quality of ISM drugs for acceptance to science led world.
ISM: Indian Systems of Medicines.
***In-situ* Conservation:** Refers to conservation of plants within their natural habitats.
Medicinal Plants: Refer to those plants that are used in official and various traditional systems of medicines throughout the world.
MAPs: Medicinal and Aromatic Plants.
WHO: World Health Organization.

4.11 SELF ASSESSMENT QUESTION

4.11.1 Multiple choice Questions

1- Botanical name of mint is-
(a) *Mentha arvensis* (b) *Abemoschus moscatus*
(c) *Pelargonium graveolens* (d) *Vetiveria zizanioides*

2- *Cymhopogon martini* belongs to family-

(a) Lamiaceae (b) Poaceae
(c) Orchidaceae (d) Malvaceae

3- Common name of *'Chlorophytum borivilianum'*-
(a) Ashwagandha (b) Jasmine
(c) Tulsi (d) Safed musli

4- 'Madhunasini' is used in the treatment of –
(a) Diabetes (b) Vomiting
(c) Leprosy (d) Cough

5-Asoka is a –
(a) Herb (b) Shrub
(c) Tree (d) Climber

Answer Key:

4.11.1: 1-(a), 2-(b), 3-(d), 4-(a), 5-(c)

4.12 REFERENCS

- Chopra, RN., Nayar, S.L. and Chopra, 1.c., (1996) *Glossary of Indian Medicinal*
- *Plants.* Council of Scientific and Industrial Research, New Delhi.
- Chadha K.L. and Gupta, R (1969) (ed.) *The Wealth of India*, Council of Scientific
- and Industrial Research, New Delhi.
- Chadha, K.L. (ed.) (2006) *Advances in Horticulture*, Vol l l (Eds.), Malhotra
- Publishing House, New Delhi. 935p.
- Kirtikar, K.R and Basu, B.D. (2006) *Indian Medicinal Plants,* 49, *lenght volume*
- Leader Road Allahabad, India.
- Parotta J.A. Healing plants of Peninsular India, (2001) CABI Publication, of 44 p.
- Sivarajan, v.v. and Balachandran, Indira (1994) *Ayurvedic Drugs and their Plant*
- *Sources.* Oxford & IBH Publishing Co. Pvt., New Delhi, 570p.
- *Websites*
- http://www.nmpb.nic.in1
- http://www.indianmedicine.nic.inlhtmllplantslplants.htrn
- http://www.frlht.org.inImeta/
- http://www.cabi.org/ AbstractDatabases.asp ?SubjectArea=&PID=51
- http://www.nrc-map.org:8080IWEBPAGES_CODEIDHMAPlHome.jsp

4.13 SUGGESTED READING

- Chopra, RN., Nayar, S.L. and Chopra, 1.c., (1996) *Glossary of Indian Medicinal*
- *Plants.* Council of Scientific and Industrial Research, New Delhi.
- Chadha K.L. and Gupta, R (1969) (ed.) *The Wealth of India*, Council of Scientific
- and Industrial Research, New Delhi.
- Chadha, K.L. (ed.) (2006) *Advances in Horticulture*, Vol l l (Eds.), Malhotra
- Publishing House, New Delhi. 935p.
- Kirtikar, K.R and Basu, B.D. (2006) *Indian Medicinal Plants,* 49, *lenght volume*
- Leader Road Allahabad, India.
- Parotta J.A. Healing plants of Peninsular India, (2001) CABI Publication, of 44 p.
- Sivarajan, v.v. and Balachandran, Indira (1994) *Ayurvedic Drugs and their Plant*
- *Sources.* Oxford & IBH Publishing Co. Pvt., New Delhi, 570p.
- *Websites*
- http://www.nmpb.nic.in1
- http://www.indianmedicine.nic.inlhtmllplantslplants.htrn
- http://www.frlht.org.inImeta/
- http://www.cabi.org/ AbstractDatabases.asp ?SubjectArea=&PID=51
- http://www.nrc-map.org:8080IWEBPAGES_CODEIDHMAPlHome.jsp

4.14 TERMINAL QUESTIONS

4.14.1 Short answer type of Questions:

1- Define medicinal plants.
2- Define aromatic plants.
3- Why is conservation of MAPs important?

4.14.2 Long answer type of Questions:

1- What are the habit wise different types of medicinal and aromatic plants?
2- Give few examples of tree medicinal plants.
3- Why is conservation of the MAPs important? What are different methods used Medicinal and Aromatic Plants for the processing of medicinal and aromatic plants?
4- Discuss any 3 medicinal plants given in your syllabus.

UNIT-5 FODDER AND FIBRE CROPS

Contents

5.1 OBJECTIVES

After studying this unit, you should be able to:

- enumerate the region of origin of fibre crops;
- discuss about the different type of fibres;
- describe the important fibre crops of the world;
- describe the morphology, cultivation, varieties and uses of major fibre crops.
- Discuss about fodder crops

5.2 INTRODUCTION

Earlier units in this course have provided information about uses of various crop plants. Crop plants have been cultivated since ancient times for various uses such as food, wood and medicines. Plants have been cultivated in different parts of the world for getting cereals, pulses, spices, fibres, oils, beverages and timber. This present unit will provide you information about the important Fodder and fibre yielding crops grown in different parts of the world.

5.3 GENERAL ACCOUNT

The use of fibre obtained from plants for clothing has been recorded since prehistoric times. Early humans obtained fibre from plants which later on was spun and weaved to get threads by interlocking strands. Fibre consists of long narrow cells having thick walls but narrow lumen. The cells are non-living but impart strength and rigidity to the plant body. They occur singly or in groups/bundles closely cemented to each other. Many plant species are rich source of vegetable fibre. Vegetable fibres are mainly composed of cellulose which forms its main structural component. This macromolecule is made up of many glucose units. Plant fibres have been classified into different types depending upon the morphological nature and structure. They are mainly classified into three types- 1) soft stem or bast fibres, 2) hard leaf or structural fibres and 3) surface fibres.

Bast fibres - These fibres are found associated with the phloem, pericycle and cortex. They are found mostly in dicotyledonous plants. They are durable and capable of resisting bleaching. Commercial bast fibres are produced by plants mainly- flax, jute, hemp, kenaf.

Structural fibres - They include strands of small, short lignified cells ensheathing xylem and phloem. They are mainly found in leaves of monocotyledonous plants. They are highly lignified and coarser.

Surface fibres - This type of fibres are produced on the surface of stems, leaves, fruits and seeds. The fibres arise as epidermal outgrowths of the seeds or inner wall of fruits. Cotton is the main plant in this category. According to their use the fibres are classified as textile fibres, brush fibres, filling fibres, natural fibres and paper making fibres. The fibres that are used in the manufacture of fabrics are called textile fibres. For manufacture of fabrics, the fibres are twisted together into threads or yarn and woven. Cotton, along with some quantities of flax, ramie and hemp are used for this purpose. Some fibres are used in the manufacture of brushes. These include sisal and istle (hard fibres), broomcorn (inflorescence of *Sorghum vulgare*) and strong and stiff fibres of piassava (fibres from palm leaves and stem). Flat strands or strips are woven into hats, baskets and roof of houses. Some fibres are used for filling of cushions and mattresses. These include cotton, jute, hard fibres and several grasses. Various wood fibres, grasses and sedges are used for making paper.

Fodders crops are cultivated plant species that are utilised as livestock feed. Fodder refers mostly the crops which are harvested and used for stall feeding. Fodder crops are the plant species that are cultivated and harvested for feeding the animals in the form of forage (cut green and fed fresh), silage (preserved under anaerobic condition) and hay (dehydrated green fodder).

5.4 IMPORTANT FIBRE CROPS

The major fibre yielding species include cotton, coconut, jute, hemp, flax, kenaf etc.

5.4.1 *Gossypium*

Family: Malvaceae

Vernacular name: cotton

n = 13, 26

The cotton has been cultivated in South East Asia and Central America since ancient times. India has been the most primitive center of cotton from where it was introduced to China and Egypt around 600 B.C. In the nineteenth century its cultivation spread in tropical, subtropical and warm temperate parts of the world. Its cultivation has been noted throughout India, Myanmar, Malaysia, China, Korea and Japan. India and Africa are the largest producers of cotton mainly of *C. arboreum*. The four cultivated cotton species with large number of varieties and hybrid forms are classified into two types i.e. i) American or the new world cotton represented by *G. hirsutum* and *G. barbadense*, ii) the Asiatic or the old world cotton consisting of *G. arboreum* and *G. herbaceum*.

G. arboreum (Ceylon cotton)

The plants are annual or perennial shrubs with the height up to three meters. The leaves are five to seven lobed (Fig.7.3). The fruits or bolls are tapering structures profusely pitted having prominent glands in the pits. The fruits open widely when ripe. They contain up to 17 seeds per loculus. The seeds are covered with grayish green or rust colored short hairs called fuzz.

G. herbaceum (Levant cotton)

n=13

The species is native to tropical Africa, Middle East and grown in China, Indonesia, India, Pakistan, Iran, Iraq, Turkey, Greece. The plants are shrubby, reaching a height of 1 m. The leaves are three to five lobed. The incisions in the leaf extend to half the length of the lamina. The bracteoles are widely flaring and boll is three celled, rounded, beaked and smooth surfaced (Fig. 7.2). The fruit opens at maturity with three to four loculi each having up to 11 seeds. The seeds bear two coats of hairs, long lint hairs and short fuzz hairs.

G. barbedense

n=26

The plant is native of South America. It is known for its lint length and fineness of the lint. It has two varieties – Sea Island cotton and Egyptian cotton. Sea Island cotton is one of the finest varieties of cotton and largely grown in West Indies, Fiji and islands of the coast of Florida, Georgia and Southern Carolina. The fine spun yarn is used in the manufacture of laces, cambric and fine hosiery. Egyptian cotton is grown under irrigated conditions of Nile river valley of Egypt and Sudan. The fibre is durable and hence used in the manufacture of goods that require huge strength such as automobile tyre fabric and high quality hosiery. The plants are tall, annual shrubs reaching a height up to three meters. The plant bears few ascending vegetative branches. The leaves are three to five lobed. The corolla is bright yellow in color with red to purple spots near the base. The bolls are usually large, dark green and prominently pitted with oil glands. The bracteoles are large divided at the apex with 10-15 long acuminate teeth. The fruit is three to four valved each having five to eight seeds having fuzzy ends. In Sea Island cotton, the fibres are white, light/cream coloured, soft and lustrous.

G. hirsutum (upland cotton)

n=26

The cotton is native to Mexico and Central America. It is grown in most parts of the world. It constitutes 95 per cent of the world production. Besides United States it grows in Brazil, Uganda, Africa, Iraq, China, Turkey, Greece, India and Pakistan. Most of the world's cotton comes from USA, China, India, Pakistan, Uzbekistan, Turkey, Brazil, Turkmenistan, Greece and Australia. India ranks third in the production of cotton. The major cotton producing states in India are Maharashtra, Gujarat, Andhra Pradesh, Karnataka, Punjab, Haryana and Madhya Pradesh. On the basis of length of staple its two varieties are recognized which include American upland short staple cotton with the length of about 16 to 27mm and American upland long staple cotton with the length of 28 to 38 mm.

Morphology

The plants are generally shrubs or trees with vegetative branches. The main stem of the plant is monopodial in growth and possesses spirally arranged leaves. The leaves bear two kinds of buds- axillary and extra axillary. The plant shows dimorphic branching. The vegetative branches are monopodial while the fruiting branches are sympodial. The vegetative branches develop from the axillary buds of the nodes of lower stem while the fruiting branches arise from the extra axillary buds of the upper nodes. Vegetative branches are morphologically similar to the main stem and do not bear flowers. The secondary (fruiting) branches bear a flower at the tip. From the axil of the subtending leaf, a branch develops that terminates into a fruiting point. The flowers are borne opposite to the leaf on the fruiting branch. The leaves are large, palmately lobed (three to five lobed) cordate, hairy. The flowers are large, showy, white or pale yellow and usually without purplish spot at the base. The flowers are surrounded by involucres of bracts that are generally persistent. The flowers turn pink or red on second day of blooming. The bolls are large, rounded, green and smooth leathery capsules. The fruit consist of three to five locules or chambers (Fig. 7.4). The seeds are covered all over with a long hairs or lint or short hairs or white fuzzy coating. The capsule cracks at maturity along the sutures and contents expand into a white fluffy mass which is pushed outside the carpel. The cotton fibres represent epidermal elongations of the seed coat cells. The fibres attain maturity and full length during the first twenty five days of boll development. A mature fibre looks like a translucent, flattened twisted more or less tubular structure with broad base and an untwisted tapering apical end. A raw cotton fibre consists of 94percent cellulose, protein 1.3 per cent, pectic substances 0.9 per cent. The fibres are classified as long staple and short staple fibres. The long staple fibres are of American or Egyptian origin and have length of 1 to 2.5 inches, good texture and lusture. Short staple fibres are of Indian origin and have length of about 0.3-0.7 inches and are coarse and lustureless. Cotton bolls are handpicked. The fibre is taken out and it is spun into yarn and woven into cloth. The fibre passes through various processes such as ginning, baling, carding, picking and combing. Because of its superior quality, cotton is widely used in textile industry.

Cultivation

Cotton is a tropical crop. The crop requires abundance of sunshine and a warm temperature of 21-43° C. The cultivation requires adequate soil moisture i.e. about 100 cm of rainfall during early stages of growth and a dry season during flowering and fruiting. Harvesting is done six months after sowing.

Uses

The fibre possesses high tensile strength and remarkable resistance. The fibre is used to make innumerable clothing and furnishing items. The absorbent cotton (prepared by removing waxy or oily coating) is used in bandage making and medical purposes.

5.4.2 *Cocos nucifera*

Vernacular name: Coconut

Family: Arecaceae

n = 16

Commercial coir is obtained from the fibrous husk of the fruits of coconut palm. The fibre is light with high elasticity and high resistance. India is the largest producer of coir and its products. About 40 per cent of the nuts produced are used for production of fibre. The fibre is used in the manufacture of mats, rugs, carpets and bags. The fruits are harvested when still green to obtain coir. The fruit is dehusked. The husk is then subjected to retting to remove tough interstitial mass. After retting the husks are taken out of water and thoroughly and repeatedly washed to remove dust. Fibre obtained from coconut has resilience, durability and resistance to water and used in the manufacture of cordage, cables, coir fibres are used in the manufacture of mats, cushion seating, packing material and boards. Distribution, morphology, cultivation and uses of coconut have already been discussed in Unit 6 Oils and fats.

5.4.3 *Crotolaria juncea*

Vernacular name: sunhemp
Family: Fabaceae
n = 8

It is a species of Asian origin and grown since prehistoric times. It is used as a source of bast fibre in India. It has spread to other countries and grown for fodder or green manure. It is grown as a commercial fibre crop in India, Bangladesh and Pakistan. In India, Orissa, Madhya Pradesh, Uttar Pradesh, Bihar, Maharashtra and West Bengal are the major sun hemp producing states.

Morphology

The plant is a tall, erect annual about 1-3 m tall with strong tap root system penetrating the soil. The roots produce nodules which are branched and lobed (Fig. 7.5). All vegetative parts of the plant are covered with hairs. The leaves are small, lanceolate and subsessile. Flowers are small, yellow and borne in axillary racemes. The fruit is a long pod with pointed beak and contain kidney shaped seeds. Out of the three varieties, green, white and Dewghuddy, white variety produces nearly 60 per cent of the fibre.

Cultivation

The crop is well adapted to tropical and subtropical climate with light loamy well drained soils. Sunhemp is widely cultivated in tropical and subtropical areas of the world. It is grown at a large scale in India, Bangladesh and Brazil. The plant grows well at temperature of 18-27° C and areas that receive rainfall below 200 mm.

Uses

The bast fibre produced by the plant consists of ribbon shaped strands which are light in grey to yellow in color. The fibres possess great tensile strength and durability. The fibre strands are lustrous and resistant to moisture. The fibre is used in the manufacture of ropes, twines, cords, canvas, matting and soles for shoes.

5.4.4 *Corchorus spp*.

Vernacular name: Jute
Family: Tiliaceae
n = 7

It is one of the most important sources of bast fibres. It is widely cultivated along with cotton among all the natural fibres. The fibre is obtained from stem. The two most cultivated species are *C. capsularis* and *C. olitorius.* It is believed that the plant derived its name from 'Korkorus" which was used by Greeks. In India this fibre has been used as a sack-cloth since ancient times. In earlier times India produced about 99 per cent of the total jute but today about 80 per cent of the total production comes from India and Bangladesh. It has been also cultivated in China, Thailand, Russian Federation, Vietnam and Myanmar. In India, it is mainly produced in the states of West Bengal, Bihar, Assam and Andhra Pradesh.

Morphology

The plants are woody branched annuals which can grow up to 3.5 m in height having simple ovate, serrate margined leaves. Flowers are solitary, or arranged in cymes. *C. capsularis* is tall branched annual with ovate glabrous leaves containing a glycoside 'corchorin'. Flowers are yellow, small and produce globular, wrinkled capsules flattened at the top. The plants of *C. olitorius* are also tall bearing shining upper and a rough undersurface. The flowers are yellow, large and produce long, cylindrical ridged capsule with elongated beak.

Cultivation

C. capsularis is grown as a rainy season crop which grows well on warm, humid, rich loamy soil with annual rainfall ranging from 150-250 cm, temperature of 17-38° C and humidity around 70-90 per cent. The plants are harvested at the stage when 50 per cent of fruiting is there because both yield and quality of fibre is good. The fibres are separated by retting. The process usually takes 10-30 days and time of the process depends upon the maturity of the crop, water, temperature and depth of immersion. Generally the bundles of fibres are stacked upright in about 0.6 m of water for two to three days. The retting removes the bark.

Uses

The fibres are yellow in colour and possess silk like lustre. They are stiff, brittle and possess low stretch ability and durability. The fibres contain about 63 per cent cellulose. The major use of jute is in the manufacture of sacks, bags, rugs, ropes, blankets, carpets, curtains, upholstery etc.

5.4.5 *Hibiscus cannabinus*

Vernacular name: Kenaf, Java, jute

Family: Malvaceae

n = 18

The plant is used for fibre which is a substitute of jute. Kenaf is also known as Deccan hemp or Java Jute. The plant is grown in many countries of tropics and subtropics such as India, Thailand, Brazil, China, Cuba and Mexico. The fibre is extracted from the lower portion of the stem.

Morphology

The plant possesses a long, slender, unbranched stem about 2-3 m in height. The leaves are usually cordate or palmately divided. The flowers are large, showy and arise in the axil of leaves (Fig. 7.7). The fruit is globose capsule with a pointed tip. The fruit produces brown seeds at maturity. The major variety is *H. sabdariffa*. The fibre strands are long (1-3 m), coarser, tougher and stronger.

Cultivation

The plant is cultivated mainly in tropics and subtropics at temperature above 20° C. The plant prefers well-drained humus rich fertile soil. The plant requires rainfall of about 57 to 400 cm and annual temperature of 11 to 28° C for its growth.

5.4.6 *Cannabis sativa* (Hemp)

Vernacular name: hemp

Family: Cannabinaceae

n = 10

It is one of the oldest fibres known to mankind. It originated in central and western Asia. Later on it spread to China and Europe. The major hemp producing countries are Romania, Hungary, Poland, Yugoslavia, India, China, Japan, Chile, Peru, Iran and Turkey.

Morphology

The plant is a hollow stemmed annual bearing dark green palmately compound leaves. The plants are dioecious. The female plants are shorter, robust while the male plants are taller and slender. Male flowers are borne in axillary and terminal panicles. Female flowers are sessile and arranged dense in a spike. The fruits are smooth, shining achene enclosed by a calyx and large bract. The fibre is obtained mainly from the male plants. The harvesting is done at the time of pollination. The premature harvesting can result in lower yield and weak, soft fibre. The delayed harvesting results in harsh and brittle fibre. The plant is chopped 2 to 3 cm above ground with the help of knife and the cut stems are spread on ground for drying followed by retting. The fibre strands are yellowish, grey or green and possess strength and durability.

Cultivation

The plant is grown in nearly all temperate regions of the world with temperatures ranging from 17^0 to 27^0 C and rainfall of about 75 cm per annum.

Uses

The fibre is used in the preparation of canvas, cables, webbing, twine, rope and artificial sponges. Hemp is used in the manufacture of carpet, warp, canvas, webbing sacking, rape, cables. Hemp oil is used in making paint, varnish, soaps.

5.4.7 *Linum usitatissimum* (Flax)

Vernacular name: flax or linseed

Family: Linaceae
n = 15

The plant has been cultivated since prehistoric times. The presence of flax has been noted since old European and Egyptian civilizations. Nowadays it is cultivated in temperate parts of Europe. The leading producers are France, Russian Federation, Ukraine, Czech Republic and Egypt.

Morphology

The plant is an annual herb with slender stem bearing alternately placed small ovate, or lanceolate leaves. The flowers are white or blue present in loose, terminal leafy racemes or open cymes. The fruit an indehiscent globular capsule enclosed in a persistent calyx. Flax fibre is essentially a crop of temperate climate. The fibres occur in discrete groups or aggregates of many of cells in the pericycle (bast or stem fibres). The number of fibrous bundles is about 30 with each bundle consisting of ten to forty individual fibres. The fibres after extraction are dried in sun and subjected to the process of rippling, steeping, retting and hackling. The fibres obtained from leaves and stem are subjected to rippling while the fibres obtained from small branches are subjected to retting by immersing them in water tank for several days.

Cultivation

The plant grown well in sandy, loam soil and cool temperate climate.

Uses

The fibres are fine, durable and flexible. The fibres are used in the preparation of cambrics, damasks, sheetings, laces for apparels and household furnishings. The coarser grades are used in the manufacture of canvas, ducks, toweling, twine, bagging and industrial sewing threads.

5.5 FODDER CROPS

Fodder crops are the plant species that are cultivated and harvested for feeding the animals in the form of forage (cut green and fed fresh), silage (preserved under anaerobic condition) and hay (dehydrated green fodder). Forage or fodder crops provide the bedrock to sustainable agriculture. Defined as the edible parts of plants, other than separated grain, that provide feed for grazing animals or that can be harvested for feeding forages play an important role in beef cattle industry while also enhancing crop diversity, wildlife habitat, and soil ecosystem services.

Forage crops can be an important tool for producers, provided the right crop is selected careful management is required to ensure that the crop is fully utilized in its most productive and nutritious phases of growth. Pests and diseases must also be managed to minimize their impact on productivity. A well-considered grazing strategy is important in maximizing the productive potential of a fodder crop. Forage crops can either be grown exclusively for hay or silage production or grazed before being set aside for fodder conservation. The timing of both grazing events and the cutting for hay or silage are critical to ensuring that the quality and quantity of conserved fodder are optimized.

Most of the dairy animals in India are reared on crop residues. Availability of cultivated fodder, dry fodder and concentrates is deficient by 36%, 40% and 44% respectively. It is therefore necessary to increase area of cultivation under fodder crops. In rain fed crops Maize, Sorghum, Millet, Anjan, Cow-Pea, Pawna, Marvel. In The Rabi Season Oat, Burseem, Lucern, Maize and again in summer, depending on type of soil Sorghum, Cow-Pea, Maize can be taken. Some are discussed below-

5.5.1-Oat (*Avena sativa*)

Oat is one of the most important cereal fodder crops of *rabi* season in North, Central and West Zone of the country. It provides soft and palatable fodder rich in crude protein (10-12%). The chemical composition of green fodder varies with the stage of harvest. Oat is also used as straw, hay or silage. Its grain makes a good feed particularly for horses, sheep and poultry.

Climatic requirement: Oats are well adapted to cooler environment. Its optimum growth is attained in sites with 15-25° C temperature in winter with moist conditions. Although, it can tolerate frost up to some extent but its fodder yield and quality is reduced due to hot and dry conditions.

Soil: Oat grows the best in loam to clay loam soil with adequate drainage. They produce satisfactory yields on heavy or light soils with proper moisture. It can be grown under moderate acidic or saline conditions also.

Seed rate and sowing: A seed rate of 60-70 kg/ha is recommended for uniform stand in oats. Low tillering varieties should be sown with 20-25 cm row spacing while higher tillering type should be sown 30 cm apart. Sowing of seed should preferably be done in line with seed drill or *pore/kera* behind the plough. Sowing time varies from one location to other. Normally, oat sowing should be started in early October to end of November in North-West to East Zone of the country. For regular supply of fodder from December to March, scattered sowing is also advocated.

Manures and fertilizers: The requirement of oats for manures and fertilizers is less as compared to other *rabi* cereals. It depends upon number of cuts taken. In general, addition of 20-25 tonnes of farmyard manure (FYM) before 10-15 days of sowing with the application of 80 kg N, 40 kg P_2O_5/ha to single cut and a dose of 120 kg N, 40 kg K_2O/ha to multicut varieties attains good crop growth. In double and multicut varieties, top-dressing of 40 kg N/ha after first cut and two equal split doses of 40 kg N/ha after first and second cut should be done respectively.

Irrigation: Oats require 4-5 irrigations including the pre-sowing irrigation. If soil is dry, first irrigation is given before preparing the seedbed. Subsequent irrigations are given at intervals of about one month mostly after each cut. Timely irrigation improves the tillering remarkably, which contributes to higher forage yield.

Weed control: Oat is infested with winter season grassy and broad-leaved weeds mostly found as in wheat. Effective control of weeds in oats can be obtained with weeder cum mulcher at 4 week crop stage followed by application of 2, 4-D @ 0.37 kg a.i./ha at 6 weeks crop stage.

Harvesting: Proper stage of harvesting determines the herbage yield and quality of Oat. The harvesting of single cut oat varieties is done at 50% flowering (about 50-55 days of sowing). In double cut varieties, first cut should be taken at 60 days followed by second cut at 50% flowering stage. However, in multicut varieties, first cut is recommended at 60 days, second cut at 105 days and third cut at 50% flowering. For seed production, the crop should be left for seed after the first cutting, which should be taken 50-55 days after sowing. For good re-growth, first cut should be taken 8-10 cm above the soil surface.

Yield: The average green fodder yield from single, double and multi-cut varieties of oat ranges from 30-45, 40-55 and 45-60 tonnes/ha respectively. If crop is left for seed, 25 tonnes/ha green fodder from first cut and 2.0-2.5 tonnes/ha seed and 2.5-3.0 tonnes/ha straw is obtained.

5.5.2-Sorgum (*Sorghum bicolor*)

Sorghum as a green foliage is very popular in most parts of north India and nearly 2.5 million ha area is planted during *kharif*. In summer, under irrigated conditions, multicut sorghum is very popular. Forage sorghum is characterized by quick growth, high biomass accumulation, and dry matter content and wide adaptability beside drought withstanding ability. It is also suitable for silage and hay making.

Varieties: There are improved varieties and hybrids capable of yielding on an average 50 tonnes/ha in single cut varieties and up to 70 tonnes/ha in multi cut varieties. The dual-purpose varieties and hybrids, CSV 15 and CSH 13 are suitable for both forage and grain production. A promising dual-purpose *kharif* variety SPV 1616 was released as CSV 20 for the states of Andhra Pradesh, Tamil Nadu, Maharashtra, Karnataka, Madhya Pradesh and parts of Gujarat. It has distinct superiority in fodder yield. An early high-yielding hybrid SPH 1290 has been released as CSH 23 for *kharif* season for the Zones 2 and 3 during 2005. This hybrid matures early (103 days) and is superior to the early checks, CSH 14 and CSH 17 for grain and fodder yields. It is also relatively less susceptible to shoot fly, stem-borer and grain mold compared to the checks. A forage sorghum hybrid CSH 20 MF was released in 2005 by GBPUA&T, Pantnagar, for tan, dark green heavy foliage with green midrib. This has medium thick juicy stem and resistant to foliar diseases.

Field preparation and sowing: Normally 2-3 harrowing are required before taking up planting as rainfed crop and sown with the onset of monsoon. Seed rate of 12-15 kg/ha for singlecut and 20-25 kg/ha for multicut sorghum is required. Optimum spacing is 45 cm between rows for multicut sorghum and 30 cm for single cut sorghum. As regards fertilizer application 100 kg N and 60 kg P_2O_5/ha for multicut sorghum and 80 kg N and 40 kg P_2O_5 /ha for single cut sorghum is recommended. In forage sorghum, the mixed cropping is also practiced with fodder legumes, viz. cowpea and cluster-bean, in 2:1 ratio to improve fodder yield and quality.

Harvesting: Since HCN is present in sorghum especially in early stages up to 40-50 days, proper care has to be exercised during harvesting for avoiding HCN poisoning. Single cut varieties are harvested at 50% flowering to full bloom stage and in multicut varieties the first harvest is taken at 55 days after sowing and subsequent cuts at 40 days interval.

5.5.3-Pearl millet (*Pennisetum glaucum*)

Pearl millet is the fourth most important grain crop next to rice, wheat and sorghum. The crop is cultivated for grain as well as fodder in the semi arid tropical regions of Africa and Asia including India. In India, annual planting area is around 10 million ha producing nearly 7.5 million tonnes of grains. It is grown mainly in Rajasthan, Maharashtra, Gujarat, Uttar Pradesh, Haryana, Karnataka, Tamil Nadu and Andhra Pradesh.

Pearl millet traditionally is an indispensable component of dry farming system. With the advent of pearl millet hybrids in mid sixties, its cultivation doubled. The crop is mainly confined to low fertile water deficit soils. Because of its remarkable ability to withstand and grow in harsh environment, reasonable and assured harvests are obtained. The crop responds to nitrogen, cultural management, and water harvesting.

Soil and climate: The crop is mostly grown in *kharif* season from June to October. Crop grows on a wide range of soils from very light soils from sand dunes in Rajasthan to red loams of Karnataka and Maharashtra.

Seed rate and sowing: The recommended spacing is 45 cm between rows and 10-12 cm between plants within row. The seed rate of 8-10 kg/ha for single cut and 12-15 kg/ha for multicut is required to obtain desired yields.

Manures and fertilizers: It responds well to applied nutrients. Besides recommended dose of fertilizers, application of 8-10 tonnes of FYM is also helpful as it conserves moisture. An application of 20-40 kg N/ha in 2 split doses is recommended in Rajasthan, while in Gujarat, Haryana and Maharashtra, 60-80 kg N/ha is recommended as optimum. Application of 20 kg $ZnSO_4$/ha enhanced grain and fodder yields. Also foliar application of $ZnSO_4$/ha at tillering and pre-flowering stage increased grain and fodder yield. Maximum grain yield was recorded in plots of dust mulching when trial was conducted to mitigate the adverse effect of drought stress under rainfed condition. Spray of 0.1% thiouorea at tillering and flowering stages also helped to mitigate drought stress.

Inter-cultivation and weed management: The fields should be maintained free from weeds for the first 30 days as it is very important to ensure good crop growth. Two inter-cultivation and one hand weeding is necessary to minimize weed competition. Chemical weed control with Atrazine @ 0.5 kg ai/ha given as pre-emergence spray is also useful.

Diseases and pest management: Crop is comparatively less prone to pests and diseases. However, downy mildew among diseases, shoot fly and root grub among pests are prevalent in many states. Choice of diseases resistant variety is an important step in effectively managing the diseases. A seed treatment with Apron 35 SD @ 2 g a.i./kg seeds followed by Ridomil 25 WP (1,000 ppm) spray 20-25 days later will effectively check the disease. Rotation of different varieties and hybrids in alternate years is also effective in arresting spread of downy mildew. Seed treatment with *neem* oil 5 ml/kg seed + spray of 5% (*neem*-seed-kernel extract (N.S.K..E.) at 50% flowering was found effective in controlling pests. Plant-protection measures are essential for white-grub and shoot fly. White-grub infestation is managed by mixing of Phorate 10G or Quinalophos 5G @ 12 kg /ha with seed and applying in furrows at sowing. Four varieties, MH 1336, MH 1364, MH 1392, and Pusa 383, were found to be resistant to smut ergot and blast**.**

Pearl millet-based cropping systems: In Rajasthan, intercropping of pearl millet with cluster bean or *moth* bean or cowpea or green gram in 2: 1 proportion is followed. This not only covers the risk due to failures of monsoon but also provides the grain legumes which help in better nutritional security and as source of additional income. In most parts of north India, Andhra Pradesh, Maharashtra, Tamil Nadu, and Karnataka, intercropping of pearl millet with pulses is followed, viz. red gram/ green gram/ cowpea/ horsegram/ clusterbean.

Harvesting and storage: When grain moisture is around 20%, pearl millet is harvested as the grains are prone to spoilage during storage. It is very important to bring down moisture to 12% or less for safe storage. Improved storage structures, viz. metal bins made out of GI sheets, are suitable for safe storage of grains. The stover is a valuable feed for cattle.

5.5.4-Maize (*Zea mays*)

Maize in India ranks fifth in total area and third in total production and productivity. The level of production has to be raised because of substantial demand as food, feed and poultry feed. Maize can successfully be grown as *kharif*, *rabi* and *zaid* crop. Presently, the maize crop is grown in 20-30% irrigated conditions only.

Varieties: Mostly maize is grown during rainy season. Some cultivars require 60-70 days to mature; others require 100-110 days to mature. Grain colour also varies from yellow to orange to white. Mainly flint types are preferred.

Soil: Very sandy soils rapidly respond to management practices than those that are fine textured. Intermediate texture of loam to silt loam in surface horizon and little higher content of clay as silt loam to silty clay loam in subsoil is the most ideal. Soil pH of 7.5-8.5 supports good crop growth, as the crop is grown under rainfed conditions it is important that soil must have good water holding capacity, with proper drainage system to avoid water logging conditions.

Seed rate and sowing time: About 50-60 kg seed would be needed to sow one hectare. Seed should be grown 5 cm deep into soil for good germination, seedling growth and vigour. Transplanting should be avoided as the plant cannot cope up with main crop stand. It is preferred to sow 10-15 days before start of rain which will give 15% higher yield.

Manures and fertilizers: A balanced application of 60-12 kg N, 40-60 kg P and 40kg K/ha is recommended. Early maturing varieties require less quantity than full season maturity crops. It is also advisable to apply 20 kg zinc sulphate /ha along with basal dose of fertilizer. One-fourth of nitrogen and entire quantity of phosphorus, potassium and zinc should be applied 5-7 cm deep before sowing. The rest of the doses are applied at knee-high stage and after emergence of flag leaf but before tassel emergence.

Plant population: A population of 65,000-70,000 plants /ha at harvest is optimum for realizing higher yields. For attaining desired level of plant density, a row to row and plant to plant spacing of 75 cm × 18 cm or 60 cm × 22 cm should be maintained.

Irrigation: To ensure high and stable yield, it is desirable to give 1 or 2 irrigations at critical stages. Flowering and grain-filling stages are most critical; the crop should be irrigated at these stages, if rain fails.

Intercropping: Short-duration varieties of pulse crop, oilseed crop and vegetable can successfully be grown as intercrop. A ratio of 2 rows of maize with 1 row of other desired crop can be adopted.

Harvesting: In absence of irrigation, crop can be harvested at any stage, at pre-flowering it can be used as fodder and at dough stage green ear and stover may be used for cattle. For fodder purpose, the milk to early dough stage is preferred for higher yield and protein content. For silage, late dough stage is preferred.

5.5.5-Berseem *(Trifolium alexandrinum)*

Berseem is the prominent legume fodder crop of *rabi* in entire North West, Zone, Hill Zone and part of Central and Eastern Zone of the country. Berseem makes most digestible and palatable green fodder to the cattle and especially milch animals are very much benefited with berseem. It provides fodder with high tonnage over a long period from November to May in 5 - 6 cuts. It has 20-24% crude protein and 70% dry matter digestibility. It is very good soil builder and adds about 0.38-0.46% organic carbon, 15 -26 kg available phosphorus and 45 kg available nitrogen to the soil.

Climatic requirements: Berseem prefers dry and cool climate for its proper growth. Best productive crop can be obtained between 15-25° C temperatures. Its regenerative growth is retarded during severe cold or frosty period or at temperature above 40°C. It can be grown successfully in areas which receive annual rainfall of 150-250 cm or even lower but the irrigation must be assured.

Soil: Berseem can be grown on all types of soils except very light sandy soils. Well-drained clay loam soils rich in calcium and phosphorus are ideally suited for its cultivation. The crop can be grown successfully on alkaline soils having good water retention capacity. The crop can tolerate mild acidity also.

Field preparation: The seeds being very small, berseem requires a fine seedbed. One deep ploughing with soil turning plough and 2 harrowings are essential. The field may be laid out in to smaller beds of convenient size according to topography and source of irrigation water.

Sowing time: After the arrest of rains, sowing of berseem can be done from last week of September to first week of December in North West to Eastern and Central India. The time of sowing berseem is ideal when mean day temperature is 25° C, which is recorded mostly in the first to third week of October in north India.

Seed rate: The optimum seed rate is 25 kg/ha, which may be increased up to 35 kg in early or late sown conditions. For yield compensation in first cutting, 1.5 kg mustard should be sown along with berseem. For elimination of chicory weed (*kasani*), the seed should be poured in 1% common salt. Floating chicory seed should be taken out and remaining seed of berseem should be sown.

Seed treatment: Seed treatment with *Rhizobium* culture is essential, when the berseem crop is to be grown first time in the field. Before treating the seed, it should be first soaked into fresh water for about 8-12 hours. For better sticking of culture with seed, the culture is prepared with jaggery. About 1.5 litres of water is mixed with 150 g of jaggery and boiled. After cooling, 2.5 packets of berseem culture are mixed with it and then seed is well mixed and dried in a cool shady place.

Sowing method: There are two methods for sowing of berseem i.e. dry and wet bed. For satisfactory germination and good plant stand, wet method is better. Seed should be sown in beds of convenient size by broadcast method after flooding the beds with 5-6 cm deep water. Before sowing seeds, the water in the beds should be stirred thoroughly with the help of puddler or rake so as to break the clods and capillary to avoid leaching during successive irrigations. The crop should be re-irrigated after 5-6 days of sowing when germination is complete.

Manures and fertilizers: Berseem, being a legume crop, requires less nutrient replenishment in the soil. For obtaining good yield, 20 kg N and 80 kg P_2O_5/ha should be applied as basal dose. In saline or light textured soil, addition of 20 tonnes of well-decomposed FYM is beneficial. FYM may be excluded if the previous crop of the rotation was liberally manured and fertilized.

Irrigation: The depth and frequency of irrigation is decided by soil type, number of cuttings and nature of berseem crop, i.e. sole or mixed. First two very light irrigations (4-6 cm depth) should be given at 5-6 days interval. Subsequent irrigations may be given at an interval of 10 days in October, 12-15 days in November to January, 10-12 days in February-March and 8-10 days in April-May. Thus, about 12-15 irrigations will be needed during the entire crop season. Normally the crop should be irrigated after each cutting.

Weed control: Chicory, the associated weed of berseem should be eliminated for higher herbage and good quality fodder. Application of Fluchloralin @ 1.2 kg a.i./ha at pre planting stage controls the chicory and other weeds effectively. However, floating of berseem in 10% common salt is effective against chicory only.

Harvesting: The first cutting should be taken at 50-55 days after sowing of crop. The subsequent cuttings should be taken at 25-30 days interval. The number of cuts depends upon rate of growth and temperature during the life cycle of the crop.

Yield: A good berseem crop can give 100-120 tonnes/ ha green fodder and 15-20 tonnes/ha dry fodder.

5.5.6-Lucerne *(Medicago sativa)*

Lucerne is a valuable leguminous forage and hay crop which is generally grown in areas where water supply is inadequate for berseem. Its deeper root system makes it very well adaptable to dry areas with irrigation facility. It grows well as rainfed or unirrigated crop in high water table areas. It is an important winter fodder crop in Rajasthan, Gujarat, and parts of Tamil Nadu, Kerala and in Leh area of Laddakh. It is perennial (3-4 years), persistent, productive and drought tolerant forage legume which contains 15% crude protein with 72% dry matter digestibility. It supplies green fodder for a longer period (November - June) in comparison to berseem (December - April).

Climatic requirements: Lucerne is adapted to relatively dry conditions and it may tolerate heat as well as cold. It cannot be grown under humid conditions with high temperature. It has wide ecological amplitude and can grow at 2,500 m asl to hot summer with 49°C with adequate moisture available in the soil.

Soil: Lucerne needs sandy loam to clayey soil but heavy soils need an efficient drainage system as the crop does not tolerate water logging. It cannot thrive on alkaline soils but can be grown on acid soils with liberal application of lime. Lucerne prefers a fertile soil which is rich in organic matter, calcium, phosphorus and potash.

Field preparation: Like berseem, lucerne also needs very fine seedbed, as the seeds are very small. One deep ploughing with 2-3 harrowings followed by planking is sufficient.

Sowing time: The best sowing time of the crop is mid-October to early November. However, sowing date may spread from early October in the North to late December in the East and South Zone. In the temperate zone, spring sowing is done in March.

Seed rate and seed treatment: The seed rate depends upon method of sowing and type of the crop, i.e. pure or mixed stands. In case of broadcast method, a seed rate of 20-25 kg/ha should be used while line sowing needs only 12-15 kg/ha but in case of intercropping, it requires only 6-12 kg/ha. Like berseem, seed treatment with *Rhizobium* culture is beneficial.

Method of sowing: Line sowing is preferred over broadcasting. Like berseem, 10– 20 m long beds should be made along with slope with irrigation channels 4-5 m apart. Water-soaked seed is sown in shallow furrows at row distance of 30 cm by seed drill or *kaira* at sufficient soil moisture.

Manures and fertilizers: Lucerne being a leguminous crop requires less nitrogen. However, due to perennial nature of the crop, it is beneficial to add well-decomposed FYM @ 20-25 tonnes/ha before sowing in the first year. Normally, 20 kg N and 100 kg P_2O_5/ha should be applied as basal dose for good harvest. Application of molybdenum and boron may be done based on soil test. In subsequent years, annual supplementation of 80 kg P_2O_5 and 40 kg K_2O/ha should be done.

Irrigation: To attain good germination, pre-sowing irrigation is essential. The crop needs very frequent irrigation during its early growth period at an interval of about one week but once the plants are established, subsequent irrigations are provided at an interval of 15-20 days during winter and 10-12 days during spring and summer seasons. Proper drainage should be ensured to avoid water logging in rainy season.

Weed control: Lucerne takes a long time to establish and therefore heavy weed infestation occurs up to first cutting. The sowing in lines makes weeding easier. Trifluralin, @ 4 kg/ha should be applied before sowing for good harvest. The *akasbel* (*Cuscuta reflexa*) should be removed from the field and burnt. The *akasbel* should not be allowed to set seed in any case.

Harvesting: The first cut should be taken at 55-65 days after sowing and the subsequent cuts may be taken at 30-35 days interval. In general, annual lucerne gives 4-5 cuts while in the perennial crop, 7-8 cuts can be taken.

Yield: Annual lucerne yields green fodder to the tune of 65-80 tonnes/ha while perennial crop may provide 80-1,100 tonnes/ha.

5.5.7-Cowpea (*Vigna unguiculata*)

Cowpea is native to Africa and Asia and is now cultivated throughout the tropics and sub tropics. It is used as pulse, vegetable fodder and green manure. It is of considerable importance in dryland farming.

Soil and climate: It is adapted to variety of soil types, viz. red loam, black clay loam, coarse gravel, sandy loam, light sandy soils. It is also grown in sloppy land in hilly tracts and heavy loam soils. It is more tolerant to heavy rainfall than any other pulse crop. It suffers from water stagnation and heavy drought. It thrives well under the temperature range of 21- 35°C.

Cropping system: The crop is usually grown as dryland *kharif* crop and can also be grown as pre-monsoon and late monsoon crop. It is also grown as second crop during *rabi* after rice in southern parts of country.

Cultivation: Fields should be prepared well for sowing. The crop is sown in the first week of July in the hills and in the second fortnight of March in lower hills and in October in plains. One hand weeding or hoeing 30-35 days after sowing or application weedicide Pendimethalin @ 1.0-1.5 kg a.i /ha immediately after sowing helps in control of weeds. The crop requires adequate moisture. In plains, 3-4 irrigations are required. About 120 kg N and 80 kg P/ha are recommended. Half the nitrogen is applied as basal dose and half for top dressing. The crop matures in 120-125 days. The row to row spacing is 30-45 cm. The recommended seed rate is 20-25 kg/ha. Seed yield up to 1.0 tonnes/ha is obtained.

Suitability and Practices of Conservation: Feeding strategies based on conserved fodder include feeding of dry fodder (hay, dried crop residues or grazing of dried grasses), silage (preserved green fodder or grasses) and standing hay/stover (standing mature fodder crop or crop residue). Depending on the local availability of labour and other inputs, a particular conservation technique may or may not be suitable on a farm. Dry feeding Straws are a major source of roughage for ruminants, particularly after the monsoon, but also during planting and in the early wet season.

Integrated nutrient and pest management

The fertilizer management strategies in fodder crops aim at increasing the herbage production per unit area and time along with improvement in forage quality parameters and maintenance of soil health. The requirement of fodder crops for nutrients particularly nitrogen is comparatively higher. Biofertilizers, the products containing living cells of different types of microorganisms, play important role in enhancing fodder production and also cutting down the usage of chemical fertilizers. Different types of biofertilizers include nitrogen fixers (symbiotic and nonsymbiotic bacteria) *Rhizobium, Azotobacter, Azospirillum, Azolla* and blue green algae, Phosphate solubilizers (bacteria and fungi)- *Bacillus polymyxa*, *Pseudomonas* and *Aspergillus* etc. , Mycorrhizal fungi –VAM (Vesicular arbuscular mycorrhizae), Sulphur and iron oxidizing bacteria, etc., PGPR (Plant growth promoting rhizobacteria) are available now. However, a reliable system of quality control and efficient system of storage, transportation and management of biofertilizers is required for its wider applicability.

The requirement of fodder crops for nutrients particularly nitrogen is comparatively higher. This is due to the fact that fodder crops are desired to produce luxuriant vegetative growth with succulent and nutritive herbage in a short period. Thus, the fertilizer management strategies in fodder crops aim at increasing the herbage production per unit area and time along with improvement in quality parameters.

5.6 SUMMARY

In this unit you have studied that:

1-Many plant species are rich source of fibres. Depending upon the morphological nature and structure, plant fibres have been classified into different types mainly soft stem or bast fibres, hard leaf or structural fibres and surface fibres.

2-The major fibre yielding species include cotton, jute, hemp, coconut and kenaf. Cotton is one of the most important commercial fibres crop. It has been cultivated in South East Asia and Central America since ancient times. The four cultivated cotton species include American or the new world cotton *G. hisutum* and *G. barbadense* and the Asiatic or the old world cotton *G. arboreum* and *G. herbaceum*.

3-Sunhemp, jute, coconut and flax are the other fiber producing plants that are cultivated on a large scale. Most of these varieties produce bast fibres which possess high tensile strength and durability.

4-Commercial coir is obtained from the fibrous husk of the fruits of coconut palm. The fibre is light with high elasticity, high resistance. India is the largest producer of coir and its products.

5- The bast fibre produced by the sunhemp plant possesses great tensile strength and durability. The fibre strands are lustrous and resistant to moisture. *Corchorus* is another important source of bast fibres.

6-Fodders crops are cultivated plant species that are utilised as livestock feed.

7-Fodder refers mostly the crops which are harvested and used for stall feeding. Fodder crops are the plant species that are cultivated and harvested for feeding the animals in the form of forage, silage and hay (dehydrated green fodder). The some major fodders crops are oat, sorgum, pearlmillet, maize, berseem, Lucerne and cowpea.

5.7 SELF ASSESSMENT QUESTIONS

5.7.1 Fill in the blanks:

i) Fibres are mainly composed of ………………. .
ii) Soft fibres obtained from plant stem are called as …………………… .
iii) For manufacture of …………………, the fibres are twisted together into threads or yarn and woven.
iv) Commercial coir is obtained from the fibrous husk of the fruits of ……………………… .
v) The botanical name of sunhemp is ………………………… .
vi) ……………………… plant derived its name from the word 'Korkorus" used by Greeks.

Answer Key:

5.7.1: i) cellulose, ii) bast fibres, iii) fabrics, iv) coconut palm, v) *Crotolaria juncea*, vi) Jute

5.8 REFERENCES

- https://icar.gov.in/files/forage-and-grasses.pdf
- https://www.bighaat.com/blogs/kb/forage-crops-and-its-importance-in-agriculture
- https://edepot.wur.nl/333855

5.9 TERMINAL QUESTIONS

1. Differentiate between bast and surface fibres.
2. Enlist the major uses of jute.
3. Describe the morphological features of the cotton plant.
4. Give brief description of morphology and uses of Sunhemp.
5. Write short notes on:
a) Kenaf
b) Coconut
c) Flax
6- What are fodder crops? Discuss in detail about any one fodder crop.

UNIT-6 BEVERAGES AND NARCOTICS

Contents

6.1 OBJECTIVES

After reading this unit the students will be acquainted to the;

- Major plant species used in making beverages.
- Origin, cultivation and production of some beverages.
- Major plant species used in making narcotics.
- Origin, cultivation and production of some narcotics.

6.2 INTRODUCTION

Beverages and narcotics have been the integral part of our society since the early days of civilization. Beverages are used by every age group of humans. Generally kids use milk and fruit juices, adults use milk, fruit juices, soft drinks, alcoholic and non-alcoholic drinks (like tea, coffee) as beverages. Apart from beverages some plants and their parts or extracts are used for narcotic purposes. The legal use of narcotics is not allowed due to their helucinogenic and negative physiological effects. In the commencing sections of this chapter we are going to study various types of beverages and narcotics (Fig. 6.1).

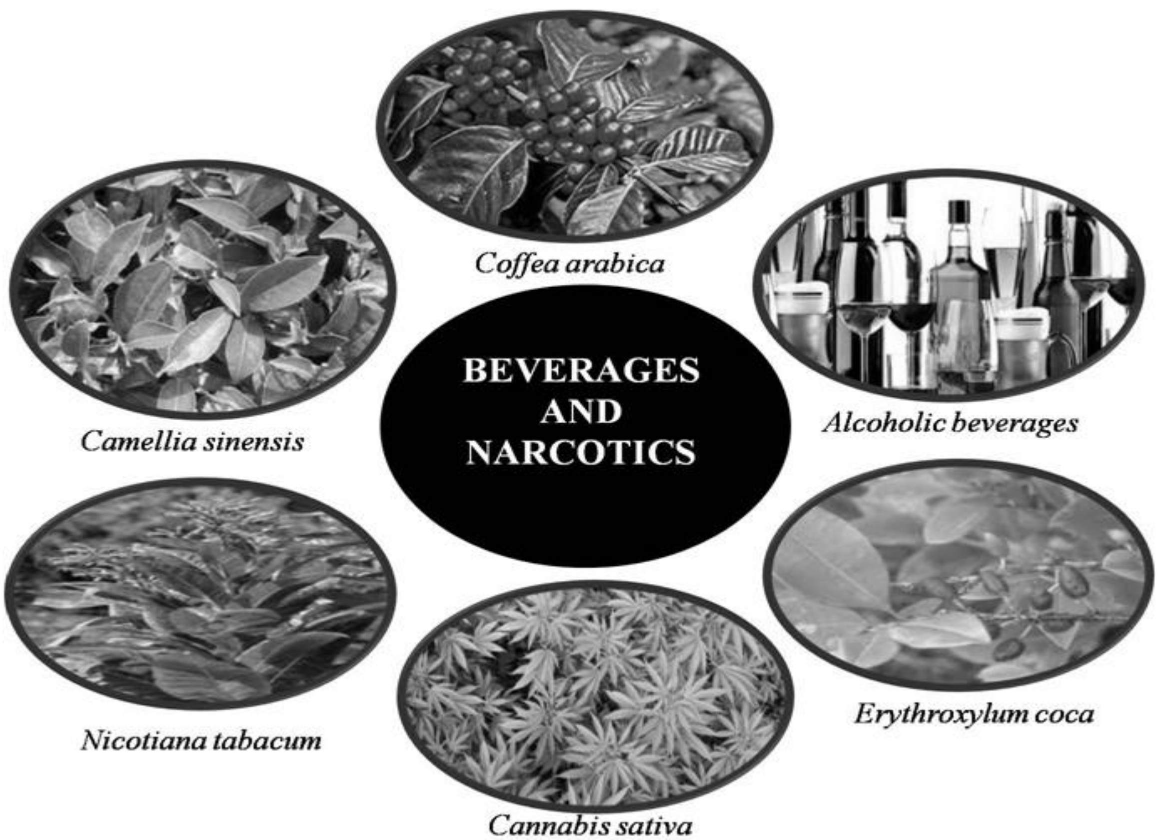


Fig. 6.1: Some commonly used beverages and narcotics

6.3 BEVERAGES

Cells of the human body have 70% of water and hence we cannot survive for longer period without water. In the beginning of civilization humans quenched their thirst with water. After the agricultural revolution we started domesticating animals and had a new source of liquid diet which is milk. Apart from milk, fruits were the best source of liquid diet and are very refreshing due to the presence of vitamins and sugars. Now in modern age we have modified the fruit juices to soft drinks which are synthetic fruit juices with sugar, fruit acids and other flavorings. In addition, some drinks have no nutritive value but they have made their way in our daily routine (e.g. coffee and tea). These drinks in their own have zero nutritional value but are the vehicle for large intakes of sugar, milk or lemon. Some drinks are used for their sense numbing qualities like the beers and wines. The alcohol present in these fermented drinks also provides the energy. Beverages can be broadly classified into two groups alcoholic beverages and non-alcoholic beverages. The classification of the beverages is given is Fig. 6.2.

6.3.1 Alcoholic beverages

Alcoholic beverages are consumed to enhance sociability, escape problems, get drunk, for enjoyment, or for ritualistic reasons but the science behind the alcohol is that it lowers the activity of our brain. Alcoholic beverages are mistakenly believed as stimulants, but technically they are a type of protoplasmic poison which exerts a depressant effect on the central nervous system. Alcoholic beverages are categorized chiefly into two groups, the fermented beverages and distilled beverages.

Fermented beverages are made by the fermentation of sugars present in the substances used to ferment. *Distilled beverages* are acquired by repeated distillation of fermented liquors.

6.3.1.1 Fermented beverages: On the basis of the material used in fermentation, fermented beverages can be classified into two groups, wines and beers.

i. Wines: These are made from fermented fruit juices. Various fruits are used in wine making e.g. apple, black currents, grapes and pear etc.

Origin: According to the archaeological studies wine making (vinification) was started in ancient Mesopotamia and at the coastal regions of Caspian Sea between 6000 and 4000 BC. Almost every kind of sugar- or starch-based plant material has been used to prepare alcoholic beverages. Chiefly the wine is made from grape fruits (*Vitis vinifera*). The major producing regions are Australia, Africa, Europe and United States.

