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B.Sc. III YEAR

Economic Botany, Genetics And Plant Breeding

DEPARTMENT OF BOTANY
SCHOOL OF SCIENCES
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ECONOMIC BOTANY, GENETICS AND PLANT BREEDING

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CONTENTS

BLOCK-1 ECONOMIC BOTANY

UNIT-1 CEREALS, MILLETS AND LEGUMES

1.1 OBJECTIVES

After reading this unit students will be able-

- To study origin, domestication, genetics, cultivation and production of cereals, millets and legumes.
- To establish link between biology and anthropology and exploiting ways humans use cereals, millets and legumes for food and other purposes.

1.2 INTRODUCTION

Economic botany is the commercial exploitation of plants by people. It contributes significantly to anthropology, biology, conservation, botany, and other related field of science.

Economic plants are defined as being useful either directly, as in food, or indirectly, as products we use or that enhance the environment. Plants that humans use for food are of high economic importance. The present chapter describes commercial use of cereals, millets and legumes including anthropology, biology, cultivation, production, conservation, botany and related aspects of these food crops.

1.3 CULTIVATION, PRODUCTION AND USES OF CEREALS AND MILLETS

1.3.1 Wheat

Wheat (*Triticum* spp.) is a cereal grain that belongs to the family Poaceae (family of grasses). It originates from the Levant region of the Near East but now cultivated worldwide. Wheat represents staple food in most countries in the world and inevitable part of human life. Proteins and starch isolated from wheat have application in numerous industries. The world production of wheat was 713 million tons in 2014, making it the third most-produced cereal after maize (1,016 million tons) and rice (745 million tons).

World trade in wheat is greater than for all other crops combined. Globally, wheat is the leading source of vegetable protein in human food, having a higher protein content than other major cereals, maize (corn) or rice. There are six wheat classifications: 1) hard red winter, 2) hard red spring, 3) soft red winter, 4) durum (hard), 5) hard white, and 6) soft white wheat. The hard wheat have the most amount of gluten and are used for making bread, rolls and all-purpose flour. The soft wheat are used for making flat bread, cakes, pastries, crackers, muffins, and biscuits.

Origin and domestication

Wheat is one of the first cereals known to have been domesticated. The archaeological record suggests that this first occurred in the regions known as the Fertile Crescent. Cultivation of wheat began to spread beyond the Fertile Crescent after about 8000 BC. The spread of cultivated emmer wheat (*Triticum turgidum* subsp. *dicoccum*) has been traced starting in the Fertile Crescent sometime before 8800 BC. Archaeological analysis of wild *emmer* (*T. dicoccoides*) indicates that it was first cultivated in the southern Levant with finds dating back as far as 9600 BC. Genetic analysis of wild einkorn (*T. monococcum*) wheat suggests that it was first grown in the Karacadag mountains in south-eastern Turkey. The cultivation of emmer reached Greece, Cyprus and India by 6500 BC; Egypt shortly after 6000 BC, and Germany and Spain by 5000 BC. By 3000 BC, wheat had reached England and Scandinavia. A millennium later it reached China. The first identifiable bread wheat (*T. aestivum*) with sufficient gluten for yeasted breads has been identified using DNA analysis in samples from a granary dating to approximately 1350 BC in Greek Macedonia.

Genetics

Wheat genetics is more complicated than that of most other domesticated species. Some wheat species are diploid, with two sets of chromosomes, but many are stable polyploids, with four sets of chromosomes (tetraploid) or six (hexaploid). Einkorn wheat (*T. monococcum*) is diploid (AA, two complements of seven chromosomes, 2n=14). Most tetraploid wheats (e.g. emmer and durum wheat) are derived from wild emmer, *T. dicoccoides*. Wild emmer is itself the result of a hybridization between two diploid wild grasses, *T. urartu* and a wild goatgrass such as *Aegilops searsii* or *A. speltoides*. The hybridization that formed wild emmer (AABB) occurred in the wild, long before domestication, and was driven by natural selection. Hexaploid wheats evolved in farmers' fields. Either domesticated emmer or durum wheat hybridized with yet another wild diploid grass (*A. tauschii*) to make the hexaploid wheats, spelt wheat and bread wheat. These have three sets of paired chromosomes, three times as many as in diploid wheat.

Genes for the 'dwarfing' trait, first used by Japanese wheat breeders to produce short-stalked wheat, have had a huge effect on wheat yields world-wide, and were major factors in the success of the Green Revolution in Mexico and Asia, an initiative led by Norman Borlaug. Dwarfing genes helped prevent the problem of lodging, planting of semi-dwarf wheat worldwide increased yields and responded better to nitrogenous fertilizer.

In 2012, an essentially complete gene set of bread wheat has been published. Random shotgun libraries of total DNA and cDNA from the *T. aestivum* cv. Chinese Spring (CS42) were sequenced. This sequence data provides direct access to about 96,000 genes, relying on orthologous gene sets from other cereals and represents an essential step towards a systematic understanding of biology and engineering the cereal crop for valuable traits.

Plant breeding

In traditional agricultural systems wheat populations often consist of landraces, informal farmer-maintained populations that often maintain high levels of morphological diversity. Although landraces of wheat are no longer grown in Europe and North America, they continue to be important elsewhere. The origins of formal wheat breeding lie in the nineteenth century, when single line varieties were created through selection of seed from a single plant noted to have desired properties. Modern wheat breeding developed in the first years of the twentieth century and was closely linked to the development of Mendelian genetics. The standard method of breeding inbred wheat cultivars is by crossing two lines using hand emasculation, then selfing or inbreeding the progeny. It takes ten or more generations before release as a variety or cultivar in conventional plant breeding. The major breeding objectives include high grain yield, good quality, disease and insect resistance and tolerance to abiotic stresses, including mineral, moisture and heat tolerance. Wheat has also been the subject of mutation breeding, with the use of gamma, x-rays, ultraviolet light, and sometimes harsh chemicals. The varieties of wheat created through this methods are in the hundreds (varieties being as far back as 1960), more of them being created in higher populated countries such as China.

Nutritional value

Much of the carbohydrate fraction of wheat is starch. Wheat starch is an important commercial product of wheat, but second in economic value to wheat gluten. The principal parts of wheat flour are gluten and starch. In wheat, phenolic compounds are mainly found in the form of insoluble bound ferulic acid and are relevant to resistance to wheat fungal diseases. Alkylresorcinols are phenolic lipids present in high amounts in the bran layer (e.g. pericarp, testa and aleurone layers) of wheat and rye (0.1-0.3% of dry weight).

Production

Wheat is grown on more than 218,000,000 hectares, larger than for any other crop. With rice, wheat is the world's most favoured staple food. It is a major diet component because of the wheat plant's agronomic adaptability with the ability to grow from near arctic regions to equator, from sea level to plains of Tibet, approximately 4,000 m above sea level. In addition to agronomic adaptability, wheat offers ease of grain storage and ease of converting grain into flour for making edible, palatable, interesting and satisfying foods. Wheat is the most important source of carbohydrate in a majority of countries.

