

BBYET-143

ECONOMIC BOTANY AND PLANT BIOTECHNOLOGY

VOL

1

ECONOMIC BOTANY AND PLANT BIOTECHNOLOGY

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ECONOMY BOTANY AND PLANT BIOTECHNOLOGY

Economic Botany and Plant Biotechnology is an elective course of four credits and is divided into four blocks. Block 1 and 2 deals exclusively with Economic Botany and encompasses a detailed discussion on the importance of plant and plant products used in our daily life as food, shelter, clothing, furniture, medicines, spices and condiments, beverages, essential oils and many more. Block 3 introduces you the various facets of plant biotechnology-its methods and applications and future prospects, while Block 4 focuses on the various techniques and applications of biotechnology.

Economic botany has become more important and relevant because of an exponential increase in human population which has put an extra strain on various resources. In the time of increasing food shortage and decreasing arable land resources, a study of alternative food resources and improvement in the productivity of the existing food crops becomes imperative.

Block 1 is divided into four units. Unit 1 begins with the account of the centres of origin of cultivated plants. N.I. Vavilov's concepts have been explained giving example of plants belonging to the New and the Old world. Domestication of plants and the evolution of new crops are also included. In Unit 2 you will study about cereals- the most important sources of plant food - their origin, morphology, nutritional attributes, production strategies, high yielding varieties and uses.

Study of legumes constitutes Unit 3 where a botanical description, nutritional qualities and uses of some widely consumed legumes in India is given. Unit 4 is related to an in-depth study of spice yielding plants that are very important in providing flavor and aroma to tasteless food and stimulating the flow of gastric juices. Some selected spices have been described with reference to their origin, distribution, morphology, cultivation and uses.

Block 2 is a compilation of five units based on beverage, fiber, timber, medicinal and oil yielding plants. Unit 5 includes study of distribution, agro-climatic conditions, salient morphological features, cultivation, harvesting, processing methods and uses of tea, coffee and cocoa. In addition, non-alcoholic beverages have also been mentioned.

Oils and fats of plant origin have been described in Unit 6. This unit provides an overview of oil and fats obtained from groundnut and mustard with special reference to their chemical structure, classification and importance of food and as energy resources.

Unit 7 encompasses a study of fibers of plant origin with special emphasis on a detailed description of the economic botany of cotton. Unit 8 is exclusively devoted to the discussion on important medical plants, their active principle, medicinal value and their role in ethnobotany.

Last Unit 9 of this block relates to the timber yielding plants and their role in human society. The secondary growth of angiosperms and gymnosperms result in production of wood that varies in strength, texture and other characters, thus have diverse uses. A detailed description of wood of teak and pine is included in this unit.

Block 3 on Plant Biotechnology has three units (units 10 to 12) which are exclusively devoted to introduction to biotechnology and plant tissue culture. Unit 10 gives you an overview of biotechnology, the methods involved and its various applications. This unit makes you aware of the unlimited range of possibilities of plant tissue culture including their usage in rapid clonal propagation. Unit 11 provides a lucid account of the composition of media used in tissue culture, experiments and applications of totipotency, organogenesis and embryogenesis. Techniques such as protoplast fusion have also been discussed.

Unit 12 deals with further aspects of tissue culture. In this unit, topics such as micro propagation, production of androgenic and gynogenic haploids, embryo culture and some other practical applications in terms of secondary metabolite production have been discussed in detail. A comprehensive account of germplasm conservation has been given in the last part of the unit.

The last block 4 i.e. block compiles three units 13, 14 and 15 which will make you understand the modern molecular aspects of biotechnology. Unit 13 relates to the molecular techniques employed in biotechnology viz. DNA fingerprinting, DNA sequencing, ELISA and use of molecular markers.

Unit 14 discusses the methodology of logistics of recombinant DNA technology. Aspects of cloning vectors and genomic libraries have been described along with state of the art of CRISPER technology for gene editing.

The last Unit of this block summarizes the applications of Plant Biotechnology. It presents an up to date account of its role in agriculture, horticulture, herbicide and pest resistant crops along with specific examples of genetic engineered crops like golden rice, Bt cotton, Flavr Savr tomato.

Objectives

After going through this course, you will be able to :

- ❖ describe the centres of origin, domestication, breeding and improvement of cereal crops like wheat, rice; origin and morphological attributes, cultivation, nutritional attributes and uses of major pulse crops of India;
- ❖ comprehend the importance of major spices used in India along with their description and uses;
- ❖ explain the morphology, processing and uses of non-alcoholic beverages like tea and coffee;
- ❖ appreciate description of the major oil producing crops of India, and study the important fiber crops like cotton;
- ❖ appreciate the significance of commonly used medicinal plant species and list botany of major timber plants;
- ❖ comprehend various facets of plant biotechnology taking the example of plant tissue culture;
- ❖ describe the methodology and application of plant tissue culture, micropropagation, haploid production and germplasm conservation;
- ❖ appreciate the techniques employed in biotechnological studies and those employed in recombinant DNA technology; and
- ❖ explain the rationale of evolving genetically engineered crops for their herbicide and pest resistance attributes and improved quality traits.

Block

1

CEREALS, LEGUMES AND SPICES

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BLOCK 1 : CEREALS, LEGUMES AND SPICES

The Block 1 deals with theories related to the origin, cultivation and domestication of crop plants, the major cereal, legume crops and spices of importance. We have four units in this block which provide details about origin and domestication of crop plants. Vavilov's contribution in finding the centres of plant diversity and origin of important crop plants have been discussed along with the importance of genetic diversity and reasons for the genetic loss. In this block you will study in detail about origin, cultivation, morphology and uses of various important cereals, legumes and spices used throughout the world.

Unit 1 of this block introduces you to the concept of centres of origin of cultivated plants. A detailed account of the Vavilov's primary and secondary centres of origin will make you appreciate the natural centres of diversity, the concept of the Old world and the New world species.

You will study about the basic or staple diet yielding plants are the topic of study of the Unit 2. Cereals are the members of family Poaceae. A detailed discussion of taxonomy, origin, distribution, cultivation, important varieties, botanical characteristics, nutrient composition and uses of major cereals viz. wheat and rice has been provided. Role of these cereals in shaping civilization has also been explained.

Unit 3 of this Block is devoted exclusively to study of legumes and gives a very lucid account of the major legume crops along with their usage as a source of protein especially in a vegetarian diet. Morphology, nutritional value and uses of major pulse crops like gram, soybean, groundnut, cowpea, mungbean, and many more have been described.

Unit 4 entitled 'Spices' includes some very informative account of plant species which provide aroma, flavor, and pungency to our food and are integral part of Indian food. Spices obtained from underground parts such as rhizome, flower buds, flower, bark, fruits and seeds have been included in this unit along with their medicinal value. A brief description of condiments has also been provided in this unit.

Objectives

After studying this block you will be able to :

- ❖ describe the centres of origin of cultivated plants as described by N.J. Vavilov; and list out the Old and the New world cultivated plants
- ❖ appreciate the close relationship between cereals and man, origin, cultivation, morphology, breeding, improvement and uses of wheat, rice.
- ❖ appreciate the distribution, cultivation, morphology of widely used legumes; and explain the nutritional importance of legumes; and
- ❖ describe the origin, botanical description, uses and importance of spices.



UNIT 1

ORIGIN OF CULTIVATED PLANT

Structure

1.1	Introduction	1.5	Evolution of New Crops
	Objectives		Mapping and Cloning of Domestication Related Genes
1.2	Concept of Centres of Origin		Effect of Selection on Domestication Related Genes
	Vavilov's Work	1.6	Summary
1.3	Domestication of Plants	1.7	Terminal Questions
	Genetic Basis of Domestication	1.8	Answers
	Domestication Syndrome		
1.4	Significance and loss of Genetic Diversity		
	Genetic Erosion		
	Bottle Neck Effect		
	Conservation		

1.1 INTRODUCTION

Human have learned to cultivate plants for leading a settled life. The process of cultivation of plants for fulfilling the needs for food and fodder began during the middle stone age (Mesolithic age). Human civilization got transformed from food gatherers to food producers. The onset of neolithic i.e. new Stone Age led to the advent/invention of tools made of stone, which were later used for the development of agriculture. With the passage of time, it became more advanced as better tools were developed and used in agriculture. This became important as it fulfilled the basic needs of food, shelter and clothing. The fruits, vegetables cereals and fodder for cattle provided by plants formed the basis of every day needs of humans. Crops such as rice, wheat, maize,

sorghum, sugarcane, potato, beans and soybean were domesticated primarily in almost all parts of the world. This unit provides you a description about the major centres of origin of crop plants and their subsequent distribution in different parts of the world.

Objectives

After studying this unit, you should be able to:

- ❖ explain the concept of domestication of crop plants;
- ❖ list the centres of origin of various crop plants;
- ❖ explain about crop genetic diversity and enlist the causes for its loss;
- ❖ discuss the concept of cultivation of crop species; and
- ❖ appreciate the evolution of new crops.

1.2 CONCEPT OF CENTRES OF ORIGIN

Alexander von Humboldt (1807) opined that the origin of many useful plants is not known. This means that some crops lack a defined centre of origin but genomic and archeological data support the concept of centres of origin, diversity and history of cultivated species.

Alphonse de Candolle (1883) studied 247 cultivated species and his work **Origin of Cultivated Plants** provided information about the ancestral forms of plants, their origin of domestication and history of cultivated plants. He considered many facts such as works of ancient botanists, traveler's accounts, Chinese writings, archaeological and ethnological findings before compiling his work.

The plants of economic value were divided into six classes:

1. Plants of old world origin

These include

- a) Plants cultivated for 4000 years and more, e.g. almond, fig, peach, apple, pear, apricot, grape, rice, hemp, barley, millet, tea, cabbage, wheat and olive etc.
- b) Plants cultivated for 2000 years and more, e.g. alfalfa, oats, radish, cherry, carrot, beet, cherry, plum, walnut, poppy, nutmeg, and yam etc.
- c) Plants cultivated for less than 2000 years, e.g. coffee, okra, artichoke, muskmelon, raspberry, and strawberry etc.

2. Plants of new world origin

- a) Plants cultivated for over 2000 years and probably more than 4000 years, e.g. cocoa, maize, sweet potato, tobacco etc.
- b) Plants cultivated before the time of Columbus, e.g. avocado, cotton, pineapple, squash, potato, tomato, pumpkin, vanilla, and guava etc.

- c) Plants cultivated since the time of Columbus, e.g. *Cinchona*, blackberry, rubber, blueberry, strawberry, peacan etc.

De Candolle's work regarding the domestication of cultivated plants has been accepted till date. He pointed that cultivated plants originated at some time in the remote past from the wild ancestors in some restricted areas of the world. These areas include China, South West Asia, and tropical America. He proposed that each crop has a single region of origin. He suggested that all the cultivated forms of *Brassica* have wild forms native to Europe and Siberia and the species undergo change during cultivation.

Darwin (1868) proposed that modifications in the wild plant gave rise to cultivated plants. The concept of plant domestication is based on **Centres of origin**. The process in which wild plants get evolved into crop plants through artificial selection is known as **domestication**. This is generally done by hybridization, followed by selective breeding. This hypothesis was initially proposed by Alphonse de Candolle (1890) and later described by Nikolai Vavilov (1926). According to the concept, the domestication occurred in a few discrete "centres". The centres have been identified on the basis of the resemblance and diversity of phenotypes in modern germplasm, archaeological remains of cultivated species and their wild ancestors. The evolution of crop plants has been a more complex and continuous process. It is often characterized by multiple independent domestication events.

The greatest diversity in land races and in wild relatives is typically found near regions where they were first domesticated. Landraces are the **populations of cultivated plants** having a distinct identity and origin. They are often genetically diverse and locally adapted. Crops, such as sorghum, sugarcane, and peanuts were probably domesticated over broad areas rather than in a well defined centre. Useful landraces of some crops have been found in parts of the world other than those in which they were originally domesticated.

1.2.1 Vavilo'v Work

Nikolai Ivanovich Vavilov, an agronomist and geneticist was a pioneer in the field of exploration of plants and introduction of species from other areas. He is considered as one of the greatest investigators in crop geography, collection of cultivated plants and their wild relatives. He is widely known for his concept of gene centre for cultivated plants and their wild progenitors. He explored plants by sending expeditions all over the world. He created an inventory of diverse forms of important cultivated plants and their distribution all over the world. He noted that distribution of plants is not uniform. A wide range of genetic variability is noted in some restricted areas, for example Ethiopia for wheat and South America for potato.

Vavilov's defined "centres of origin" for most crops included areas of Mexico and Central America (for corn, maize and upland cotton), China (for soybean), and West Asia (for wheat and alfalfa). Vavilov's time, ideas about centres of origin were further refined.

Few regions having mountains and hills in the tropics and subtropics have been considered as the regions of high plant wealth. They have been called as

regions of **gene diversity**. It has been suggested that from these regions the origin and dispersal of species occurs. The species have migrated from these regions to different parts of the world. The variations from cultivated types to wild species have been reported from these areas. For example- potato, the primary centre of origin is Andes of South America. The region shows variation from tuber forming cultivated type to wild type non-tuber forming species. The dominant genes are restricted to this region.

Initially Vavilov (1926) suggested the presence of six geographic centres for cultivated plants but later he recognized 11 centres for the same. Some of the centres of origin of cultivated plants proposed by Vavilov are given below:

Chinese centre - It is one of the earliest centres of origin of cultivated plants. It includes mountainous regions of Central and Western China and adjacent lowlands. About 136 endemic plant species has been listed from this region. These mainly include millets, soybean, bamboo, onion, pear, cherry, citrus, sugarcane, cinnamon, tea, egg plant, cucurbits and many legumes.

Indian centre - This includes areas of Assam and Myanmar. About 117 plants have been considered to be endemic. These include rice, sugarcane, coconut, palm, cotton, black pepper, eggplant, cinnamon and many legumes.

Indo-Malayan centre - This includes Indo-China and the Malay Archipelago. Around 55 plants have been listed from this region. These include banana, coconut, sugarcane, black pepper, sunhemp, nutmeg, clove and sugarcane.

Central Asiatic region - The region covers Northwest India (including Punjab, Kashmir and Northwest provinces), Afghanistan, Uzbekistan, Tajikistan and Western China. About 43 plants listed from the region include wheat, peas, beans, lentil, hemp, cotton, carrot, garlic, spinach, apricot, pistachio, almond, apple and pear.

Eastern centre - The area includes regions such as Asia minor, Iran, Transcaucasia and highlands of Turkmenistan. About 83 plants found in the region include nine species of wheat and rye, fruits crops such as cherry, pomegranate, walnut, quince, almond, fig and forage crops like alfalfa and Persian clover.

Mediterranean region - The area includes border of Mediterranean Sea. Around 84 plants originated from this region include olives, vegetables such as cabbage, turnip, asparagus, forage plants such as white clover, Egyptian clover, crimson clover, oil yielding plants like rape, mustard, cereals such as wheat and spice plants like caraway, anise, thyme, sage, peppermint, and hops.

Abyssinian centre - It includes Ethiopia (Abyssinia), Eritrea and parts of Somalia. Thirty eight species native to the region include wheat, barley, sesame, castor, bean, coffee and okra.

South-Mexican and Central American centre - The area includes southern parts of Mexico, Guatemala, Honduras and Costa Rica. The plants found in the region are varied and include maize, bean, squash, sweet potato, red pepper, sisal, papaya, guava, cocoa and tobacco.

South American centre - This centre includes three regions.

- a) **The Peruvian Ecuadorean Bolivian centre** - The region has high mountains and plants native to the uplands include potato, tomato, lima bean, pumpkins, cocoa, quinine tree, tobacco and Egyptian cotton.
- b) **The Chilian centre** - The region is supposed to be the origin of potato.
- c) **The Brazilian-Paraguayan centre** - The region is believed to be the origin of groundnut, cassava, pineapple, rubber tree and cashew nut.

These areas or centres constitute only a small part (about 2-3%) of the total land area on earth. According to Vavilov about 85% species of the 640 species listed by him are supposed to be originated in the old world which includes Asia, Europe and Africa and the remaining might have come from new world i.e., America. Most of the centres of diversity include tropical zones.

Temperature fluctuations in this area are mainly responsible for origin of diversity of plant forms. The climatic conditions of the region provide a suitable environment for the establishment of the species. He later distinguished the centres as primary and secondary gene accumulation centres. The process of domestication from the native wild relatives begins in the primary centres and is characterized by dominant genes. The cultivated plants were later introduced into other regions and this lead to a considerable increase in their diversity. In this way, a secondary gene centre develops from the cultivated plants. This centre gets characterized by the diversity of recessive genes and does not have wild relatives. The Abyssinian centre is rich in plant varieties such as wheat, barley, pea, flax and lentil but the wild relatives are not found in the region. Wild varieties are located thousands of kilometers away from the source. If the species occupies a region for long time it shows larger number of variables. The secondary regions develop due to ecological diversity, farming practices, migration of humans and biological dynamics such as hybridization, segregation and selection.

The small areas rich in variety of species within a centre have been called as **agro-ecological groups** by Vavilov. Later on Harlan (1951) used the term microcentre for the region which contains variation of one or more crops. He identified three microcentres for wheat in Turkey. Gene microcentres for other crops such as maize, lupine, peas and several cucurbits have been found in Turkey. Microcentres were also detected in the areas of Transcaucasia, parts of Iran and Afghanistan. The microcentres or several plants coincide with each other and are generally located in the plains or mountains, near areas of civilization or far from it. These centres represent the breakdown of the geobotanical pattern of variation and the process of evolution still continues in the region.

According to Vavilov, most of the cultivated plants have multiple centres of origin. The primary crops are domesticated directly from wild plants, e.g. wheat, rice, barley, soybean, flax, cotton, maize and potato. Vavilov suggested two distinct centres for origin of wheat- one originating from Southwest Asia and other coming from Mediterranean region. Barley was suggested to be domesticated in Southwest Asia, North Africa and Southeast

Asia. Vavilov initially suggested 5 gene centres which were later on increased to eight along with three sub centres. Later, Darlington and Janaki Ammal (1945) modified the number of centres to 12 further increasing it to 15 in 1973. Zhukovsky (1968) proposed a series of twelve 'micocentres or megagene' centres covering almost the whole world.

Vavilov's work was later not accepted as the analysis of crop plants suggested that the study of origin and evolution of cultivated plants is much more complex.

- i) Studies later proved that Vavilov's contention that a region with the greatest genetic diversity is also the centre of origin is no longer acceptable. The centre of diversity of maize is in Peru though the archaeological evidence and distribution of wild relatives indicated that maize was domesticated in Mexico. Similarly in case of tomato the centre of diversity i.e. Mexico and distribution of related wild species do not coincide.
- ii) Vavilov's view that that a primary centre generally has high frequency of dominant alleles towards the centre and a recessive gene towards the periphery is not accepted. Workers could not point out the centres of origin for wheat, maize and oil palm.
- iii) Vavilov's assumption that the centres of development are limited mainly to mountainous regions is also no longer valid. Some crops such as maize exhibit high diversity in the plains as well.
- iv) Some crops such as bottle gourd has no centres of diversity but domesticated through the range of their wild ancestors. Sorghum is another crop for which neither the centre of the diversity or distribution has been known.
- v) Many crops did not originate in the Vavilovian centres at all or originated in more than one centre. Some species that did not originate in the centres proposed by Vavilov include *Momordica balsamia*, *Momordica charantia*, *Urena lobata*. Oat is another plant which is supposed to have no single centre of origin. Species such as *Sorghum*, common bean, banana have been supposed to have evolved over a vast geographical range and domesticated over a wide area.
- vi) Several crops have found to have restricted place of origin. e.g., *Digitaria iburua* in West Africa, *Setaria geniculata* in Mexico.

However for some crops the centre of domestication could not be identified because of lack of evidence.

Zhukovsky (1968) proposed the idea of megagene centres where the species were domesticated. The centres cover areas such as Canada, Brazil, northern Siberia, Norway, Britain etc. He divided the world into different megagene centres. These centres are China, Indo-china Indonesia, Australia-New Zealand, Indian subcontinent, Central Asia, Mediterranean costal region, Africa, Europe-Siberia, Bolivia-Peru-Chile, North America.

Each crop has been domesticated in different location at different times or simultaneously domesticated at different places, hence a single centre of its origin cannot be proposed. The wild species were collected from different areas and were introduced into different regions. The germplasm has been received from the wild relatives. Wheat, maize, sugarcane, cassava, sorghum and potato have shown periodic infusion of germplasm from their wild relatives. Harlan (1971) did not agree to the earlier proposed areas of centres and demonstrated that plant domestication occurred in the regions south of the Sahara and north of the equator ranging from Atlantic to Indian Ocean. He proposed that such a large area could not be termed as centre. He proposed the concept of centres and non centres. Centres are the region or places of agricultural origin whereas non-centres include regions where the agriculture has been introduced. Three independent systems introduced by him include-

Centres - A1-North east, B1- North Chinese, C1- Central American

Non-Centres - A2-African, B2-South-east Asian and South Pacific, C2- South American.

Hawkes (1983) proposed an alternative scheme to clarify the concept of nuclear centres of agricultural origin and regions of diversity. The nuclear centres of agricultural origin are the places where the agriculture first began and later became the regions of diversity. These include the areas in which the crops spread from the nuclear centres. Interestingly, these regions somewhat correlate with the Vavilov's centres. The recently listed centres of origin and production of agricultural crops does not relate to the centres of origin (Table 1.1).

Table 1.1: Various centres proposed for crop plants.

Crop	Centre of origin	Centre of production
Citrus spp.	South east Asia	United States
Clove	Moluccas	Zanzibar
Cocoa	South America	Ghana
Coffee	Ethiopia	Central and south America
Groundnut	South America	India, China
Maize	Tropical America	Middle West US
Nutmeg	Moluccas	West Indies
Pineapple	Brazil	Hawaii
Potato	Peru	Eastern Europe
Rubber	Brazil	South East Asia
Soybean	North east Asia	United states
Wheat	Central Asia	North-Central America

More than a half dozen different independent centres of domestication have been identified to date (Fig. 1.1).

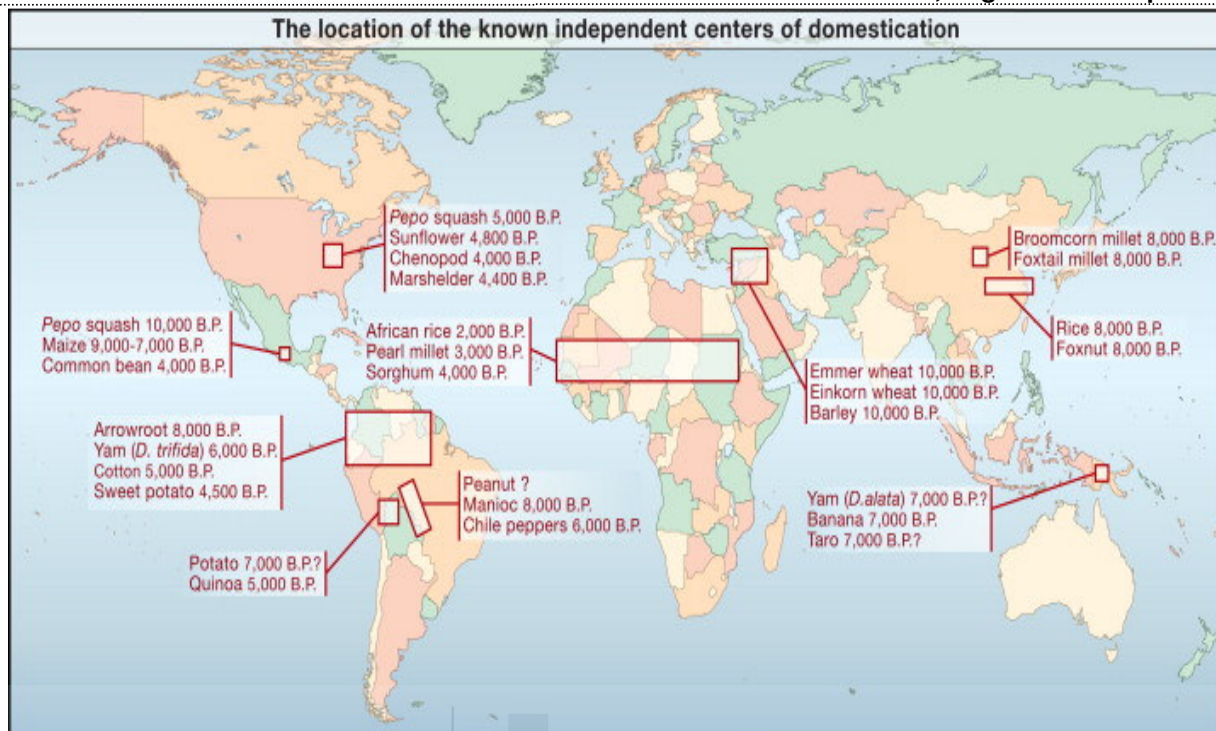


Fig. 1.1: Centres of Origin of various crops.

SAQ 1

- a) Fill in the blanks with suitable words
- proposed that modification in the wild plants gave rise to cultivated plants.
 - The hypothesis of 'Centre of origin' was given by.....
 - Evolution of crop plants has been a and process.
 - The regions rich in variety of species within a centre are known as
 - created inventory of diverse forms of cultivated plants.
 - Region that contains variation of one or more crops is
 - has been considered as primary centre of origin of potato.
- b) Give the centre of origin for the following crop plants.
- | | |
|---------------|--------------|
| i) Clove | vi) Soybean |
| ii) Cocoa | vii) Rubber |
| iii) Potato | viii) Coffee |
| iv) Groundnut | ix) Wheat |
| v) Maize | |

1.3 DOMESTICATION OF PLANTS

The cultivation of crops has been the major reason for the human settlement in the earlier times. The process of domestication began on the lower slopes of the mountains and fertile slopes of Tigris and Euphrates valleys in northern Iraq (old world) and the Tehuacan valley of Mexico (New World). These areas have been considered as the ancient settlements (about 7000 B.C). Early man has been considered as the first breeder because he domesticated plants and used the products as food. The migration from one continent to another led to spread of plants to many regions of the world. The earliest foundation of the scientific study of plants was pioneered by Greek and Roman botanists – Theophrastus, Dioscorides, Aristotle, Galen and several others. This is also mentioned in the ancient works like ***De Materia Medica***.

The process of domestication involves transition from gathering wild plants to cultivation of the same for their use. The Neolithic humans domesticated a large number of plant species to create a reliable source of nutrition for themselves. Crop plants comprise a large variety of species ranging from annual grasses, perennial trees, shrubs and medicinal herbs. World-wide production of crops is dominated by a few major crops such as wheat, rice, maize, potato, sugar cane, and soybean.

Domestication is a process that has been studied since the time of Mendel. His experiments with the domesticated garden pea improved understanding of the variation in domesticated and wild species. Studies by Darwin (1859) mentioned about various cultivars of plants and suggested that selection alters the cultivated taxa. The selection process involves various steps which mainly include (a) harvesting of wild plants, and (b) selection of wild plants to modify plant characteristics (architecture, flowering time, dormancy, size). Inspired by Darwin's work, Stemann proposed a selection-driven model for process of domestication.