Process: Vinification is very easy process anyone can ferment grape juice for days and allow the yeasts (*Saccharomyces cerevisiae* var. *ellipsoideus*), present in the natural waxy bloom of fruit, to convert sugars to alcohol although with time the process has become more elaborate. The science of wine making is called as Oenology.

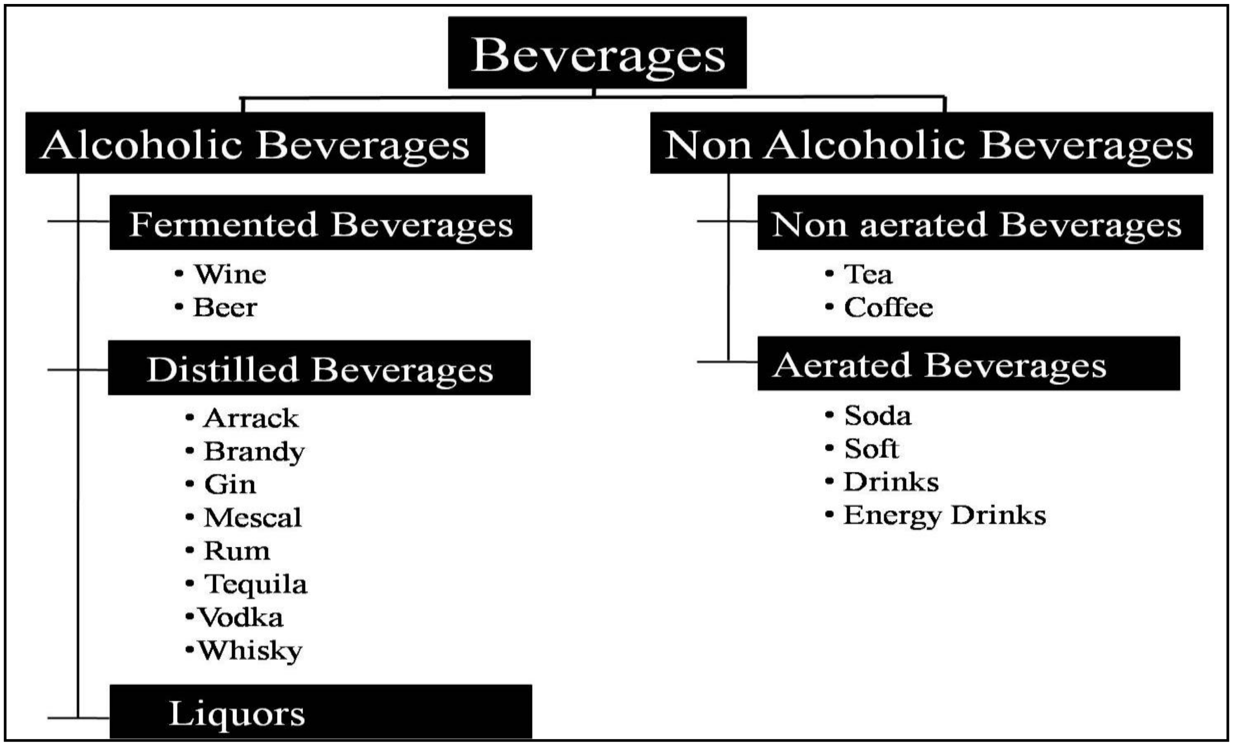


Fig. 6.2: Classification of the beverages

The grapes are crushed to produce pulp which is then transferred to a fermenting tank where yeast's enzymes transform the sugar into alcohol under anaerobic conditions at around 68ºF. Sometimes to increase the alcohol content, the cane or beet sugars may be added to the pulp a process called chaptalization. After that the juice is separated from skin and seeds and then it moves through two settling vats where the fining process removes impurities, it is filtered, sometimes heated and then cooled. Now it is ready to be aged in oak barrels (aging in oak barrels allows slow chemical changes which improves the flavor) and after the aging process the wine is bottled.

The aroma, taste and flavor of wine constitute its quality which is due to the presence of fruit's sugars, polyphenols or tannins, vitamins, minerals, organic acids, amino acids, pigments and odiferous compounds. The alcohol content of wine ranges from 7-16 per cent. Because of the inability of yeast to survive in the presence of high alcohol content it is impossible to produce a wine naturally with a higher content since in the absence of yeast fermentation is stopped.

Types: On the basis of color, sweetness, alcohol content, variety of grapes, the presence of carbon dioxide and the fermentation temperature, wines can be categorized into the following types:

(*a*) *Dry wines*: These are just the opposite of sweet wines. They only have 0.2 per cent sugar content because the fermentation is allowed to go on until almost all the sugar is used up.

***(b) Flavoured wines*:** These wines are made by adding flavor of aromatic herbs and spices to white wines. The examples are anise (*Pimpinella anisum*), cinnamon (*Cinnamomum verum*) and wormwood (*Artemisia absinthium*) etc.

***(c) Fortified wines*:** These wines are made by adding alcohol with wines. These have high alcohol content (18-22 per cent). The examples are Port, Sherry and Vermounths etc.

***(d) Red wines*:** The red or purple grapes are used for making red wine. The anthocyanin pigments, present in the grapes skin, give the red colour. The fermentation temperature is kept between 22 to 25 °C. It has been reported that due to the presence of 'reservatrol' red wine has cardio-protective and anti-cancerous properties. It lowers blood pressure and LDL (bad cholesterol) but tend to improve HDP (good cholesterol).

***(e) Sparkling wines*:** The characteristic feature of this wine is the bubble formation on opening the bottle and on pouring in the glass (e.g. in champagne). The bubbles form because the wine is bottled before the fermentation is complete so that the carbon dioxide is released within the bottle and cannot escape.

***(f) Sweet wines*:** As the name suggests it contains high sugar content around 18 per cent and to make this happen the fermentation is stopped before the sugar is completely fermented.

***(g) White wines*:** To make white wines the skins of white grapes are separated from the pulp prior to fermentation and then fermented at 15 to 18 °C.

ii. Beers are made from fermented cereals. The cereals used in beer making are barley, maize, rice, rye and wheat etc.

During fermentation, in case of wines, the sugar present in the fruit juices gets converted into alcohol and in case of beers, first the starch and other polysaccharides present in cereal seeds get degraded into sugars and then sugars produce alcohol. The reactions are involved in the process of fermentation are mentioned below:

$$\underset{\text{Starch}}{2(C_6H_{10}O_5)_n} + nH_2O \xrightarrow[\text{(from malt)}]{\text{Diastase}} \underset{\text{Maltose}}{nC_{12}H_{22}O_{11}}$$

$$\underset{\text{Maltose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{\text{Maltase}} \underset{\text{Glucose}}{2C_6H_{12}O_6}$$

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow[\text{Anaerobic}]{\text{Yeast (zymase)}} \underset{\text{Ethyl alcohol}}{2C_2H_5OH} + 2CO_2$$

Origin: Beer became a cultural thing in western Iran, Mesopotamian plains, Egypt, Roman Empire, and Europe. The oldest proof of beer is 6000 years old Sumerian stone tablet in

Mesopotamia portraying the people drinking a beverage through straws from a communal bowl. In different parts of world various kinds of grains are used to make the beer for example maize and cassava in Africa, wheat in China, rice in Japan, barley in Egypt, corn in South American counterparts, rye in Russia and sweet potatoes in Brazil. However, barley is still the first choice for beer production. Barley beer was known to the ancient Babylonians, Assyrians and Sumerians as well as the Egyptians and Romans. It was a popular drink particularly during the Middle Ages because it was much safer to drink than water. For a long time, the monasteries remained the chief centers of the beer supply, and the monks used to add 'hops' to the beers until around 800 AD. Not only did the hops help to clear (acting as a natural filter), impart bitterness, flavour and aroma to the beer but also acted as a preservative.

Process: Do you know that the first time beer was made as an accident? There was some rain soaked barley grains out in the open in a clay pot and then they were spontaneously fermented by wild yeast in the air. The basic process looks very simple but now with the advent of science and technology the whole process has changed drastically in the last 200 years. Firstly the starch present in cereals converted to maltose this process is called first malting process then afterwards the brewing of maltose is performed. The commonly used plants for beer production are barley, wheat, rice maize, millets and inflorescences of many varieties of plams. The process of beer making is explained below in the flow chart.

The foaming of beer is because of the release of carbon dioxide. The alcohol content of beer varies from 3-7 per cent. Apart from alcohol beer contains sugars, dextrins, various proteins, vitamins (vitamin B6) and minerals (phosphates).

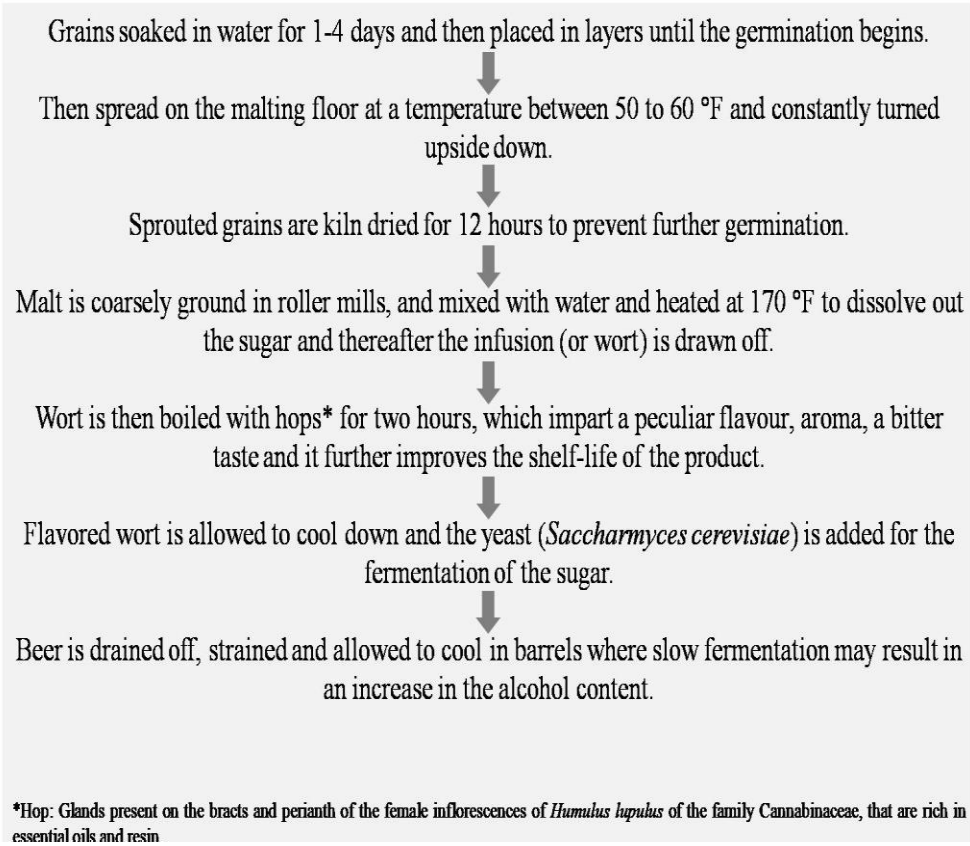
Types: The beers are mainly divided into two categories named as heavy and light beers. The brewing temperature is responsible for the heavy and light beers. Some major beers are being mentioned below:

(a) Ale beer**:** It is brewed with top-fermenting yeast, *S. cerevisiae* at high temperature. The alcohol content varies from 4-7 per cent.

(b) Bock beer**:** It is a strong, dark beer, usually made in spring from the new malt and hops.

(c) Lager beer**:** It was made during 15^{th} century in southwest Germany when they first noticed that beer stored in the caves during the winter continued to ferment. It is produced from malted barley and fermented at low temperatures [46°–55°F (bottom fermentation)] and these are stored for several months in near-freezing temperature. There are two types of lagers, Pilsner and Munich. Pilsner beer is comparatively bitter because of the strong hop component and Munich beer is less bitter due to its week hop component. Among all the beers lagers have the lions share (94 %) in the global beer market.

(d) Porter beer**:** It is dark brown beer with a slightly burnt taste, made from inferior grades of malt. The ageing is done for 40 to 60 days.



(e) Root beer**:** It consists of fermentation of infusion of different roots, sarsaparilla, ginger and wintergreen, etc. with the addition of sugar and yeast.

(f) Stout beer**:** It is produced from roasted barley and inferior grades of malt. Stout beer is much heavier, and more caramel is added to give color and body. It is aged for one year.

6.3.1.2 Distilled beverages: Distilled beverages are acquired through the distillation of fermented fruit juices. As mentioned above that naturally high alcohol content wines cannot be produced due to the killing of yeast in high alcohol content, so to produce higher alcohol content beverages the fermented fruit juices are distilled. Then they are aged and given extra flavor with essences. Here are some examples of distilled beverages mentioned below:

(a) Arrack**:** It is obtained from the distillation of fermented rice and molasses or fermented juice of palms. It is largely produced in various countries of Asia.

(b) Brandy**:** It has the alcohol content ranging from 65-70 %. The major producers are France, Greece, Germany, Italy, South Africa, Spain and United States.

***(c) Gin*:** It is made by the distillation of fermented barley malt and rye and added some juniper oil (obtained from the fleshy cones or 'berries' of *Juniperus communis*). The major producers are Britain, Holland and United States.

***(d) Mescal*:** It is obtained from the distillation of fermented *Agave* sap and fibrous pulp. The major producer is Mexico.

***(e) Rums*:** It is obtained by distilling the fermented molasses and sugarcane juice. The major producers are Caribbean region, United States and West Indies.

***(f) Tequila*:** It is achieved by distillation of the fermented juice of the heads of *Agave tequilana*. Major producers are Jalisco and Mexico.

***(g) Vodka*:** It is mainly produced from potatoes. The major producers are Finland, Poland and Russia.

***(h) Whisky* (*also spelled whiskey*):** It is distilled from fermented cereals. The major producers are Canada, Ireland, Scotland and United States.

6.3.1.3 Liqueurs: Liqueurs are made by mixing the various ingredients (such as alcohol, sugar, water and flavorings) together by the professional. Sometimes the blending of the ingredient is so complex that it is a trade secret. A variety of fruits, spices and condiments are used for flavoring. A myriad of liqueurs are made globally which are mentioned in the Table 6.1.

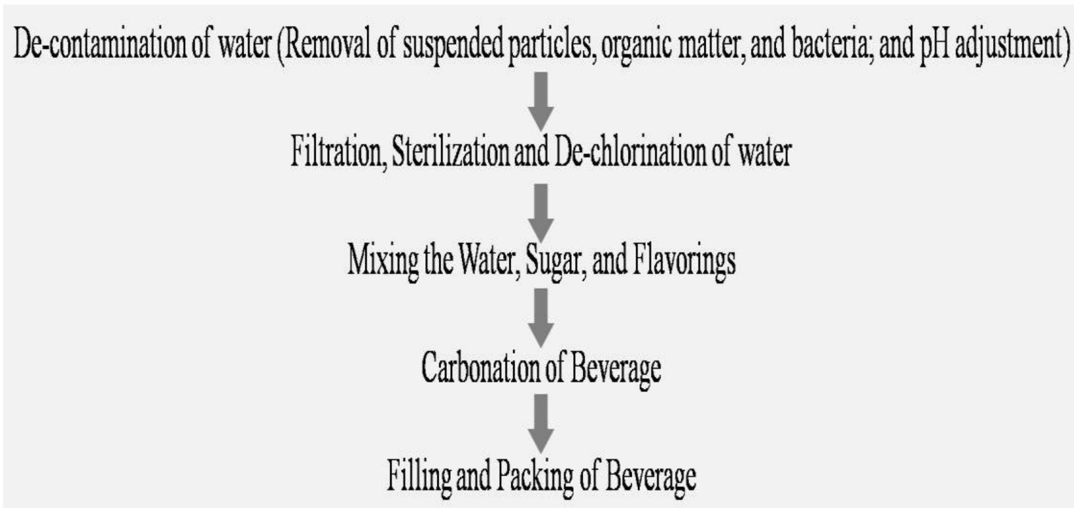
6.3.2 Non-Alcoholic Beverages

These are consumed due to the presence of alkaloids in them which show refreshing and stimulating effects on human body. These help in reducing tiredness and increasing the mental activity. Caffeine can stimulate the production of digestive juices and excretion of uric acid. Non-alcoholic beverages (Table 6.2) are now become an essential element of our everyday routine. Non-alcoholic beverages can be categorized into two broad categories, aerated and non-aerated beverages:

6.3.2.1- Aerated Beverages: Aerated beverages are popularly known as carbonated drinks. The global annual consumption of soft drinks is roughly about 34 billion gallons. The very first aerated beverage was mineral water which was patented in 1809 and was called "soda water“. This soda water was made of water and sodium bicarbonate mixed with acid to add bubbles. Aerated beverages are chiefly made of carbonated water, sugar, and flavorings.

Based on the constituents of the products aerated beverages can be classified into three categories Soda, Soft drinks and Energy drinks. ***Soda*** is made by mixing CO_2 gas in drinking water; ***Soft drinks*** (e.g. Coca-Cola, Pepsi etc.) are made of carbonated water, sweetener, and natural or artificial flavouring and may also contain caffeine, colourings, and preservatives; and

Energy drinks (e.g. Red Bull, Monster etc.) contain high methylxanthines (including caffeine), B vitamins, carbonate water, high fructose corn syrup. The process of making an aerated beverage is explained below in a flow chart:



6.3.2.2- Non-aerated Beverages: There are two main non-aerated beverages tea and coffee, which are being described here in brief:

i. Tea

Botanical Name: *Camellia sinensis*

Characteristic Features: It is an evergreen or semi-evergreen woody cultivated shrub; Leaves alternate, elliptic to lanceolate with toothed margins. Leaves have oil glands which give the characteristic fragrance and aroma. Yellow-centered white or pinkish fragrant flowers are borne in leaf axils either singly or in groups of two to four. At maturity, they produce three celled woody capsules, each compartment of which contains a brown seed, about 1.25 cm in diameter.

Origin: It is supposed to be originated either in India or China or both. The large-leaved Indian varieties probably originated from wild plants near the source of the Irrawaddy river in Assam or northern Myanmar; whereas the narrow-leaved Chinese types probably had a separate origin in China itself. The from China and India tea spread to the whole world and England is the largest importer of tea in the west.

Cultivation: Cultivation of tea can be done in all subtropical areas and the mountainous regions of the tropics. The plant is grown in open fields or terraced hillside where rainfall is at least 150 cm per annum, well-distributed throughout the year. An average monthly temperature of 21-32°C is essential for vigorous growth. The bushes thrive best in deep, well-drained, acidic soils (pH between 4.0 and 6.0) that are rich in humus, and cannot be grown in alkaline soils. It is a shade loving plant and shows more vigorous growth under the partial shade provided by leguminous trees, such as *Albizia procera*, *A. chinensis*, *Dalbergia assamica*, *Derris robusta*, *Gliricidia sepium* and *Erythrina* spp.

Harvesting: The terminal bud containing 2-3 young leaves are plucked. The plucked leaves must not be compressed in the basket and also should not be collected in one hand while plucking.

Production: The total world's production of tea in 2012 was 48, 18,118 tones. The top three tea producing nations were China (17, 14,902 metric tons), India (10,00,000 t) and Kenya (3,69,400 t).

ii. Coffee

Botanical Name: *Coffea arabica*

Characteristic Features: It is an evergreen shrub or small tree. Stem has a series of five or sometimes six buds in leaf axils and a dimorphic pattern of branching; Leaves opposite, ovate or elliptic with margins, sometimes undulate, opposite, glabrous and glossy with prominent acuminate tips, and are characteristic in having inter-petiolar stipules; Flowers snow white, star-like, borne in dense axillary clusters, short-lived; Young fruits are green, turning crimson red at maturity, six to nine months after blossoming; Ripe fruit (coffee cherry), differentiated into outer, thin, deep crimson exocarp, middle yellowish mucilaginous or fleshy mesocarp, and inner hard cartilaginous parchment endocarp having two or one oval seeds (coffee beans).

Origin: It is indigenous to the tropical rainforests of Ethiopia, from their Coffee reached Europe in the seventeenth century. In India coffee was introduced and planted by the British around 1700.

Cultivation: It is a crop of cooler and less humid climates of mountainous regions from 600-1700 m. It grows best at 20 °C temperature and an annual rainfall of 150 cm. Coffee plantations perform best on deep, slightly acidic, well-drained fertile loam of lateritic or volcanic origin. Coffee plants are usually raised from seeds in nurseries and later transplanted to the field.

Harvesting: The ripe coffee fruits are picked either by hand or by shaking the coffee bushes and then collecting the fallen berries on sheets of muslin or mats spread underneath. Before releasing in the market the coffee beans are processed. The most common method of processing is through the dry method. In this method the gathered cherries along with twigs are spread out in thin layers in the open sun or in hot air driers. Then the dried skin is separated from the pulp and then bagged and stored in warehouses. This method is applied in the processing of Brazilian coffee.

Production: The total world's production of coffee in 2012 was 88, 26,903 tons. Brazil was the largest producer, accounting for approximately 3 million tons of green coffee beans, followed by Vietnam (12, 92,389 t), Indonesia (6, 57,200 t), Colombia (4,64,640 t), India (3,14,000 t).

Table-6.1: List of some Alcoholic Beverages

Type	Products	Chemical composition	Source of beverage	Scientific name of source plant
Fermented (Sugar based)	Wine	86% alcohol, 12% glycerol, and polysaccharides.	Grapes	*Vitiis vinifera*
	Cidar	Acetic acid, Malic acid, Polyphenols, pectin, vitamin B and C, and other minerals.	Apple	*Malus domestica*
	Perry	5-8% alcohol and contains high amount of sugars (sorbitol).	Pear	*Pyrus communis*
	Mead	5-20 % alcohol.	Apple	*Malus* sp.
	Ginger beer	4-5 % alcohol.	Ginger	*Zingiber* sp.
	Sake, Saki	9-16 % alcohol.	Rice	*Oryza* sp.
	Pulque	4-6 % alcohol.	Aloe	*Agave* sp.
	Chicha	3 % alcohol.	Maize, Goosefoot plant	*Zea* sp., *Chaenopodium* sp.
	Kava	Methysticum, dihydromethysticin, kavain, dihydrokavain, yangonin, and desmethoxyyangonin		*Piper methystichum*
	Palm Wine	4 % alcohol.		*Borassus*, *Nipa*, *Raphia*, *Jubaea*
	Kvass	1-2 % alcohol.		*Hordeum*, *Secale*
Brewed and fermented (starch based**)**	Rice wine	25% alcohol and remaining sugars.	Rice	*Oryza sativa*
	Japanese rice wine	18-20 % alcohol by volume.	Rice	*Oryza sativa*
	Beer	4-6% alcohol by volume.	Barley and hops	*Hordeum vulgare*
Distilled	Whiskey	40% and more % alcohol.	Barley, corn, rye, and wheat.	*Hordeum* vulgare, *Zea mays*, *Secale cereal*, *Triticum aestivum*
	Rum	40-50% alcohol, acetic acid, other acid and sugars.	Sugarcane	*Saccharum officinarum*
	Gin	40% alcohol and wide range of terpene compound.	Juniper berries	*Juniperus communis*
	Vodka	96% alcohol and trace amounts of esters, aldehydes, methanol, acetates.	Potatos	*Solanum tuberosum*
	Taquila	35-55% alcohol.	Blue agave	*Agave tequilana*
	Brandy	60% alcohol.	White grapes	*Vitis* sp.
	Calvados	30-40% alcohol and low molecular weight esters.	Apple or pear	*Malus domestica* or *Pyrus communis*
	Tia maria	20% alcohol	Coffee beans, sugar	*Coffea Arabica*

Table- 6.2: List of some Non-Alcoholic Beverages

S.No.	Type	Products	Chemical composition of beverage	Source of beverage	Botanical name of source
1.	Non aerated	Tea	Caffeine (3%) and Rich in polyphenols.	Tea plant An evergreen shrub.	*Chemellia sinensis*
		Coffee	Caffeine and Alkaloids.	Coffee plant	*Coffea arabica*
		Juices	Various sugars and organic acids.	Orange, grapes, and apple	*Citrus sinensis*, *Vitis vinifera*, *Malus domestica*
		Hibiscus iced tea	Vitamin C and anthocyanins.	Roselle Jamaican Hibiscus	*Hibiscus sabdariffa*
		Chamomile tea	Hamazulene, α-pinene, β-Pinene, ά-bisabolol, ά-bisabololoxide A, trans-b-farnesene and Chrysanthenone.	Common Chamomile or German Chamomile	*Matricaria recutita*
2.	Aerated	Soda	CO_2 gas in drinking water (Carbonated water).	-	-
		Soft drinks (Coca cola, Pepsi, Fanta, Dew, 7 UP etc)	Carbonate water, sweetener, and natural or artificial flavouring. May also contain caffeine, colourings, and preservatives.	Water, CO_2, sweeteners, and flavouring agents.	-
		Energy drinks (Red bull, Monster, Rockstar, NOS, Amp).	Contains high methylxanthines (including caffeine), B vitamins, carbonate water, high fructose corn syrup.	-	-

6.4 NARCOTICS

In the beginning narcotics were used for pleasure, excitement or to run away from the struggle of daily life for a little while whereas now they are also used to relieve pain, produce sleep, and quiet anxiety and fears. Narcotics contain various chemicals which stimulate or depress the central nervous system. Stimulants increase the functional activity of the body and do not affect the consciousness of consumer examples are caffeine beverages, tobacco, betel and coca. However, tobacco is more harmful and may cause mouth cancer and lung cancer.

The true narcotics (depressants) are injurious even in trace amounts and if consumed in larger dose can cause delusions, coma, seizure, complete paralysis and death. The continuous use of narcotics makes the user addict and deteriorates the mental, moral and physical well being e.g. opium, morphine, heroin etc).

Classification: Based on the effects of these narcotics they can be categorized into three groups: hypnotics, sedatives and hallucinogens. The classification of the narcotics is given in the Fig.6.3.

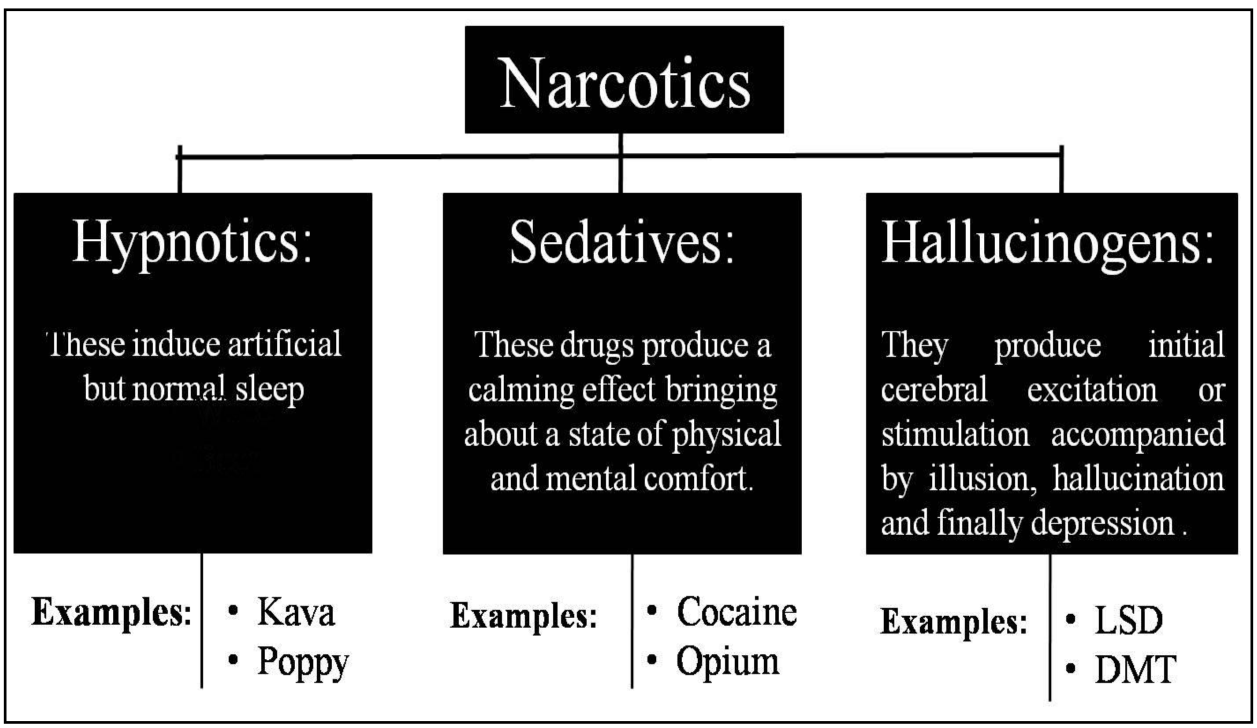


Fig. 6.3: Classification of the Narcotics

***i. Hypnotics*:** These induce artificial but normal sleep. Example: kava- kava (*Piper methysticum*, family-Piperaceae), is indigenous to Fiji and other Pacific Islands.

ii. Sedatives**:** These drugs produce a calming effect, bringing about a state of physical and mental comfort accompanied by a reduction or even suspension of mental activity and finally leading to complete suppression of consciousness, for example, cocaine and opium.

iii. Hallucinogens**:** They produce initial cerebral excitation or stimulation accompanied by illusion, hallucination, fantastic colored visions, unusual amusement and fear and intense cerebral depression later. The hallucinogens also distort the mind and even alter the personality. The user loses all his feeling of earthly existence. His awareness of memory, powers of observation and ability to reason are impaired. Space and time become more and more disorganized. Owing to a misjudgment of distances, the user may tumble headlong while negotiating steps. Examples: LSD (d-lysergic acid diethylamide), Psilocybin (4-phosphoryloxy-N,N-dimethyltryptamine)—also known as magic mushroom**s,** Peyote (Mescaline)—also known as buttons, DMT (Dimethyltryptamine)—also known as Dimitri

Major narcotic plants are given in Table 6.3. Some important narcotic plants are also describing in detail.

i. Tobacco:

Botanical Name: *Nicotiana tabacum*

Characteristic features: It is an annual herb, about 1.2-2.7 m long. It appears like shrub because of the lateral branches. Leaves are large, alternate, ovate, lanceolate and sessile. Glandular hairs on the surface of the leaves secrete gums and oils which make the surface sticky. Flowers are tubular, borne in a terminal panicle, pink or white. Fruit is capsule having various seeds.

Origin: Tobacco was first found by Christopher Columbus and his men on the island of Tobago in 1492. The natives were using it to smoke chew and other various purposes. In Spain it was introduced by a Spanish physician in 1558 and from there it was introduced to southern Europe and the Middle East. In France, it was introduced in 1560 by a French Ambassador to Portugal named Jen Nicot. In the honor of Jen Nicot the plant was named *Nicotiana* by Linnaeus. In 1565, it was introduced into England from Florida by Sir John Hawkins. After that the Portuguese and Spanish explorers carried tobacco to different parts.

Cultivation: It is mainly tropical crop but can be grown in varied agro-climatic conditions. It requires very moist soil and average temperature of 27 °C. It demands well-drained alluvial, loam and silt loam soils with a pH of 5.0 to 6.5.

Harvesting: The crop is harvested when the leaves become greenish yellow, brittle and tough. Either the whole plant is cut off close to the ground or only the mature leaves are picked individually by hand. Freshly harvested leaves are left to wilt overnight as they contain 75-85% moisture.

Table-6.3: Major narcotic plants, parts use and their chemical composition

S. No.	Name of narcotic drugs	English name of source plant	Local name of source plant	Botanical name of source plant	Part of plant to be used for purpose	Chemical composition of drugs
1	Ayahuasca/ Huasca	Ayahuasca	-	*Banisteriopsis caapi*	All parts of the plant.	Contains beta-carboline alkaloids with monoamine oxidase inhibitor action, mainly harmine, and harmaline.
2	Betel nut	Betal nut	Supari	*Areca catechu*	Seeds	Contains tannin, gallic acid, gum, lignin, iron peroxide, magnesium sulphate, and other salts.
3	Cocaine	Coca	-	*Erythroxylum coca*	Leaves	Contains benzoylmethylechonine.
4	Dhatura	Jimsonweed	Dhatura	*Datura stramonium*	Leaves and Spiky seed pods.	The leaves and seeds contain potent alkaloids (hyoscamine and hyoscine) that cause hallucinations.
5	Heroin	Opium poppy	Afeem	*Papaver somaniferum*	Resins and latex of seed capsule.	Morphine is an active ingredient. Heroin is a synthetic form of Opium.
6	Marijuana/ Hash/Dope/ gunja	Cannabis	Bhang	*Cannabis sativa*	All parts of the plant. But most concentrated part is flowering tops of female.	The most active ingredient is tetrahydrocannabinol (THC).
7	Opium	Opium poppy	Afeem	*Papaver somaniferum*	Seed capsules	Contain two group of alkaloid. Phenanthrenes and isoquinolines.
8	Salvinorin	Salvia	Neela Phool	*Salvia divinorum*	Leaves	Active ingredient is Salvinorin A.
9	Tobacco	Tobacco	Tambaakoo	*Nicotiana tobacum*	Leaves	Nicotine is a chief active ingredient in the tobacco.

Production: In 2012, the global production of tobacco is 74, 90,661 tons. The top three tobacco producing nations were China (3.2 million tons), India (8, 75,000 tons), Brazil (8, 10,550 tons).

Uses: It is used in two main ways chewing and smoking. Various additives (glycerine, sugar, tannins, honey, vanilla, chocolate and rum) are used to improve the quality (aroma and taste) of tobacco products for smoking and chewing. It is used in various forms such as Bidi, Cigarettes, Cigar, Pipe, Hukkah etc. The alkaloid nicotine is used in agriculture as an insecticide. Tobacco seeds are free from nicotine so the refined tobacco seed oil can be used as a substitute for groundnut oil and can be used for illumination and in the oil paint and varnish industries. The seed cake is used as a feed for cattle and horses. Tobacco was also used as medicine (gastro-intestinal disorders) and sedative. On oxidation nicotine gives nicotinic acid which is used in making of various vitamins.

ii. Cannabis

Botanical Name: *Cannabis sativa*

Characteristic features: The plant is a tall, robust, annual, dioecious herb; leaves are palmately divided; flowers small, greenish yellow in color; male flowers arranged in long drooping axillary and terminal panicles with few leaves; female flowers in short axillary leafy spikes; glandular hairs found on whole plant surface; fruit is an achene.

Origin: It is a native of Central and Western Asia, but now extensively cultivated in both temperate and tropical regions of the world.

Cultivation: It is a weed growing on wasteland. However if cultivated for commercial purposes then it is recommended to be grown on a fertile well-drained soil. Since the plant is a weed there are no specific requirements for its cultivation.

Harvesting: The first sign to identify that the crop is ready to harvest is the white hair-like fuzzy stigmas protruding out of the seed bract on buds are turning reddish-brown. When half to three quarters of the stigmas have turned reddish-brown then it is the time to harvest the crop. The second sign is the color of the head of the trichomes. The trichomes are transparent in the early stages and become milky white at maturity and turn brown at last. When the head of the trichomes are milky white in color then the crop is ready to harvest.

Production: Since it is not legal to produce *Cannabis* in fields, except the areas where government itself gives the license to cultivate it, so there is no authentic and reliable data to present here.

Uses: Cannabis is mainly used for the narcotic purposes. It is consumed in various forms such as bhang, ganja and charas. **Bhang** is made up of dried leaves, stems and flowering shoots of male and female plants. It has low resin content and thus the drug is less potent. Its decoction in water or milk is used as a beverage. It is also smoked in dry form mixed with tobacco. **Ganja** is the dried unfertilised female inflorescence with full resin contents. It was used medicinally as a sedative and hypnotic. It is also used for smoking and in beverages. **Charas** consists of the undiluted, unadulterated sticky yellow exudation from the leaves, and unfertilised inflorescences of cultivated female plants.

The resinous exudate is the most valued part of the plant because it contains the highest concentration of physiologically active tetrahydrocannabinol (THC), an active hallucinogenic compound. A number of other chemical compounds have been isolated from the resin. More important among them are cannabidiolic acid, tetrahydrocannabinol-carboxylic acid, cannabigerol, cannabichromene and tetrahydrocannabinol.

Its continuous use for longer periods leads to moral and mental depravity. Addicts are of weak character and mentally abnormal and considered outcasts of the society.

iii. Coca

Botanical Name: *Erythroxylum coca*

Characteristic features: It is an evergreen, shrub or a small tree; leaves are dark green, alternate and ovate with prominent stipules; flowers are small, white and born in axillary clusters; fruit is small reddish orange drupe.

Origin: It is a native of the Andean highlands and is traditionally cultivated in the tropical regions of Bolivia, Ecuador and Peru, all collectively account for more than 98 per cent of the global land planted. It is also cultivated in other regions of the world for example Chile, Colombia, Indonesia, Mexico, Sri Lanka and West Indies.

Cultivation: It grows best thriving best at altitudes of about 900-2750 m. It prefers loose, humus-rich soil which is regularly supplemented with plant compost. It can be propagated by cutting but is generally raised from seeds, the seedlings being kept shaded in the nursery for eight to ten months.

Harvesting: Harvesting is carried out two to three years after planting. The leaves are handpicked three to four times in a year, but collections made during April and September are the most valuable.

Uses: Cocaine has been much used as a local anesthetic. It is also employed as a tonic for the digestive and nervous systems, but as it is a habit-forming drug its use should be supervised by physicians. In small doses, cocaine induces a pleasing excitation, increased physical strength, mental alertness, increased working capacity, relief from fatigue and a reduction of hunger, because of local anesthesia of the stomach. The stimulation is, however, short lived, and is followed by a feeling of utter fatigue and mental depression. This prompts the user to repeat the dose to restore his sense of well-being. Habituation may develop in a very short time, even weeks. Overdoses of cocaine may lead to restlessness, convulsions and hallucination. The victim may see imaginary insects and feel them crawling over his skin. Death may sometimes occur because of respiratory paralysis.

Like coca chewing, cocaine is also habit-forming. The cocaine powder is called 'snow' in illicit traffic and is generally sniffed. Some addicts prefer to mix cocaine with heroin, producing what is known as 'speed ball' because of its immediate effects. Cocaine addicts soon lose their desire for food and are likely to suffer from malnutrition. Eventually, they develop digestive problems, muscular twitching, insomnia, mental, moral and physical deterioration, often resulting in death.

6.5 SUMMARY

Beverages are being used since the dawn of civilization to refresh and energize the body. In the beginning the beverages were very simple such as water and fruit juices but with the advancement of civilization and science and technology various types of beverages were manufactured. On the basis of the chemical composition beverages are of two types alcoholic and non-alcoholic. Beverages which contain alcohol are called alcoholic and the rest of the drinks fall into the non-alcoholic category. Based on the method of manufacturing, alcoholic beverages are further divided into two categories, fermented and distilled alcoholic beverages. Fermented beverages produced by fermented fruit juices and have low alcoholic content (e.g. beers and wines) but on the other hand distilled beverages are produced by the process of distillation of the fermented fruit juices and have high alcohol content (e.g. Rum, whisky, vodka, gin, brandy). Various plant species are used in the process of beverage making such as Grapes, Apple, Rice, Barley, etc. Controlled use of the alcoholic beverages is fine but excessive and continuous consumption may lead to addiction and finally liver failure. Today the alcohol industry is of millions of dollars which is a positive thing for the global economy but on the other hand alcoholic beverages also are a cause of liver problems and social disgrace.

Humans have also used plants for smoking or chewing to get pleasure or for some physiological effect. The plants used for narcotic purposes have some stimulating effect because they possess various alkaloids. Based on the effects they produce narcotics can broadly be classified into two groups mild narcotics and hard narcotics. Mild narcotics does not produce much effect on the consciousness of the consumer e.g. betel, cola and tobacco. Hard or true narcotics exhibit detrimental effects even in small amounts and when used in large doses may lead the addict to the lowest depths of depravity and degradation and cause stupor, coma, convulsions, and even death e.g. cannabis, coca and opium.

6.6 GLOSSARY

Alkaloids: Natural bases containing nitrogen found on plants.

Anesthesia: Loss of bodily sensation with or without loss of consciousness.

Beverages: Any liquid suitable for drinking.

Consciousness: An alert cognitive state in which you are aware of yourself and your situation.

Depressant: Capable of depressing physiological or psychological activity or response by a chemical agent.

Hallucination: Illusory perception; a common symptom of severe mental disorder.

Narcotics: A drug that produces numbness, often taken for pleasure or to reduce pain; extensive use can lead to addiction.

Stimulant: A drug that temporarily quickens some vital process.

6.7 SELF ASSESMENT QUESTIONS

6.7.1 Multiple Choice Questions

1-Botanical name of tea is:

(a) *Camellia sinensis* (b) *Cannabis sativa*

(c) *Papever somniferum* (d) *Coffea arabica*

2. Vodka is made from:

(a) Barley (b) Banana

(c) Rice (d) Potato

3. Which one is distilled alcoholic beverages:

(a) Lager (b) Ale

(c) Wine (d) Gin

4. Cocaine is made from:

(a) *Cannabis sativa* (b) *Erythroxylum coca*

(c) *Cola nitida* (d) *Nicotiana tabacum*

5. Which plant species is the major source of beer:

(a) Barley (b) Wheat

(c) Rice (d) Potato

6. Which fruit species is the major source of wine?

(a) Black grapes (b) Banana

(c) Pineapple (d) Orange

7. Which narcotic product is called ‘snow’ in illicit trafficking?
(a) Cocaine powder (b) Hashish
(c) Heroin (d) Sparkling wine

8. Cocaine plant belongs to which family:
(a) Erythroxylaceae (b) Cannabinaceae
(c) Sterculiaceae (d) Solanaceae

9. Which type of beer holds the largest market share:
(a) Lager beer (b) Ale beer
(c) Root beer (d) Stout beer

10. Tequila is the popular drink of which nation:
(a) Mexico (b) Unites States of America
(c) Brazil (d) Russia

Answers Key:

6.7.1: 1-(a), 2-(d), 3-(d), 4-(b), 5-(a), 6-(a), 7-(a), 8-(a), 9-(a), 10-(a)

6.8 REFERENCES

- Kochhar S. (2016) Economic Botany: A Comprehensive Study. Cambridge University Press. doi:10.1017/9781316286098.003
- Hill Albert F. (1937) Economic Botany. Mcgraw-Hill Publications.

6.9 SUGGESTED READINGS

- Kochhar S. (2016) Economic Botany: A Comprehensive Study. Cambridge University Press. doi:10.1017/9781316286098.003
- Hill Albert F. (1937) Economic Botany. Mcgraw-Hill Publications.

6.10 TERMINAL QUESTIONS

6.10.1 Short answer type questions:

1-Write short notes on Cannabis, Beer and Tea.
2-What is the economic importance of Alcoholic beverages?
3-What is the process of beer production?
4- Explain the three types of narcotics obtained from Cannabis?
5- Name five common alcoholic beverages?

6.10.2 Long answer type questions:

1-Write in detail about two major non-alcoholic beverages?

2-Write in detail about three major narcotic plant species?

UNIT-7 TIMBER AND NON-TIMBER

Contents

7.1 OBJECTIVES

After studying this unit, you should be able to:

- list the important wood yielding plants and describe their important features;
- list the properties and characteristics of different woods and various uses;
- describe the processing of various woods for commercial use; and
- explain the process of papermaking.
- know about non-timber forest products

7.2 INTRODUCTION

By now you have studied that we use plants for various purposes such as foods, beverages and medicines. In addition, several plant products provide us shelter and clothing. From the time immemorial, food, clothing and shelter have been the three great necessities of mankind. Wood is the most familiar and most important forest products. The wood has contributed a lot to the advancement of civilization. Today, the wood is the most widely used commodity other than food and clothing. It is one of the most important and versatile of the raw materials of the industry. Wood is produced as a result of secondary growth in gymnosperms and dicotyledonous plants. Woody tissues help in increasing weight of the plant. Besides timber and fuel, woody tissues yield many useful products such as gum, resin, turpentine, paper, rayon, cork, and rubber. Plant fibres also provide the raw material for various products such as cloth, mats, bags, and ropes. In this unit you will study about the timber and Non-timber plants and their various uses.

7.3 GENERAL ACCOUNT

Wood has been an important and indispensable forest product used by mankind for ages. Primitive man used it for construction of shelters, implements and utensils. Several indigenous tree species from the natural forests are being used for various ways, as fuel, for construction, timber products, and as raw material in the paper industry. It became an inexhaustible natural resource because of overexploitation and decline in the forest area. Wood continues to play an important role in our lives, hence need to be used with proper care. Despite the availability of various metals and synthetic products, we have not been able to find substitutes for wood till date. Judicious utilization and care is needed to keep the forest plantations alive. You will now study about four such sources of wood which are used at commercial scale in India.

Timber plants are usually medium to large trees which are cut to extract the wood. It is also known as “**lumber**” in US and Canada. Timber trees are broadly classified into trees of soft, semi-hard and hardwoods. **Hardwood** is derived from angiospermous (mainly dicotyledonous) plants. They have a superior quality that last for years. Hardwood plants provide the best quality wood as they possess more resistance and are used for construction of high end furniture, floors, ceilings and even houses. Wood obtained from oak, birch, beech, is called hardwood. **Softwoods** are obtained from gymnosperms (mainly coniferous. Softwood is generally used in the manufacture of products such as crates of vegetables, crafts and even paper.

Wood used in construction, furniture and paper pulp is timber and products produced or derived from them are timber products. The products produced from the stems are often called timber products. Products produced/derived from woody parts of plants are termed as wood products. Timber has a high strength to weight ratio.

Non-timber forest products (NTFPs) refers to a wide array of economic or subsistence materials that come from forests, excluding timber. Similar terms include "nonwood," "minor," "secondary," and "special" or "specialty" forest products.

There are many kinds of animal and plant resources that are derived from forests, including fruits, nuts, mushrooms, essential oils, florals, medicinal products, herbs and spices, dyes, resins, and animal products such as honey and wild game. These products are often gathered from natural forests. Others may be produced with varying degrees of cultivation and domestication, either within a forest ecosystem or as part of a planted forest system such as an agroforestry or forestry project.

NTFPs represent income opportunities from forests and forestry that do not involve cutting down trees for wood products. In forests with low timber production potential, NTFPs represent the major actual or potential source of income. In other cases, management of a forest for NTFPs does not preclude the option to harvest timber, as well.

While NTFPs are traditionally used and appreciated by peoples of many cultures worldwide, the significance of these products for sustainable economic growth, cultural endurance, and environmental health is receiving increasing recognition by governments and other official agencies.

7.4 IMPORTANT TIMBER YIELDING PLANTS

About 500 timber species are known whose trunk and branches provide wood. Some of the important timber trees are Khair (*Acacia catechu*), Babla (*Acacia nilotica*), Chatim (*Alstonia scholaris*), Itchri (*Anogeissus acuminata*), Kadam (*Anthocephalus chinensis*), Shimul (*Bombax ceiba*), Kamdeb (*Calophyllum polyanthum*), Batna (*Castanopsis tribuloides*), Shisham (*Dalbergia sissoo*), Garjan (*Dipterocarpus alatus*), Gamari (*Gmelina arborea*), Sundari (*Heritiera fomes*), Telsur (*Hopea odorata*), Sidha (*Lagerstroemia parviflora*), Aam (*Mangifera indica*), Tali (*Palaquium polyanthum*), Batna (*Quercus spicata*), Bhobinut (*Samanea saman*), Sal (*Shorea robusta*), Dharmara (*Sterospermum personatum*), Mahogony (*Swietenia macrophylla* and *S. mahagony*), Teak (*Tectona grandis*), Toon (*Toona ciliata*). International trade code of flora and fauna governs the timber species suitable for commercialization and export.

You will now study about four such sources of wood which are used on a commercial scale in our country.

7.4.1 *Tectona grandis*

Family: Verbenaceae
Common names: Teak, Rangoon or Burma teak, Moulmein teak, Singur, Sangwan
n = 12, 18

Distribution: It is native to South-east Asia and Malaya and is one of the most important commercial timber crops of the tropics. Myanmar and Thailand have extensive teak forests. In India, teak forests are present in the states of Madhya Pradesh, Maharashtra, Gujarat, Karnataka, Rajasthan, Kerala, Tamil Nadu, and Andhra Pradesh.

Characteristics: Teak is a large, deciduous tree with a probable age of over 200 years (Fig. 7.1). Teak is a tropical, flowering tree growing up to 40 m in height and 1 m in bole diameter. The flowers are fragrant, white, and small. Leaves are large, ovate-elliptic, papery, often hairy on the lower surface. Fruits are globose. Teak is highly valued for its wood which is of superior quality. Highly durable and water resistant, it is used for boat building, exterior construction, veneer, furniture, carving, etc.

Fig. 7.1: Photograph showing teak plantations

The sapwood is white and rather susceptible to attack by termites and wood rotting fungi. The heartwood is golden yellow to golden brown when freshly sawn, turning darker after exposure and is relatively immune to insect attack. The wood is greasy to touch and smells like old leather. It is hard, and does not warp, split, or crack and is thus valuable for general construction. It is resistant to decay and termites even when unprotected by preservatives and is renowned for its stability. Teak wood is not very difficult to work with and it takes very good polish. The grain is normally straight, and the texture is coarse and uneven. The average weight is between 609-689 kg/m3 when dry. It shows distinct growth rings. The wood is ring porous and is marked by the presence of large vessels. The vessels of early wood are distinctly larger than those of the late wood. The pores seem to be arranged in concentric circles when seen in a transverse section. Tyloses are quite common.

Uses: Teak ranks among the best timbers of the world. It is the chief source for railway carriage and wagon wood of India. It is superior to oak in ship building. Its wood is used in construction of houses; building bridges; making cabinets and boats; for carving; plywood manufacture; for flooring; making toys, and in many other ways.

7.4.2 *Dalbergia sissoo* Roxb

Family: Fabaceae
Common names: Shisham, Rosewood
n = 10

Distribution: *Dalbergia* is a genus of tropical trees providing valuable dark timber. *D. latifolia* (Indian rosewood) and *D. sissoo* (sissoo) are important Asian species and are amongst the finest of India's cabinet and furniture woods. Sissoo occurs throughout the sub-Himalayan tracts to Assam. Indian rosewood is found in central and southern India and also in sub-Himalayan tracts. Other common *Dalbergia* species are *D. nigra* (Brazilian rosewood), *D. melanoxylon* (African blackwood), *D. retusa* (cocobolo) and *D. stevensonii* (Honduras rosewood).

Characteristics: *Dalbergia sissoo* is a medium to large tree which grows upto 10 to 15 m metres in height. It is a deciduous tree. Leaves are compound, with about five alternate leaflets. Leafstalk (petiole) measures about 15 cm long, each leaflet widest at the base with a fine pointed tip. The trees have panicles of small, yellow or white papilionaceous flowers. Flowers occur in dense clusters on short stalks. The dry fruit is a pale brown pod, flat, thin and papery, about 7 cm. Seed are visible from within pod. The sapwood is white to brownish, and the heartwood is golden brown to dark brown. The pale, straw-colored sapwood is clearly demarcated from the heartwood (Fig. 7.2).

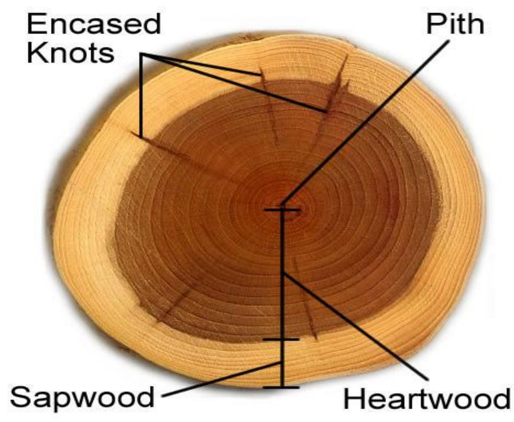


Fig. 7.2: T.S. stem of *Dalbergia* showing Heartwood and Sapwood

It is a durable, heavy wood with an average weight of 800-850 kg/m3. In Indian rosewood the sapwood is yellowish, but the heartwood varies from dull brown to almost purple. It is a durable wood, especially under water. It weighs around 800-960 kg/m3. Although not easy to work with, it carves well.

Uses: *Dalbergia* provides wood for high class furniture and cabinets. It is valued as a construction and general-purpose timber and is used for railway sleepers, musical instruments, hammer handles, shoe heels and tobacco pipes. It is good for charcoal making and is used for decorative veneers as well.

7.4.3 *Pinus roxburghii, P. wallichiana*

Family: *Pinaceae*

Common names*:* Chir, Blue pine

n = 12

Distribution: In India, *Pinus roxburghii* (chir) and *P. vallichiana* (kail) are the two most popular species of *Pinus* that yield timber. *P. roxburghii* occurs in the outer hill ranges of Siwalik and the valleys of Himalayas. *Pinus wallichiana* occurs at higher altitudes. Pines are common in Himachal Pradesh, Jammu and Kashmir, Punjab, and Uttar Pradesh. Other commercial pine timbers come from *P. strobus* (American yellow pine), *P. monticola* (Western white pine). *P. sylvestris* (Scots pine), *P. ponderosa* (Ponderosa pine) and many more.

Characteristics: Pines are generally tall trees that bear characteristic needle-like leaves, and distinct male and female cones. Pines have two types of branches, long shoots and short shoots, and three types of leaves, primordial, scale, and adult. The triangular scale leaves (lance-shaped), are borne on the long shoots of older trees. Both long and short shoots develop in the axils of the deciduous scale leaves. The needlelike photosynthetic adult leaves, with two or more resin canals, are borne in fascicles (bundles) of two to five (rarely, up to eight or solitary) at the tip of each short shoot. Pine timber falls into two broad categories - the soft or white pines, and the hard, yellow or pitch pines. The former have soft, light-colored wood-tinged pink in the heartwood and nearly white in the sapwood. The latter have a resinous, heavy, hard, strong, and durable wood, with a pronounced, grain pattern. The wood is light, easy to work but not durable. The timber is straight grained and has little resin.

Soft pines, such as white, sugar, and piñon pines, have relatively soft timber, needles in bundles of five (less commonly, one to four), stalked cones with scales lacking prickles, and little resin. Their wood is close-grained, with thin, nearly white sapwood. The leaf sheaths of the leaf clusters are deciduous. Hard pines, such as Scotch, Corsican, and loblolly pines, have relatively hard timber, needles in bundles of two or three (rarely, five to eight), cone scales with prickles, and large amounts of resin. Their wood is coarse-grained and usually dark-coloured, with pale, often thick sapwood; the sheaths of the leaf clusters are persistent.

Uses

Soft pines are used for making matches, crates, boxes and rough carpentry work. Hard pine is used in construction of buildings, bridges and ships.