In the Punjab region of India and Pakistan, as well as North China, irrigation has been a major contributor to increased grain output. More widely over the last 40 years, a massive increase in fertilizer use together with the increased availability of semi-dwarf varieties in developing countries has greatly increased yields per hectare.

World trade

The largest exporters of wheat in 2009 were, in order of exported quantities: United States, EU-27, Canada, Russian Federation, Australia, Ukraine and Kazakhstan. The largest importers of wheat in 2009 were, in order of imported quantities: Egypt, EU-27, Brazil, Indonesia, Algeria and Japan. EU-27 was on both export and import list, because EU countries such as Italy and Spain imported wheat, while other EU-27 countries exported their harvest. The Black Sea region - which includes Kazakhstan, the Russian Federation and Ukraine - is amongst the most promising area for grain exporters.

1.3.2-Paddy

Paddy or rice (*Oryza* sp.) is one of the most cultivated grains in the world. It belongs to the family Poaceae and has two cultivated species *Oryza sativa* (Asian rice) or *Oryza glaberrima* (African rice). As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population, especially in Asia. Rice also plays an important role in certain religions and popular beliefs. Genetic evidence has shown that rice originates from a single domestication 8,200–13,500 years ago in the Pearl River valley region of China. There are many varieties of rice that differ in size, texture, colour and taste. Rice cultivation is well-suited to countries and regions with low labour costs and high rainfall, as it is labour-intensive to cultivate and requires ample water. However, rice can be grown practically anywhere, even on a steep hill or mountain area with the use of water-controlling terrace systems. Although its parent species are native to Asia and certain parts of Africa, centuries of trade and exportation have made it commonplace in many cultures worldwide.

Origin and domestication

There have been plenty of debates on the origins of the domesticated rice. Genetic evidence shows that all forms of Asian rice, both *indica* and *japonica*, spring from a single domestication that occurred 8,200–13,500 years ago in China of the wild rice *Oryza rufipogon*. A 2012 study, through a map of rice genome variation, indicated that the domestication of rice occurred in the Pearl River valley region of China based on the genetic evidence. From East Asia, rice was spread to South and Southeast Asia. Before this research, the commonly accepted view, based on archaeological evidence, is that rice was first domesticated in the region of the Yangtze River valley in China.

Cultivation and cultivars

While most rice is bred for crop quality and productivity, there are varieties selected for characteristics such as texture, smell, and firmness. There are four major categories of rice worldwide: indica, japonica, aromatic and glutinous. The different varieties of rice are not considered interchangeable, either in food preparation or agriculture, so as a result, each major variety is a completely separate market from other varieties. It is common for one variety of rice to rise in price while another one drops in price.

Rice can be grown in different environments, depending upon water availability. Generally, rice does not thrive in a waterlogged area, yet it can survive and grow herein and it can also survive flooding. The major types of rice are: i) Lowland, rainfed, which is drought prone, favours medium depth; waterlogged, submergence, and flood prone, ii) Lowland, irrigated, grown in both the wet season and the dry season, iii) Deep water or floating rice, iv) Coastal Wetland, and v) Upland rice, well known for its drought tolerance.

Rice cultivars also fall into groups according to environmental conditions, season of planting, and season of harvest, called ecotypes. Some major groups are the Japan-type (grown in Japan), "buly" and "tjereh" types (Indonesia); "aman" (main winter crop), "aus" ("aush", summer), and "boro" (spring) (Bengal and Assam). Cultivars exist that are adapted to deep flooding, and these are generally called "floating rice".

The largest collection of rice cultivars is at the International Rice Research Institute (IRRI) in the Philippines, with over 100,000 rice accessions held in the International Rice Genebank. The National Gene bank of India at ICAR-National Bureau of Plant Genetic Resources, New Delhi also holds over 100,000 accessions. Rice cultivars are often classified by their grain shapes and texture. Indian rice cultivars include long-grained and aromatic Basmati (grown in the North), long and medium-grained Patna rice, and in South India (Andhra Pradesh and Karnataka) short-grained Sona Masuri (also called as *Bangaru theegalu*). In the state of Tamil Nadu, the most prized cultivar is *ponni* which is primarily grown in the delta regions of the Kaveri River. Kaveri is also referred to as *ponni* in the South and the name reflects the geographic region where it is grown. In the Western Indian state of Maharashtra, a short grain variety called Ambemohar is very popular. This rice has a characteristic fragrance of Mango blossom.

Aromatic rice have definite aromas and flavours; the most noted cultivars are Thai fragrant rice, Basmati, Patna rice, Vietnamese fragrant rice, and a hybrid cultivar from America, sold under the trade name Texmati. Both Basmati and Texmati have a mild popcorn-like aroma and flavor. In Indonesia, there are also *red* and *black* cultivars.

Rice genome

Draft genomes for the two most common rice cultivars, *indica* and *japonica*, were published in April 2002. Rice was chosen as a model organism for the biology of grasses because of its relatively small genome (~430 megabase pairs). Rice was the first crop with a complete genome sequence.

Production

Rice is grown in about 160 million hectares area worldwide with total production of about 740 million tonnes. The average world farm yield for rice was 4.5 tonnes per hectare. Rice is mainly cultivated by small farmers in holdings of less than 1 ha. Rice is vital for the nutrition of much of the population in Asia, as well as in Latin America and the Caribbean and in Africa; it is central to the food security of over half the world population. Developing countries account for 95% of the total production, with China and India alone responsible for nearly half of the world output. The three largest producers of rice are China, India, and Indonesia. Among the six largest rice producers, the most productive farms for rice were in China producing about 7.0 tonnes per hectare.

Nutritional value

Rice is the staple food of over half the world's population. It is the predominant dietary energy source for several countries in Asia and the Pacific, in North and South America and countries in Africa. Rice provides 20% of the world’s dietary energy supply, while wheat supplies 19% and maize (corn) 5%. The nutrition value of rice varies based on a number of factors. It depends on the strain of rice, that is between white, brown, red, and black (or purple) varieties of rice - each prevalent in different parts of the world. It also depends on nutrient quality of the soil rice is grown in, whether and how the rice is polished or processed, the manner it is enriched, and how it is prepared before consumption. Highly coloured rice strains, such as black (purple) rice, derive their colour from anthocyanins and tocols. Scientific studies suggest that these colour pigments have antioxidant properties that may be useful to human health. In purple rice bran, hydrophilic antioxidants are in greater quantity and have higher free radical scavenging activity than lipophilic antioxidants. Anthocyanins and γ-tocols in purple rice are largely located in the inner portion of purple rice bran.

Rice is a good source of protein and a staple food in many parts of the world, but it is not a complete protein: it does not contain all of the essential amino acids in sufficient amounts for good health, and should be combined with other sources of protein, such as nuts, seeds, beans, fish, or meat.