Domestication of cultivated species by farmers also brought subsequent genetic changes in the plants. Farmers can be considered as first plant breeders. Knowledge of the evolutionary relationships between crops and their wild progenitors facilitated more efficient exploitation of the genetic resources. Useful genetic variations recognized by farmers and chosen wild plants were harvested and reselected to develop improved populations having desirable traits. Sophisticated crop breeding programs developed by farmers enabled introduction of desirable traits from one cultivar to another. The domesticated forms showed limited resemblance to their wild ancestors because of selection of genes from domesticated plants. The genetics of crop domestication and crop gene pools assist in accelerating the transition from plant breeding to plant engineering and crop domestication to crop super-domestication.

Hybridization and selection both have played an important role in origin of crops and the process of domestication since early times. Hybridization of plants was known to occur in the cultivated ornamental species *Dianthus* early in the 18th century. Plant hybridization involving intra- and interspecific hybridization helps to achieve crop improvement. The present day hexaploid ($2n = 6x = 42$) wheat variety was developed by hybridization of tetraploid wheat (*Triticum turgidum* ssp. *dicoccum*, $2n = 4x = 28$) and diploid goat grass

(*Aegilops tauschii*, $2n = 2x = 14$), a weed. Modern strawberries (*Fragaria × ananassa*) have been developed as a result of hybridization between North American *F. virginiana* and South American *F. chiloensis*.

1.3.1 Genetic Basis of Domestication

Various techniques have been applied to detect and characterize the **genetic basis of domestication** of genes in a given species. **Top-down** and **bottom-up** approaches provide information about genetic basis of domestication. **Top** or **up** refers to a specific phenotype, while **bottom** or **down** refers to the underlying genotype responsible for that trait.

A **top-down** approach starts by studying a particular phenotype (visible changes). Analysis of the phenotypic traits between wild and domesticated taxa helps in genetic study of domestication traits. The phenotypic differences in traits such as plant architecture or seed size are studied for the genetic analysis of population. These approaches are precise in finding causal variants involved in the evolution of specific traits.

Bottom-up approach starts by analyzing the genetic variation within genomes in order to detect potential signals of selection related to the domestication process and finally associate such evolutionary signals to important loci and domestication phenotypes. This approach detects loci underlying a larger fraction of selected traits (e.g., morphological, developmental, physiological, and biochemical).

The domestication traits are studied on an allelic basis. Epigenetics, substitution, insertion, deletion, duplication, transposon activity or chromosome rearrangement have been noted in domesticated species. Studies indicate that the domestication syndrome has a relatively simple genetic basis, with some individual loci making large contributions to the phenotypic differences between crop plants and their close wild relatives. Now we will study about the concept of domestication syndrome.

1.3.2 Domestication Syndrome

During domestication wild species are genetically modified to create a new form of a altered plant to meet human needs. The evolution of domesticated forms of plants involves selection of traits. The similar traits across different species plants are selected, giving rise to the concept of the **domestication syndrome**. The domestication syndrome is defined as the collection of phenotypic traits associated with the genetic change in a domesticated form of an organism from its wild progenitor. The domestication syndrome includes grain retention (as seen in rice, barley, wheat, soybean), reduction of lateral branching (as noted in maize, sunflower), or modification of flowering-time (as seen in sunflower, maize, soybean). These changes facilitate harvest, increase yield, and alter the timing of the growing season. This helps in expansion of cultivation zone beyond the native range and well adapted to new environment.

Domestication restricts the self propagating capacity of species maize and cauliflower are good examples of such forms. Compared to their progenitors, plants are more robust with determinate growth and increased apical

dominance. Crops have larger but fewer fruits or grains per plant than their progenitors. The domesticated plants show loss of natural seed dispersal (i.e. seeds remain attached to the plant for easy harvest by humans) (Fig. 1.2). A variety of physiological changes such as loss of seed dormancy, changes in photoperiod sensitivity, and synchronized flowering have also been noted in domesticated plants.

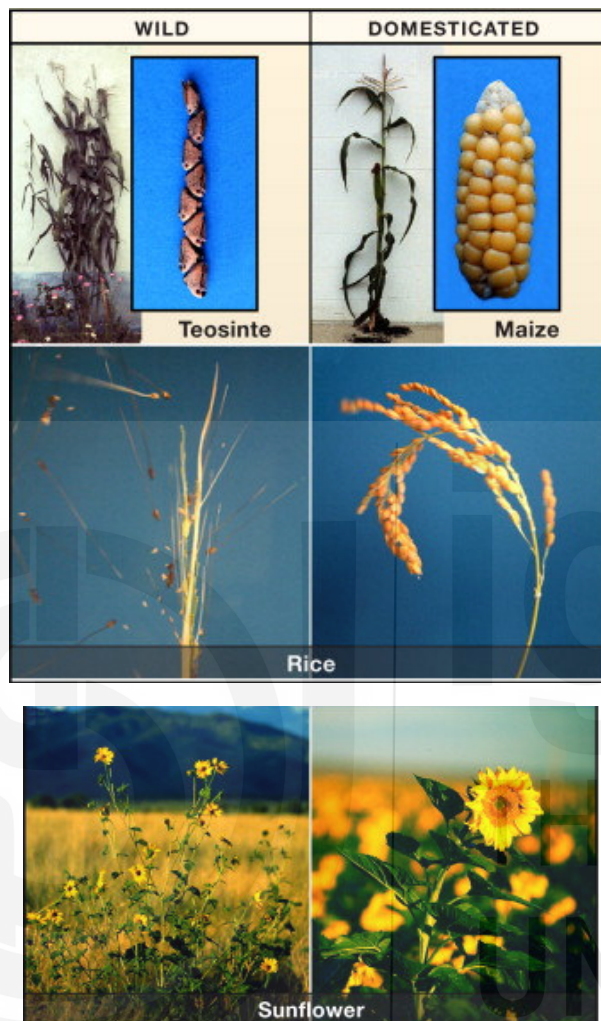


Fig. 1.2: Some crop plants showing differences in wild and domesticated plants.

Investigators suggested that phenotypic characteristics common across crop plants help in finding out the agents of selection as well as process of domestication. The data from FAO suggests of major phenotypes that have been domesticated include both high and low yielding crops of the world.

The traits associated with the domestication syndrome in crops have been established on the basis of selection because of humans (conscious selection or intentional selection for a trait) or as a result of environmental factors (natural, automatic, non-intentional or unconscious selection that occurs because of technology or practice).

The term **unconscious selection** was introduced by Darwin whereas its modern concept was developed by C .D. Darlington. Unconscious selection or automatic selection helps us in finding out the differences that distinguish domesticated seed crops from their wild progenitors. These include loss of natural dispersal mechanisms, rapid seed germination, larger propagules, simultaneous ripening, and loss of mechanical protection as well as changes

in the breeding system. Thus, weeds have also evolved rapidly under selection with crops. Use of molecular techniques has provided a new insight into the plant domestication and its future course.

SAQ 2

- a) State whether the statements are “True’ or ‘False’.
 - i) Domestication is the transition from gathering of wild plants to cultivation of the same.
 - ii) The domesticated crops show resemblances to their wild ancestors.
 - iii) Hybridization has proved useful in crop improvement.
 - iv) Top down approach is based on analyzing the genetic variation within genomes in order to detect potential signals of selection related to the domestication process.
 - v) Conscious selection is based on selection of a trait.
- b) Differentiate between:
 - i) Top-down and bottom-up approaches for genetic basis of domestication
 - ii) Conscious or unconscious selection

1.4 SIGNIFICANCE AND LOSS OF GENETIC DIVERSITY

Genetic diversity is described as the amount of genetic variability among individuals of a variety, or population of a species. The major components of genetic diverse include different forms found in different populations, their distribution and overall distinctness. The variation in genetic diversity arises from mutation and recombination. Selection, genetic drift and gene flow act on the alleles present in different populations.

Genetic diversity is the basis of survival and adaptation of the species. Genetic variation found in traditional landraces and wild species is important for continued progress of crop improvement. The genetic diversity in a species is important because it helps in determining the ways required to conserve it. Diverse genetic resources help in selection and breeding of plants with desired characteristics, thus increasing agricultural productivity.

Most centres of diversity are found primarily in today’s developing countries where crops were first domesticated. The crop genetic resources include wild or weedy relatives of plants that share a common ancestry with a crop species. Landraces are varieties of crops improved by farmers over many generations without the use of modern breeding techniques. Improved germplasm contains one or more traits of interest that has been incorporated by scientific selection or planned crossing. These varieties are well adapted to a specific environment.

Landraces of the cereal crops such as rice, wheat, and corn (maize) have been identified. Rice landraces are concentrated in Southeast Asia, with some also found in the Indian subcontinent. Wheat landraces were concentrated in West Asia and North Africa with some also found in Ethiopia, China, and in Indian subcontinent. Certain isolated areas in Mediterranean Europe grow wheat landraces. Faro, or *Triticum dicoccum* is grown in Italy. Twenty three percent of the area planted with durum wheat, 12 percent of the area planted with winter bread wheat and landraces, Only 3 percent of the spring bread wheat area in developing countries were still planted with landraces. As with the other cereals, corn's wild relatives tend to concentrate in their zone of origin (in the case of corn, in Mexico and Central America), and landraces are most diverse in this zone.

Crop genetic diversity may also decline with (1) reduction in total number of varieties, (2) concentration of area planted in a few favored varieties, or (3) reduction in the genetic distance between these varieties.

The direct-use benefits of crop genetic resources are measured in terms of increased output, higher quality, better resistance to pests, diseases, and other stress, and other characteristics found in improved crop varieties. These benefits come from the genetic resources contained in precursor wild relatives and involve efforts of farmers who domesticated the crop and developed landraces through selection. Diverse genetic resources have been a source of large gains in agricultural productivity. Genetic diversity remains a particular concern because greater genetic uniformity in crops can increase vulnerability to pests and diseases.

The role of collectors who compile the work and gene banks that assembled, preserve the genetic material in the form of landraces and wild relatives is also important. Thereafter plant breeders play a role in developing improved crop varieties. Plant breeders usually focus on diversity within a crop species or within the secondary and tertiary gene pools for that species. The tertiary gene pool consists of those species that can be crossed with the cultivated species only with difficulty, such as with genetic engineering.

1.4.1 Genetic Erosion

Genetic erosion refers to the loss of genetic diversity or loss of genes or alleles. Loss of genetic diversity (genetic erosion), includes the loss of individual genes or particular combinations of genes. Broadly it can be referred to as loss of varieties and crop species. Loss of varieties and crops occurs rapidly in crops because of various reasons such as

- replacement of traditional varieties by modern commercial or non-food crops
- cultivation of high-yielding varieties,
- natural catastrophes, and
- destruction and modification of natural habitats harbouring wild species.

Genetic erosion has been reported in many commercially important crops. The cultivation of genetically uniform, high-yielding, modern cultivars results in loss

of about three-quarters of the genetic diversity of agricultural crops. Climate change has also emerged as another threat to crop germplasm. Germplasm is the plant genetic resources such as seeds or plant parts that are maintained for the purpose of plant breeding, preservation, and other research purposes. Intensive development activities, habitat destruction due to modern agriculture and poor knowledge of germplasm and of its scientific, social, cultural and economic importance are some of the other factors causing loss of this treasure. Introduction of high-yielding varieties and a number of landraces carrying vast amount of genetic diversity are lost from farmers' fields in many countries.

In India, the area under cultivation of foxtail, finger millets and other small millets declined mainly because of poor yield, unavailability of improved cultivars, and shift of focus to other crop species. Habitat loss is one factor contributing to a decline in crop genetic diversity. The loss of wild relatives occurs mainly through habitat conversion for agricultural use.

The populations having a narrow range of genotypes and those which are not able to reproduce under less favorable conditions become extinct. The plant species has become restricted in the marginal habitat because of limitations in its physiological tolerance. Reduced genetic variability is a key step in the extinction process. Area under cultivation of traditional crops such as proso, barnyard, little and kodo millets is decreasing all around the world mainly because of increasing importance of a few selected crop species. In China, proso millet continued to be a very important crop until the beginning of the twentieth century, but recently there has been significant reduction in its cultivation due to the adoption of modern high-yielding varieties of major crops like rice, wheat, and maize. Drastic decline in cultivated area (5.34 million ha during 1955-1956 to 0.80 million ha during 2011-2012), and production (2.07 Mt during 1955 to 0.46 Mt during 2011-2012) of six small millets (finger, foxtail, proso, little, barnyard, and kodo millets) has been noticed in India. Decline in cultivation of small millets is mainly due to low productivity, non-availability of high-yielding varieties, lack of production and processing technologies, and introduction of high-yielding commercial crops.

1.4.2 Bottleneck Effect

Domestication is basically a selection process. Our ancestors selected some preferred individuals of progenitors to grow and propagate. Hence much of the diversity found in the progenitor species has been lost. After many generations of selection, the genome of a crop will undergo dramatically reduced genetic diversity, known as a genetic bottleneck. Inbreeding in cross-pollinated crops and small outcross populations results in deleterious effects and loss of fitness of the population due to recombination between undesirable genes (recessive identical alleles) (Fig. 1.3). In natural population, drastic reductions in population size referred to as **genetic bottleneck** leads to loss of genetic diversity and increased susceptibility to infectious pests and diseases that can cause extinction of crop species. Genetic models that predict the proportion of initial heterozygosity retained per generation have been proposed. It is generally estimated through an equation having the formula $[1 - (1/2N_e)]$ where N_e is the effective population size, usually less than N , the actual

population size. Thus a population of $N_e = 10$ individuals loses 5% of its heterozygosity per generation. This indicates that severe bottlenecks degrade heterozygosity and genetic diversity. Heterozygosity is the condition of genetic variability in which two different alleles are present at a locus. It is important in plant breeding programs because it is usually associated with the presence of genetic variability.

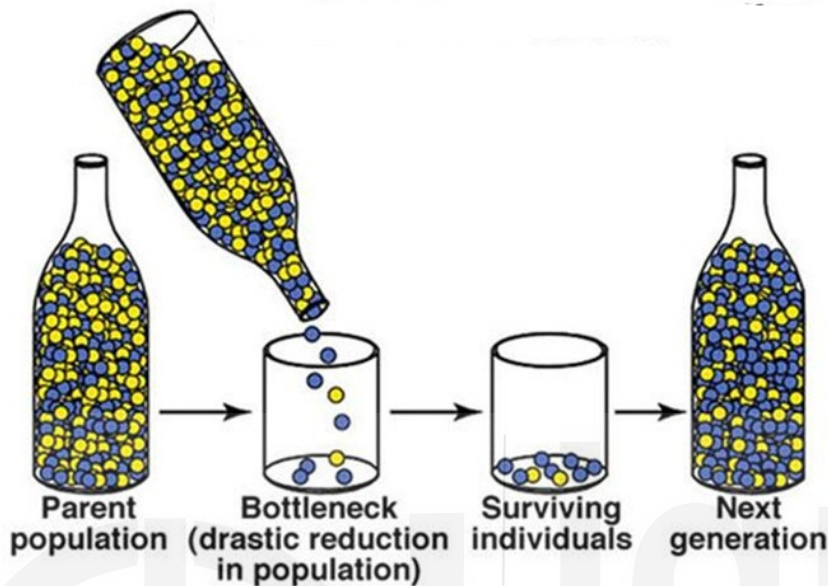


Fig. 1.3: A diagrammatic representation of Bottleneck concept of genetic loss of diversity.

1.4.3 Conservation

Genetic diversity can be conserved in the form of cultivated varieties and wild varieties. The wild varieties need to be conserved or preserved to maintain the natural biodiversity. Conservation can be done either under *in situ* (in their natural setting) or *ex situ* (outside their natural setting) conditions. Crop genetic resources are mostly conserved *ex situ* but they can also be done *in situ* by maintaining wild relatives of cultivated varieties on land and cultivated varieties in fields. The plant materials are kept under controlled conditions and periodically regenerated (planted and grown) in order to maintain seed viability.

In situ conservation of agricultural genetic resources is carried out within the ecosystems of farmers' fields or wild lands. *In situ* conservation provides knowledge about species development and evolutionary processes. *Ex situ* conservation method removes genetic material from its environment for long-term conservation. Botanical gardens and gene banks are common examples of this conservation. These methods can be used to store large amounts of genetic material. The world's gene banks presently hold more than four million accessions or specific samples of crop varieties. The samples of many of the world's cereal landraces are now stored in gene banks. The U.S. National Gene Bank System (the National Plant Germplasm System, or NPGS) is today one of the largest *ex situ* collections in the world. *Ex situ* conservation allows plant breeders an easier access to genetic resources.

Efforts related to enhancement of genetic diversity have focused on crop breeding programs. Plant breeding aims at genetic enhancement by creating new varieties with higher yields and better resistance.

SAQ 3

- a) Define the terms:
 - i) Landraces
 - ii) Genetic diversity
 - iii) Conservation
- b) Answer in one word:
 - i) Landraces of are concentrated in Southeast Asia, with some also found in the Indian subcontinent.
 - ii) The gene pool consists of those species that can be crossed with the cultivated species only with difficulty, such as with genetic engineering.
 - iii) is plant genetic resources such as seeds or plant parts that are maintained for the purpose of plant breeding, preservation, and other research purposes.
 - iv) is the condition of genetic variability and is important in plant breeding.
 - v) In conservation method, genetic material is removed from its natural environment to get long-term conservation.

1.5 EVOLUTION OF NEW CROPS

Humans have selected plant varieties for desired traits and replanted them. The pace of genetic improvement increased with time and modern breeding techniques were developed. These facilitated selection of specific desirable traits. Breeders have crossed different parental material and selected traits to achieve high yields and improved quality for all types of crops. Breeders have also sought resistance to pests, diseases, drought, and other stress.

1.5.1 Mapping and Cloning of Domesticated Related Genes

A single gene that controls more than one trait is called pleiotropic gene.

The genes for domestication that had been cloned shown to possess diverse transcription factors. Mapping of genes had facilitated the cloning of domestication-related genes and revealed the molecular basis of domestication-related changes. An analysis of domestication genes across diverse germplasm provides information about the place and origin of the domesticated crop plant.

Undesirable secondary effects associated with pleiotropic genes could limit selection for favorable domestication alleles during early stages of the differentiation of a crop from its wild progenitor. It has been suggested that alleles for traits of the domestication syndrome that appear in wild cultivars

evolved prior to domestication for e.g. in wheat, the *Q* gene is pleiotropic for many domestication traits. The wild-type allele *q* is associated with traits such as fragile rachis and that grain attached to chaff. The domestication of allele *Q* is associated with traits such as tough rachis and free-threshing grain. *Q* is not a wild progenitor of wheat but human selection post-domestication might have resulted in up-regulation of *Q* resulting in much higher effect of *Q* (more than twice) than *q*.

Differences in nucleotide sequence and/or levels of transcription of different alleles also affect the phenotypes produced by target genes. Example- two genes related to spikelet shattering in rice (*sh4* and *qSH1*) have been cloned. Traits such as loss of seed dispersal, loss of seed dormancy or loss of protection against herbivores are often regulated by recessive alleles and have been considered disadvantageous in wild plants. These recessive alleles play a role in inbreeding associated with domestication in many crops. Their effects get masked in the heterozygotes that make up the bulk of wild populations.

In a number of studies, quantitative trait loci (QTL) that affect different elements of the domestication syndrome are located at the small chromosomal region suggesting either pleiotropy or close linkage of the concerned gene(s). The alleles for the trait of domestication have been found in wild populations. In azuki bean (*Vigna angularis*) domestication has reduced seed yield per plant because of selection of determinate plants with larger pods and fewer large seeds per pod than its progenitor wild relative. The wild relatives of crops represent a reservoir of genes for potential use in agriculture. Many families of transcriptional regulators involved in domestication have been known. The gene structure is conserved for similarities within a given family of transcriptional regulators.

1.5.2 Effects of Selection on Domestication Genes

The research studies have been conducted to understand how crop plants evolved from their wild relatives and spread around the world. Rapid development of genomic resources and tools has made it possible to conduct genetic mapping and conduct population genetic studies. This has proved helpful in finding out the molecular basis of domestication and evolution in diverse crop species. The study of crop evolution has led to establishment of high-quality reference genomes for crops and their wild relatives.

Characterization of genome can be done using novel methodologies such as archaeogenetics, epigenomics, and genome editing. Research on genes related to crop domestication has provided information about the complex process of gene evolution, networking, regulation and expression in important plants.

Molecular techniques help in identification of position of domestication-related genes and also provide information about the effects of selection and number of generations required for domestication. Although domestication is a rapid evolutionary change but in cereals the transition of characters that changed wild populations into domesticated crops it took many centuries or millennia to do so.

DNA technologies have proved useful in understanding the process of domestication in relation to genome duplication. Genomic comparison of crops and their wild progenitors has been considered as a new approach to detect potentially useful diversity in wild progenitors for crop improvement. Genome sequencing techniques proved useful in elucidating the evolution of domestication-related genes. Detection of domestication-related genes has become possible using QTL analysis across the genome. The domestication genes can be detected based on the selection profile of comparative sequences. Molecular markers and QTL technique showed that when the allelic arrangement differed from these parental genotypes, the seed yields were higher.

Gene expression is generally dependent on hierarchically organized networks of regulators. The number of these regulators can be increased several-fold in polyploids. Information related to accumulation of domestication-related traits and their genome distribution has opened new avenues to attain higher yield.

Gene duplication is an evolutionary phenomenon in plants. Among duplicated genes are a class called nearly identical paralogs (NIPs) that appear to be of recent origin. According to an estimate, about one third of genes are tandem duplicates due to unequal recombination or transposition events.

Study of polyploidy provides a means of elucidating the effects of dramatic genome change on gene expression and regulation. Both allopolyploidy and autopolyploidy leads to development of novel phenotypes which you have read in BBYCT-135 (Plant Anatomy and Embryology). Allopolyploidy results in increased allelic diversity while autopolyploidy results in increased allelic copy number. Polyploidy is common in plants and provides selective advantages such as fixation of heterosis, duplication enabling evolution of gene function, and alteration of regulation. The oilseed crop *Brassica napus* (canola) derived from crosses between *B. oleracea* ($2n = 18$, CC genome) and *B. rapa* ($2n = 20$, AA genome) is an allopolyploid and provides information about the heterozygosity and its effects on evolutionarily important traits. In allopolyploid cotton, some homoeologous genes have been assigned different functions and gene expression is compartmentalized to different tissue types.

Super-domesticates can be constructed with knowledge-led approaches using the range of current technologies. The term **super-domestication** refers to the processes that lead to development of a domesticate using new technologies. The domestication generally have increased yield which could not be selected in natural environment or from a naturally occurring variation. The genome manipulations overcomes the barriers to gene exchange and leads to formation of super-domesticates with dramatically increase yields, resistances to biotic and abiotic stresses, and other new characters. Hybrid rice has been considered as a super-domesticate.

The plant breeders have been conducting research to change crops. This includes change of crops from C_3 to C_4 photosynthesis. Hence conversion of a crop from C_3 to C_4 photosynthesis has been considered as a super-domesticate.

SAQ 4

Answer in one word :

- a) The process of development of a new domesticated variety using new technologies.
 - b) The technique that shows that allelic rearrangement is similar to parental genotypes.
 - c) Traits such as loss of seed dispersal and protection against herbivory is regulated by environmental factors.
 - d) In wheat, this pleiotropic gene is responsible for domestication traits.
 - e) The gene that regulates spikelet stalking in rice.
-

1.6 SUMMARY

- Plants have been cultivated since the time of early man. Studies were carried to explore the origin of major crop plants. Vavilov's proposed that crop plants originated in some specific restricted areas known as "Centres of Origin". According to him about 85% species listed are supposed to be originated in the old world which includes Asia, Europe and Africa and remaining might have come from new world i.e. America. Most of the centres of diversity include tropical zones.
- The concept of domestication of cultivated plants was elucidated by other workers. Studies suggested that origin and evolution of cultivated plants is much more complex. Zhukovsky (1968) proposed the idea of megagene centres where the species were domesticated. Harlan (1956, 1961) proposed that crops have diffuse origins.
- The process of domestication involves transition from gathering wild plants to cultivation of the same for their use. Domestication of cultivated species brought genetic changes in the plants. The crop domestication and gene pools assist in applying techniques such as plant breeding, plant engineering and crop domestication to crop super-domestication.
- Various techniques have been applied to detect and characterize the genetic basis of domestication of genes in a given species. Top-down and bottom-up approaches provide information about genetic basis of domestication.
- Genetic diversity is the amount of genetic variability among individuals of a variety, or population of a species. Genetic variation found in traditional landraces and wild species is important for continued progress of crop improvement. Diverse genetic resources help in selection and breeding of plants with desired characteristics, thus increasing agricultural productivity.

- Genetic diversity can be conserved in the form of cultivated varieties and wild species related to cultivated varieties. Conservation can be done either *in situ* (in their natural setting) or *ex situ* (outside their natural setting) conditions.
- Rapid development of genomic resources and tools has made it possible to conduct genetic mapping and population genetic studies to reveal the molecular basis of domestication and evolution in diverse crop species. The genes for domestication possess diverse transcription factors.

1.7 TERMINAL QUESTIONS

1. Enumerate the salient findings of Vavilov's work.
2. Give two examples of:
 - i) Plants of the old world
 - ii) Plants of the new world
3. Explain Superdomestication in plants.
4. Define is genetic erosion and describe the major reasons causing it.
5. Describe the Bottle neck concept of loss of genetic diversity.
6. Explain *ex situ* and *in situ* conservation.
7. Explain the top down and bottom up techniques for domestication of a crop species.

1.8 ANSWERS

Self-Assessment Questions

1. a)
 - i) Darwin
 - ii) Alphonse de Candolle
 - iii) complex, continuous
 - iv) agroecological group
 - v) Vavilov
 - vi) Microcentre
 - vii) Andes of South America
- b)
 - i) Clove - Moluccas
 - ii) Cocoa - South America
 - iii) Potato - Peru
 - iv) Groundnut - South America
 - v) Maize - Tropical America

- vi) Soybean - North east Asia
 - vii) Rubber - Brazil
 - viii) Coffee - Ethiopia
 - ix) Wheat - Central Asia
2. a) i) True; ii) False; iii) True; iv) False; v) True
- b) i) Refer to Subsection 1.3.1.
- ii) Refer to Subsection 1.3.2.
3. a) i) Landraces are the populations of a cultivated plant with a known origin, distinct identity, often genetically diverse and locally adapted.
- ii) Genetic diversity is described as the amount of genetic variability among individuals of a variety, or population of a species.
- iii) The process of preservation of genetic diversity in both cultivated and wild varieties. The wild varieties need to be conserved to maintain the natural biodiversity. Conservation can be done either *in situ* (in their natural setting) or *ex situ* (outside their natural setting) conditions.
- b) i) Rice
- ii) Tertiary
- iii) Germplasm
- iv) Heterozygosity
- v) *Ex situ*
4. a) Super domestication
- b) QTL technique
- c) Recessive alleles
- d) Q
- e) *Sh4*

Terminal Questions

1. Refer to Subsection 1.2.1.
2. i) almond, fig, peach, apple, fax, pear, apricot, hemp, barley, millet, tea, cabbage, olive.
- ii) cocoa, maize, sweet potato, tobacco.
3. Super-domestication refers to the processes that leads to domestication of crop species with characters such as increased yield selected from

naturally occurring variations. Super-domesticates can be constructed with various approaches using a wide range of modern technologies such as gene mapping and cloning of domestication-related genes, orthologues of domestication genes, genome evolution, gene and genome duplication using many new techniques.

4. Refer to Subsection 1.4.1.
5. Refer to Subsection 1.4.2.
6. Refer to Subsection 1.4.3.
7. Refer to subsection 1.3.1.

Acknowledgements

Fig. 1.1 : Source:

Doebley et al. (2006) The Molecular Genetics of Crop Domestication. Cell, 1309-1321.