7.4.4 *Cedrus deodara*

Family: Pinaceae

Common name: Deodar, Himalayan cedar

n=12

Cedrus has four species namely *C. atlantica* (Atlas cedar), *C. brevifola* (Cyprian cedar), *C. libani* (Cedar of Lebanon), *C. deodara* (Deodar Cedar Tree, Himalayan Cedar). There are some false cedars also reported from other areas. Even though false cedars aren't officially in the genus Cedrus, knowing the varieties commonly identified as cedar, especially in North America. These include Alaskan Yellow Cedar (*Cupressus nootkatensis*), Bermuda Cedar (*Juniperus bermudiana*), Eastern Red Cedar Tree (*Juniperus virginiana*), Incense Cedar (*Calocedrus decurrens*), Northern White Cedar (*Thuja occidentalis*), Port Orford Cedar (*Chamaecyparis lawsoniana*), Siberian Pine (*Pinus sibirica*), Spanish Cedar (*Cedrela odorata*), Western Red Cedar (*Thuja plicata*).

Distribution: The tree is native to mountainous areas of the Mediterranean region and one to the western Himalaya. Cedar is one of the most important and strongest Indian softwood growing mainly in the northwestern Himalayas in Kashmir, Himachal Pradesh, Uttar Pradesh and Punjab.

Characteristics: It is a tall tree about 45-60m in height. The tree has horizontal spreading branches giving it a characteristic skyscraper appearance. Trunks are large with massive, irregular heads of spreading branches. Young trees are covered with smooth, dark-gray bark that becomes brown, fissured, and scaly with age. The Leaves are needlelike, three-sided, rigid and scattered along the long shoots and clustered in dense tufts at the ends of short spurs. Female cones are large, barrel-shaped, resinous, greenish or purplish and borne on short stalks. They are covered by broad, thin, closely overlapping woody scales, each with a claw like projection.

Cedar wood is light, soft, resinous, and durable. Its sapwood is white in colour and the heartwood is light yellow, turning brown on exposure to air. The timber is durable and resistant to insects. Wood is fine and uniform in texture. True cedars are evergreen and have aromatic, often red or red-tinged wood that is resistant to decay and insects.

Uses

The wood is manly used in making railway coaches, beams, posts, doors, window frame and construction of bridge. It is also used in making pencils, chests, closet linings, carving, fence posts and packing. Distilled oil from the wood is used in many toiletries.

7.5 DIFFERENT USES OF WOOD

Woods are being put to different uses and processed to make them suitable for the requisite purpose. Different woods are used for different purposes. Some of the common examples are discussed below.

Processing wood for use: Trees are felled by cutting across the trunk as close to the ground as possible. The side branches are then removed, and the trunks are cut into suitable lengths, known as saw logs. The powered saws are now used instead of the hand saws in several parts of the world; hence the processing of fresh logs is becoming increasingly mechanized. Wood is unique among the various raw materials and no replacement has been found to it. Its uses are numerous such as fuel, construction work, furniture, containers, mechanically reduced products, chemically derived products and so on.

Fuel

The wood is used as a fuel for heating and cooking from prehistoric times. Recently this practice has been replaced to some extent by fossil fuels or electricity. Still, wood is largely consumed for fuel rather than any other purpose. Wood is an excellent fuel, since 90% of the oven dried wood is combustible. Woods vary greatly in their fuel value and this depends mainly on their density, chemical composition, and the amount of moisture. The hardwoods such as beech, oak, maple, and birch best fuel woods serve as the best fuel wood. The average calorific value of seasoned wood is around 4600 cal/kg.

1. Construction Materials

Poles - Employed chiefly for telephone, telegraph, and electrical transmission lines. Durable wood, which is light, straight, and strong to resist stresses, is used. Coniferous trees are the principal source of wood. Such woods are also used in construction of shelters.

Pilings - Used for the construction of docks, bridges, and wharves. These are straight, round timber, driven beneath water for construction work. Pines are commonly used and so is oak, the latter mainly for dock and harbour work and for marine pilings.

Posts - Used for the erection and maintenance of fence lines along farm and ranch boundaries, railroads, and highways. Strength, lightness, and durability are the main requirements. Any available local species can be used.

Mine timbers - Include a variety of wooden supports such as props or legs, crossbars or caps used in tile construction of mine tunnels to prevent debris from falling or where the underground formations are likely to cave in. Mostly those hardwoods that are durable and strong and resistant to decay and corrosion are employed for the purpose.

Railroad ties or sleepers or cross ties - Used to support and hold railroad rails. The wood used need to be durable, treatable and able to withstand the impact and pressure of heavy and speedy traffic, hold spikes and screws and be easily available and inexpensive. Oak is the most widely used wood for this purpose. The wood is usually treated with preservatives and can last up to 30 years.

Veneers - These are thin sheets of wood of uniform thickness, produced by peeling, slicing, or sawing logs. Veneers are made by one of the following three methods - rotary cutting, slicing, or sawing. Of these, rotary cutting is the most common method employed. Logs selected for this process are debarked and softened by steaming or steeping in hot water. This facilitates cutting and minimizes the danger of splitting. They are then crosscut to desired lengths. Many woods like *Douglas* fir, *Ponderosa* pine and Poplars are used. Fine veneers are made from expensive woods like walnut, teak, and rosewood.

Plywood - It is a thin board made up of an odd number of three or-more very thin sheets of veneers glued together under pressure, ranging in thickness from 3-25 mm. Successive veneers are positioned in such a way that the grain of each is at right angles to the adjoining sheet (in a cross-banded way), making the structure as strong and even stronger than the wood itself. The major advantage of plywood over solid woods is dimensional stability and that it is much less likely to warp or twist than ordinary wood. Plywood has the strength distributed in both directions, and the nails and screws can be driven close to the edge without any danger of splitting. Also, it can be molded, and it comes in much larger sizes and can be used for making partitions, walls arid roofs. Durable timbers such as oak and teak are used. Plywood is used for inner cabinet work, roof and wall sheathing, flooring, automobile body parts, boards, ceilings, counters, desks, drawers, and furniture.

2. Containers

Cooperage - It's the art of making wood containers such as barrels, tubs, tanks, and the construction of wooden pipelines for transporting city water supplies. There are two principal divisions of the cooperage industry, namely, slack (or dry) cooperage made for packaging, storing, and transporting dry material, and tight (or wet) cooperage for holding liquids such as beer, whisky, and wine syrups. Woods selected for slack cooperage must be cheap, light, easy to work, elastic and free from warping. Pine, beech, oak, and maple are commonly employed. For making tight cooperage the inner walls are coated with an inert material such as paraffin, silicate of soda or glue to prevent leakage and contamination of liquids. Hardwoods, especially oak are commonly used because of their strength and durability, impenetrable nature, and thermal insulation properties. Woods used for the purpose are red gum, white ash, yellow birch, and Douglas fir.

3. Chemical Products

Wood is mainly made up of cellulose, hemicellulose, lignin and varying amounts of tannins, resins, gums, and latex. It serves as a basic raw material for deriving several chemical products using various methods. Some examples are given below:

Wood distillation - This is an ancient process. One of the chief sources of wood for destructive distillation is the waste left by lumbering operations and sawmills. The wood is heated in a cast iron or steel retort or oven in the absence of air. Charcoal residue is left behind in the retort, and the escaping vapors are conducted through water-cooled condensers. The condensate (pyroligneous acid) is allowed to settle, and tar and oils are separated out from the liquid above. Meanwhile the non-condensable gases are trapped and are used to help heat the oven.

Based upon the kind of wood used, distillation can be classified into hardwood and softwood distillation. Denser and heavier woods like sugar maple, birch, oak, and beech are employed in hardwood distillation and the products are:

i) charcoal - the solid residue,

ii) pyroligneous acid - a yellowish green, ill smelling liquor or condensate consisting of water, acetic acid, methanol, and dissolved tar,

iii) wood tar - the water insoluble fraction that settles at the bottom of the aqueous pyroligneous acid, and

iv) the non-condensable wood gas, used as fuel or for illumination purposes.

On the other hand, softwood distillation utilises resinous pinewoods, chiefly of long leaf and slash pines. The principal distillation products are charcoal, wood turpentine, pine oil, dipentine, pine tar, tar oils, wood gas and a small amount of wood alcohol (methanol) and acetic acid.

Tapping for naval stores industry - The term 'Naval Stores' was initially used to designate the pitch obtained by tapping pine trees. Pitch and its derivatives were used extensively by the European maritime industry in the late sixteenth century for caulking the planks of wooden sailing ships and for water proofing riggings and hawsers. The species used now-a days are the long leaf and slash pines in the USA, maritime pine *(Pinus pinaster)* in Europe, and *Pinus roxburghii* in India. Besides pines, Douglas fir, spruces and larches are the other conifers tapped for the purpose. Three different types of products are obtained by this industry: (i) gum turpentine and gum rosin, derived from the gum (oleoresin) bled from living trees; (ii) wood turpentine and wood rosin, obtained by the action of steam and suitable solvents on macerated or chipped stumps and roots left behind after lumbering; and (iii) sulphate turpentine and sulphate rosin, important byproducts of pulp mills employing the sulphate process for pulping resinous woods.

Crude turpentine is collected by tapping when the trees have attained a girth of 23 cm or more. The bark near the base of the tree is shaved off and a shallow slanting cut is made a few centimeters above the ground level. A v-shaped metal trough is fixed to direct the flow of crude turpentine into a collecting vessel. A shallow wound is then made in the bark above the gutter, from which the exudates drips. Chipping on all sides takes 10-20 years; the tree is then abandoned as these wounds never heal because the cambium is removed in the process. The crude turpentine contains about 20% spirit of turpentine, 65% rosin, 5 to 10% water, some plant tissues and dust. It is distilled in steam distillation plants to isolate its useful components. The distillate consists of water and spirits of turpentine while the hot molten amber to dark-red residue that remains behind is the rosin of commerce. Spirit of turpentine is used as a thinning material in the paint and varnish industry, as a solvent for rubber and gutta-percha, and for the manufacture of printing cloth, waters proofing compounds, leather dressings, synthetic camphor, many pharmaceuticals such as liniments and many other chemicals. Rosin is used for preparing paints and varnishes, polishes, waxes, soaps, oil cloth, 'linoleum', sealing wax, printing ink, roofing and floor covering adhesives, plastics, rubber, wood preservatives, disinfectants, drugs, and chemicals. Rosin is also used in the paper industry for sizing, i.e., for imparting luster and weight, and hindering absorption of ink or moisture. Rosin oil is used in the manufacture of greases, lubricants, and solvents.

4. Cellulose Derived Products

Cellulose is a carbohydrate [($C_6H_{10}O_5$),] and is an important component of cell walls. Cotton was originally used as a source of cellulose, but now wood pulp is generally employed. It is used in the manufacture of such products as paper and rayon.

Manufacture of wood pulp - Woods are converted into a fibrous mass (wood pulp) by any of the following three processes - (i) mechanical (most economical and highest yielding), (ii) chemical, and (iii) semi-chemical.

i) Mechanical pulping (or ground wood process) - Only the light-colored and long-fibred coniferous woods especially spruce are used. In India, salai wood (*Boswellia serrata*) is most widely used for the process. The debarked wood is ground against a rapidly revolving grindstone. The pulp obtained is washed and processed further. The process is high yielding (about 95% of the dry weight of wood). However, lignin and other non-cellulose products do not get removed and the pulp and its products deteriorate in strength and turn yellow with age. But the paper has good opacity, bulk, and printing quality. Such pulp is largely used for newsprint, wrapping and wall papers.

ii) Chemical pulping- Softwoods with little or no resin (spruce, fir, hemlock) and some hardwoods are used in this process. The wood chips are cooked in various chemical solutions at high temperatures to dissolve lignin, hemicellulose, and other non-cellulose components of cell walls, leaving behind nearly pure cellulose fibers in the form of a pulp. Although it is a low-yielding process (45-60%), it gives a high-grade paper, and most of the wood pulp currently used is prepared by chemical methods. The bark of the wood is removed, and the logs arc reduced to small chips (12-25 mm long and 3-4mm thick). Pulping is carried out in large steel digesters by the sulphite, sulphate, or the soda process. Steam is blown in until the desired pressure and temperature are obtained. At the end of the cooking process, the entire steam is blown out through a valve at the bottom of the digester. The sudden release of pressure blows the chips apart and the fibers are separated. The sulphite pulp is used in the manufacture of printing, bond, tissue and wrapping papers, in rayon and newsprint. Soda pulp (mixed with sulphite pulp) is used in the manufacture of printing paper for books, and better grade magazines. Sulphate pulp is used for making a strong brown kraft wrapping paper (used in craft work and as cover paper), paper bags and paper board.

(iii) Semi-chemical pulping - Hardwoods are generally used in this process. Wood chips are at first softened by mild chemical action and thereafter defibration is accomplished by mechanical action. This method yields 65- 85% pulp of the dry weight of wood. The higher yield in comparison to chemical pulping is because of the retention of about 50% of the lignin and 30-40% of the hemi-cellulose. Neutral sodium sulphite is the chemical widely used in cooking. Wood is still in the form of solid soft chips after cooking and is defibered mechanically. These pulps are well suited for making corrugated board, roofing felt, insulating board, and low-grade wrappings. Good quality newsprint is manufactured from a mixture of semi-chemical pulp from softwoods and mechanical pulp from hardwoods.

5. Paper Making

Cotton and linen rags were the principal sources till the last century and are still used for the manufacture of the finest grade paper. Presently, wood fibers are the most important raw materials used. About 97% of the world's paper and paperboard is made from wood pulp, of which nearly 85% is derived from coniferous woods like spruces (*Picea* spp.), firs (Abies spp.) and pines (*Pinus* spp.). The hardwoods used in paper making are poplar (*Populus* spp.), birch (*Betula* spp.), beech (*Fagus* spp.) and eucalyptus (*Eucalyptus* spp). Other paper making materials include textile fibers such as jute, hemp, Manila and sisal hemp, crop wastes and rejects from textile factories or cotton linter recovered during the processing of cotton seed. In India, the main fibrous raw materials are bamboos (especially *Bambusa arundinacea* and *Dendrocalamus strictus),* sabai-grass (*Eulaliopsis binata),* bagasse and salai-wood *(Boswellia serrata).* Rags, hemp ropes, jute wastes, and wastepaper are also converted into pulp.

The pulp is then washed, screened, bleached, and lapped. Screening holds back knots, uncooked chips and other foreign matter and separates the pulp into different grades by regulating the size of perforations in the screen. The remaining non-cellulose fraction is removed by bleaching with chlorine and its compounds. It whitens the pulp and helps in the removal of residual lignin. The pulp may need to be bleached several times. Washing with water follows bleaching.

Pulp obtained from chemical and semi-chemical processes is subjected to a treatment called beating. Besides separating the fibers from one another, it shortens and bruises them. Consequently, they cling firmly forming a uniform sheet on the paper-making machine later. The degree of beating influences the texture of the paper obtained. A variety of materials are added to the pulp stock in the beater to improve the quality of the paper. Mineral fillers give weight and opacity to the paper by filling the interstices. China clay, talc, calcium sulphate, zinc sulfide, titanium oxide and calcium carbonate are some important fillers. Sizings such as rosin, soap, wax, and starch make the surface smooth and impervious to ink. Currently, emulsions like polyvinyl acetate, polyesters, vinyl chloride and acrylic resins are also being used for sizing.

After the pulp has been mixed thoroughly with all the ingredients, it is sent to the paper-making machine. External sizings can be applied to dry sheets of paper. This paper is then calendared by passing it between pairs of highly polished rollers to impart a smooth finish.

7.6 NON-TIMBER FOREST PRODUCTS

A wide array of goods are classified as non-timber forest products. They include both animal and plant products. Some involve little processing, serving local markets or family needs; others involve complex management and processing and are bound for national or international markets. Below are some examples of non-timber forest products.

Simple technology processing: Food (e.g. fruits, nuts, berries, root crops, sugar plants) Culinary herbs Mushrooms (e.g., for food or medicinal uses) Wild game Food insects Handicraft materials (e.g. rattan, bamboo, beads) Floral products (e.g. cut flowers, moss, vines, cut greens).

Intermediate processing: Herbal medicines (e.g. kava, ginseng) Vegetable oils Dyes, tannins, colorants Honey Seeds or propagative materials.

Complex processing: Essential oils (e.g. lemon grass, vetiver, patchouli, tea tree oil) Pharmaceuticals and medicinal Herbs, spices, flavorings (e.g. vanilla, cinnamon) Resins, gums, saps, and oils (e.g. rubber, latex) Fiber plants (e.g. sisal, wauke, hau)

The Importance of Non-timber Forest Products

For millennia, nontimber forest products have been essential for subsistence and economic activities all around the world. NTFPs are also among the oldest and most long-standing of internationally traded commodities, dating back thousands of years to ancient times continuing in the present day.

According to the United Nations Food and Agriculture Organization (FAO 1997), it has been estimated that:

- 80 per cent of the population of the developing world use NTFPs to meet some of their health and nutritional needs
- Several million households worldwide depend heavily on NTFP products for income
- The estimated total value of world trade in NTFPs is approximately US$1,100 million.
- Recently, the importance of NTFPs is being rediscovered. Forests are being valued not simply for their timber, but as intricate systems capable of sustained generation of a great diversity of resources and services. NTFPs have substantial environmental, economic, and cultural impacts.

7.7 STATUS OF NON-WOOD FOREST PRODUCTS

Non-wood forest products (NWFPs) deserve special mention because of their grant potential to support an economic development consistent with the principles of Sustainable Forest Management (SFM). Non-wood forest products (NWFPs) cover a wide range of products (goods & services) from thatching materials to medicinal plants. These products are essential needs of local communities. Some NWFPs, such as latex, gums, resins, essential oils, flavours, fragrances and aroma chemicals help to promote value added processing, niche marketing and export trade. Non-wood forest products (NWFPs) can provide increased employment opportunities and income earning capabilities. Deriving the full benefits of some of the high value NWFPs, requires specialized/ sophisticated skills ranging from bio prospecting, at the resource end to quality control, storage and packaging at the market end. Management of NWFPs will decide the sustainability of forestry in future.

Regeneration Status and Production of Various Categories of NWFPs

We have tried to very briefly discuss the regeneration status of the various plant and tree species under the categories of leaves, bamboos, flosses, tannins and dyes etc. The section includes the local name, brief distribution, uses and regeneration potential.

7.7.1 Leaves

1. *Diospyros melanoxylon*

Commonly known as "tendu", but also called "abnus" in Andhra Pradesh, "kendu" in Orissa and West Bengal, "tembru" in Gujarat, "kari" in Kerala, "tembhurni" in Maharashtra and "balitupra" in Tamil Nadu.

Uses: Leaves are used as wrappers of tobacco to produce bidi. Off – cuts of leaves are burned and the ash is used in tooth powder.

Distribution: The species is abundant in Madhya Pradesh, Orissa, Maharashtra, Andhra Pradesh, Bihar, Rajasthan, Uttar Pradesh, Gujarat, Tamil Nadu and West Bengal. It generally grows in dry mixed deciduous forests occurring alongside *Shorea robusta* and *Tectona grandis*.

Regeneration: Under natural conditions, seed germinates in the rainy season and seedling production is plentiful. Seedlings tolerate considerable shade but for optional development more light is required. Seedlings resist frost and drought but are vulnerable to excessive dampness. The profusion and tenacity of root suckers ensure the survival and spread of the species without planting. About 40 percent of fresh seed germinates. Germination starts after 36 days and is complete in 80 days. It is the best raise seedling in long narrow baskets and transplants the seedlings with the second rains. Coppicing yields the best quality leaves and also facilitates easy collection.

Annual production and value: Around 300,000 tons of bidi leaves are produced annually in

India, of which over 85 percent is collected from Madhya Pradesh, Orissa, Maharashtra and Andhra Pradesh. The values of these leaves are based on an average price of Rs. 15,000 per ton, but rates vary from state to state, according to demand, availability of leaves and location of *bidi* making industries.

2. Bauhinia vahlii

Local name of Bauhinia vahlii is "Mahul" in Uttar Pradesh and Madhya Pradesh, and "siali" in West Bengal and Orissa.

Uses: Leaves are used for making cups and plates and for wrapping foods.

Distribution: It is a giant climber and one of the most abundant Indian Bauhinia species. The species is distributed in the sub- Himalayan region up to 3,000 meters above sea level in Assam, Central India, Bihar, Eastern and Western Ghats. Commercial collection of leaves is done in Madhya Pradesh, Orissa and Andhra Pradesh.

Regeneration: The species grows naturally in the forests. No efforts to regenerate it artificially are made. It is usually considered a weed because of the damage it does to healthy trees by climbing and spreading over them.

Annual production and value: In Madhya Pradesh, about 780 tons of leaves are collected, valued at approximately Rs. 2 million. In Orissa, over 160 tons of dried leaves and 86 million leaf plates are marketed annually. Collectors receive only about Rs. 1.50 per kg and earn only Rs. 8 to 10 per day. Therefore, collection of Bauhinia leaves is done only as a last resort during the low- income.

7.7.2-Bamboos

Over 100 species of bamboo occur naturally in India. *Bambusa arundinacea, B. tulda, B. polymorpha, Dendrocalamus strictus, D. hamil-tonii, Melocanna baccifera and Ochlandra travancorica* are the most important species because of their wide availability. *Dendrocalamus strictus* and *Bambusa arundinacea* are the two principal economic species.

Uses: Because of its fast growth, easy propagation, soil binding properties and early maturity, bamboo is an ideal species for afforestation, soil conservation and social forestry programs. Bamboo is strong, straight and light. It is hard and hollow and easy to work. It comes in many sizes and has long fibres. Such characteristics make bamboo highly versatile. Among bamboo's medicinal properties is banslochan, a secretion found in the culums used as a cooling tonic, aphrodisiac and as a treatment for asthma and coughing.

Distribution: It is found almost everywhere. Its distribution is governed largely by rainfall, temperature, altitude and soil conditions. Most bamboo requires a temperature of 8^0 to 36^0C, a minimum of 1,000 mm of rainfall annually and high humidity for good growth. Bamboo is an important constituent of many deciduous and evergreen forests and extends from tropical to mild temperate regions. It grows on flat alluvial plains up to altitudes of 3,050 m above mean sea level.

Regeneration: Between seedling periods, reproduction of bamboo is by asexual means. In bamboo clumps, rhizomes grow under-ground and produce new culms as annual shoots. This process continues until the plant produces flowers and seeds, then dies. The most common method of vegetative reproduction is by rhizomes or offset planting. Bamboo flowers gregariously after long periods although sporadic flowering occurs almost every year. During the years of gregarious flowering, the forest floor is carpeted with seedlings and the areas are naturally regenerated.

Annual production and value: The price of bamboo varies with its end use. Most of the annual cut is used in making paper or rayon for which producers receive about Rs. 300 per ton. The value of the potential annual cut is Rs. 1,367 million.

7.7.3 Gums and Resins

Gums are translucent, amorphous substances which are degradation products of the cell wall of woody species. They exude spontaneously from trees and are soluble in water. Resins also are exudates but are soluble in alcohol not water. Resins often occur mixed with a high percentage of essential oils known as oleoresins. When oleoresins include some gum, as in the case of exudation from gums as in the case of exudation from *Boswellia serrata*, they are called oleoresins.

Uses: Commercial gums enter the market in the form of dried exudates. The varieties having the least color and highest adhesive power and viscosity are the most valuable. The finer grades are used in clarifying liquors, "finishing" silk, and in the preparation of quality water colors. In the cosmetics and pharmaceutical industry, gums serve to emulsify or bind mixtures in creams lotions and ointments. Resins are used in the manufacture of lacquers and varnishes. Resinous substances can be used for waterproof coatings. They are used in medicines for sizing paper, for incense and in the preparation of sealing wax and other products. Oleoresins are used in perfumery and medicines for making varnishes and lacquers as fixative and in scenting soaps.

Annual production and value: Madhya Pradesh has the potential to produce as much gum karaya as the rest of India combined. Approximately 1,400 tons of gum karaya are collected annually from other states valued at about Rs. 60 million. Production of other gums is about 1,900 tons fetching Rs. 12 million annually. About 46,000 tons of oleoresins are obtained from *Pinus roxburghii* each year, valued at approximately Rs. 2.8 million.

7.7.4 Oil seed

India has about 86 different oil seed is collected from *Shorea robusta*, *Madhuca indica*, *Mangifera indica*, *Garcinia indica*, *Azardirachta indica*, *Pongamia globra*, *Schleichera trijuga*, *Salvadora oleoides*, *S.persica* and *Actinidaphne hookeri.*

Uses: Sal (*Shorea robusta)* seed cotyledons yield the well known sal butter used for cooking and lighting. Mahua (*Madhuca indica)* seed is used in the production of washing soaps, refined oil can be utilized for cooking and also used in jute industry and in the manufacture of lubricating greases, candles, bathing oils, fatty alcohols and stearic acid. It is good laxative and is used in treating habitual constipations, piles and hemorrhoids. Karanj (*Pongamia globra)*, both the seed and oils are poisonous but they possess remarkable medicinal properties. The seed is carminative, purifies and enriches the blood and is used for inflammation, earache, lumbago and chest ailments. The oil is styptic, anti- helminthic and good for rheumatism and cutaneous infections and as a remedy for scabies and herpes. Kusum (*Schleichera trijuga*) oil produced is utilized by the soap industry. It is used in hair dressing and in medicines used in treating skin diseases, rheumatism and headaches. Neem (*Azardirachta indica*) oil is used in soap and local medicines. Mango (*Mangifera indica*) seed oil is used as a cocoa butter substitute. Khakan (*Salvadora oleoides*) and pisa (*Actinidaphne hookeri*) oils are used in making soap. The fruit of khakan is edible and is fed to cattle to increase milk yield.

Annual production and value: Sal seed is collected and marketed on a commercial scale. The potential production is estimated at 5.5 million tons but current collection is only 100,000 tons, valued at Rs. 200 million. Mahua has a potential kernel production of 1.1 million tons but the annual collection is around 25,000 tons, valued at about Rs. 17 million.

7.7.5 Essential oils

It is also called volatile oils, are liquids which possess a pleasant taste and strong aromatic odor. They occur in about 60 plant families and are frequent or abundant in the Labiatae, Rutaceae, Geraniaceae, Umbellifereae, Asteraceae, Lauraceae, Graminae and Fabaceae families. Any part of the plant may be the source of essential oil. They are used in making perfumes, soap and other toiletries. Many have therapeutic and antiseptic properties. Several others are used as solvents in the paint and varnish industries, as insecticides and deodorants and in the manufacture of synthetic scents and flavors. The important essential oils produced in India are oils of sandalwood, Lemon grass, palmarosa, eucalyptus, khus and linaloe.

Estimated production of some of the important essential oils produced in India are about total 2,830 tons.

7.7.6 Fibers and Flosses

A. Fibers: Fiber falls into three categories, soft, hard and surface. Soft fibers are obtained from the bast or stem of plants; hard fibers from the leaf; and surface fibers are those which are borne on the surfaces of stem, leaves, seeds etc. based on their general use they are classified as textile fibers, brush fibers, plaiting and weaving fibers, filling fibers, natural fabrics and paper making fibres. The most important fibers coming from the forests of India are from the families of Bambacaceae, Sterculiaceae, Tiliaceae, Fabaceae, Asclepiadaceae, Myrtaceae, Moraceae, Urticaceae, Palmaceae, Musaceae and Gramineae. Various species are commonly used by cottage industries but only *Agave sisalana* and *Sterculia villosa* have commercial importance. Agave fibers are used in making ropes and mats. The fiber is also useful for cordage, twins and nets.

Regeneration: Agave plants usually grow in semi-arid tropical regions. They are propagated from rhizomes or bulbils. *Sterculia villosa* is mainly found in Uttar Pradesh, Tamil Nadu and

Kerala, although it is scattered throughout most of India.

Annual production and value: It is estimated that around 2,500 tons per annum of agave fibers are produced in the country, with a present value of Rs. 45 million.

B. Flosses: Flosses are obtained from certain wild fruits. Important species are *Bombax ceiba* and *Ceiba pentandra*. Bombax ceiba grows throughout the Indian plains and Deccan plateau. *Ceiba pentandra* trees are found in Western and Southern states and the Andaman Islands.

Uses: The floss from Bombax ceiba is obtained from capsule and is known as "Indian kapok". The floss is soft and strong and used in life-saving devices for boats, stuffing for cushions, pillows and mattresses, thermal insulation and sound proof covers and walls.

Flosses obtained from the fruit of Ceiba pentandra are elastic and are used in the manufacture of life belts and buoys.

Annual production and value: About 300 tons of kapok are produced annually in India with a value of Rs. 30 million.

7.7.7 Grasses

Grasses are used for paper making, cattle fodder, matting, ropes, thatching and in manufacturing furniture, baskets and screens.

Regeneration: *Eulaliopsis binata, Saccharum munja, Cenchrus ciliaris, Vetiveria zizanioides, Thysanolaena maxima* and some other fodder grasses are planted using cutting, slips or seeds.

Annual production and value: Some 0.3 to 0.4 million tons of grass could be harvested annually in India. Some 60,000 to 80,000 tons of sabai grass are purchased each year by paper mills. The price of sabai grass is around Rs. 300 per ton.

7.7.8 Tannin and dyes

A. Tannin: Tannins are polyphenolic compounds widely distributed among India's flora. They occur in varying concentrations in all plant material, but only certain plants contain concentrations permitting commercial exploitation. Tannins are classified as condensed or hydrolizable. Different parts of plants may contain different types of tannins.

Uses: Ninety **(**90) percent of the total vegetable tannins in the world are used by the leather industry. India has the largest livestock population in the world.

The important tannin yielding plants species are *Terminalia chebul* (Myrobalan), *Acacia mollissima* (Wattle), *Acacia nilotica* (Babul), *Cassia auriculata* (avaram) etc.

Annual production and value: Around 78,000 to 100,000 tons of myrobalan nuts are estimated to be produced annually, valued at 15 to 20 million. Over 23,000 tons of wattle barks are harvested every year, valued at Rs. 38 million. Annual production of avaram bark is estimated at 23,000 tons, valued at about Rs. 35 million.

B. **Dyes:** Over 2,000 plant pigments are known of which only a few are of a commercial importance. Various parts of plants like roots, stems, bark, leaves, fruits and seed may contain colouring material which can be exploited commercially. Some plants have more than one colour depending upon which parts of the plants are used. Dyes are substances that impart colour to a material and are generally soluble in water. The pigments are generally not soluble in water. To be applied to a staining material they are first ground into a fine powder and thoroughly mixed with some liquid (dispersing agent). Vegetable dyes have not been able to successfully compete with artificially dyes in recent years.

7.7.9 Drugs and Spices

India's medicinal plant wealth is comprised of about 1,500 species. Every region of India has contributed to its development. Drugs have been classified depending upon the plant organ from which they are derived: roots and other underground parts, bark, wood, leaves, flowers and fruit and seed. The important species are *Dioscorea deltoidea, Salanum khasianum, Costus speciosus, Datura stramonium, Atropa acuminate, Rauwolfia serpentine* and *cassia angustifolia.*

7.7.10 Spices

Spices are aromatic vegetable products characterized by pungency, strong flavors and sweet or bitter taste. They occur naturally in some forests and are also cultivated in some regions. The important spice–yielding plants are *Alpinia glanga* (greater galangal), *Cinnamomum zeylancium* (cinnamon or dalchini), *Curcuma spp. (*haldi), *Elettaria cardamomum* (cardamom) and *Piper longum* and *P.nigrum* (pepper).

7.7.11 Animal products

A. Lac: Commonly known as "shellac" in its refined flake form, lac is a resinous secretion from the insect *Laccifer lacca*, which feeds on the plant sap.

Uses: Lac is presently used for various purposes in plastics, electrical, adhesive, leather, wood finishing, printing, polish and varnish, ink and other industries. It is also the principal ingredients of sealing wax.

Annual production and value: About 14,500 to 20,000 tons of stick lac is produced annually in India. Its price varies from Rs. 4,500 to 16,000 per ton depending upon quality most of the produced sells around Rs. 14,000 per ton. Thus, the total value of the annual production in India is Rs. 203 million to Rs. 280 million.

B. Honey and wax: Honey forms a natural nutritious food for the rural people. It is also used widely for medicinal purposes. Two species of bees, *Apis dorsata* (rock bee) and *Apis indica* (Indian bee) produce honey. The former is wild in montane and sub-montane regions throughout India.

Annual production and value: About 250 tons of rock bee honey and 98 tons of Indian bee honey are produced annually. At a price of Rs. 40 per kg, the total value of honey produced is Rs. 139 million. Bee's wax is used in the manufacture of furniture and floor polishes, dressing and water proofing of leather goods. About 28 tons of waxes are produced annually, valued at approximately Rs. 1.6 million.

C. Silk: India produces four kinds of silk: mulberry, tassar, muga and eri. Silk is obtained from cocoons of silk worms. Its production has four components; 1) cultivation of host plants for silk worms, 2) rearing silk worms up to cocoon stage, 3) reeling of cocoons into continuous filaments called raw silk and 4) silk throwing and weaving by which filaments are twisted and woven into fabrics. The silk worm Bombyx mori is fed on mulberry leaves cultivated in plantations. There are other silk worms which are found wild on forest trees; the best known of these is *Antheraea paphia*, which produces the famous tassar silk of India. It feeds on several trees such as *Anogeissus latifolia, Terminalia tomentosa, T. arjuna, Lagerstroemia parviflora* and *Madhuca indica.*

Annual production and value: Estimated annual production of tassar silk is 130 tons. Production of other types of silk exceeds 10,000 tons.

7.7.12 Edible plant products

Natural forests supplement the food supply for human beings. Several forest fruits and seeds, flowers, rhizomes, tubers, roots, barks etc. are consumed by people during periods of food scarcity and in normal times. A number of tree species provide such edible products. Important fruits are from *Bachanania lanzan* (Chironji), *Anacordium occidentale* (kaju), *Pinus gerardiana* (chilgoza), *Emblica officinalis* (aonla), *Tamarindus indica* (tamarind), *Aegle marmelos* (bel), *Feronia elephantum* (kaitha), *Artocarpus lakoocha* (Barhal), *Syzygium cumini* (jamun), *Annona squamosa* (custard apple), *Carrisa opaca* (karaunda), *Juglans regia* (akhrot), *Moringa oleifera* (drum stick) and *Zizyphus jujube* (ber).

The following forest species are particularly important in producing delicacies consumed by rural people: *Buchanamia lanzan* is commonly known as chironji, achaar or char. It is frequently found in dry, mixed deciduous forests of Uttar Pradesh, Bihar, Madhya Pradesh, Orissa, Maharashtra, West Bengal and Andhra Pradesh. The market price is about Rs.120 per kg.

Anacardium occidentale is a small tree, known as cashew nut or kaju. It is grown in Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Goa and Western Maharashtra. The average yield of kernels per tree ranges from 9 to 18 kg. The price of raw kernel is Rs. 30 per kg and that of processed nut is from Rs. 80 to 120 per kg. *Pinus gerardiana* is an evergreen pine known as “chilgoza” or “neoza”. The species is endemic to a part of Himachal Pradesh in the Himalayan dry temperate forests. A tree on an average yield about 7.4 kg of seeds.

Natural regeneration is limited because local inhabitants aggressively collect the cones to extract the chilgoza nuts. Attempts to raise chilgoza plantations by sowing have not succeeded because the seeds are readily eaten by various animals. Some success has been achieved, however, in planting seedlings and by heteroplastic grafting. About 140 tons of nuts are produced every year. They are priced at approximately Rs. 100 per kg.

7.8 SUMMARY

- Timber plants are usually medium to large trees which provide wood. These are trees are broadly classified into trees of soft, semi-hard and hardwoods. Hardwood is derived from angiospermous (mainly dicotyledonous) plants, while Softwoods are obtained from gymnosperms (mainly coniferous).
- Teak, shisham, pine and cedars are the major timber yielding trees from the forests of India. These are important commercial timber crops. Distribution, wood characteristics and specific uses of these species has been discussed.
- Wood procured from diverse sources is used for various purposes such as fuel, construction material, containers, chemical products, medicines.
- Wood is processed to get pulp which is used in the manufacture of paper. Mechanical and chemical processing of the pulp is done to get paper.
- A wide array of goods are classified as non-timber forest products. They include both animal and plant products.
- The Non-timber forest products are- Food (e.g. fruits, nuts, berries, root crops, sugar plants) Culinary herbs Mushrooms (e.g., for food or medicinal uses) Wild game, Food insects Handicraft materials (e.g. rattan, bamboo, beads) Floral products (e.g. cut flowers, moss, vines, cut greens).
- Nontimber forest products have been essential for subsistence and economic activities all around the world.

7.9 GLOSSARY

Antihelminthic: Medicine used to destroy parasitic worms.

Axillary: Situated in or growing from an angle between a branch or leaf and the axis from which it arises.

Archaeological: study of remains (such as tools, pottery, jewelry, stone walls, and monuments) of past human life and activities.

Bacteriostatic: Compound or drug that inhibits growth and reproduction of bacteria.

Carminative: A drug that helps in preventing formation of gas in stomach or intestine.

Coagulant: A substance that causes blood or another liquid to get thickened

Decorticating: The process of removing the outer coverings (such as husk) from something seed.

Dorsal: Something present on the on or toward the upper side of the body.

Endemic: Growing or existing in a certain place or region.

Ethnological: Study of different societies and cultures.

Expectorant: A medicine used to treat cough or promotes the expulsion of mucus from the respiratory tract.

Fungiostatic: An agent that inhibit the growth of fungi.
Glabrous: Smooth surface.
Heterozygosity: Presence of two different alleles of a particular gene or genes by an individual.
Hybridization: The process breeding with an individual of another species or variety.
Impervious: Anything which is not influenced or affected by something.
Inventory: A detailed list of something.
Parched: Extremely or completely dried.
Perforation: Presence of holes in something.
Peristalsis: Contraction and relaxation of a tubular muscular system, especially the alimentary canal.
Phenotype: Observable physical characteristics of an individual.
Plaigiotropic: Plant part or organ that tends to take up an oblique or horizontal position with relation to the main axis.
Progenitor: Parent or direct ancestor of an organism.
Prostrate: Lying face down or bending downward.
Pungent: Something with a strong smell or taste.
Rudimentary: Not developed.
Sessile: Directly attached by its base without a stalk or peduncle.
Stimulant: An agent or drug that increases the functional activity or efficiency of an organism.
Stomachic: An agent or drug that stimulate gastric activity.
Ubiquitous: Something that is found everywhere or in several places at the same time.
Ventral: Something present on the upper or toward the front part of the body.

7.10 SELF-ASSESSMENT QUESTIONS

7.10.1 State whether the statements are 'True' or 'False'

i) The advantage of using plywood is that the tensile strength is equal in all directions.
ii) The most valuable timber is obtained from Sal.
iii) Plywood is made from common timber.
iv) Timber from Himalayan Cedar is rarely attacked by white ants or fungi.
v) Seasoning of timber is done to increase its moisture content.
vi) The heart wood represents the central core which is surrounded by annual rings.
vii) Charcoal, pyroligneous acid and wood tar are the principal products of hardwood distillation.

7.10.1 Answer Key

i) True; ii) False; iii) True; iv) True; v) False; vi) True; vii) False

7.11 SUGGESTED READING

- Michael H. Ramage, Henry Burridge, George Fereday, Thomas Reynolds, Darshil U.Shah, Guanglu Wu, Li Yu, Patrick Fleming, Danielle Densley-Tingley, Julian Allwood, Paul Dupree, P.F. Linden, Oren Scherman The wood from the trees: The use of timber in construction. Renewable and Sustainable Energy Reviews Volume 68, Part 1, February 2017, Pages 333-359.

7.12 REFERENCES

- Source:https://www.google.co.in/imgres?imgurl=https%3A%2F%2Fpreviews.123rf.com%2Fimages%2Fyotrak%2Fyotrak1207 %2Fyotrak120700225%2F14653832-teak-trees-in-anagricultural-forest-thailand.jpg
- Source: https://plantlet.org/wpcontent/ uploads/2020/10/IMG_20201024_182510.jpg
- https://www.google.co.in/imgres?imgurl=https%3A%2F%2F www.quintadosouriques.com%2Fwp-content%2Fuploads% 2F2021%2F05%2Fdalbergia sissoo-1540375.jpg
- Source: https://vinishsethi.files.wordpress.com/2015/01/wood_cross _section_001.jpg
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- b)https://www.google.co.in/imgres?imgurl=https%3A%2F%2Fus.123rf.com%2F450wm%2Falfredosaz%2Falfred osaz2010%2Falfredosaz201000157%2F157071537-stone-pine-branch-with
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- https://agroforestry.org/the-overstory/212-overstory-53-nontimber-forest-products-an-introduction

7.13 TERMINAL QUESTIONS

1. Write a brief account of two commercially important timber yielding plants of our country. State its distribution, morphological characteristics and uses.
2. Write short notes on the following:
    i) Wood distillation
    ii) Taping for Naval stores
    iii) Making of wood pulp
3. Give a brief account of various steps involved in making of paper.
4. What are non-timber forest products? Describe about any two non-timber forest products.

UNIT-8 SUGAR AND STARCH, ENERGY CROPS

Contents

8.1 OBJECTIVES

After reading this unit you would be able to:

- Introduce to sugar, starch and energy crops.
- Define the sugar yielding plants;
- Explain the general description, systematic position, morphology, cultivation and economic importance of sugarcane and sweet potato;
- Compile or prepare the list of sugar and starch yielding plants;
- Describe the starch yielding plants and explain about potato and cassava.
- Explain about by-products of sugarcane and starch products.
- Describe the energy crops and its types and sources.

8.2 INTRODUCTION

The cells of the body require a constant and steady supply of energy to perform basic and essential functions properly. The majority of cells lean toward this energy in the simplest form of starch that is available. However, this is typically not feasible and can necessitate additional digesting. Sugar and starch, are two forms of carbohydrates, belong to a class of organic substances that typically include carbon, hydrogen, and oxygen in the ratio 1:2:1. Carbohydrates are also known as saccharides, the word saccharide comes from Greek word Sakkron which means Sugar. They are the major source of energy in many organisms, serve to store energy, and are structural components in some organisms.

The carbohydrates are divided into three major classes depending on the number of monomer units: monosaccharides, oligosaccharides and polysaccharides. Monosaccharides, which have the general formula CnH2nOn and cannot be further hydrolyzed into simple carbohydrates, are the least complicated carbohydrates. They are the building blocks of the more complex oligosaccharides and polysaccharides. On the basis of number of carbon in main chain monosaccharides are also classified as trioses, tetroses, pentoses, hexoses and heptoses. The most common plant monosaccharides are glucose and fructose.

Oligosaccharides (Oligo: few) are composed of short chains of monosaccharide units, joined by characteristic linkages called glycosidic bonds and yield simple sugars on hydrolysis. Disaccharide and trisaccharide are the names for oligosaccharides with two and three monosaccharide units, respectively. Sucrose, maltose are two common examples of disaccharides. Sucrose ($C_{12}H_{22}O_{11}$) is disaccharides because on hydrolysis it gives one molecule of glucose and one molecule of fructose.

Polysaccharides are complex molecules of high molecular weight. They are made up of a lot of repeating monosaccharide units joined by glycosidic connections. Similar to disaccharides, they can be hydrolyzed to release their individual sugars. The two most prevalent polysaccharides in plants are starch and cellulose.

In general, polysaccharides are amorphous, insoluble in water, and tasteless, whereas monosaccharides and oligosaccharides are crystalline solids, soluble in water, and sweet to taste. These substances are collectively referred to as sugars. There are two main types of carbohydrates found in food sources which are called basic carbohydrates, which include necessary sugars, and complex carbohydrates, which include starch and fibre. Carbohydrates make up the bulk of the dry weight of plants. Although there are many kinds, sugars, starches and the celluloses predominate.

The idea of energy crops has been around for many years, even though the phrase may be unknown to people. Indeed, up until the discovery of oil in 1859, agricultural and forestry crops, as well as their byproducts, were a significant source of energy. The world is now more aware than ever of the need to lessen dependence on fossil fuels due to declining fossil fuel sources and the growing understanding that rising carbon dioxide emissions are causing climate change. Because of this, there is now more interest in promoting bioenergy, particularly biofuels, as a renewable energy source. Theoretical biomass resources are potentially the world's largest sustainable bioenergy source including about 220 billion oven-dry tons or 4,500 EJ (Electron Jule) of annual primary production. By 2050, of these, there may be 273- 1381 EJ/yr provided by bioenergy crops (Smeets et al., 2007). The base for bioenergy is agricultural plants that act as thermochemical energy storage systems and solar energy collectors. Biomass produced from bioenergy crops will be helpful in the fight against GCC (Global Carbon Council) and boost the use of renewable energy sources globally (Karp and Shield, 2008). However, a potential mitigation strategy that involves the use of biological systems to store carbon and lower GHG (Green House Gases) emissions faces sophisticated and contentious equity issues (IPCC, 2007; Lal, 2008a). Additionally, they absorb an identical quantity of carbon dioxide that is produced when burned, thus technically their combustion produces no net carbon dioxide emissions (carbon sequestration).

Conventional grain and oilseed crops, crop residues, perennial herbaceous and woody crops, perennial oilseed crops, halophytes, and algae etc. are potential bioenergy crops that are anticipated help tackle GCC (Eisenbies et al., 2009). The present unit introduces you to about Sugar, starch and energy crops. Some common, important sugar and starch yielding crops and energy crops are listed in the following table 8.1.

Table 8.1: List of some important sugar, starch and energy yielding crops

S. N.	Botanical Name	Common Name	Family
A. Sugar Yielding Plants			
1	*Saccharum officinarum* L.	Sugarcane	Poaceac
2	*Beta vulgaris* L.	Sugarbeet	Chenopodiaceae
3	*Acer saccharum* Marshall	Sugar maple	Sapindaceae
4	*Hordeum spp.*L.	Barley	Poaceac
5	*Sorghum bicolor* L. Moench	Sweet sorghum	Poaceac

6	*Phoenix dactylifera L.*	Wild date Palm	Arecaceae
7	*Caryota urensi* L.	Toddy palm, Sago Palm	Arecaceae
8	*Cocos nucifera* L.	Coconut Palm	Arecaceae
B. Starch Yielding Plants			
1	*Solanum tuberosum* L.	Potato	Solanaceae
2	*Manihot esculenta* Crantz.	Cassava	Euphorbiaceac
3	*Canna edulis* Achira	Queensland arrowroot	Cannacene
4	*Colocasia esculenta* L.	Tam	Araceae
5	*Alocasic macrorrhiza* (L.) G.Don	Gaint taro	Araceae
6	*Curcuma angustifolia* Roxb.	East Indian Arrowroot	Zingiberaceae
7	*Dioscorea alata* L.	Greater Asiatic Yam	Dioscoreaceae
8	*Dioscorea rotundata* Poir	White Guinea Yam	Dioscoreaceae
9	*Dioscorea cayenensis* Lam.	Yellow Guinea Yam	Dioscoreaceae
10	*Dioscorea bulbifera* Benth.	Air Potato	Dioscoreaceae
11	*Dioscorea trifida* L.	Cush-Cush, Yampee	Dioscoreaceae
12	*Caryota urens* L.	Sago Palm	Arecaceae
13	*Cycas circinalis* L.	Sago Palm, Queen sago	Cycadaceae
14	*Cycus revolute* Thunb.	Japanese Sago Palm	Cycadaceae
15	*Zea mays* L.	Maize	Poaceae
16	*Triticum spicies* L.	Wheat	Poaceae
17	*Oriza sativai* L.	Rice	Poaceae
C. Energy crops			
1	*Panicum virgatum* L.	Switchgrass	Poaceae
2	*Pennissetum purpureum* Schum.	Elephant grass	Poaceae
3	*Populus* spp.	Poplar	Salicaceae
4	*Salix* spp.	Willow	Salicaceae
5	*Prosopis* spp.	Mesquite	Fabaceae
6	*Miscanthus* spp.	Silvargrass	Poaceae
7	*Medicago sativa* L.	Alfalfa	Fabaceae
8	*Phalaris arundinacea* L.	Reed canary grass	Poaceae

8.3 SUGAR CROPS

Without the use of sugar as an energy source and a sweetener, it would be difficult to envisage our lives. All of the ancient world's great civilizations, however, were sugar-free. Although honey is mentioned in all three of these sacred texts—the Bible, Talmud, and Koran—neither of them specifically mentions sugar or sugarcane. Undoubtedly, honey was the first sweetening agent used by our ancestors, and man domesticated bees to ensure a constant supply (apiculture). Up until the Middle Ages, sugar was a scarce resource in Europe and was only consumed by the upper class. It was offered as medication in "apothecaries" stores. But by the end of the fifteenth century, sugar had taken the place of honey as a sweetener, and in the nineteenth and twentieth century's, it was a cheap and widely available meal for all people.

The term "sugar" refers broadly to a variety of carbohydrates with varying degrees of sweetness. Sugars, however, form a single unit of the atom, sometimes known as a monosaccharide. These sugar atoms can exist as glucose, fructose, or mannose. Then, starches again form lengthy chains of solitary sugar atoms joined by a strong linkage.

All green plants produce sugar, ensuring that they all have some sugar content. However, much of the manufactured product is used directly in plant metabolize that very little usually accumulates. Storage sugars are found in a variety of plant parts, including the roots of some plants (like beets, carrots, and parsnips), the stems of others (like sugar maples and sorghum), the flowers of some plants (like palm trees), the bulbs of some plants (like onions), and many fruits. There are several kinds of sugar, principal among which are sucrose or cane sugar, glucose or grape sugar and fructose or fruit sugar. They all appear to provide the plant with a reserve food supply.

Sugar is essential to human nutrition. It makes the ideal nourishment because it can be easily assimilated by the body. Its primary benefit is as an energy-producing substance, and it is particularly well suited for use after strenuous activity. The purification, refinement, and extraction of sugar from plant tissues have given rise to a sizable industry. Particularly valuable plant-based products include sugar. It is only surpassed in importance by wheat, maize, rice, and potatoes. However, there aren't many sources for this sector. The only commercial sources of sugar are sugar cane, sugar beet, sugar maple, maize, sorghum, and a few palms. All of these plant species store sucrose as their primary form of sugar.

8.3.1 SUGARCANE (*Saccharum* L. spp.)

8.3.1.1 General Account

Sugarcane is an industrial crop, produced from either sugarcane (*Saccharum* spp.) or sugar beet (*Beta vulgaris*). It is a monocotyledonous crop with a tall growth habit that is grown in tropical and subtropical areas of the world, primarily for its capacity to store high concentrations of sucrose, or sugar, in the stem Along with making a sizable contribution to the national exchequer; it directly or indirectly employs more than a million people. The cane is put to a variety of stressors and environmental conditions in commercial agriculture. Red rot disease and unpredictable moisture availability in the subtropics of India seriously reduce cane productivity. It is an industrial crop with a production volume of 300 million tonnes in India and an area of roughly 4 million hectares.

Modern sugarcane cultivars that are cultivated for sugar production are founded on interspecific hybrids between *Saccharum spontaneum* and *S. officinarum* (*Saccharum* spp.) that were then subjected to repeated backcrosses to *S. officinarum* (Fig. 8.1). The majority of commercially available types today were developed through crossings between existing commercial or pre-commercial hybrids. An old crop, sugarcane has been used as a garden crop since about 2500 BC. The People's Republic of China (hence referred to as "China"), Papua New Guinea, and India are regarded to be the origins of the ancestral species that gave rise to sugarcane. Today, sugarcane is primarily grown as a commercial crop in South America (such as Argentina, Brazil, and Colombia), North and Central America (such as Guatemala, Mexico, and the United States), Asia (such as China, India, and Thailand), Africa (such as Egypt, Kenya, and South Africa), Australia, and the Pacific Islands. Around the world, several cultivation techniques are used.

Fig. 8.1 Sugarcane crop in farmer field (Source: https://www.indiaspend.com/....Sugarcane**)**

Sugarcane is the primary source of sugar, it is tropical by origin and cultivated in all the warm nations. India, Cuba, Pakistan and Brazil are the main producers of sugar. Significant productions are also carried out in the southern United States, the West Indies, many Central and South American nations, Mexico, Egypt, Java, China, Taiwan, Philippines, South Africa, and Australia. The largest producer of sugarcane is Cuba, which is also referred to as the "world's sugar bowl." It is thought that sugarcane began in the South Pacific, most likely in New Guinea, and then expanded throughout most of Southeast Asia.

It is known that sugarcane has been grown in India from prehistoric times, and by the end of the fourth century B.C., it had become a significant crop. Alexander's soldiers discovered the locals making "honey" from a grass-like substance without the help of bees during the invasion of India (327 B.C.). These grasses indeed contained the plant's sweet juice, and the name *Saccharum* has been assigned to them. In China, sugarcane cultivation began before the first century B.C. At the start of the sixth century A.D., it arrived in Persia (now Iran). It is believed that Columbus brought it from the Canary Islands to the New World. This plant had a wide geographic distribution by the 17th century. Almost every state in India grows sugarcane, with Uttar Pradesh leading the way, followed by Tamil Nadu, Maharashtra, Andhra Pradesh, Karnataka, Haryana, Punjab, Bihar, Orissa, Gujarat, and Rajasthan. Sugarcane accounts for around 2% of all farmed land in India. This crop needs rich soil, a lengthy growing season, an abundance of water year-round, at least 200-225 cm of annual rainfall, temperatures ranging from 16 to 50°C, and an average temperature of 26°C. It requires a short, dry season during later stages when sugar is being stored in the Stem.

8.3.1.2 Sugarcane growing regions

The chief sugarcane producing regions lie between 30 degree north and south of the equator. Cuba is called sugar bowl of the world. The list of 05 sugar producing countries of the world as per latest report of the United Nations Food and Agricultural Organization are given below:

Rank	Country	% Yield
1	Brazil	37.8%
2	India	19.6%
3	China	6.9%
4	Thiland	5.4%
5	Pakistan	3.2%

In India more than four million acres of land are under sugarcane cultivation. The Indian Institute of Sugarcane Research (IISR) situated in Lucknow. The list of top five sugarcane producing states in India:

Rank	States
1	Uttar Pradesh
2	Maharashtra
3	Karnataka
4	Tamilnadu
5	Andhra Pradesh

8.3.1.3 Origin

There are two geographic origins of sugarcane cultivation:

1) Islands in the South Pacific, particularly New Guinea, are home to the most diversity in the genus Saccharum. The majority of botanists believe that cultivated sugarcane originated in this area, migrated eastward, and finally established itself as an important crop in various South East Asian nations.