Environment impact of rice cultivation

Rice cultivation on wetland rice fields is thought to be responsible for 11% of the anthropogenic methane emissions. Rice requires slightly more water to produce than other grains. Rice production uses almost a third of Earth’s fresh water. Methane is twenty times more potent a greenhouse gas than carbon dioxide. A 2010 study found that, as a result of rising temperatures and decreasing solar radiation during the later years of the 20th century, the rice yield growth rate has decreased in many parts of Asia, compared to what would have been observed had the temperature and solar radiation trends not occurred. The yield growth rate had fallen 10–20% at some locations.

“Golden rice”

Rice kernels do not contain vitamin A, so people who obtain most of their calories from rice are at risk of vitamin A deficiency. German and Swiss researchers have genetically engineered rice to produce beta-carotene, the precursor to vitamin A, in the rice kernel. The beta-carotene turns the processed (white) rice a "gold" colour, hence the name "golden rice." The beta-carotene is converted to vitamin A in humans who consume the rice. Although some rice strains produce beta-carotene in the hull, no non-genetically engineered strains have been found that produce beta-carotene in the kernel, despite the testing of thousands of strains. Additional efforts are being made to improve the quantity and quality of other nutrients in golden rice. The International Rice Research Institute is currently further developing and evaluating Golden Rice as a potential new way to help address vitamin A deficiency.

1.3.3-Maize

Maize (or corn), *Zea mays* L., is a cereal crop and is a member of the grass family Poaceae. Maize is grown around the world and is one of the globe's most widely used food staples. Maize varieties are directly used for food and animal feed or processed to make food and feed ingredients (such as high fructose corn syrup, corn starch and lysine) or industrial products such as ethanol and polylactic acid (PLA). The leafy stalk produces ears which contain the grain, which are seeds called kernels. The six major types of maize are dent, flint, pod, popcorn, flour, and sweet.

Origin and domestication

Most historians believe maize was domesticated in the Tehuacan Valley of Mexico. The Olmec and Mayans cultivated it in numerous varieties throughout Mesoamerica. Beginning about 2500 BC, the crop spread through much of the Americas. The region developed a trade network based on surplus and varieties of maize crops. After European contact with the Americas in the late 15^{th} and early 16^{th} centuries, explorers and traders carried maize back to Europe and introduced it to other countries. Maize spread to the rest of the world because of its ability to grow in diverse climates. Sugar-rich varieties called sweet corn are usually grown for human consumption as kernels, while field corn varieties are used for animal feed, various corn-based human food uses (including grinding into cornmeal or masa, pressing into corn oil, and fermentation and distillation into alcoholic beverages like bourbon whiskey), and as chemical feed stocks.

An influential 2002 study has demonstrated that all maize arose from a single domestication in southern Mexico about 9,000 years ago. The study also demonstrated that the oldest surviving maize types are those of the Mexican highlands. Later, maize spread from this region over the Americas along two major paths. This is consistent with a model based on the archaeological record suggesting that maize diversified in the highlands of Mexico before spreading to the lowlands.

Maize is the domesticated variant of teosinte. The two plants have dissimilar appearance, maize having a single tall stalk with multiple leaves and teosinte being a short, bushy plant. The difference between the two is largely controlled by differences in just two genes. Several theories had been proposed about the specific origin of maize in Mesoamerica. It is a direct domestication of a Mexican annual teosinte, *Zea mays* ssp. *parviglumis*, native to the Balsas River valley in south-eastern Mexico, with up to 12% of its genetic material obtained from *Zea mays* ssp. *mexicana* through introgression. The teosinte origin theory was proposed by the Russian botanist N.I. Vavilov in 1931 and the later American Nobel Prize-winner George Beadle in 1932. It is supported experimentally and by recent studies of the plants' genomes. Teosinte and maize are able to cross-breed and produce fertile offspring. A number of questions, however, still remain unanswered.

Different forms of maize

Many forms of maize are used for food, sometimes classified as various subspecies related to the amount of starch each has, Flour corn: *Zea mays* var. *amylacea;* Popcorn: *Zea mays* var. *Everta;* Dent corn : *Zea mays* var. *indentata;* Flint corn: *Zea mays* var. *indurate;* Sweet corn: *Zea mays* var. *saccharata* and *Zea mays* var. *rugosa;* Waxy corn: *Zea mays* var. *certain;* Amylomaize: *Zea mays;* Pod corn: *Zea mays* var. *tunicata*, and Striped maize: *Zea mays* var. *japonica.* This system has been replaced (though not entirely displaced) over the last 60 years by multivariable classifications based on ever more data. Agronomic data were supplemented by botanical traits for a robust initial classification, then genetic, cytological, protein and DNA evidence was added. Now, the categories are forms (little used), races, racial complexes, and recently branches.

Genetics

Maize is a diploid with 20 chromosomes (n=10). The combined length of the chromosomes is 1500 cM. Some of the maize chromosomes have what are known as "chromosomal knobs": highly repetitive heterochromatic domains that stain darkly. Individual knobs are polymorphic among strains of both maize and teosinte. Barbara McClintock used these knob markers to validate her transposon theory of "jumping genes", for which she won the 1983 Nobel Prize in Physiology or Medicine. Maize is still an important model organism for genetics and developmental biology today.

Primary sequencing of the maize genome was completed in 2008. On November 20, 2009, the consortium published results of its sequencing effort in *Science*. The genome, 85% of which is composed of transposons, was found to contain 32,540 genes (By comparison, the human genome contains about 2.9 billion bases and 26,000 genes). Much of the maize genome has been duplicated and reshuffled by helitrons-group of rolling circle transposons.

Plant breeding, cultivation and production

Maize is the most widely grown grain crop throughout the Americas, with 332 million metric tons grown annually in the United States alone. Approximately 40% of the crop-130 million tons-is used for corn ethanol. Genetically modified maize made up 85% of the maize planted in the United States in 2009.

Maize reproduces sexually each year. This randomly selects half the genes from a given plant to propagate to the next generation, meaning that desirable traits found in the crop (like high yield or good nutrition) can be lost in subsequent generations unless certain techniques are used. Since the 1940s the best strains of maize have been first-generation hybrids made from inbred strains that have been optimized for specific traits, such as yield, nutrition, drought, pest and disease tolerance. Both conventional cross-breeding and genetic modification have succeeded in increasing output and reducing the need for cropland, pesticides, water and fertilizer. CIMMYT, Mexico operates a conventional breeding program to provide optimized strains. The program began in the 1980s. Hybrid seeds are distributed in Africa by the Drought Tolerant Maize for Africa project.

Genetically modified (GM) maize is one of the 25 GM crops grown commercially. Grown since 1997 in the United States and Canada, 86% of the US maize crop was genetically modified in 2010 and 32% of the worldwide maize crop was GM in 2011. As of 2011, Herbicide-tolerant and insect-resistant maize varieties are grown in many countries across the world. In September 2000, up to $50 million worth of food products were recalled due to contamination with Starlink genetically modified corn, which had been approved only for animal consumption and had not been approved for human consumption, and was subsequently withdrawn from the market.