Fig. 1.2 : Source:

[https://www.google.co.in/imgres?imgurl=https%253A%252F%252Fels-jbs-prod-cdn.jbs.elsevierhealth.com%252Fcms%252Fattachment%252F898438bc-d230-41ac-a0d9-8469242587f%252Fgr1_lrg.jpg&imgrefurl=https%253A%252F%252Fwww.cell.com%252Fabstract%252FS0092-8674\(06\)01592-3&tbnid=pjaRnb94YfXoJM&vet=12ahU](https://www.google.co.in/imgres?imgurl=https%253A%252F%252Fels-jbs-prod-cdn.jbs.elsevierhealth.com%252Fcms%252Fattachment%252F898438bc-d230-41ac-a0d9-8469242587f%252Fgr1_lrg.jpg&imgrefurl=https%253A%252F%252Fwww.cell.com%252Fabstract%252FS0092-8674(06)01592-3&tbnid=pjaRnb94YfXoJM&vet=12ahU)

Fig. 1.3 : Source:

https://www.google.co.in/imgres?imgurl=https%253A%252F%252Fwww.nps.gov%252Farticles%252Fimages%252Fgenetics.jpg&imgrefurl=https%253A%252F%252Fwww.nps.gov%252Farticles%252Fbison-bellows-12-3-15.htm&tbnid=RyYLt27h78HMsM&vet=12ahUKEwj-29TGjYH2AhU7_jgGHWtJB_kQMygLegUIARDQAQ.i&docid=1QitXZeThY

UNIT 2

CEREALS |

Structure

2.1	Introduction	2.4	Rice
	Objectives		Origin, Taxonomy and Distribution
2.2	Major Cereal Crops		Cultivation
2.3	Wheat		Morphological Characters
	Origin, Taxonomy and Distribution		Important Varieties and Uses
	Cultivation	2.5	Summary
	Morphological Characters	2.6	Terminal Questions
	Important Varieties and Uses	2.7	Answers

2.1 INTRODUCTION

Food is essential for good health as well as survival of human beings. Human beings depend on plants (and on animals that eat plants) for their food. The food we eat provides minerals and nutrients required for good health. The nutrients provide materials for building, repairing or maintaining body tissues. They also regulate body processes and serve as fuel to provide energy. Nutrients are classified into five main groups: carbohydrates, fats, proteins, minerals and vitamins. All of these are important in the daily diet and are obtained from different plants.

The cereals or grain crops are the most important sources of food for human and provide the basic or staple diet. They contain carbohydrates, proteins, fats, minerals and vitamins. They have a good nutritive value. The cereals have been considered as the first plants to be cultivated or domesticated. They have been grown and used by human since ancient times. It is believed that barley and wheat were grown in Western Asia about 9000 years ago. This provided the basis of civilizations of Mesopotamia, Sumeria, Babylon, Egypt, Rome and Italy. Rice served as the important cereal for the regions of South East Asia while maize has been considered to be cultivated by the civilizations in the New World.

The cereals not only serve as food for man, but are also important for many industrial purposes. Cereals as well as other grasses are also used as fodder for livestock. Only few of the more than 10,000 species of the grass family have been domesticated by man. Interestingly no new species have been introduced into cultivations during the past 2000 years or more.

Objectives

After studying this unit, you should be able to:

- ❖ enlist the region of origin of cereal crops;
- ❖ appreciate the major cereal crops of the world;
- ❖ describe the origin, cultivation, varieties and uses of wheat; and
- ❖ describe the origin, cultivation, varieties and uses of rice.

2.2 MAJOR CEREAL CROPS

Cereals are among the first plants to be domesticated by human during the early times. The cereal crops have been an important part of every civilization. The ancient civilization of Mesopotamia - Sumerian, Babylonian, Assyrian and Chaldean depended on wheat and barley. India, China and Japan depend on rice as well as wheat for their daily food. The Egyptian, Greek and Roman civilizations used wheat and barley as their major food source.

The word cereal has been derived from the '*cerealia munera*' which means gift of *Ceres*- the Roman goddess of grain, harvest and agriculture. This has been reported in Roman mythology. She was worshipped by the farmers and the people of Rome. A festival called '*cerealia*' honored the Goddess each year from April 12 to April 19. Later these were identified as plants with small grains and named as '*cereals*'. The grains of wheat and barley became the major part of the offerings given to god by Romans. In Japan, the ancient Shinto religion has many special ceremonies dealing with abundant harvest and good health. Here rice is the most important cereal. The festival called '*Baisakhi*' (13th April) in northern India is also associated with agriculture and the first grain harvested is offered to the God. These and several other evidences show that there has been a very close relationship between the cereals and man since ancient times.

Cereals are the members of grass family Poaceae and are grown for their starchy 'seeds'. Some other botanically unrelated plants have also been used in a similar manner as cereals and have a similar grain chemical composition. These are referred as '*pseudocereals*'. Buckwheat (*Fagopyrum esculentum*), quinoa (*Chenopodium quinoa*) and amaranthus (*Amaranthus spp.*) are few examples of pseudocereals. Cereals were used for food by popping or parching the grain. Later the grains were ground into coarse meal which when soaked in water made porridge. Baked cakes or bread appeared later in the course of time.

Cereal crops provide essential nutrients and energy in the everyday human diet through direct human consumption. The term "cereals" refers to members

of the Poaceae family and includes: wheat (*Triticum*), rye (*Secale*), barley (*Hordeum*), oat (*Avena*), rice (*Oryza*), millet (*Pennisetum*), corn (*Zea*), sorghum (*Sorghum*).

Cereals were preferably selected as the food crops because of some attributes which include- i) great adaptability to varying environmental conditions leading to their rapid colonization in different ecological habitats ii) easy cultivation iii) high yield per unit area iv) compact grains which can be handled, stockpiled and transported easily v) grain having good nutritive value i.e. having high percentage of carbohydrates, protein, fats, vitamins and minerals.

Most of the cereals are herbaceous annuals. The stem is erect, usually cylindrical, hollow except at nodes and possess intercalary meristem. The primary, secondary, tertiary and quaternary tillers arise from the subterranean nodes of primary, secondary or tertiary stems. The leaves are alternate and distichous, exhibit parallel venation and consist of two distinct parts- leaf sheath and lamina. A thin membranous outgrowth called 'ligule' is found at the junction of leaf sheath and lamina. The inflorescence may be spike of spikelets as in case of wheat, barley, rye or panicle of spikelets as observed in case of oats, rice and sorghum. The main axis of inflorescence is called rachis while that of spikelet is called rachilla. Each spikelet contains one to seven spikes with a pair of glumes. Each floret is enclosed in a long, slender awn like lemma and palea. The perianth is reduced and represented by two membranous hygroscopic scales called lodicules. Stamens are mostly three to six. The gynoecium is single but bears two feathery stigmas. The flowers open through enlargement of lodicules in presence of water and are best adapted for wind pollination. The grain is one seeded indehiscent fruit or caryopsis in which pericarp is fused with the seed coat. The endosperm forms the main part of the grain and consists of large cells packed with starch grains.

Wheat, rice, corn, barley, oats and rye are the six major cereals of the world. Rye and oats are dominantly use in the colder regions near North Pole. Wheat and barley are consumed as major cereals in warm temperate regions while maize and millets predominate in tropical regions. The Egyptians, Greeks and Romans cultivated small seed varieties known as millets. These have also become the part of food in China, Japan, India and African countries. In rest of the world, they are used as birdseed. The major millet varieties include finger millet (*Eleusine coracana*, popularly known as ragi), foxtail millet (*Setaria italica*), Japanese barnyard millet (*Echinochloa frumentaca*), pearl or bulrush millet (*Pennisetum americanum* popularly known as bajra). In regions of Africa, India, pearl and finger millet are important staple crops. Cereals such as wheat, rice or maize form the staple food of about a quarter of the world population. Barley, oats, rye, sorghum and millets together make up staple food for the rest of the world.

Rice is one of the leading food crops of the world, maize (corn) and wheat being the other two. There are about 10,000 varieties of rice in the world. The Asian continent dominates in terms of global rice production. China and India are leading producers of rice. More than 3.5 billion of the world's population use rice as their staple food. This accounts to about half of the people living in the world.

Maize is called as 'Pampered Corn' because its dispersal (release of grains from cob) and propagation is done by man.

Maize is another crop widely cultivated throughout the world. The United States of America produces 40 percent of the world's harvest. Other maize producing countries include China, Brazil, Mexico, Indonesia, India, France and Argentina. The maize plant thrives well in regions with 50-100 cm of rainfall and temperature ranging between 21 °C to 27 °C. Fertile well-drained alluvial or red loams rich in nitrogen are the best soil for its growth.

Rye is a type of cereal grain that belongs to the wheat family. This plant is native to the central and eastern regions of present-day Turkey. Archaeological evidence suggests that the plant has been cultivated since Neolithic era. It is grown in many regions around the world. Germany is the largest producer of rye followed by Poland and Russia.

Sorghum is a cereal grown around the world. Early species of sorghum were discovered in Australia, Africa, parts of Indian Ocean, Mesoamerica, as well as parts of the Pacific Ocean. The United States of America leads the world in sorghum production with a production total of 11.5 million metric tons. Other sorghum producing countries are India, Nigeria, Mexico, Sudan, China and Ethiopia. Sorghum grows well in areas with warm climates. Sorghum has a wide range of uses, which include human food, animal feed, and the production of alcoholic beverages and biofuels. The plant has a high nutritional value as it is rich with essential nutrients. It grows well in areas having mean monthly temperature of 26 to 33 °C. It requires more than 30 cm of rainfall for growth. Loamy and sandy soils are best suited for its growth. It can grow in plain areas as well as raised slopes (about 1200 metres high).

India leads the world in millet production, followed by the African countries of Nigeria and Niger. Millet constitutes a variety of small-grained, warm-weather, annual cereals that are part of the grass family. Millet is grown widely around the world for use as food and fodder. Millets are important crops in the semiarid tropical regions and are indigenous to many parts of the world. For centuries, millets have served as an important staple food in parts of Asia and Africa.

SAQ 1

- a) Fill in the blanks
 - i) Most of the cereals belong to the family
 - ii) A thin membranous outgrowth present at the junction of leaf sheath and leaf lamina in leaves of cereals is called
 - iii) The main axis of inflorescence in cereals is known as
 - iv) In cereals forms the main part of the grain.
- b) Give two examples of the following:
 - i) Millets
 - ii) Pseudocereals
 - iii) Cereals that form the staple food of the most of the world.

2.3 WHEAT

Botanical name : *Triticum aestivum* Linn.

Family : Poaceae

Common name : Gahuen

2n = 42, A B&D genome

Wheat is the world's most important food plant for more than one third for the world's population. Millions of people throughout the world depend on foods made from the kernels (seeds or grains) of the wheat plant. It is probably the oldest crop known in cultivation. Long before the beginning of agriculture, people gathered wild wheat for food. It is believed that agriculture originated in the Middle East and wheat is supposed to be the first crop cultivated in ancient times. Archeological evidences have shown the presence of carbonized wheat grains at the Neolithic sites in Jarmo in Northern Iraq, and in Central and North Eastern Europe dating back to the period 6750 B.C. to 7500 B.C. These observations suggest that wheat spread rapidly and widely throughout Asia and Europe after its domestication in the Middle East.

There are various kinds of wheat. The most widely cultivated wheat is called the common wheat or the bread wheat. We owe much to the Russian Botanist Nikolai Vavilov (1887-1943) for our knowledge of wheat. He studied more than 31,000 samples of wheat from different parts of the world and classified them as different varieties. This knowledge was later supplemented with information from cytology, physiology and biochemistry obtained by Japanese and American scientists to provide us valuable data about the wheat varieties of the world. It is therefore, necessary to know about the taxonomy of the different wheat varieties. This information will help you to understand the origin and distribution of different wheat varieties.

2.3.1 Origin, Taxonomy and Distribution

Vavilov classified the wheat into 14 species. All the wheat species are classified in the genus *Triticum*. They are member of the Family Poaceae (Gramineae), sub family Poideae and the tribe Triticaceae. The different species of wheat can be grouped into three categories on the basis of their cytology.

Box 2.1: Cytology of wheat

There are diploid wheat having $2n=14$ chromosomes, tetraploid wheat with $2n=28$ chromosomes; and hexaploid wheat with $2n = 42$ chromosomes. Detailed cytological analysis of wheat species revealed that there are 3 different genomes. The diploid wheats have been recognized as having the *AA* genome. The tetraploids and hexaploids are not autopolyploids (i.e., possessing similar genomes to the diploid). They are allopolyploids with dissimilar genomes. The tetraploid wheat has the *AABB* genome while the hexaploid wheat has the *AABBDD* genome. This cytological knowledge along with other evidences helped us to know about the origin and evolution of wheat as well as about other grasses which contributed to the evolution. The cytological studies were made by T. Sakamura (1918) in Japan and later by an American Scientist Karl Sax. The three groups of wheat were proposed by German biologist August Schultz in 1913 on the basis of anatomical, morphological and chemical studies.

The oldest known wheat is the diploid wheat. The tetraploid and hexaploid varieties have been believed to have originated from ancient diploid wheat and related wild natural grasses by hybridization followed by chromosomal doubling.

Four different genomes A, B, D and G representing four different sets of seven chromosomes have been recognized in wild and cultivated species. There are wild and domesticated (cultivated) species of the diploid wheat. The 14 chromosome wheat probably is the most ancient and includes species wild einkorn known as *Triticum boeoticum* Boiss and cultivated einkorn known as *T. monococcum*.

This is a diploid wheat ($2n=14$; AA genome) which was widespread in Western Asia. It exhibits considerable genetic variation. The cultivated einkorn wheat called *Triticum monococcum* L. evolved from the wild type and has the same AA genome. This wheat possess one grained spikelets, the fruiting stalks are brittle and fragile, and the grains remain firmly enclosed in the glumes. Wild einkorn is probably the one of the ancestors of all the cultivated forms. Cultivated einkorn differs from its wild ancestor in having large kernels. Wild einkorn is believed to have originated in Middle East and South eastern Europe, while the cultivated einkorn is supposed to have origin in South eastern Turkey and spread to Europe from Spain to Scandinavia.

The wheat 28 chromosome tetraploid consist of seven species mainly wild emmer, *T. dicoccoides* (AABB) found growing in the Middle East. It has originated as a result of cross between *T. boeoticum* (AA) and *T. speltoides* (BB). Wild emmer i.e. *Triticum dicoccoides* Koern is the oldest known tetraploid wheat. It is found in Palestine and Syria. According to Sarkar and Stebbins (1956) the tetraploid emmer wheat developed as a result of hybridization between *T. monococcum* (AA) and *T. speltoides* (BB) or a related species. From wild emmer, the cultivated emmer or *Triticum dicoccum* Schubl have evolved by mutation, domestication and selection. Another tetraploid wheat called durum or *Triticum durum* Desf. also evolved from wild emmer. Both wild and cultivated forms have covered grains. It is now grown in limited extent in mountainous regions of Europe, Turkey, Iran, Ethiopia. Tetraploid wheats are widely cultivated in the Middle East.

Tetraploid varieties *T. durum* with naked grains is one of the important wheat varieties grown today. It is extensively grown in Italy, Spain and United States of America. There are several tetraploid wheat varieties. These have originated by hybridization between the diploid wheat closely related wild grasses. They have 2 distinct genomes, the AA component is obtained from the diploid wheats while the BB component was contributed by the diploid grass called *Aegilops speltoides* ($2n=14$; BB genome). Hybridization followed by chromosome doubling resulted in the origin of the tetraploid wheats.

Wheat with 42 chromosomes are the most recently evolved varieties and are the most common cultivated wheat. The common hexaploid wheat varieties mainly include *Triticum spelta* Linn. and *T. aestivum* Linn. All of these are the products of hybridization of 28 chromosome wheat (AABB) with a wild chromosome relative (DD) almost a grass of the genus *Triticum tausschii* (*Aegilops squarrosa*) (a weed growing in wheat fields) followed by doubling of

chromosomes to give rise to plant with six sets of seven chromosomes (AABBDD). A very large number of varieties of *Triticum aestivum* or breadwheat are cultivated in different parts of the world. The fruiting stalk of *T. aestivum* is tough, does not shatter grains during harvesting. The glumes open easily during threshing.

Two other hexaploid varieties of wheat are dwarf wheat, *T. spharococcum* and club wheat *T. compactum*. The former is endemic in central and North Western India but not grown now a days. The plants are short, profusely tillered. The ear heads are small and possess small rounded grains. The kernels of short wheat have been discovered at most ancient sites of Mohenjodaro, Sind dated 2000 B.C. Club wheat is also dwarf in habit but possess stiff, strong jaw, short dense spikes having small kernels.

Kihara (1924), McFadden and Sears (1946) and Sears (1948) have suggested that the hexaploid wheat originated through crossing of tetraploid emmer (AABB) and *T. tauschii* (DD). The latter contributed genes for the high gluten content of hexaploids and made them better adapted to the extreme environmental conditions. Spelt wheat was developed by McFadden and Sears, Kihara by making a cross between *T. dicoccoides* and *T. tauschii*. It was suggested that the D genome was derived from *T. tauschii*.

According to Vavilov the center of origin of diploid wheat has been Asia Minor. The tetraploid wheat originated in Abyssinia and North Africa, while the hexaploid was from Central Asia. The wheat spread throughout Asia and Europe after its domestication. Bread wheat was grown in Nile valley by 5000 B.C. in Euphrates and Indus valleys by 4000 B.C., in China by 2500 B.C. and England by 2000 B.C.

2.3.2 Cultivation

Wheat is one of the most cultivated crops. It is grown from the regions in the range of equator to 60°N and 40°S but the greatest concentration is reported from warm temperate regions. The regions have cool winters followed by a dry and warm summer suitable for the ripening of the grain. Moderate rainfall between 30 and 90 cm is suitable for cultivation.

It covers a wide area around the world including the parts of China, United States, Russian Federation, Canada, Germany, Ukraine, Turkey, Pakistan, United Kingdom, Iran and Argentina (Table 2.1). China is the leading producer of wheat and India is third largest producer of wheat.

Wheat requires a cool climate with moderate rainfall. The ideal temperature for growth of wheat is 10°- 15° C and for summer varieties it ranges between 21° to 26° C. Wheat can be grown on any type of soil but best growth has been noted in silt and clay loams having pH not less than 5.8. The wheat growing in India is restricted to areas of Indo Gangetic plain covering the areas of Uttar Pradesh, Punjab, Haryana, Bihar and some parts of Rajasthan. The areas of wheat cultivation also include black soil regions of Madhya Pradesh, Maharashtra, Andhra Pradesh and Karnataka. Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Bihar are the major wheat producing states of India. *T. durum* is the commonly grown in India (about 85 percent of the area) followed by small area covered by emmer, *T. dicoccum*. The growth period of wheat is generally 150-160 days.

The wheat cultivated in temperate areas includes two types- the spring wheat and the winter wheat. The spring wheat is a slow growing variety having a period of 100 days and does not require low temperature during early phases of growth. The variety is sown in March-May and harvested in August-September. The winter wheat is of long duration and need to be cultivated at low temperature during initial growth phase. The crop is sown in October-November and harvested in May-July. In India wheat is basically a winter crop but is also grown during summers.

Table 2.1: Wheat production by different countries of the world.

Rank	Country	Wheat Production (Tonnes)
1	China	134,340,630
2	India	98,510,000
3	Russian Federation	85,863,132
4	United States of America	47,370,880
5	France	36,924,938
6	Australia	31,818,744
7	Canada	29,984,200
8	Pakistan	26,674,000
9	Ukraine	26,208,980
10	Germany	24,481,600

2.3.3 Morphological Characters

The wheat plant is a typical grass with all characteristic features of the family Poaceae (Graminaeae). Young wheat plants are bright green. They turn golden brown when the grain is mature. The plant is an annual with numerous “Tillers” (Fig.2.1).

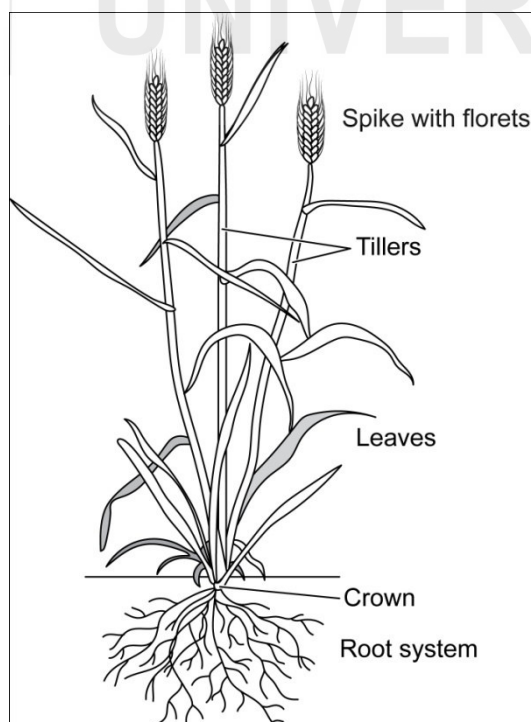


Fig. 2.1: Tillering habit in wheat.

It has two types of roots, primary or seminal which develop from the embryo and secondary or coronal which are adventitious and develop from the basal underground nodes of the main axis and the tillers. The primary roots live only for six to eight weeks while the secondary roots represent the permanent root systems of the plant.

The main stem (culm) as well as tillers are erect cylindrical structures. Each is made up of 5-7 nodes and grows to a height 0.3 to 1.5m. The lower internodes are short but the upper ones are longer. These are hollow and usually glabrous.

The leaves show an alternate arrangement. Each leaf has a basal sheath. It encircles the stem and forms a complete tube in its lower region. The sheath splits higher up and continues into the lamina or blade. The lamina is flat, long, narrow with an acuminate tip. It shows parallel venation and more stomata on the adaxial surface. The graminaceous stomata are characteristic of the family Gramineae; dumbbell shaped guard cells having special 'bulliform' cells are present in adaxial epidermis. At the junction of the sheath and lamina, there is a colourless membranous ligule. A pair of auricles is also present at the base of the lamina.

The inflorescence is a terminal spike made up of numerous spikelets. The inflorescence axis is tough and does not shatter (break up) when the grain is ripe. The spikelets are in two rows on alternate sides of the axis. Each spikelet is sessile with 2-5 florets (Fig. 2.2). The spikelet consists of a pair of sterile glumes, a shortened rachilla and 2-5 pairs of fertile glumes. Each pair of fertile glumes consists of an outer lemma and an inner palea (Fig. 2. 2).

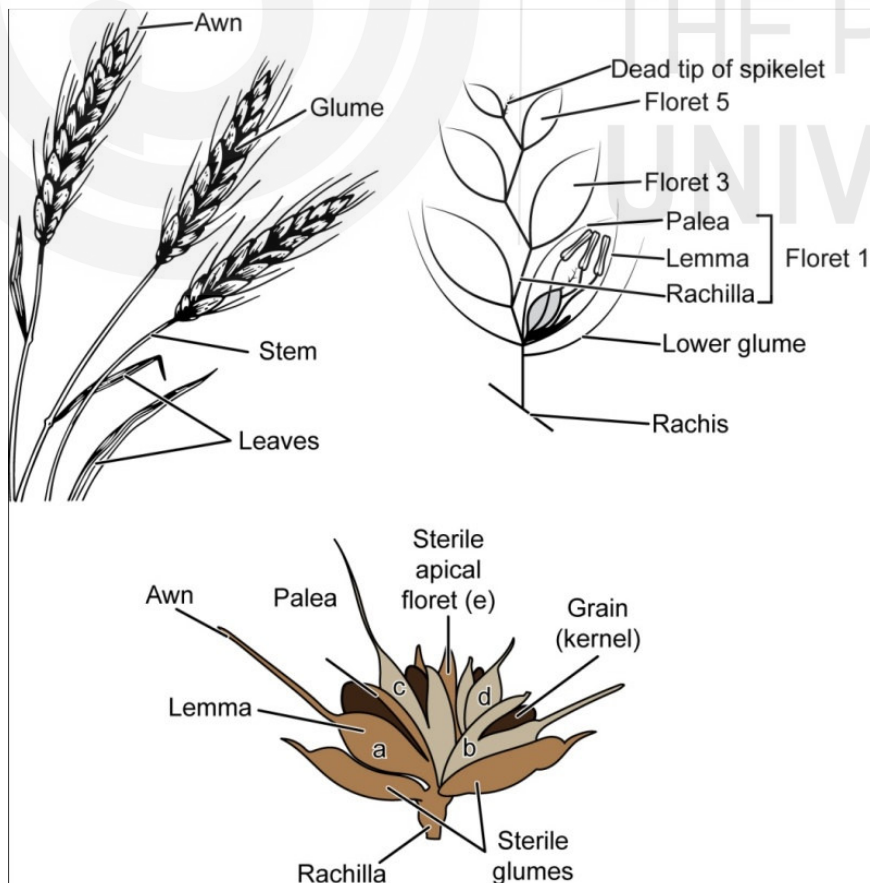


Fig.2.2: Spikelet of wheat showing glumes, florets and floral parts.

These fertile glumes enclose the floret. The apex of the lemma is usually extended into an awn. The floret consists of 2 lodicules which represent the perianth and regulate the opening of the flower. There are 3 stamens with slender filaments and bilobed versatile anthers (Fig. 2.3). The gynoecium is monocarpellary (or according to some taxonomists tricarpellary syncarpous) with a superior ovary and 2 terminal styles having feathery stigmas. There is a single ovule.

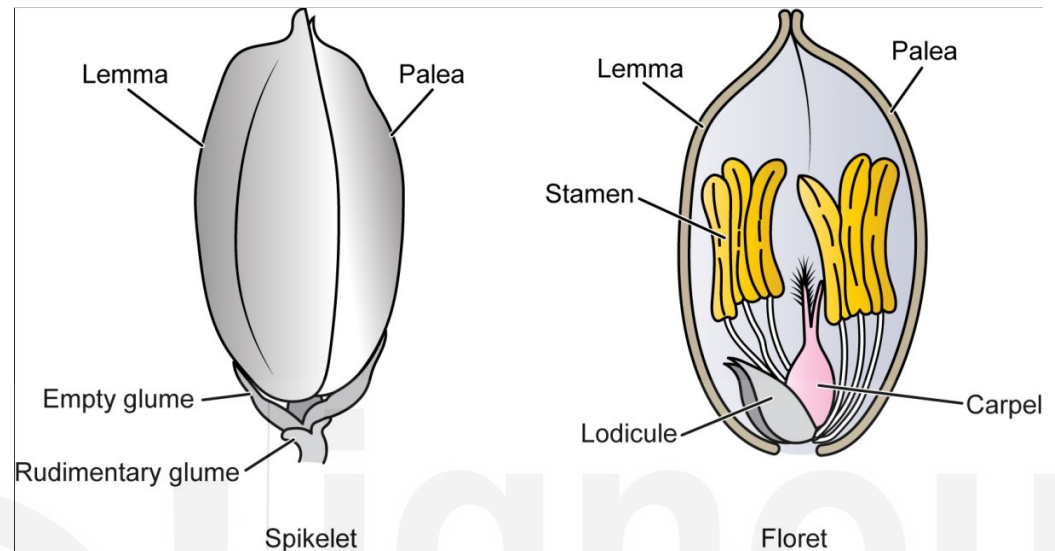


Fig. 2.3: Structure of the floret of the *Gramineae* with Lemma and palea.