2) North India is the second centre. The tall, large, barreled tropical species *S, officinarum* maybe originated from *S. robustum* in New Guinea. As it migrated outwards it became modified to the new natural habitat with species of related *Erianthus maximus* or *Sclerostachya fusca*. The North Indian sugarcane *S. sinense* (Chinese or Japanese cane) and *S. barberi* (Indian canes) are believed to have originated in North India by natural hybridization between migrating form of *S. officinarum* the *S. spontaneum* (wild cane).

8.3.1.4 Systematic Position:

Kingdom	Plantae (Plants)
Sub-kingdom	Tracheobionta (Vascular plants)
Super-division	Spermatophyta (Seed plants)
Division (Phylum)	Magnoliophyta (Flower bearing plants)
Class	Liliopsida (Monocotyledons)
Subclass	Commelinidae
Order	Poales
Family	Poaceae (Grass family)
Genus	*Saccharum* L.
Species	*officinarum*

8.3.1.5 General Description

Sugarcane belongs to the genus *Saccharum* L., traditionally placed in the tribe Andropogoneae of the grass family (Poaceae). The cereal genera *Sorghum* and *Zea*, as well as tropical and subtropical grasses, are all a part of this group.

According to D'Hont et al. (1998), the genus Saccharum consists of six species: *S. spontaneum*, *S. officinarum*, *S. robustum*, *S. edule*, *S. barberi*, and *S. sinense*. These are polyploid or aneuploid and are native to the old world. These species are building blocks for all breeding work because they intercross and hybridize easily. Today, interspecific hybrid sugarcane makes up the majority of the crop. The programme of producing these hybrids is known as "Nobilisation". The chief characters of five species are as follows:

S. officinarum (2n=80) known as noble or thick cane. It is soft, thick-stemmed, large barreled with a low fibre and high sucrose content. Although this species is a significant source of sugar, it cannot be farmed successfully in the majority of locations since it is vulnerable to nearly all of the serious illnesses that have been recorded on the crop. However, *S. officinarum* is not a simple polyploid, as it is both an autopolyploid (more than two sets of homologous chromosomes derived from a single species) and also an allopolyploid (possessing two or more unlike sets of chromosomes) (Sreenivasan et al., 1987).

S. barberi (2n=82 to 124) known as Indian cane. The species resembles a cross between a wild and a noble cane. These types often have a strong root system, tiny barrels, increased fibre content, and a considerable amount of juice. They have become prominent because of immunity to Sereh (a blackening and degeneration of the fanlike tops, is caused by an East Indian virus.).

S. sinense (2n=116 to 118) commonly known as Chinese or Japanese canes. These are hard and small-barreled. It has a great vigour, has wide adaptability and matures early. It may be grown in north India and is tolerant to light frost and drought. Despite having less sugar than canas, they are nevertheless fairly resistant to root rot, sereh, and some even have mosaic disease resistance.

S. spontaneum **(**2n=40 to 128) known as wild cane. It is an active, slender, grassy form, frequently with thin stalks, virtually devoid of sucrose. It is drought-resistant, immune to sereh, mosaic, and root rot, and has a deep penetrating root system. It is utilised extensively in breeding programmes.

S. robustum (2n=80) wild cane. This species has the tallest canes, is quite vigorous, and is highly adaptable. It is resistant to disease and has a high fibre but low sugar content. The breeding programme for cane is extremely dependent on this species.

8.3.1.6 Morphology

Sugarcane is a perennial rhizomatous giant grass that grows 3 to 8 metres tall and often has a diameter of 3.8 to 6.0cm, it has a thick, strong aerial stem. It develops in clumps (stands). The cane can be virtually white, yellow, deep green, purple red, or violet in colour. The stem is joined; the joints are smaller at the base and gradually get longer and thicker as they rise, reaching a maximum beyond which they get smaller and smaller until they end in an inflorescence (Fig. 8.2).

A cane joint is made up of five obvious components:

i) A node, which is the place where the stem and leaf sheath are joined;
ii) The root band, which consists of a number of tiny, translucent dots known as the root primordia or initials;
iii) The intercalary meristem, a small meristematic zone slightly above the root band that is in charge of internode growth;
iv) The internode, a structure in the shape of a barrel that is covered in a very thick waxy bloom; and
v) The lateral buds, which are arranged alternately on the stem's opposite sides and are protected from harm by the leaf sheath's tight wrapping around the internode (Fig. 8.3).

Anatomically, the stem (rind) is made up of many layers of lignified cells with thick walls that protect the cells beneath. Internally, it is made up of soft, light-colored tissue called pith, in which numerous fibro-vascular bundles are embedded. A significant portion of the juice—between 85 and 88 percent of the weight of the fresh cane juice—is present in the parenchyma cells that surround them. The juice has a sugar level that ranges from 12 to 17%. The leaves are constructed using a standard graminaceous pattern and are alternately attached in two rows on either side of the stem at the nodes. The leaf blade is a long, flat structure with a finely serrated edge that is typically 2.5–10 cm wide and 0.9–1.5m or longer. It is frequently covered with hairs that cause painful skin punctures.

The light silvery auburn inflorescence, often known as a "tassel" or a "arrow," is an open panicle with feathers or wool that is between 0.3 and 0.6 metres in length and is only produced by experimental or leftover plants. The base of each spikelet is wrapped by a ring of long, silky hairs, giving the inflorescence its distinctive silky appearance. The blade of the leaf that immediately encircles the inflorescence is fairly short (0.6-0.9 m), while the leaf sheath is quite

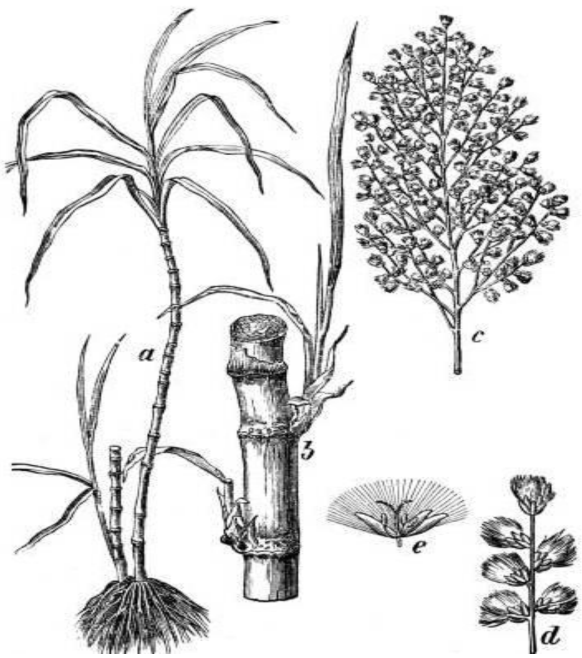

Fig. 8.2 Plant parts of sugarcane: (a) Whole plant, (b) Piece of mature cane with lateral buds, (c) Inflorescence, (d) Arrangement of the Spikelets (Racemose) (e) A flourished spikelet (Source: https://www.istockphoto.com/photos/sugar-cane)

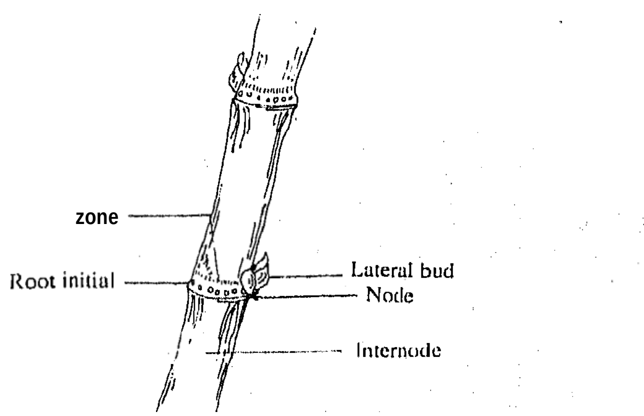

Fig. 8.3 Sketch of cane stalk with two node, internode, root initial and lateral bud

lengthy and is referred to as the flag.Both spikelets have a similar structural layout, with the lower flower being represented only by a sterile lemma and each containing a pair of glumes that encircle both florets. The lemma is, however, missing in the upper flower of *S. offlcinarum* (but is present in *S. spontaneum* and its hybrids) whereas the palea is a small, thin, narrow structure. Despite this, the higher fertile flower's palea is tightly encircled by the lemma of the lower flower. A centrally located gynoecium with two styles that finish in feathery stigmas, two lodicules, three stamens, and three stamens are all present (Fig. 8.4). Caryopsis is the name of the fruit. The seeds only remain viable for a very short period of time.

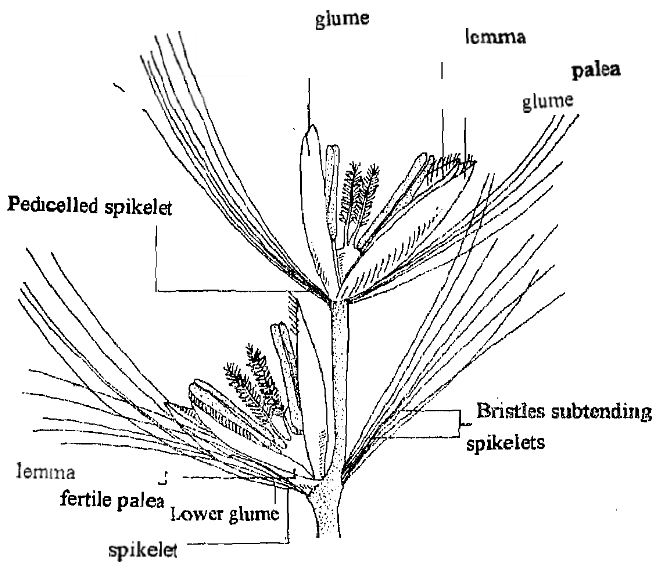

Fig. 8.4 A part of sugarcane inflorescence showing paired spiaklets (Source: Cobley & Steele, 1976)

8.3.1.7 Propagation

Sugarcane is propagated vegetatively by stem cuttings of three to five joints, known as "seed cane" or "seed pieces," or by ratooning, in which dormant buds on the portion of the cane left underground after harvesting sprout in two to three weeks, producing a new crop, commonly referred to as "stubble" or "ratoon crop" (Fig. 8.5). However, the yield almost invariably decreases gradually with subsequent ratoon crops. Every three to four years, fields are typically removed and replanted with new seedlings.

The cutting is often obtained from sugarcane plants that are 8 to 12 months old or from ratoons that are 6 to 8 months old. They are expected to be free of pests and illness. The top third of the cane is where setts should be harvested. Sections of stem cuttings containing two or more buds or eyes, typically three, may be used for planting. Either horizontally or at a 45° angle can be used when planting them in the bottom of furrows. Sometimes, two cuttings are placed next to one another. One joint with one pre-germinated bud is used for quick multiplication. In order to prepare the setts for planting, organic mercury compounds are frequently used. A properly prepared seedbed that is moist at the time of planting is necessary for good sprouting, and planting is typically done early in the rainy season. Depending on the local climate, the plant crop, the first harvest after planting, matures in 9 to 24 months. It is often planted in the majority of the tropics during the rainy season, maturing 15–16 months later. In some countries, it stays on the land for two years. The field is removed, and a fresh plant crop is sown, after the stubbles have produced 2-4 or more ratoon crops, each of which takes about a year to mature. Sometimes a fallow period is left before replanting. The period of the plant and ratoon crop before replanting is known as the crop cycle. About 30-40% of the crop is ratooned.

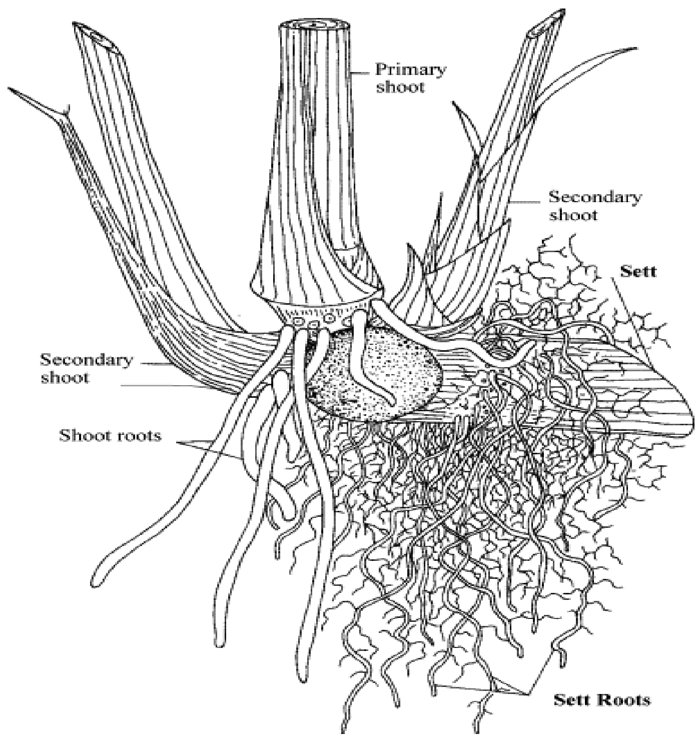

Fig. 8.5 Underground part of a cane cutting bearing primary, secondary and tertiary shoot/stalk (Source: Smith et al., 2005)

8.3.1.8 Harvesting

Sugarcane is harvested when it reaches the stage of maturity as at this time it is with the highest sucrose content. Ripeness tests are often conducted on arbitrary samples collected throughout the entire field at intervals of 7–10 days. This can be accomplished by cutting the entire cane or by using a hand refractometer to analyse the juice from the upper and bottom thirds' central internodes of standing canes. Ripeness is also determined by experience, visual inspection, and field history. The sucrose content of cane at the time of delivery to the manufacturer is the basis for modern cane evaluation. In the majority of tropical nations, plant crops are ready for harvest in 14–18 months, whereas ratoon or stubble crops are ready in 12 months. It is conventional to harvest the ratoon crops first, which will be ploughed out, then the plant crop, and finally the ratoons, which will be ratooned once more. Most nations use cutlasses to manually cut the cane. Cut closely to the ground, the crop. In modern plantations, it is also harvested by enormous cutting machines. After being freed of the dried leaves, they are quickly transported to manufacturers to be processed. The cut cane quickly starts to deteriorate (the labile sugar undergoes inversion into glucose and fructose), although for the first 48 hours, the impact on milling and recovery is minimal.

8.3.1.9 Chemical Composition

The plant's entire dry matter is made up of 50–60% millable cane, 30–40% tops and trash, and 10% roots and stubble. Age, environment, and cultural contexts all have an impact on chemical makeup. Except when ripened under perfect conditions, the leafy tops have a high proportion of reducing sugars and a low proportion of recoverable sucrose. The amount of sucrose, $C_{12}H_{22}O_{11}$ in the stem rises with age and is typically highest near the base, however variations exist depending on the degree of ripeness. The 26% organic matter consists of 9-16% of fibre and the rest is mainly sugars. A juice, approximately 85-88% of the weight of cane is made up of water and sucrose, with a little amount of glucose and fructose as well as small amounts of mineral salts and nitrogenous compounds. Depending on how ripe the cane is, the total solids in the juice are typically 20–22%, with 80–95% sucrose. The total amount of raw sugar recovered for every 100 tonnes of millable cane is typically 9 to 1.3 tonnes. At the moment of entry into the plant, efficient modern manufacturers recover roughly 87% of the total sucrose that was initially present in the cane.

About 20% of the final raw molasses is made up of water, 35% sucrose, and 14% reducing sugar. Bagasse is made up of 25–55% water, 44%–47% fibre, and 2.3–3.0% sucrose.

8.3.1.10 Manufacture of Sugar

The following procedures are used to produce cane's white, crystalline sugar:

1. Extraction of Juice: The best cane to process is clean, ripe, and devoid of debris, tops, and foreign objects. With the aid of crushers, the freshly cut cane stalks are broken down into smaller pieces, and the juice is extracted by passing the pieces through thick, ridged steel rollers. To achieve thorough extraction of the juice, several further expressions are necessary. Sprays of water are applied on the cane after each expression to aid in a full recovery. The residue is referred to as "bagasse." The expressed juice is a cloudy, pleasant, dark-greyish fluid that contains contaminants such organic acids, minerals, proteins, colloidal colouring agents, gums, cane bits, and other foreign objects.

2. Purification of Juice: The juice is first filtered to get clear of the suspended and insoluble particles, and then it goes through defecation, carbonation, and sulphitation to get eliminate of all the dissolved non-sugars. In order to eliminate free organic acids and phosphates as insoluble calcium salts, the juice is heated with a precise amount of lime during defecation. Proteins and colloidal colouring materials are removed from the solution by forming a thick scum on the surface. By filtration through canvas, the precipitated calcium salts and scum are eliminated. The surplus lime is subsequently removed as calcium carbonate during the carbonation process, which also causes calcium sucrate to break down into soluble black sugar. Sulfur dioxide is added to the filtered carbonated juice during sulphitation to finish neutralising the lime and breaking down the calcium sucrate.

3. Concentration and crystallisation: Now that the juice has been cleansed, it is directed to evaporators where it is heated under reduced pressure until it thickens to syrup. Additionally, partial vacuum boiling keeps sugar from deteriorating and browning. Finally, the concentrated raw syrup is heated in a vacuum pan until it crystallises, creating a thick, sticky mass (massecuite) in which some of the sugar is expelled as crystals. The next step is to swirl this mother liquor (molasses) and sucrose crystal mixture in open tanks, or crystallisers, until it begins to crystallise. Finally, the massecuite is fed into centrifugal machines, where the molasses passes through a filter and the crude sugar is collected in a basket, ready for removal after a fast rinse with water. The raw syrup is combined with the molasses, which still contains some crystallizable sugar. To get clear of as much sugar as possible, this is done three or four times. The raw centrifugal sugar is reddish brown or somewhat grey in colour and contains 96% sucrose. It is usually exported in this form, further refining being done in the importing country.

4. Refining and Drying of Crystals:

Diatomaceous earth is added after the raw sugar has been redissolved in hot water to eliminate any remaining contaminants. By using carbon black as a treatment, the solution is made into a colourless, glittering liquid. After vacuum concentration, the transparent syrup is centrifuged to extract the pure, sparkling sugar crystals. The crystals are subsequently dried in sizable rotating dryers with a strong hot air current. The dried granulated sugar crystals are now graded according to size on inclined vibrating screens before being packaged and delivered for export.

In India and other regions of Asia, a sizable volume of juice is evaporated over an open flame in a huge shallow iron pan with flared edges. When the boiling syrup reaches a temperature of 118–1200°C, the thick, semisolid mass is rapidly transferred to wooden troughs or moulds, where it cools and solidifies. In India, it is referred as as "gur" or "jaggery."

8.3.1.11 By-products in sugarcane industry

The sugar mill crushes sugarcane into a variety of products for various end purposes. Up to 31 items may be made in Cuba from sugarcane, but the majority of these have very little economic value. Refined sugar, raw sugar, molasses, alcohol, rum, bagasse, syrups, dextran, candy, crude wax, and glucose are some of these. It is estimated that 100 tonnes of sugarcane will yield 14.3 t of raw sugar, 27.2 t of bagasse, 5.2 t of filter cake, 2.6 t of molasses, and 50.7 t of waste water (Allen et al., 1997). There are five main byproducts of the sugarcane are given below:

i) Ethanol

- In the majority of countries some sucrose is fermented to create ethanol (Schubert, 2006). According to Goldemberg and Guardabassi (2009), Brazil used 47% of its sugarcane crop to produce ethanol in 2006, yielding 17.8 billion litres and providing around 40% of the country's automobile fuel (Orellana and Neto, 2006). In the 2010–11 growing season, sugarcane was used to make 54% of the crop, or 27.6 billion litres, of ethanol (Conab, 2011). Vinasse, the fermentation byproduct, is applied as fertiliser to farms in Brazil (Cheavegatti-Gianotto et al., 2011). In India, 300 distilleries use molasses to create 3.2 billion litres of ethanol annually (Gopinathan and Sudhakaran, 2009). Additionally, sugarcane juice is fermented and distilled to make alcoholic drinks like cachaca in Brazil or rum (although in some countries this is made from molasses).

ii) Bagasse

- Bagasse is the fibrous part of sugarcane that is left remaining after the juice has been extracted. After the juice has been extracted, the fibrous part of the sugarcane is known as bagasse. According to Cheavegatti-Gianotto et al. (2011), for every tonne of sugarcane processed, 240–280 kilogrammes of bagasse are produced. Fibers, water, and comparatively small amounts of soluble substances make up this substance (mostly sugar). Bagasse consists of two types of fibre: the long cellulose fibres in the rind, and the shorter, softer fibres in the pith of the cane stem.
- Bagasse cellulose fibres are useful for paper production because they are longer (1-1.5 mm) than hardwood fibres (0.7-1 mm) but shorter (2.5-5 mm) than softwood fibres. For the purpose of producing high-quality paper, the stem pith material, which makes about 25–35% of the bagasse dry weight, must be removed (Dunlap and Callihan, 1969). In other countries, bagasse has also been used to create fibre board, a building material that may be used to make cabinets and laminate flooring, and particleboard (Almazan, 1994).
- Bagasse is utilised as animal feed, although its use is restricted by its low digestion, even for ruminants. Bagasse undergoes steam treatment to increase its digestibility so that it can be used to fatten cattle (Allen et al., 1997; Pate, 1982; UN Industrial Development Organisation, 2002).
- Bagasse has also been used as shrimp food (Freeman, et al., 1992). It is burnt for heat to produce steam as a source of power to run the sugar mills, with excess energy directed to the electricity grid in a number of mills, including those in Australia (Mackintosh, 2000), Brazil (Cheavegatti-Gianotto et al., 2011) and Mauritius (Deepchaud, 2005).
- In the future, bagasse might also be used to make biofuels like ethanol (Sainz and Dale, 2009).
- Bagasse is used to make furfural, which is a liquid that is colourless, flammable, volatile, and fragrant. 1 tonne of furfural requires 25 tonnes of bagasse. It has a wide range of industrial applications, including as a selective solvent for lubricating oil refinement and as an intermediary in the synthesis of nylon and resins.
- Bagasse can be utilised in the management of waste water and is a powerful bio-sorbent. For instance, bagasse is effective at adsorbing typical pollutants present in synthetic waste water, such as chromium, cadmium, copper-nickel, and dyes (Khan and Amin, 2005; Khattri and Singh, 1999).

iii) Molasses

- Molasses is the thick, syrupy byproduct that remains after sucrose has been extracted from cleared sugar juice (syrup). Although it depends on a variety of variables, the yield of molasses is roughly 3.0% per tonne of cane. The average molasses composition is water 20%, other carbohydrates 4%, sucrose 35%, nitrogenous compounds 4.5%, fructose 9%, non-nitrogenous acids 5%, glucose 7%, ash 12%, and other reducing sugars 3%. The "C" molasses (final or blackstrap molasses) is employed in the fermentation of alcohol, as a supplement to stock feed, and as a fertiliser for cane fields (Mackintosh, 2000; Sreenivasan et al., 1987).

iv) Cane tops

- Cane tops have no true market worth. They can be compared to fair quality fodder, which has an average feed value of roughly 2.8 MJ (Mega Joule) of metabolizable energy per kilo of dry matter when it is fresh. However, cane tops should be gathered and carried from the cane fields to the feedlot.

Filter mud / press mud

- The precipitated impurities contained in the cane juice, after removal by filtration, form a cake of varying moisture content called filter mud. This cake contains much of the colloidal organic matter anions that precipitate during clarification, as well as certain non-sugars included in these precipitates.

v) Other products

- Plant matter left over after sugarcane stalks are harvested is known as trash. According to estimates, each acre of sugarcane produces 10 t of waste (Karve et al., 2001). In some areas of Australia, rubbish is typically retained in the field as mulch or it may be baled and utilised as low-grade cow feed, garden mulch, or both. In India, machinery has been created to convert waste into solid briquettes that may be used as fuel (Karve et al., 2001).
- The waxy exterior of the stalk, which is concentrated mostly at the nodes, and the lipids present in the entire cells make up sugarcane wax (Allen et al., 1997). Sugarcane wax is utilised in cosmetics and pharmaceuticals, including cholesterol-lowering products.
- Filter cake or press mud (the solids left over after filtering the cane juice), and sugarcane ash (which is the residue created when the sugarcane bagasse is burned as fuel in the boilers) are frequently used as fertilisers on sugarcane farms (Cheavegatti-Gianotto et al., 2011). These provide a good supply of many plant nutrients, although nitrogen may need to be added (Calcino, 1994). Sugarcane ash has been proven to promote banana growth in Australian banana plantations (Broadley et al., 2004), and sugarcane and maize (corn) growth in Cuba improved after ash application (Onelio et al., 2011).
- One of the sugarcane's advantageous phytochemicals is glycolic acid, which is used in cosmetics particularly for skin renewal. (Allen et al., 1997).

8.3.1.12 Economic Importance of Sugarcane

Sugarcane and sugar play significant role in economy of India, trade and livelihood. India is the largest consumer and the second-largest producer of sugar in the world. The sugar business is one of the most significant agricultural sectors in the nation, having an impact on the life of around 5 crore farmers and others who depend on them who grow sugarcane on an area of almost 50 lakh hectares. There are more than 700 installed sugar factories in the nation, with a crushing capacity of over 340 lakh MT of sugar and an annual turnover of roughly Rs 80,000 crore. These figures demonstrate the significant contribution that the sugar sector makes to India's economy. A total of 399.83 million tonnes of sugarcane are expected to be produced throughout the nation in 2020–21.The production of sugarcane during 2020-21 is higher by 39.40 million tonnes than the average sugarcane production of 360.43 million tones. (Annual Report 2020-21). There are several uses of sugarcane these are following:

1. Sugarcane is a vital supply of sugar, a key component of the human diet and a major source of energy.
2. A large quantity of sugar is used in the production of alcoholic beverages, soft drinks, candy, ice cream, and chocolates, as well as in the canning business.
3. Sugar is a sweetening substance used by cereal producers.
4. It is utilised in pharmaceuticals, explosives, photographic equipment, and hair tonics.
5. It is useful for producing adhesives, silvering mirrors, and tanning leather.
6. Cane wax is extracted with solvents and used to make paper coating, polishes, and cosmetics.
7. The filter cake is used as a fertiliser because of its high calcium, nitrogen and phosphorus content.
8. Thick noble canes are chewed, which are relatively soft, high in juice and sugar, and low in fibre.
9. Bagasse is used as mulch for plants, boiler fuel, and as a litter or bedding for livestock and poultry. Additionally, it is utilised in the production of paper, cardboard, plastics, insulating fiberboard, and furfural. The nylon and oil refining industries both depend on furfural.
10. Molasses, a significant by-product of the cane sugar industry, is used to make a variety of chemicals, including industrial alcohol, vinegar, glycerol, lactic acid, and citric acids, as well as for animal feed and the production of alcoholic beverages like rum.
    - It has 15% reducing sugars and 35% sucrose.It is this 50% of fermentable sugar which gives it its principal value as an industrial raw material.
    - Rum is produced by the fermentation of molasses by the yeast *Saccharomyces cerevisiae* followed by distillation.
    - Molasses are also used for manufacture of dry ice. Acetone and butanol are produced by fermentation of molasses with *Clostridium* bacteria.

Commercial uses

- Sugarcane is primarily consumed as refined sugar or other primary products, and it is grown for its sucrose content.
- Juice from raw sugarcane, also called as "chediraz" in northern India, "caldo de cana" or "garapa" in Brazil, and "aseer asab" in Egypt, can be extracted by squeezing or chewing the plant.
- Sugarcane is cultivated in various countries, where it is either consumed locally or sold fresh at juice shops, cafes, and restaurants.
- In addition to commercial processing, sugarcane is also processed informally by boiling and cooling the juice to create cakes of unrefined brown sugar, also known as "jaggery," "gur," and "khandsari" in India, "rapadura," and "panela" in Brazil.
- In India it is estimated that 16.5 million tonnes of sugar are produced compared with 10 million t of these traditional sweeteners (Kansal, 1998).
- In 2014, world production of sugarcane was estimated to be about 1 900 million t, which was grown on approximately 27.2 million hectares. Brazil was the largest producer at 737 million t (FAOSTAT, 2014). The world production of sugar from sugarcane is approximately six times that from sugar beet, the other major source of sugar.

8.3.2 *SUGAR BEET* (*Beta vulgaris* L.)

8.3.2.1 Introduction

Another significant source of sugar is the sugar beet (*Beta vulgaris* L.). It was derived from the wild *B. maritima*, which is still found wild on European seacoasts. There have been instances when beet sugar has matched or even surpassed cane sugar. But by the 21st century, beet sugar production was only approximately one-third that of cane sugar.

Although sugar beet was known since before the Christian era it was not used as a source of sugar until modern times. Beets that have been cooked make a great vegetable, and the leaves can be used in place of spinach. Although the presence of sugar in tubers was originally noticed in 1590, Maregraf (a German chemist) was the first to recognise its potential in 1747. Around 1800, both in Germany and France, the industry officially started. Napoleon encouraged the use of it as an embargo against British imports. He was ridiculed because of this and a famous cartoon pictured him dipping a sugar beet into his coffee. After that, interest in sugar beets decreased, although it later returned in Germany in 1935 and France in 1829. Since then, it has been an increasingly significant crop in several European nations. The beet business did not really start in the United States until 1879, despite earlier attempts.

The majority of beet sugar has been produced in Central Europe, while California, Colorado, and Idaho are the main states in the United States where this crop is grown. It might be noted that in the manufacture of rum in Europe, the flavor when the rum is derived from beet sugar differs substantially from that prepared from sugar cane. The former tends to be much more aromatic and has a distinctly unique taste.

8.3.2.2 Origin

The centre of origin of sugar beet (*Beta vulgaris* L.), is believed to be the Middle East, near the Tigris and Euphrates Rivers. . It is assumed that wild beets moved north along the Atlantic coast and west into the Mediterranean. Wild beets on the Canary Islands developed numerous unique species (*B. patellaris*, *B. webbiana, and B. procumbens*), most of which are annual in nature due to their geographic isolation (Cooke and Scott, 1993). The emergence of the species *B. trigyna, B. lomatogona,* and *B. macrorhiza* was further facilitated by the movement of wild kinds north into the mountains of Turkey, Iran, and Russia's Caucasus Mountains (Cooke and Scott, 1993). These species are somewhat perennial in growth habit. Finally, wild beet spread east through most of Eastern Asia. Cultivated sugar beet is likely to have originated from wild maritime beet (*B. vulgaris* subsp. *maritima*) through breeding selection (Cooke and Scott, 1993).

8.3.2.3 Systematic Position:

Kingdom	Plantae (Plants)
Sub-kingdom	Tracheobionta (Vascular plants)
Super-division	Spermatophyta (Seed plants)
Division (Phylum)	Magnoliophyta (Flower bearing plants)
Class	Magnoliopsida (Dicotyledons)
Subclass	Caryophyllidae
Order	Caryophyllales
Family	Chenopodiaceae
Genus	*Beta*
Species	*vulgaris*

8.3.2.4 General Description

The sugar beet (*Beta vulgaris* L.) belongs to the family Chenopodiaceae. There are 105 genera and about 1400 species in this family (Watson and Dallwitz, 1992). Members of this family are dicotyledonous and usually herbaceous in nature. Economically important species in this family include sugar beet, fodder beet/mangolds, red table beet, Swiss chard/leaf beet (all *B. vulgaris*), and spinach (*Spinacia oleracea*).

Although sugar beet is typically a biannual species, in some circumstances it can function as an annual (Smith, 1987). The sugar beet plant first produces a sizable, succulent taproot, followed by a seed stalk the following year. Typically sugar beet root crops are planted in the spring and harvested in the autumn of the same year. For seed production, however, an overwintering period of cold temperatures of 4 to 7°C (vernalization) is required for the root to bolt in the next growing season and for the reproductive stage to be initiated (Smith, 1987).

During the first growing season, the vegetative stage, the sugar beet plant is described as having glabrous leaves that are ovate to cordate in shape and dark green in colour. From an underground stem, the leaves grow into a rosette (Fig. 8.6). At the stem-taproot junction, a white, fleshy taproot that is noticeably enlarged emerges (Duke, 1983). A blooming stalk extends (bolts) from the root during the second growth season, the reproductive stage. This angular seed stalk, which can reach a height of 1.2 to 1.8 metres, develops into an inflorescence.

Small leaves and a huge petiolate leaf are appearing at the stem's base. As the stem grows, less petiolate leaves and finally sessile leaves appear. At the leaf axils, secondary shoots develop forming a series of indeterminate racemes (Forster *et al.*, 1997). These flowers are small, sessile and occur singly or in clusters. Sugar beets produce a perfect flower consisting of a tricarpellate pistil surrounded by five stamens and a perianth of five narrow sepals. Petals are absent and each flower is subtended by a slender green bract (Smith, 1987).

The ovary develops into a fruit that is embedded at the base of the flower's perianth. Every fruit has a single seed, which can be spherical or kidney-shaped. The ovaries are enclosed by the common receptacle of the flower cluster (Duke, 1983). A monogerm seed (holding only a single embryo) is formed when a flower occurs singly. The multigerm beet seed is formed by an aggregation of two or more flowers (Cooke and Scott, 1993).

Fig. 8.6 Sugar beet: (1) Complete plant with tap root (2) Aerial part (Leaves)

8.3.2.5 Cultivation

The optimal growing conditions for sugar beet, a white-rooted biennial, are areas with summertime temperatures between 20 and 22 °C. In the Southwest's irrigated areas, it yields well in the winter. This plant can grow in almost any healthy soil. From seeds, plants must be thinned until they are 8–10 inches apart. It is necessary to do extensive weeding and deep cultivating. The crop is less expensive to grow than sugar cane since it is easily machine harvested. In temperate climates the seeds are sown in April and the roots are allowed to remain in the ground until October because the sugar content increases in that position. Before the ground hardens, beets are dug out, their tops are cut off to minimise sugar loss, and they are then stored. The best plants are saved for seed, which has gradually improved things via selection.

8.3.2.6 Manufacture of Sugar

- Extraction of the juice is a simpler process than for sugar cane because the roots are soft and pulpy. Initially, they were rasped to a pulp and the juice was extracted using a bag, but later, a diffusion method was employed.
- The roots are cleaned, divided into thin strips, and heated in a series of tanks with running water. This method allows for the extraction of about 97% of the sugar. After the waste beet pulp is removed, the insoluble contaminants in the raw juice are precipitated out by a process called as carbonation. For this, lime is added to the raw juice to coagulate some of the non-sugars and carbon dioxide is added to precipitate calcium carbonate. The contaminants settle out with it, and filtration is used to separate out the juice that has been purified. The process is repeated several times during which sulfur dioxide is added to adjust the alkalinity.
- A clear liquid is left after filtration, which is concentrated, crystallized and centrifuged just as with cane sugar. The massecuite (A suspension of sugar crystals and residual syrup) is reboiled several times. It is difficult to differentiate between raw beet sugar and raw cane sugar for they are for all practical purposes identical in composition and appearance.

8.3.2.7 Economic Importance of sugar beet

Middle Eastern cultures were the first to employ sugar beets. The oldest descriptions of sugar beet plants as having swollen roots can be found in documents from the 12th century (Toxopeus, 1984). The breeding of beets to boost the sugar content of their roots didn't start in Germany until the late 18th century (American Sugar beet Growers Association, 1998). Original forms of sugar beet were derived from white Silesian beet, which had been used as a fodder crop and contained only about 4% sugar. Repeated selection and breeding have raised the sugar content to its present level. The following uses of beets as a crop plant are given below:

- Sugar beet is used for the production of sugar. By-products of sugar production as pulp, molasses, fibre etc, are used as feed.
- The leaves of the sugar beet plant may also be utilised as animal fodder in regions where animals are raised.

- Molasses has more recently been produced using sugar beet. Among other fermentation processes, molasses is used to produce alcohol (penicillin production, etc.).
- Sugar beet roots are processed into white sugar, pulp and molasses for food, feed or industrial applications and are rarely used as a raw commodity.
- A typical sugar beet root consists of 75.9% water, 2.6% non-sugars, 18.0% sugar and 5.5% pulp. In the sugar fraction 83.1% is recovered as crystalline sucrose, 12.5% is recovered as molasses (Bichsel, 1987).
- By-product known as dried sugar beet pulp are used as a flavour, aroma, texture, colour and body of a variety of foods.
- Another important by-product is sugar beet molasses, a viscous liquid containing about 48% sucrose, which cannot be economically crystallized.
- Sugar beet molasses is used for production of yeast, chemicals, pharmaceuticals, as well as in the production of mixed cattle feeds.
- By-products of the industry include the green tops, which are used for cattle feed and fertilizers; the wet or dried pulp, which is a valuable cattle and sheep feed; the filter cake, which is used as a manure; and the molasses, which is used for stock feeding or for industrial alcohol.

8.3.3 OTHER SUGAR YIELDING PLANTS

8.3.3.1 Sugar Maple

Sugar maple, (*Acer saccharum* Marshall), also called **hard maple** or **rock maple**m is large tree in the Sapindaceae (soapberry) family. It is native to Eastern North America and widely grown as an ornamental and shade tree. It is commercially important and the sap of the tree used in making maple syrup, maple sugar, and hardwood lumber useful in furniture manufacture and flooring.

Although various maple species produce sweet sap, the Sugar Maple (*Acer saccharum* Marshall) and the Black Maple (*A. nigrum* Michx.f) are the most significant. A notable tree in the northern region of the eastern deciduous forest zone is the sugar maple. It naturally reproduces and has a lifespan of 300–400 years. The red and silver maples give a comparatively small yield and are not of commercial interest. The sap begins to flow about the middle of March and continues for about a month. This is a period of warm, sunny days and cold nights. The best flow comes when the temperature reaches 25°F at night and 55°F during the day. The preferred location for tapping is the first three inches of sapwood, about 4.5 ft. above the ground.

The maple-sugar industry reached its peak in 1869 when 45-million pounds were produced. With the advent of cane sugar it ceased to be an important commodity. Today the product is very pure and the demand is increasing for the syrup especially. Southeastern Canada is the leading producer while in the United States Vermont, New York, Ohio, Michigan and Wisconsin produce small amounts.

8.3.3.2 Palm Sugar

Several species of palm provide a fourth source of commercial sugar all of which is only available in the tropics and subtropics. The species utilized are the Wild Date (*Phoenix sylvestris*), the Palmyra Palm (*Borassus flabellifer*), the Coconut (*Cocos nucifera*), the Toddy Palm (*Caryota urens*), and the Gomuti Palm, (*Arenya pinnata*). Some of the oil palms also yield sugar. The date palm is tapped similar to that of a maple and the sap is obtained from the tender upper portion of the stem. In the other palm species the sap is secured from the unopened inflorescences. Usually the tip of these is cut off and the sap oozes out and is collected in various containers. The yield of this sweet juice is known as *toddy*, amounts to 3-4 quarts per day for a period of several months. The sap has a sugar content of about 14%. It is boiled down to a syrupy consistency and poured into leaves to cool and then hardens into the crude sugar known as *jaggary*. Some of this has reached European markets. Three quarts of juice yield about one pound of sugar. The *toddy* is often fermented to make the beverage known as *arrack*. The palm sugar industry is very old in India where over 100,000 tons were still being produced yearly by the mid 1900's.

8.3.3.3 Sorghum Syrup

The stem of the Sweet Sorghum (*Sorghum vulgare* var. *saccharatum*), contains a juice that is used in making syrup. To differentiate between true syrup and a molasses it is necessary to realize that syrup is the product obtained by merely evaporating the original plant juice so that all the sugar is present. On the other hand, molasses is the residue left after a juice has been concentrated to a point where much of the sugar has crystallized out and been removed. The sweet sorghum is a wild plant of the tropics and subtropics which has long been cultivated in many parts of the world. The juice is a poor source of sugar, but yields nutritious and wholesome syrup. The stems are easily crushed and the juice is evaporated in shallow pans. On the average about 11-million gallons were being made in the United States by the mid 1950's. Similar syrup has also been made from sugar cane by clarifying the juice and evaporating it to a consistency where the water content is 25-30%.

8.3.3.4 Agave Syrup & Sugar

Agave syrup, also known as Maguey syrup or Agave nectar, is a sweetener commercially produced from several species of Agave, including *Agave americana*, *A. tequilana* (blue agave) and *Agave salmiana* plants. Blue-agave syrup contains 56% fructose as a sugar providing sweetening properties (Mellado-Mojica, E., Lopez, 2015). Agave is basically a desert plant, which is a native to the Southern United States and Latin America. The extracts of this plant are used to make Tequila and sweet Agave Syrup. Traditionally, Agave and its nectar were used in Mexico for many years and it was believed that the Agave nectar had medicinal properties. The sap of the Agave plant was boiled to make a sweetener. In fact, the sugar present in Agave is fermented for a long time to make Tequila (beverage).

Traditionally, Agave nectar was used extensively in Mexico for its sweet taste and was believed to have multiple health benefits. However, the goodness of agave nectar depends on the process of extraction and preparation of the syrup.

The Agave plant is cut and the sugary sap is extracted. This extract contains high amounts of sugar and healthy fiber like Fructans (polymer of fructose molecules), which are believed to be good for metabolism and help in managing insulation sensitivity. However, the commercial production of Agave nectar destroys the goodness of health enriching components which get broken during the course of production. This is because Agave sugars are treated with enzymes and excessive heat, which destroys the healthy properties.

8.3.4 OTHER SWEETENING RESOURCES

8.3.4.1 Glucose Sugar

Dextrose or grape sugar is other names for this sugar. Many of the higher plant's organs contain it in trace amounts, and fruits in particular exhibit it. However, starch is used to manufacture commercial glucose.

8.3.4.2 Fructose

This fruit sugar, also known as laevulose, occurs in combination with glucose in many fruits. It is advantageous since diabetics can take it and is somewhat sweeter than cane sugar. Inulin, a carbohydrate found in the tubers of various plants, including the Dahlia (*Dahlia pinnata*), Jerusalem artichoke/ Sunchoke/ Sunroot (*Helianthus tuberosus*), is used to make commercial fructose.

8.3.4.3 Mannose

Mannose does not occur free in nature so that it must be obtained by hydrolysis from several complex compounds. It is readily oxidized from the juice of the Manna Ash (*Fraxinus ornus* L.), a tree in Sicily (largest Mediterranean island) and southern Europe. The juice oozes from slits made in the bark and dries into a very sweet flake like material known as manna. Its use is primarily in medicine.

8.3.4.4 Maltose

Maltose is also occasionally present in plants in a free form, but it is readily made from starch by the enzyme diastase. It is mostly employed in the brewing sector. Maltose syrup is sometimes used as a substitute for glucose and in medicine. Maltose that is obtained from rice starch has been used in Japan as a flavoring for over 2,000 years.

8.3.4.5 Honey

Flowers that are attractive usually produce a sweet substance called nectar. This serves to attract various insects that are necessary for pollination of the plant. Nectar is composed mainly of sucrose with some fructose and glucose. It is used as food by bees, and some of it, after partial digestion, is converted into honey and stored for future use. During this process the sucrose is changed to an invert sugar, which is a mixture of fructose and glucose. Honey contains 70-75% invert sugar along with proteins, mineral salts and water. The sugar has a tendency to crystallize out. Honey was most likely the first sweetening substance used by humans. Beekeeping is one of the very oldest industries.

The flavor and quality of honey vary depending on the source of the nectar. Flowers that contain essential oils impart a typical taste. The bees favor certain plants and these are often cultivated near the apiaries. Clover, Alfalfa, Buckwheat, Lindens and some of the mints and citrus are among the favorites. Honey is an excellent food for it is almost pure sugar. It is also used in medicine, in the tobacco industry and in the manufacture of a fermented beverage called mead. The best quality honey is derived from the Tupelo tree in SE United States and from wild plant sources in southern Mexico and Central America.

8.4 STARCHES AND STARCH PRODUCTS

Starch is a polysaccharide or complex carbohydrate that is made up of a chain of glucose molecules joined together in covalent bond called glycosidic bonds. It is one of the principal nutrients or supplements that should be added to our day to day diet since they give us enough energy for the entire day. Carbohydrates are sugars that come in two distinct sorts that are simple and complex forms. The basic type of Carbohydrates is otherwise called sugars, and the latter that is complex structure is known as starch. Most green plants make starch to store excess glucose that they create during photosynthesis. In plastids, which are where the enzymes for their synthesis take place, carbohydrates are largely stored as starch, which appears as grains (up to 150 in size) there. The photosynthesis-produced glucose is converted into starch in the chloroplast. Translocated sucrose is converted into starch in leucoplasts or amyloplasts, which can persist in this form for months before being hydrolyzed by amylase, in the parenchyma cells of roots and other storage organs, as well as in many seedlings. Each leucoplast produces only one starch grain, so that the grain appears to be free in the cytoplasm. Starch is composed of *α-d* glucose residues of two different kinds -amylose and amylopectin

Amylose is a long, unbranched helix-shaped molecule that contains 200–1000 glucose units. It is soluble in hot water and is therefore the kind of starch used commercially as 'soluble starch' (e.g., for starching clothes). Amylopectin is a shorter molecule (containing 40-60 units) but forms a highly branched helix. Most grains and legumes include 70–80% of it (corn has approximately 100% and peas have 30%) of the total amount of starch. Because of their helical structure, starch molecules may cluster in granules. Starch is deposited in concentric layers in grains, and various species have distinctive patterns (Fig. 8.7). Thus, the presence of adulterants can be checked in commercial products like maize and potato starch.

Starch is one of the most significant and extensively used vegetable products, and it serves as the main source of reserve nutrition for green plants. A complex carbohydrate, that is. It is kept as grains in cells with thin walls. There are various varieties of starch, which vary in terms of the physical and microscopic features as well as the size and form of the grain. Although nuts, legumes, and other plant organs may also contain significant amounts of starch, underground tubers and cereal grains are the most significant sources. Besides being a staple food for animals and humans, it also has many industrial applications. Pure starch comes in the form of a tasteless, odorless, white powder; and is extracted from plants, therefore, making up a large portion of modern human diets. They stain characteristically bluish-black with a solution of Iodine Potassium Iodine.

Our primary source of starchy meals is cereal. One or more of the cereal grains served as the foundation for all significant civilizations. However, many people who live in areas that are not well adapted for cultivating grains still rely heavily on foods like potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*), yam (*Dioscorea alata*), cassava (*Manihot esculenta*), and banana (*Musa sapientum*) as key components of their diets. Despite being distantly related, these plants have a lot in common. All are of tropical origin, with the exception of the potato, which is a lowland species. They are vegetatively multiplied. They are all excellent sources of carbohydrates (food for energy), but because they are all lacking in proteins, eating virtually solely from one of them can result in significant illnesses. For commercial purposes, starch is obtained from the stem tubers of potato *(Solanum tuberosum*), the root tubers of cassava (*Manihot esculenta*) and the rhizomes of arrowroot (*Maranta arundinacea*). In this unit potato and cassava are discussed in detail and some important commercial starches are described.

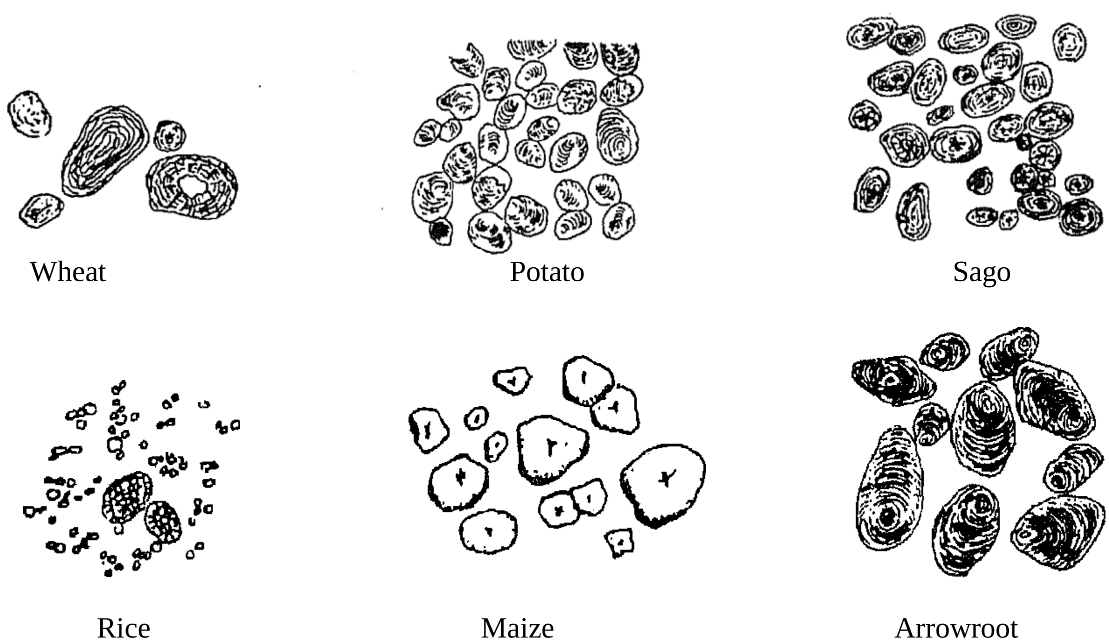

Fig. 8.7: Starch grains from different crops showing their characteristic patterns for each species

8.4.1 POTATO

8.4.1.1 Systematic Position:

Kingdom	Plantae (Plants)
Sub-kingdom	Tracheobionta (Vascular plants)
Super-division	Spermatophyta (Seed plants)
Division (Phylum)	Magnoliophyta (Flower bearing
Class	Magnoliopsida (Dicotyledons)
Subclass	Asteridae
Order	Solanales
Family	Solanaceae
Genus	*Solanum*
	tuberosum

8.4.1.2 General Description

Solanum tuberosum (2n=48), commonly known as potato belongs to family Solanaceae. Various wild *Solanum* species produce small potato-like tubers, which from time immemorial have been grubbed from the ground by the Indians. One or more of these was domesticated in the Andes Mountains of Bolivia and Peru, certainly prior to 2000 A.D., to become the cultivated *S. tuberosum.*

The potato was most probably first seen by an European in 1537, when the Spanish landed in what is now known as Columbia. In the decades that followed, monks and explorers of the New World got familiar with it, and by 1570 it had been returned to Europe. Before 1600, it was grown all across the continent; by 1663, it had reached Ireland. According to legend, the cultivated potato arrived in North America for the first time in 1621. However, the potato was not widely planted until 1700. One reason for its sudden prominence in Europe during the 1700s was that reigning sovereigns recognizing its food potential compelled the people by royal edict to plant it (Germany, 1744; Sweden, 1764). In Ireland (the Irish were perhaps the first to recognize the potential of potato as a staple food and started to grow it as a crop by the middle of seventeenth century) especially, the potato was adopted as a mainstay food on which the Irish peasants survived until 1845-46, when the 'potato blight' (a fungal disease caused by *Phytophthora infestans*) swept across Europe, blackening the leaves of the plant and causing the tubers to rot. The failure of the so-called 'Irish potato' to support the Irish people produced one of the worst famines in the history of the Western World, followed by an unparalleled migration, death and emigration to America reduced the population of Ireland. If the tremendous genetic variability of the potato in its South American homeland had been available, the famine would have been avoided and history might have turned out differently. It is possible that the Irish introduction came from a single, limited genetic source. The potato was introduced from Ireland to New England, earning it the moniker "Irish" even before the Irish immigrants arrived in the

United States. To distinguish it from "sweet potato," it is sometimes referred to as "white potato" (member of a different family).

There are two theories as to how cultivated potatoes came to be: (1) they may have developed directly from an ancestor of *Solanum stenotomum* through a process of straightforward chromosomal duplication; or (2) they may have developed as a naturally occurring amphidiploid hybrid between the more ancient diploid *Solanum stenotomum* and the diploid weed *S. sparsipilum*.

In India, the major potato producing states are Uttar Pradesh, West Bengal, Punjab, Gujarat, Madhya Pradesh and Tamil Nndu. In the hilly tracts, the potato is grown as a summer crop, while in the plains it is a winter crop. The food value of potato varies depending on the variety, growth conditions, storage and handling. Analyses have indicated its composition to be 70-81% water, 8-28% starch, and 1-3% protein, 2-3 % fibres, and 0.1 % fat and with varying amino acid composition with traces of minerals (potassium, phosphorus, iron and, magnesium) and other food elements.

High temperature is not a good thing for tuberization. As a result, in subtropical climates, potato is only grown during the winter period. A rich, friable, porous, well-drained, acidic, light soil and a cold, humid climate with mean annual temperatures between 15°C and 21°C provide for the ideal setting. Short days and a lack of nitrogen in the soil favour early tuberization while lengthy days and high nitrogen soil content favour heavy plant development. Plants are typically developed from disease-free tubers that are either planted whole or divided into sets or sections. With at least one bud or eye in each part, large seed potatoes are divided into multiple pieces. The best way to prevent apical dominance is to cut them at a right angle to the main axis. Tubers need a dormancy period of about 3 months but some varieties need 7 months of dormancy (*Solanum tuberosum*). Green potatoes contain a poisonous glycoside, solanin, which in high concentrations may cause sickness and even death in both humans and livestock. This compound is also present in sprouts

8.4.1.3 Morphology

It is a 60-90 cm tall, erect, branched, somewhat spreading plant that bears tubers. Despite being a perennial plant, it is grown as an annual. Early in the stem's growth, the aerial portion is upright; subsequently, it spreads out more. The aerial stem, except from the nodes, is hollow and frail. Adventitious roots are developed in groups of three to four at the nodes of the main underground stem, which is more or less spherical and substantial and produces horizontal branches (stolons) from the axillary buds (Fig. 8.8).

Typically, the first few leaves that grow from the "seed" portion are simple, but later leaves are compound and irregularly imparipinnate. Each leaf comprises a single terminal leaflet, 2-4 pairs of broad lateral primary oval leaflets with whole or serrated margins, and small secondary leaflets (folioles) spaced out between primary leaflets (Fig. 8.8). The leaflets are more or less opposite and are densely hairy when young but at maturity the hairs are confined to the midribs and lateral veins. The 1eaves are spirally arranged on the main stem with two small basal leaf-like stipules clasping the main stem.

The tuber is the small, obviously enlarged apical region of the stolon, which is packed with food reserves. It has a shortened, thicker stem with buds or eyes in the axils of scale-like, quickly shed leaves, and it has a crude leaf scar (eyebrow) or ridge. The eyes may be shallow, medium or deep, the eyebrow being well marked (semi-circular) towards the heel or the attached end where the tuber is attached to the stolon. Each eye is made up of a simple leaf scar and a group of at least three buds that are arranged in a little depression to resemble a lateral branch with immature internodes. Around the tuber, the eyes are arranged spirally, but they are more numerous towards the heel or basal end of the tuber than they are near the apical or rose end. The tubers come in a wide range of sizes, shapes, and colours. Either the skin is smooth or rough.