Maize is widely cultivated throughout the world; the United States produces 40% of the world's harvest. Other top producing countries include China, Brazil, Mexico, Indonesia, India, France and Argentina. Maize and cornmeal (ground dried maize) constitute a staple food in many regions of the world. Maize is central to Mexican food. Introduced into Africa by the Portuguese in the 16th century, maize has become Africa's most important staple food crop.

Uses

Maize meal is made into a thick porridge in many cultures. Maize meal is also used as a replacement for wheat flour, to make cornbread and other baked products. Popcorn consists of kernels of certain varieties that explode when heated, forming fluffy pieces that are eaten as a snack. Roasted dried maize ears with semi hardened kernels, coated with a seasoning mixture of fried chopped spring onions with salt added to the oil, is a popular snack food in Vietnam. An unleavened bread called *makki di roti* is a popular bread eaten in the Punjab region of India and Pakistan.

Nutritional value

Chicha and *chicha morada* (purple chicha) are drinks typically made from particular types of maize. The first one is fermented and alcoholic, the second is a soft drink commonly drunk in Peru. Corn flakes are a common breakfast cereal in North America and the United Kingdom, and found in many other countries all over the world. Maize is a major source of starch. Cornstarch (maize flour) is a major ingredient in home cooking and in many industrialized food products. Maize is also a major source of cooking oil (corn oil) and of maize gluten. Maize starch can be hydrolyzed and enzymatically treated to produce syrups, particularly high fructose corn syrup, a sweetener; and also fermented and distilled to produce grain alcohol.

In a 100 gram serving, maize kernels provide 86 calories and are a good source (10-19% of the Daily Value) of the B vitamins, thiamin, niacin, pantothenic acid (B5) and folate. In moderate amounts, they also supply dietary fibre and the essential minerals, magnesium and phosphorus whereas other nutrients are in low amounts. Maize is the subject of genetic engineering research to improve levels of carotenoids, such as provitamin A, beta-carotene.

Maize produces a greater quantity of biomass than other cereal plants, which is used for fodder. Digestibility and palatability are higher when ensiled and fermented, rather than dried.

1.3.4-Bajra

Pearl millet (*Pennisetum glaucum*) is the most widely produced millet worldwide and is cultivated extensively in Africa and India since pre-historic times.

Origin and domestication

The centre of diversity, and suggested area of domestication, for the crop is in the Sahel zone of West Africa. Recent archaeobotanical research has confirmed the presence of domesticated pearl millet on the Sahel zone of northern Mali between 2500 and 2000 BC. Cultivation subsequently spread and moved overseas to India. The earliest archaeological records in India date to around 2000 BC, and it spread rapidly through India reaching South India by 1500 BC, based on evidence from the site of Hallur. Cultivation also spread throughout eastern and southern Africa. Records exist for cultivation of pearl millet in the United States in the 1850s, and the crop was introduced into Brazil in the 1960s.

Cultivation, production and uses

Because pearl millet millets require little water and are highly drought resistant, they grow well in arid and semi arid regions of the world such as in countries surrounding the Sahara desert in Africa and in dry areas in India and Asia. Further, pearl millet is an attractive agricultural crop for farmers in these regions because under good conditions, it can yield two harvests per year and is resistant to pests and pathogens. In the Sudan region of Africa, dietary surveys show that millet consumption was the primary source of food calories, respectively yielding up to 70% of total daily energy.

Pearl millet is well adapted to growing areas characterized by drought, low soil fertility, and high temperature. It performs well in soils with high salinity or low pH. Because of its tolerance to difficult growing conditions, it can be grown in areas where other cereal crops, such as maize or wheat, would not survive. Today pearl millet is grown on over 260,000 km^2 of land worldwide. It accounts for approximately 50% of the total world production of millets.

India is the largest producer of pearl millet, Rajasthan is highest producing state in India. Pearl millet is an important food across the Sahel region of Africa. It is a main staple (along with sorghum) in a large region of northern Nigeria, Niger, Mali and Burkina Faso. In Nigeria it is usually grown as an intercrop with sorghum and cowpea, the different growth habits, growth period and drought vulnerability of the three crops maximising total productivity and minimising the risk of total crop failure. It is often ground into flour, rolled into large balls, parboiled, liquefied into a watery paste using fermented milk and then consumed as a beverage. This beverage called "fura" in Hausa is popular drink in northern Nigeria and southern Niger.

Recently more productive varieties of pearl millet have been introduced, enabling farmers to increase production considerably. To combat the problem of micronutrient malnutrition in Africa and Asia, a study of serving iron-biofortified pearl millets which is bred conventionally without genetic modification to a control group is proved to have higher level of iron absorbance by the group.

1.3.5- Jowar

Jowar (*Sorghum* spp.) is a coarse, upright growing grass that is used for both grain and forage production. Most species are native to Australia, with some extending to Africa, Asia, Mesoamerica, and certain islands in the Indian and Pacific Oceans. One species, *Sorghum bicolor,* is grown for grain, while many others are used as fodder plants, either intentionally cultivated or allowed to grow naturally, in pasture lands. The plants are cultivated in warm climates worldwide and naturalized in many places.

Origin and domestication

S. bicolour originated in north-eastern Africa, with domestication having taken place there around 5,000–8,000 years ago. The largest diversity of cultivated and wild sorghum is also found in this part of Africa. The secondary centre of origin of sorghum is the Indian Subcontinent, with evidence for early cereal cultivation dating back about 4,500 years.

Cultivation, production and uses

Grain sorghum is also called "milo" and is a major feed grain for cattle. Grain sorghum doesn’t require a lot of water and can survive long, hot summers. It is a principal feed ingredient for both cattle and poultry, in northern India it is very common as a forage crop and fed to animals fresh or as silage or hay. Sweet sorghum is used to a limited extent in producing sorghum syrup and ‘jaggery’ (raw sugar) in India and has recently gained importance in ethanol production

Sorghum is ground, cracked, steam flaked, and/or roasted. It can be cooked like rice, made into porridge, malted for beer, baked into flatbreads and popped like popcorn. Sorghum originated in Egypt 4,000 years ago and today is Africa's second most important cereal. Africa now produces 20 million tons of sorghum per year, a third of the world total.

The leading producers of *Sorghum bicolor* in 2011 were Nigeria (12.6%), India (11.2%), Mexico (11.2%) and the United States (10.0%). Sorghum grows in a wide range of temperature, high altitudes, toxic soils and can recover growth after some drought. Sorghum is cultivated in many parts of the world today. In the past 50 years, the area planted with sorghum worldwide had increased 66%. In many parts of Asia and Africa, its grain is used to make flat breads that form the staple food of many cultures. The grains can also be popped in a similar fashion to popcorn.