The fruit is a caryopsis. It is a one seeded, dry indehiscent grain. Usually two grains develop in each spikelet. Each grain is oval with convex dorsal surface and a centrally grooved ventral surface. A tuft of hairs is present at the tip of the grain. The fruit wall and the seed coat are completely fused and these layers constitute the bran of the grain. Bran encloses the endosperm which forms the major portion (about 82-86%) of the grain. This is mainly made up of starch and gluten. The outermost layer of the endosperm is the aleurone which contains vitamins, minerals, and proteins but does not contain gluten. The small embryo is present at the basal end of the grain. It consists of the plumule and radical. The plumule is enclosed in a sheath called the coleoptiles. A coleorhiza or root sheath encloses the radical (Fig. 2.4). A fleshy shield like cotyledon called the scutellum is also present.

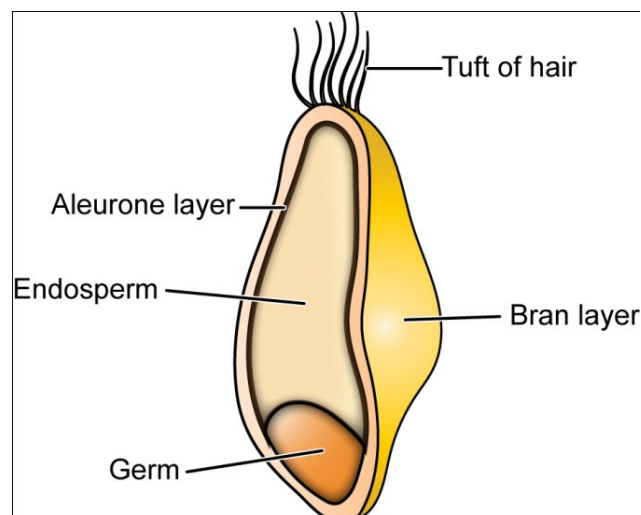


Fig. 2.4: Anatomy of wheat grain showing coleorhizae and radicle.

2.3.4 Important Varieties and Uses

Breeding and improvement in wheat

The varieties of crop plants have been improved by man. The selection of plants for better growth, good grain quality and other useful traits has been done earlier. The wheat research in India was primarily initiated at Imperial Agricultural Research Institute (IARI) Pusa, Bihar. During the sixties, the Indian Agricultural Research Institute (IARI), New Delhi started working on wheat programme. All India Coordinated Wheat Improvement Project was initiated in 1965, was subsequently upgraded in 1978. More than 316 wheat varieties suited to different agro-ecological conditions and growing situations have been released so far.

In India, in the early 1900s varieties such as P.4, P.5, P.6 were developed which became internationally very famous. Later at Indian Agricultural Research Institute (IARI) Pusa, New Delhi wheat breeding programmes were carried out and new varieties were developed. The varieties showed resistance to various types of rusts. This proved to be a landmark in the improvement of wheat. Dr. M.S. Swaminathan was recognized as the Father of Green Revolution in India for his contribution in improvement in wheat.

On December 11, 2020, the Nepal Agricultural Research Council (NARC) announced the release of six new wheat varieties. The varieties were developed by the International Maize and Wheat Improvement Center (CIMMYT). These included Borlaug 100, a variety well known for being high yielding, drought- and heat-resilient, and resistant to wheat blast, as well as high in zinc. New varieties are Zinc Gahun 1, Zinc Gahun 2, Bheri-Ganga, Himganga, Khumal-Shakti and Borlaug 2020. The varieties are tailored for conditions in a range of wheat growing regions in the country - from the hotter lowland, or Terai, regions to the irrigated as well as dryer mid- and high-elevation areas - and for stresses including wheat rust diseases and wheat blast. The five high-zinc, biofortified varieties were developed through conventional crop breeding by crossing modern high yielding wheat with high zinc progenitors such as landraces, spelt wheat and emmer wheat.

Wheat varieties

The major varieties of wheat grown in India are Lerma Rojo, Sonora 64 (exotics); Kalyansona, Sonalika, Chotti Lerma, Sharbati Sonora; HD 2009 (Arjun), HD 2280, HD 2285, HD 2327, HD 2329, HD 2204, HD 2278, HD 2189, HD 2307, HD 2402 (all by Late Shri U.S. Mathur at IARI); WL 711 (by Dr. K.S. Gill, PAU, Ludhiana); WH 147, C 306, WH 157, WH 283, WH 291 (All by Shri Dhani Ram Vasudeva at HAUS, Hisar); UP 262, UP 2003 (by GBPUAT, Pant Nagar); VL 42 (by VPKAS, Almora); HUM 234, Raj 1555 Raj 1972 (by RAU, Durgapura, Jaipur) and Lok 1 (by MACS, Pune)

Uses

The wheat varieties also show change in their chemical composition which is influenced by edaphic or climatic factors. The wheat can be soft or hard. The soft wheat possesses a white starchy interior and is generally low in gluten content. It is used for making cakes, cookies and pastries. The hard wheat is dark and vitreous and shows no starchy area. It is high in gluten content and is used for making flour.

Wheat is consumed in various forms. In some areas, it is consumed at every meal in some form or the other. The grain is ground into flour which is used for making bread. The flour contains gluten, a protein which makes the dough elastic. This elasticity of the dough is essential in making bread, as it allows the dough to rise when it is baked with yeast. In India and other parts of the world, 'Unleavened bread' (chapaties) is made from wheat flour. Besides chapaties, it is also used for making tandoori roti, paratha, poori, etc. Refined wheat flour (maida) is used for making cakes, biscuits, pastries and other products. Coarsely ground wheat called semolina (sooji) is used for various preparations such as sweet, halwa, Kharabath or upma. Wheat porridge is also made from hard grains. The tetraploid wheats such as *Triticum durum* are important for making macroni, spaghetti, vermicelli, noodles etc.

The wheat grain is rich in nutrients including protein, starch, vitamins, essential minerals such as iron and phosphorus. Whole wheat flour made from the entire grain is more nutritious than white flour made by using roller mills. Here only the soft white inner part of the grain which is mainly the starchy endosperm is ground into flour. This process removes the 'wheat bran' i.e. outer covering of the grain, as well as the 'wheat germ', i.e. the embryo. These parts of the grain contain the nutritious vitamins, minerals as well as the proteins.

Besides food, wheat is also used in several other ways. The bran is an important constituent of livestock and poultry feed. Glutamic acid obtained from wheat is used in the manufacture of monosodium glutamate (MSG). This salt has little flavor of its own but enhances the flavor of other food. Wheat is used industrially for the manufacture of starch, gluten, alcohol, adhesives, polish etc. Wheat straw is used as a livestock feed, compost and for making baskets, hats, strawboards, paper or even simple toys.

SAQ 2

a) Answer in one word:

- i) Wheat plants belong to the genus.
- ii) Russian botanist that provided knowledge about wheat.
- iii) Number of chromosomes present in most evolved varieties of wheat.
- iv) Inflorescence of wheat.
- v) The specialized leaf like structure enclosing the floret.
- vi) Protein present in wheat flour.

b) Answer in short:

- i) Continents of origin of wheat
- ii) Ideal time for the growth of wheat
- iii) Nutrients present in wheat

2.4 RICE

Botanical Name: *Oryza sativa* Linn.

Family : Poaceae

Common Name: Chaval, Dhan.

n = 12

More than half of the people of the world eat rice as the main part of their diet. Nearly all the people who depend on rice for food live in Asia. Most taxonomists have identified about 20 species of rice, but only two are cultivated and are of economic importance. The Asian rice, *Oryza sativa* Linn. is the main cereal crop in Southern and Eastern Asia. It is also cultivated in other parts of the world. The African rice – *Oryza glaberrima* Steud is grown mostly in West Africa. The two species differ in glume pubescence and ligule size. In addition to these structural differences, the pericarp in *O. glaberrima* is red. The following account deals with the more important species *Oryza sativa*.

Rice paper is not made from rice, but from the pith of *Tetrapanax papyriferum* (Hook) K. Koch, a tree from Taiwan belonging to the family Araliaceae.

2.4.1 Origin, Taxonomy and Distribution

Rice (*Oryza sativa*) originated in South East Asia. The exact place and period of its origin or domestication is not known with certainty. It has been cultivated in China for nearly 5000 years. Yung Shao excavations in China show remains of rice. These have been dated 2600 B.C. There are many religious ceremonies associated with rice since ancient times. Evidences suggest that rice may have originated in China.

A second hypothesis suggests that rice may have originated in India and then spread to China and other parts of South East Asia. Archeological excavations from Lothal in Gujarat have revealed charred grains of rice. This has been dated to 2300 B.C. and is believed to be an extension of the Harappa culture of the Indus Valley Civilization. There are also records of rice in ancient Hindu scriptures and literature. Carbonized grains of rice have also been found from Hastinapur in Uttar Pradesh.

The evidences of use of rice in numerous traditional and religious ceremonies in India such as birth, marriage and even death suggested of its ancient origin in India. It has been proposed that rice might have spread from India to China, Indonesia, Japan and other south East Asian regions. It may also have spread westwards to Iran, Iraq, Egypt and neighboring areas.

Rice was introduced to Europe from India in 300 B.C by Alexander the Great. It was produced commercially in South Carolina in 1685.

The International Rice Research Institute (IRRI) was set up in Philippines by the joint efforts of the Ford and Rockefeller Foundations for the study of this important cereal crop. The samples of rice from different parts of the world were collected between 1962 and 1965 to build up a germplasm bank. More than 10,000 varieties of rice were recognized and interestingly about 60 per cent of these were found in India. This suggested that there was a great

genetic diversity in the rice grown in our country. From an evolutionary point of view this is important because greater the diversity, more are the chances of adaptation to the environment. The cultivation of rice in marshy areas with intervening mountains as well as the presence of wild species in the region has helped in the natural selection of different varieties.

Two divergent views have been provided regarding the cultivation of rice. These include polyphyletic i.e. originating from several species and monophyletic i.e. evolving from a single species. The polyphyletic theory suggests that *O. sativa* and *O. glaberrima* evolved independently in their respective regions. *Oryza rufipogon* of Asia has given rise to most varieties of *O. sativa*. Some forms also originated from *O. minuta*, *O. barthii* or *O. breviligulata* has been found to be the progenitor of *O. glaberrima*.

Taxonomists suggest that cultivated rice have a monophyletic origin i.e., it originated from one ancestor. The two cultivated species, *Oryza sativa* and *O. glaberrima* have evolved from a common ancestor. The search for this ancestor has shown the occurrence of a wild rice *Oryza longistaminata* (also called *Oryza perennis*) which could be the progenitor of both cultivated species. The origin of this is traceable to the Gondwana arid super continent. Due to continental drift and splitting of this super continent, the present day Africa, Madagascar, South East Asia, Australia, South America, Antarctica etc. were formed in pre-historic times. The original ancestral species of rice found in the Gondwana land adapted to the regions in West Africa and South East Asia. This led to the evolution of *Oryza sativa* on one hand and *Oryza glaberrima* on the other.

Rice is grown over an area of about 146 million hectares in the tropical and subtropical parts of the world. Asian countries produce the most rice worldwide. Top 10 rice producing countries in the world today are India, China, Indonesia, Bangladesh, Thailand, Vietnam, Burma, Philippines, Cambodia, and Pakistan (Table 2.2).

Table 2.2: Major rice producing countries of the world reported by the year 2019.

Rank	Country	Rice Production (million metric tons)
1	China	146.73
2	India	118.87
3	Indonesia	34.7
4	Bangladesh	35.85
5	Vietnam	27.1
6	Thailand	17.66
7	Burma	12.7
8	Philippines	11.9
9	Japan	7.61
10	Brazil	7.61

China, India, Bangladesh, Japan, Pakistan account for about 85 per cent of the world rice production (Fig. 2.5).

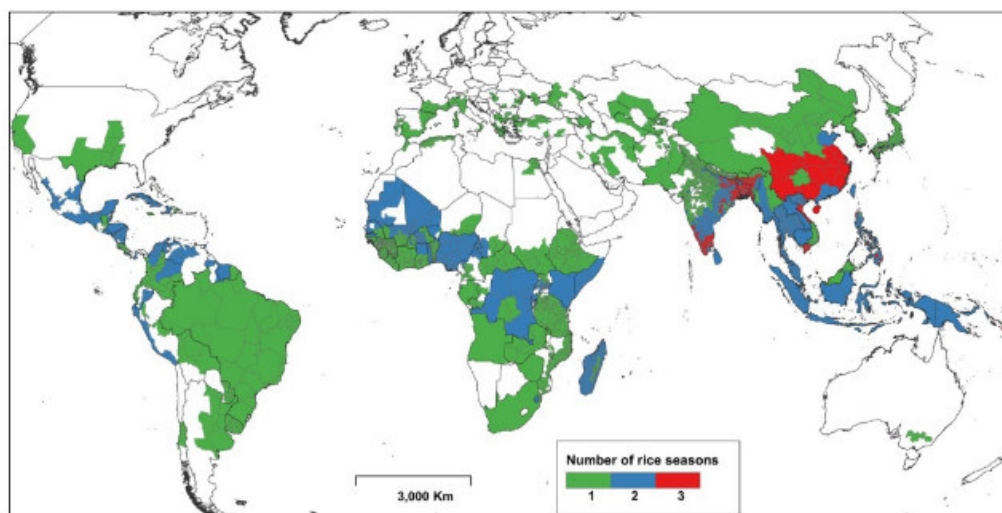


Fig. 2.5: Map showing major rice producing countries of the world.

Some quantity of rice is also grown in south European countries like Italy, Spain and United States. China is the leading producer of the rice in the world. India ranks second in the rice production. In India about 42.5 million hectares of land is under rice cultivation which includes states of West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab, Tamil Nadu, Orissa, Bihar and Madhya Pradesh.

2.4.2 Cultivation

It is a kharif crop which requires hot and humid climate for cultivation. High temperature (above 25°C) and high humidity with annual rainfall above 100 cm are favourable for the growth of rice. Rice can be grown on many soil types ranging from sandy loams, lateritic soils and alluvial soils. The rice crop needs a swampy soil where the land is submerged under water for 60-90 days during the growing season. The crop requires rainfall ranging from 120-200 cm. The crop thrives well under conditions of high temperature and humidity. Rice requires abundant rainfall or good water supply through irrigation and flooded fields during the earlier part of its growing season in June-July.

Rice varieties may be classified on the basis of their period of maturity. Some varieties mature in less than 110 days, some take 110 to 140 days to mature, some take 150-170 days to mature while very late maturing varieties take about 180 days to mature. The major subspecies of rice include *Oryza sativa* sub sp. *indica*, *Oryza sativa* sub sp. *japonica*, *Oryza sativa* sub sp. *javanica*.

2.4.3 Morphological Characters

The rice plant is a semi-aquatic, freely tillering, annual grass. It has a cylindrical jointed stem (culm) about 50-150 cm tall. The root system is fibrous. The primary root emerges on germination and it is followed by two additional roots. Adventitious roots are then produced from the basal nodes of the primary stem and tillers (Fig. 2.6). The roots can be grown under low oxygen concentrations. They form a dense surface mat and they are highly branched and have a profusion of root hairs.

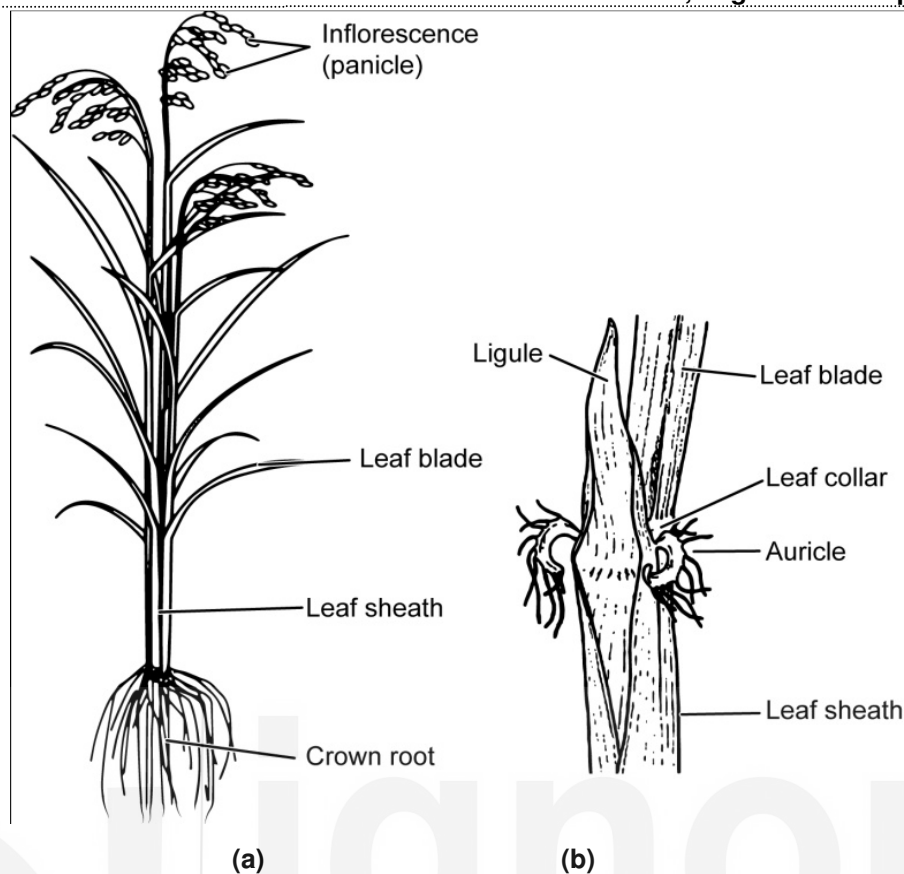


Fig. 2.6: Rice a) Basal part of the main rice culm shows adventitious roots; b) A leaf joint showing ligule and auricles.

The stem or culm is usually erect, smooth and 6-10 mm in diameter. The nodes are solid but the internodes are hollow. Above each node there is a prominent pulvinus and an intercalary meristem. The lower internodes are short, and become progressively longer towards the apex. There are 10-20 internodes on each stem.

The first leaf at the base of the culm and each tiller is rudimentary. It consists of a bladeless prophyllum. All other leaves on the plant have a sheath and lamina. The leaves are borne alternately on the stem in two ranks one at each node. Each leaf consists of the sheath, blade, ligule and auricles. The sheath is split down its entire length and encircles the node. The lower sheaths are longer than the internodes but after the 10th leaf the sheath becomes progressively shorter than the internodes.

The sheath is finely ribbed and glabrous. At the junction of the sheath and blade, there is a triangular membranous ligule. It is usually colorless and tends to split with age. On either side of the ligule there are small fringed appendages called auricles. The leaf blade is narrow. The lamina of the uppermost leaf below the auricle is wider and shorter than the other leaves. This is called the "boot or flag leaf".

The inflorescence is a loose terminal panicle 14-42 cm long. The main axis bears a variable number of primary branches. The angle at which the primary branches are borne determines the compactness of the inflorescence (Fig. 2.7). The primary branches bear secondary branches each of which has one or more spikelets. Each spikelet is bilaterally compressed and has a single bisexual floret. The pedicel is short and firm. There are two glumes of equal

length. The lemma is large, boat shaped and rigid. It is hard, keeled and strongly five-nerved. The apex may be pointed or extended to form an awn. The palea is narrow, keeled and three-nerved. The apex of the palea is projected as a solid point which forms the apiculus of the caryopsis with the apex of the lemma. Each floret has two broad lodicules, six stamens in two whorls and the gynoecium with a single ovule. There are two styles with white or purplish plumose stigmas. The fruit is a caryopsis closely enclosed in the husk formed by the lemma and palea. This is called paddy. During milling the hull is removed and the rice grain is separated (Fig. 2.7).

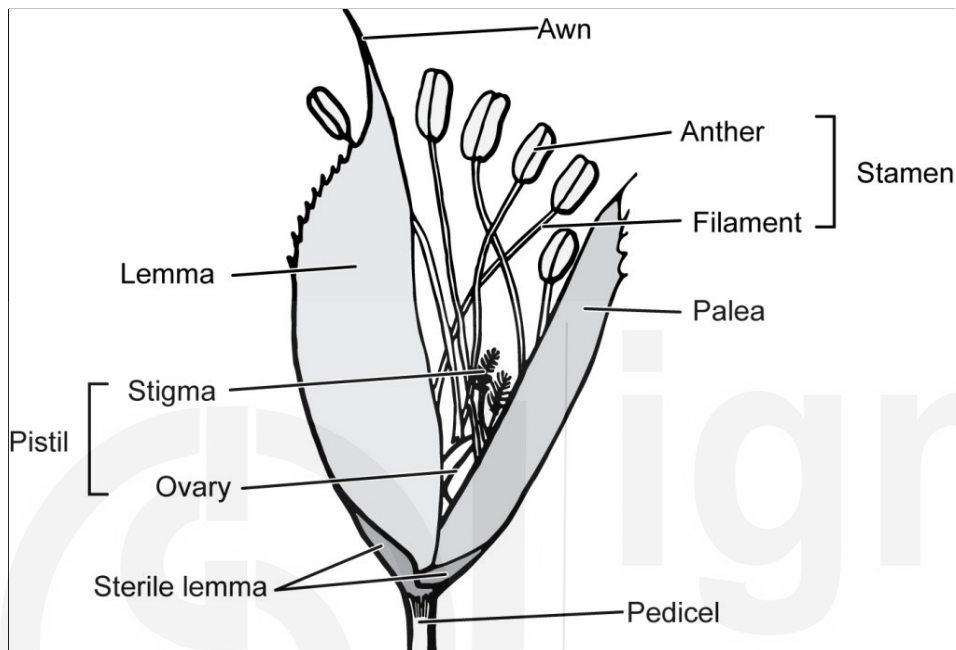


Fig. 2.7: A portion of the rice panicle showing lemma and palea removed to expose the flower with stamens.

In India about half of the rice produced is parboiled. The paddy is steeped in cold or hot water for varying period upto 3 days. It is then steamed at low pressure and dried. The hull is then removed by milling. Parboiling results in less breakage of the grain during milling. The important nutrients are also retained in the grain and the grain can be stored for longer period. However, it is important to ensure that clean water is used and parboiling done under hygienic conditions so as to obtain good quality grain. Improper parboiling leads to inferior color and unpleasant odor in the grain.

2.4.4 Important Varieties and Uses

First we will describe breeding and improvement in rice varieties and then its uses.

Breeding and improvement in rice

Rice breeding has been done continuously to get improved varieties over time. High-yielding varieties developed in the 1960s and 1970s at the International Rice Research Institute (IRRI) benefited farmers. IR8, a rice variety was the first variety developed through breeding. It was a high rice yielding variety. IR8 had a very high grain yield but showed poor grain quality, lack of resistance from disease and insect and late maturity. The varieties improved on these traits were developed and released over the next two decades. During the

early 1980s, one of the most popular varieties grown was IR36. In addition to its disease and insect resistance, it showed high yield in a period of only 111 days from seed compared to 130 days for IR8. In 1985, IRRI-developed variety IR64 which was released in Philippines. It represented a breakthrough as it showed excellent palatability of cooked rice with other traits found in previous varieties. Because of its wide adaptation, early maturity, and improved quality, it became a standard for high-quality rice. It has also been used extensively as a parent in breeding programs and genetic analysis. In addition to its high yield, early maturity and disease resistance, it had excellent cooking quality. This variety showed resistance to blast and bacterial blight diseases. Many valuable genes have been introduced into IR64 through backcross breeding. The breeding program at IRRI focused on combining the different traits desired by farmers, including high yield, resistance to biotic and abiotic stresses, early maturity, and improved grain quality.

In India, systematic research on hybrid rice was initiated during 1989 when the Indian Council of Agricultural Research (ICAR) four years (1989–1993) of research efforts resulted in development of hybrid rice. The first hybrid variety APRH-1 was released in Andhra Pradesh in 1993–1994. So far, 117 rice hybrids have been developed, suitable for different ecology and duration ranging from 115 to 150 days. This accounted for 6.8 percent of total rice area in the country. ICAR-Indian Institute of Rice Research (ICAR-IIRR) contributed a lot to the development of improved rice varieties. National rice research institute has developed three popular rice hybrids, viz., Ajay, Rajalaxmi, and CR Dhan 701 for irrigated-shallow lowland ecosystem.

Many dwarf or semi dwarf varieties of rice have been developed and commercialized. These include IR 8, IR 36, IR 72 (exotics); Krishna, Ratna, Vijaya, Padma, Jaya, Pankaj, Cauveri, Jamuna, Kanchi, Sabarmati, Jayanthi Pusa 2-21, Rasi, Sasyasraed, SWarna, Savitri, Sita, Triveni, Usha, Neela, Swarnadhan, Vikas, Sonasali, Vikramarya, IET 9278, IET 9996, IET 10300, Basmati 370, IET 8579, IET 8580, IET 10364; Sattari, Hira and Kalyani 2 (early maturing-70 days);

Hybrid rice varieties

APRH 1, APRH 2 (for Andhra Pradesh), TNRH 1 (for Tamil Nadu) and KRH 1 (for Karnataka)

Being an important cereal, rice supplies about half the calories in the daily diet of millions of people in South East Asia. It is an excellent source of carbohydrates and also has small amounts of proteins, minerals and vitamins. Rice has very little fat and is easy to digest. About 90 percent of the rice is cooked and eaten in various ways with pulses, vegetables, fish or meat. It may be boiled in plain water, or made into pulao. Rice may also be consumed in the form of idli, dosa and other preparations popular not only in South India but also in other parts of the world. Rice pudding can be made by cooking rice in milk and adding sugar and nuts. Powdered rice may be cooked to serve as a substitute for milk to babies. This is the only cereal which can be used in this manner. Rice flour is also used in confectionery, ice creams, pastries etc. Rice starch is used as food, in laundry and also in the cosmetic and textile industries.

Parched rice is made by mixing the grain in hot sand in open vessels. The grain begins to crackle and swell, after which it is sieved. Rice flakes are made by soaking paddy in water for 2-3 days, followed by boiling in water for a few minutes. The water is drained, the grains are cooled and then heated until the husks burst open. The grain is then flattened and the husk removed. Puffed or popped rice is made by heating the rice in sealed containers for one hour at 288°C. The moisture of the grain is converted into steam and when the pressure is released, the grains swell or expand to several times of their original size.

Alcoholic beverages are made from rice. 'Saki' in Japan and 'Wang Esin' in China are popular. Several byproducts of rice have also been useful in various ways.

Rice husk is used as fuel for rice mills, for making hardboard and as an abrasive. Furfural is also made from rice hull. Rice bran, obtained during polishing brown rice for producing white rice, is used as a livestock and poultry feed. Oil, extracted from the bran, is used for cooking and in the manufacture of soap. Rice straw is fed to cattle. It is also used for making straw board, thatches, mats and hats.

SAQ 3

State whether the statements are 'True' or 'False'.

- i) Rice originated in South East Asia.
 - ii) Rice husk is used as fuel for rice mills.
 - iii) China is the largest producer of rice.
 - iv) Inflorescence of rice is Spike.
 - v) Rice is the food for more than one third for the world's population.
-

2.5 SUMMARY

- Cereals are the most important as staple food crops. It has been possible to correlate the close association of cereals with human civilization and the development of agriculture. Wheat and rice have become the most important sources of food. Barley, oats and rye are the other cereal crops. Small-grained cereal crops are referred as millets.
- Wheat is probably the oldest crop known in cultivation. The modern cultivated wheat has been shown to be a hexaploid which arose through hybridization. The origin and evolution of the common bread wheat has been documented through cytogenetical studies.
- Rice is another important cereal crop which is cultivated mainly in Asia. The plant is semi-aquatic tillering grass. The grains are borne in panicles.