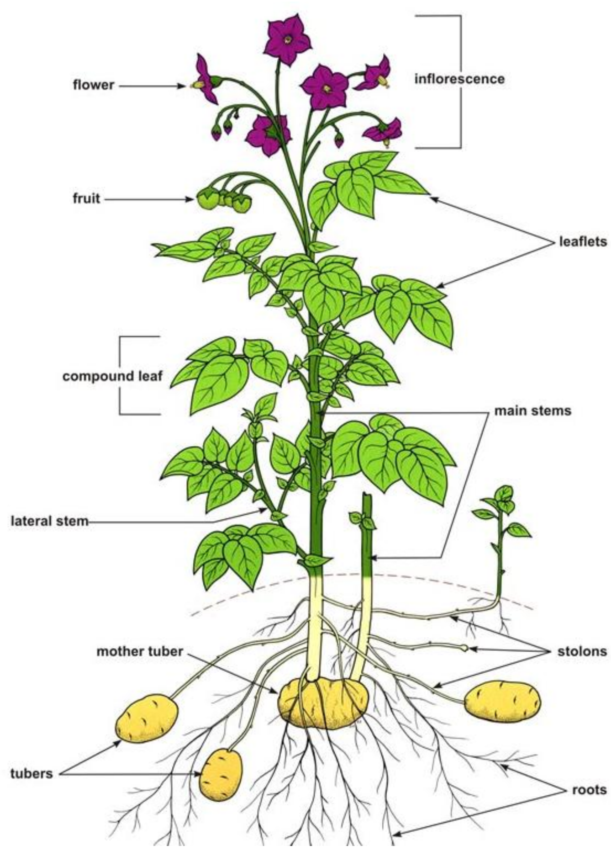

Fig. 8.8 Potato: Whole plant (Source: https://cipotato.org/potato/how-potato-grows)

Each eye is made up of a simple leaf scar and a group of at least three buds that are arranged in a little depression to resemble a lateral branch with immature internodes. Around the tuber, the eyes are arranged spirally, but they are more numerous towards the heel or basal end of the tuber than they are near the apical or rose end. The tubers come in a wide range of sizes, shapes, and colours. Either the skin is smooth or rough.

8.4.1.4 Methods of Breeding

The three primary techniques for potato breeding are introduction, hybridization, and selection. The main technique used to create inter-varietal crosses between commercial varieties to combine desirable traits is called hybridization. Such a cross may involve two or more kinds and be a multihybrid. Commercial potato varieties are heterozygous because they are vegetatively reproduced; clonal selection is typically used in F1, the generation after hybridization. Main breeding work is done in long day summers in Shimla-CPRI (Central Potato Research Institute) and the crop is grown as a short day winter crop in plains. However, selections are difficult to make in varieties adapted to the conditions in plains. For this crosses are made at Shimla and $\mathbf{F_1}$ seeds are sent to regional stations at Patna and Jalandhar, where they are grown and selections are made during short-day conditions.

A few of the many desirable characteristics of tubers are maintaining quality, size, shape, colour, texture, skin thickness, and nutritional content. Now a day's older varieties are being replaced by new varieties such as , Kufri Chandramukhi, Kufri Kissan, Kufri Kundnn, Kufri Sindoori, Kufri Chamtkar, and Kufri Alankar. Most recent are Kufri Bahar, Kufri Badshah, Kufri Jyoti and Kufri Lalima.

8.4.1.5 Economic Importance and Uses

- Potatoes are consumed, as a fresh vegetable, in the daily diet in a variety of ways-boiled, steamed, fried, baked or roasted. A number of delicacies like cutlets, "papar" are prepared. Potato flour (up to 4%) can be mixed with wheat flour for bread making.
- They are processed into a variety of goods, including potato crisps, chips, frozen French fries, potato flour, and canned potatoes.
- Fresh potatoes are important source of Vitamins B and C.
- Additionally, potato starch is used to make adhesives.
- Farina, sometimes known as potato starch, is frequently used in laundries and is good for scaling paper.
- In order to make industrial alcohol, potato starch is first transformed into sugars, which are then fermented by yeast to produce alcohol.
- Potato is also a good substrate for the growth of microbes. In experimental work, the fluid from boiled potatoes has long been employed as a vehicle for nutrients.
- The Russian alcoholic beverage "vodka" is made by fermenting boiled potatoes.

8.4.2 CASSAVA (*Manihot esculenta* Crantz)

8.4.2.1 Systematic Position

Kingdom	Plantae (Plants)
Sub-kingdom	Tracheobionta (Vascular plants)

Super-division	Spermatophyta (Seed plants)
Division (Phylum)	Magnoliophyta (Flower bearing plants)
Class	Magnoliopsida (Dicotyledons)
Subclass	Rosidae
Order	Euphorbiales
Family	Euphorbiaceae
Genus	*Manihot*
Species	*esculenta*

Manihot esculenta (n=18), commonly called cassava, manioc, yuca, tapioca is a species of the tropical lowlands belongs to woody shrub of the spurge family (Euphorbiaceae). As a result of its ability to adapt to poor soil and random cultivation, it has become a staple crop in many of the world's developing and underdeveloped countries. In one to three years after planting, this perennial shrub yields a high output of tuberous roots. It generates remarkable amounts of carbohydrates, far more than maize or rice. The sixth-most significant staple food in the world now is cassava. It is the second most significant root crop in the tropics, directly just after sweet potato. It is grown in every tropical country and over 200 different varieties of the plant are known. It can be grown easily from stem cuttings. The root tubers won't severely degrade if kept in the ground until needed. Root vegetables are consumed after being steamed or boiled.

Brazil is the origin of cassava (S. America). Because it cannot survive extreme cold, this crop does not flower well in the cold climate of north India. However, it can sustain significant rainfall. The Portuguese, Dutch, or Spanish were the first colonizers in India to introduce this plant to Travancore (Southern Kerala). It is an important crop of Kerela and also forms staple food crop of West coast districts for many people. It is now being introduced in Tamil Nadu, Andhra Prdesh, Gujarat, Assam and Maharashtra.

The best soil for this crop is well-drained garden loam. Cuttings of short stems from the previous crop are used as planting material. Just before the rainy season, portions are taken that are relatively fresh and buried into the soil either flat or erect but slanting. It can be grown as a pure stand or is frequently inter-planted with other food crops. It usually takes a week for seeds to sprout. The maximum number of branches per plant, which grows to a height of roughly 2.5–3.0 m when properly established, is three. Plants should be pruned and not allowed to reach a height of more than 1.8 m in order to promote healthy root growth. Mature roots are about 7-10cm in diameter and 30-45 m in length and weigh 1-2 kg. Some of the giant roots may weigh as much as 10kg. In rare cases each plant produces about 4-5 good sized roots.

Morphology

The entire shrub, which has a brief lifespan, is covered in latex. By means of a secondary thickening process, tubers appear as swellings on adventitious roots that are close to the stem (Fig. 8.9). They differ widely in terms of their quantity, form, size, depth at which they pierce the ground, and colour of the internal tissue and cork on the outside. These are (a) the outer skin or peridelm, with cork layers that can be smooth or rough, white, light to dark brown, pink, or red; (b) the thin rind or cortex, usually white but tinged pink or brown; and (c) the core or pith, consisting of parenchymatous cells rich in medium-sized starch grains with stellate hilum, few vascular bundles and latex tubes, usually white but may be yellow or red tinged. This is the edible portion. In addition to tubers, fibrous, adventitious roots develop horizontally and vertically. Old tubers become lignified.

The height and branching patterns of stems vary widely. Branches are often glabrous, thin, and have leaves near the apex and noticeable leaf scars below. The periderm and leaf scars range in colour from silvery-grey to greenish-yellow, pale or dark brown, and purple-streaked dark brown.

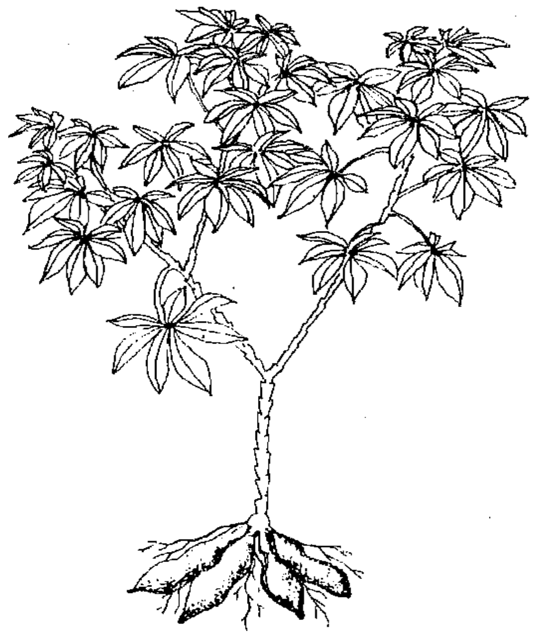

Fig. 8.9 Whole plant of Cassava showing roots stem and leaves

The leaves are big, palmate, spirally arranged, and vary in size and colour. Typically, petioles are longer than lamina. The lamina has 3–9 lobes, usually 5-7, and is extensively palmate. Stipules typically have 3-5 lanceolate lobes and are deciduous. The lobes are ovate-lanceolate, with an entire edge, a thin base, and an acuminate lip. Petiole and midrib green to deep red. Red, green, and yellow variegated versions of the lamina are also occurs.

Near the tips of branches, axillary racemes of flowers are produced. These are unisexual, with the female flowering in the base and the male flowering in the same inflorescence. The flowers are extremely tiny. The corolla is not present, but the calyx lobes are coloured. Ten stamens, divided into two whorls of five each, are present in the male flowers. The female flower's gynoecium is trilocular and tricarpellary, with one ovule per locule. The fruit is a 1.5 cm long globular capsule with six longitudinal, three-celled wings. 3-5 months after pollination and seed germination, the endocarp of woody plants explodes when it ripens. The seeds are ellipsoid, greyish with brown markings, and have a distinct caruncle.

The plant is cultivated in hot climates. It grows very easily and does not require much labour. Stem cuttings of few inches in length are sown in holes dug at intervals of 1meter. Different varieties take different time to mature. Some varieties produce mature fibers within six months to a year while others take 18 months to2 years to mature. Secondary growth occurs in the adventitious roots to form tubers. Tubers have a starch content of about 30%. Older tubers are not edible due to lignification of cells. In healthy plants, the Fibers form in a cluster at the base of the stem and vary in size from small to very long, cylindrical structures that reach a length of 0.90 cm. A dense network of typical fibrous roots could be growing around them. Although big and better quality crops can be obtained after a period of 16 months or more, these are typically harvested after 8 months. The plant continues to grow new steins as a result of the leftover roots, making it perennial.

The cassava varieties are generally classified as "bitter" or "sweet," depending on whether they contain a high or low content of a cyanogenic glycoside. Before eating, sweet cassavas don't require any particular preparation, whereas bitter varieties must be cooked, pressed, shredded, or otherwise processed to remove the poisonous liquid or lessen its toxicity. Since the fine glycoside content fluctuates between different cultivars and plants, there is no apparent distinction between these two groups. In sweet varieties it tends to concentrate in the skin and in bitter it tends to concentrate in skin and cortex of tuber. In sweet varieties the main storage region is relatively free of glycoside.

The Central Tuber Crops Research Institute (CTCRI) was established in 1963 at Trivandrum. It maintains tuberous crop collection from our country and from outside. There are over 1300 collections of cassava, of which 250 kinds are foreign-grown. An effort is undertaken to find high-yielding, excellent cassava varieties that are resistant to the mosaic disease. H-97, H-165, and H-226 are examples of hybrid and superior quality forms that have been isolated as a result of inter-varietal hybridization. High starch content is determined for the cultivar H-97. Tetraploids with an average protein value of 3.9% have been created, in contrast to diploids with a value of 1.8%. The protein value of high producing cultivars is being increased.

Economic uses

The use of cassava is diverse.

- The entire root can be boiled; however, it lacks much flavour on its own and has a heavy, sticky consistency. After being boiled, it is served as a vegetable like sweet potatoes or potatoes.
- It is heated, dried, and then shred into a meal known as farinha/flour (in Brazil), which can be consumed on its alone if necessary or combined with other foods and sauces.
- Tapioca is prepared by grating the peeled roots, the mass soaked in water for several days, kneaded, strained, dried, and then heated to partly hydrolyze the starch to sugar and gel. It

swells up into lumps and these lumps and starch are known as Topioca pearls. Tapioca is used for puddings, biscuits and confectionery.

- These are also used by cutting thin slices after removing rind which is boiled moderately then dried and stored. These chips can be eaten like potato chips or ground into meal and eaten like pomdge.
- Cassava also has several industria1, uses and its starch in some form or the other is a marketable commodity in general world trade. Starch is used in the preparation of adhesives for laundry, for paper sizing and as a source of sugars, alcohol and acetone.
- In lowland tropical South America, the beer is still prepared by chewing the roots; by salivation the starch is converted into sugars followed by fermentation by wild yeasts.
- In Africa, the leaves are used as a pot-herb, since they may contain up to 30% proteins. Their wider use might help prevent malnutrition among people who subsist mainly on cassava.
- Tapioca flour is prepared by a special process. The tubers are peeled, washed and grated or ground. The compressed pulp is then separated from latex and the juice extracted by squeezing the mass in a bag, the starch comes out like n stream of milk and impurities remain inside the cloth bag. Squeczing/kneading is continued with fresh changes of water till starch stops coming and only water came out, a smooth layer of starch settles at bottom and clear water is decanted off. Wet starch is first dried in sun and then on a hot plate.
- The starch is used as animal fodder.
- The juice of bitter varieties is used to produce "cassareep" which is used in prepare sauces. The juice is fermented into alcoholic beverages.

8.4.3 OTHER SOURCES OF COMMERCIAL STARCH

The manufacturing of starch for industry involves a comparatively small number of plants. Potato, maize, wheat, rice, cassava, arrowroot, and sago are the principal ones.

8.4.3.1 Corn Starch

It is obtained from the grains of maize (*Zea mays* L.). Indian corn is the source of over 80 percent of the starch that is made in the United States. The grains are soaked in warm water with a small amount of sulfurous acid to loosen the intercellular tissue and prevent fermentation. Then the corn is ground so as not to injure the embryos. The ground material is placed in germ separators where the embryos are removed. The starch material is then ground very fine and is either passed through sieves of bolting cloth or is washed in perforated cylinders to remove the bran. The resulting milky liquid is run onto slightly inclined tables where the starch grains settle out and the remaining material flows off. The starch is later collected and dried in kilns and is then ready for the market. The best grades of cornstarch are used for food while inferior grades are for laundry starch and sizing and as a basis for glucose.

8.4.3.2 Potato Starch

It is obtained from tubers of potato (*Solanum tuberosum*). Waste potatoes are utilized for making starch. These are washed and reduced to a pulp in graters or rasping machines. The resulting paste is passed through sieves to remove fibrous matter. After washing the solid starch is separated by sedimentation, the use of inclined tables, or centrifuging, and is then dried. Potato starch finds uses in the textile industry and as a source of glucose, dextrin and industrial alcohol. Europe is the principal producer.

8.4.3.3 Wheat Starch

It is obtained from the grains of bread wheat (*Triticum aestivum*). The oldest commercial sources of starch were from wheat. It was known to the Greeks and was widely used in Europe in the 16th Century in connection with the linen industry. The gluten in wheat makes the removal of the starch a difficult process. It is accomplished by extraction with water or by the partial fermentation of the grain. Wheat starch is used mostly in the textile industry.

8.4.3.4 Rice Starch

It is obtained from the grains of rice (*Oryza sativa*). Rice grains that are broken or imperfect are used for making rice starch. These are softened by treating with caustic soda and are then washed, ground and passed through fine sieves. More alkali is added and after a time the starch settles out as a sediment. This is removed, washed and dried. Occasionally dilute hydrochloric acid is used to free the grains. Rice starch has found use in laundry and for sizing.

8.4.3.5 Cassava Starch

The starch obtained from cassava (*Manihot esculenta*). Cassava flour and tapioca are used in industry mainly as sizing materials and as the source of certain starch products.

8.4.3.6 Arrowroot Starch

The tubers of several tropical plants provide a source for arrowroot starch. West Indian arrowroot (*Maranta arundinaceae*), Florida arrowroot (*Zumia floridana*), Queensland arrowroot (*Canna edulis*), and East Indian arrowroot (*Curcuma angustifolia*) yield arrowroot starch. The tubers of these plants are peeled, washed and crushed and the pulp is passed through perforated cylinders, where a stream of water the starch into settling tanks. Arrowroot starch is easily digested and used for preparing broth for children. It also finds some use in laundries.

8.4.3.7 Sago Starch

It is obtained from sago palm (*Metaxylon sagu*). The pith of the stem of the sago palm is the source of the commercial sago starch. It. Is cultivated is in Malaya and Indonesia. The flowers appear when the trees are about 15 years old and just prior to this time the stems store up a large amount of starch. The trees are felled and the starch pith is removed. This is ground up, mixed with water and strained through a coarse sieve. The starch is freed from the water by sedimentation and washed and dried. This is known as sago flour. Commercial sago is prepared from this by making a paste and rubbing it through a sieve in order to cause granulation. The product is dried in the sun or in ovens and appears as hard shiny grains, known as pearl sago. Both sago starch and pearl sago are used almost entirely for human consumption.

8.4.4 STARCH PRODUCTS

8.4.4.1 Soluble Starch

Starch grains are insoluble in cold water but they readily swell in hot water until they burst to form a thin, almost clear solution or paste. This soluble starch has been used for finishing textiles and in the paper industry.

8.4.4.2 Dextrin

When starch is heated or treated with dilute acids or enzymes it becomes converted into a tasteless, white, amorphous solid known as dextrin or British Gum. Dextrin possesses adhesive properties and has been used as substitutes for mucilage, glue and natural gums. Bread loaves brushed with dextrin aids in crust formation. In steel manufacture, the sand for the cores used in casting is held together with dextrin. Other uses include cloth printing, glazing cards and paper and making pasteboard.

8.4.4.3 Glucose

When starch is treated with dilute acids for a long time it becomes more completely hydrolyzed and is converted into glucose sugar. Often the same factory that extracts the starch also converts it into glucose. This operation is done in large copper boilers under pressure. About six pounds of dilute hydrochloric or sulfuric acid are used for each 10,000 pounds of starch. After all the starch has been converted, the free acids are neutralized with caustic soda. The liquid is then decolorized with boneblack and concentrated into thick syrup. One of the common brands of corn syrup is “Karo.” Glucose may be considered as an inferior substitute for cane sugar. However, it is an excellent food material. Its use is in table syrup, for sweetening, in candies, jellies and other kinds of cooking. It is often mixed with maple syrup, brown sugar, honey or molasses it is used for making vinegar and in brewing.

8.4.4.4 Industrial Alcohol

Starch is the source of an enormous quantity of industrial alcohol. Maize and potatoes constitute the chief sources, although the other starches and even cellulose, various products of the sugar industry and fruit juice may be utilized. The process converts the starch into sugar by means of diastase and the fermentation of the sugar by yeasts to yield alcohol. The operations are carried out under different conditions from those followed in making alcoholic beverages. When fermentation has stopped, the alcohol is extracted from the mash by fractional distillation. The alcohol thus formed as a result of the fermentation of sugar is known as ethyl alcohol, as distinguished from methyl or wood alcohol, a product of the destructive distillation of wood. To render it unpalatable, ethyl alcohol is often "denatured:" by adding methyl alcohol or other substances. Industrial alcohol is the most important and most widely used solvent and is the basic material in the manufacture of hundreds of products. It is also used in medicine, pharmacy and other industries.

8.4.4.5 Nitro-Strach

Starch and cellulose are chemically very similar products. Cellulose reacts with nitric acid to form nitrocellulose while starch yields nitro starch. Nitrostarch is a very safe explosive if the ingredients are absolutely pure. Tapioca starch was originally imported for this purpose but during World War-I cornstarch was used as a source.

8.5 ENERGY CROPS

"Energy crops" is a term used to describe biorenewables, bioenergy and biofuel crops. Bioenergy is "energy derived from recently living material such as wood, crops, or animal waste." Bioenergy crops are defined as any plant material used to produce bioenergy. These crops have the capacity to produce large volume of biomass, high energy potential, and can be grown in marginal soils. They can positively impact the environment to reduce the level of carbon dioxide, emission of greenhouse gases and soil erosion. Bioenergy can contribute to reducing the overall consumption of fossil fuels. It can take the form of solid material (Biomass) for combustion or liquid products (Biofuels) that can be used to power vehicles. Both biomass and biofuels can be derived from dedicated energy crops, agricultural co-products or waste materials. The major groups of source of energy crops are grain and seed crops, sugar crops, oil crops, dedicated biomass crops and algae. Switchgrass (*Panicum virgatum* L.), Elephant grass (*Pennissetum purpureum* Schum.), Poplar (*Populus* spp.), Willow (*Salix* spp.), Mesquite (*Prosopis* spp.), etc. have been touted as the crops with the most widespread promise.

On the basis of biomass production and their use as energy crop they are classified into five types namely, traditional bioenergy crops, first-, second- and third-generation bioenergy crops, dedicated energy crops and halophytes. The first-generation bioenergy crops include corn, sorghum, rapeseed and sugarcane, whereas the second generation bioenergy crops are switchgrass (*Panicum virgatum* L.), silvargrass (*Miscanthus* spp.), alfalfa (Medicago sativa L.), reed canary grass (*Phalaris arundinacea* L.), Napier grass (*Pennisetum purpureum* Schumach.) and other plants. The third-generation bioenergy crops contain boreal plants, crassulacean acid metabolism (CAM) plants, eucalyptus and microalgae.

1. Traditional Bioenergy crops

Traditional biofuels derived from natural vegetation or from crop residues. Such biofuels still are the main energy source in number of countries (e.g., Bhutan 86%, Nepal 97%) but they are not sustainable, their exploitation may contribute to land degradation and desertification and are unable to mitigate the impact of GCC.

2. First generation bioenergy crops (FGECs)

The vast majority of current liquid biofuels production is based on FGECs. It can also be used for food therefore; their raw materials compete with food for fertile land and inputs. For example corn, sugarcane, oil palm and rapeseed. Biofuels derived from FGECs rely on fermentation of sugars to produce ethanol or on trans-esterfication of plant oils to produce biodiesel.

3. Second generation bioenergy crops (SGECs)

The SGECs are likely to be more efficient than FGECs and to supply fuel made from cellulose and non-oxygenated, pure hydrocarbon fuels such as biomass-to-liquid fuel. Biofuels produced biochemically or thermo-chemically from lingo-cellulosic SGECs, have more energy content (GJ/ha/yr) than most FGECs biofuels. They may have a larger potential for cost reduction and avoid numerous environmental issues. Early SGECs comprise perennial forage crops such as Switchgrass (*Phalaris arundinacea* L.), alfalfa (*Medicago sativa* L.), Napier grass (*Pennisetum purpureum* Schumach.), and *Cynodon* spp (Oliver et al., 2009). The capacity of *Miscanthus* to fix CO2 ranges from 5.2 to7.2 tC/ha/yr, which results in a negative C balance (Boe and Beck, 2008; Jakob et al., 2009).The contribution of non-edible plant oils (e.g., from *Jatropha curcas* L., Euphorbiacea; 30-50% oil) and soapnut (*Sapindus mukorossi* and *S. trifoliatus*; 52% oil), as new sources for biodiesel production have the advantage of not competing with edible oils produced from crop plants (Ram et al., 2008).

4. Third generation bioenergy crops (TGECs)

The TGECs comprise microalgae, CAM plants, Eucalyptus species, and boreal plants. Algae has the ability to produce biodiesel, whereas boreal and CAM plants have the potential to provide feedstock for direct cellulose fermentation and eucalyptus for thermo-conversion-based bioenergy production. African palm (22% oil), coconut (55–60% oil), grain of castor bean (45–48%), and peanut (40–43%) are among the TGECs oleaginous crops being studied for biodiesel production. By absorbing CO2 emitted from power plants or producing biomass through photosynthesis, they can contribute to lowering GHG emissions.

5 Dedicated bioenergy crops (DECs)

DEC has been proposed as a strategy to produce energy without impacting food security or the environment. Their Genetic resources requirements for biological, chemical or physical pretreatment are more environmentally friendly and will contribute more to GCC mitigation (Petersen, 2008). They are beneficial in providing certain ecosystem services, including C sequestration, biodiversity enhancement, salinity mitigation, and enhancement of soil and water quality. Its include:

i) Cellulosic crops including short rotation trees and shrubs such as eucalyptus (*Eucalyptus* spp.), poplar (*Populus* spp.), willow (*Salix* spp.), and birch (*Betula* spp.);

ii) Perennial grasses such as giant reed (*Arundo donax*), reed canary grass (*Phalaris arundinacea*), switchgrass (*Panicum virgatum*), elephant grass (*Miscanthus gigantus*), Johnson grass (*Sorghum halepense*) and sweet sorghum (*Sorghum bicolor*); and

iii) Non-edible oil crops such as castor bean (*Racinus communis*), physic nut (*Jatropha curcas*), oil radish (*Raphanus sativus*), and pongamia (*Pongamia* spp).

8.5.1 Characteristics of Bioenergy Crops

Potential bioenergy crops are being considered for species of plants with rapid growth, resistance to biotic and abiotic challenges, and little need for biological, chemical, or physical pretreatments. The following are some traits of energy crops:

8.5.1.1 Agronomic and architectural traits

Agronomically, bioenergy crops should have low-input for establishment, low-input for fossil fuels, adaptable to marginal soils, and produce high levels of biomass and energy that are expected to help combat Global Climate Change (GCC). Additionally, from an agronomic perspective, they ought not to be restricted to having low proportions of dry matter allocated to reproductive structures, a long canopy lifespan, perpetual growth, sterility to prevent escape, and low moisture content at harvest. The design of a dedicated bioenergy crop (DEC plant) should reduce competition amongst plants and effectively increase weed competition, maximise radiation interception and Water Use Efficiency (WUE), hasten field drying, and make mechanical harvesting easier. This can be achieved by adjusting branching habit, having a thick, straight, upright stem and resistance to lodging. Trees can be optimized to have short stature to increase light access and enable dense growth, large stem diameter, and reduced branching to optimize energy density for transport and processing.

8.5.1.2 Physiological and eco-physiological traits

A plant that produces bioenergy can be viewed of as a thermochemical energy storage system and solar energy collector. To increase plant biomass and the generation of bioenergy, a variety of physiological and ecophysiological features that are required to improve radiation interception, radiation, water usage efficiency, and nutrient use efficiency as well as to confer environmental sustainability should be targeted. Ecophysiological characteristics that can alter thermal time sensitivity in order to extend the growing season and boost above-ground biomass without reducing below-ground biomass include: high growth rate, response to light competition, canopies with low extinction coefficients, leaf traits for efficient light capture (including optimum leaf area index (LAI), and specific leaf area(SLA), C4 or CAM photosynthetic pathway coupled with large water use efficiency, long canopy duration, large capacity for C-sequestration and nutrient cycling, and low nutrient (e.g., N and S) requirements and content of above-ground biomass.

8.5.1.3 Biochemical composition and caloric content

The energy content, or heat value, released when a material burns in air is expressed by the caloric value of the substance. Because plants vary in their biochemical makeup (carbohydrates, proteins, lipids, organic acids, etc.) and in the amount of glucose required to produce one unit of these organic compounds, the availability of energy from different biomass types varies when moisture content is taken into account, leading to variations in energy output. In addition to having an impact on energy yield, biomass yield and composition impact GHG profiles and the ability of bioenergy crops to mitigate GCC. For example, hybrid poplar produces the largest energy yield (6.15 MJ/m2/yr), followed by switchgrass (5.8) then reed canary grass (4.9); however, reed canary grass has the largest net GHG emission ratio of 3.65, as compared with switchgrass (2.42) and hybrid poplar (2.37).

8.5.2 Converting Crops to Energy

There are four primary methods of converting energy into usable forms are direct combustion, thermal conversion (pyrolysis, gasification), biological conversion (anaerobic digestion, fermentation), and chemical conversion (transesterification).

8.5.2.1 Direct Combustion

The earliest and currently most popular method for turning biomass into heat, electricity, and combined heat and power (CHP) is direct burning (CHP). It is applicable at all scales from domestic to industrial, using boilers that range from small domestic stoves (1 to 10kW) to the largest devices used in power and CHP plants (45 MW). Biomass of many different forms can be used, including wood chip, pellets and different straws. The most efficient combustion is achieved when dedicated biomass boilers are used. However, solid biomass particles can also be mixed with coal in cofiring or cogeneration, enabling the large power-generation industries to reduce their carbon footprint by incorporating biomass as a percentage of their feedstock.

8.5.2.2 Thermal Conversion

However, energy is not directly created from biomass during thermal conversion processes, which employ high temperatures. Instead, the biomass is transformed into energy carriers like oil, methanol, synthetic gases, or gases with better energy densities (and cheaper transport costs). These carriers may also have superior combustion properties and/or more predictable and controlled combustion characteristics. Pyrolysis and gasification, the two primary thermochemical reactions, differ depending on whether oxygen is present.

Pyrolysis takes place at temperatures between 400 and 800 °C in the full absence of oxygen (Laird et al., 2009). The majority of the cellulose, hemicelluloses, and lignin that together make up the lignocellulosic fraction break down and create gases during this process. Some of the vapours in these gases condense as they cool to create bio-oil, which has the potential to replace fuel oil and serve as a raw material for the creation of synthetic gasoline or diesel. Charcoal is made from the leftover biomass, which primarily consists of lignin.

Partial oxidation and temperatures of about 800 °C are needed for gasification. A portion of the biomass is burned to form "producer gas" and charcoal. The charcoal chemically reduces the carbon dioxide (CO_2) and water (H_2O) in the production gas to generate carbon monoxide (CO) and hydrogen (H_2). Producer gas contains water, nitrogen (if air is used as the oxidising agent), 18–20% H_2, 18–20% CO, 8–10% CO_2, 2-3% methane (CH_4), trace amounts of higher hydrocarbons (such as methane and ethane), and numerous impurities, including small char particles, ash, tars, and oils. Air, oxygen, steam, or a combination of these can all be used to perform the partial oxidation step in the gasification process. When air is used, a low heating value gas is produced that is suitable for use in boilers, engines and turbines but not for transporting in pipelines, because of the low energy density. Gasification with oxygen or steam produces a medium heating value gas, which is suitable for limited pipeline distribution, as well as a synthesis gas or ‘‘syngas’’ (typically 40% CO, 40% H_2, 3%CH_4 and 17% CO_2, dry basis). Syngas can be used to make methanol, ammonia and diesel using Fischer–Tropsch synthesis, (Wright and Brown, 2008) first developed by F. Fischer and H. Tropsch in 1923.

8.5.2.3 Biological Conversion

Anaerobic digestion and fermentation are the two basic biological conversion processes. Both technologies have advanced considerably. Bacteria break down organic molecules during anaerobic digestion (AD), which occurs when there is no oxygen present. Almost any organic material, such as waste paper, grass clippings, food waste, industrial effluents, sewage, and animal waste, can be treated. The end product is a biogas that contains roughly 60% methane and 40% CO_2. Biogas can be burnt to generate heat or (once it is scrubbed) electricity. It can also be used as a biofuel. A solid and liquid residue called digestate is also produced, which can be used as a soil conditioner. The amount of biogas and the quality of digestates obtained vary according to the feedstock used. More biogas will be produced if the feedstock is putrescible, which means it is more liable to decompose. The use of sewage and manure produces less biogas as the animal that produced it has already removed some of the energy content.

Fermentation, followed by distillation, is the biological conversion process used for converting sugars to ethanol or, depending on the microbial strain, other low molecular weight alcohols. Most ethanol fermentation is based on Baker’s yeast (*Saccharomyces cerevisiae*), which requires simple (monomeric) sugars as raw material. Conventional yeast fermentation produces 0.51 kg of ethanol from 1 kg of any of the C6 sugars, such as glucose and mannose, or sucrose.

Polymeric carbohydrates are also present in all cell walls of the plant and potentially provide the most abundant source of carbon for bioenergy and biofuel production available on earth. However, in this form the sugars are not readily accessible, existing in the form of fibres, sometimes interlinked with lignin, and additional steps of pretreatment and hydrolysis are required to release the sugars for fermentation.

Fermentation and distillation to produce ethanol from sugar have been at the heart of the brewing and of the wine and spirit industries for a long time in human history. The same well-developed and efficient procedures have been used effectively to produce alcohols that can be used as fuels for internal combustion engines.

8.5.2.4 Chemical Conversion

Essentially, biodiesel is the fatty acid methyl esters (FAME) created from various oil-containing crops. Transesterification is the major chemical conversion process that produces biodiesel. The truth is that lipids and oils can all be utilised as feedstock for the production of biodiesel, whether they are produced directly by crops or are sourced from processed vegetable oil from the food industry.

The first step in making biodiesel is pressing the crop to obtain a liquid oil fraction and an oil cake byproduct, which can be fed to cattle. Because of their extremely high viscosity, poor thermal and hydrolytic stability, and unfavourable ignition characteristics, liquid vegetable oils can be utilised directly as engine fuels, but this needs engine modification. In order to convert the huge, branched molecular structure of the oils into smaller, straight-chained molecules resembling those of regular diesel, transesterification is used. There are three primary paths: the oil is transformed into its fatty acids and then into biodiesel via (i) base-catalyzed transesterification, (ii) direct, acid-catalyzed transesterification, and (iii) third-party transesterification.

8.5.3 Brief Description of the Some Biofuel Crops

8.5.3.1 Corn - The majority of the ethanol is produced with this crop. Warm water is mixed after the corn kernels have been ground. Then yeast is included. The mixture ferments, or turns into an energy source in the form of alcohol, thanks to the yeast. Ethanol produced from maize or sugarcane has the advantage of generating less carbon monoxide, nitrogen oxide, and sulphur into the atmosphere when compared to energy products like gasoline. Additionally, ethanol lowers smog, which might make people's lives healthier, particularly in urban areas.

8.5.3.2 Rapeseed - Biofuels are made with the help of rapeseed oil. For this, rapeseed is first crushed or processed. Nowadays, rapeseed oil is a widely used biodiesel fuel. In fact, Canola has an advantage over Rapeseed in the market. Canola is another variety of rapeseed. Unlike other rapeseed varieties, canola has less uric acid, making it healthier for both people and animals to consume.

Since most vegetable oils contain a higher percentage of saturated fat, which results in crystal formation and lower engine efficiency, biodiesel produced from vegetable oil generally does not perform well in cold climates. Canola oil has less saturated fat than other cooking oils, which makes it difficult for ice to form in colder climates.

8.5.3.3 Sugarcane - Sugarcane, in addition to corn, is used to make ethanol. Ethanol made from sugarcane is six times less expensive than ethanol made from corn.

8.5.3.4 Palm Oil - This edible oil is made from the palm tree fruit and is one of the most energy-efficient biodiesel fuels. When compared to gasoline, biodiesel made from palm oil is better for the environment since it produces less carbon dioxide into the atmosphere.

8.5.3.5 Jatropha - Another major source of biofuel since it has features that can help the world become less reliant on crude oil. When water is scarce, the Jatropha shrub grows swiftly and lives without much difficulty. Furthermore, Jatropha seeds contain 40 percent oil.

The Jatropha bush has a 50-year lifespan, and it can thrive even if the area is infested with pests or suffers from drought. Surprisingly, this plant is the focus of India's biodiesel business, which finally benefits the farming community financially. Scientific estimates indicate that roughly 2.47 acres (1 hectare) of Jatropha can produce around 0.83 tons or **752 kilograms to 2.20 tons**, i.e. 1995.81 kilograms of oil.

8.5.3.6 Soybean - This crop is processed into soyabean oil, which is then used to make biodiesel. Soybean oil provides the majority of biodiesel used in industry in the United States. Motor vehicles, particularly heavy equipment and buses, may run on pure soybean biodiesel or a blend of biodiesel and diesel, and soybean biodiesel is environmentally better than maize biodiesel, according to the **National Academy of Sciences**.

8.5.3.7 Cotton seed – It's the oil that comes from crushing cotton seeds. After that, the cotton oil is converted into biodiesel. According to studies, more than 1 gallon (3.78 litres) of cottonseed is required to replace one gallon (3.78 litres) of normal diesel fuel. Cottonseed generates 35 gallons (132.5 litres) of oil per acre, according to University of California specialists, which is approximately 33 percent less than rapeseed oil.

8.5.3.8 Sunflower - Sunflower seed crop is rich in oil, therefore this oilseed turns out be an important biofuel crop. According to the National Sunflower Association, 1 acre, i.e. 0.4 hectares of sunflowers can produce 600 pounds (272.1 kilograms) of oil. Refineries either process the sunflower oil into biodiesel or utilize the plant waste as biomass, and then involve fueling factories and power plants.

8.5.3.9 Wheat - Wheat is used in manufacturing Ethanol. In the US, nearly 90% of ethanol is produced through the corn. Therefore wheat contributes less in conversion to ethanol. In Europe, the use of wheat as an energy crop is on the rising trend.

8.5.3.10 Switch Grass -Another biofuel crop, it has the ability to lessen global warming while lowering the world's reliance on oil. Switch grass, which contains cellulose, performs better than maize at producing ethanol by using less energy than conventional or fossil fuels. Additionally, there is a significant decrease in greenhouse gas emissions because cellulose ethanol has higher energy content than corn ethanol. In the long run, scientists are experimenting with a variety of methods to determine switch grass as the best alternate source of energy. However, there are no big switch grass plantations or farms at present.

8.6 SUMMARY

- Sugar and starch, are two forms of carbohydrates, belong to a class of organic substances that typically include carbon, hydrogen, and oxygen in the ratio 1:2:1. They are the major source of energy in many organisms, serve to store energy, and are structural components in some organisms.
- There are two main types of carbohydrates found in food sources which are called basic carbohydrates, which include necessary sugars, and complex carbohydrates, which include starch and fibre. Carbohydrates make up the bulk of the dry weight of plants. Although there are many kinds, sugars, starches and the celluloses predominate.
- The term "sugar" refers broadly to a variety of carbohydrates with varying degrees of sweetness. Sugars, however, form a single unit of the atom, sometimes known as a monosaccharide. These sugar atoms can exist as glucose, fructose, or mannose. Then, starches again form lengthy chains of solitary sugar atoms joined by a strong linkage.
- Sugar is essential to human nutrition. It makes the ideal nourishment because it can be easily assimilated by the body. Its primary benefit is as an energy-producing substance, and it is particularly well suited for use after strenuous activity.
- The only commercial sources of sugar are sugar cane, sugar beet, sugar maple, maize, sorghum, and a few palms. All of these plant species store sucrose as their primary form of sugar.
- Sugarcane is the primary source of sugar, it is tropical by origin and cultivated in all the warm nations. India, Cuba, Pakistan and Brazil are the main producers of sugar.
- Sugarcane belongs to the genus *Saccharum* L., traditionally placed in the tribe Andropogoneae of the grass family (Poaceae).
- Sugar- and starch producing crops produce sugar or starch in large amounts, and therefore are grown commercially Sugarcane is an industrial crop, produced from either sugarcane (*Saccharum* spp.) or sugar beet (*Beta vulgaris*).
- Starch is a polysaccharide or complex carbohydrate that is made up of a chain of glucose molecules joined together in covalent bond called glycosidic bonds. It is one of the principal nutrients or supplements that should be added to our day to day diet since they give us enough energy for the entire day. For commercial purposes, starch is obtained from the stem tubers of potato *(Solanum tuberosum*), the root tubers of cassava (*Manihot esculenta*) and the rhizomes of arrowroot (*Maranta arundinacea*).
- Cereal starch is mainly obtained from bread wheat (*Triticum aestivum*), maize (Zea mays), and rice (*Oryza sativa*). Starch from the sago palm, Metroxylon sagu, provides the staple food for the populations of the South-western part of the Pacific Ocean.

- Bioenergy crops are defined as any plant material used to produce bioenergy. They are grown and maintained at lower costs for biofuel production. These crops have the capacity to produce a large volume of biomass, high energy potential, and can be grown in marginal soils. They can positively impact the environment to reduce the level of carbon dioxide, emission of greenhouse gases and soil erosion.
- The bioenergy crops are classified into five types namely, first-, second- and third-generation bioenergy crops, dedicated energy crops and halophytes.
- The first-generation bioenergy crops include corn, sorghum, rapeseed and sugarcane, whereas the second-generation bioenergy crops are switchgrass, miscanthus, alfalfa, reed canary grass, Napier grass and other plants.
- The third-generation bioenergy crops contain boreal plants, crassulacean acid metabolism (CAM) plants, eucalyptus and microalgae.

8.7 SELF ASSESSMENT QUESTIONS

8.7.1 Multiple Choice Questions

1. What are energy crops?
a) Crops that produce energy
b) Crops grown to feed people
c) Crops grown to remove Pathogen
d) Crops grown to be used in generating energy

2. Bioenergy is the energy obtained from………………….
a) Herbaceous plant b) Natural Gas
c) Biomass d) Coal

3. Which of the following is the type of bioenergy?
a) Fossil fules b) Solar energy
c) Biofules d) Chemical energy

4. Raising crops for the production of ethanol is known as
a) Chemical energy b) Energy cropping
c) Energy plantation d) Biomass production

5. Which of the following optons include energy crops?
a) Sugarcane, Millets and Tamato
b) Sugarcane, Potato and Tapioca
c) Sugarcane, Potato and Tamato

d) Sugarcane, Tapioca and Banana

6. Production of bio ethanol is through fermentation of ________ and starch components

a) Sugar b) Alcohol

c) Spices d) Milk

7. Silvargrass and Alfalfa is the example of

a) Third-generation bioenergy crops

b) First-generation bioenergy crops

c) Traditional bioenergy crops

d) Second-generation bioenergy crops

8. Source for arrowroot starch are

a) *Maranta arundinaceae* b) *Curcuma angustifolia*

c) *Zumia floridana* d) All of the above

9. Modern sugarcane cultivation which is done for the production of sugar is interspecific hybrids founded on between

a) *Saccharum officinarum* and *S. robustum*

b) *Saccharum spontaneum* and *S. officinarum*

c) *Saccharum officinarum* and *S. barberi*

d) None of the above

10. Bagasse is used to make which of the following

a) Furfural b) Paper

c) Both a & b d) Farinha

8.7.2 Fill in the Blanks

1) GCC stands……………….

2) The Indian Institute of Sugarcane Research (IISR) situated in …………………

3) *S. spontaneum* and *S. robustum are knoem as…………….*

4) …………………..is the thick, syrupy byproduct that remains after sucrose has been extracted from cleared sugar juice (syrup).

5) Starch is a polysaccharide that is made up of a chain of glucose molecules joined together in covalent bond called……………………….

6) Fresh potatoes are important source of …………………..

7) *Manihot esculenta*, commonly called ………………….

8) Bioenergy can contribute to ………………the overall consumption of fossil fuels.

Answer key:

8.7.1: 1-(d); 2-(c); 3-(c); 4-(b); 5-(b); 6-(a); 7-(d); 8-(d); 9-(b); 10-(c)

8.7.2: 1) Global Carbon Council; 2) Lucknow.; 3) wild cane; 4) Molasses; 5) glycosidic bonds; 6) Vitamins B and C; 7) cassava; 8) reducing

8.8 REFERENCES

- Allen, C.J. et al. (1997), "New technologies for sugar milling and by-product modification", In: Keating, B.A. and J.R. Wilson (eds.), *Intensive Sugarcane Production: Meeting the Challenges Beyond 2000*, Proceedings of the Sugar 2000 Symposium, CABI, Wallingford. ". United Kingdom., pp. 267-285.
- Almazan, O. (1994), "Past, present and future of sugarcane by-products in Cuba", *Cooperative Sugar*, 26(4):253-258.
- American Sugar Beet Growers Association. (1998). http://members.aol.com/asga/sugarbeet.htm
- Annual Report 2020-21. Department of Agriculture, cooperation and Farmer's welfare, Minister of Agriculture & Farmer's welfare, Govt. of India, Krishi Bhawan, New Delhi. pp8.
- Bichsel, S.E. (1987), An overview of the U.S. sugar beet industry. Proceedings of the Symposium on the chemistry and processing of sugar beet. Denver, Colorado. 108 pp.
- Boe, A. and Beck, D.L. (2008), Yield components of biomass in switchgrass. *Crop Sci.*, 48: 1306-1311.
- Broadley, R. et al. (2004), Subtropical Banana Grower's Handbook, Queensland Department of Primary Industries, pp. 1-206.
- Calcino, D.V. (1994), Australian Sugarcane Nutrition Manual, SRDC/BSES, Indooroopilly, Australia.
- Cheavegatti-Gianotto, A. et al. (2011), "Sugarcane (*Saccharum X officinarum*): A reference study for the regulation of genetically modified cultivars in Brazil", *Tropical Plant Biology*, 4(1): 62-89. *http://dx.doi.org/10.1007/s12042-011-9068-3*.
- Conab (2011), "Acompanhamento da Safra Brasileira: Cana-de-acucar", Report No. Terceiro Levantamento, January.
- Cooke, D.A. and Scott, R.K. (1993), The Sugar Beet Crop. Chapman and Hall, Publishers. 675 pp.
- D'Hont, A. et al. (1998), "Determination of basic chromosome numbers in the genus *Saccharum* by physical mapping of ribosomal RNA genes", *Genome*, 41(2): 221-225. *http://dx.doi.org/10.1139/g98-023*.
- Deepchand, K. (2005), "Sugar cane bagasse energy cogeneration–Lessons from Mauritius", Parliamentarian Forum on Energy Legislation and Sustainable Development, Cape Town, South Africa.

- Duke, J.A. (1983), Handbook of Energy Crops: *Beta vulgaris* L. http://www.hort.purdue.edu/newcrop/duke_energy/Beta_vulgaris.html.
- Dunlap, C.E. and C.D. Callihan (1969), "Fermentative utilization of sugar cane bagasse", *American Society of Sugar Cane Technologists,* Vol. 16, pp. 82-90, available at: *https://archive.org/stream/americansocietyo1617amer/americansocietyo1617amer_djvu.txt*
- Eisenbies, M.H., Vance, E.D., Aust, W.M., and Seiler, J.R. (2009), Intensive utilization of harvest residues in Southern Pine Plantations: quantities available and implications for nutrient budgets and sustainable site productivity. *Bioenergy Research*. 2: 90-98.
- FAOSTAT (2014), FAO Statistics online database, "Production / Crops, - sugarcane, Year 2014", Food and Agriculture Organization of the United Nations, http://faostat3.fao.org/home/E (accessed 10 February 2016).
- Forster, V., Marrese, D., Staska, K., Trinks, K., and Stander, J.R. (1997). Petition for Determination of Non regulated Status: Glufosinate Tolerant Sugar Beet, Transformation Event T120-7. AgrEvo USA Comapany, Wilmington, Delaware. 67 pp.
- Goldemberg, J. and Guardabassi, P. (2009), "Are biofuels a feasible option?", *Energy Policy*, 37(1): 10-14. *http://dx.doi.org/10.1016/j.enpol.2008.08.031*.
- Gopinathan, M.C. and Sudhakaran, R.B., (2009), "Biofuels: Opportunities and challenges in India", *In Vitro Cellular & Developmental Biology-Plant*, 45(3): 350-370. *http://dx.doi.org/10.1007/s11627-009-9217-7*.
- https://faculty.ucr.edu/~legneref/botany/sugcellu.htm.
- https://krishijagran.com/agripedia/what-are-biofuel-crops-or-energy-crops/.
- https://krishijagran.com/agripedia/what-are-biofuel-crops-or-energy-crops/
- https://www.indiaspend.com/nearing-desertification-marathwada-isnt-giving-up-water-guzzling sugarcane-heres-why/
- https://www.istockphoto.com/photos/sugar-cane-%28saccharum-officinarum%29.
- https://www.slideshare.net/RashmiYadav45/sugar-yeilding-plants
- https://www.slideshare.net/zohaibkhan404/energy-crops-their-worldwide-usage-data and?from_action=save
- IPCC. 2007, Climate Change (2007) Impacts, adaptation and vulnerability. In: Parry M.L., Canziani O.F., Palutikof J.P., Linden van der P.J., Hanson C.E. (edt.)Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, pp 976.
- Jakob, K., Zhou, F., and Paterson, A.H. (2009), Genetic improvement of C4 grasses as cellulosic biofuel feedstocks. *In Vitro Cell Dev Biol.,* 45: 291-305.
- Kansal, S. (1998), "Factors determining Indian sugar production and its comparative advantage", Proceedings of the Fiji/FAO 1997 Asia Pacific Sugar Conference, Food and Agriculture Organization, Rome, pp. 78-92, www.fao.org/docrep/005/x0513e/x0513e16.htm.
- Karp, A. and Shield, I., (2008). Bioenergy from plants and the sustainable yield challenge. *New Phytologist.* 179, pp.15-32.

- Karve, P. et al. (2001), "A chain of technologies for using sugarcane trash as a household fuel", *Boiling Point*, 47: 16-18.
- Khan, N.A. and Amin, W.H.W.M. (2005), "Kinetics of cadmium uptake by sugarcane bagasse", *Waste and Wastewater Asia*, September/October.
- Khattri, S.D. and Singh, M.K. (1999), "Colour removal from dye wastewater using sugarcane dust as an adsorbent", *Adsorption Science and Technology*, 17(4): 269-282.
- Laird, D.A., Brown, R.C., Amonette, J.E. and Lehmann, J. (2009), *Biofuels, Bioproducts and Biorefining*, 3: 547.
- Lal, R. (2008a), Sequestration of atmospheric CO2 in globalcarbon pools. *Energy* & *Environmental Science*.1, pp. 86-100.
- Mackintosh, D. (2000), "Sugar milling", In: Hogarth, M. and Allsopp, P. (eds.), *Manual of Cane Growing*, Bureau of Sugar Experiment Stations, Indooroopilly, Australia, pp. 369-377, *www.sugarresearch.com.au/icms_docs/166965_Chapter_17_Sugar_Milling.pdf*.
- Mellado-Mojica, E., Lopez, M. G (2015), "Identification, classification, and discrimination of agave syrups from natural sweeteners by infrared spectroscopy and HPAEC-PAD". *Food Chemistry*. 167: 349–57. doi:10.1016/j.foodchem.2014.06.111. PMID 25148997
- Oliver, R.J., Finch, J.W., and Taylor, G. (2009), Second generation bioenergy crops and climate change: a review of the effects of elevated atmospheric CO2 and drought on water use and the implications for yield. *GCB Bioenegy* 1: 97-114.
- Onelio, F. et al. (2011), "Fertilizing effects of combined application of sugarcane ash with mycorrhiza fungi and compost in different Cuban soils", Tropentag 2010: World Food System –A Contribution from Europe, 14-16 September, Zurich, Switzerland.
- Orellana, C. and Neto, R.B. (2006), "Brazil and Japan give fuel to ethanol market", *Nature Biotechnology*, 24: 232, *http://dx.doi.org/10.1038/nbt0306-232*.
- Pate, F.M. (1982), "Value of treating bagasse with steam under pressure for cattle feed", *Tropical Agriculture*, 59:293-297.
- Ram, S.G., Parthiban, K.T., Kumar, R.S., Thiruvengadam, V. and Paramathma, M. (2008), Genetic diversity among *Jatropha* species as revealed by RAPD markers. *Genet Resour Crop Evol.*, 55: 803-809.
- Sainz, M.B. and Dale, J. (2009), "Towards cellulosic ethanol from sugarcane bagasse", *Proceedings of the Australian Society of Sugar Cane Technologists*, 31:18-23. *www.assct.com.au/media/pdfs/2009-M-29-Sainz-Dale.pdf*.
- Schubert, C. (2006), "Can biofuels take center stage?", *Nature Biotechnology*, 24: 777-784.
- Smeets, E.M.W., Faaij, A.P.C., Lewandowski, I.M. And Turkenburg, W.C., (2007), A bottom-up assessment and review of global bio-energy potential to 2050. *Progress in Energy and Combustion Science*. 33, pp.56-106.
- Smith, D.M., Inman-Bamber, N.G., and Thorburn, P.J. (2005). Growth and function of the sugarcane root system, *Field Crops Research*, 92: 2–3, pp 169-183

- Smith, G.A., (1987). Sugar beet: Principles of Cultivar Development. Fehr, W.R. (ed.) MacMillan Publishing Company, pp.577-625.
- Sreenivasan, T.V. et al. (1987), "Cytogenetics", In: Heinz, D.J. (ed.), *Sugarcane Improvement through Breeding*, Elsevier, Amsterdam, Netherlands, pp. 211-253.
- Toxopeus, H. (1984), De historie van de Europese kruisbloemige en bietegewassen. Bedrijfsontwikkeling 15:537-542.
- UN Industrial Development Organisation (2002), "Hydrolysed bagasse to make animal feed.
- Freeman, D.W., Duerr, E.O., and Leber, K.M. (1992), "Use of bagasse as a feed input to semi-intensive shrimp growout ponds", *Journal of the World Aquaculture Society*, 23(1):23-30. *http://dx.doi.org/10.1111/j.1749-7345.1992.tb00747.x*.
- Watson, L., and Dallwitz, M.J. (1992), "The Families of Flowering Plants: Descriptions, Illustrations, Identification, and Information Retrieval." Version: 15th October 1998. http://biodiversity.uno.edu/delta/.
- Wright, M.M. and Brown, R.C., Boateng, A.A. (2008), Distributed processing of biomass to bio-oil for subsequent production of Fischer-Tropsch liquids. *Biofuels, Bioproducts and Biorefining*, 2:229-38.

8.9 SUGGESTED READINGS

- Pandey, B.P., Economic Botany, S. Chand & Company Ltd. India.
- Kochhar, S.L., Economic Botany: A comprehensive study, Cambridge University Press, 2016 680 pages.

8.10 TERMINAL QUESTIONS

8.10.1 Short Answer Type Questions

1. Explain in brief about four primary methods of converting energy into usable forms.
2. Write a note on the economic importance of sugarcane.
3. Describe in brief about Cassava?
4. Write a short note on sources of commercial starch.
5. Describe in brief about biofuel crops.
6. Write a short note on characteristics of bioenergy Crops

8.10.2 Long Answer Type Questions

1. What are Sugar crops? Explain about sugarcane in detail.
2. What are Energy crops? Describe in detail its characteristics and types.
3. Give a detailed account on starch and starch products.
4. Describe in detail about sugar beet with its economic importance

BLOCK-3 PLANT CONSERVATION

UNIT-9 PRINCIPLES OF CONSERVATION

Contents

9.1 OBJECTIVES

After reading this unit students will be able-

- to know about the Conservation of plant biodiversity
- to learn about the Principles of conservation
- to learn about Extinction of plant biodiversity
- to understand about the Environmental status of plant based on International Union for Conservation of Nature (IUCN)

9.2 INTRODUCTION

Biodiversity constitutes the most important working component of a natural ecosystem. It helps to maintain ecological processes and deals with the degree of nature's variety in the biosphere. The term biodiversity was first coined by Water & Rosen in 1985. Biodiversity refers to the variability among living organisms and constitute terrestrial, marine, aquatic ecosystems and the ecological complexes. It reflects the number, variety & variability of living organisms and includes diversity within species (genetic diversity), between species (species diversity) and between ecosystems (ecosystem diversity).