The species can be used as a source for making ethanol fuel, and in some environments may be better than maize or sugarcane, as it can grow under harsher conditions. It typically has protein levels of around 9%, enabling dependent human populations to subsist on it in times of famine, in contrast to regions where maize has become the staple crop. It is also used for making a traditional corn broom. The reclaimed stalks of the sorghum plant are used to make a decorative millwork material marketed as Kirei board. Sweet sorghum syrup is known as molasses in some parts of the U.S., although it is not true molasses.

In India, where it is commonly called *jwaarie, jowar, jola*, or *jondhahlaa*, sorghum is one of the staple sources of nutrition. An Indian bread, *jowar roti* or *jolada rotti*, is prepared from this grain. In some countries, sweet sorghum stalks are used for producing biofuel by squeezing the juice and then fermenting it into ethanol. Texas A&M University in the United States is currently running trials to find the best varieties for ethanol production from sorghum leaves and stalks in the USA.

Nutritional value

Sorghum grain contains 11.3% protein, 3.3% fat and 56–73% starch. Its protein content is higher than corn and about equal to wheat. Its fat content is lower than corn but higher than wheat. It is relatively rich in iron, zinc, phosphorus and B-complex vitamins. Tannins, found particularly in red-grained types, contain antioxidants that protect against cell damage, a major cause of diseases and aging. The protein and starch in sorghum grain are more slowly digested than those from other cereals, and slower rates of digestibility are particularly beneficial for people with diabetes. Sorghum starch is gluten-free, making sorghum a good alternative to wheat flour for individuals suffering from celiac disease.

Plant breeding

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) , and national program partners in Asia and sub-Saharan Africa, assessed the ‘spillover’ potential of sorghum varieties and hybrids. This aimed to find out how successful these varieties were in areas outside those that they were originally bred for. It has often been argued that, in heterogeneous environments, returns on the investment in breeding new varieties will be low, because new cultivars will tend to perform well in only the locations that they were initially bred for. However, the study demonstrated that this was not the case. In fact, cultivars originating from collaborative national and international research can prove to be highly transferable across different environments.

Improved varieties occupy approximately 36% of Tanzania’s sorghum area. They are widely popular, mainly for their early maturity (and thus drought tolerance) and high yield – 10–38% higher than local varieties. Adoption has been stimulated by interventions by ICRISAT and local partners to strengthen local seed systems and community-based seed production.

Genome

The genome of *Sorghum bicolor* was sequenced between 2005 and 2007.

1.4 CULTIVATION, PRODUCTION AND USES OF LEGUMES

1.4.1-Pigeon Pea

The pigeon pea (*Cajanus cajan*) is a perennial legume from the family Fabaceae. Since its domestication in South Asia at least 3,500 years ago, its seeds have become a common food grain in Asia, Africa, and Latin America. Pigeon peas, a popular vegetable in tropical countries, are healthy and versatile. Ripe pigeon peas are a common ingredient in dhal, an Indian split-pea soup. Immature pigeon pea seeds, also called green pigeon peas, are reputed as an old folk medicine remedy for liver and kidney ailments, according to Purdue University, but they offer real health benefits today. They are a nutrient-rich addition to rice or a variety of other foods and can supplement your diet with protein, fibre, vitamins and minerals.

Origin and domestication

The cultivation of the pigeon pea goes back at least 3,500 years. The centre of origin is the eastern part of peninsular India, including the state of Odisha, where the closest wild relatives (*Cajanus cajanifolia*) occur in tropical deciduous woodlands. Archaeological finds of pigeon pea include those from two Neolithic sites in Odisha, Gopalpur and Golbai Sassan dating between 3,400 and 3,000 years ago, and sites in South India, Sanganakallu and Tuljapur Garhi, also dating back to 3,400 years ago. From India it travelled to East Africa and West Africa. There, it was first encountered by Europeans, so it obtained the name Congo Pea. By means of the slave trade it came to the American continent, probably in the 17th century.

Cultivation

Today, pigeon peas are widely cultivated in all tropical and semitropical regions of both the Old and the New Worlds. Pigeon peas can be of a perennial variety, in which the crop can last three to five years (although the seed yield drops considerably after the first two years), or an annual variety more suitable for seed production.

Pigeon peas are an important legume crop of rainfed agriculture in the semiarid tropics. The Indian subcontinent, eastern Africa and Central America, in that order, are the world's three main pigeon pea-producing regions. The crop is cultivated on marginal land by resource-poor farmers, who commonly grow traditional medium- and long-duration (5–11 months) landraces. Short-duration pigeon peas (3–4 months) suitable for multiple cropping have recently been developed.

Pigeon peas are very drought-resistant, so can be grown in areas with less than 650 mm annual rainfall. With the maize crop failing three out of five years in drought-prone areas of Kenya, a consortium led by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) aimed to promote the pigeon pea as a drought-resistant, nutritious alternative crop. World production of pigeon peas is estimated at 4.3 million tons. About 82% of this is grown in India. These days it is the most essential ingredient of animal feed used in West Africa, especially in Nigeria, where it is also grown.

Uses

In India, split pigeon peas (*toor dal*) is one of the most popular pulses, being an important source of protein in a mostly vegetarian diet. In regions where it grows, fresh young pods are eaten as a vegetable in dishes such as *sambar*. In Ethiopia, not only the pods, but also the young shoots and leaves are cooked and eaten. In some places, such as the Caribbean coast of

Colombia, Dominican Republic, Panama and Hawaii, pigeon peas are grown for canning and consumption.

Pigeon peas are in some areas an important crop for green manure, providing up to 90 kg nitrogen per hectare. The woody stems of pigeon peas can also be used as firewood, fencing and thatch.

Genome sequence

The pigeon pea is the first seed legume plant to have its complete genome sequenced. The sequencing was accomplished by a global research partnership, the International Initiative for Pigeonpea Genomics (IIPG), led by ICRISAT with partners such as BGI –Shenzhen (China), US research laboratories like University of Georgia, University of California-Davis, Cold Spring Harbour Laboratory, and National Centre for Genome Resources, European research institutes like the National University of Ireland Galway and also support from the CGIAR Generation Challenge Programme, US National Science Foundation and in-kind contribution from the collaborating research institutes. It is the first time that a Consultative Group on International Agricultural Research (CGIAR)-supported Centre such as ICRISAT led the genome sequencing of a food crop. In parallel, a group of 31 Indian scientists from the Indian Council of Agricultural Research also published its genome sequence.

Nutritional value

Pigeon peas contain high levels of protein and the important amino acids methionine, lysine, and tryptophan. Methionine+Cystine combination is the only limiting amino acid combination in pigeon pea. In contrast to the mature seeds, the immature seeds are generally lower in all nutritional values, however they contain a significant amount of vitamin C (39 mg per 100 g serving) and have a slightly higher fat content. Research has shown that the protein content of the immature seeds is of a higher quality.