- Cereal crops besides being used as food are of importance for industrial purposes and can be used as fodder for livestock.
- Breeding techniques improved the plant varieties to get more yield and enhanced survival rate by having more traits for tolerance inserted into the plants.

2.6 TERMINAL QUESTIONS

1. Differentiate between cereals and pseudocereals.
2. What are millets? Give examples.
3. Describe some characteristic features of wheat plants.
4. How the modern day wheat was developed from the hybridization process?
5. Name some wheat and rice producing states in India.
6. Enumerate major uses of wheat and rice.

2.7 ANSWERS

Self-Assessment Questions

1. a) i) Poaceae
ii) Ligule
iii) Rachis
iv) Endosperm
b) i) Finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*),
ii) Buckwheat (*Fagopyrum esculentum*), quinoa (*Chenopodium quinoa*)
iii) Wheat, Rice
2. a) i) *Triticum*
ii) Nikolai Vavilov
iii) 42
iv) Terminal spike
v) Glume
vi) Gluten
b) i) Refer to Subsection 2.3.1.
ii) Refer to Subsection 2.3.2.
iii) Refer to Subsection 2.3.4.
3. i) True; ii) True; iii) True; iv) False; v) False

Terminal Questions

1. Refer to Section 2.2.
2. Refer to Section 2.2.
3. Refer to Subsection 2.3.3.
4. Refer to Subsection 2.3.1.
5.
 - a) Wheat- Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Bihar are the major wheat producing states of India.
 - b) Rice- West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab, Tamil Nadu, Orissa, Bihar and Madhya Pradesh.
6. Refer to Subsection 2.3.4 and 2.4.4.

Acknowledgements

Fig. 2.5 : <https://www.google.co.in/imgres?imgurl=https%253A%252F%252Fmedia.springernature.com%>

Table 2.1 : Source: <https://worldpopulationreview.com/country-rankings/wheat-production-by-country>

Table 2.2 : Source: <https://www.statista.com/statistics/255937/leading-rice-producers-worldwide/>

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LEGUMES |

Structure

3.1	Introduction	3.5	Summary
	Objectives	3.6	Terminal Questions
3.2	General Account	3.7	Answers
	Nutritional Value		
	Bioactive Compounds and Health Benefits		
3.3	Major Legume Crops		
3.4	Important Legumes		
	Soybean		
	Cow pea		
	Pigeon pea		
	Gram		
	French Beans or Common Bean		
	Pea		
	Beans		

3.1 INTRODUCTION

Food is a basic necessity of life as it supplies the nutrients that the body needs for generating energy, building and repairing tissues, and regulating body processes. The body uses proteins present in the food to build and repair tissues. Proteins exist in every cell and are essential to plant and animal life. Of the various foods consumed by humans, the legumes are one of the most important source of proteins. These plants have been consumed by man since times immemorial as an important constituent of the daily diet in many parts of the world. They have been used to supplement the diet consisting of cereals. In addition, their seeds have a low water content that makes more suitable for long distance transportation and long storage. They grow rapidly and can be cultivated easily. The value of legumes in improving and maintaining soil fertility has been recognized by man since ancient times. That is why these plants are ideal candidates for crop rotation. Many species of legumes have nodules on their roots which act as nitrogen fixing sites.

Objectives

After studying this unit, you would be able to:

- ❖ prepare a detailed account of origin and distribution of the widely found legumes species;
- ❖ identify the legumes on the basis of their morphological features;
- ❖ enlist uses of common legume crops;
- ❖ prepare a brief account of some widely used legume crops; and
- ❖ explain the importance of legumes to man.

3.2 GENERAL ACCOUNT

Legumes are consumed as green vegetables, as green shelled seeds, or as dry seeds. The dry seeds of legumes are commonly called **pulses**. They are also termed as **grain legumes** or **beans**. The varieties of legumes used as green vegetables have fleshy-walled pods with less fiber in the younger stages. The pulses contain 17 to 30 percent proteins on a dry weight basis. The richest source of proteins amongst legumes is the soybean which provides more than 40 percent protein on a dry weight basis. Besides proteins, legumes also contain carbohydrates (mainly starch), fats, calcium and iron. When the seeds are soaked in water and allowed to sprout, they serve as an excellent source of vitamin C. The seeds also contain niacin, thiamine, and riboflavin. Interestingly, the amino acids of legumes complement those of the cereals. The legumes have adequate amounts of lysine, tryptophan and threonine but are low in methionine, cystine and cysteine. These sulphur-containing amino acids are present in adequate amounts in cereals which are low in lysine and threonine. It is for this reason that cereals and legumes have been used together in the diet of man in different parts of the world. This provides the correct balance of amino acids.

This unit gives you detailed information about the important legume crops such as soybean, gram and pea consumed throughout the world. The information on important pulse crops of India will also be provided to you.

3.2.1 Nutritional Value

Legumes are nutritionally valuable foods. They provide proteins (20-45 per cent along with essential amino acids), carbohydrates (60 percent) and dietary fiber (5-37 percent). They also provide essential minerals and vitamins.

In addition to their nutritional superiority, legumes also possess economical, cultural, physiological and medicinal value because of their beneficial bioactive compounds. Research have shown that bioactive compounds present in legumes possess antioxidant properties and play a role in the prevention of cancer, heart diseases, osteoporosis and other degenerative diseases. The legumes prove beneficial to diabetic patients as they help in weight management. Incorporation of legumes in diet especially can play a major role in eradicating protein-energy malnutrition especially in developing Afro-Asian countries. Legumes are also used in the development of functional foods to promote human health.

Some nutritional advantages of legumes:

- they possess twice the protein content present in cereal grains.
- they are generally low in fat, free of saturated fats and contain no cholesterol (except soybeans and peanuts that contain significantly high levels of mostly mono and polyunsaturated fatty acids).
- they are rich in energy-yielding carbohydrates but have a low glycemic index rating for control of blood glucose.
- they are good source of B-group vitamins (folate), iron, zinc, calcium and magnesium.
- they are abundant in fibre (both insoluble and soluble).
- they contain phytonutrients such as isoflavones, lignans, and protease inhibitors). Soybeans are rich in phytoestrogens which reduce the risk of cancers (breast, prostate), heart disease, osteoporosis and problems associated with menopause.
- they are free of gluten and hence suitable for people with coeliac disease or gluten sensitivity.
- they contain relatively low quantities of amino acid methionine but sufficient quantities of the essential amino acid lysine. The nutritional content of some important legume crops is given in table 3.1.

Table 3.1: Nutritional content of some legumes.

Parameters	Peanut	Chickpea	Lentil	Pea	Kidney bean	Black bean	Soybean	Pinto bean
Calories	427	269	230	125	215	227	298	245
Protein (g)	17.3	14.5	17.9	8.2	13.4	15.2	28.6	15.4
Folate (%)	27	71	90	24	23	64		74
Manganese (%)	76	84	49	22	22	38	71	39
Copper (%)	-	29	29	-	17	20		-
Iron (%)	-	26	-	-	17	-	49	-
Fiber (g)	5.9	12.5	15.6	8.8	13.6	15	10.3	15.4
Thiamine (vitamin B1) (%)	22	-	22	30	20	28	23	22
Vitamin K(%)	-	-	-	48	-	-	41	-

3.2.2 Bioactive Compounds and Health Benefits

The bioactive compounds present in legumes include phytosterols, isoflavones, saponins, alkaloids, and carbohydrates. Lunasin, a peptide found in soybean, wheat, barley, rice and rye acts as an anti-inflammatory, anticancerous, antioxidant and cholesterol lowering compound. It arrests cell division in cancer cells and protect DNA from oxidative damage. As an anticancer agent, it disturbs histone acetylation and deacetylation. Bowman-

Birk inhibitor (BBI), *protease* inhibitor produced by soybean, lentil and pea prevents the diseases such as prostate, breast and colon cancers. Proteasome activity increases in cancer cells and proteasome inhibition causes homeostasis disruption of cancer cells. Hence BBI is useful in prevention of cancer.

Another set of proteins viz. lectins found in legumes possess anticancerous properties. These proteins possess the capacity to agglutinate cells due to their binding to specific carbohydrate residues on the cell surface. Soybean agglutinins have been found to inhibit tumor growth in rat. Isoflavones has been demonstrated to play a role in several biological activities such as reduction of osteoporosis, prevention of cancer and cardiovascular disease (Table 3.2).

Table 3.2: Health benefits of some legumes.

Health effects	Legumes					
	Soybean	Gram	Pigeon pea	Mung bean	Lentils	Peas
Help in preventing cancer	✓	✓				
Help in improving blood circulation	✓					
Help in maintaining blood pressure		✓	✓	✓	✓	
Help in improving metabolic activity or digestion				✓		✓
Help in boosting digestive health			✓			
Help in boosting heart health	✓	✓	✓	✓	✓	✓
Help in preventing birth defects						
Help in controlling diabetes	✓	✓		✓		✓
Help in improving bone health	✓	✓				
Helps in weight gain	✓					
Helps in weight loss		✓	✓	✓		✓
Reduces inflammation		✓			✓	
Cures anemia		✓	✓			
Boosts immunity			✓	✓	✓	✓

✓ presence of that property in the plant.

They have also been used for the treatment of symptoms of menopause.

Saponins found in soybean, lentils, chickpea and other beans have also been known to possess anticancerous properties and have proven beneficial effects on hyperlipidemia. Studies have reported reduction in coronary heart disease

after consumption of legumes because of their high phytosterol and saponin content. Studies have proven that legumes lower blood glucose and insulin responses. Legumes induce protective effect on type 2 diabetes mellitus (DM) due to their high fiber content, low glycemic index and presence of bioactive compounds like isoflavones, lignans. In addition, phenolic compounds, phytic acid and saponins help to reduce colon cancer.

3.3 MAJOR LEGUME CROPS

Fabaceae is a large family of flowering plants. You shall find a detailed taxonomic account of this family in Paper Plant Ecology and Taxonomy-BBYCT-133 of this course. The term legume in the botanical sense refers to the entire plant as well as to the fruit which is a simple, dry, dehiscent pod. All the cultivated legumes consumed as food are classified in the subfamily Papilionatae (also called Papilionoideae, Faboideae, or Lotiadeae). The different pulse crops of this group are classified in three tribes – the Vicieae, the Hedysareae, and the Phaseoleae. Pulses such as lentil (*Lens esculenta*), pea (*Pisum sativum*), gram (*Cicer arietinum*), broad bean (*Vicia faba*) and others are members of the tribe Vicieae. The most common legume which is also an important oilseed crop is groundnut (*Arachis hypogaea*). It is a member of the tribe Hedysareae. Other legumes such as the soybean (*Glycine max*), cowpea (*Vigna unguiculata*), pigeon pea (*Cajanus cajan*), the green gram or mung (*Vigna radiata*=*Phaseolus aureus*), black gram (*Phaseolus mungo*), cluster bean or guar (*Cyamopsis tetraganoloba*), moth bean (*Vigna aconitifolia* = *Phaseolus aconitifolia*) are classified in the tribe Phaseoleae.

Legumes are cultivated all over the world. India is the world's single largest producer of pulses. The fact that a wide variety of pulses grow in India all around the year makes these plants even more important in the agricultural economy of the country. The Directorate of Pulse Development of the Ministry of Agriculture, Government of India recognizes the following as the major pulse crops (see Table 3.3).

Table 3.3: The major pulse crops of our country.

Botanical Name	Name in English	Common name
<i>Cicer arietinum</i>	Chick pea or Bengal gram	Channa
<i>Cajanus cajan</i>	Pigeon pea	Arhar or Tur
<i>Dolichos uniflorus</i>	Horse gram	Kulthi
<i>Lathyrus sativus</i>	Chickling vetch or grass pea	Khesari dal
<i>Lens esculenta</i>	Lentil	Masur
<i>Phaseolus aureus</i>	Green or golden gram	Mung
<i>Phaseolus mungo</i>	Black gram	Urd
<i>Pisum sativum</i>	Pea	Matar

The major legume/pulse producing states in India are Rajasthan, Madhya Pradesh, Uttar Pradesh, Orissa, Andhra Pradesh, Tamil Nadu, and West Bengal. Chick pea and pigeon pea are the two most important pulse crops

cultivated in about 45 percent of the total area under legume cultivation. The remaining 55 percent of the area is used for cultivating all the other pulses. Chickpea and pigeon pea together provide about 55 percent of the total pulses produced in the country.

SAQ 1

- a) Match the legumes given in the Column A with their botanical names given in the Column B.

Column A	Column B
i) Green gram	1. <i>Pisum sativum</i>
ii) Soybean	2. <i>Cicer arietinum</i>
iii) Pigeon pea	3. <i>Cajanus cajan</i>
iv) Black gram	4. <i>Vigna radiata</i>
v) Pea	5. <i>Glycine max</i>
vi) Groundnut	6. <i>Arachis hypogea</i>

- b) Write botanical names of 5 major pulse crops of India.

3.4 IMPORTANT LEGUMES

Besides India, pulses are also grown in different parts of the tropics and subtropics. The major pulse growing countries other than India are China, Brazil, Mexico, Nigeria and Turkey. Europe, America and Africa grow small quantities of legume crops for consumption as pulses. Groundnut and soybean are legumes rich in fatty oils, are generally classified as oilseeds and are usually not treated as pulses.

Although the legumes are important sources of protein and oils, many of them also contain toxic substances. Fortunately most of these toxic substances are detoxified during cooking or by just pre-soaking the seeds in cold or ward water. However, two legumes are known to cause diseases in humans. The grass pea or chickling vetch or khesari dal (*Lathyrus sativus*) contains a neurotoxin and an osteotoxin which brings about crippling or paralysis of the lower limbs. This is called **lathyrism** and is caused by prolonged consumption of khesari dal. Similarly the broad bean or Bakla (*Vicia faba*) causes an acute anemic condition called **favism**. It is caused by eating uncooked or partially cooked seeds or by inhaling the pollen of plant. Interestingly, this disease affects only the males and is common in the Mediterranean region.

To summarize, legumes or pulse crops are very important plants. They are valued for their nitrogen fixing property, high protein content, easy cultivation and rapid growth, easy storage and transportation. They enrich the soil, provide food for man and serve as excellent green fodder and feed for livestock. Now you will be provided a detailed account of some important pulses cultivated in India.

3.4.1 Soybean

Botanical name: *Glycine max* L.

Family : Fabaceae

Common names: Soybean, Bhat, Ramkurthi

n=20

This ancient oriental legume has become a very important source of oil and protein, besides being used as an animal feed. In the last 30 years or so, interest in this plant has grown rapidly after the recognition of its potential as a 'wonder bean'.

Origin and Distribution

The soybean originated in China. It is perhaps the oldest crop cultivated in the Orient. Food products prepared from the seeds have been important in the diet of the people for centuries. The cultivated soybean – *Glycine max* is not found in the wild state. It is believed to have arisen from *Glycine soja* (also called *Glycine ussuriensis*). This slender, prostrate, twining legume occurs wild in many parts of Eastern Asia. Another wild species, *G. tomentella* (or *G. tomentosa*) could have contributed to the origin and evolution of the cultivated *G. max* by hybridizing with *G. soja*.

After the World War II, the United States of America has become the leading producer of soybean. China now ranks second in production, followed by Brazil. Other soybean growing areas include Indonesia, Mexico, Russia, Korea, Japan, Argentina, Columbia and India.

Soybean was introduced into India in about 1880, but it is only in recent times that its cultivation has started on large scale. It can be grown successfully all over the country. It is cultivated commercially in Assam, Uttar Pradesh, Himachal Pradesh, Nagaland, Manipur, Madhya Pradesh, Maharashtra and Gujarat.

Cultivation

Soybean is a subtropical plant. Its cultivation extends from the tropics to temperate regions. The climatic conditions required for the growth of this legume are very similar to those of maize. The crop is generally grown in areas where the summer is hot and rather damp. An evenly distributed rainfall during the growing period and more or less dry weather during seed ripening are necessary. Soybean can grow on different kinds of soil, but soils with high calcium content are considered best for its cultivation. It requires a specific strain of the bacterium, *Rhizobium japonicum* for nitrogen fixation. The bacteria need to be inoculated into the soil if soybean is to be introduced into a new area.

Soybean is a short day plant. The period for maturity of the crop varies from 75-200 days depending on the variety sown and the adaptation to particular latitudes. The crop is raised from seed and may be harvested manually or with the help of combines.

Morphology

The soybean plant (Fig. 3.1) is an erect, much branched, annual herb covered with grey hairs. The plants may be creepers or twiners in some varieties and the twining habit increases in the shade. The tap root system is well developed and spread up to 30-60 cm of the soil. Small spherical nodules are present. The stem is erect and grows up to 50 cm to 180 cm in height depending on the variety. The leaves are large, hairy, alternate stipulate and have a long petiole. Each compound leaf is usually trifoliate (9 or 5-foliate). The leaflets are ovate to lanceolate (Fig. 3.1a) and have short pointed stipules at the base. In many cultivars, the leaves drop when the pods begin to mature.

The inflorescences are short, axillary racemes having 3-15 flowers. A large number of flowers do not form fruits and drop off. The flowers are small and vary in color from nearly white to deep purple (Fig. 3.1b). The pods arise in clusters and are hairy. Each pod is usually compressed and slightly curved. The seeds are small, globose with small hilum. Generally 2-3 seeds develop in each pod. The color of the seeds varies from creamy white to yellow, various shades of grey and brown or combination of these colors.

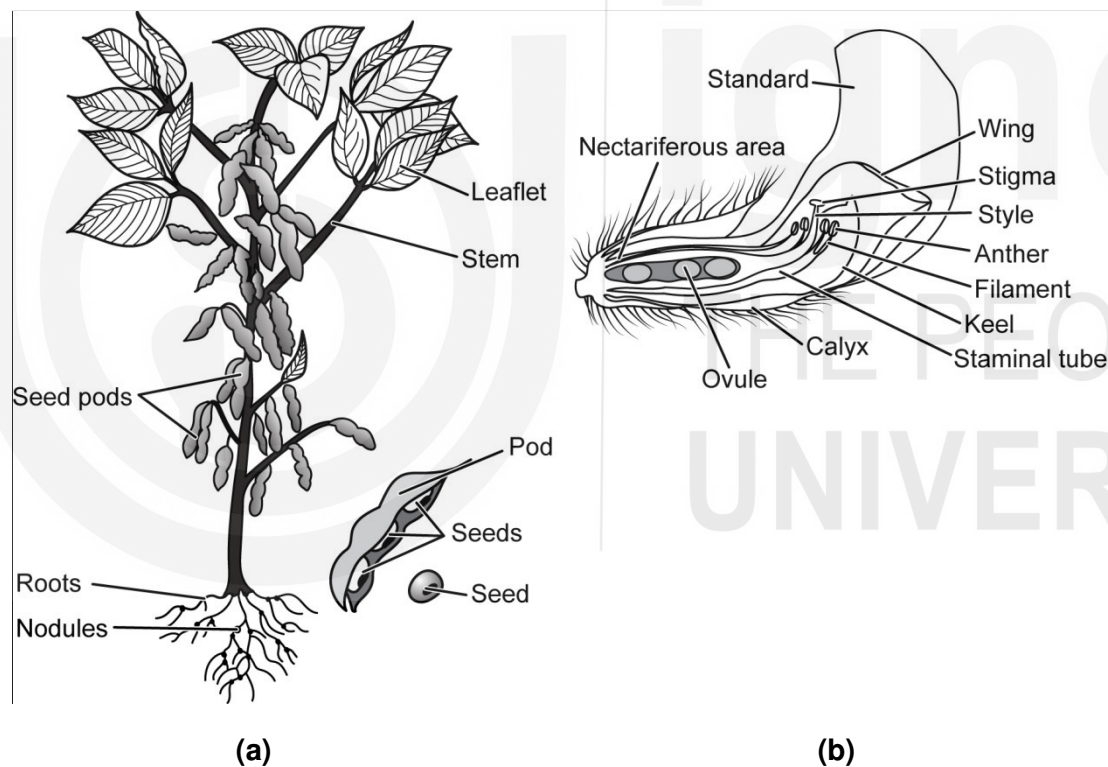


Fig. 3.1: *Glycine max*, Soybean. a) Whole plant, pod and seeds; b) longitudinal section of flowers.

Uses

The high protein and oil content, makes soybean one of the most valuable legumes. Soybeans are grown mainly as a food crop in China, Japan and other South East Asian Countries. The plant has been used in various ways. The unripe seeds are eaten as a vegetable. The mature dried seeds are eaten whole, split or sprouted like chick pea or gram. The mature seeds may also be ground into flour and mixed with other flours to make bread, chapattis and other banking products. The high protein and low carbohydrate content of soybean flour complements cereal grain flour to provide a balanced nourishing

diet. Whole seeds can be eaten after boiling, baking or roasting them. They can be processed to make soya milk or soybean milk. This is a valuable protein supplement for preparing infant food, curds and cheese. A very tasty soya sauce is made by fermenting cooked seeds with wheat flour and salt using the fungus *Aspergillus oryzae*.

The seeds are also an important source of fat. Semi-drying edible oil extracted from them is widely used. Besides its use in the food industry, the oil also goes in the manufacture of soaps, printing inks, lubricants, greases, and other industrial products. It is also mixed with other drying oils in the paint and varnish industry.

The whole plant can be used as a forage or fodder and as green manure. The oil cake obtained after the extraction of oil is a rich protein source for cattle and livestock feed. Synthetic fiber can also be manufactured from this protein. Thus this important leguminous plant has numerous uses.

3.4.2 Cowpea

Botanical name: *Vigna unguiculata* L.

Family: Fabaceae

Common names: Cowpea, Lobia, Chowli

n = 11

There is no mention about the taxonomy of this important pulse crop of the tropics and subtropics. Many botanists consider the different cultivated forms of cowpea as distinct varieties as they can cross freely and there is free-gene flow. They are therefore all classified under the single species *Vigna unguiculata* as different varieties:

- *V. unguiculata* var. *unguiculata*
- *V. unguiculata* var. *sinensis* (Common cowpea)
- *V. unguiculata* var. *sesquipedalis* (Yardlong cowpea or asparagus pea)

Origin and Distribution

Cowpea is an important pulse crop cultivated since ancient times in Africa and Asia. There are references to this pulse crop in ancient Sanskrit literature also. In Africa this legume is widespread both in the wild state as well as in cultivation. It is believed that the cultivated varieties originated from wild types in Central Africa. According to Vavilov, cowpea may have originated in India and spread to other parts of the world. Cultivated cowpeas are now common in many tropical and subtropical regions. The main cowpea producing countries are Nigeria, Uganda, USA, India, China, the Mediterranean region, S. Africa, and Australia.

Cultivation

This pulse crop can be grown under diverse environmental conditions. The crop requires warm weather for its growth. It is a drought resistant crop, hence can be easily grown in regions having low rainfall. Cowpeas grow well on different types soils. The crop matures in about 3 months.

Morphology

The cowpea (Fig. 3.2) is an annual herb with an erect, prostrate or climbing habit. It grows vigorously, becoming bushy and attaining a height of about 1.5 meters. The stem is glabrous but hairy at the nodes. The tap root is well-developed with numerous large nodules containing bacterial colonies. The leaves are large, trifoliate and have long petioles (Fig. 3.2a). A pair of large stipules surrounds the petiole. Each leaflet is subtended by small stipels.

The inflorescence is an axillary raceme or fascicle with few flowers which are generally crowded near the tip. The flowers occur in alternate pairs on the thickened nodes of the inflorescence axis. The flowers have the typical papilionaceous organization (Fig. 3.2c). The corolla varies in colour from white, light pink, purple, violet or even light blue. The fruit is a legume or pod (Fig. 3.2b) whose size varies considerably in the different varieties of cowpea. The pods are long, cylindrical and somewhat constricted between the seeds. In the yard-long cowpea, *Vigna unguiculata* var. *sesquipedalis* – the pods may grow from 30-100 cm in length, while in the other varieties the pods grow from 10-30 cm in length.

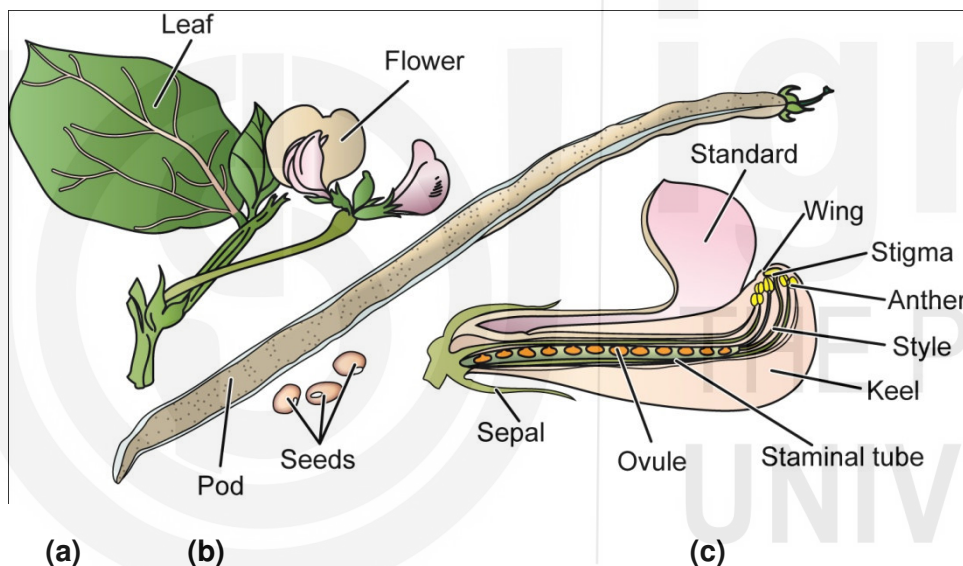


Fig. 3.2: *Vigna unguiculata*. a) A flowering shoot with leaves, flowers; b) A fruit; c) flower in longitudinal section.

The number of seeds varies according to the length of the pod. The seeds are variable in shape and size (Fig. 3.2b). They may be globular or kidney-shaped, smooth or wrinkled, and of different colors. They can be white, cream colored, yellow, green, red, brown or black. In the white seeded types which are commonly cultivated, the seeds have a characteristic black mark around the hilum and are commonly called “black eyed cowpeas”. The seeds are rich in protein (more than 20 percent of the dry weight), besides about 50 percent carbohydrates. They also contain minerals and small quantities of fats.

Uses

The tender pods are used as a green vegetable. The mature dried seeds are consumed as a pulse mostly whole, but sometimes also in split form. They can be ground into flour which can be used in preparation of various food items. The plants are also used as a green livestock feed or are dried to be used as hay. The plants can also be ploughed into the land as a green manure.

3.4.3 Pigeon Pea

Botanical name: *Cajanus cajan* L.

Family: Fabaceae

Common names: red gram, Congo pea

n = 11

The plant is native of Africa. It is believed to be cultivated in Egypt from about 2000 B.C. India is the largest producer of pigeon pea. In India, its cultivation is confined to states of Maharashtra, Uttar Pradesh, Madhya Pradesh, Gujarat, Karnataka, Andhra Pradesh and Orissa.

Morphology

It is a perennial woody shrub about 1-4 m tall. The plant bears trifolately compound leaves with relatively narrow, lanceolate and hairy leaflets (Fig. 3.3 a). The flowers are borne on racemes 4-12 cm long. The pods are 5-10 cm long (Fig. 3.3 b).