India is a mega diverse country having only 2.4% of the world's land area but accommodates 7-8% species of flora and fauna. It includes more than 45,000 species of plants and 91,000 species of animals. It is situated at the tri-junction of the Afro-tropical, Indo-Malayan and Palearctic realms, all of these support rich biodiversity. India is a diverse nation, which has 10 biogeographic zones. A comparison of status of biodiversity between Indian and World scenario is depicted in **Table 1**.

Table 1: Comparison between the Number of Species in India & the World

Group	Number of Species in India	Number of Species in the World	(%) India
Mammals	350	4627	7.6
Birds	1224	9702	12.6
Reptiles	408	6550	6.2
Amphibians	197	4522	4.4
Fishes	2546	21,730	11.7
Flowering Plants	15,000	2,50,000	6

(Source: Centre for Ecological Sciences, Indian Institute of Science http://ces.iisc.ernet.in)

Plant Biodiversity

With an estimated 29,105 species of algae, bryophytes, pteridophytes, gymnosperms and angiosperms, India holds 9.13% of the world's known floral diversity in these groups. The richness of Indian plant species as compared with the world is shown in the table given below-

Table: Indian plant species as compared with the world

	India	**World**	**% India**
Algae	7244	40800	17.75
Bryophytes	2504	14500	17.27
Pteridophytes	1267	12000	10.56
Gymnosperms	74	650	11.38
Angiosperms	17926	250000	7.17
Total	29015	317950	9.13

(Source: India's Fifth National Report to the Convention on Biological Diversity, MoEF, GOI)

As defined by the Convention on Biological Diversity (CBD), Biodiversity also known as biological diversity is "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems"

Biodiversity is the life support system. Organisms depend on it for the air to breathe, the food to eat, and the water to drink. Wetlands filter pollutants from water, trees and plants reduce global warming by absorbing carbon, and bacteria and fungi break down organic material and fertilize the soil. It has been empirically shown that native species richness is linked to the health of ecosystems, as is the quality of life for humans. The ecosystem services of biodiversity is maintained through formation and protection of soil, conservation and purification of water, maintaining hydrological cycles, regulation of biochemical cycles, absorption and breakdown of pollutants and waste materials through decomposition, determination and regulation of the natural world climate.

Despite the benefits from biodiversity, today's threats to species and ecosystems are increasing day by day with alarming rate and virtually all of them are caused by human mismanagement of biological resources often stimulated by imprudent economic policies, pollution and faulty institutions in-addition to climate change. To ensure intra and intergenerational equity, it is important to conserve biodiversity. Some of the existing measures of biodiversity conservation include; reforestation, zoological gardens, botanical gardens, national parks, biosphere reserves, germplasm banks and adoption of breeding techniques, tissue culture techniques, social forestry to minimize stress on the exploitation of forest resources.

Plants are universally recognized as a vital part of the world's biological diversity and an essential resource for the planet. In addition to the small number of crop plants used for basic food and fibres, many thousands of wild plants have great economic and cultural importance and potential, providing food, medicine, fuel, clothing and shelter for vast numbers of people throughout the world. Plants play a key role in maintaining the planet's basic environmental balance and ecosystem stability and provide an important component of the habitats for the world's animal life. At present, a complete inventory of the plants of the world has not been assembled, but it is estimated that the total number of vascular plant species may be of the order of 300,000. Of particular concern is the fact that many are in danger of extinction, threatened by habitat transformation, over-exploitation, alien invasive species, pollution and climate change. The disappearance of such vital and large amounts of biodiversity sets one of the greatest challenges for the world community: to halt the destruction of the plant diversity that is so essential to meet the present and future needs of humankind. The Global Strategy for Plant Conservation is proposed to address this challenge. While the entry point for the Strategy is conservation, aspects of sustainable use and benefit-sharing are also included.

Biodiversity can be classified under Three Levels (Types)

1. Species diversity
2. Genetic diversity
3. Ecosystem or ecological diversity.

Species diversity

Species diversity Species diversity refers to biodiversity at the most basic level and is the ‘variety and abundance of different types of individuals of a species in a given area. Species is a basic unit of classification and is defined as a group of similar organisms that interbreed with one another and produce viable offspring. These may include bacteria, viruses, fungi, plants (algae, bryophytes, pteridophytes, gymnosperms, angiosperms) and animals (unicellular protozoans, arthropods, mollusks, fish, herps and mammals). The tropical areas support more diverse plant and animal communities than other areas. The regions that are rich in species diversity are called hotspots of biodiversity.

Genetic diversity

It refers to the variations among the genetic resources of the organisms. Every individual of a particular species differs from each other in their genetic constitution. That is why every human looks different from each other. Similarly, there are different varieties in the same species of rice, wheat, maize, barley, etc.

Ecological diversity

An ecosystem is a collection of living and non-living organisms and their interaction with each other. Ecological biodiversity refers to the variations in the plant and animal species living together and connected by food chains and food webs. It is the diversity observed among the different ecosystems in a region. Diversity in different ecosystems like deserts, rainforests, mangroves, etc., includes ecological diversity.

9.3 CONSERVATION OF PLANT BIODIVERSITY

Conservation needs different strategies, they can be species based or habitat based or ecosystem based. Some species are given importance at national level while some need treatment at international levels. Most of the conservation is done at *in situ* and *ex situ* conditions. In this unit we will discuss what these conditions mean, what is the difference between them and what are the methods and techniques used. We have also described some important projects such as project tiger and how this project had helped in increasing tiger populations. Some techniques such as seed bank and tissue culture are also proving very helpful in conservation of plants which fulfill several of our needs.

In-situ conservation means "on-site conservation". It is the process of protecting an endangered plant or animal species in its natural habitat, either by protecting or cleaning up the habitat itself, or by defending the species from predators. The benefit to *in-situ* conservation is that it maintains recovering populations in the surroundings where they have developed their distinctive properties. Wildlife conservation is mostly based on *in-situ* conservation. This involves the protection of wildlife habitats. Also, sufficiently large reserves are maintained to
enable the target species to exist in large numbers. The population size must be sufficient to enable the necessary genetic diversity to survive within the population.

***Ex-situ* conservation** means, literally "off-site conservation". It is the process of protecting population of an endangered species of plant or animal by removing it from an unsafe or threatened habitat and placing it, or part of it, under the care of humans. While *ex-situ* conservation is comprised of some of the oldest and best known conservation methods known to human, it also involves newer, sometimes controversial laboratory methods. *Ex-situ* conservation, while helpful in human's efforts to sustain and protect our environment, is rarely enough to save a species from extinction. It is to be used as a last resort or as a supplement to *in-situ* conservation because it cannot recreate the habitat as a whole: the entire genetic variation of a species, its symbiotic counterparts, or those elements which, over time, might help a species adapt to its changing surroundings. Furthermore, *ex-situ* conservation techniques are often costly. Plants and animals living in *ex-situ* breeding grounds have no natural defense to the diseases and pests new to the species.

Strategies for Conservation of Biodiversity

1- Maintain flawless (viable) landscapes - the aim of this strategy is to provide protection along with priority actions such as repair historic impacts or removal of threats and improve the ecological integrity by maintaining long-term viability of the more intact (core) landscapes of the region.

2- Reverse declines – here the strategy involves in bringing back the lost ecological sites so as to reinstate critical ecological processes by improving the habitat of shrubby systems and open woodland and eventually help in bringing back declining species

3- Recover threatened species and ecological communities –the aim of this strategy is to fortify the perseverance of species that are on the verge of extinction in the wild thus indirectly protecting ecosystems from failing. The work here is done not at a community level but is based on individual species as each has their own unique requirements for survival. The actions are based on implementing measures for increasing their distribution and abundance while trying to put a stop to their decline.

4- Control emerging threats –the aim is to educate people of the threats that are knocking at the door before the final extinction happens. Some of the threats are climate change and the introduction of invasive species.

5- The submissive adaptation to improve the elasticity of natural systems and allowing them to adapt to change can be done by various activities such as by maintaining functional areas and ensuring that there are representatives for the environments and that the associated processes for removing and minimizing existing stressors are done. Active adaptation can be done by influencing ecological processes to moderately direct the nature of adaptation by activities like restoring habitats and system dynamics. Identifying and protecting climate refugees and managing/restoring connectivity by increasing the matrix permeability and functional connectivity. Transformation can be done to fundamentally alter ecological processes in an aim to prevent irreversible changes from happening. The relevant activities would include keystone structuring of revised systems (eco-engineering and transformation) and species translocations or ex situ conservation (genetic preservation).

Biodiversity Conservation Policies and Programmes: National and International

The IUCN (International Union for Conservation of Nature), helps governments at national by preparing national biodiversity policies, whereas it provides advice to environmental conventions such as the Convention on Biological Diversity, CITES and the Framework Convention on Climate Change in an international level. It also councils the UNESCO on natural world heritage.

There is a formally accredited permanent observer mission to the United Nations in New York. It’s been stated in their website that they are the only international observer organization in the UN General Assembly with proficiency regarding issues concerning the environment, specifically biodiversity, nature conservation and sustainable natural resource use.

It has solemn relations with the Council of Europe, the Food and Agriculture Organization of the United Nations (FAO), the International Maritime Organization (IMO), the Organization of

American States (OAS), the United Nations Conference on Trade and Development (UNCTAD), the United Nations Environment Programme (UNEP), the UNEP World Conservation Monitoring Centre (UNEP-WCMC), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Intellectual Property Organization (WIPO) and the World Meteorological Organization (WMO).

9.4 PRINCIPLES OF CONSERVATION

The biological conservation revolves around the five basic principles:

• Preserve diversity of species/communities
• Prevent extinction of populations/species
• Maintain ecological complexity
• Allow evolution to continue
• Recognize the intrinsic value of biological diversity.

Principle 1 Protection of species and species' subdivisions will conserve genetic diversity: At the population level, the important processes are ultimately genetic and evolutionary because these maintain the potential for continued existence of species and their adaptation to changing conditions. In most instances managing for genetic diversity directly is impractical and difficult to implement. The most credible surrogate for sustaining genetic variability is maintaining not only species but also the spatial structure of genetic variation within species (such as sub-species and populations). Maintenance of populations distributed across a species' natural range will assist in conserving genetic variability. This ensures the continuation of locally adapted genetic variants. Retaining a variety of individuals and species permits the adaptability needed to sustain ecosystem productivity in changing environments and can also be get further diversity (future adaptability). This will be particularly important given climate change; for example, the genetic potential of populations at the northern edge of their range in biological conservation. may be particularly important to help facilitate species adaptation to changes. Species that are collapsing towards the edge (versus centre) of their range and disjunct populations (where a local population is disconnected from the continuous range of the species) are also particularly important to consider, given climate change, in order to conserve genetic diversity and enable adaptation.

Principle 2 Maintaining habitat is fundamental to conserving species: A species habitat is the ecosystem conditions that support its life requirements. Our understanding of habitat is based on our knowledge of a species' ecology and how that determines where a species is known to occur or likely to occur. Habitat can be considered at a range of spatial and temporal scales that include specific microsites (e.g., occupied by certain invertebrates, bryophytes, some lichens), large heterogeneous habitats, or occupancy of habitat during certain time periods (e.g., breeding sites, winter range areas). Therefore conserving habitat requires a multi-scale approach from regions to landscapes to ecosystems to critical habitat elements, features and structures.

Principle 3 Large areas usually contain more species than smaller areas with similar habitat: The theory of island biogeography illustrates a basic principle that large areas usually contain more species than smaller areas with similar habitat because they can support larger and more viable populations. The theory holds that the number of species on an island is determined by two factors: the distance from the mainland and island size. These would affect the rate of extinction on the islands and the level of immigration. Other factors being similar (including distance to the mainland), on smaller islands the chance of extinction is greater than on larger ones. This is one reason why larger islands can hold more species than smaller ones. In the context of applying the theory more broadly, the “island” can be any area of habitat surrounded by areas unsuitable for the species on the island. Therefore a system of areas conserved for biodiversity that includes large areas can effectively support more viable populations.

Principle 4 All things are connected but the nature and strength of those connections vary: Species play many different roles in communities and ecosystems and are connected by those roles to other species in different ways and with varying degrees of strength. It is important to understand key interactions. Some species (e.g., keystone species) have a more profound effect on ecosystems than others. Particular species and networks of interacting species have key, broad-scale ecosystem level effects while others do not. The ways in which species interact vary in addition to the 8 strengths of those interactions. Species can be predator and/or prey, mutualist or synergist. Mutualist species provide a mutually beneficial association for each other such as fungi that colonize plant roots and aid in the uptake of soil mineral nutrients. Synergistic species create an effect greater than that predicted by the sum of effects each is able to create independently. The key issue is that it is important to determine which among the many interactions are the strong ones because those are the ones toward which attention needs to be directed.

Principle 5 Disturbances shape the characteristics of populations, communities, and ecosystems: The type, intensity, frequency and duration of disturbances shape the characteristics of populations, communities and ecosystems including their size, shape and spatial relationships. Natural disturbances have played a key role in forming and maintaining natural ecosystems by influencing their structure including the size, shape and distribution of patches. The more regions, landscapes, ecosystems and local habitat elements resemble those that were established from natural disturbances, the greater the probability that native species and ecological processes will be maintained. This approach can be strengthened by developing an improved understanding of how ecosystems respond to both natural and anthropogenic disturbances, thus creating opportunities to build resilience in the system. For example, high frequency, low intensity fires have shaped ponderosa pine ecosystems while low frequency, high intensity fires have shaped lodgepole pine ecosystems. Maintaining these ecosystems means restoring fire and/or designing management practices such as harvesting to reduce the differences between a managed landscape and a landscape pattern created by natural disturbance. Since ecosystems can change dramatically at the site level due to natural disturbances, considering their composition and structure of habitats at the landscape level may be more useful.

For terrestrial ecosystems, this means taking into account: • species composition; • the amount and patch size distribution; • the variety and proportion of seral stages of terrestrial habitat from young to old; and • the diversity of within community structure (e.g., a variety of amounts of snags and coarse woody debris within forest stands). It is important to recognize that for some less mobile species, distribution of habitat is potentially as influential as amount of habitat (i.e., patch size; connectivity.

Principle 6 Climate influences terrestrial, freshwater and marine ecosystems: Climate is usually defined as all of the states of the atmosphere seen at a place over many years. Climate has a dominant effect on biodiversity as it influences meteorological variables like temperature, precipitation and wind with consequences for many ecological and physical processes, such as photosynthesis and fire behaviour. For example, major temperature fluctuations in surface waters in the Pacific Ocean due to El Nino climatic events can influence weather and significantly warm temperatures throughout much of biological conservation. This in turn can increase some wildlife populations or impact the migration timing of some migratory bird populations.

9.5 EXTINCTION

A species is extinct when the last existing member dies. Extinction therefore becomes a certainty when there are no surviving individuals that can reproduce and create a new generation. Extinction is the termination of a kind of organism or of a group of kinds (taxon), usually a species. The moment of extinction is generally considered to be the death of the last individual of the species, although the capacity to breed and recover may have been lost before this point. Because a species' potential range may be very large, determining this moment is difficult, and is usually done retrospectively. This difficulty leads to phenomena such as Lazarus taxa, where a species presumed extinct abruptly "reappears" (typically in the fossil record) after a period of apparent absence.

More than 99% of all species that ever lived on Earth, amounting to over five billion species, are estimated to have died out. It is estimated that there are currently around 8.7 million species of eukaryote globally, and possibly many times more if microorganisms, like bacteria, are included. Notable extinct animal species include non-avian dinosaurs, saber-toothed cats, dodos, mammoths, ground sloths, thylacines, trilobites, and golden toads.

Through evolution, species arise through the process of speciation—where new varieties of organisms arise and thrive when they are able to find and exploit an ecological niche—and species become extinct when they are no longer able to survive in changing conditions or against superior competition. The relationship between animals and their ecological niches has been firmly established. A typical species becomes extinct within 10 million years of its first appearance, although some species, called living fossils, survive with little to no morphological change for hundreds of millions of years.

In June 2019, one million species of plants and animals were at risk of extinction. At least 571 species have been lost since 1750, but likely many more. The main cause of the extinctions is the destruction of natural habitats by human activities, such as cutting down forests and converting land into fields for farming.

9.5.1 Causes of Extinction

As long as species have been evolving, species have been going extinct. It is estimated that over 99.9% of all species that ever lived are extinct. The average lifespan of a species is 1–10 million years, although this varies widely between taxa. There are a variety of causes that can contribute directly or indirectly to the extinction of a species or group of species. "Just as each species is unique", write Beverly and Stephen C. Stearns, "so is each extinction ... the causes for each are varied—some subtle and complex, others obvious and simple". Most simply, any species that cannot survive and reproduce in its environment and cannot move to a new environment where it can do so, dies out and becomes extinct. Extinction of a species may come suddenly when an otherwise healthy species is wiped out completely, as when toxic pollution renders its entire habitat unliveable; or may occur gradually over thousands or millions of years, such as when a species gradually loses out in competition for food to better adapted competitors. Extinction may occur a long time after the events that set it in motion, a phenomenon known as extinction debt.

Assessing the relative importance of genetic factors compared to environmental ones as the causes of extinction has been compared to the debate on nature and nurture. The question of whether more extinctions in the fossil record have been caused by evolution or by competition or by predation or by disease or by catastrophe is a subject of discussion; Mark Newman, the author of *Modeling Extinction*, argues for a mathematical model that falls in all positions. By contrast, conservation biology uses the extinction vortex model to classify extinctions by cause. When concerns about human extinction have been raised, for example in Sir Martin Rees' 2003 book **Our Final Hour,** those concerns lie with the effects of climate change or technological disaster.

Currently, environmental groups and some governments are concerned with the extinction of species caused by humanity, and they try to prevent further extinctions through a variety of conservation programs. Humans can cause extinction of a species through overharvesting, pollution, habitat destruction, introduction of invasive species (such as new predators and food competitors), overhunting, and other influences. Explosive, unsustainable human population growth and increasing per capita consumption are essential drivers of the extinction crisis. According to the International Union for Conservation of Nature (IUCN), 784 extinctions have been recorded since the year 1500, the arbitrary date selected to define "recent" extinctions, up to the year 2004; with many more likely to have gone unnoticed. Several species have also been listed as extinct since 2004.

1-Genetics and demographic phenomena

If adaptation increasing population fitness is slower than environmental degradation plus the accumulation of slightly deleterious mutations, then a population will go extinct. Smaller populations have fewer beneficial mutations entering the population each generation, slowing adaptation. It is also easier for slightly deleterious mutations to fix in small populations; the resulting positive feedback loop between small population size and low fitness can cause mutational meltdown.

Limited geographic range is the most important determinant of genus extinction at background rates but becomes increasingly irrelevant as mass extinction arises.[42] Limited geographic range is a cause both of small population size and of greater vulnerability to local environmental catastrophes.

Extinction rates can be affected not just by population size, but by any factor that affects evolvability, including balancing selection, cryptic genetic variation, phenotypic plasticity, and robustness. A diverse or deep gene pool gives a population a higher chance in the short term of surviving an adverse change in conditions. Effects that cause or reward a loss in genetic diversity can increase the chances of extinction of a species. Population bottlenecks can dramatically reduce genetic diversity by severely limiting the number of reproducing individuals and make inbreeding more frequent.

2-Genetic pollution

Extinction sometimes results for species evolved to specific ecologies that are subjected to genetic pollution—i.e., uncontrolled hybridization, introgression and genetic swamping that lead to homogenization or out-competition from the introduced (or hybrid) species. Endemic populations can face such extinctions when new populations are imported or selectively bred by people, or when habitat modification brings previously isolated species into contact. Extinction is likeliest for rare species coming into contact with more abundant ones; interbreeding can swamp the rarer gene pool and create hybrids, depleting the purebred gene pool (for example, the endangered wild water buffalo is most threatened with extinction by genetic pollution from the abundant domestic water buffalo). Such extinctions are not always apparent from morphological (non-genetic) observations. Some degree of gene flow is a normal evolutionary process; nevertheless, hybridization (with or without introgression) threatens rare species' existence.

The gene pool of a species or a population is the variety of genetic information in its living members. A large gene pool (extensive genetic diversity) is associated with robust populations that can survive bouts of intense selection. Meanwhile, low genetic diversity (see inbreeding and population bottlenecks) reduces the range of adaptions possible. Replacing native with alien genes narrows genetic diversity within the original population, thereby increasing the chance of extinction.

3-Habitat degradation

Habitat degradation is currently the main anthropogenic cause of species extinctions. The main cause of habitat degradation worldwide is agriculture, with urban sprawl, logging, mining, and some fishing practices close behind. The degradation of a species' habitat may alter the fitness landscape to such an extent that the species is no longer able to survive and becomes extinct. This may occur by direct effects, such as the environment becoming toxic, or indirectly, by limiting a species' ability to compete effectively for diminished resources or against new competitor species.

Habitat degradation through toxicity can kill off a species very rapidly, by killing all living members through contamination or sterilizing them. It can also occur over longer periods at lower toxicity levels by affecting life span, reproductive capacity, or competitiveness.

Habitat degradation can also take the form of a physical destruction of niche habitats. The widespread destruction of tropical rainforests and replacement with open pastureland is widely cited as an example of this; elimination of the dense forest eliminated the infrastructure needed by many species to survive. For example, a fern that depends on dense shade for protection from direct sunlight can no longer survive without forest to shelter it. Another example is the destruction of ocean floors by bottom trawling.

Diminished resources or introduction of new competitor species also often accompany habitat degradation. Global warming has allowed some species to expand their range, bringing unwelcome competition to other species that previously occupied that area. Sometimes these new competitors are predators and directly affect prey species, while at other times they may merely outcompete vulnerable species for limited resources. Vital resources including water and food can also be limited during habitat degradation, leading to extinction.

4-Predation, competition, and disease

In the natural course of events, species become extinct for a number of reasons, including but not limited to: extinction of a necessary host, prey or pollinator, inter-species competition, inability to deal with evolving diseases and changing environmental conditions (particularly sudden changes) which can act to introduce novel predators, or to remove prey. Recently in geological time, humans have become an additional cause of extinction (some people would say premature extinction of some species, either as a new mega-predator or by transporting animals and plants from one part of the world to another. Such introductions have been occurring for thousands of years, sometimes intentionally (e.g. livestock released by sailors on islands as a future source of food) and sometimes accidentally (e.g. rats escaping from boats). In most cases, the introductions are unsuccessful, but when an invasive alien species does become established, the consequences can be catastrophic. Invasive alien species can affect native species directly by eating them, competing with them, and introducing pathogens or parasites that sicken or kill them; or indirectly by destroying or degrading their habitat. Human populations may themselves act as invasive predators. According to the "overkill hypothesis", the swift extinction of the megafauna in areas such as Australia (40,000 years before present), North and South America (12,000 years before present), Madagascar, Hawaii (AD 300–1000), and New Zealand (AD 1300–1500), resulted from the sudden introduction of human beings to environments full of animals that had never seen them before and were therefore completely unadapted to their predation techniques.[51]

5-Coextinction

Coextinction refers to the loss of a species due to the extinction of another; for example, the extinction of parasitic insects following the loss of their hosts. Coextinction can also occur when a species loses its pollinator, or to predators in a food chain who lose their prey. "Species coextinction is a manifestation of one of the interconnectednesses of organisms in complex ecosystems ... While coextinction may not be the most important cause of species extinctions, it is certainly an insidious one." Coextinction is especially common when a keystone species goes extinct. Models suggest that coextinction is the most common form of biodiversity loss. There may be a cascade of coextinction across the trophic levels. Such effects are most severe in mutualistic and parasitic relationships. An example of coextinction is the Haast's eagle and the moa: the Haast's eagle was a predator that became extinct because its food source became extinct. The moa were several species of flightless birds that were a food source for the Haast's eagle.

6-Climate change

Extinction as a result of climate change has been confirmed by fossil studies. Particularly, the extinction of amphibians during the Carboniferous Rainforest Collapse, 305 million years ago. A 2003 review across 14 biodiversity research centers predicted that, because of climate change, 15–37% of land species would be "committed to extinction" by 2050. The ecologically rich areas that would potentially suffer the heaviest losses include the Cape Floristic Region and the Caribbean Basin. These areas might see a doubling of present carbon dioxide levels and rising temperatures that could eliminate 56,000 plant and 3,700 animal species. Climate change has also been found to be a factor in habitat loss and desertification.

7-Sexual selection and male investment

Studies of fossils following species from the time they evolved to their extinction show that species with high sexual dimorphism, especially characteristics in males that are used to compete for mating, are at a higher risk of extinction and die out faster than less sexually dimorphic species, the least sexually dimorphic species surviving for millions of years while the most sexually dimorphic species die out within mere thousands of years. Earlier studies based on counting the number of currently living species in modern taxa have shown a higher number of species in more sexually dimorphic taxa which have been interpreted as higher survival in taxa with more sexual selection, but such studies of modern species only measure indirect effects of extinction and are subject to error sources such as dying and doomed taxa speciating more due to splitting of habitat ranges into more small isolated groups during the habitat retreat of taxa approaching extinction. Possible causes of the higher extinction risk in species with more sexual selection shown by the comprehensive fossil studies that rule out such error sources include expensive sexually selected ornaments having negative effects on the ability to survive natural selection, as well as sexual selection removing a diversity of genes that under current ecological conditions are neutral for natural selection but some of which may be important for surviving climate change.

9.6 ENVIRONMENTAL STATUS OF PLANT BASED ON INTERNATIONAL UNION FOR CONSERVATION OF NATURE (IUCN)

International Union for Conservation of Nature (IUCN): The International Union for Conservation of Nature and Natural Resources (IUCN), with its headquarters are in Gland, Switzerland, is an international organization working in the field of nature conservation and sustainable use of natural resources. It is involved in data gathering and analysis, research, field projects, advocacy, and education. IUCN's mission is to "influence, encourage and assist societies throughout the world to conserve nature and to ensure that any use of natural resources is equitable and ecologically sustainable". It plays a role in the implementation of several international conventions on nature conservation and biodiversity. IUCN is the world's main authority on the conservation status of species. The IUCN Red List of Threatened Species The IUCN Red List of Threatened Species (also known as the IUCN Red List or Red Data List), Established in 1964, has evolved to become the world's most comprehensive information source on the global conservation status of animal, fungi and plant species. It is a critical indicator of the health of the world's biodiversity. It uses a set of criteria to evaluate the extinction risk of thousands of species and subspecies. These criteria are relevant to all species and all regions of the world. Far more than a list of species and their status, it is a powerful tool to inform and catalyze action for biodiversity conservation and policy change, critical to protecting the natural resources we need to survive. It provides information about range, population size, habitat and ecology, use and/or trade, threats, and conservation actions that will help inform necessary conservation decisions. The IUCN Red List is produced by the Red List Partnership: Bird Life International; Botanic Gardens Conservation International; Conservation International; International Union for Conservation of Nature (IUCN); Nature Serve; Microsoft; Royal Botanic Gardens, Kew; Sapienza University of Rome; IUCN Species Survival Commission; Texas A&M University; Wildscreen; and Zoological Society of London

IUCN Categories of Threatened Species

The International Union for Conservation of Nature (IUCN) is a leading international organization working in the field of nature conservation and sustainable use of natural resources. It was established in 1948 and evolved as world's largest environment network and plays a key role to save biodiversity at global level. IUCN includes over 1400 members of both governmental and non-governmental organizations. The IUCN publishes IUCN Red List of Threatened Species. In 1969, India became a State Member of IUCN. The Office of IUCN India located in New Delhi was established in 2007.

The IUCN Red List of Threatened Species, founded in 1964, is the world's most comprehensive inventory of the global conservation status of biological species. As per the relative risk of extinction, the red data list contains 7 categories. There are categories given below along with some Indian species.

Extinct (EX) – No known individuals remaining

Extinct in the Wild (EW) – Known only to survive in captivity, or as a naturalized population outside its historic range

Critically Endangered (CR) – Extremely high risk of extinction in the wild

Endangered (EN) – High risk of extinction in the wild.

Vulnerable (VU) – High risk of endangerment in the wild

Near Threatened (NT) – Likely to become endangered in the near future

Least Concern (LC) or Lowest risk - Does not qualify for a more at risk category.

Red Data Book

The Red Data Book is a public document that is created for recording endangered and rare species of plants, animals, fungi as well as some local subspecies that are present in a particular region.

The Red Data Book helps us in providing complete information for research, studies and also for monitoring the programs on rare and endangered species and their habitats. This book is mainly created to identify and protect those species which are on the verge of extinction.

History of the Red Data Book

The name of this book has its origins in Russia, it was originally known as the Red Data Book of the Russian Federation or the RDBRF. The book was based on research conducted between 1961 and 1964 by biologists in Russia. Hence, it is also called the Russian Red Data Book.

Currently, the International Union for Conservation of Nature maintains the Red Data Book. IUCN is the world's most detailed inventory centre of the global conservation status of biological species. The **International Union for Conservation of Nature** (**IUCN**) was founded in 1948 with an aim to maintain a complete record of every species that ever lived.

The Red Data Book contains the complete list of threatened species. The main aim behind this documentation is to provide complete information for research and analysis of different species.

The Red Data Book contains colour-coded information sheets, which are arranged according to the extinction risk of many species and subspecies.

- Black represents species that are confirmed to be extinct.
- Red represents species that are endangered
- Amber for those species whose status is considered to be vulnerable
- White is assigned for species that are rare
- Green for species that were formerly endangered, but their numbers have started to recover
- Grey coloured for the species that are classified as vulnerable, endangered, or rare but sufficient information is not available to be properly classified.

In a nutshell, the Red Data Book indexes species as:

- Threatened
- Not threatened
- Unknown

Furthermore, The Red Data Book also has information as to why a species has become extinct along with the population trends and the extent of its range (distribution).

Advantages of the Red Data Book

- It helps in identifying all animals, birds and other species about their conservation status.
- It is used to evaluate the population of a particular species.
- The data available in this book can be used to evaluate the taxa at the global level.
- With the help of this book, we can estimate the risk of taxa becoming globally extinct.
- Provides a framework or guidelines for implementing protective measures for endangered species.

Disadvantages of the Red Data Book

- The information available in the Red Data Book is incomplete. Many species, both extinct and extant are not updated in this book.
- The source of the book's data has been speculated and has been mired in controversy.
- This book maintains the complete record of all animals, plants, other species but it has no information about the microbes.

Red Data Book of India

Red Data Book of India includes the conservation status of animals and **plants** which are endemic to the Indian subcontinent. The data for this book is provided through surveys which are conducted by the Zoological Survey of India and the Botanical Survey of India under the guidance of the Ministry of Environment, Forest and Climate Change.

Red Book Data: List of Threatened Flora and Fauna in India

- Sumatran Rhinoceros (***Dicerorhinus sumatrensis***)
- Hangul deer (***Cervus canadensis hangul***)

- Himalayan Brown or red Bear ***(Ursus arctos isabellinus)***
- Pygmy Hog (***porcula salvania)***
- Andaman White-toothed Shrew ***(Crocidura andamanensis***)
- Kondana Soft-furred Rat (***Millardia kondana)***
- Elvira Rat or Large Rock Rat (***Cremnomys Elvir***).
- Namdapha Flying Squirrel (***Biswamoyopterus biswasi***)
- Malabar large-spotted civet(***Viverra civettina)***
- Red panda (***Ailurus fulgens)***
- Asiatic wild dog (***Cuon alpines***).
- Wild ass ***(Equus hemionus)***
- Brow-antlered deer***(Rucervus eldii)***
- Golden Langur(***Trachypithecus geei)***
- White-bellied Musk Deer(***Moschus leucogaster)***
- Hispid hare/ Assam rabbit (***Caprolagus hispidus)***
- Indian hog deer (***Axis porcinus)***
- Lion tailed macaque (***Macaca Silenus)***
- Tibetan antelope ***Pantholops hodgsonii)***
- Nilgiri langur (***Trachypithecus johnii)***
- Nilgiri tahr (***Nilgiritragus hylocrius)***
- Ganges river dolphin (***Platanista gangetica***)

Threatened flora species are:

- Milkwort (*Polygala irregularis*)and Environmental Conservation- II
- Bird's foot (*Lotus corniculatus*)
- Assam catkin yew (*Amentotaxus assamica)*
- Moa, skeleton, fork fern, and whisk fern (*Psilotum nudum*)
- Umbrella tree, kudai vel (Tamil) (*Acacia planifrons*)
- Indian mallow, thuthi (Tamil) and athibalaa (Sanskrit) (*Abutilon indicum*)
- Ebony tree (*Diospyros celibica*)
- Malabar lily (*Chlorophytum malabaricum*)
- Spider wort (*Belosynapsis vivipara*)
- Malayuram, Malavuram (*Pterospermum reticulatum*)
- Jeemikanda (Gujarat) (*Ceropegia odorata*)
- Musli (*Chlorophytum tuberosum*)

9.10 REFERENCES

- https://www.cbd.int/decision/cop/?id=7183

- https://profiles.uonbi.ac.ke/mmuchai/files/jwl330_princ_of_biodiv_conserv_muchai_notes_sep_2019_ok_final.pdf
- https://ncert.nic.in/textbook/pdf/lebo115.pdf
- https://epgp.inflibnet.ac.in/epgpdata/uploads/epgp_content/S000004BY/P000092/M020115/ET/1493613342PrinciplesofConservation.pdf
- https://byjus.com/biology/red-data-book/
- https://en.wikipedia.org/wiki/Extinction

9.8 TERMINAL QUESTIONS

1-Define Biodiversity. Discuss about the Conservation of plant biodiversity.

2-Describe the Principles of conservation.

3- Give a detail account of causes of Extinction.

4- Write a detail note on International Union for Conservation of Nature (IUCN).

5- What is Red Data book? Describe in detail about the Red data book.

UNIT-10 STRATEGIES FOR *IN-SITU* CONSERVATION

Contents

10.1 OBJECTIVES

After reading this unit student will be able-

- to know about the International efforts and Indian initiatives for conservation of wild biodiversity
- to learn about the Protected areas in India- Sanctuaries, National parks, Biosphere reserves, Sacred groves, Wetlands, Mangroves and Coral reefs
- to understand about the strategies for *in-situ* conservation

10.2 INTRODUCTION

India is an extremely diverse country with only 2.4% of the world's land area, but is home to 7-8% of flora and fauna species. It includes more than 45,000 plant species and 91,000 animal species.

The term biodiversity was first introduced by Water & Rosen in 1986 in the National forum at Smithsonian Institute, Washington. Biodiversity refers to the variability between living organisms and the forms of terrestrial, marine, aquatic ecosystems and ecological complexes. It reflects the number, variety and variability of living organisms and includes diversity within species (genetic diversity), between species (species diversity) and between ecosystems (ecosystem diversity). In other words, the occurrence of different types of ecosystems, habitats, species, genes, gene pools in a particular place and various parts of earth is called biodiversity. The United Nations Conference on Environment and Development, held in Rio de Janeiro in 1992, brought the topic of biodiversity conservation into the global spotlight and helped put this important issue on the agenda of world leaders. The World Conservation Union has tried to clarify the definition of "biodiversity" and demonstrate its value: IUCN interprets biodiversity as more than just "genetic makeup", covering all species of plants, animals and microorganisms and the ecosystems (including ecosystem processes) to which they belong. Commonly considered at three levels—genetic diversity, species diversity, and ecosystem diversity—biodiversity refers to the complex mosaic of environmental materials and gradients that interact with the organisms that surround them to sustain life at all levels (McNeely, 1990).

The protection and management of biodiversity in pursuit of sustainable resource development is called biodiversity conservation. Biodiversity conservation has three main objectives: 1. Preservation of species diversity. 2. Sustainability of species and ecosystems. 3. Sustaining essential life and ecological processes. The conservation of biological diversity is the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of the genetic resources and the protection of species from extinction or harm.

Conservation of biodiversity is carried out in different ways. They are-in situ conservation and ex-situ conservation. Ex-situ methods focus on species conservation in botanical gardens, zoos, gene banks, and captive breeding programs. In-situ methods use protected areas as "repositories" of biological information. Many scientists and conservationists believe that until methods are available to easily determine which of the millions of species and varieties will have economic value, conservation *in-situ* through the protection of natural areas should be the primary means of maintaining these resources. However, a rigid approach to conservation is almost impossible to implement and even less likely to be sustained over time. It would be more appropriate to pursue proactive alternatives to high-impact development activities and implement carefully thought-out strategies for in-situ methods to incorporate protected areas into the development mix in light of population growth trends and the need of economic development, particularly in developing countries.

10.3 INTERNATIONAL EFFORTS AND INDIAN INITIATIVES

The proper maintenance of biodiversity and raise awareness of its importance is essential for survival on earth.

10.3.1 INTERNATIONAL EFFORTS FOR BIODIVERSITY CONSERVATION

Biodiversity is the number and variety of living organisms considered to all levels, from genetic variants belonging to the same species through array of species, to array of genera, families and still higher taxonomic level. It includes a wide range of ecosystems that include both communities of organisms within specific habitats and the physical conditions in which they live. There are several international initiatives and structures for the conservation or protection of biodiversity, some of which have been adopted by law in the countries that have signed the agreement. Some of the major and high impact conventions are listed below:

The World Heritage Convention

The convention concerning the Protection of the World Cultural and Natural Heritage was adopted in 1972 at the UNESCO. It came into force in 1975. India approved the convention in 1977. It enhances public knowledge, awareness and appreciation for the heritage sites. Currently, there are 194 State Parties to the convention.

The International Union for Conservation of Nature and Natural Resources (IUCN) (now called as World Conservation Union (WCU)

It was established in 1948 to bring together governmental and non-governmental agencies from around the world to conserve biodiversity and natural resources and promote their sustainable use at the local, national and international levels. 81 countries from all over the world are its members and the headquarters of the organization is located in Gland, Switzerland.

The Convention on International Trade in Endangered Species (CITES)

The Convention was signed in Washington DC in March, 1973, and in July 1975 CITES entered in force, basically to prohibit the overexploitation and international trade in wild species. CITES has been among the conservation agreements with the largest membership, with now 184 parties, and nearly 37,000 species protected by the convention.

Convention on Biological Diversity (CBD)

The Convention entered into force on December 29, 1993 with the objectives of conservation of biological diversity, sustainable use of resources and fair and equitable sharing of benefits arising from the use of nature resources. 196 countries have adopted this convention, including India.

International Treaty for Plant Genetic Resources for Food and Agriculture (ITPGRFA)

The International Treaty on Plant Genetic Resources, was adopted in 2001, also known as the International Seed Treaty, is a comprehensive international agreement in accordance with the Convention on Biological Diversity, aimed at ensuring food security through conservation, exchange and sustainable use of the world's plant genetic resources for food and agriculture, and fair and equitable sharing of the benefits derived from their use to achieve sustainable agriculture and food security.

Ramsar Convention on wetlands of International Importance

The Convention was adopted in the Iranian city of Ramsar in 1971 and came into force in 1975. This is an international collaboration of 171 parties to the Ramsar Convention. It provides the framework for the conservation and wise use of wetlands and their resources.

The Convention on Migratory Species (CMS)

The Convention on Migratory Species of Wild Animals (CMS) was signed in 1979. It provides a global platform for the conservation and sustainable use of migratory animals and their habitats. Managed by UNEP, CMS develops and promotes regional and global agreements relating to terrestrial, aquatic and avian migratory species throughout their range.

In the period from the early 1970s to the early 1980s, at a time when the new, high-yielding varieties were rapidly replacing local varieties in many parts of the South, there was growing concern that an irreplaceable resource was being lost and that concerted efforts were needed at the international level to conserve this resource.

International conservation organizations play an important role in disseminating environmental information widely. IUCN originated the idea of compiling lists of endangered species to draw attention to the plight of endangered species. These lists are known as the Red Data Book

(RDB). Of these, species fall into one of several categories ranging from "extinct" to "vulnerable" or "rare", depending on the level of threat to their existence. The first internationally applicable RDB was published in 1996. 'Red' stands for 'danger' and the concept has been adopted by many different countries, including the UK. RDBs open doors for government agencies responsible for protecting the environment, as well as non-governmental organizations (NGOs) interested in maintaining diversity.

10.3.2 NATIONAL INITIATIVES FOR BIODIVERSITY CONSERVATION

In India, various laws regulate wildlife conservation, as well as overall biodiversity. Chief among these is the Wildlife Protection Act of 1972, made to protect wild animals, birds, and plants. State and Union government of India has developed a number of Wildlife Acts for the enforcement of conservation strategies (Table-1).

Table-1: Wildlife Acts

S.No.	Act	Year
1-	Madras Wild Elephant Preservation Act	1873
2-	All India Elephant Preservation Act	1879
3-	The Wild Birds and Animals Protection act	1912
4-	Bengal Rhinoceros Preservation Act	1932
5-	Assam Rhinoceros Preservation Act	1954
6-	Wildlife (Protection) Act	1972 (amended in 1983, 1986 and 1991)
7-	Forest Conservation Act	1980 (amended in1988)
8-	The Environment (Protection) Act	1986
9-	The Biodiversity Act	2002 (implemented in 2004)
10-	The National Environmental Policy	2006

The main government advisory body is the Indian Board of Wildlife (IBWL) of India, established in 1952 and reconstituted under the chairmanship of the Prime Minister in 1991; it oversees the control of unethical activities that could harm biodiversity, the establishment of protected areas, and the sustainable use of ecological services.

Other non-governmental organizations include, among others, the World Wide Fund for Nature, the Wildlife Preservation Society of India, the Dehradun and Bombay Natural History Society, and so on, as contribute to the management and preservation of natural flora and fauna.

Steps Taken By Government for Biodiversity Protection

The Indian government has taken several steps to protect biodiversity. Among the important measures are:

1-Wildlife Protection Act, 1972 is an Act passed by the Indian Parliament is enacted to protect plants, birds and animals. The Wildlife Protection Act is a framework law to protect wild plants and animals. This law includes provisions relating to the protection of plants and animals, hunting, harvesting and other ancillary matters related to this law. It has six schedules spread across India. Under this law, different types of penalties are also imposed for violations of the law contained therein. This Act consists of 66 articles and six appendices.

2- Wetlands Rules (Conservation and Management), 2010. Drafted by the Ministry of Environment and Forests to make sure better conservation and management and prevent degradation of existing wetlands in India.

3- National Plan for Conservation of Aquatic Ecosystems (NPCA): launched in 2015, aims for comprehensive conservation and restoration of lakes and wetlands.

4- The Wildlife Crime Control Bureau was constituted on 2007, created to complement the existing state machinery to deal with the wildlife crime consequences beyond state and national borders. It controls illegal trade in wildlife, including endangered species.

5- The Indian Government has banned the use of diclofenac in veterinary medicine due to the rapid population decline of gyps vulture. The Bombay Natural History Society has started a programme to conserve these vulture species.

6- Integrated Development of Wildlife Habitats (IDWH) is an ongoing, centrally funded program that includes three components: Protected Area Support, Protecting Wildlife outside Protected Areas, and Restoration Programs to Save Critically Endangered Species and Habitats.

7- The National Biological Diversity Act (NBA) 2002 aims to protect biological resources manage their sustainable use and promote fair and equitable sharing of benefits from the use of biological resources and knowledge with the local communities.

8- The Central Bureau of Investigation (CBI) has been empowered under the Wild Life (Protection) Act 1972 to arrest and prosecute wildlife offenders.

9- The State Governments have been requested to increase patrolling in and around the Protected Areas and strengthen field formations.

10- The Government of India has also undertaken important wildlife protection projects such as Tiger Project, Elephant Project, Crocodile Protection Project, UNDP Sea Turtle Project, Rhinoceros Project, the great Indian bustard and other ecological development projects. Some of them are explained in detail below:

It was shortly ago when human intervention was minimal and wildlife thrived without any danger surrounding its existence. However, with the time and expansion of industrialization, farming, ranching and other development projects, we are at a stage where several species of animals have been declared extinct and some other species are about to become extinct. Habitat loss and destruction, habitat fragmentation and degradation, large-scale killing of wildlife for their fur, bones, teeth, flesh and meat all result in great loss of wildlife around the world. This therefore requires the government to take immediate actions and measures to conserve wildlife.

This requires careful control and a rational approach to wildlife protection. Some steps are as follows:

Important Wildlife Protection Projects by Indian Government

Project Tiger

Project Tiger was launched by the Government of India with the support of WWF-International in 1973 to ensure that the Bengal tiger population is well maintained in its natural habitat. It was launched from Jim Corbett National Park in Uttarakhand. It was a first-of-its-kind project in India to conserve India's tiger population and protect it from poaching and other threats. This project is funded by the Ministry of Environment, Forests and Climate Change. The National Tiger Conservation Authority (NTCA) is the immediate controlling authority. According to the 2018 census, the number of tigers is 2,967, which is 33% more than the 2014 census and more than double the 2006 census. Project Tiger looks after 50 tiger reserves covering 72,749 square kilometers, green cover to preserve the Royal Bengal Tiger population.

The tiger reserve action plan is based on the following key principles:

1-Complete elimination of all human interference from core areas, as well as careful rationalization of activities in buffer zones

2-Restricting habitat management practices to only restore ecosystem damaging activities

3- Monitoring of changes over time in flora and fauna for research.

Project Elephant

This initiative was launched in 1991-1992 by the Government of India's Ministry of Environment and Forests to provide financial and technical support to wildlife management efforts with the goal of ensuring the long-term survival of elephant populations in their natural habitats. There have been lines drawn to restore elephants' lost and degraded habitats, including the construction of migration corridors, the mitigation of man-elephant conflict, and the establishment of a data base on elephant migration and population dynamics. It also aims to improve the quality of life of people who live near habitats through sustainable development. The Project is being mainly implemented in 16 States / UTs , viz. Andhra Pradesh, Arunachal Pradesh, Assam, Chhattisgarh, Jharkhand, Karnataka, Kerala, Maharashtra, Meghalaya, Nagaland, Orissa, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh, West Bengal.

Gir Lion Project

The Gir forest in Saurashtra peninsula of Gujarat is the only surviving habitat of the Asian lion (Panther leon persica). A five year plans scheme was thus prepared in 1972 by the government of Gujarat for this project. In 1968, there were 177 lions in the Gir. This number increased to 180 in 1974.

Crocodile Conservation Project

The project arose from a proposal to develop a crocodile farming industry in India. Dr. H.R. Bustard, an FAO expert, was invited as a consultant by the Government of India in 1974. Based on his report and guidance, the Crocodile Conservation Project was launched in various states in 1975. The Project has not only produced a large number of crocodiles, but it has also contributed to conservation in a variety of related fields. This scheme focuses on the gharial, the longest living crocodile, which lives in rivers in the northern plains of the Indian subcontinent, the saltwater crocodile, also known as a man-eater, which is thought to be the largest crocodile species on Earth, and mugger crocodiles, which live in freshwater habitats such as lakes, marshes, and rivers. The overall strategy for crocodile rehabilitation was to protect them in their natural habitats, quickly rebuild the population through captive breeding (rear and release), and train personnel for the job. This conservation project for Indian crocodiles is quite remarkable because it appears to be restocking approximately 4000 gharial/Alligator, 1800 mugger/crocodile, and 1500 saltwater crocodiles.

UNDP Sea Turtle Project

The sea turtle project began in 1999 at the Indian Institute of Wildlife in Dehradun, with the collaboration of UNDP and India's Ministry of Environment, Forest, and Climate Change. This is a geographically focused project that establishes guidelines for development activities in the area with the goal of protecting turtle breeding areas from other types of disruptions.

Steps Taken By Indian Government to Protect Biodiversity

Along with the above-mentioned wild animal conservation projects, the Government of India has also initiated a few schemes to protect biodiversity and reduce the mortality of critically endangered, endangered, and threatened animals. Here are a few important steps taken by the Government of India to protect wildlife:

1. The Wildlife Protection Act of 1972 established Protected Areas such as National Parks, Sanctuaries, Conservation Reserves, and Community Reserves for wildlife and imposed penalties on those who engaged in illegal hunting.
2. The Wetland Rules 2010 have been drafted to protect wetlands in India. The Central Government has also launched the National Plan for Conservation of Aquatic Eco-System, which assists states in the proper management of all wetlands.
3. The Wildlife Crime Control Bureau was established to combat the illegal trade of wildlife and endangered species.
4. The Central Government initiated the Integrated Development of Wildlife Habitat Scheme, which was later modified by including a new component, Recovery of Endangered Species, which included animals such as Hangul/stag deer in Jammu and Kashmir, Vultures in Punjab, Haryana, and Gujarat, Snow Leopard in Jammu and Kashmir, Himachal Pradesh, Uttarakhand, and Arunachal Pradesh, Swiftlet in Andaman and Nicobar Islands, Nilgiri Tahr in Tamil Nadu, Sangai Deer in Manipur.

5. The state government is also given financial and technical assistance to improve the protection and conservation of the specified species.
6. State governments have been asked to reinforce field formations and increase patrolling in and around Protected Areas.
7. The Government of India increased anti-poaching efforts and implemented a special patrolling strategy for the monsoon season. Also, an anti-poaching squad will be deployed.
8. The Government of India established the National Tiger Conservation Authority to strengthen tiger conservation. A Special Tiger Protection Force (STPF) has also been formed and is operating in Karnataka, Maharashtra, and Odisha.
9. E-surveillance has begun in Assam's Kaziranga National Park and the borders of Madhya Pradesh Ratapani Wildlife Sanctuary.

Some steps in the direction of Wildlife conservation that can be taken are as follows:

1- Survey and collection of all the information about wildlife, specially their number and growth, inventory, taxonomically validate, and threats should be assessed.
2- Protect habitat by preserving forests and also define the boundaries of their natural habitat.
3- Establishment of a network of protected areas, including national parks, wildlife sanctuaries, conservation areas, and community reserves.
4- Keep wildlife safe from pollution and natural hazards and also prohibit all hunting and capture of wildlife.
5- Impose restrictions on the export and import of wildlife products, as well as harsh penalties for those who engage in these activities.
6- Establishing specific sanctuaries for specific animals whose numbers are declining and whose protection must be ensured; and finally, raising public awareness in order to attain their participation in terms of volunteering and funding.
7- Raise national and international awareness about wildlife conservation.
8- A system of wildlife management is adopted through trained personnel.
9- Establishing Biosphere Reserves to protect representative ecosystems.

The government and non-governmental organisations (NGOs) in India are taking a keen interest in wildlife conservation. The 1972 Wild Life Protection Act includes several provisions for wildlife conservation. Aside from that, every year from October 1st to 7th, a Wild Life Conservation Week is celebrated.

10.4 PROTECTED AREAS IN INDIA FOR CONSERVATION OF WILD BIODIVERSITY

One of the strategies used in environmental resource management is the establishment of protected areas. A protected area is defined as "an area of land and sea dedicated specifically to the protection and maintenance of biological diversity, as well as natural and associated cultural resources, and managed through legal or other effective means" (IUCN, 1994. P.7). There are numerous ways to establish protected areas. The two most common mechanisms are government action (often at the national level, but also at the regional or local level) and land purchases by private conservation organisations. Partnerships between governments of developing countries in the tropics and international conservation organizations, multinational banks, and governments of developed countries are becoming more common. They provide funding, training, and scientific and management expertise to help developing countries establish protected areas.

The primary reasons for establishing and managing protected areas are as follows:

- Scientific research
- Wilderness protection
- Preservation of species and genetic diversity
- Maintenance of environmental services
- Protection of specific natural and cultural features.
- Tourism and recreation
- Education
- Sustainable use of resources from natural ecosystems
- Maintenance of cultural and traditional attributes.

Conserving rare and endangered species, it is necessary to protect their natural habitats and take specific measures to prevent unplanned exploitation and illegal trade. The two known conservation methods are in-situ (conservation in natural habitats) and ex-situ (preservation outside of natural areas).

In situ conservation: The protection of organisms in their natural habitat, either by protecting or cleaning up the habitat itself, or by defending the species from predators, is known as in-situ or "on-site" conservation. The *in-situ* approach need to protect a group of typical ecosystems or biodiversity-rich regions through a network of protected areas. These are the terrestrial or marine areas that are solely dedicated to the preservation of biological diversity and its associated resources. Because the species are being conserved in their natural habitats, this is the best method. Natural habitats are declared as protected areas. In conservation biology, *in-situ* wildlife conservation is a comprehensive system of protected areas. There are many different categories of protected areas that are managed with different goals to benefit society. This system of protected areas includes different categories such as: Wildlife Sanctuaries, National Parks, Biosphere Reserves, Sacred groves, Wetlands, Mangrove, Coral reefs etc.

Protected areas in India

Protected Area	Status
National parks	106
Wild life sanctuaries	565
Biosphere reserves	18
Wetlands	64
Mangroove *	38
Coral reefs *	04

(Source: www.wiienvis.nic.in (As on December, 2021)

(Source: National Wildlife Database, Wildlife Institute of India)

10.4.1- Wildlife Sanctuaries

Wildlife sanctuaries in India are home to rare species of flora and fauna. A wildlife sanctuary is an area where animals are protected and kept safely in their natural habitats. Animal capture, killing, and poaching are all strictly prohibited in these areas. A wildlife sanctuary is a location that is solely for the use of wildlife. It includes animals, birds, reptiles, insects, and other creatures. Most importantly, they keep endangered and rare animals so that they can live in peace while maintaining a viable population. Furthermore, no human activities or disturbances are permitted in these areas. The surroundings of wildlife habitats are also protected, with no disturbances permitted. Wildlife sanctuaries exist to protect natural habitats and the animals that inhabit them. The country has many beautiful sanctuaries that are surrounded by large rivers, forests, and mountains. In India, there are 565 existing wildlife sanctuaries covering an area of 122560.85 km^2, which is 3.73% of the geographical area of the country (National Wildlife Database, May. 2022).

Similar to National Parks, these are also government owned areas, but limited human activities such as harvesting of timbers, collection of forest products, cultivation of lands *etc.* are allowed in wildlife sanctuaries as long as these do not interfere with the wildlife environment.

Importance of Wildlife Sanctuaries

There are a number of reasons for establishing wildlife sanctuaries. Some of the reasons are listed below:

- They provide a safe place for animals, free from the threat of poaching and habitat destruction.
- Wildlife sanctuaries are established to protect endangered species.
- Protecting the animals in their natural environment is beneficial because it is difficult to always relocate them from their natural habitat
- Endangered species are closely monitored in wildlife sanctuaries. If they reproduce and multiply while under protection, a few specimens can be kept for breeding in conservation parks to ensure their survival.
- Biologist activities and research are permitted in wildlife sanctuaries.