1.4.2-Pea

The pea is most commonly the small spherical seed or the seed-pod of the pod fruit *Pisum sativum*. Each pod contains several peas. Pea pods are botanically fruit, since they contain seeds and developed from the ovary of a (pea) flower. Peas have a long history as multipurpose edible plants popular among chefs and even royalty. They are cool season green vegetables that grow in numerous climates. Peas are ideal for vegetable gardens as they are easy to grow and provide a nutritious ingredient for many recipes or as a simple stand alone dish.

Origin and domestication

The wild pea is restricted to the Mediterranean basin and the Near East. The earliest archaeological finds of peas date from the late neolithic era of current Greece, Syria, Turkey and Jordan. In Egypt, early finds date from *ca.* 4800–4400 BC in the Nile delta area, and from *ca.* 3800–3600 BC in Upper Egypt. The pea was also present in Georgia in the 5th millennium BC. Farther east, the finds are younger. Peas were present in Afghanistan *ca.* 2000 BC, in Harappa, Pakistan, and in northwest India in 2250 -1750 BC. In the second half of the 2^{nd} millennium BC, this pulse crop appears in the Gangetic basin and southern India.

Cultivation

A pea is a most commonly green, occasionally golden yellow, or infrequently purple pod-shaped vegetable, widely grown as a cool season vegetable crop. The seeds may be planted as soon as the soil temperature reaches 10 °C, with the plants growing best at temperatures of 13 to 18 °C. They do not thrive in the summer heat of warmer temperate and lowland tropical climates, but do grow well in cooler, high altitude, tropical areas. Many cultivars reach maturity about 60 days after planting. Peas have both low-growing and vining cultivars. The vining cultivars grow thin tendrils from leaves that coil around any available support and can climb to be 1–2 m high. A traditional approach to supporting climbing peas is to thrust branches pruned from trees or other woody plants upright into the soil, providing a lattice for the peas to climb. Branches used in this fashion are sometimes called pea brush. Metal fences, twine, or netting supported by a frame are used for the same purpose. In dense plantings, peas give each other some measure of mutual support. Pea plants can self-pollinate.

Uses

Peas have been a part of French and Asian cuisine for over 1,000 years. In India, fresh peas are used in various dishes such as *aloo matar* (curried potatoes with peas) or *matar paneer* (paneer cheese with peas), though they can be substituted with frozen peas as well. Peas are also eaten raw, as they are sweet when fresh off the bush. Split peas are also used to make *dhal*, particularly in Guyana, and Trinidad, where there is a significant population of Indians. In order to freeze and preserve peas, they must first be grown, picked, and shelled. Usually, the tenderer the peas are, the more likely the peas will be used in the final product. The frozen peas are then packaged and shipped out for retail.

Nutritional value

Peas are starchy, but high in fibre, protein, vitamin A, vitamin B6, vitamin C, vitamin K, phosphorus, magnesium, copper, iron, zinc and lutein. Dry weight is about one-quarter protein and one-quarter sugar. Pea seed peptide fractions have less ability to scavenge free radicals than glutathione, but greater ability to chelate metals and inhibit linoleic acid oxidation.

Varieties

There are many varieties (cultivars) of garden peas. *PMR* indicates some degree of powdery mildew resistance; *afila* types, also called semi-leafless, have clusters of tendrils instead of leaves. These are so called dwarf varieties which grow to an average height of about 1m. Extra dwarf are suitable for container growing, reaching only about 25 cm. Semi-tall reaches about 1.5m and tall grows to about 2m. Other variations of *P. sativum* include, *P. sativum* var. *macrocarpon* is commonly known as the snow pea, and *P. sativum* var. *macrocarpon* ser. cv. is known as the sugar or snap pea. Both of these are eaten whole before the pod reaches maturity and are hence also known as *mange-tout*, French for "eat all". The snow pea pod is eaten flat, while in sugar/snap peas, the pod becomes cylindrical, but is eaten while still crisp, before the seeds inside develop.

Peas in science

In the mid-19th century, Austrian monk Gregor Mendel's observations of pea pods led to the principles of Mendelian genetics, the foundation of modern genetics. He ended up growing and examining about 28,000 pea plants in the course of his experiments. Mendel chose peas for his experiments because he could grow them easily, develop pure-bred strains, protect them from cross-pollination, and control their pollination. Mendel cross-bred tall & dwarf pea plants, green & yellow peas, purple & white flowers, wrinkled & smooth peas, and a few other traits. He then observed the resulting offsprings and came out with three famous laws, Law of Segregation, Law of Independent Assortment and Law of Dominance. Unwittingly, Mendel had solved a major problem with Charles Darwin's theory of evolution: how could new traits be preserved and not blended back into the population? But Darwin never learned about it. Mendel's work was published in an obscure Austrian journal and was not rediscovered until about 1900.

1.4.3-Green Gram

The moong bean, *Vigna radiata* (L.) Wilczek is a plant species in legume family and has been grown in India since ancient times. Native to the Indian subcontinent, it is still widely grown in Southeast Asia, Africa, South America and Australia. It is also cultivated in hot, dry regions in Southern Europe and the Southern United States. It is used as an ingredient in both savoury and sweet dishes.

Origin and domestication

The moong bean was domesticated in India, where its progenitor (*Vigna radiata* subsp. *sublobata*) occurs wild. Archaeological evidence has turned up carbonized moong beans on many sites in India. Areas with early finds include the eastern zone of the Harappan civilization in Punjab and Haryana, where finds date back about 4500 years, and South India in the modern state of Karnataka where finds date back more than 4000 years. Some scholars therefore infer two separate domestications in the northwest and south of India. In South India there is evidence for evolution of larger-seeded moong beans 3500 to 3000 years ago. By about 3500 years ago moong beans were widely cultivated throughout India. Cultivated moong beans later spread from India to China and Southeast Asia.

Uses

Moong beans are commonly used in various cuisines across Asia. Whole cooked moong beans are generally prepared from dried beans by boiling until they are soft. Moong beans are light yellow in colour when their skins are removed. Moong bean paste can be made by dehulling, cooking, and pulverizing the beans to a dry paste. Although whole moong beans are also occasionally used in Indian cuisine, beans without skins are more commonly used; but in Kerala, whole moong beans are commonly boiled to make a dry preparation often served with rice gruel (*kanji*). Dehulled moong beans can also be used in a similar fashion as whole beans for the purpose of making sweet soups. Moong beans in some regional cuisines of India are stripped of their outer coats to make moong *dal*. In Tamil Nadu, Telangana and Andhra Pradesh, steamed whole beans are seasoned with spices and fresh grated coconut in a preparation called *sundal*. In south and north Indian states, moong beans are also eaten as pancakes. These are usually eaten for breakfast. This provides high quality protein that is rare in most Indian regional cuisines. *Pongal* or *kichdi* is another recipe that is made with rice and moong beans without skin. In Kerala, it is commonly used to make the *parippu* preparation in the Travancore region. It is also used, with coconut milk and jaggery, to make a type of *payasam*.