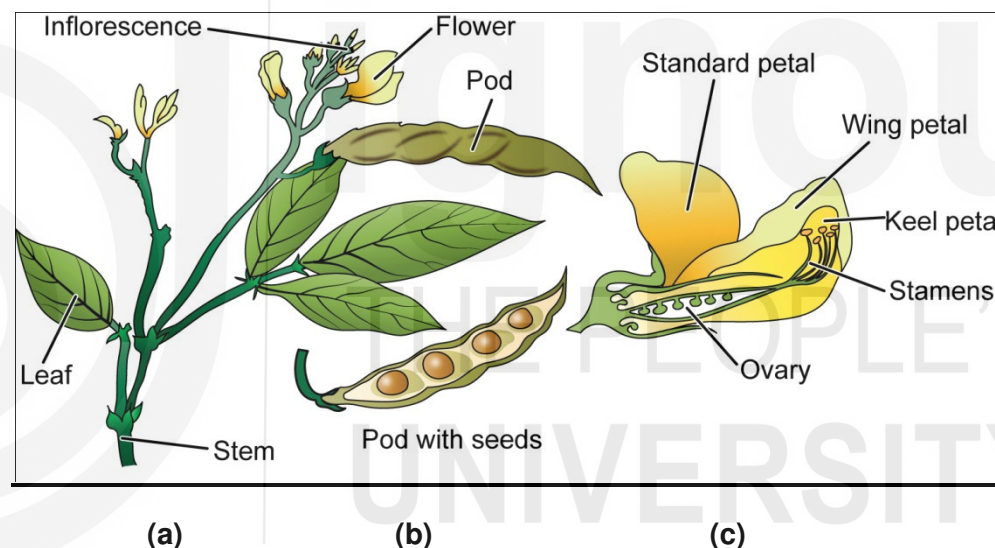


Fig. 3.3: *Cajanus cajan*. a) A flowering shoot with leaves, flowers and fruit; b) a typical fruit; c) longitudinal section of flower.

Cajanus cajan var. *bicolor* is a perennial, late maturing bushy plant that bears purple flowers. *Cajanus cajan* var. *favus* type is relatively short and early maturing. Plants are small with green glabrous pods having usually three seeds.

The plant is ubiquitous in New and old world tropics. It is a deep rooted, drought resistant crop growing in semi arid areas having rainfall less than 60 cm. The crop is mostly grown along with sorghum and bajra. It is grown under rainfed conditions to permit development of roots. The crop takes six to ten months to mature.

Uses

The plant is used in the form of split pulse or dal. It is a very important food in south India. The pulse is a rich source of proteins, calcium and phosphorus. The green pods are also used as vegetable.

3.4.4 Gram

Botanical name: *Cicer arietinum* L.

Common name: chick pea/Bengal gram

Family: Fabaceae

n=8

The plant is believed to have originated in Southwest Asia. It is considered as one of the oldest pulse crops known and cultivated in Asia and Europe. It has been introduced all over the world including tropical America, Africa, Australia. In India, it is cultivated mainly in the states of Madhya Pradesh, Rajasthan, Uttar Pradesh, Maharashtra, Haryana, Karnataka, Bihar and Gujarat.

Morphology

The plant is a branched erect, spreading annual, 20-25 cm tall. The leaves are imparipinnate with 9 to 15 pairs of ovate, elliptic, obovate leaflets with serrate margins (Fig. 3.4 a). The flowers are varying in color from white to pink (Fig. 3.4 b). The pods are small, inflated and contain one or more seeds which are angular with prominent beak and a small hilum at the anterior end. The crop is well adapted to arid and semi arid regions with low to moderate rainfall and a cool dry climate. The seed is rich in proteins, carbohydrates and fiber.

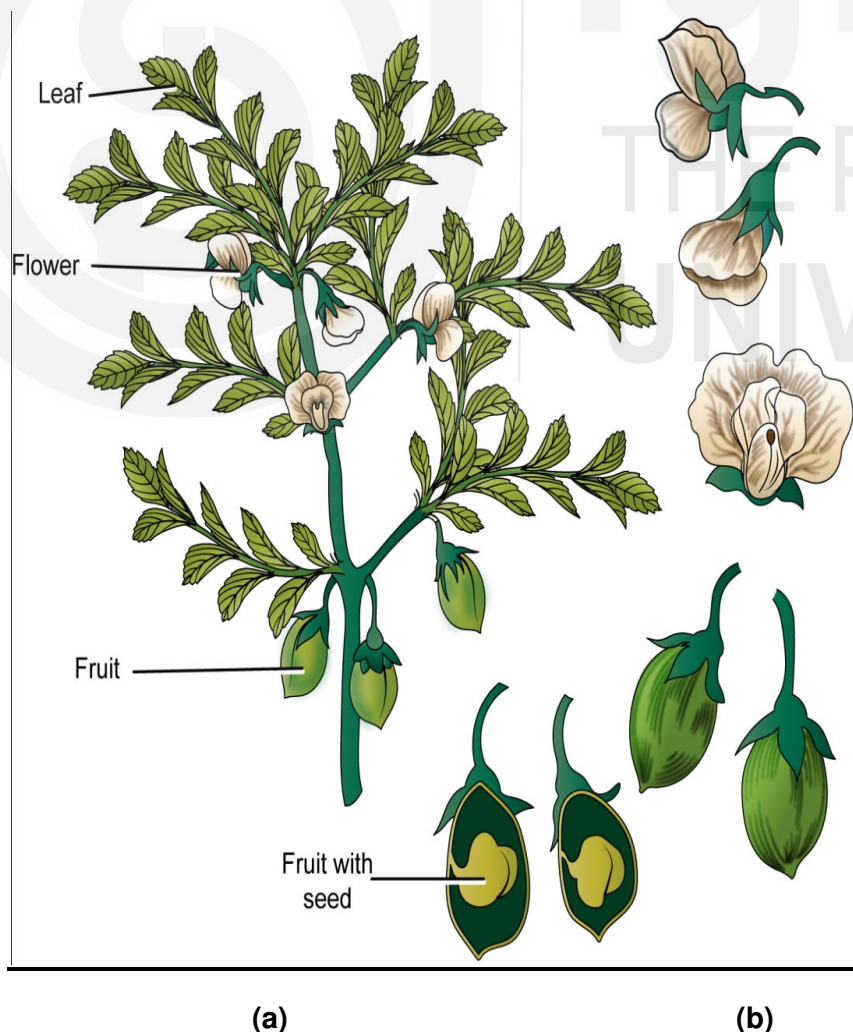


Fig. 3.4: *Cicer arietinum* a) A flowering shoot with leaves; b) flowers and fruit.

Uses

Chick pea is used as a nutritious pulse crop in India. The seeds can be eaten raw, roasted, parched or boiled in split form i.e. dal. Tender leaves are used as vegetable. Gram flour (besan) is used in preparation of many snacks and sweets.

3.4.5 French Bean or Common Bean

Botanical name: *Phaseolus vulgaris*

Common names : Kidney bean, Runner bean, Shap bean, and Salad bean

Family: Fabaceae

n=11

This is the best known widely cultivated species of the genus *Phaseolus*. It is of new World origin and is cultivated in many parts of the tropics and subtropics, and in temperate regions. The plant is supposed to have originated in North, Central and South America. The old records of the plant date back to about 6000 B.C. in Peru. The plant has been introduced into Europe in the sixteenth century by Spanish and Portuguese and later transferred to Africa and other parts of the world. The crop is extensively grown in Brazil, United States of America, Mexico, Italy and Turkey.

Morphology

The species is polymorphic and different varieties have adapted to local requirements. Several varieties differing in their habitat, flower colour, size and shape of pods have been found under cultivation. There are both bush or dwarf cultivars and trailing vine or pole type cultivars. The former variety is determinate in growth while the later grows continuously, bear racemes in their leaf axils and stems continues to elongate. Some varieties are raised for forage, some for seed and some for green beans.

The stem is slender, herbaceous and angled. The leaves are alternate, trifoliate, hairy and well marked with pulvinus at the base. The leaves are ovate and flowers are arranged on axillary racemes (Fig. 3.5 a). The flower structure is Papilionoideae. The pods are yellow or green. They are slender, straight, with prominent beaks, glabrous and contain four to six seeds (Fig. 3.5 b).

The crop is well adapted to wide range of climatic conditions. It is grown during warm period in the temperate areas and during cold conditions in the tropical areas. The crop best thrives in loamy soil.

Uses

The green immature pods are eaten as a vegetable and straw is used as a cattle feed. The beans serve as a rich source of proteins, fats, carbohydrates and fibers.

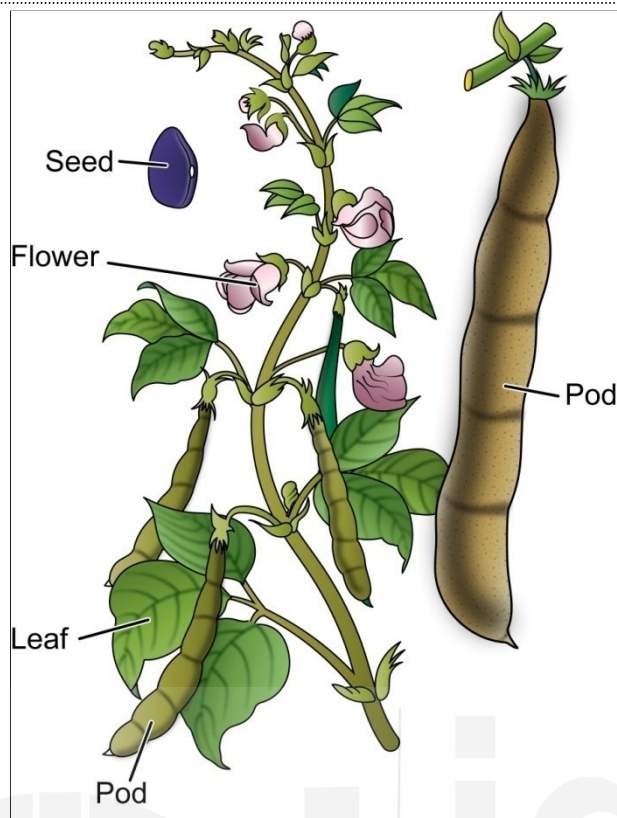


Fig. 3.5: a) Shoot of *Phaseolus vulgaris* showing flowers and fruits; b) Fruit.

3.4.6 Pea

Botanical name : *Pisum sativum* L.

Common name : Pea

Family : Fabaceae

n = 7

Pea was domesticated in Central or Western Asia and spread from Europe to east of India, Tibet and China. The plant is a native of temperate zones of the northern Hemisphere. Ninety percent of the total production of peas comes from France, Russian Federation, Ukraine, China, Bangladesh and Canada. Other producers include India, Denmark, Switzerland, and United States. In India, pea is grown as a winter crop in plains and summer crop in hills. The states of Uttar Pradesh and Madhya Pradesh are the major producers of pea followed by Bihar and Assam.

Morphology

Pisum sativum sp. *hortense* (garden pea) is a robust but less hardy plant. The plant bears large pods with seeds. The seeds are green, round smooth and rich in sugar. *P. sativum* sp. *arvense* (field pea) is hardy and bears stipules with red spot. The flowers are pink or purple. The pods and seeds are small. The seeds are angular and brownish grey in colour. The seeds are rich in starch. The garden and field pea are referred to as *P. sativum* and *P. arvense*. It is assumed that *P. arvense* is a descendent of *P. sativum* subsp. *elatius*, wild relative indigenous of Mediterranean region. *P. sativum* arose from the mutation from *P. arvense* or hybridization between *P. sativum* subsp. *elatius* and *P. arvense* followed by backcrossing.

The plant consists of a climbing or trailing annual plant with slender hollow stem. The species is available in both bush and vine form. The leaves are pinnately compound with three pair of leaflets terminated by branching tendrils. The leaflets are ovate/elliptic, entire. The stipules are large, leaf like, ovate and sometimes larger than leaflets. The pink, white or purple flowers are borne singly in axils or racemes (Fig. 3.6).

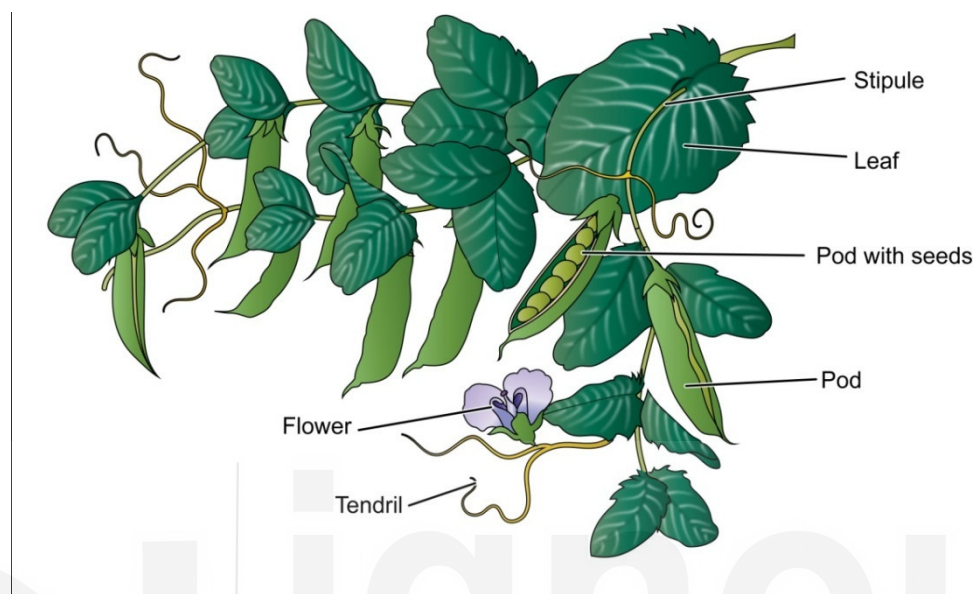


Fig. 3.6: Pea plant showing flowers and fruits.

The pods are swollen, compressed, straight/curved, glabrous, 3-12 cm long. Each pod contains two to ten seeds. The seeds are angular or globose, smooth or wrinkled. The plant requires a moderately cool growing season, a fair amount of rainfall and a temperature range of 13-18°C. The crop grows well on the soil with pH 6 to 7.5.

Uses

The peas are harvested when immature to be used as vegetable. The dry mature seed is a rich source of protein, fats, carbohydrates and fiber.

SAQ 2

- a) Fill in the blanks with appropriate words:
 - i) Legumes have protein content than cereals.
 - ii) Soybean contains which are known to reduce the risk of cancer.
 - iii) is the largest producer of *Cajanus cajan*.
 - iv) The flour of is extensively used for the preparation of snacks and sweets.
- b) Name the following:
 - i) richest source of proteins amongst the legumes.
 - ii) legume that causes *lathyrism*.
 - iii) legume that causes acute anemic condition called favism.

3.4.7 Beans

Many different kinds of beans are cultivated throughout the world. These include the kidney beans, lima beans, soybeans, wax beans, string beans, and green-shed beans. Besides having vitamins and minerals, they are rich in proteins and carbohydrates. They are good sources of energy. Beans can be consumed as green vegetables or as dried seeds. They, besides enriching the soil, also provide valuable green fodder for cattle. A brief description of some important beans is presented below.

i) Lima Bean (*Phaseolus limensis*= *Phaseolus lunatus*)

n = 11

Lima bean (Fig.3.5) is the most nutritious member of the pea family. It is high in protein value and rich in iron, calcium, and vitamins. This wide flat bean is a native of tropical America. It is grown in many warm regions of the world.

ii) Green gram (*Phaseolus aureus*)

n = 11

The green gram or mung is a very important pulse crop of India. The plants are erect, sub erect branched annual 0.3 to 1.3 m in height. The leaves are alternate and trifoliately compound. The purplish yellow flowers occur in cluster of 10 to 22 present on a long axillary raceme. The pods are grey, green or brown when mature and contain 15 small seeds.

Green gram is considered as the most wholesome amongst the pulses. The dried beans are eaten as a whole or split as a dal. The green pods are eaten as a vegetable. The seeds are also sprouted and eaten as a salad or snack which is very nutritious.

iii) Black gram (*Vigna mungo*)

n = 11, 12

The black gram or urd is a highly prized pulse for vegetarian diet in India. It probably originated in India and spread to other tropical areas. It is an erect, sub erect annual herb up to 0.8 m in height. The leaves and stems are covered with reddish brown hairs. The leaves are large, trifoliate each leaflet is ovate to lanceolate about 5-10 cm long. The flowers are small, yellow clustered at the top of short hairy peduncle. The pods are narrow, cylindrical septate and covered with hairs and short hooked beaks. Each pod contains six to ten oblong seeds.

iv) Cluster Bean (*Cyamopsis tetragonoloba*)

n= 7

It is commonly known as Guar. This bean is probably indigenous to India and has been cultivated since ancient times for fodder, green manure and as a vegetable. The plant is now cultivated in United States for gum production. The seeds contain a mucilaginous substance which is used in the paper and textile industries.

The plant is a bushy annual with stiff branches. These are angular, grooved and covered with white hairs. The small pinkish white flowers arise in dense axillary racemes. The pods are linear, ridged, and compressed. These arise in clusters, hence the name cluster bean.

Thus the different kinds of beans serve as important crops in different parts of the world.

SAQ 3

- a) Name the countries which are the largest producer of
- Soybean
 - Peas
 - Gram
 - French bean
- b) State whether the statements are 'True' or 'False'.
- Major legume crops belong to the family Lamiaceae.
 - Cluster bean has a haploid chromosome number of 7.
 - The amino acids of legumes compliment those of cereals.
 - Legume consumption is not advisable for people with gluten sensitivity.

3.5 SUMMARY

- The legumes or pulses are important food plants in a vegetarian diet. All legumes are classified in the family Fabaceae (Leguminosae). They have very high protein content and are also rich in carbohydrates and fats. The legumes grow rapidly and enrich the soil by fixing atmospheric nitrogen. Thus, the legumes are important in crop rotation.
- The legume plants are characterized by fruit which is simple, dry, dehiscent pod or legume.
- The pulse crops are cultivated all over the world. India is the largest producer of pulses in the world. Different kinds of legumes are cultivated around the year in almost all the states of the country. Chick pea and pigeon pea are two important pulse crops constituting 55 percent of the total pulses produced in the country.
- India is the second largest producer of groundnut (*Arachis hypogea*) which is mainly used for extracting edible oil from the seeds.
- Chickpea or chana (*Cicer arietinum*) is one of the oldest known pulse crops. This is a very important legume today and 70 percent of the world's production is obtained from India.

- Pea (*Pisum sativum*) is a well-known legume and is extensively cultivated in the Northern Hemisphere. The seeds are highly nutritious and besides proteins, carbohydrates and minerals, they also contain vitamins A, B and C. The fresh green seeds are consumed as a vegetable.
- Soybean (*Glycine max*) is an ancient oriental legume and its cultivation extends from the tropics to the temperate regions of the world. The seeds are small and globular. This is one of the most valuable legumes because of the high protein and oil content of the seeds. Cowpea (*Vigna unguiculata*) is an important pulse crop of the tropics and subtropics. The tender pods as well as the mature seeds are used as food.
- Beans constitute an important category of leguminous plants and are amongst the most nourishing vegetables. These are cultivated throughout the world and the more important of these are the kidney bean, lima bean, cluster bean, common bean, rice bean, and horse gram.
- Black gram and green gram are two important pulses of the genus *Phaseolus* which may have originated in India. Black gram (*Phaseolus mungo*) and green gram (*Vigna radiata/Phaseolus aureus*) are cultivated as kharif or rabi crops in different parts of India. Both are used as important pulses in the vegetarian diet and also used for many culinary preparations.

3.6 TERMINAL QUESTIONS

1. What is a legume? Why are legumes important in crop rotation?
2. Enumerate the uses of following legumes:
 - a) soybean
 - b) pigeon pea
 - c) black gram
3. “The legumes help in controlling various diseases”. Discuss.
4. Legumes are considered as nutritional foods. Explain.

3.7 ANSWERS

Self-Assessment Questions

1. a)
 - i) *Vigna radiata*
 - ii) *Glycine max*
 - iii) *Cajanus cajan*
 - iv) *Cicer arietinum*
 - v) *Pisum sativum*
 - vi) *Arachis hypogea*

- b) Lentil - *Lens esculenta*
Pea - *Pisum sativum*
Gram - *Cicer arietinum*
Broad bean - *Vicia faba*
Green gram - *Phaseolus aureus*
- 2. a) i) higher
ii) phytoestrogens
iii) India
iv) gram (*Cicer arietinum*)
b) i) Soybean is the richest source of proteins amongst the legumes.
ii) *Lathyrus sativus* (khesari dal) causes lathyrism.
iii) *Vicia faba* or broad bean
- 3. a) i) United States of America
ii) France, Russian Federation
iii) United States of America, Africa
iv) Brazil, United States of America
b) i) False; ii) True; iii) True; iv) False

Terminal Questions

- 1. Refer to Section 3.2.
- 2. a) Refer to Subsection 3.4.1.
b) Refer to Subsection 3.4.3.
c) Refer to Subsection 3.4.7.
- 3. Refer to Section 3.2.
- 4. Refer to Subsection 3.2.1.

UNIT 4

SPICES |

Structure

4.1	Introduction	4.4	Economic Importance of Spices
	Objectives		
4.2	General Account	4.5	Summary
4.3	Important Spice Plants	4.6	Terminal Questions
	Ginger	4.7	Answers
	Turmeric		
	Cinnamon		
	Saffron		
	Cardamom		
	Capsicum		
	Clove		
	Black pepper		
	Coriander		

4.1 INTRODUCTION

The story of spices is one of the most interesting chapters in the history of the plant kingdom. Spices have played an important role in shaping the course of history. Historically, spices have been responsible for the rise and fall of empires and the great sea voyages to explore the distant corners of the globe. They have been connected with adventure, conquests, exploration and exploitation around the world. In the latter half of the fifteenth century, both Portugal and Spain explored sea routes to the Spice Islands (Moluccas). Christopher Columbus sailed west from Spain in 1492, hoping to reach the Spice Islands ahead of the Portuguese, but he failed in his primary mission. Instead, he discovered the America and also helped in the discovery of two of the three important New World spices viz. all spice (*Pimenta officinalis*) and red pepper (*Capsicum* spp.). The third important New World spice is vanilla (*Vanilla planifolia*). In early part of the eighteenth century spices were smuggled away and planted around the world, especially in the West Indies. Nowadays, substantial plantations are grown in America. However, the vast majority of spices are still obtained from the wetter parts of the tropics, chiefly Asia.

India produces 2.5 million tonnes of spices and exports about 450,000 tones.

In India, the major spices produced are pepper, cardamom, ginger, turmeric and chillies. Black pepper is one of the most important Indian spices, and is known as the 'King of Spices' or black gold of India. Next comes cardamom also called the 'Queen of Spices', through which India earns a lot of foreign exchange. Some other important spices grown in India include aniseed, caraway, celery, coriander, cumin, dill, fennel, fenugreek, garlic, onion, saffron and vanilla. In India, spices are grown mainly in states of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra, Orissa, Rajasthan and Bihar.

In this unit we will describe in detail some of the important spices which are commonly used in Indian cooking.

Objectives

After studying this unit, you should be able to:

- ❖ differentiate between the terms spices, condiments and herbs;
- ❖ appreciate the importance of spices in our life;
- ❖ give botanical description of plants and their parts used as spices;
- ❖ list the place of origin of the spices; and
- ❖ enumerate the uses of various spices.

4.2 GENERAL ACCOUNT

According to the International Organization for Standardization (ISO) there is no marked distinction between **spices** and **condiments**. The term **spice** is used for aromatic plant products or mixtures thereof, either as whole or in ground form. It is rather loosely applied to an assortment of dried barks, roots, seeds, fruits and flower parts. A spice is a dried seed, fruit, root, bark or vegetative substance used in nutritionally insignificant quantities as a food additive for the purpose of flavoring. Spices tend to be associated with cooking to enrich and give a **distinctive depth of color and flavor to food**. Spices which impart aroma, flavor and piquancy (tangy or sharp distinctive flavor) to foods are generally tropical in origin.

Spices are obtained from various plant sources. To name some of them, Fennel, caraway, mustard, nutmeg, black pepper, and cumins are used in the form of dry fruits and seeds. Bark of Cinnamon and Cassia is the source of spices where as dried flower buds of cloves are aromatic. Arils of mace and stigma of saffron are used as spices. Turmeric and ginger are used in the form of rhizomes while asafoetida resin is a popular spice.

Condiments on the other hand are spices that are usually added to food after cooking. A condiment is a spice, sauce or a spice mixture which is mainly added to food dishes to give a specific flavor or to supplement a dish. When the aromatic vegetable product comes from a temperate plant, it is considered as a culinary herb (non-woody), as in case of bay leaves, coriander, fennel, mustard, etc. Food items like pickles, sauces and mustards are considered to be condiments.

4.3 IMPORTANT SPICE PLANTS

Most of the chemicals responsible for the distinctive tastes and smells of herbs, spices and condiments are compounds known as essential oils (volatile oils). These volatile oils are usually terpenes and are found in specialized plant cells, glands or vessels that occur in any or all parts of a plant. In some instances these essential oils are produced by plants to attract animals that may serve as pollinators or help in fruit dispersal.

There are about 70 spices grown in different parts of the world. Spices can be grouped according to (i) different systems of classification such as botanical analogies (similarity between unlike plants) or families, (ii) economic importance (major and minor spices), (iii) similarity in methods of cultivation, (iv) similarity in plant parts used as spice such as root, rhizome, bark, bud, flower, fruit, seed and leaves.

In this Unit the classification and description of the nine spices is based on similarity in plant parts from which they have originated: rhizome (ginger and turmeric), bark (cinnamon), bud (clove), flower-stigma (saffron), fruit (capsicum, pepper and coriander), seeds (mustard, cardamom).

4.3.1 Ginger

Botanical name: *Zingiber officinale* Roscoe

Family: Zingiberaceae

Common name: Adrak

n = 11

Origin and distribution: Ginger is indigenous to South-east Asia. The plant was introduced from India to east Africa by the Arabs in the thirteenth century and Portuguese later carried it to other parts of the tropics in the sixteenth century.

It is now cultivated in several parts of the world. The most important regions are India, Jamaica, Sierra Leone and Australia. India is the world's largest producer and exporter of ginger. About 70 per cent of the total production comes from Kerala. It is also cultivated in West Bengal, Orissa, Karnataka, Madhya Pradesh and Gujarat.

Morphology

The ginger plant is an erect, perennial herb. It has a thick hard, laterally compressed, often palmately branched rhizome (hands). It is covered with small scale leaves and fine fibrous roots (Fig. 4.1). Minute sacs containing essential oil and resin are distributed throughout the rhizome, but mainly in the epidermal tissue. The characteristic aroma of ginger is due to a volatile oil (ginger oil containing Zingiberine), and its pungency is due to a non-volatile oleoresin (gingerin) which contains pungent principles like gingerol and shogaol.

The leafy shoots arise annually. They are erect, 60-90 cm tall, and are closely invested by the sheathing leaf bases. The leaves are alternate, linear-lanceolate and about 5-20 cm long (Fig. 4.1).