- A few sanctuaries accept injured and abandoned animals and rehabilitate them before reintroducing them into the forest.
- Wildlife sanctuaries protect and preserve endangered species from humans and predators.
- Wildlife sanctuaries and national parks also serve as a location for researchers to conduct research on wildlife and their ecosystems.

Some Wildlife Sanctuaries in India

S.No.	Name of Wildlife Sanctuaries	State
1-	Bandipur Wildlife Sanctuary	Karnataka
2-	Bhitarkanika Wildlife Sanctuary	Orissa
3-	Gibbbon Wildlife Sanctuary	Assam
4-	Dachigam Wildlife Sanctuary	Jammu and Kashmir
5-	Sunderbans Wildlife Sanctuary	West Bengal
6-	Bharatpur Bird Sanctuary	Rajasthan
7-	Periyar Wildlife Samctuary	Kerela
8-	Mundanthurai Wildlife Sanctuary	Tamil Nadu
9-	Govind Wildlife Sanctuary	Uttarakhand
10-	Chilika Lake Bird Sanctuary	Odisha

10.4.2- National parks: National parks are set up for preserving flora, fauna and landscapes and historic objects of an area. It is a reserve of land, usually owned by a national government that protected from most human development and pollution. They are large areas of scenic and national beauty maintained for scientific educational and recreational use. They are not usually used for commercial extraction of resources. A national park is a protected area for wildlife where they can freely use the habitats and natural resources. Human intervention is not permitted in these protected areas. These reserves also prohibit hunting and other related activities.

The primary goal of a national park is to protect the natural environment of the area and to conserve biodiversity. An international organization, the International Union for Conservation on Nature (IUCN), and its world commission on protected areas, has defined "National parks as its category II type of protected areas. Hailey National Park was established in 1936 as India's first national park. The Indian government has the authority to designate an area as a national park if it has sufficient ecological, geomorphological and natural significance. All of these national parks are classified as protected areas by the International Union for the conservation of Nature (IUCN). According to the December 2020 survey, India has 106 national parks covering an area of 44,378 KM^2, which is 1.35 % of the country's geographical area.

Jim Corbett National Park

Jim Corbett National Park is appropriately known as the "paradise of tigers" as it is home to numerous tigers and has breathtaking landscapes with a wide variety of flora and fauna. Hailey national park was rechristened afterwards in honour of Jim Corbett (1875–1955), a renowned naturalist and conservationist who from 1907 to 1939 hunted down man-eating tigers in Kumaon region of Uttarakhand. The Jim Corbett National Park covers a total area of 1318.54 sq km and is located in the districts of Nainital and Pauri in Uttarakhand. The park is famous for royal Bengal tigers and Asiatic elephants. It contains over 586 species of resident and migratory species of birds making it one of the richest bird regions in India. Bird life international has declared the area as “important bird area”. The primary objective of the park's establishment was to safeguard Bengal tigers (Panthera tigris tigris). The Bengal Tiger, Asiatic Elephant, Leopard, Wild Boar, Sloth Bear, Jackal, Mongoose, and Crocodile are some of Corbett's most well-known native wildlife. The launch of the "Save the Tigers" project in India took place at Jim Corbett National Park. Project Tiger was established in 1973 with the stated goals of conserving existing ecosystems and preserving the ecological balance of the natural world. The goal of the project is to create a natural connection between people who live on the edges of national parks and wildlife sanctuaries and the animals and plants that live there.

Some Major National Parks in India

S.No.	**National parks**	**State**	**Prominent animal**
1-	Jim Corbett National Park	Uttarakhand	Royal Bengal Tiger
2-	Gir National Park	Gujarat	Asiatic Lion
3-	Kaziranga National Park	Assam	One-horned rhinoceros
4-	Bandipur National park	Karnataka	Tiger
5-	Tadoba national Park	Maharashtra	Tiger
6-	Kanha National Park	Madhya Pradesh	Swamp deer
7-	Manas National Park	Assam	Pygmy Hog, Water buffalo
8-	Keibul Lamjao National Park	Manipur	*Hog deer*
9-	Ranthambore National Park	Rajasthan	Tiger
10-	Dudhwa National Park	Uttar Pradesh	Tiger, Swamp deer

In contrast to a wildlife sanctuary, a national park is a protected area reserved for the conservation of only animals, where human interference in any form, including the harvesting of timber, the collection of minor forest products, and private ownership rights is not permitted. The majority of the rules apply to both national parks and sanctuaries, although there are four significant exceptions:

1-All rights of people within a national park have to be settled, while in a sanctuary certain rights can be allowed,

2- Grazing livestock is not permitted in national parks, however it is permitted in sanctuaries under certain conditions.
3-A sanctuary can be upgraded to a national park, but a national park cannot be downgraded as a sanctuary, and
4-Boundaries of sanctuaries are not well defined and controlled biotic interference is permitted, while the boundaries of a national park are well defined and no biotic interference is permitted.

10.4.3- Biosphere reserves

'Biosphere Reserves' were established in 1971 as part of UNESCO's 'Man & Biosphere' (MAB) programme. The main purpose of this programme is to achieve a sustainable balance between natural ecosystems and biodiversity. A biosphere reserve is a habitation area that includes both terrestrial and coastal ecosystems and provides a pathway for sustainable use. The state governments meticulously maintain the biosphere reserves, which are widely recognized internationally. The first biosphere reserve of the worlds was established in 1979. In India, the government has established 18 Biosphere Reserves whose sole purpose is to protect natural habitats. All flora, fauna, and humans are completely protected in these areas. Nilgiri Biosphere Reserve, India's first biosphere reserve, was established in 1986, covering an area of 5520 km. The second biosphere reserve, the Nanda Devi biosphere reserve, covering an area of 5860 sq.km was established in 1988.
The purpose of the formation of the biosphere reserve is to-
a. Conserve all forms of life in their entirety, including their support systems.
b. Serve as a referral system for monitoring
c. Evaluate changes in natural ecosystems.

Biosphere reserves may include a number of contiguous national parks, sanctuaries, and reserves. Biosphere reserves are protected areas of land or coastal environment that are divided into different zones for various purposes. Biosphere reserves are divided into three interconnected zones: the core area, the buffer zone, and the transition zone.
1- Core Zone: The natural or core zone is an undisturbed ecosystem that is legally protected. Human involvement is strictly prohibited in this zone and is treated without any disturbance. It **may contain endemic plants and animals.**
2- Buffer Zone: The buffer zone surrounds the core area. This is used for research and education while not interfering with the core zone. It allows for restoration, limited tourism, fishing, grazing, and other activities to reduce the impact on the core zone. Research and educational activities will be promoted.
3-Transition Zone: The outermost part is the transition zone. It is an area that protects the animal, plant, and human communities that live in these areas. This is a zone of cooperation where conservation knowledge and management skills are applied and uses are managed in accordance with the purpose of the biosphere reserve.

The following are the objectives of the Biosphere Reserve Programme (BRP):
1- Conserve diversity and integrity of plants, animals and micro-organism.
2- Provide long-term *in-situ* conservation of genetic diversity.
3- Promote and facilitate basic and applied research and monitoring.
4- Provide opportunities for education, awareness and training.
5- Ensure the sustainable use of natural resources by employing the most appropriate technology.
6- Disseminate the experience so as to promote sustainable development elsewhere.

Importance

- **Development:** Linkages with protected areas will lead to overall economic, cultural and social development.
- **Restoration:** Appropriate restoration of all damaged ecosystems and habitats.
- **Land Use Planning:** Different groups work together to find comprehensive land management solutions
- **Conservation** is the preservation of species, ecosystems, genetic diversity and landscapes without affecting the organisms that inhabit them
- **Healthy Ecosystems:** Natural problems such as erosion, water resources and soil quality are regularly monitored and protected.
- **Education and Research:** provide information on the conservation, restoration and development of ecosystems, and the steps to restore landscapes affected by human activities

List of Biosphere Reserves in India

S.No.	Name	Year	Location (State)
1-	Nilgiri,	1986	Western Ghats
2-	Nandadevi	1988	Uttarakhand
3-	Nokrek	1988	Meghalaya
4-	Gulf of Mannar	1989	Tamil Nadu
5-	Sunderbans	1989	West Bengal
6-	Manas	1989	Assam
7-	Great Nicobar	1989	Andaman and Nicobar Islands
8-	Simlipal	1994	Odisha
9-	Dibru-Saikhowa	1997	Assam
10-	Dehang-Dibang	1998	Arunachal Pradesh
11-	Panchmarhi	1999	Madhya Pradesh
12-	Khangchendzonga	2000	Sikkim
13-	Agasthyamalai	2001	Western Ghats
14-	Achanakamar-Amarkantak	2005	Madhya Pradesh
15-	Kuchchh	2008	Gujarat
16-	Cold desert	2009	Himachal Pradesh

17-	Seshachalam	2010	Andhra Pradesh
18-	Panna	2011	Madhya Pradesh

10.4.4-Sacred Groves: Sacred groves are a fine example of in-situ conservation of biodiversity. In many tribal areas, a part of the forest is set aside. All the plants and animals in this part are worshipped and no harm is done to them. This part is called sacred grove. Sacred groves are the trees which are considered as socially, religiously, medicinally or culturally important. The common examples are- *Ficus benghalensis* (Banyan tree) and *Ficus religiosa* (Peepal tree). Sacred groves help in creating awareness about biodiversity conservation. This consciousness has been passed down through generations to tribal people. Some of the sacred groves in India are as follows-

Khansi and jaintia hills in Meghalaya, Western ghat regions of Karnataka and Maharashtra, Aravalli hills of Rajasthan, Sarguja, Bastar and Chanda areas of Madhya Pradesh.

10.4.5-Wetlands: Wetlands are defined as "lands that transition between terrestrial and aquatic eco-systems, with the water table usually at or near the surface or the land covered by shallow water." A wetland is an area of land with moist soil. Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters (Ramsar 1971). Wetlands include natural wetlands such as rivers, lakes, and coral reefs as well as man-made wetlands such as farm ponds, canals, and irrigated agricultural lands. Wetlands are the most biologically diverse ecosystems, supporting a wide range of animal and plant life.

The characteristic vegetation of aquatic plants, adapted to the special hydric soil, is the main characteristic that sets wetlands apart from other land forms or bodies of water. Wetlands have a variety of ecological functions, such as water purification, flood control, carbon sink, and shoreline stability. The largest wetlands include the Amazon River Basin, the west Siberian Plain, and the Pantanal in South America. Wetlands naturally occur on every continent except Antarctica.

Ramsar Convention: An intergovernmental environmental treaty established in 1971 by UNESCO, the Ramsar convention designates Ramsar as a wetland site. The convention came into force in 1975. The name of the convention comes from the location, Ramsar, Iran. However, a site must fulfill at least one of the nine requirements outlined by the Ramsar convention of 1971 in order to be designated as a Ramsar site. These requirements include supporting vulnerable, endangered, or critically endangered species or threatened ecological communities; regularly supporting 20,000 or more water birds; and serving as an important fish food source, spawning ground, nursery, or migration route that is necessary for the survival of fish stocks. The aim of the Ramsar list is “to develop and maintain an international network of wetlands which are important for the conservation of global biological diversity and for sustaining human life, through the maintenance of their ecosystem components, processes and benefits".

During the years 1985/86 the Government of India implemented the National Wetland Conservation Programme (NWCP) in closed collaboration with the concerned state government. As of now, the Ministry has identified 115 wetlands under the programme that urgently need conservation and management efforts. The scheme was started with the following objectives:

1- To establish national policy guidelines for the management and conservation of wetlands.

2- To undertake intensive conservation measures in priority wetlands

3- To monitor program implementation

4- Creating an inventory of wetlands in India.

Wetlands are land areas that are seasonally or permanently saturated with water. They generally have unique characteristics of moist soils, aquatic vegetation, frog species, sand turtles, and waterfowl. The main types of wetlands include marshes, swamps and bogs.

Five major wetland are-

Wetlands can generally be classified into five basic systems, namely: Lacustrine, Riverine, Palustrine, Marine and Estuarine.

1- Marine: Coastal wetland including coastal lagoons, rocky shores, and coral reefs.

2-Estuarne: It includes deltas, tidal marshes, and mangrove swamps

3- Lacustrine: Wetlands associated with lakes.

4- Riverine: Wetlands along rivers and streams

5- Palustrine: meaning marshy- 'marshes', swamps and bogs.

Categories of Wetlands

Wetlands vary widely because of regional and local differences in soils topography, climate, vegetation and other factors, including human disturbance.

1-Coastal (Tidal wetlands): As the name suggests, United States coastal/tidal wetlands are found along the Atlantic, Pacific, Alaska, and Gulf Coasts. They are closely associated with our country's estuaries, where sea water meets with freshwater to form an environment of different salinity. Salt water and fluctuating water levels (due to tides) combine to create a fairly challenging environment for most plants. Certain grasses and grasslike plants that adapt to the saline conditions form the tidal salt marshes that are found along the Atlantic, Gulf, and Pacific coasts.

2-Inland (Non-tidal wetlands): Inland/non-tidal wetlands include floodplains along rivers and streams (riparian wetlands), isolated depressions surrounded by dry land (playas, pools, "potholes", etc.), along the edges of lakes and ponds, and most common in other lowlands lying areas where groundwater intersects the soil surface or where precipitation sufficiently saturates the soil (vernal pools and bogs).

3-Man-made wetlands: Any type of wetland that has been formed or maintained by humans for purposes such as Aquaculture ponds, ponds includes farm ponds, stock ponds, small tanks, irrigated land, includes irrigation channels and rice fields, Seasonally flooded agricultural land, Water storage areas, reservoirs, barrages, dams, impoundments, canals and drainage channels, ditches.

Types of Wetlands

Wetlands have generally been divided under following headings –

1. Marshes – Marshes are grassy areas with shallow water. Marshes can be freshwater or saltwater, and the amount of water in them varies with the seasons and, in the case of saltwater marshes, with the tide. Freshwater marshes are home to soft-stemmed and herbaceous plants (such as grasses) and shrubs (such as rushes, sedges, and saltbush). Marshes are home to a variety of animals, including beavers, alligators, newts, shrimp, and turtles. Freshwater marshes are common along the shores of lakes and rivers. Saltwater marshes are found along coastlines, inlets, and estuaries where they are affected by tides and often receive fresh water from surrounding land, rivers, or ground water.

2. Swamps – Swamps are slow-moving rivers, streams, or isolated low areas with more open and deeper water than marshes. Swamps are low-lying areas near rivers or coastal areas with trees (for example, Cypress trees in freshwater and mangrove trees in saltwater) and woody shrubs rather than grasses and herbs. The Sunderbans in West Bengal are an example of swamp soil that is poorly drained and water-logged. Alligators, snakes, insects, bobcats, beavers, and a wide variety of birds live in swamps.

3. Bogs and Fens – A bog is a freshwater wetland with a spongy peat base that forms in an old glacial lake. Rain supplies the majority of the bog's water. A fen is a fresh water peat wetland dominated by grasses, sedges, reeds, and wildflowers that grow in high pH (alkaline) ground water. Bogs have nutrient-deficient soil. Evergreen trees and shrubs, as well as a thick carpet of sphagnum moss, cover the floor. Bogs also have some carnivorous plant species. Bogs are home to a small number of animals. These include red deer, dragonflies, and birds such as grouse and plover.

Importance of Wetlands:

1- The wetlands primarily provide water for irrigation, fisheries, non-timber forest products, water supply, and restoration as ecosystem goods.

2- Tanks, ponds, lakes, and reservoirs are examples of wetlands that have provided multiple-use water services, such as irrigation, domestic use, fisheries, recreational use, ground-water recharge, flood control, and silt capture.

3- The maintenance of biodiversity, nutrient removal, flood control, ground water recharge, carbon sequestration, and toxics retention are among the major services.

4- Wetland sediments are long-term stores of carbon, while short-term stores are the biomass (plants, animals, bacteria and fungi) present in wetlands and dissolved constituents in surface and groundwater.

5- Wetlands help mitigate the effects of floods by absorbing water and slowing the flow of floodwaters.

6- Wetlands are important in promoting species diversity. Some vertebrates and invertebrates depend on wetlands throughout their life cycle, while others are associated with these areas only during certain stages of life.

Wetlands Conservation

Wetlands are one of the most productive environments on earth. They are the cradle of biodiversity, providing the water and primary productivity on which the country's plant and animal species depend for survival. They support high concentrations of birds, mammalian, reptile, amphibian, fish and invertebrate species. Wetlands are also important repositories of plant genetic material. For example, rice, a common wetland crop, is a staple food for more than half of humans. In recent years, the multiple roles of wetland ecosystems and their value to humanity have been increasingly understood and documented. This has resulted in significant expenditures to restore lost or degraded hydrological and biological functions of wetlands.

Some Important Wetland in India

S.No.	Name	Location (State)
1-	Renuka	Himanchal Pradesh
2-	Bhoj	Madhya Pradesh
3-	Chilka	Odissa
4-	Sundarban Wetland	West Bengal
5-	Rudra Lake	Tripura
6-	East Kolkata Wetlands	West Bengal
7-	Rasikbil	West Bengal

10.4.6- Mangroves

Mangroves are actually coastal wetlands, where small trees grow in salt water and provide a unique ecosystem for wildlife, birds, reptiles and aquatic animals. Salt marshes, marshes, estuaries and mangrove forests are formed by the coastal environment; it is home to many species of reptiles and amphibians. The Ministry of Environment and Forests started the Mangrove Conservation Program in 1987. The ministry has so far identified 38 mangrove areas for intensive protection and management in the country. According to FAO- Mangroves are the characteristic littoral plant formations of tropical and subtropical sheltered coastlines. Mangrove ecosystems are special habitats at the boundary between land and sea. The term 'mangrove' applies to a particular ecosystem in the intertidal zone of the tropics and subtropics, and the plant communities in that ecosystem are called 'mangrove vegetation'. Mangroves are small trees that grow in salty forest habitats or in saline coastal waters and are found in tropical intertidal zones. Mangrove forests are known to exist in the deltas of the Ganges, Godavari and Kaveri rivers in India. Mangrove trees and shrubs are unique trees and shrubs that grow in saline and low-oxygen environments. A wide variety of species and aquatic organisms depend on these forests for their survival.

Characteristics of Mangroves

1- Mangroves are essentially an evergreen terrestrial plant that grows on protected coasts, usually tidal flats, deltas, estuaries, bays, streams and offshore islands.

2- The best places are where rivers carry large amounts of silt or on increasingly sandy shores.

3- They have high physiological adaptability to salt stress and water-rich anaerobic mud.

4-It needs to be exposed to strong sunlight and can absorb fresh water from salt water and brackish water.

5- It produces pneumatophores (blind roots) to overcome respiration problem in the anaerobic soil conditions.

6- Mangroves come in many different configurations. Some species (e.g. Rhizophora) send arching prop roots down into the water. While other (e.g. Avicennia) sends vertical “Pneumatophores” or air roots up from the mud.

7- Most mangrove vegetation has lenticellated bank which facilitates more water loss, produces coppices. The leaves are thick and have glands that secrete salt. Mangroves exhibit a viviparous mode of reproduction. That is, the seed germinates within the tree itself (before falling to the ground). This is an adaptive mechanism to overcome germination problems in salt water.

8- Some secrete excess salt through their leaves as if you look closely, you can see crystals of salt on the back of the leaves; others block absorption of salt at their roots.

9-Adventitious roots that emerge above the ground from the main trunk of a tree are called stilt roots.

Role of Mangroves

1-Mangrove forests stabilize the coastline by reducing erosion caused by storm surges, currents, waves and tides.

2- Mangroves protect water quality by removing runoff nutrients and pollutants before rainwater reaches seagrass habitats and coral reefs.

3- Mangroves enhance natural recycling of nutrients.

4- Provide a safe and favorable environment for breeding, spawning, rearing of several fishes.

5-Mangrove systems provide shelter to a range of wildlife species including birds, deer and honey bees.

6-It supplies woods, fire wood, medicinal plants and edible plants to local people.

7-Mangroves serve as nesting areas for coastal birds such as little blue herons, great egrets and brown pelicans. Many birds depend on mangroves for part of their seasonal migrations. Even dead mangroves play an important role, providing roosting areas for bird species

8-It provides numerous employment opportunities to local communities and augments their livelihood.

Some mangroves sites in India

S.No.	**Mangrove sites**	**State/Union territories**
1-	Sundarban Groves	West Bengal
2-	Mahanadi Mangroves	Orissa
3-	Krishna Godavari Mangroves	Andhra Pradesh
4-	Mangroves of Gujarat	Gujarat
5-	Ratnagiri Mangroves	Maharashtra
6-	Goa Mangroves	Goa
7-	Cauvery Deltaic Mangroves	Tamil Nadu
8-	Andaman Nicobar Mangroves	Andaman and Nicobar

10.4.6 Coral reefs: Coral reefs are shallow-water tropical marine ecosystems characterized by high biomass production and a rich diversity of flora and fauna. According to Thomas wayland Vaughan (1917), a ridge of mound of limestone, the upper surface of which is near the surface of the sea and which is formed of calcium carbonate by the actions of organisms, chiefly corals. Coral reefs consist of hundreds to thousands of colonies of small individual corals called polyps. These marine invertebrates have hard calcium carbonate exoskeletons and are sessile. That is, they are permanently fixed in one place. For the growth of coral reefs water temperature should not be below 20°C. The optimum temperature for coral reef growth is between 23°C and 25°C. The temperature should not exceed 35°C. Corals can only survive in saltwater conditions with an average salinity of 27% to 40%. Coral reefs grow in shallow waters less than 50m deep, but the depth should not exceed 200m.

Coral Reefs are often called the "Tropical Rainforests of the Sea", for their astounding richness of life and extraordinary uniqueness. They are one of India's oldest and most dynamic ecosystems. Coral reef ecosystems, often called the rainforests of the sea, account for almost a quarter of all marine biodiversity, although they cover only 0.2% of the total seafloor area. They not only provide sanctuary for a myriad of marine life but also play an important role in protecting coastlines from erosion.

Scientists generally agree on four different classifications of coral reefs i.e. fringing reefs, barrier reefs, atolls, and patch reefs.

1-Fringing reefs: It grows around islands and continents near the coast. They are separated from the coast by narrow, shallow lagoons. A fringing reef is the most common type of coral reef. Examples- South florida reef, Mehetia island, Sakau island in New Hebrides.

2-Barrier reefs: Barrier reefs also parallel to the coastline, but are separated by deeper and wider lagoons. It reaches the surface at its shallowest point and forms a "barrier" for transport. For example- The great barrier reef of Austria is the largest barrier reef in the world.

3-Atolls: Atolls are rings of coral that form protected lagoons, usually in the middle of the ocean. Atolls usually form when islands surrounded by fringing reefs are submerged or when the surrounding sea level rises. For example- Fiji Atoll, Trent Atoll of w-carolinas, suvadivo in the Maldives (biggest Atoll in the world), Funafoothis Atoll of Ellice.

4-Patch reefs: Patch reefs are small isolated coral reefs that grow from island platforms or open floors of continental shelves. They usually occur between fringing and barrier reefs. They vary greatly in size and rarely reach the surface of the water.

Formation of coral reefs: Many theories have been put forward to explain the formation of coral reefs. Among them two theories are more important.

1- Darwin's subsidence Theory: According to this theory, coral reefs were first formed as fringing reefs that were close to sloping shores, they became barrier reefs when the shores sank with water channel between them and the land. If the land is an island which sinks completely than an atoll is formed. Thus, sinking or subsidence has caused the thickness of the reefs.

2- Daly's Glacial- Control theory: The development of ice caps during the last glacial period decreased the ocean's water level (60 to 70 meters). At that time extreme cold temperatures predominant. As ice melted and temperature increased which is ideal for the growth of reefs. Atolls and barrier reefs are created as a result.

Factors affecting Coral Reefs

- **Extreme climate conditions:** These corals decline as a result of the high water temperatures because they cannot survive there. Scientists predict that as ocean temperatures rise at an increasing rate, the majority of the world's coral reefs will soon begin to decline.
- **Coastal development:** These coral reefs suffer significant harm from the construction of coastal infrastructure and tourist resorts on or nearby.
- **Pollution:** The poisoning of coral reefs can result from toxic pollutants that are dumped directly into the ocean because they raise the seawater's nitrogen level, which promotes an algal overgrowth.
- **Sedimentation:** Construction on islands and coasts causes soil erosion, which raises the amount of sediments in rivers. As a result, it can suffocate corals by depriving them of the light they require to survive.

Importance of Coral Reefs

1- Coral reefs act as a physical barrier, a wall, against tidal surges, severe weather, ocean currents, tides, winds, and waves that hit coastlines. By doing this, they prevent coastal erosion, flooding, and infrastructure damage. As a result, they help to lower the enormous expenses associated with the destruction and displacement caused by extreme weather occurrences.

2-They provide habitats and shelter for many marine organisms.

3- They provide the nitrogen and other necessary nutrients needed by marine food chains. They aid in the fixing of both carbon and nitrogen. They help in the recycling of nutrients. For records of recent climatic events that can be tested scientifically, coral reef research is crucial.

4- Coral reefs play a key role in the fishing industry. There are many fishes that spawn there, and young fish stay there before moving on to the open ocean. Fishing and tourism at the Great Barrier Reef bring in more than 1.5 billion dollars annually for Australia's economy.

5- Coral reefs are a major indicator of the health of the world's ecosystems. They act as an early warning indicator of what might happen to other, less vulnerable systems, like river deltas, if climate change is not urgently addressed.

6- Coral species are being researched as potential therapies for some cancers or cell ageing. The Caribbean sea squirt (*Ecteinascidia turbinata*), has a chemical that is being used to treat difficult cancers. 50% of current cancer medication research focuses on marine organisms found on coral reefs. Some hard coral species are used in bone grafts.

7- The skeletons of coral, which are marine invertebrate animals, make up the large underwater structures known as coral reefs. The largest class of organisms in the phylum Cnidaria is anthozoans, which include corals.

8- Polyps are the individual corals that make up a coral. The polyp resembles a tin can that has only one open end, and that end has a mouth that is surrounded by a ring of tentacles. The corals can catch small organisms that swim too close to the stinging cells on their tentacles, known as nematocysts.

Threats to Coral Reefs

Coral reefs face a large number of threats, both direct and indirect, from human activities. Scientists believe all coral reefs will face threats by 2050, with 75% of them facing high-risk threats. Some of these threats are as follows:

1-Over-fishing for food, aquarium trade, trinket trade, medicinal purposes is a big threat. Over-fishing of certain species on or adjacent to coral reefs can affect the reef’s ecological balance and biodiversity. For example, over fishing of herbivorous fish can lead to high levels of algal growth.

2-Marine pollution in the form of oil (often spilled into the sea), ballast water discharge, and solid waste dumping from ships also damages coral reefs in the region.

3- Global warming and associated climate change poses serious new threats to already stressed coral reefs. It is also threatened by acidification.

4-Coral reefs are being destroyed in many areas as reefs and colorful reef fish are collected for aquariums and the gem trade.

5-Coral bleaching occurs as ocean temperatures rise. Corals have a narrow temperature tolerance, so they release symbiotic algae in response to stress. Without algae, there would be no source of life, it would cease to exist.

Coral Reefs in India

India has its coastline extending over 7500 kilometres. There are a very small number of coral reefs in India because of the subtropical climate. India has several significant coral reef systems, including those in Palk Bay, the Gulf of Mannar, the Gulf of Kutch, the Andaman and Nicobar Islands, and the Lakshadweep Islands. Among all these coral reefs, the Lakshadweep reef is an example of atoll while the rest are all fringing reefs.

Palk Bay

Situated in the south-east coast of India, Palk Bay is separated from the Gulf of Mannar by the Mandapam Peninsula and the Rameshwaram Island and is centred on 9 °17’N and 79° 15′. The one fringing reef in the Palk Bay is 25-30km long, and less than 200m wide lies in the east-west direction of the Pamban channel. This coral reef has a maximum depth of about 3m.

The Gulf of Mannar

Situated around a chain of 21 islands, the Gulf of Mannar lies between Tuticorin and Rameswaram at a stretch of 140 km. These 21 islands are part of the Manor Barrier Reef, which is 140 km long and 25 km wide, between latitudes 8°47' and 9°15'N, and longitudes 78°12'E and 79°14'E.

Andaman and Nicobar Islands

The Andaman and Nicobar Islands lie between 6°-14° N lat and 91°-94° E longitude. Located in the southeastern part of the Bay of Bengal, it consists of 350 islands, of which only 38 are inhabited. These islands stretch south from Burma's Irrawaddy Delta to the Arakan Yoma Range. All islands in the Andaman and Nicobar group are mostly fringing reefs.

The Gulf of Kutch

The Gulf of Kutch is located in the northern part of the Saurashtra Peninsula, between 22°15'-23°40' north latitude and 68°20'-70°40' east longitude, covering an area of about 7350 km^2. These reefs are fringing reefs, about 170 km long and 75 km wide at the mouth, which narrows at a longitude of 72° 20′. Due to the accumulation of mud on various reefs, these reefs are in a state of severe degradation.

Lakshadweep Islands

In the Arabian Sea, the Lakshadweep Islands lie between 8° to 12°3'N latitude and 71° to 74°E longitude, approximately 225 to 450 km off the coast of Kerala. With an area of 32 km2, the islands consist of 36 small islands, 12 atolls, 3 coral reefs, 5 submerged banks and lagoons occupying about 4200 km2. These islands have a warm and humid climate, with water temperatures of 28-31°C and salinity of 34%-37%.

Some Coral reef sites

S.No.	State	Site
1-	Gujarat	Gulf of Kutch
2-	Tamil Nadu	Gulf of Mannar
3-	Andaman and Nicobar	Andaman and Nicobar Coral reef
4-	Lakshadweep	Lakshadweep

(Source: Annual Report MoEF&CC 2020-21)

10.5 SUMMARY

Biodiversity refers to the variability between living organisms and the forms of terrestrial, marine, aquatic ecosystems and ecological complexes. Biodiversity can be conserved by protecting its whole ecosystem. The two basic approaches for the conservation of biodiversity are in-situ conservation and ex-situ conservation. In-situ method involves the protection of species in their natural habitat example- wildlife sanctuaries, National parks, biosphere reserve, wetlands, mangroves, coral reefs etc. There are several international initiatives and structures for the conservation or protection of biodiversity. Some of the major and high impact conventions are the world heritage convention. The international union for conservation of nature and natural resources (now called as world conservation union), the convention on international trade in endangered species etc. In India, various laws regulate wildlife conservation, as well as overall biodiversity. The Indian government has taken several steps to protect biodiversity such as wildlife protection act 1972, crocodile conservation project, Project tiger, project elephant, and UNDP sea turtle project etc.

10.6 GLOSSARY

In-situ conservation: The process of preserving a threatened plant or animal species in its natural habitat is known as in-situ conservation.

Biosphere reserves: A biosphere reserve is a habitant area that includes both terrestrial and coastal ecosystems and provides a pathway for sustainable use.

Coral reef: Formation produced by massive colonies containing billions of tiny coral animals, called polyps, that secrete a stony substance (calcium carbonate) around themselves for protection. When the coral die, their empty outer skeletons from layers and cause the reef to grow. Coral reefs are found in the coastal zones of warm tropical and subtropical oceans.

Wildlife Sanctuary: An area, usually in natural condition which is reserved or set aside by a governmental or private agency for the protection of natural fauna or particular species of animals.

Wetland: An area that is saturated by surface, or ground water having life adapted under those conditions. Swamps, bogs, fens, marshes, and estuaries are examples of wetlands. These are a major refuge for wildlife including many rare species.

Mangrove: Mangroves are tropical plants that are adapted to loose, wet soils, salt water, and being submerged by tides on a regular basis.

Peatland—A generic term of any wetland that accumulates partially decayed plant matter (peat).

Coral bleaching: Coral bleaching is when water is too warm, corals will expel the algae (zooxanthellae) living in their tissues causing the coral to turn completely white.

10.7 SELF ASSESSMENT QUESTION

10.7.1 Multiple Choice Questions

1. Which one of the following is the first national park established in India?

(a) Jim Corbett National Park (b) Kaziranga National Park
(c) Ranthambore National Park (d) Dachigam National Park

2. When was the Project Tiger launched in India?

(a) 1972 (b) 1973
(c) 1970 (d) 1980

3. Which of the following is not a zone of biosphere reserve?

(a) Buffer zone (b) Transition zone
(c) Core zone (d) Mid zone

4- What is the protection and conservation of species in their natural habitat called?

(a) Off-site conservation (b) Ex-situ conservation
(c) In-situ conservation (d) No conservation

5-Bog ecosystem wetland receives water only from-

(a) Ground water (b) Rain
(c) Rivers (d) Streams

6-The state where Jim Corbett National Park is located-

(a) Goa (b) Uttar Pradesh
(c) Uttarakhand (d) Chattisgarh

7-What is the correct abbreviation for IUCN?

(a) International union for conservation of Nuts

(b) International union for conservation of Nature
(c) International union for conservation of Natural habitat
(d) International union for conservation of Numbers

8-Sacred groups are useful in-
(a) Conserving endangered and rare species
(b) Spreading environmental awareness
(c) Ensuring the sustainable flow of water in rivers
(d) Preventing soil erosion

9- A category of threatened species include:
(a) only vulnerable species
(b) endangered and rare species
(c) Only endangered species
(d) endangered, vulnerable and rare species

10-Which of the following is not an example of an in-situ conservation strategy?
(a) Biosphere (b) Sacred groves
(c) Zoo (d) National park

Answer Key:

10.7.1: 1-(a), 2-(b), 3-(d), 4-(c), 5-(b), 6-(c), 7-(b), 8-(a), 9-(d), 10-(c)

10.8 REFERENCES

- http://www.oas.org/dsd/publications/unit/oea04e/ch04.htm
- https://www.cbpbu.ac.in/userfiles/file/2020/STUDY_MAT/BOTANY/27-04-20/Dr.Aninda%20Mandal%20for%204th%20Sem(%20Special%20Paper%20PRM%20)-In%20situ%20Conservation..pdf
- https://www.slideshare.net/resgmasheikh/conservation-strategies
- https://legalstudymaterial.com/wildlife-conservation-efforts-in-india-importance-of-wildlife-conservation/
- https://www.yourarticlelibrary.com/environment/ecosystem/complex-ecosystem-in-india-wetlands-mangroves-coral-reefs-forests/11171
- https://www.cbd.int/brc/
- https://www.vedantu.com/biology/conservation-of-biodiversity
- https://www.yourarticlelibrary.com/biodiversity/conservations-of-biodiversity-in-situ-conservation-and-ex-situ-conservation/30144

- https://www.ranthamborenationalpark.com/blog/wildlife-conservation-initiatives-indian-government/
- https://wii.gov.in
- https://coral.org/en/coral-reefs-101/types-of-coral-reef-formations/
- https://byjus.com/free-ias-prep/coral-reefs/
- https://www.insightsonindia.com/world-geography/physical-geography-of-the-world/oceanography/coral-reefs/importance-of-coral-reefs/
- Source: National Wildlife Database, Wildlife Institute of India

10.9 SUGGESTED READINGS

- P.D.Sharma, 'Ecology and Environment', Rastogi Publication, Meerut
- R.S.Shukla & P.S.Chandel, 'A textbook of Plant Ecology', S.Chand & Company pvt. Ltd., New Delhi
- B.P.Pandey, Botany for Degree Students, S.Chand & Company pvt. Ltd., New Delhi

10.10 TERMINAL QUESTIONS

10.10.1 Short Answer Type Questions:

1- What is the importance of wildlife sanctuaries?

2-Write short notes on:

(a) Sanctuary

(b) Project tiger

3-What are the benefits of wetlands?

4- How are Coral Reefs formed?

5-What are the benefits of Coral Reefs?

10.10.2 Long Answer Type Questions:

1- What is a biosphere reserve? Write a short account of protected areas network of India.

2- Write a brief account of International agencies engaged with conservation of biodiversity.

3-What are wetlands? Discuss the types and importance of wetlands.

4-Define mangrove. Describe the characteristic of mangroves.

5-What are coral reefs? Discuss the importance and threats of coral reefs.

UNIT-11 STRATEGIES FOR *EX-SITU* CONSERVATION

Contents

11.1 OBJECTIVES

After reading this unit student will be able-

- To understand the various components of *ex-situ* conservation of biological diversity;
- To study the mechanism of *ex-situ* conservation and strategies for conservation of plants, animals and micro-organisms;
- To study the conservation process of threatened species;
- To study the institutional mechanism of *ex-situ* conservation in India.

11.2 INTRODUCTION

For much of the time man lived in a hunter-gather society and thus depended entirely on biodiversity for sustenance. But, with the increased dependence on agriculture and industrialization, the emphasis on biodiversity has decreased. Indeed, the biodiversity, in wild and domesticated forms, is the sources for most of humanity food, medicine, clothing and housing, much of the cultural diversity and most of the intellectual and spiritual inspiration. It is, without doubt, the very basis of life. Further that, a quarter of the earth's total biological diversity amounting to a million species, which might be useful to mankind in one way or other, is in serious risk of extinction over the next 2-3 decades. On realization that the erosion of biodiversity may threaten the very extinctionof life has awaked man to take steps to conserve it.
During the last decade, the IUCN have developed strategies for Conservation of Nature and Natural Resources with hold up from World Bank and other institutions. On the whole, the conservation plan has a holistic approach and encompasses whole spectrum of biota and activities ranging from ecosystems at the macro level (*in-situ* conservation) to DNA libraries at the molecular level (*ex-situ* conservation).

Definition

Ex-situ conservation literally means, "off-site conservation". It is the process of protecting an endangered species of plant or animal by removing part of the population from a threatened habitat and placing it in a new location, which may be a wild area or within the care of humans. While *ex-situ* conservation comprises some of the oldest and best known conservation methods, it also involves newer, sometimes controversial laboratory methods.
Ex-situ conservation, using sample populations, is done through establishment of gene banks, which include genetic resources centres, zoos, botanical gardens, culture collections etc.

11.3 ADVANATAGES OF EX-SITU CONSERVATION

The conservation of biodiversity can be achieved through an integrated approach balancing *in-*

situ and *ex-situ* conservation strategies. The preservation of species *in-situ* offers all the advantages of allowing natural selection to act, which cannot be recreated *ex-situ*. The maintenance of viable and self-sustainable populations of wild species in their natural state represents the ultimate goal, but habitat destruction is inevitable and endangered species need to be preserved before they become extinct. *Ex-situ* conservation provide the opportunity to study the biology of, and understand the threats to, endangered species in order to eventually consider successful species recovery programmes, which would include restoration and reintroduction. It also has the advantage of preserving plant material and making it available for research purposes, without damaging the natural populations. Their conservation *ex-situ* is therefore complementary to *in-situ* conservation and can act as an "insurance policy" when species are threatened in their natural habitats It is the process of protecting an endangered species of plant or animal by removing part of the population from a threatened habitat and placing it in a new location, which maybe a wild area or within the care of humans. *Ex-situ* conservation has several purposes:

- Rescue threatened germplasm.
- Produce material for conservation biology research.
- Enlarge the germplasm for storage in various *ex-situ* facilities.
- Supply material for various purposes to remove or reduce pressure from wildcollecting.
- Grow those species with recalcitrant seeds that cannot be maintained in a seed store.
- Make available material for conservation education and display.
- Produce material for reintroduction, reinforcement, habitat restoration and management.

11.4 EX-SITU CONSERVATION: PRINCIPLES AND PRACTICES

Ex-situ conservation is the chief mode for preservation of genetic resources, which may include both cultivated and wild material. Generally seeds or *in-vitro* maintained plant cells, tissue and organs are preserved under appropriate conditions for long term‟ storage as gene bank. This requires considerable knowledge of the genetic structure of population sampling techniques, methods of regeneration and maintenance of variety of gene pools, particularly in cross-pollinated plants.

These *ex-situ* collections of living organisms (living collections, seed banks, pollen, vegetative propagules, and tissue or cell cultures) need to be managed according to strict scientific and horticultural standards to maximize their value for conservation purposes. Thus they need to be correctly identified, documented and managed and an efficient information management system put in place. Integrated conservation management can also ensure that *ex-situ* collections can support *in-situ* conservation, through habitatrestoration and species recovery.

There are two ways or modes of *Ex-situ* conservation.

1. Conventional methods
2. Biotechnological aspects

11.5 CONVENTIONAL METHODS OF EX-SITU CONSERVATION

11.5.1 Gene Banks

Plant genetic resources gene banks store, maintain and reproduce living samples of the world's huge diversity of crop varieties and their wild relatives. They ensure that the varieties and landraces of the crops and their wild relatives that underpin our food supply are both secure in the long term and available for use by farmers, plant breeders and researchers.

Gene banks conserve genetic resources. The most fundamental activity in a gene bank is to treat a new sample in a way that will prolong its viability as long as possible while ensuring its quality. The samples (or accessions as they are called) are monitored to ensure that they are not losing viability. A cornerstone of gene bank operations is the reproduction-called regeneration-of its plant material. Plant samples must periodically be grown out, regenerated, and new seed harvested because, even under the best of conservation conditions, samples will eventually die.

To conserve and regenerate genetic resources, gene banks first must collect genetic resources. But gene banks aren't built just to conserve genetic resources; they are intended to ensure that these resources are used, whether it is in farmers' fields, breeding programmes or in research institutions. This means making sure the collections areproperly characterized and documented; and that the documentation is available to those who need it. The information systems used by gene banks are becoming increasingly important tools for researchers and breeders seeking data on the distribution of crops and their wild relatives.

11.5.2 Field Gene banks

Field gene banks or living collections are the main conservation strategy for long-lived perennials, recalcitrant species and vegetatively propagated species. Their main limitationis that they take a great deal of space and are difficult to maintain and protect from natural disasters. They are susceptible to the spread of diseases and may suffer from neglect. Furthermore, out-breeders require controlled pollination for regeneration from seed. In many circumstances they are the only available option for the conservation of important germplasm. When displayed, the plants have an important educational value and can easily be accessed for research purposes.

The conservation of germplasm in field gene banks involves the collecting of materials and planting in the orchard or field in another location. Field gene banks have traditionally been used for perennial plants, including:

- Species producing recalcitrant seeds;
- Species producing little or no seeds;
- Species that are preferably stored as clonal material; and
- Species that have a long life cycle to generate breeding and/or planting material.

Field gene banks are commonly used for such species as cocoa, rubber, coconut, coffee, sugarcane, banana, tuber crops, tropical and temperate fruits, vegetatively propagated crops, such as wild onion and garlic, and forage grasses.

11.5.3 Seed Banks

Undeniably, the most cost-effective method of providing plant genetic resources for long-term *ex-situ* conservation is through the storage of seeds under very specific conditions, following techniques well developed for crop plants by organisations such as the International Plant Genetic Resources Institute (IPGRI), previously the International Board of Plant Genetic Resources (IBPGR) and the Food and Agricultural Organisation of the United Nations (FAO). The main advantage of seed banking is that it allows large populations to be preserved and genetic erosion to be minimized by providing optimum conditions and reducing the need for regeneration (Given, 1987).

Endangered plants may also be preserved in part through seed banks or germplasm banks. The term seed bank sometimes refers to a cryogenic laboratory facility in which the seeds of certain species can be preserved for up to a century or more without losing their fertility. It can also be used to refer to a special type of arboretum where seeds are harvested and the crop is rotated. For plants that cannot be preserved in seed banks, the only other option for preserving germplasm is *in-vitro* storage, where cuttings of plants are kept under strict conditions in glass tubes and vessels.

However, when a natural population still exists, it may be advisable to re-collect rather than regenerate a new supply from the previous collection as damage can occur such as mutations associated with the loss of viability during storage. The success of long-term conservation of seeds is dependent on continuous viability monitoring and regenerationor re-collection when the viability of the sample drops below a minimum level (Eberhart, Roos & Towill, 1991). It is important to realize that however much care is taken during seed collection, regeneration and storage, natural selection cannot be simulated and some artificial selection will be unavoidable, which inevitably leads to unpredictable genetic changes (Ashton, 1988).

The recommended preferred standards for long-term seed storage of orthodox species recommended by IPGRI is to dry the seeds to a moisture content of below 7% and seal the dried seeds in a moisture-proof container such as laminated foil bags, aluminium cansor glass jars for storage at a low temperature of -18ºC. Clearly this is only applied to true orthodox species of crops and their relatives. However because less is known about wild species, a temperature of -4ºC and moisture content of 7-8% is advisable to begin with. The activities in seed banks should take the following sequence: collection, seed preparation, seed drying, packaging, storage, periodic germination tests, seed regeneration, re-storage and documentation at each stage of activity.

When plant species are recalcitrant or long-term conservation cannot be achieved throughseed banking, different methods have been developed with their respective merits, suchas field gene banks, in vitro germplasm collections, pollen and DNA banks. This is in many cases the main problem faced by botanic gardens dealing with many different species of which, a great proportion are be recalcitrant. They need to develop complementary conservation techniques and adopt different methods. Example:

- Indian clover, *Trifolium amoenum*, is an example of a species that was thought to be extinct, but was rediscovered in 1993 by Peter Connors in the form of a single planta site in western Sonoma County. Connors harvested seeds and grew specimens of this critically endangered species in a controlled environment.

- A tank of liquid nitrogen, used to supply a cryogenic freezer (for storing laboratory samples at a temperature of about −150°C).
- The Wollemi Pine is an another example of a plant that is being preserved via *Ex- situ* conservation, as they are being grown in nurseries to be sold to the general public.

Ex-situ conservation of plant genetic resources can be achieved through different methods such as seed banks, field gene banks, *in vitro* storage methods, pollen banks and DNA banks. The major consideration for long-term conservation of germplasm collections is the determination of the seed behavior of each individual species to be preserved during storage under dry conditions and cold temperatures. If the seeds can be dried to low percentage humidity such as below 8%, in the majority of cases, the seeds will then withstand very cold temperatures of below 20°C. When the seeds tolerate these conditions and remain viable after many years of storage, they are classified as orthodox (desiccation tolerant) as opposed to recalcitrant (desiccation intolerant) when they do not. However, there might be many other reasons why a particular species cannot be preserved in seed banks, such as a very low production of seed or long-life cycle species, such as trees and perennials. Their conservation as seeds would make the study of their biology difficult.

11.5.4 Community seed banks

Seed banks don't have to be high-tech and managed by governments or businesses. Germplasm conservation in the form of seed in most convenient since seeds occupies a relatively small space. Their transport to various introduction centers and gene banks is also economical but the draw backs in conservation by seed are:

- Loss of viability over passage of time and susceptibility to insect or pathogen attack.
- Inability to maintain distinct clones except for inbreed and apomicts species.
- Non-applicability to vegetatively propagated crop such as *Dioscorea*, *Ipomoea*, *potato* etc.

In many developing countries, farmers rely on informal seed systems based on local growers retention of seed from previous harvests, storage, treatment and exchange of this seed within and between communities. The informal seed sector is typically based on indigenous structures for information flow and exchange of seed. Seed banks managed within this local seed system operate on a small scale at the community level with few resources.

These community seed banks and the institutions that support them are extremely important in the preservation of local varieties and for agricultural production. Much could be gained from learning more about these seed banks and working with communities to improve them. In spite of this, informal seed banks have until now received little attention or support from the scientific community or the state.

11.5.5 Botanical gardens

Botanical gardens and zoos are the most conventional methods of ex-situ conservation, all of which house whole, protected specimens for breeding and reintroduction into the wild when necessary and possible. These facilities provide not only housing and care for specimens of endangered species, but also have an educational value. They inform the public of the threatened status of endangered species and of those factors which cause the threat, with the hope of creating public interest in stopping and reversing those factors which jeopardize a species' survival in the first place. They are the most publicly visited ex-situ conservation sites.

The history of botanic gardens can be traced as far back as the Hanging Gardens of Babylon, built by Nebuchadnezzar in 570 BC as a gift to his wife. Early botanic gardens were designed mainly for the purpose of recreation. By the 16th Century, however, they had also become important centers for research. They promoted the study of taxonomy and became a focal point for the study of aromatic and medicinal plants. More recently, they have taken on significant conservation responsibilities and they often have conservation facilities, such as seed banks and tissue culture units.

Botanical gardens hold living collections. Indeed botanical garden conservation could be considered as field gene bank or seed gene bank or both, depending on the conservation method being used. However, they tend to focus their conservation efforts on wild, ornamental, rare and endangered species. Most of the germplasm conserved in botanical gardens do not belong to the plant genetic resources for food and agriculture.

A botanic garden which wishes to start a small seed bank /gene bank would be advised to start with collecting germplasm that is very well documented from their living plant collection. This would allow them to experiment with a wide range of species and find suitable facilities and techniques for their particular needs. Once the set up is organised and functional, it would be advisable to collect accessions directly from the wild in order to distribute a wider genetic variability and to reduce the effect of domestication on the genetic makeup of the accessions.

Last two hundred years, efforts of botanic gardens in collecting plant material, and the great efforts on crop germplasm collection during the 1970s and the 1980s, there are a large number of gene banks and germplasm collections around the world. According to the FAO and World Information & Early Warning System (WIEWS) database, it is estimated that there are now more than 2000 botanic gardens known around the world in over 150 countries. Together, they maintain more than 6 million accessions in their living collections and 142 million herbaria specimens in the botanic garden herbaria. 60% of the total numbers of accessions are known to be stored in medium-term or long-term facilities, 8% in short-term facilities and 10% in field gene banks, in vitro and under cryopreservation. Clearly, seed storage is the predominant form of plant genetic resource conservation, accounting for about 90% of the total accessions held *ex-situ*.

It is very difficult to give an estimate of the type of collections stored around the world as such information is known for only a third of the accessions in the WIEWS database. However, it has been estimated that 48% of all accessions are advanced cultivars or breeders' lines, while over a third are landraces or old cultivars and about 15% are wild or weedy plants or crop relatives.

Some famous international and national botanic gardens/ research centers/ institutes

International

Royal Botanical Garden, Kew, England: Largest botanical garden in world and its herbarium is also largest in world, having 6 million specimens.

CIAT: International Center for Tropical Agriculture located at Palmira, Columbia

ICARDA: International Center for Agriculture Research in Dry Areas located at Allepo, Syria

ICRISAT: International Center for Agriculture Research for Semi Arid Tropicslocated at Patencheru, (Hyderabad) India.

IRRI: International Rice Research Institute located at Manila, Philippines.

CITES: Convention on International Trade in Endangered Species of Wild Faunaand Flora.

National

Indian Botanical Garden, Calcutta: Largest Botanical Garden in India and itsherbarium is largest in India, having 1 million specimens.

NBRI: National Botanical Research Institute located at Lucknow (UP) formally known as National Botanical Garden.

BSI: Botanical Survey of India started working in 1890 and is connected with plant exploration and writing up of regional floras and also preparation of flora of India.

IARI: Indian Agricultural Research Institute or **Pusa Institute** located at New Delhi. It was initially established at village Pusa in Darbhanga District of Bihar in 1905 under the name **Imperial Agricultural Research Institute**. After a severeearthquake, this institute was shifted to New Delhi in 1936 under the same name. But after independence, it was renamed as Indian Agricultural Research Institute.

FRI: Forest Research Institute located at Dehradun (Uttarakhand), established in 1906 under name Imperial Forest Research Institute (IFRI), but after independence, name was changed to FI. This institute is connected with researchers on different aspects of forest trees and also provides training to forest officers.

11.6 BIOTECHNOLOGY METHOD OF EX-SITU CONSERVATION

Biotechnology is the third wave in biological sciences and represents such an interface ofbasic and applied sciences, where gradual and subtle transformation of science into technology can be witness. Biotechnology is also defined as the applications of scientific and engineering principles to the processing of material by biological agents to provide goods and services. United States Congress’s office of Technology Assessment defined biotechnology as any technique that used living organisms to make or modify a product, to improve plants or animals or to develop microorganisms for specific used. The document focuses on the development and application of modern biotechnology based on new enabling techniques or recombinant-DNA technology, often referred to as genetic engineering.

Since biotechnology involves the use of all life forms for human welfare. Therefore, extinction of wild species and destruction of ecosystems has been a major concern of policy markers and environmentalists. A discussion on biotechnology involving biodiversity is relevant, because biodiversity is being utilized to provide genes from wild species for biotechnological exercises.

Several biotechnological tools are now available to tackle various specific problems and to enhance the potentials of grass covers such as feeding value, propagation and persistence. Basically, in range grasses, several tools of biotechnology, comprising endosperm and anther culture, somaclonal variation protoplast culture and fusion, transformation, etc., can address breaking the apomictic barrier for recombination for recombination of desired traits. The grass biotechnologists are actively engaged to achieve this goal. Besides, the mapping of genes, isolation, cloning and characterization of important genes/ traits in range species as well as in other crops can ultimatelyimproves the value of grass cover through genetic transformation in the pasture species. It is envisaged that by following these approaches anti-quality factors can be suppressed and the digestibility of allows even tracking the genes for polyphonic traits and the metric traits like seed production; the biomass would also be hopefully improved. The current certainly go a long way in adding to the fertility and diversity of grass covers. Propagation of specific genotypes of endangered but useful species on a large scale in a short time frame is possible through the modern biotechnological approaches.

11.6.1 *In-vitro* Conservation

Conservation *in-vitro* is wholly dependent upon the techniques of plant cell, tissue and organ culture, and is appropriate in situations where conventional seed storage cannot or is not to be employed.

In particular *in-vitro* conservation used for vegetatively propagated material species with recalcitrant seed and material biology. This later material may have been costly and limited in quantity and have characteristics whose stability during repeated mitotic divisions and following meiosis are unknown. It is, therefore prudent to conserve stocks of this material to ensure consistency in subsequent experimentation of production processes, and as definitive source of reference material.

The material stored *in-vitro* may be protoplast, isolated cells grown in suspension or on semi-solid medium, meristem cultures at various stages of development or organized plantlet. It can be assumed that genetic stability within the *in-vitro* systems increase as the complexity of the cultured material, with completely differentiated plantlets in culture having the least risk of genetic alteration during an in-vitro excursion (Karp, 1989). Consequently, if the storage conditions are to permit some level of growth and metabolic activity then organized plantlets are the conservation material of choice, but where growth is to be completely inhabited as in cryopreservation exercised, shoot meristems may be the more suitable explains (Ford-Lloyd and Jackson, 1986; Wihters, 1987) where cell or protoplast cultures are to be maintained and there is no choice as to a preferred level of organization then care must be taken to ensure the maximum genetic stability, preferable by opting for cryopreservation.

At the simplest level conservation *in-vitro* is achieved by repeated sub-culture continuing the protection from adverse environmental conditions and pathogens that is inherent in the *in-vitro* systems. This is expensive both in terms of labour and the basic material of the culture process and whilst least demanding in terms of the level of available technology, has a considerable risk of material loss due to human error or the failure in- vitro security e.g. the invasion of pathogen during transfer.