Moong bean sprouts are germinated by leaving them in water for four hours of daytime light and spending the rest of the day in the dark. Moong bean seeds are sprouted for fresh use or canned for shipment to restaurants. Sprouts are high in protein (21%–28%), calcium, phosphorus and certain vitamins. Because they are easily digested they replace scarce animal protein in human diets in tropical areas of the world. Because of their major use as sprouts, a high quality seed with excellent germination is required. If the moong bean seed does not meet sprouting standards it can be used as a livestock food with about 1.5 ton of moong bean being equivalent to 1.0 tons of soybean meal for protein content.

1.4.4-Black Gram

Black gram, also known as Urd bean, is a beans grown in Indian subcontinent. It is largely used to make dal from the whole or split, de-husked seeds.

Origin and domestication

Black gram originated in India where it has been in cultivation from ancient times and is one of the most highly prized pulses of India. It has also been introduced to other tropical areas mainly by Indian immigrants.

Cultivation, production and uses

It is very nutritious and is recommended for diabetics, as are other pulses. It is very popular in Punjabi cuisine of India and Pakistan where it is known as "maash". The coastal Andhra region in Andhra Pradesh is famous for black gram after paddy. The Guntur District ranks first in Andhra Pradesh for the production of black gram.

The beans are boiled and eaten whole or after splitting into dal; prepared like this it has an unusual mucilaginous texture. Ground into flour or paste, it is also extensively used in culinary preparation like dosa, idli, vada, and papad. When used this way, the white lentils are usually used with the black skin removed. It has been historically used as cementing agent along with other ingredients in the construction of several historic buildings. In medieval times, this bean was used in making crucibles impermeable.

Nutrition

Black gram is very nutritious as it contains high levels of protein (25g/100g), potassium (983 mg/100g), calcium (138 mg/100g), iron (7.57 mg/100g), niacin (1.447 mg/100g), Thiamine (0.273 mg/100g), and riboflavin (0.254 mg/100g). Black gram complements the essential amino acids provided in most cereals and plays an important role in the diets of the people of Nepal and India. Black gram has been shown to be useful in mitigating elevated cholesterol levels.

1.4.5-Rajmash

Rajmash (*Phaseolus vulgaris*), the common bean (also known as the field bean, French bean, garden bean or snap bean, etc.), is a herbaceous annual plant grown worldwide for its edible dry seed or unripe fruit that are both known as "beans". Its leaf is also occasionally used as a vegetable and the straw as fodder. Its botanical classification, along with other *Phaseolus* species, is as a member of the legume family *Fabaceae*, most of whose members acquire the nitrogen they require through an association with rhizobia, a species of nitrogen-fixing bacteria.

Origin and domestication

The wild *P. vulgaris* was native to the Americas and was domesticated separately in Mesoamerica and in the southern Andes region, giving the domesticated bean two gene pools which remain separate to this day. Along with squash and maize (corn), beans are one of the "Three Sisters" central to indigenous North American agriculture.

Description

The common bean is a highly variable species that has a long history of cultivation. All wild members of the species have a climbing habit, but many cultivars are classified as "bush beans" or "pole beans", depending on their style of growth. These include the kidney bean, the navy bean, the pinto bean, and the wax bean. The other major types of commercially grown bean are the runner bean (*Phaseolus coccineus*) and the broad bean (*Vicia faba*).

The common bean is a highly variable species with a long history. Bush varieties form erect bushes 20–60 cm (8–20 in) tall, while pole or running varieties form vines 2–3 m (7–10 ft) long. All varieties bear alternate, green or purple leaves, which are divided into three oval, smooth-edged leaflets, each 6–15 cm (2–6 in) long and 3–11 cm (1–4 in) wide. The white, pink, or purple flowers are about 1 cm long, and they give way to pods 8–20 cm (3–8 in) long and 1–1.5 cm wide. These may be green, yellow, black, or purple in colour, each containing 4–6 beans. The beans are smooth, plump, kidney-shaped, up to 1.5 cm long, range widely in colour, and are often mottled in two or more colours.

Dry beans: Similar to other beans, the common bean is high in starch, protein, and dietary fibre, and is an excellent source of iron, potassium, selenium, molybdenum, thiamine, vitamin B_6, and folate. Dry beans will keep indefinitely if stored in a cool, dry place, but as time passes, their nutritive value and flavour degrade and cooking times lengthen. Dried beans are almost always cooked by boiling, often after being soaked in water for several hours. Dry common beans take longer to cook than most pulses: cooking times vary from one to four hours, but are substantially reduced with pressure cooking. Dry beans may also be bought cooked and canned as refried beans, or whole with water, salt, and sometimes sugar.

Green beans and wax beans: The three commonly known types of green beans are: string or snap beans, which may be round or have a flat pod; stringless or French beans, which lack a tough, fibrous "string" running along the length of the pod; and runner beans, which belong to a separate species, *Phaseolus coccineus*. Green beans may have a purple rather than green pod, which changes to green when cooked. Wax beans are *P. vulgaris* beans that have a yellow or white pod. Wax bean cultivars are commonly grown; the plants are often of the bush form. Compared to dry beans, green and wax beans provide less starch and protein and more vitamin A and vitamin C. Green beans and wax beans are often steamed, boiled, stir-fried, or baked in casseroles.

Shelling beans: Shell, shelled, or shelling beans are beans removed from their pods before being cooked or dried. Common beans can be used as shell beans, but the term also refers to other species of beans whose pods are not typically eaten, such as lima beans, soybeans, peas, and faba beans. Fresh shell beans are nutritionally similar to dry beans, but are prepared more like a vegetable, often being steamed, fried, or made into soups.

Popping beans: The *nuña* is an Andean subspecies, *P. v.* subsp. *nunas* (formerly *P. vulgaris* Nuñas group), with round, multicolored seeds that resemble pigeon eggs. When cooked on high heat, the bean explodes, exposing the inner part, in the manner of popcorn and other puffed grains.

Varieties

Many well-known bean varieties belong to this species. Both bush and running (pole) varieties exist. The colours and shapes of pods and seeds vary over a wide range.

Production

Beans are grown in every continent except Antarctica. Brazil and India are the largest producers of dry beans, while China produces, by far, the largest quantity of green beans. Worldwide, 23 million tonnes of dry common beans and 17.1 million tonnes of green beans were grown in 2010.

1.4.6-Gram

Chickpea, also known as garbanzo bean, is a legume and belongs to the pea family. It originates from Turkey, Syria and Iran. Cultivation of chickpea started 7000 years BC. It was popular and widely consumed in the ancient Egypt, Greece and Rome. Chickpea is still one of the most widely cultivated and consumed crops in the world (especially in the poor communities in Africa and Asia). Chickpea grows on a well-drained soil in warm and arid areas that provide enough sun. It is sensitive to frost and heavy rainfall. Chickpea is prone to fungal diseases that can decrease harvest drastically. There are 43 species and numerous varieties of chickpea that are mainly cultivated as a source of food. Other than that, chickpea has application in textile industry and industry of dyes.