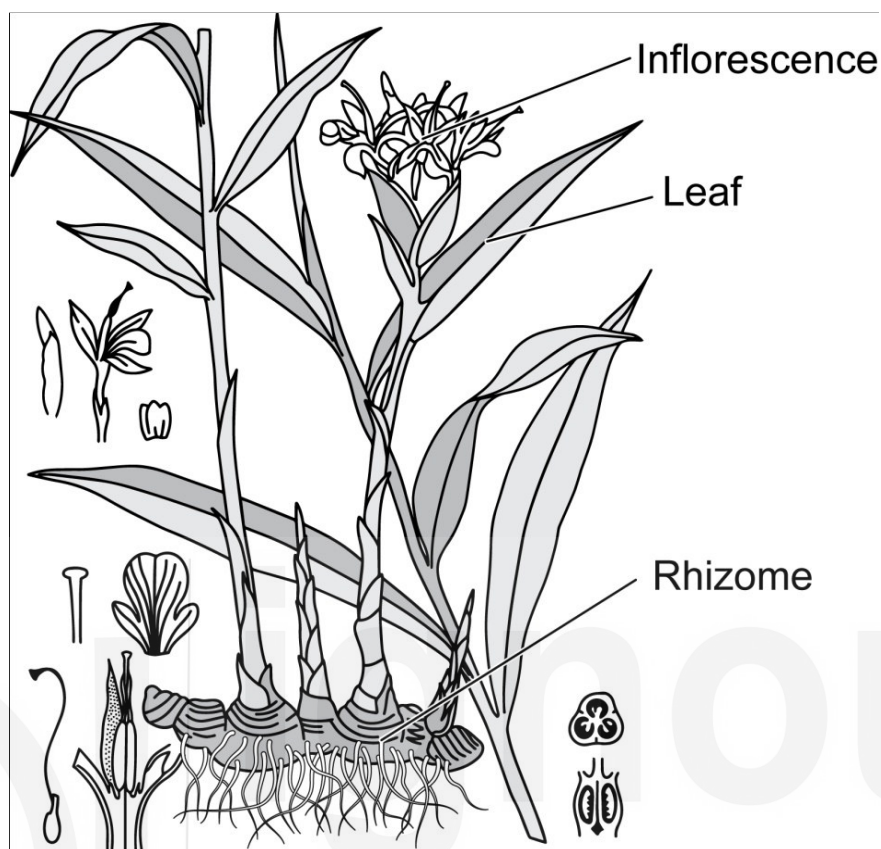


Fig. 4.1: *Zingiber officinale* plant showing rhizome and Inflorescence.

Uses

- i) **In Food Preparations:** It is widely used for culinary purposes in the preparation of ginger bread, biscuits, cakes, puddings, soups and pickles.
- ii) **Recovery of starch and manufacturing soft drinks from exhausted ginger (after recovery of volatile oil):** Starch can be obtained from ginger residue after the recovery of oleoresin. Likewise, vitaminised effervescent or plain ginger powder can be obtained from the exhausted ginger.
- iii) **Alcoholic Beverages:** Ginger is also used for flavoring beverages, such as ginger beer, ginger ale and ginger wine.
- iv) **In Medicine:** According to the Ayurvedic system of medicine, ginger is considered to be a stimulant and carminative and helps in the expulsion of gas in the stomach).
- v) **Ginger oil:** It is used (a) as a flavourant in non-alcoholic beverages, confectionery and pickles, (b) in pharmaceutical industry as a carminative, rubefacient (causing redness, as of the skin), in gastritis and dyspepsia (indigestion), and (c) in perfumery as it imparts a distinctive smell of the oriental type.

4.3.2 Turmeric

Botanical name: *Curcuma longa* L. syn. *C. domestica* Val.

Family: Zingiberaceae

Common name: Haldi

n = 31, 32

Origin and distribution

Turmeric is indigenous to southern Asia. It is not known in a wild state. It has become naturalized in some areas in drier parts of eastern Java. The cultigens are a sterile triploid which do not fruit. They might have arisen by continued selection and cultivation by vegetative propagation from unknown wild ancestors, of which *Curcuma aromatica*, a wild diploid ($2n = 42$) in India, may have been one parent.

Turmeric is cultivated extensively in India, Sri Lanka, Indonesia, China, Taiwan, Indochina, Peru, Haiti and Jamaica. India is by far the largest producer in the world. The main turmeric growing states are Andhra Pradesh, Maharashtra, Orissa, Tamil Nadu, Karnataka and Kerala and in northeast in Khasi and Jaintia hills.

In India, about 150000 tons of crude turmeric is produced annually, of which about 92 per cent is consumed in India and rest is exported.

Morphology

Turmeric is a perennial herb up to 1 m tall. It has a central or main thickened rhizome 'bulb' bearing many primary, secondary or tertiary rhizomes which are known as fingers. The thick short stem bears a tuft of 6-10 large broad, lanceolate leaves with long leaf stocks. The leaves bear acuminate apex. The flowers are pale yellow borne in dense short spike terminating the stem. The plant is a sterile triploid. Leaf sheaths form a pseudostem (Fig.4.2).

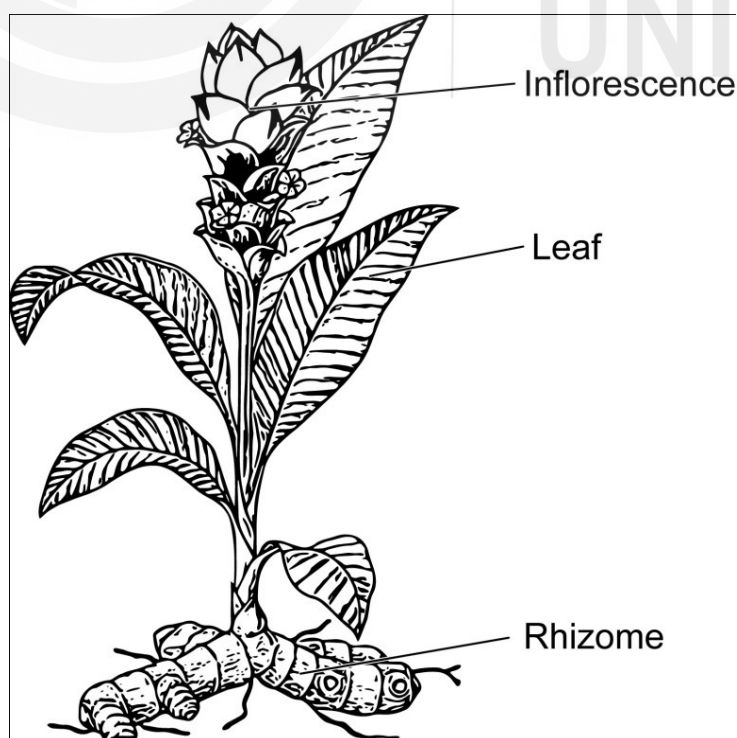


Fig. 4.2: *Curcuma longa* plant showing rhizome and Inflorescence.

The plant is propagated vegetatively. Both fingers and bulbs are used as the source of seed. The plant thrives well in hot, moist tropical climate. The main rhizome along with fingers is carefully taken out of the soil. The green turmeric is cured and processed before marketed. Curing involves boiling the rhizomes in water over slow fire until they become soft. The cooked rhizomes are dried in sun. The cured and finished turmeric is deep yellow to orange. The characteristic odor is because of essential oils. The main constituents are d- α phellendrene, d-sabinene, cineol, borneol, zingiberene, sesquiterpenes and curcumin. The color is because of curcumin. Curcumin is obtained from rhizomes. Curcumin is reported to induce many health benefits (Fig. 4.3).

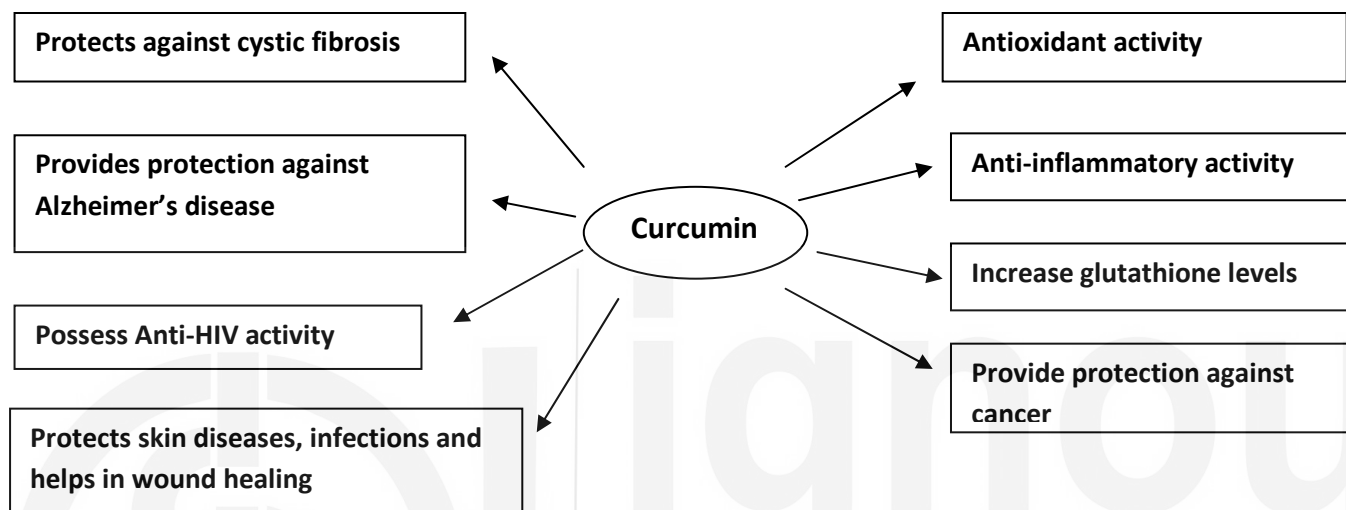


Fig. 4.3: Health benefits of Curcumin.

Uses

In India, the plant is used as a spice. The dry rhizomes are powdered and powder obtained is used a spice and dye. The spice forms an important component of curries. It is also used as a medicine, in confectionary and used for dying clothes. It aids in digestion, acts as a blood purifier, tonic and is used as a remedy for common colds. It also forms an important component in many of the religious rituals in the country.

4.3.3 Cinnamon

Botanical name : *Cinnamomum verum* J.S. Persl

Cinnamomum zeylanicum

Family : Lauraceae

Common name : Dalchini

n = 12

Origin and distribution

The plant is indigenous to Sri Lanka and South India. It has been one of the oldest trade items from the Far East. Arabs carried it by land route to Arabia and from there to Egypt and Europe. Sri Lanka produces nearly 60% of the total production. Besides this Seychelles, South India, China, Malaysia and Indonesia are the producers.

The plants thrive well in the regions with annual rainfall of 200-250 cm and mean temperature of 27°C. A hot and moist climate is considered ideal for its cultivation. After two to three years of growth the plants are cut back or 'coppiced' to induce formation of new shoots from the suckers. Each coppicing produces new shoots which get ready for cutting within three years.

Morphology

The plant is a small, evergreen tree attaining a height of 9-12 m. It is grown as 'coppiced' i.e. cut back bush under cultivation. The leaves are large (12-17 cm), leathery, pointed glossy green above and dull grey below. The leaves possess three to five prominent ribs. The flowers are small, inconspicuous and produce dark purple or black berries (Fig. 4.4).

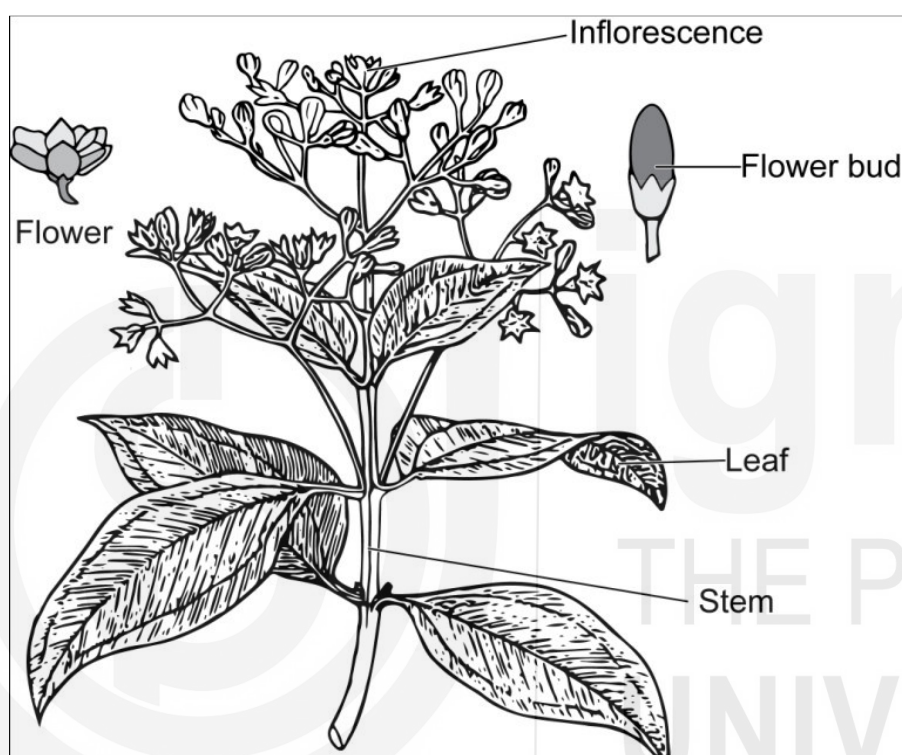


Fig. 4.4: a) *Cinnamomum verum* plant showing fruits; b) Inflorescence.

The longitudinal slits are made lengthwise in the shoot and bark is peeled off in three-foot length. The bark is tied in bundles and left for 24 hrs to ferment. The corky outer layer of the bark is scrapped off and allowed to dry which makes it contract and curl inward in the form of a hollow tube like structure-the quills. The quill should be about 1 cm wide and 4 mm thick.

Uses

Cinnamon has a pleasing fragrant odor and a warm, sweet aromatic taste. It is used as a flavoring agent in cakes, pastries, beverages and a constituent of curry powder. It has been used since ancient times as a tonic and breathe sweetener. The bark is composed of essential oil with cinnamaldehyde as the main component. In addition, oil is used in soaps, pharmaceuticals and dental preparations.

Leaves of *C. tamala* (Tejpat) are extensively used in Indian cookery as flavouring agents. These are also effective against flatulence and stimulate urine formation.

4.3.4 Saffron

Botanical name: *Crocus sativus* L.

Common name: Kesar or Jafran

Family: Iridaceae

$n=12$

Origin and distribution

It is one of the oldest and most expensive spices. It has been used as a condiment, medicine and a natural dyestuff. The plant is believed to be a native of southern Europe and Asia Minor. It has been cultivated in Spain, Turkey, Italy, Greece, Austria, England, Iran, China and India. In India, the plant is cultivated mainly in the Pampore in Kashmir and Kishtwar region of Jammu.

Morphology

It is a low growing perennial herb with a globular underground corm which bears six or more radical, narrow, linear leaves. The flowers are violet or blue and are borne singly. The deep red or orange funnel shaped stigmas are used as a spice (Fig. 4.5).

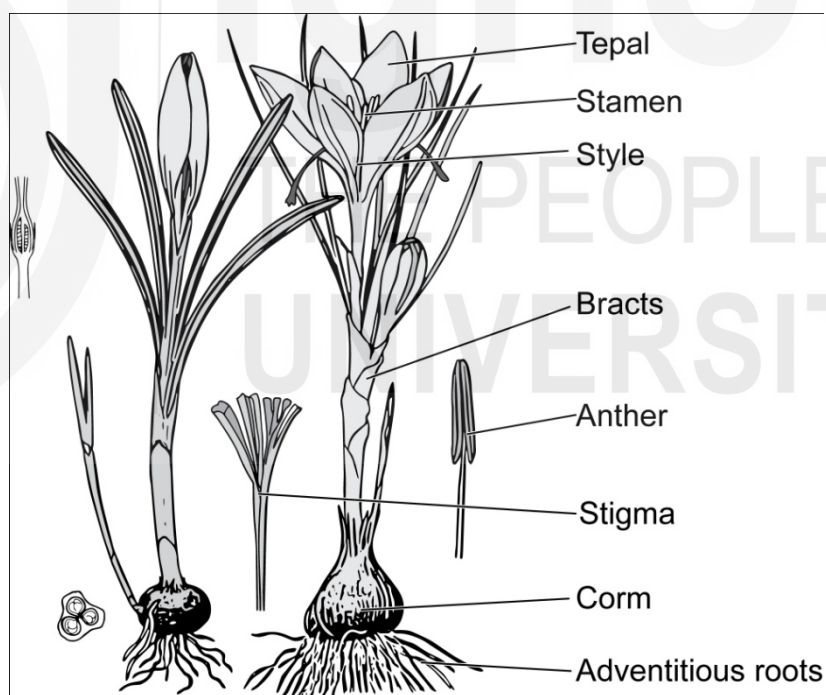


Fig. 4.5: Plant of *Crocus sativus* showing inflorescence.

The plants are propagated by planting young cormlets. The plants are cultivated in conditions of low rainfall. The conditions that are ideal for cultivation are cold and with a warm subtropical climate. The flowering generally occurs in the period of October- November. Stigmas are handpicked everyday as the flowers open and dried. The dried saffron is packed for marketing. The red tips of stigma have been considered as the world most expensive spice. The spice has a characteristic aromatic odor and a pungent, bitter taste. The spice is a rich source of riboflavin and contains a reddish pigment-crocin.

Uses

Saffron is a popular ingredient of many dishes as it is used as a coloring agent. It is used for flavoring butter, cheese, pudding and confectionary. It is also used as a tonic and stomachic. Saffron is used in treatment of asthma, cough, whooping cough (pertussis), and as an expectorant. It is also used for sleep problems (insomnia), cancer, atherosclerosis, flatulence (intestinal gas), depression, Alzheimer's disease, heartburn, and blood pressure. It helps in preventing anxiety and stress. It possesses anti-inflammatory activity and improves skin health. In women it is used for relieving menstrual cramps and premenstrual syndrome (PMS), while in men its use prevents early orgasm (premature ejaculation) and infertility.

Saffron extracts are used as fragrance in perfumes and as a dye for cloth.

SAQ 1

- a) State whether the statements are 'True' or 'False'.
- i) Ginger is extensively used as hair oil.
 - ii) Cinnamon tree is grown as cut back bush 'coppiced'.
 - iii) Saffron is obtained from dried anthers.
 - iv) The characteristic yellow color in curcumin is due to Zingiberene.
 - v) Majority of the spices are cultivated in Asia.
- b)
- i) Differentiate between 'spice' and 'condiment'.
 - ii) Describe the major uses of ginger and turmeric.

4.3.5 Cardamom

Botanical name: *Elettaria cardamomum* L.

Family: Zingiberaceae

Common name: choti elaichi

n=24

Origin and distribution

The plant is indigenous to south India and Sri Lanka. It grows as a wild and is a tropical plant. It has been used since centuries as a masticatory and flavoring agent. India is the leading producer of cardamom with production amounting to 80 per cent of the world's output. In India, its cultivation is restricted to states of Kerala, Karnataka and Sikkim. Besides Sri Lanka, Guatemala and Thailand are the other producers of cardamom. After India, Guatemala is the second largest exporter of the crop.

Two varieties of cardamom are known viz. *E. cardamomum* var. *major* and the *E. cardamomum* var. *cardamomum*. Variety *E. cardamomum* major is a wild variety of Sri Lanka and southern half of Western Ghats.

The plant is a tropical species. The cultivation is restricted to high altitude areas with annual rainfall of about 300 cm. The plant grows well in soil rich in humus and shady places protected by thinned canopy. The plants are propagated vegetatively by segmentation of rhizomes. The plants give fruits after three years of plantation.

Morphology

The plant is an herbaceous perennial. It possesses an underground rhizome which gives erect leafy shoots (Fig. 4.6). The leaves are distichous, dark green, lanceolate with acuminate apex and sheathing leaf bases. The flowers are borne on long panicles that emerge directly from the root stock. The fruit is a creamy white, oblong-ovoid, shortly beaked three sided capsule with a fibrous papery, longitudinally wrinkled pericarp. The seeds in each loculus are pressed together separating into a single mass. Each seed is about 3 mm long and reddish brown. The seed coat is wrinkled and covered by membranous aril. The seed consists of starchy white perisperm enclosing the endosperm and the embryo. The seeds have a pleasing aroma and a characteristic warm, slightly pungent taste. The aroma of cardomum is because of presence of volatile oil contained in seeds which are held together by a loosely attached papery structure - the aril. The chief components of the essential oil include terpinyl acetate, linalyl acetate, cineol, terpineol, turpinene, sabinene and limonene.

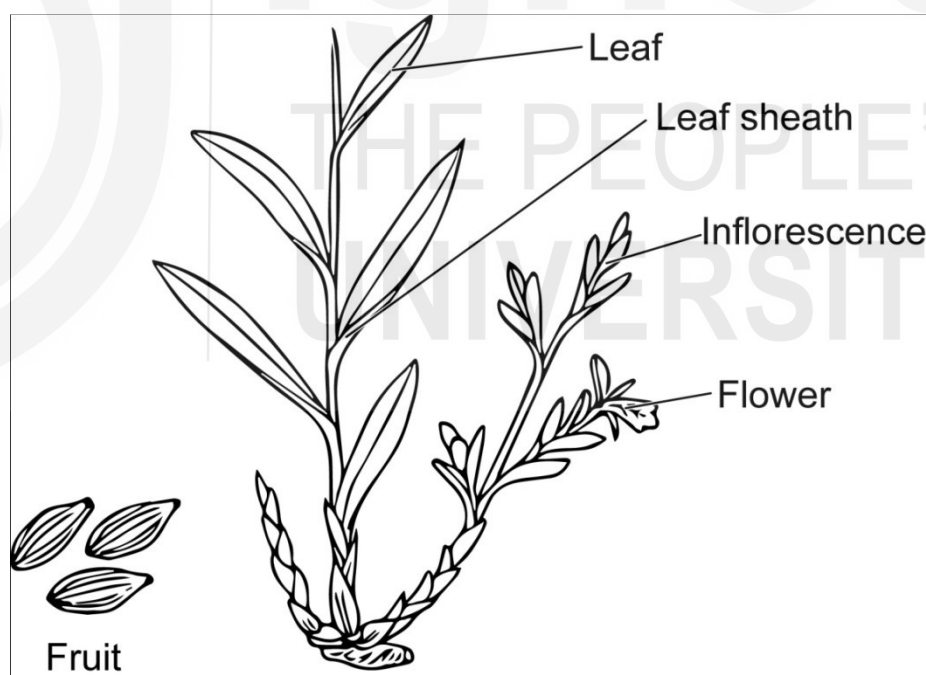


Fig. 4.6: *Elettaria cardomomum* plant with inflorescence.

Uses

The seeds as a whole or in powdered form are considered as the most valuable Indian spices. The spice forms an important component of curries, pickles, sausages, cakes and confectionary. In India, the fruit is also used as a mouth freshener. It is also used for flavoring coffee, liquors and tobacco. The oil obtained from the fruit is used as a condiment and flavoring beverages. It possesses medicinal value as a stimulant and carminative.

Cardamom has been found to possess various medicinal uses (Fig. 4.7).

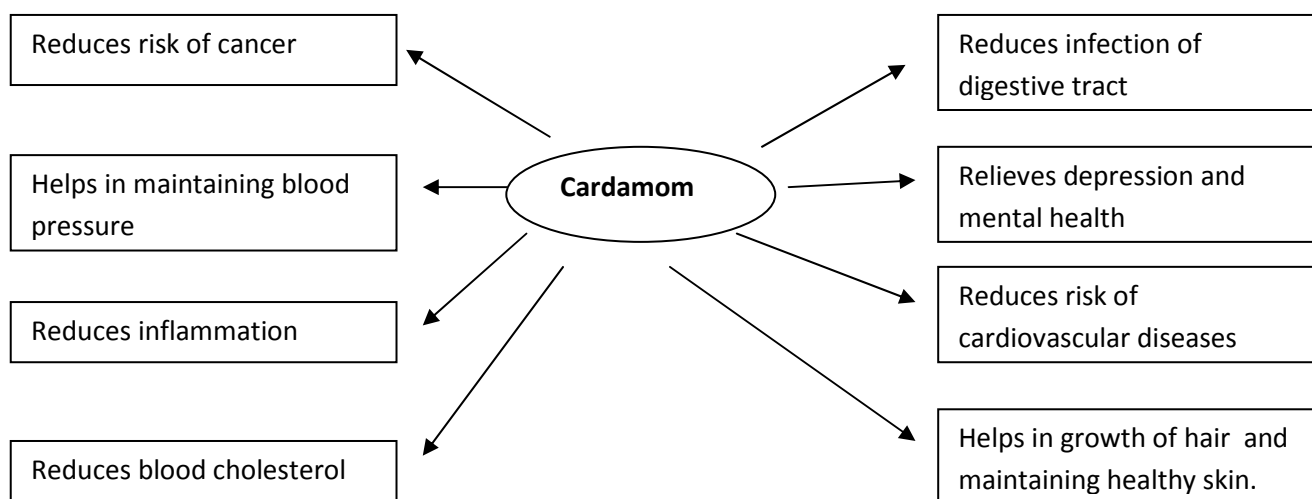


Fig.4.7: Health benefits of Cardamom.

4.3.6 *Capsicum*

Botanical name: *Capsicum annum* / *C.frutescens* Linn.

Common name: chilli or red pepper

Family: Solanaceae

n= 12

Origin and distribution

The plant is indigenous to American tropics, subtropics and West Indies. Chillies have been considered to be the native in tropical America. *Capsicum* has been recovered from ancient sites in Peru. Columbus brought the fruits of the plant to Spain from where they were introduced to other parts of the world. The cultivation and use of *Capsicum* as a condiment spread throughout the Europe as well as tropical areas of Africa and Asia.

The adaptability of the plant to various environments leads to diversity of forms, differing in their growth habit, size, color, shape, flavor and pungency of the fruit. Five cultivated species of *Capsicum* have been recognized (Heiser, 1969). These include *C. annum*, *C. frutescens*, *C. chinese*, *C. pendulum*, *C. pubescens*. Among all, *C. annum* is the species widely grown species and is found all over the world. The species cultivated in the United States of America and Europe belongs to it. Fruits of *C. annum* are less pungent than *C. frutescens*. This includes all large sweet, bell peppers and small sized fruiting types producing paprika. Spain, Hungary, Yugoslavia, Bulgaria, Romania, Morocco are the main producers of paprika.

C. frutescens is cultivated mainly in the tropics and warmer regions of United States of America. The fruits are more pungent. The crushed and powdered fruits produce condiment known as cayenne pepper. The plants are grown on a commercial scale in India. Thailand, Mexico, Japan, Uganda, Nigeria, Ethiopia and Tanzania are some of other producers of chilly. India is the largest exporter of chillies. In India, the plant is grown in the states of Karnataka, Orissa, Maharashtra, Rajasthan, Tamil Nadu, West Bengal, Gujarat and Madhya Pradesh.

The plant is grown from seeds in the nursery and the seedlings are planted in field when they are four to five weeks. Capsicum grows well in warm moist climate with annual rainfall of 75-125 cm. The plant thrives well in sandy loam or clayey loam.

Morphology

Capsicum is a short-lived, evergreen perennial plant. Plants are bushy with the height ranging from 30 to 38cm. These plants bear fruit profusely. The stems are thin, woody with dark green branches usually bearing lance-shaped leaves (Fig. 4.8). White flowers are produced from leaf axils in early summer. The plant bears bright coloured, fleshy, pod like fruit.