Mode of propagation

There is large number of threatened/ rare/ endangered plant species on which *in-vitro* propagation of threatened plants (Table 11.1) could be achieved by the following methods.

1. Clonal propagation
2. Somatic embryogenesis
3. Organogenesis
4. Callus differentiation

Table 11.1: In-vitro regeneration of threatened/ rare/ endangered plant species

Name of Plants	Explant Used	Medium	Mode of Regeneration
Aconitum carmichaeli	Shoot tips and axillary buds	MS	Clonal multiplication
Aconitum nepellus	Nodal shoot	MS	Axillary shoot proliferation
Aconitum noveboraacense	Nodal shoot	MS	Axillary shoot proliferation
Anogeissus sericea	Nodal shoot (seedling explants)	MS	Axillary shoot proliferation
Caralluma edulis	Shoot segments	MS	Clonal multiplication
Commiphora wightii	Shoot segments	MS	Axillary shoot proliferation
Coptis teeta	Hypocotyl segment	MS	Callus culture
Feronia limonia	Axillary branching		Axillary shoot proliferation
Gerbera aurantiaca	Axillary bud		Axillary shoot proliferation
Nepenthes khasiana	Mature nodal segment		Axillary shoot proliferation
Nepenthes khasiana	Axillary bud	MS or wood plant medium	Axillary shoot proliferation
Ocotea catharinensis	Zygotic embryos	MS	Axillary shoot proliferation
Oncidium catharinensis	Seedling	Knudson Medium	Root tip culture
Picorrhiza kurroa	Axillary bud	MS	Axillary shoot proliferation
Podophyllum hexandrum	Zygotic embryos	MS	Somatic embryogenesis
Rauvolfia serpentine	Low temperature	MS	Storage
Rheum embodi	Axillary bud	Liquid	Axillary shoot proliferation
Rumex acetosella	Axillary bud	MS	Somatic embryogenesis
Santalum album	Zygotic embryos	MS	Somatic embryogenesis
Trichopus zeyanicus	Axillary bud	MS	Axillary shoot proliferation
Valeriana wallichii	Axillary bud	MS	Callus culture
Wrightia tomentosa	Axillary bud	MS	Axillary shoot proliferation

11.6.2 *In-Vitro* Storage of Germplasm and Cryopreservation

Assuming that differentiated plantlets are to be stored in-vitro, with all that this implies for genetic stability and then lowering growth temperature to slow metabolism and development has previously reduced the labour and expense for repeated subculture. The security of the culture is also improved as the frequency of the physical interventions of subculture is also reduced. Similarly, the use of osmotic stress and the addition of growth retardant to the culture medium have effectively prolonged the interval between culture transfers (Wither 1987; Prithcard et al., 1986).

The greatest genetic stability is achieved by storage of propagules, capable of regeneration *in-vitro* liquid nitrogen i.e. **cryopreservation** (Kartha 1985) where possible these propagules will be excised meristems, capable of direct regeneration into plantlets, by isolated cells or protoplasts.

Cryopreservation

In this system stability is imposed by ultra low temperature and storage is at, or close to -196^{0}C using liquid Nitrogen (or the vapour immediately above it), as practical andconvenient oxygen. At such temperature normal cellular chemical reactions do not occur as energy level are too low to allow sufficient molecular motion to complete the reaction.Water exists either in a crystalline or glassy state under these conditions and such high viscosity (> 1013 poises) that rates of diffusion are insignificant over time spans measured at least as decades. The majority of the chemical changes that might occur in a cell are therefore; effectively prevented and so the cell is stabilized the maximum extent that is practically possible.

Unfortunately, that is not to say that biological material successfully cooled to -196^{0}C is in state of complete suspended animation. Certain type of chemical reaction can still occur at these temperatures, such as the formation of the free radicals and macromolecular damage due to ionizing radiation. The only real threat to genetic stabilitycomes from such reactions, especially those that damage nucleic acids. Any damage that does occur will necessarily be cumulative as enzyme repair mechanisms are also totally inhibited at these low temperatures.

While there are as yet few quantitative data on genetic stability at ultra low temperature for higher organisms, studied by Ash wood, Smith and Grant (1977) indicate that to reach a D10 level (where D10 is the radiation dose resulting in 90% mortality of the population) a frozen cell population would have to be exposed to back ground radiation for some 32,000 years. It is also noteworthy that dimethyl sulphoxide, probably the most commonly used cryoprotectant *in-vitro* preservation and may aid in radiation damage.

The potential of conservation system for *in-vitro* material based upon cryogenic storage is therefore, clear and the technique has become relatively widely used.

11.6.3 Other Methods

i) Cold storage

Germplasm conservation by storing material in cultures at low and no-freezing temperature the ageing of plant material is slow but not completely stopped as in freezes prevention.

ii) Low Pressure and Low Oxygen Storage

Attempts have been made to development Low Pressure Storage (LPS) and Low Oxygen Storage (LOS) as feasible techniques for future conservation of cultured plant materials. In LPS, the atmospheric pressure surrounding the tissue cultures is reduced resulting in partial decrease of the pressure created by gases in contact with the plant material. On theother hand, in LOS, the atmospheric pressure (760 mm Hg) is not reduced but the inert gases (particularly nitrogen) are combined with oxygen to create low oxygen pressure.

These are found useful in both short term and long term storage. There is also belated recognition that nature is infinitely more tough tests of survival for millions of years. An effort is now onto revive culturing of plant in-vitro. A biotechnology firm in USA, *Phytera*, has for example set up and stored plant cell cultures of 5,000 spp in glass vials.

11.6.4 Germplasm Facilities in India

Recognizing the need for sophisticated facilities for research and development and providing services, the following additional germplasm facilities have been set up:

1. The National Facility for Microbial Type Culture Collection at the Institute of Microbial Technology, Chandigarh, with over 1,600 cultures in its stock.
2. The National Facility on Blue-green Algal Collection at the Indian Agricultural Research Institute, with over 500 strains and several pure culture as well as soil- based cultures, which have been supplied to farmers for production of bio-fertilizers.
3. The National Facility for marine Cyanobacteria at the Bharatidasan University, Tiruchirapalli, which is coordinating extensive surveys on the southern coast.
4. The National Facility for Plant Tissue Culture Respository at NBPGR, New Delhi, which has undertaken in vitro conservation of germplasm (Cell, Tissue, organ), for medium and long term, particularly for those species for which conventional methods are inadequate. It has 850 accessions of crop species and employes molecular methods of characterization and classification.
5. The National Facility for Laboratory Animals at Central Drug Research Institute, Lucknow and the National Institute of Nutrition, Hyderabad has made available quality animals for biomedical research and industry in the country.
6. The National Facility for Animal Tissue and Cell Culture, Pune, and autonomous institutions under Department of Biotechnology (DBT) has 1127 stock cultures comprising 594 different cell strains. The facility has supplied 401 culture consignments to 84 insttutions throughout the country. It also has 50 rectors, plasmids and genomic libraries.
7. Three National Gene Bank for Medicinal and Aromatic Plants at the Central Institute of Medicinal and Aromatic Plants, Lucknow and NBPGR, New Delhi, for the northern region; and the Tropical Botanical Garden and Research Institute,Trivendrum, for peninsular India have been established. These banks will conserve important species of proven medicinal value, which are categorized as endangered, threatened or rare and are used extensively in traditional systems of medicine, difficult to propagate, have significance for research and developmet for the future, and are of commercial values. India is the regional coordinator for Asia and also the overall coordinator for the establishment of Gene banks of Medicinal and Aromatic Plants among G-15 countries.

11.7 GENERAL ACCOUNT OF IMPORTANT INSTITUTIONS

11.7.1 Botanical Survey of India

Botanical Survey of India (BSI) was established in 1890 with the basic objectives of carrying out floristic surveys of the Indian empire. It was reviewed and reorganised in 1954. During the successive plan periods its functions have been gradually expanded. After reorganisation and establishment of 10 different regional centres throughout the country, the aims and objectives of the Survey were redefined in 1976 with a view to encourage taxonomic research and to accelerate the scientific expertise for the preparation of a comprehensive flora of the country. The objectives and perspectives of BSI were thoroughly reviewed in 2002 by the subcommittee constituted by Programme Advisory Committee for BSI & ZSI. Activities like survey and exploration of plant resources, listing of endangered species, publication of national flora, preparation of national Data Bank on herbarium and live collection, plant distribution and nomenclaturewere strengthened.

History

The British East India Company had established botanical gardens at Sibpur, Poona, Saharanpur and Madras as centres for improving botanical knowledge and experimentation under the local Governments. For example, the Saharanpur botanical garden, which dates from before 1750, was acquired by the East India Company in 1817 for growing medicinal plants. Most of the EIC botanical gardens' work was for the cultivation of plants of interest in commerce and trade.

The Botanical Survey was formally instituted on February 13, 1890 under the directionof Sir George King, who had been superintendent of Royal Botanic Garden, Calcutta since 1871. King became the first ex-officio Director of BSI. The Calcutta Gardenbecame the headquarters of the Survey and was given regional responsibility for Bengal, Assam, North East, Burma, and the Andaman and Nicobar Islands.

Objective

The prime objectives of the Survey were:

- To undertake intensive floristic surveys and collect accurate and detailed information on the occurrence, distribution, ecology and economic utility of plants in the country.
- To collect, identify and distribute materials which may be of use to educational and research institutions and,
- To act as custodian of authentic collections in well planned herbaria and to document the plant resources in the form of local, District, State and National Flora.

Research Center/ Circle

To cope up with this enormous task assigned to the Survey, the following 4 circles were established after independence, in different Botanical regions to cover the vast stretches of the country:

1. Botanical Survey of India, **Southern Circle** at Coimbatore on 10th October 1955.
2. Botanical Survey of India, **Eastern Circle** at Shillong on 1st April 1956.
3. Botanical Survey of India, **Western Circle** at Pune on 12th December 1955.
4. Botanical Survey of India, **Northern Circle** at Dehra Dun on 1st August 1956.

Simultaneously, a Central Botanical Laboratory at Lucknow was established in December, 1957 for studying the various aspects of plant biology like – cytology, plant physiology, plant chemistry, seed biology, ecology, etc.- in order to provide multidisciplinary approach to conventional taxonomy.

During the same year (1957), the Herbarium belonging to "Royal Botanic Garden", Calcutta, which was renamed as the "Indian Botanic Garden" in 1950, was transferred to Botanical Survey of India and soon this herbarium shot into fame as the "Central National Herbarium" (CAL).

In order to further strengthen the Survey for carrying out its assigned mandate more effectively and expeditiously, a number of new Circles in different phytogeographical regions were opened as follows:-

1. Botanical Survey of India, **Central Circle** at Allahabad in 1962
2. Botanical Survey of India, **Arid Zone Circle** at Jodhpur in 1972
3. Botanical Survey of India, **Andaman & Nicobar Circle** at Port Blair in 1972
4. Botanical Survey of India, **Arunachal Pradesh Circle** at Itanagar in 1977
5. Botanical Survey of India, **Sikkim Himalayan Circle** at Gangtok in 1979
6. **Botanic Garden of Indian Republic** at Noida in 2002
7. Botanical Survey of India, **Deccan Circle** at Hyderabad in 2005

Mandate

During the successive five year plan periods, the functions of Botanical Survey of India were further diversified to include various new areas such as assessment and inventorisation of endemic, rare and threatened plant species; evolving conservation strategies; studies on fragile ecosystems and protected areas like Sanctuaries, National Parks and Biosphere Reserves; monitoring of changes in floristic components; ex-situ conservation, multiplication and maintenance of germplasm of plant genetic resources, endemic and threatened species, wild ornamentals, etc.; ethnobotanical and geobotanical studies and the development of National Database on Herbarium (including Type specimens) live collections, plant genetic resources, plant distribution and nomenclature. The aims and objective of the department were redefined, reviewed during the year 1987 and survey and exploration of plant resources and inventorisation of threatened species, publication of National and State Floras and development of National database were given top priority.

After the ratification of the Convention on Biological Diversity by the Govt. of India in February, 1994 a greater role for Botanical Survey of India was envisaged, particularly with reference to the article – 7, 8, 12, 16 of the Convention on Biological Diversity (CBD). Following which the objectives and strategies of the Botanical Survey of India were further diversified.

Following are the main functions of Botanical Survey of India:

Primary Functions

- Exploration, inventorisation and documentation of phytodiversity (including non-flowering plants) in general and protected areas, hotspots, fragile ecosystems, wetlands, sacred groves in particular; publication of National, State and District Floras.
- Identification of Red list species and species rich areas needing conservation; ex- situ conservation of critically threatened taxa in the Botanical Gardens.
- Survey and documentation of traditional knowledge (ethnobotany) associated with plants
- Develop a national database of Indian plants including herbarium specimens, live specimens, Botanical paintings /illustrations etc.

Secondary Functions

- Revisionary/Monographic studies on selected plant groups.
- Qualitative analysis of nutritive value of ethno-food plants and other economicallyuseful species.
- Capacity building in plant taxonomy through refresher courses and post M.Sc. certificate course.
- Environmental Impact Assessment of areas assigned to BSI for study.
- Develop and maintain Botanical Gardens, Museum and Herbaria.
- Preparation of Seed, Pollen and Spore Atlas of Indian Plants.
- Recently, the Survey has also extended its activities to Antarctica from 16th expedition (1996 – 97) onwards for the study of Bryophytes, Fungi and Algae (except the blue-green).

11.7.2 Department of Biotechnology (DBT)

The setting up of a separate Department of Biotechnology (DBT)**,** under the Ministry of Science and Technology in 1986 gave a new impetus to the development of the field of modern biology and biotechnology in India. In more than a decade of its existence, the department has promoted and accelerated the pace of development of biotechnology in the country. Through several Research & Development projects, demonstrations and creation of infrastructural facilities a clear visible impact of this field has been seen. The department has made significant achievements in the growth and application of biotechnology in the broad areas of agriculture, health care, animal sciences, environment, and industry.

The impact of the biotechnology related developments in agriculture, health care, environment and industry, has already been visible and the efforts are now culminating into products and processes. More than 5000 research publications, 4000 post-doctoral students, several technologies transferred to industries and patents filed including US patents, can be considered as a modest beginning. Department of Biotechnology (DBT) has been interacting with more than 5,000 scientists per year in order to utilize the existing expertise of the universities and other national laboratories. A very strong peer reviewing and monitoring mechanism has been developed. There has been close interaction with the State Governments particularly through State S & T Councils for developing biotechnology application projects, demonstration of proven technologies, and training of human resource in States and Union Territories. Programmes with the states of Gujarat, Rajasthan, Madhya Pradesh, Orissa, West Bengal, Haryana, Punjab, Jammu & Kashmir, Mizoram, Andhra Pradesh and Uttar Pradesh have been evolved. Biotechnology Application Centres in Madhya Pradesh and West Bengal have already been started.

A unique feature of the department has been the deep involvement of the scientific community of the country through a number of technical task forces, advisory committees and individual experts in identification, formulation, implementation and monitoring of various programmes and activities.

In India, more than a decade of concerted effort in research and development in identified areas of modern biology and biotechnology has given rich dividends. The proven technologies at the laboratory level have been scaled up and demonstrated in field. Patenting of innovations, technology transfer to industries and close interaction with them have given a new direction to biotechnology research. Initiatives have been taken to promote transgenic research in plants with emphasis on pest and disease resistance, nutritional quality, silk-worm genome analysis, molecular biology of human genetic disorders, brain research, plant genome research, development, validation and commercialization of diagnostic kits and vaccines for communicable diseases, food biotechnology, biodiversity conservation and bioprospecting, setting up of micropropagation parks and biotechnology based development for SC/ST, rural areas, women and for different States. Necessary guidelines for transgenic plants, recombinant vaccines and drugs have also been evolved. A strong base of indigenous capabilities has been created. The field of biotechnology both for new innovations and applications would form a major research and commercial endeavor for socio-economic development in the next millennium.

Mandate

- Promote large scale use of Biotechnology
- Support R&D and manufacturing in Biology
- Responsibility for Autonomous Institutions
- Promote University and Industry Interaction
- Identify and Set up Centres of Excellence for R&D
- Integrated Programme for Human Resource Development
- To serve as Nodal Point for specific International Collaborations
- Establishment of Infrastructure Facilities to support R&D and production
- Evolve Bio Safety Guidelines, manufacture and application of cell based vaccines

- Serve as nodal point for the collection and dissemination of information relating to biotechnology.

The Department of Biotechnology (DBT) since its inception has been working for the creation of a strong and indigenous base of modern biology. Biotechnology has made incredible progress in the last two decades all over the world. Rapid advances have been achieved in the fields of recombinant DNA techniques, cell and tissue culture, immunology, enzymology, bioprocess engineering and vaccinology. Availability of new biotechnological tools and production of microbes, plants and animals with improved traits have opened up great opportunities for better products and processes. These applications have great potential in developing countries for providing opportunities for employment through value added products, and for generation of non-polluting andenvironmentally friendly technologies.

Areas where biotechnology plays a significant role are agriculture, health, environment and industry. In order to expedite field evaluation of technologies and products generated through R&D efforts, DBT has evolved a system for contract research through which such programmes will bring forth either a product or a new process in a time bound format for field testing and subsequent large scale production. Special programmes have been launched for the welfare of the poorer sections of society in terms of generation of employment and improvement in the living standards, nutrition and health etc.

Manpower Development

The Department has formulated an Integrated Programme of Manpower Development to generate a critical mass of well trained scientific personnel for the many biotechnological research, teaching and industrial activities in the country. These include Post-Graduate Teaching and Post-Doctoral Programme; Biotechnology Associateship (Overseas and National); Short-term Training Courses for Mid-Career scientists and Industrial R & D scientists; Technician Training and School Teachers Training Programmes; Programmes for Biology Teaching in Schools. DBT scholarship in biology and schemes like biotechnology publications, popular lectures by renowned scientists, support to seminar/symposia, film production etc., aimed at the popularisation of biotechnology in the country, are in full flow.

Infrastructural Facilities

To provide scientists working in the field of biotechnology adequate assistance and support, the Department had set up facilities such as, germplasm banks (microbial type culture collection, blue green algal collection, marine cyanobacteria and plant tissue culture repository), animal house facilities, biochemical engineering research and process development, genetic engineering units, oligonucleotide synthesis etc. The animal house facilities at Central Drug Research Institute, Lucknow and National Institute of Nutrition (NIN), Hyderabad have supplied over two lakh laboratory animals of around 20 speciesto several scientists in the field of biomedical research. The biomedical engineering research and process development facility has a computer controlled fermentation system ranging 30 ltr to 1,500 ltr capacity. The operational facilities are available to research personnel and industry to upgrade their processes and products. The National Facility for Marine Cyanobacteria at Tiruchinapally, is developing a technology for aquaculture feed and for the production of natural colorant. Genetic Engineering Unit at MKU, Madurai has tied up with industries to work on several industrial products.

Immunodiagnostics

A number of programmes have been adopted to develop simple, inexpensive but sensitive diagnostic kits for early detection of a variety of communicable and non- communicable diseases. The technology transfer of eight products that has taken place so far are amoebic liver abscess, hepatitis-B, blood grouping, typhoid (blood test) pregnancy detection (all developed by the National Institute of Immunology, an autonomous body under DBT), typhoid (urine test) (developed by AIIMS, New Delhi) filariasis (developed by Mahatma Institute of Medical Sciences, Wardha) and leishmaniasis (developed by CDRI, Lucknow), technology for diagnosis of leishmaniasis in another format aspergillosis, a quantitative test for typhoid fever as well as reproductive hormones are ready for transfer to industry.To accelerate the development of immuno-diagnostics a pilot plant has been established at the National Institute of Immunology, New Delhi. A recombinant DNA based AIDS detection kit with merely one drop of blood has reached at an advanced stage of development.

Vaccine Production

The Department of Biotechnology has promoted a R&D cum manufacturing unit, Bharat Immunologicals and Biological Cooperation Limited (BIBCOL) at Bulandshahr, Uttar Pradesh. Manufacturing activities are divided into two phases, Phase I involving the formulation, packaging and distribution from imported bulk of OPV and Phase II involving the indigenous production of vaccine. Phase I has already been completed. Manufacturing licence has been obtained from competent authorities.

Immunological Approaches to Fertility Control

A composite programme of Immunological Approaches to Fertility Control is being undertaken in National Institute of Immunology (NII), New Delhi; Post Graduate Institute of Medical Education and Research, Chandigarh; IISC, Bangalore; CDRI, Lucknow; Institute for Research in Reproduction, Bombay and National Institute of Health and Family Welfare (NIH&FW), New Delhi with the objective of developing safe, cost-effective, durable and reversible contraceptive vaccines for controlling fertility in men and women. Two projects, one at Indian Institute of Science, Bangalore and the other at Institute of Research in Reproduction, Bombay have carried out research to demonstrate the termination of pregnancy by interrupting vitamin carrier protein through antibodies.

Crop Biotechnology

Genetic engineering for gene isolation, transformation, transgenic plants and molecular maps based on RFLP/RAPD are the emerging areas of research to facilitate agricultural productivity. Consequently, the Department has made a concerted effort to support specific priority crops like, rice, rape mustard, chickpea, pigeon pea and wheat by R&D projects and has also set up six centres for plant molecular biology all over the country. Some of the important achievements of these programmes are:

i. To improve the nutritional quality of cereals and to study the regulation of seed storage protein gene, a gene encoding for a protein of high lysine and sulphur containing amino acid from *Amaranthus* has been cloned and sequenced.
ii. Nuclear coded male sterile genetic lines as well as their restorers are under trial in mustard.
iii. Two molecular marker technologies - RFLP and RAPD have been utilised for tagging genes responsible for blast resistance in rice.
iv. Plant regeneration from mesophyll protoplast has been achieved.
v. Two multi-institutional projects on development of cotton and quality improvement of wheat by molecule transgenic techniques were successfully launched.

Animal Biotechnology

The main areas of research in the sphere of animal biotechnology are embryo transfer technology, health care and diagnostics, nutrition, genetic resource conservation, leather biotechnology and development of bio-products. Research programmes in upstream areas of embryo transfer technology (ETT) have been funded. Significant progress has been recorded in the fields of in-vitro fertilization, in-vitro maturation, splitting and cloning of embryos. Development of indigenous hormones and biological is another rapidly emerging potential area of research. A major programme on down-stream activities of ETT, principally to take the various technologies developed to the grass-root level, has been put into action. Diagnostics and vaccines are being developed for animals including poultry. Projects involving genetic resource conservation attempts to conserve invaluable indigenous breeds have also been launched.

Aquaculture

Projects in the field of aquaculture revolve around feed development, production of transgenic fish, extraction of bio-active compounds, cryopreservation of embryos and development of disease diagnostics. A production of 8 to 10 tons in two crops per year has been demonstrated in a semi-intensive system for tiger shrimp. Carp production upto 15 tonnes per hectare per year has been demonstrated. A mission-mode programme on shrimp aquaculture under different agroclimatic zones has been launched.

Biomass, Horticulture and Plantation Crops

Research and Development projects have commenced on selected forest tree species for developing and standardizing protocols for plantlet regeneration using tissue culturetechniques from ex-plants collected from elite genotypes. Nationally important forest treespecies requiring immediate attention for development of tissue culture protocol have been identified as a priority for conducting such studies during the Eighth Plan.

Protocols have been standardized for plantlet regeneration via tissue culture technology for *Eucalyptus camaldulensis*, *E. tereticornis*, *Dendrocalamus strictus*, *Tectona grandis*, *Bambusa tulda*, *Populus deltoides* and *Anogeissus pendula*. These protocols have now been adopted for large scale production. Research programmes have been initiated on horticulture and plantation crops of economic importance - mango, citrus, banana, tea, coffee, rubber, cashew and spices. Protocols have been developed for pepper, rubber and cocoa. Large scale production of elite forest trees is under process at the Culture Pilot Plant units at NCL, Pune and TERI, New Delhi. Approximately 6.67 lakh plantlets have been produced, of which five lakh have been field planted covering an area of 150 ha in nine different states. Preliminary field data collected indicates an initial survival of 90-95per cent.

Biological Control of Plant Pests, Diseases and Weeds

The biocontrol network programme is under implementation with 29 research and development projects at various institutions/universities throughout the country for the control of serious insects, pests and diseases affecting cotton, sugarcane, pulses, oilseeds and vegetables. The principal objective has been achieved by laying greater emphasis on development of better formulations and cost effective commercially viable pilot scale technology for the production of biocontrol agents to be used under IPM of key pests and diseases. The target of 11.600 ha has been crossed in the fields of cotton, chickpea, sugarcane, tobacco, oilseeds and vegetables. With a view to promote commercialisation of biopesticides, two biocontrol pilot plants (BCPP) have been set up at two centres, TNAU and MKU. Each BCPP aims to produce sufficient quantity of biocontrol agents tocater to the requirements of 10,000 ha of chickpea, groundnut, cotton, sunflower, tobacco, castor, sugarcane, blackgram and green gram. The targets of the BCPPs have been achieved as per schedule. Sufficient quantities of Nuclear Polyhedrosis Virus (NPV) of *Helicoverpa armigera, Spodoptera litura*, Granulo viruses (GV) of *Chilo infuscatellus, Trichogramma, Trichoderma* have been produced to cover an area of 18,000 ha in the fields of the crops mentioned above. These two BCPPs serve as a model unit for private entrepreneurs taking up such a venture. The Department also supports some projects on breeding varieties resistant to biotic stresses through biotechnology in crops such as chickpea, sugarcane, rice and tobacco.

For popularising biopesticides and ensuring their large scale adaptation by the farmers, the Department arranged field days, workshops-cum-farmers mela under the Biocontrol Network Programme. During 1994-95, 10 more production units were set up in several states.

Biofertilizers

The project on Technology Development and Demonstration of Biofertilizers has resulted in technology packages like polyalkene bioreactor designs to optimise the biomass production of blue green algae, specific media components, their concentration and simple bioassay method and 136 tonnes of high quality soil based innoculum was produced.

Biotechnology Information System

A national network of distributed information centres (DICs) and distributed information sub-centres (DISCs) in specialized areas of Biotechnology under its Biotechnology Information System (BTIS) Programme has been set up. The network provides a complete information source on a) genetic material as hard data. (eg. protein and nucleic acid sequences, gene bank etc.); b) soft information (eg. bibliographic reference through CDROM etc.) and management information. Ten distributed information centres and 23 distributed information sub-centres in selected areas have been established under this system to meet the end user's information requirements. These centres are equipped with international networks like Internet, bitnet, ICGEB net etc., for accessing several biological information resources.

Industrial Biotechnology

Steps are being taken to develop products and processes with specific need based inputs in order to transform semi-finished R&D results into industrially usable products. The Task Force on Industrial Biotechnology helps in identifying such projects. At present, 30 product oriented projects are in operation which include development of diagnostic kits, liposome intercalated drug delivery system, biotechnological methods for enrichment of ores, gathering field data on efficacies of bio-pesticides, gene cloning and gene expression of epidermal growth factor in *E.coli*, optimisation of process parameters for the production of enzymes and carbohydrates, standardization of production process for edible mushrooms and process development of high fructose syrup. The areas of development include agriculture, forestry, human and animal health, as well as industrial products.

The Biotech Consortium India Limited (BVIL) has played a crucial role in bridging the gap between R&D industrial and financial institutions. A new programme, Farmers Agricultural Resource Management (FARM), a UNDP-FAO-UNIDO supported activity, was implemented. DBT will coordinate the Asian Biodiversity and Biotechnology Sub- Programme.

International Collaboration

International research and development cooperation progammes have been signed with Germany, Switzerland, USA, UK, Sweden and Russia. A programme of cooperation in biotechnology has been developed among the members of SAARC countries in the fields of health care, agriculture, animal sciences and environment. India has also been handed the overall responsibility for coordinating the activities of the G-15 nations for theestablishment of gene banks for medicinal and aromatic plants. Under the aegis of this programme, a network of three national gene banks at Tropical Botanical Garden and research Institute, Thiruvananthapuram; Central Institute of Medicinal and Aromatic Plants, Lucknow; and National Bureau of Plant Genetic Resources, New Delhi have been set up for the conservation of medicinal and aromatic plants.

Autonomous Institutions

The Department of Biotechnology has set up two autonomous institutions, National Institute of Immunology (NII), New Delhi and National Facilities for Animal Tissue and Cell Culture (NFATCC), Pune.

NII has been working on the mechanisms of the immune system so as to work out comprehensive solutions to a plethora of health problems. Till now the focus has been on the control of fertility and the diagnosis and control of communicable diseases. The main areas of research are birth control vaccines; vaccine for communicable diseases; immunodiagnostics kit development along with DNA probe for communicable diseases; drug delivery system to deliver all doses of vaccine at a single point; animal related biotechnology for reproduction of genetically superior animals of economic value; predetermination of sex of embryos; preservation of genes of rare species of animals; aquaculture biotechnology; induced breeding of major Indian crops; transgenic animals and recombinant products. So far, the Institute has delivered eight products to the industry.

Since its inception, the NFATCC has been actively involved in cell repository and supplyof cell lines. The principal objectives of the Facility are to identify, maintain, store, propagate and supply of human and animal cell lines, establishment of technology for collection, maintenance and supply of various human organs like cornea, skin and bone marrow. Presently, the Facility holds a stock of 1,500 different cell lines. The technology that maintains human cornea for an extended period has been standardized and the procedures for preservation of heart valves are being developed. The Facility has successfully developed cell culture from human foetal tissues. Studies on screening anti-malarials against chloroquine resistant malaria parasite strains have been carried out. The cell biology laboratory is functional to screen anti-cancer drugs using cell lines. The technology for maintenance and cultivation of skin as organ culture and 3D epithelia from human keratinocytes and its subsequent grafting to burns, nevi and vitiligo cases has been standardised and the results are promising. Newer approaches towards cryopreservation of tissues are being developed at the institute.

11.7.3 Indian Agricultural Research Institute (IARI)

Agriculture in India is the means of livelihood of almost two thirds of the workforce in the country. It employs nearly 62% of the country's total population and occupies 42% of its total geographical area. From a nation dependent on food imports to feed its population, India today is not only self-sufficient in grain production, but also has a substantial reserve. The progress made by agriculture in the last four decades has been one of the biggest success stories of free India. Agriculture and allied activities constitute one of the main contributors to the Gross

Domestic Product of the nation. The increase inagricultural production has been brought about by bringing additional area under cultivation, extension of irrigation facilities, the use of seed of improved high yielding varieties, better production technologies evolved through agricultural research, water management, and plant protection through judicious use of fertilizers, pesticides and cropping practices.

The Indian Agricultural Research Institute (IARI), a centenarian, is the country"s premier national Institute for agricultural research, education and extension. It has served the country by developing appropriate technologies through basic, strategic and need-based research resulting in crop improvement and agricultural productivity in harmony with theenvironment leading to the Green Revolution and served as a centre for academic excellence in the area of postgraduate education and human resource development in agricultural sciences.

Originally established in 1905 at Pusa (Bihar) with the financial assistance of an American Philanthropist, Mr Henry Phipps, the Indian Agricultural Research Institute (IARI) started functioning from New Delhi since 1936 when it was shifted to its present site after a major earthquake damaged the Institute's building at Pusa (Bihar). The institute's popular name "Pusa Institute" traces its origin to the establishment of the Institute at Pusa.

The Indian Agricultural Research Institute is the country's premier national Institute for agricultural research, education and extension. It has the status of a "Deemed-to-be-University" under the UGC Act of 1956, and awards M. Sc. and Ph. D. degrees in various agricultural disciplines.

The growth of India's agriculture during the past 100 years is closely linked with the researches done and technologies generated by the Institute. The Green Revolution stemmed from the fields of IARI. Development of high yielding varieties of all major crops which occupy vast areas throughout the country, generation and standardization of their production techniques, integrated pest management and integrated soil-water- nutrient management have been the hallmarks of the Institute's research. The Institute has researched and developed a large number of agrochemicals which have been patentedand licensed and are being widely used in the country. Over the years, IARI has excelled as a centre of higher education and training in agricultural sciences at national and international levels.

Function

The Indian Agricultural Research Institute (IARI) is India's premier institution in the field of agricultural research, higher education in agriculture (post-graduate programme) and extension education. The primary functions of the Institute are

i. Basic and applied research in the various branches of agricultural sciences,
ii. Teaching at the post-graduate level and organisation of special short-term training programmes in several aspects of agricultural sciences, both at the national and international levels and,
iii. Extension advisory work for improving farm productivity and socio-economic conditions of the farming community.

Mandate

To realize the mission laid down by the Institute, i.e., to explore new frontiers of science and knowledge, to develop human resources and policy guidance to create a vibrant, responsive and resilient agriculture, the mandate of the institute is as follows:

- To conduct basic and strategic research with a view to understanding the processes, in all their complexity, and to undertake need-based research that leads to crop improvement and sustained agricultural productivity in harmony with the environment.
- To serve as a centre for academic excellence in the area of post-graduate education and human resources development in agricultural sciences.
- To provide national leadership in agricultural research, extension, and technology assessment and transfer by developing new concepts and approaches and serving as a national referral point for quality and standards.
- To develop information systems, add value to information, share the information nationally and internationally, and serve as a national agricultural library and database.

Growth

IARI is India premier national institute for research and higher education in agricultural sciences. The Institute received the status of a "Deemed University" in 1958 under the UGC Act of 1956 and was empowered to award M. Sc. and Ph.D. degrees. Headquartered at New Delhi, it is the largest and most prestigious of the research institutes financed and administered by the Indian Council of Agricultural Research (ICAR).

The administrative and technical head of IARI is its Director. The Board of Management, with the Director as its chairman, served by four councils, namely, Research Advisory Council, Academic Council, Extension Council and Executive Council, provides the overall management direction. The Director is assisted by a Joint Director (Research), a Dean & Joint Director (Education) and a Joint Director (Extension) who is equivalent to the Directors of ICAR institutes, which are not deemed universities. A Joint Director (Administration) looks after the day-to-day administrative work. The Chief Finance and Accounts Officer has overall charge of the audit and accounts matters.

Centers

Presently the research, education, and extension activities of the Institute are carried out through a network of 20 discipline-based divisions, 5 multidisciplinary centers situated in Delhi, 8 regional stations, 2 off-season nurseries, 10 centers of All India Coordinated Research Projects and a common set of service units. The Institute also serves as the headquarters of 3 All India Coordinated Research Projects. In addition, some of the institutes like National Research Centre on Plant Biotechnology, NCIPM and Directorate of Maize Research are located in the campus.

11.7.4 The National Bureau of Plant Genetic Resources (NBPGR)

The National Bureau of Plant Genetic Resources has its Headquarters at New Delhi, located at latitude of 28° 35‟ N, longitude of 70° 18‟ E and an altitude of 226 m above mean sea level. NBPGR functions under the administrative control of the Crop Science Division of the ICAR. The Bureau draws guidelines from the Crop Science Division of ICAR, Bureau's Management Committee, Research Advisory Committee and Germplasm Advisory Committees.

The Bureau has four Divisions, two units, three cells and an experimental farm at its Headquarters in New Delhi and 10 regional/ base stations located in different phyto-geographical zones of India. Besides this, a National Research Centre on DNA fingerprinting and an All India Coordinated Research Project on Under-utilized Crops are also located at the Bureau.

Plant Exploration and Collection Division has the objectives to plan, coordinate and conduct explorations for collecting germplasm. Germplasm Evaluation Division is entrusted with the prime responsibility of characterization and evaluation of all the indigenous and exotic germplasm collections for their field performance and other important traits like resistance to biotic/ abiotic stresses and phytochemical attributes along with maintenance and regeneration. This division has an experimental farm located at Issapur about 45 km from the main campus covering an area of 40 ha. Germplasm Conservation Division is vested with the task of conservation of germplasm of various crop plants, and to undertake basic research on various aspects of seed storage and longevity. Plant Quarantine Division has the power vested by Plant Protection Advisor to the Government of India, under the Plant Quarantine (Regulation of Import into India) Order 2003 under the Destructive Insects and Pests Act (1914), to carry out quarantine of the plant germplasm imported for research purposes. It also undertakes the quarantine of material under export and issues the phytosanitary certificate. Germplasm Exchange Unithas the responsibility of introducing genetic resources of diverse crop plants and their wild relatives and distributing the same within the country, and also exports the germplasm. There is also a Tissue Culture and Cryopreservation Unit, with the main objective to conserve economic plants, for which conventional methods of storage are unsuccessful or inadequate, through in vitro and cryopreservation techniques. In addition, the Bureau has three cells, namely PGR Policy, Agriculture Research Information System and Technical Cell.

The NRCDF has facilities for molecular fingerprinting of released varieties and genetic stocks of crop plants of India. It has the objectives of standardization of molecular marker systems for DNA profiling and their application in variety identification. The NBPGR Headquarters, along with the network of 11 regional /base/ satellite stations covering different agro-climatic regions, and the linkages with 59 National Active Germplasm Sites constitute the Indian Plant Genetic Resource Management System.

Mandate

To act as nodal institute at national level for acquisition and management of indigenous and exotic plant genetic resources for food and agriculture, and to carry out related research and human resource development, for sustainable growth of agriculture.

Objectives of NBPGR

- To plan, organize, conduct and coordinate exploration and collection of indigenous and exotic plant genetic resources.
- To undertake introduction, exchange and quarantine of plant genetic resources.
- To characterize, evaluate, document and conserve crop genetic resources andpromote their use, in collaboration with other national organizations.
- To develop information network on plant genetic resources.
- To conduct research, undertake teaching and training, develop guidelines and create public awareness on plant genetic resources.

Regional station of NBPGR

1) Regional Station, Akola

The Regional Station was established at Akola in 1977 to cater to the needs of Plant Genetic Resources activities in central-peninsular India, especially Maharashtra, Goa, Daman and Diu and parts of Southern districts of Madhya Pradesh and parts of northern Karnataka. This region is a vast plateau comprising hilly tract of Satpura, Gawilgarh and Maikala ranges, plain cotton belt of erstwhile Berar, undulating Western Ghats and coastal regions (now referred to as Central Indian Region, Zone IX under NATP-PB). The experimental farm of 20 hactares is located in university campus. Amravati centre now is working as satellite centre of Akola station.

2) Regional Station, Bhowali

The Regional Station was initially established at Almora as an exploration base centre for germplasm collection activities in Kumaon and Garhwal hills. Mandate area of the regional station is now referred to at Central Himalayan Region, Zone V under NATP- PB). The centre was shifted to Bhowali in April 1986 and designates NBPGR Regional Station when Wheat Research Station (of Vivekanand Parvatiya Krishi Anushandhan Shala VPKAS) was merged with it. Earlier to shifting, this station has a long history. The Imperial Potato Research Station established in 1943, for potato seed multiplication and brown rot (Pseudomonas solanacearum) test was known as hot spot for the development of plant diseases. In 1956, with the commencement of wheat improvement scheme under PL-480, it was transferred to Indian Agricultural Research Institute (IARI) and name was changed as Wheat Research Station, Bhowali. In 1984 it was again transferred to VPKAS, till shifted NBPGR. Year of establishment: 1986.

3) **Exploration Base Center, Cuttack**

This Base Centre was established in the campus of Central Rice Research Institute with the objective of exploration and collection of indigenous crops from Orissa, West Bengal and adjoining areas in parts of Jharkhand and Chhattisgarh (now referred to as Humid/Moist Tropical East Coastal Region, Zone III under NATP-PB). Climatically, the area is sub-humid to humid in eastern and south-eastern plains. Northern plateau is an extension of Chhotanagpur plateau and spreads upto Mayurbhanj and Keonjhar districts and districts of Ganjam, Kalahandi, Phulbani and Koraput in the southern portion. The whole area is potential for collecting. Year of establishment: 1986

4) Regional Station, Hyderabad

This Regional Station was established initially as Plant Quarantine Station in ARI campus of Acharya N G Ranga Agricultural University at Rajendranagar, Hyderabad to cater to the needs of Plant Quarantine clearance work particularly on five mandate crops of ICRISAT and paddy international trial material received from IRRI, Philippines meantfor research organizations in south India. A modest beginning was made in 1977, by taking possession of 16 acres of land that was provided by the University. Central Plant Protection and Trainging Institute in collaboration with Directorate of Rice Research wereauthorized to take up the plant quarantine clearance work until the establishment of PQRS of NBPGR in 1985.

5) Regional Station, Jodhpur

This Regional Station was established in 1965 as a sub-station of erstwhile Plant Introduction Division of Indian Agricultural Research Institute in the campus of Central Arid Zone Research Institute at Jodhpur, Rajasthan (now referred to as Arid Region, Zone I under NATP-PB). The main task assigned was to acclimatize the genetic resources of tropical plants procured from abroad on a systematic basis and to collect the indigenous germplasm suited to arid/semi-arid conditions. With the creation of NBPGR in 1976, the substation was transferred to it. It has a farm area of about 6 ha with irrigation facility. The station is entrusted with the responsibility to carry out Plant Genetic Resources (PGR) activities in the states of Rajasthan, Gujarat and adjoiningareas in Haryana.

6) Regional Station, Shillong

This Regional Station was established in 1978 as the northeastern region of India at Shillong, Meghalaya representing the humid, subtropical to sub temperate ecology and climate. It is surrounded by Tibet, China in the north, Bangladesh in southwest, Myanmar in the east and Bhutan and Nepal in the north-west. The jurisdiction of this station for collection activities encompass all the eight states, namely, Assam, Meghalaya, Manipur, Nagaland, Tripura, Sikkim, Arunachal Pradesh and Mizoram (now referred to as Northeastern Region, Zone IV under NATP-PB). The station was under the administrative control of ICAR Research complex for NEH region for some period(Feburary 1983 to September 1985). Since 1986 it is again under administrative control of NBPGR. The office cum laboratory building and experimental farm at Umiam (1000m altitude) in district Ribohi are situated 20kms away from

Shillong City.

7) Exploration Base Center, Ranchi

This Base centre was established in 1988 to carry out systematic exploration for germplasm collection in the states of Bihar, parts of Jharkhand and adjoining areas in Uttar Pradesh and West Bengal (now referred to as Sub-tropical/sub-humid Region, Zone V under NATP-PB). The tribal belt of Chhotanagpur and adjoining region is a potential area for germplasm collection. It is fast developing as a centre for evaluation and maintenance of germplasm of tropical fruits and other field crops suited to the region.

8) Regional Station, Shimla

This Regional Station was established as Plant Introduction Station under Botany Division of IARI in 1960. Since 1976, it came under the control of NBPGR. Apart from the office building and laboratories, it has 7 hectares of farmland. The station has the major responsibility for the conservation and management of plant genetic resources of western Himalayas comprising Himachal Pradesh and Jammu and Kashmir (now referred to as Northwest sub-Himalayan and high attitude Himalayan Region, Zone VI under NATP-PB). A field genebank of temperate fruits and newly introduced fruit plants, and largest germplasm collection of french bean, amaranth, buckwheat is being maintained at the station. The station has also a facility of medium-term storage for conserving orthodox seeds where seeds can be stored up 12-15 years without losing viability. This station also acts as National Active Germplasm Site (NAGs) for amaranth, french bean, buckwheat and temperate fruits. It has strong linkages with State Agriculture Universities of Himachal Pradesh and Jammu and Kashmir as well as Himachal Pradesh University, Shimla.

9) Regional Station, Srinagar

This Regional Station was established in 1988 to carry out systematic exploration for germplasm collection in Jammu and Kashmir. This area has a potential for the collection of temperate fruits, vegetables, rice, millets, medicinal and aromatic plants and temperate tribal food.

10) NBPGR Regional Station, Thrissur, Kerala

This station was established in 1977 in the Kerala Agricultural University campus near Pineapple Research Station on the Mannuthy-Chirakkakode road with a farm area of 10.4 ha. Thrissur is well connected by road, rail and air. Nearest airport is Kochi International Airport at Nedumbassery (60 km). The area of jurisdiction for exploration and collection by the station is southern India comprising Kerala, Karnataka, Tamil Nadu, Pondicherry, Goa and Andaman & Nicobar Islands.

11.7.5 Council of Scientific and Industrial Research (CSIR)

The Council of Scientific & Industrial Research (CSIR) is the premier industrial research and development (R&D) organization in India. It was founded on 26 September 1942, by a resolution of the then Central Legislative Assembly. It is funded mainly by theIndia Ministry of Science and Technology and it is one of the world's largest publicly funded (R&D) organisations, having linkages to academia, other R&D organisations and industry.

Although CSIR is mainly funded by Science and Technology Ministry, it operates as an autonomous body registered under the Registration of Societies Act of 1860. The R & D activities of CSIR include various fields such as aerospace engineering, structural engineering, ocean sciences, molecular biology, metallurgy, chemicals, mining, food, petroleum, leather, and environment.

Presently Dr. (Mrs.) N. Kalaiselvi is the first woman Director-General of CSIR since August 065, 2022.

CSIR Achievements

- Achieved the first breakthrough of flowering of Bamboo within weeks as against twenty years in nature.
- First to analyze genetic diversity of the indigenous tribes of Andaman and toestablish their origin out of Africa 60,000 years ago.
- Developed the first transgenic Drosophila model for drug screening for HumanCancer.
- First to introduce DNA fingerprinting in India.
- Helped India to be the first Pioneer Investor under the UN law of Sea Treaty.
- Invented the first ever only once a week non-steroidal family planning pill in theworld by the name of *Saheli*.
- Designed India's first ever parallel processing computer Flosolver.
- Partnered more than 50,000 companies with turnover ranging from Rs 5 lakhs to Rs 500,000 crores.
- Rejuvenated India's one hundred year old refinery at Digboi using the most modern molecular distillation technology.
- Provided the critical technology for the NMP Lube Extraction Plant of capacity of 2,50,000 tonnes per year.
- Development of a versatile portable PC-based software 'Bio-Suite' for bioinformatics.
- Design of 14 seater plane 'SARAS'.
- Established first ever in the world 'Traditional Knowledge Digital Library' accessiblein 8 international languages.
- Remained in Top 3 in the list of PCT patent applications amongst all developing countries.
- Topped list of USA patents holders.
- Successfully challenged the grant of patent in the USA for use of haldi (turmeric) for

wound healing and neem as insecticide.

Research Laboratories under CSIR

- C-MMACS - CSIR Centre for Mathematical Modelling and Computer Simulation, Bangalore
- CBRI - Central Building Research Institute, Roorkee
- CCMB- Centre for Cellular and Molecular Biology, Hyderabad
- CDRI - Central Drug Research Institute, Lucknow
- CECRI- Central Electro Chemical Research Institute, Karaikudi
- CEERI - Central Electronics Engineering Research Institute, Pilani
- CFRI - Central Fuel Research Institute, Dhanbad
- CFTRI - Central Food Technological Research Institute, Mysore
- CGCRI - Central Glass and Ceramic research Institute, Calcutta
- CIMAP - Central Institute of Medicinal and Aromatic Plants, Lucknow
- CLRI - Central Leather Research Institute, Chennai
- CMERI - Central Mechanical Engineering Research Institute, Durgapur
- CMRI - Central Mining Research Institute, Dhanbad
- CRRI - Central Road Research Institute, New Delhi
- CSIO - Central Scientific Instruments Organisation, Chandigarh
- CSMCRI - Central Salt and Marine Chemicals Research Institute, Bhavnagar
- IGIB - Institute of Genomics and Integrative Biology, Delhi
- IHBT - Institute of Himalayan Bioresource Technology, Palampur
- IICB - Indian Institute of Chemical Biology, Calcutta
- IICT - Indian Institute of Chemical Technology, Hyderabad
- IIP - Indian Institute of Petroleum, Dehradun
- IMT - Institute of Microbial Technology, Chandigarh
- IITR - Indian Institute of Toxicology Research, Lucknow (Formerly known as Industrial Toxicology Research Centre)
- NAL - National Aerospace Laboratories, Bangalore
- NBRI - National Botanical Research Institute, Lucknow
- NCL - National Chemical Laboratory, Pune
- NEERI - National Environmental Engineering Research Institute, Nagpur
- NGRI - National Geophysical Research Institute, Hyderabad
- NIO - National Institute of Oceanography, Goa
- NISCAIR – National Institute of Science Communication and Information Resources, New Delhi
- NISTADS - National Institute of Science, Technology and Development Studies, New Delhi

- NML - National Mettalurgical Laboratory, Jamshedpur
- NPL - National Physical Laboratory, New Delhi
- RRL, Bhopal - Regional Research Laboratory, Bhopal
- RRL, Bhubaneshwar - Regional Research Laboratory, Bhubaneshwar
- RRL, Jammu - Regional Research Laboratory, Jammu
- NEIST (RRL), Jorhat - North East Institute of Science and Technology, Jorhat, Jorhat
- NIIST- National Institute for Interdisciplinary Science and Technology- Thiruvananthapuram
- SERC - Structural Engineering Research Centre, Chennai

11.8 SUMMARY

After going through this unit, you would have achieved the objectives stated earlier in the unit. Let us recall what we have discussed so far.

- India is one of the 12-megadiversity countries in the world. Around 1,27,000 species of microorganisms, plants and animals have been described in the country till date.
- India has had a long history of conservation and sustainable use of natural resources. National strategies and plans for the conservation, sustainable and equitable use of biological diversity are rooted in the long and rich spiritual and cultural traditions of the country.
- Institutionalized *ex-situ* conservation of biological diversity in India started with the establishment of Botanic and Zoological Gardens.
- India has a number of gene banks for the *ex-situ* conservation for plants and animals.
- Systemic surveys of flora and fauna of the country covering all the ecosystems started with the establishment of Botanical Survey of India in 1890 and the Zoological Survey of India in 1916.
- Institutional support in the assessment of biological diversity in, little known agricultural crops & their wild relatives, and floristic surveys are provided by BSI, IARI and NBPGR.
- CSIR and DBT have involved in conservation and sustainable use of medicinal plants, industries development in the conservation and sustainable use of biological diversity.
- India has taken important steps in developing new strategies and further strengthening the existing strategies for effective conservation and sustainable useof its biological diversity. Various systems and approaches for the conservation and sustainable use of biological diversity have been evolved by Government, Non- Government Organizations and local communities.

11.9 SELF-ASSESSMENT QUESTIONS

11.9.1 Multiple choice questions

1. Largest Botanical Garden in India is in

a) Kanpur b) Lucknow
c) Mumbai d) Calcutta

2. NBPGR, is a institute of …………..

a) DBT b) ICMR
c) ICAR d) CSIR

3. Which are two ways or modes of *Ex-situ* conservation?

a) Conventional and non-conventional b) Conventional and Biotechnological
c) Biotechnological and Bioinformatics d) None of the above

4. Which are the conventional methods of *Ex-situ* conservation?

a) Gene banks b) Community seed banks
c) Botanical Gardens d) All of the above

5. CIMAP, Lucknow is an institute of …………..

a) DBT b) CSIR
c) ICAR d) ICMR

6. Cryopreservation is done at temperature

a) -140°C b) -193°C
c) -196°C d) -180°C

7. An *ex-situ* conservation method for endangered species is –

a) National Parks b) Biosphere reserves
c) Wildlife sanctuaries d) Cryopreservation

8. Most active centre of biodiversity studies in India is :

a) Chennai b) New Delhi
c) Allahabad d) Varanasi

11.9.2 Fill in the blanks

a) IBP stands for…………………………………………..
b) Silent valley, which contains vary rare species of plants and animals is in…………..
c) CITES protects the trade in endangered species at …………………. Level.

d) Department of Biotechnology (DBT), came under the Ministry of…………………
e) India has a number of gene banks for the……………conservation for plants and animals.

Answer key:

11.9.1: 1-(d); 2-(c); 3-(b); 4-(d); 5-(b); 6-(c); 7-(d); 8-(b);
11.9.2: a) International Biological Programme; b) Kerala; c) International; d) Science and Technology; e) *Ex-situ*

11.10 REFERENCES AND SUGGESTED READINGS

- Alfred JRB (1990). *Taxonomy in Environment and Biology*. Zoological Survey of India, Calcutta, India.
- Alfred JRB, Darlong VT, & Sati JP (1989). Wildlife Conservation in North-East India: Problems and Realities. *Exposure* 21: 11-17.
- Arora GS and Julka JM (1994). Status Report on Biodiversity Conservation: Western Himalayan Ecosystem. IIPA, New Delhi.
- Cohen JI et al., (1991). Ex-situ Conservation of Plant Genetic Resources : Global Development and Environmental Concern. *Science* 253: 866-872.
- Connors PG (1994). Rediscovery of showy Indian clover. *Fremontia* 22: 3–7.
- Engels JMM and Visser L (2003). *A Guide to Effective Management of Germplasm Collections*. CABI, IFPRI, IPGRI, SGRP. 174 p.
- Government of India (1994). *Conservation of Biological Diversity in India: An Approach.* MoEF, GOI, New Delhi pp 48.
- Kameswara N, Hanson J, Dulloo ME, Ghosh K, Nowell A and Larinde M (2006). *Manual of Seed Handling in Genebanks*. Bioversity International, CTA (Technical Center for Agricultural and Rural Cooperation), FAO, ILRI..
- Klemn C (1993). *Biological Diversity, Conservation and Law*. IUCN, Gland, Switzerland.
- Koo B, Pardey PG and Wright BD (2004). *Saving Seeds*. CABI, IFPRI, IPGRI, SGRP.
- Pant DD (1999). Biodiversity Conservation and Evolution of Plants. *Current Science* 76: 21-23.
- Singh JS (1992). *Restoration of Degraded Land: Concept and Strategies*. Rastogi Publication, Meerut, India.
- US Fish and Wildlife Service, Arcata Division, 1655 Heindon Road, Arcata, Ca.
- Veeresh GK, Rajagopal D and Viraktamath CA (1989). *Advances in Management and Conservation of Soil Fauna.* Oxford & IBH, New Delhi.
- Wilson EO (1988). The current state of Biological Diversity. In : *Biodiversity.* National Academy Press, Washington DC pp. 3-5.
- World Conservation Monitoring Center (1992). *Global Biodiversity: Status of Earth's*

Living Resources. Chapman and Hall, London.
- World Conservation Monitoring Center (1993). *Global Biodiversity*. Chapman and Hall, London.
- World Resources Institute (1992). *World Resources, 1992-93*. Oxford University Press, New York.

11.11 TERMINAL QUESTIONS

11.11.1 Short Answer Type Questions

1- Define NBPGR and its role in *ex-situ* conservation

2- Write short notes on CSIR and IARI.

3- Write a note on *in-vitro* storage of germplasm and cryopreservation.

4- Describe in brief about Field Gene Bank (FGB)

5- Write a short note on DBT

11.11.2 Long Answer Type Questions

1- What is *ex-situ* conservation? Discuss about conventional methods of *ex-situ* conservation.

2- What are advantages of e*x-situ* conservation? Explain about biotechnological methods of *ex-situ* conservation.

3- Give a detailed account on principles and practices of *ex-situ* conservation.

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