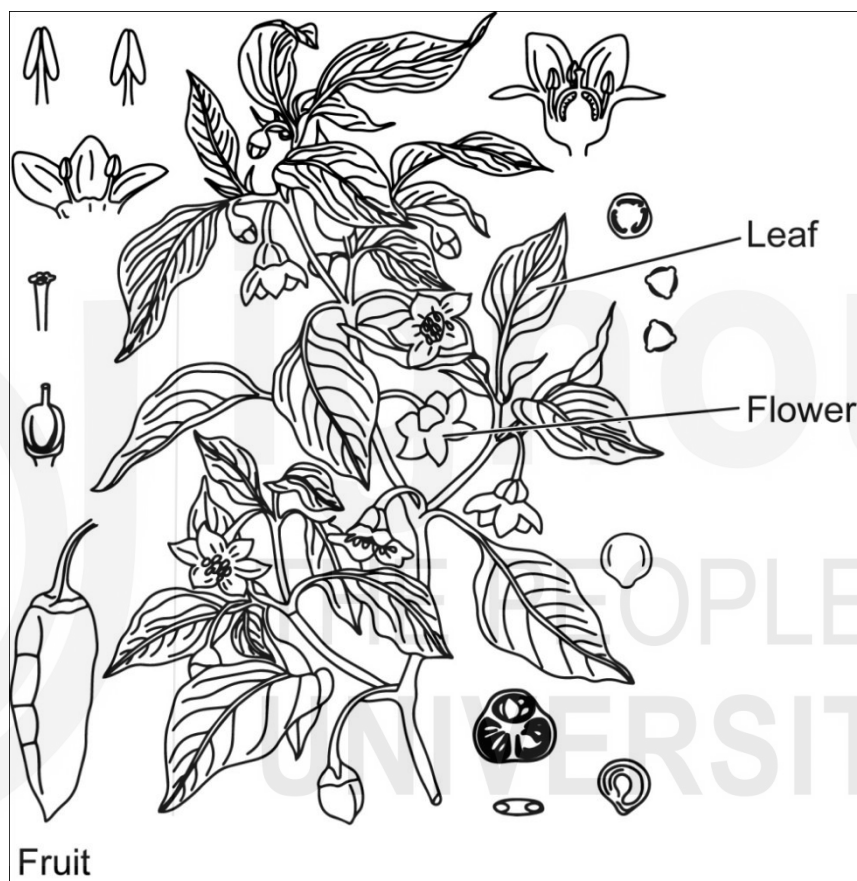


Fig. 4.8: Branch of a *Capsicum* plant showing flowers.

Uses

Chillies are dried ripe fruits of *Capsicum* species. Chillies are good source of vitamin C. A Hungarian scientist, Szent Gyorgi was awarded a Nobel Prize in 1937 for isolating vitamin C in paprika. Vitamin A and E also occur in fruits. The ripe fruits contain compounds such as capsanthin, xanthin, capsorubin, zeaxanthin, cryptoxanthin, lutein and carotenes. The pungency or spicy taste of the chillies is due to crystalline substance known as capsaicin which is concentrated in the placental region. *C. frutescens* have highest capsaicin content.

Capsicum has been used as a popular condiment that is used to add flavor or zest to foods. The small sized fruits of *C. annuum* are used as a flavoring and coloring material in cookery. The spice is also used in salads, curries and many other dishes.

4.3.7 Clove

Botanical name: *Eugenia caryophyllous* L. or *E. aromaticus* L.

Family: Myrtaceae

Common name: Clove

n=11

Origin and distribution

The tree is indigenous to the Moluccas or Spice Islands – islands in eastern Indonesia. The Dutch followed rigorous and repressive measures to maintain complete monopoly of the clove trade during seventeenth and eighteenth centuries. In 1621 they issued an order for the examination of all clove and nutmeg trees from East Indonesian Islands. In 1770, the French Governor of the Island of Mauritius managed to smuggle clove from Dutch islands. He successfully grow the plants in Mauritius and later on the plant was introduced to many tropical countries. By 1818, the clove seedlings got established in Zanzibar and nearby Pemba islands (Now Tanzania). At present these two islands are the world's largest producer of cloves, accounting to 80 per cent of the world's total production. Indonesia, Sri Lanka, India, Malaysia and Haiti are some of the other producers. In India, the cultivation of the plant is restricted to Nilgiris, Kanya Kumari in Tamil Nadu and Kottayam and Quilon districts in Kerala.

The plant thrives well in loamy soils and requires a warm, humid climate with an annual rainfall of 150 to 250 cm and a mean temperature of 16 to 38°C. The plant is propagated by seeds, generally planted in nurseries followed by transfer of seedlings to field.

Morphology

Cloves are dried unexpanded flower buds of *Eugenia*. The plant is an evergreen tree measuring 12-15 m in height. Crimson red flowers are produced in the cluster of three in wild plants. The flowers buds are picked and sun dried. The cloves have a strong pungent taste. The shape of the bud is like a nail. Each flower bud consists of a peduncle (hypanthium) - receptacle, four calyx lobes, four crimson unopened petals having numerous stamens and a central columnar style (Fig. 4.9). Hypanthium represents enlargement of receptacle. Hypanthium is a small angular peduncle flattened at the base and possesses oil glands that impart characteristic aromatic odor to clove. The bracts present over the bud get removed during drying. The ripe fruit is a purple drupe about 2 cm long and 1 cm broad.

Uses

Cloves are used extensively as a flavoring agent in curries, sauces, cakes and confectionary. They are used a major spice in India. The clove tree is a rich source of essential oil. The clove buds contain 16 per cent of essential oil, leaves have 2 percent and the stem has 4 to 6 percent. Essential oil is used in the manufacture of perfumes, soaps, toothpaste and mouthwashes. It also has a medicinal value as it relieves toothache. It also possesses carminative and antispasmodic properties. Clove oil contains eugenol (80 to 92 per cent) which is used for the manufacture of vanillin, a flavoring agent.

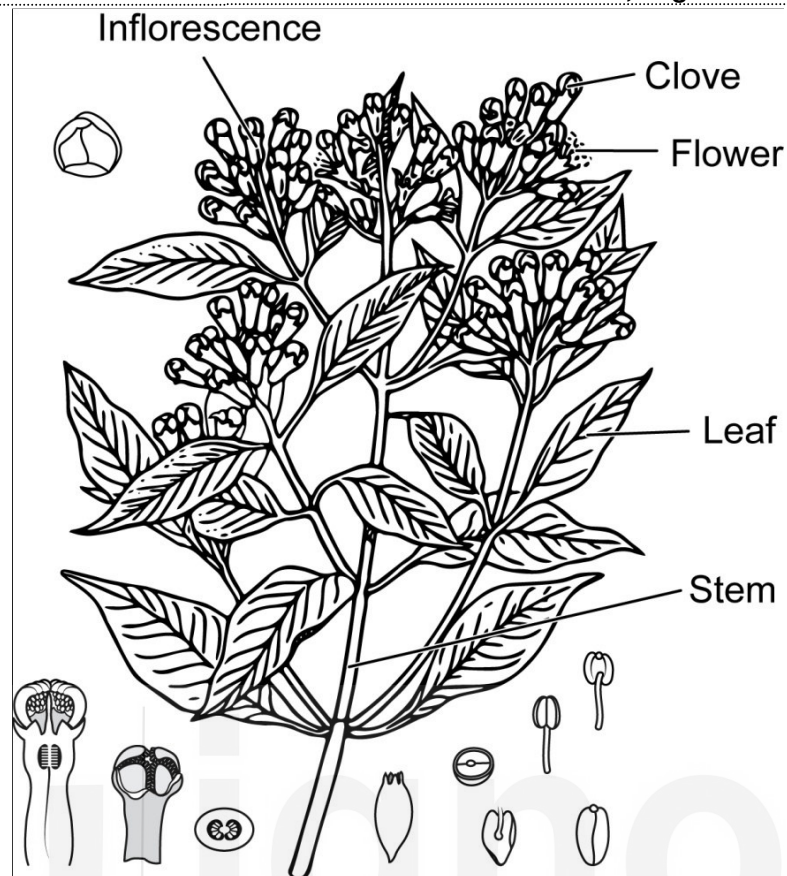


Fig. 4.9: Branch of *Eugenia caryophyllous* showing inflorescence; b) c).

4.3.8 Black Pepper

Botanical name: *Piper nigrum*

Family: Piperaceae

Common name: Black pepper

n=26

Origin and distribution

Black pepper is generally obtained from the fruits of evergreen woody perennial plant, *Piper nigrum*. The plant is indigenous to Malabar coast of southwest India. It is also cultivated in the tropics of eastern and western hemispheres. It has been an important commodity for export to European countries since the ancient times. Today also it has been considered as one of the important crops for the world trade. It is produced mainly in India, Indonesia and Malaysia. The production from these countries accounts for 65 per cent of the total world production. The other countries producing pepper include Sri Lanka, Cambodia, Thailand, Jamaica, Brazil and Ivory coast. Kerala is the major pepper producing (97%) state of India. Tamil nadu, Karnataka, Andaman and Nicobar Islands also grow some amount of pepper.

The plant thrives well in moist, hot climate with an annual rainfall of about 250 cm. A rich loam soil with high humus content is ideal for the cultivation of the crop. The plant is generally propagated using stem cuttings taken from the upper portion of the young branches. The pepper is generally cultivated as a subsidiary crop along with plantations of tea, coffee and cardamom.

Morphology

The plant is a perennial vine having a height of about 9 m or more in its wild state. The vine has two types of branching (dimorphic)- orthotropic vegetative climbing shoots bearing numerous adventitious roots, leaves and axillary buds at the swollen nodes, the roots enabling the plants to cling to tree trunks and other supports. The lateral plagiotrophic fruiting branch developing from axillary bud does not have roots. The leaves are ovate with sharp pointed ends and arranged alternately on the branches. The leaves are dark green, shining above and pale green below and about 12 to 25 cm in length. The flowers are minute, slender, pendulous, white arranged in dense spikes about 10-12 cm long (Fig.4.10). The flowers are partially enclosed within a bract. Each spike bears 50 to 60 single seeded indehiscent drupes also known as peppercorns. These are circular in shape and about 4-6mm in diameter. The color of the berries changes to red on maturity. Each berry possesses a single seed enclosed in a pericarp. The embryo is embedded in a small endosperm at the apex of the seed.



Fig. 4.10: Branch of a pepper plant showing fruits.

Two main types of pepper have been known- black and white pepper. For the black type- the berries are picked when immature (green). The spikes are red, piled in heaps and left in sun for several days to dry. On drying the pericarp becomes wrinkled and develops a dark brown or blackish colour. The seeds possess a characteristic pungent odour.

The white pepper is obtained from fully ripened berries that are greenish yellow or red in colour. The berries are picked up and soaked in water for eight

to ten days to loosen the skin. They are then rubbed to remove the outer skin. The grayish white fruits obtained are then dried in sun for several days till they turn creamy white in colour.

The aroma of pepper is because of the presence of an essential volatile oil (present in the cells of the pericarp). The pungency is caused by the non-volatile oleoresin fraction and various alkaloids. Piperine is the main alkaloid (4 to 8 per cent) present in the fruit. Other alkaloids present in low amounts include chavicine, piperidine and piperettine.

Uses

The spice is used in the preparation of sauces, soups, condiments, curries, and many types of pickles. Black pepper is consumed largely in USA while the white form is popular in Europe. The oleoresin present in pepper is known to possess bacteriostatic and fungistatic properties. The spice is also used as an aromatic stimulant for enhancing salivary and gastric secretions and also considered good in stomach aches.

4.3.9 Coriander

Botanical name: *Coriandrum sativum* L.

Family- Apiaceae

Common name: Coriander

n=11

Origin and distribution

The plant is indigenous to Mediterranean region. It grows well in the parts of Sudan and Egypt. It is extensively cultivated in Russia, Central Europe, India, Turkey, Morocco, Argentina and Romania. In India, it is grown in the states of Andhra Pradesh, Maharashtra, Tamil Nadu, Punjab, Uttar Pradesh, Himachal Pradesh and Madhya Pradesh.

Morphology

The plant is small aromatic herb about 30-70 cm in height. The plant possesses characteristic dimorphic leaves. The lower leaves are broad and deeply segmented while the upper leaves are finely divided with linear lobes. The inflorescence is compound umbel in which peripheral flowers are large, zygomorphic while the centrally located flowers are small and actinomorphic (Fig.4.11). The unripe fruit has an unpleasant odor. The dried mature coriander fruit is globular, yellowish brown and bears the remnants of the calyx. The ridges on the surface are not distinct and two mericarps are attached to carpophores.

The aroma of the fruit is because of an essential oil. The chief component of essential oil is **coriandrol** which is generally present in the concentration of 40-70 percent.

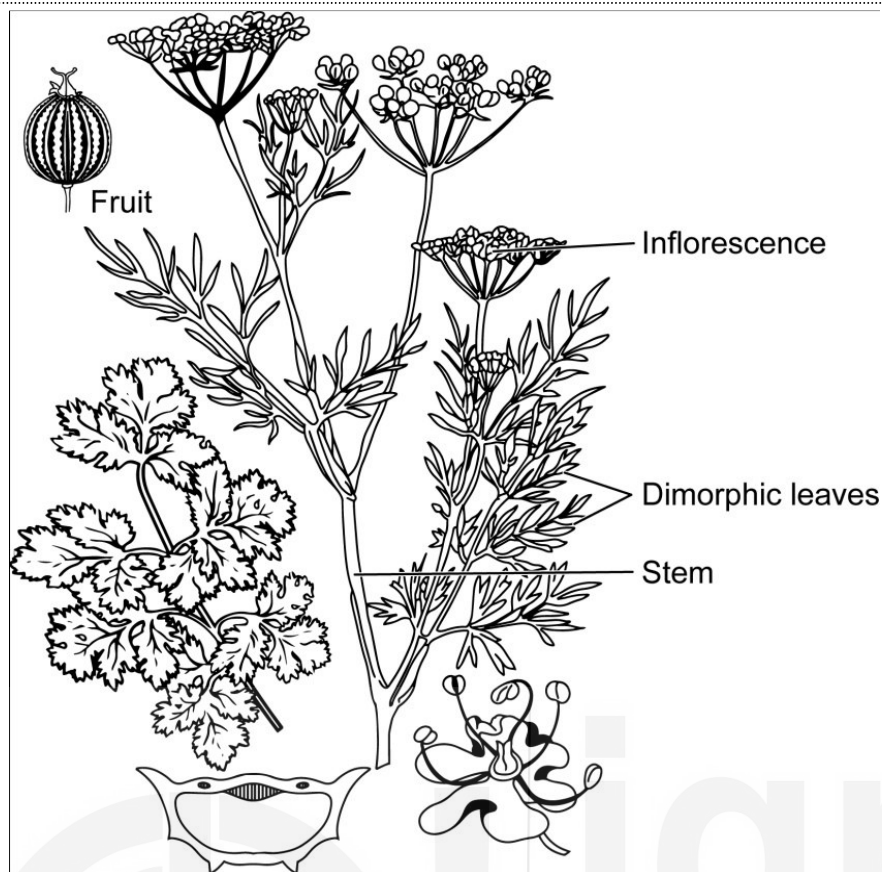


Fig.4.11: Coriander plant showing inflorescence.

Uses

The leaves are strong smelling and are used in garnishing curries and in preparations such as soups, sauces and chutneys. They are widely used as flavoring agents in curries, curd and soups. The dry seed powder is also used as a flavoring agent. In Western countries, liquors named 'gin' are flavored with coriander. Coriander oil is used for flavoring perfumes, candy, cocoa, chocolate, canned alcoholic beverages and in pharmaceutical products. Medicinally, the coriander oil is used as a carminative, tonic and diuretic.

SAQ 2

- a) Name the region of origin of the following spices.
 - i) Pepper
 - ii) Cinnamon
 - iii) Clove
 - iv) Saffron
 - v) Coriander
- b) Name the plant part used as a spice in the following plants.

i) Coriander	iv) Turmeric
ii) Clove	v) Capsicum
iii) Saffron	vi) Cinnamon

- c) Match the spices given in the Column 'A' with their families given in Column 'B'.

Column A	Column B
i) Ginger	1. Iridaceae
ii) Saffron	2. Myrtaceae
iii) Coriander	3. Piperaceae
iv) Cinnamon	4. Zingiberaceae
v) Clove	5. Apiaceae
vi) Pepper	6. Lauraceae

4.4 ECONOMIC IMPORTANCE OF SPICES

In India, the records indicate that herbs/spices have been in use for treating diseases since ancient times. **Charaka Samhita** – the most important work on Ayurvedic system of medicine deals with 700 herbs. Today in the world, there is renewed interest in herbs/spices as alternative medicines.

Spices have played a prominent role in all the civilizations including ancient China and India. They also promoted international relations amongst the various countries all over the world. Ancient Egyptians used them to perfume the person and to embalm the dead bodies to preserve from decay. Spices were considered important medicines in the middle age. Spices with strong and pungent flavours have been used in cooking and for preserving food.

Apart from their culinary value, spices are also used as

- flavouring agents
- active ingredients in Ayurvedic medicines
- colouring agents for textiles
- constituents in cosmetics and perfumery products.
- preservatives in pickles and chutneys
- compounds of medicinal value

Spices help in digestion of food. They also act as appetizers, hence also termed as 'food adjuncts' or 'accessories'.

Medicinal value

Spices act as stimulants, diuretics, carminatives, anti-inflammatory, stomachic, antibiotics, digestives, astringents, antihelminitics, expectorants and tonics. Essential oils obtained from them are used in aromatherapy and treatment of diseases such as depression, stress and anxiety. Spices possess analgesic properties, e.g. coriander and peppermint provide an analgesic effect. Spices such as cumin, coriander and celery have been proving to have anti-inflammatory effect.

Spices may also be used as bioenhancers. Piperine in black pepper has been reported to possess bioavailability enhancing activity with various structurally and therapeutically diverse drugs. Essential oils and extracts of spices like black pepper, cloves, cinnamon, and nutmeg contain active compounds like piperine, eugenol, cinnamaldehyde, and lignans. Similarly, condiments like coriander, black cumin, turmeric, garlic, and ginger are recognized for constituents like linalool, thymoquinones, curcumin, allicin, and geraniol respectively. These act as natural preventive components of several diseases and are present as antioxidants in body cells, possess anti-microbial and antibiotic activities

Spices are considered as natural antioxidants for food, the antioxidants are necessary in food in order to preserve lipid components from deterioration. Antioxidants act as defense mechanisms in the body against cardiovascular diseases, cancer, arthritis, asthma and diabetes. The antioxidant properties of spices are due to their chemical compounds especially to phenolic compounds. Essential oils, oleoresin and other spices extracts contain important antioxidant activity which can be profited by food industry. Spices with antioxidant properties include rosemary, oregano, thyme, sage, marjoram, basil, clove, turmeric, ginger, garlic, coriander, pimento etc. The most common chemical compounds that provide antioxidant properties to spices are eugenol, curcumin, gingerol, carvacol, thymol, pimento and capsaicin.

Colorants

The spices are used as colorants as they are natural sources of color. The spices tint in different colors from yellow and orange to different variations of red (except chlorophyll from herbs). The most common spices used for colouring are paprika, red pepper, mustard, parsley, ginger and turmeric. The colouring properties of spices are due to the presence of chemical compounds. The principal compounds responsible for the color are carotenoids such as beta carotene, lutein and neoxanthin.

Natural flavorants

Flavouring food is one of the most common uses for spices, almost each spice is related to a specific flavor. Each country of the world is known because of their dishes which have their own spicy flavour. Mexico is known for the use of flavors from cinnamon, vanilla, dried chilies and cocoa. England uses ginger, mustard seeds, cloves, coriander. The Arabian Peninsula is known to use a variety of spices for flavoring purposes which include black pepper, caraway seed, whole cumin, cardamom seed, fresh hot pepper, garlic and coriander.

Flavours given by spices are due to the certain families of chemicals, such as phenylpropanoids, monoterpenes and other phenol compounds. Some important chemical compounds for the flavouring potential of spices are eugenol, anethole, estragole, vanillin, piperine, beta caryophyllene, alpha pinene, carvacol, thymol, sabinene, cinnamaldehyde and gingerol. Brief description of some commonly used spices and their uses is given in Table 4.1

Table 4.1: Commonly used spices and their use.

Botanical name	Common name	Family	Part used as spice	Uses
<i>Zingiber officinale</i>	Ginger	Zingiberaceae	Rhizome	As a flavourant, medicine and supplement of perfumes
<i>Curcuma longa</i>	Turmeric	Zingiberaceae	Rhizome	As a flavourant, dye, medicine and supplement of cosmetics
<i>Crocus sativus</i>	Saffron	Iridaceae	Dried stigma	As a flavourant, colorant, medicine
<i>Eugenia caryophyllus</i>	Clove	Myrtaceae	Dried flower buds	As a flavourant, medicine and supplement of perfumes
<i>Coriandrum sativum</i>	Coriander	Apiaceae	Dried ripe fruits	As a flavourant, medicine and supplement of perfumes
<i>Piper nigrum</i>	Pepper	Piperaceae	Fruits	As a flavourant, medicine, in perfumes
<i>Capsicum annum</i>	Capsicum	Solanaceae	Fruits	As a flavourant, medicine
<i>Elettaria cardamomum</i>	Cardamom	Zingiberaceae	Dried seeds from fruits	As a flavourant, medicine
<i>Cinnamomum zeylanicum</i>	Cinnamon	Lauraceae	Dried bark	As a flavourant, medicine and supplement of perfumes

4.5 SUMMARY

- Spices have played an important role in shaping the course of history. History mention of various explorations and great sea voyages to distant corners of the globe for spice trade.
- Aromatic plant products or mixtures thereof, either as whole or in ground form are referred as spice. They generally include dried barks, roots, seeds, fruits and flower parts. Spices impart aroma, flavour, and distinctive flavour to foods. They are generally tropical in origin.
- There are about 70 spices grown in different parts of the world. The main spices used throughout the world include ginger, turmeric, clove, saffron, capsicum, pepper, coriander, and cardamom.
- Rhizomes of ginger and turmeric have been used widely across the globe. Plants are indigenous to South East Asia. Both are used in preparation of curries, confectionary and possess high medicinal value.
- Cinnamon is indigenous to Sri Lanka and South India. The bark possesses a pleasing fragrant odor and a warm, sweet aromatic taste. It is used as a flavouring agent in cakes, pastries, beverages, curries. Essential oil of bark has cinnamon aldehyde as the main component and is used in soaps, pharmaceuticals and dental preparations.

- Saffron is one of the oldest and most expensive spices. The red stigma have been used as spice. It has been used as a condiment, medicine and a natural dyestuff. The plant is believed to be a native of southern Europe and Asia Minor.
- Cardamom is indigenous to South India and Sri Lanka. It grows as a wild and tropical plant. The seeds as a whole or in powdered form are used as spice. It has been used as a masticatory and flavoring agent and forms important component of curries, pickles, sausages, cakes and confectionary.
- Capsicum is indigenous to American tropics, subtropics and West Indies. They have been considered to be the native in tropical America. The fruits are use as a spice.
- Clove tree is indigenous to the Moluccas or Spice Islands – islands in eastern Indonesia. Dried unexpanded flower buds of *Eugenia are used* as spice. Cloves have a strong pungent taste and are extensively used as a flavoring agent in curries, sauces, cakes and confectionary. Essential oil from clove is used in the manufacture of perfumes, soaps, toothpaste and mouthwashes.
- Pepper plant is indigenous to Malabar coast of Southwest India. The characteristic aroma is because of the presence of an essential volatile oil. Pungency is caused by the non-volatile oleoresin fraction. The spice is used in the preparation of sauces, soups, condiments, curries, and pickles. The oleoresin present in pepper is known to possess bacteriostatic and fungiastatic properties.
- The coriander plant is indigenous to Mediterranean region. The aroma of the fruit is because of an essential oil that contains coriandrol (40-70 per cent). The leaves and seeds are used as flavoring agents in preparations such as soups, sausages, curries, chutneys.

4.6 TERMINAL QUESTIONS

1. Enumerate the importance of spices in cookery.
2. Name of the regions where the spices are cultivated in India.
 - a) Ginger
 - b) Turmeric
 - c) Saffron
 - d) Piper
 - e) Clove
3. Describe two medicinally important spices.

4.7 ANSWERS

Self-Assessment Questions

1. a) i) False; ii) True; iii) False; iv) False; v) True

b) i) **Spice** is a dried seed, fruit, root, bark or vegetative substance used in nutritionally insignificant quantities as a food additive for the purpose of flavoring. Spices tend to be associated with cooking to enrich and give a **distinctive depth of color and flavor to food**. Most of the spices are generally tropical in origin.

Condiments are the spices that are usually added to food after cooking. These include aromatic vegetable product and are considered as a culinary herb (non-woody), bay leaves, coriander, fennel, mustard etc.

ii) **Ginger** - The plant rhizome is mainly used in food preparations. It is used for culinary purposes in the preparation of ginger bread, biscuits, cakes, puddings, soups and pickles. It is used as a flavourant in non-alcoholic beverages, confectionery and pickles. Ginger is also used for flavoring beverages, such as ginger beer, ginger ale and ginger wine. It is considered to be a stimulant, carminative and is used in the treatment of gastric disorders.

Turmeric - The dry rhizomes are powdered and powder obtained is used as a spice and dye. The spice forms an important component of curries. It is also used as a medicine, in confectionery and used for dyeing clothes. It aids in digestion, acts as a blood purifier, tonic and is used as a remedy for common colds. It also forms an important part in many of the religious rituals in the country.

2. a) i) Piper - The plant is indigenous to Malabar coast of Southwest India.

ii) Cinnamon - The plant is indigenous to Sri Lanka and South India.

iii) Clove - The tree is indigenous to the Moluccas or Spice Islands found in eastern Indonesia.

iv) Saffron - The plant is a native of southern Europe and Asia Minor.

v) Coriander - The plant is indigenous to Mediterranean region and is found in the parts of Sudan and Egypt.

vi) Cardamom - The plant is indigenous to South India and Sri Lanka.

- b)
 - i) Coriander - seeds and leaves
 - ii) Clove - dried flower buds
 - iii) Saffron - stigma of flower
 - iv) Turmeric - dry rhizome
 - v) Capsicum - fruit
 - vi) Cinnamon - dry bark
- c)
 - i) Zingiberaceae
 - ii) Iridaceae
 - iii) Apiaceae
 - iv) Lauraceae
 - v) Myrtaceae
 - vi) Piperaceae

Terminal Questions

1. Refer to Section 4.4.
2.
 - a) **Ginger** - About 70 per cent of the total production comes from Kerala. It is also cultivated in West Bengal, Orissa, Karnataka, Madhya Pradesh and Gujarat.
 - b) **Turmeric** - India is by far the largest producer of turmeric in the world. Turmeric growing states are Andhra Pradesh, Maharashtra, Orissa, Tamil Nadu, Karnataka and Kerala and in northeast in Khasi and Jaintia hills.
 - c) **Saffron** - In India, the plant is cultivated mainly in the Pampore in Kashmir and Kishtwar region of Jammu.
 - d) **Piper** - Kerala is the major pepper producing (97 percent) state of India. Tamil nadu, Karnataka, Andaman and Nicobar Islands also grow some amount of pepper.
 - e) **Clove** - In India, the cultivation of the plant is restricted to Nilgiris, KanyaKumari in Tamil Nadu and Kottayam and Quilon districts in Kerala.
3. Refer to Subsections 4.3.2 and 4.3.5.