Origin and domestication

Chickpeas originated in the Middle East, the region of the world whose varied food cultures still heavily rely upon this high protein legume. The first record of chickpea being consumed dates back about seven thousand years. They were first cultivated around approximately 3000 BC. Their cultivation began in the Mediterranean basin and subsequently spread to India and Ethiopia. Chickpeas were grown by the ancient Egyptians, Greeks and Romans and were very popular among these cultures. During the 16th century, chickpeas were brought to other subtropical regions of the world by both Spanish and Portuguese explorers as well as Indians who emigrated to other countries. Today, the main commercial producers of chickpeas are India, Pakistan, Turkey, Ethiopia and Mexico.

Genome sequencing

Sequencing of the chickpea genome has been completed for 90 chickpea genotypes, including several wild species. A collaboration of 20 research organizations, led by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) identified more than 28,000 genes and several million genetic markers. Scientists expect this work will lead to the development of superior varieties. The new research will benefit the millions of developing country farmers who grow chickpea as a source of much needed income, as well as for its ability to add nitrogen to the soil in which it grows. Production is growing rapidly across the developing world, especially in West Asia where it has increased four-fold over the past 30 years. India is by far the world largest producer but is also the largest importer.

Chickpea types

The plant grows to between 20–50 cm (8–20 inches) high and has small feathery leaves on either side of the stem. Chickpeas are a type of pulse, with one seedpod containing two or three peas. It has white flowers with blue, violet or pink veins.

There are three main kinds of chickpea. *Desi* has small, darker seeds and a rough coat. It is grown mostly in India and other parts of the Indian subcontinent, as well as in Ethiopia, Mexico, and Iran. *Desi* means 'country' or 'local' in Hindustani; its other names include *Bengal gram* or *kala chana* ("black chickpea" in both Hindi and Urdu) or *chhola boot*. *Desi* is probably the earliest variety because it closely resembles seeds found both on archaeological sites and the wild plant ancestor *Cicer reticulatum* of domesticated chickpeas, which only grows in southeast Turkey, where it is believed to have originated. *Desi* chickpeas have a markedly higher fibre content than other varieties, and hence a very low glycemic index, which may make them suitable for people with blood sugar problems. The *desi* type is used to make *chana dal*, which is a split chickpea with the skin removed. Bombay chickpeas (*Bambai*) are also dark but slightly larger than *desi*. They too are popular in the Indian subcontinent.

Kabuli are lighter-coloured, larger and with a smoother coat, and are mainly grown in the Mediterranean, Southern Europe, Northern Africa, South America and Indian subcontinent. The name means "from Kabul" in Hindi and Urdu, and this variety was thought to come from Kabul, Afghanistan when it was introduced to India in the 18th century. An uncommon black chickpea, *ceci neri*, is grown only in Apulia, in southeastern Italy. It is larger and darker than the *desi* variety.

Green chickpeas are common in the state of Maharastra, India. In Marathi, they are called *harbhara*. Chana dal is also called *harbara dal*. Tender, immature harbara roasted on coal before the skin is removed is called *hula* in Marathi.

Uses

Chickpeas are usually rapidly boiled for 10 minutes, and then simmered for a longer period. Dried chickpeas need a long cooking time (1–2 hours) but will easily fall apart when cooked longer. If soaked for 12–24 hours before use, cooking time can be shortened by around 30 minutes. Chickpeas can also be pressure cooked.

Mature chickpeas can be cooked and eaten cold in salads, cooked in stews, ground into a flour called gram flour (also known as chickpea flour and *besan* and used frequently in Indian cuisine), ground and shaped in balls and fried as falafel, or stirred into a batter and baked to make farinata or panelle.

Chickpes also has many popular uses in Iberian Peninsula, Portugal, Spain, Egypt, Arabian cuisine, Italy, American cuisines, Burma, Philippines, Mexico, etc.

Some varieties of chickpeas can be popped and eaten like popcorn. Chickpeas and Bengal grams are used to make curries and are one of the most popular vegetarian foods in the Indian subcontinent and in diaspora communities of many other countries. Popular dishes in Indian cuisine are made with chickpea flour, such as *mirchi bajji* and *mirapakaya bajji Telugu*. In India, as well as in the Levant, unripe chickpeas are often picked out of the pod and eaten as a raw snack and the leaves are eaten as a leaf vegetable in salads.

Nutritional value

Chickpeas serve as an energy and protein source not only in human nutrition but also as animal feed. Raw chickpeas have a lower trypsin and chymotrypsin inhibitor content than peas, common beans and soybeans. This leads to higher nutritional values and fewer digestive problems in non-ruminants. Non-ruminant diets can be completed with 200g/kg of raw chickpeas to promote egg production and growth of birds and pigs. Higher amounts can be used when chickpeas are previously treated with heat.

Chickpeas are a nutrient-dense food, providing rich content (> 20% of the Daily Value, DV) of protein, dietary fibre, folate, and certain dietary minerals such as iron and phosphorus.

Thiamin, vitamin B6, magnesium and zinc contents are moderate, providing 10-16 percent of the DV. Chickpeas have a Protein Digestibility Corrected Amino Acid Score of about 76 percent, which is higher than fruits, vegetables, many other legumes, and cereals.

Compared to reference levels established by the United Nations Food and Agricultural Organization and World Health Organization, proteins in cooked and germinated chickpeas are rich in essential amino acids like lysine, isoleucine, tryptophan and total aromatic amino acids. A 100 g serving of cooked chickpeas provides 164 kilocalories. Carbohydrates make up 68 percent of calories, most of which (84 percent) is starch, followed by total sugars and dietary fibre. Lipid content is 3 percent, 75 percent of which is unsaturated fatty acids for which linoleic acid comprises 43 percent of total fat.

Production

Chickpeas are grown in the Mediterranean, western Asia, the Indian subcontinent, Australia, the Palouse region, and the Great Plains. India is the world leader in chickpea (Bengal gram) production, and produces some fifteen times as much as the second-largest producer, Australia. Other key producers are Pakistan, Turkey, Burma, Ethiopia and Iran.

1.4.7-Lentil

The lentil (*Lens culinaris*) is an edible pulse of the legume family, known for its lens-shaped seeds. It is about 40 cm tall, and the seeds grow in pods, usually with two seeds in each.

Origin and domestication

Lentils have been part of the human diet since aceramic (before pottery) Neolithic times, being one of the first crops domesticated in the Near East. Archeological evidence shows they were eaten 9,500 to 13,000 years ago.

Description

The colours of lentil seed range from yellow to red-orange to green, brown and black. Lentils also vary in size, and are sold in many forms, with or without the skins, whole or split.

The seeds require a cooking time of 10 to 40 minutes, depending on the variety-shorter for small varieties with the husk removed, such as the common red lentil- and have a distinctive, earthy flavor. Lentil recipes are used throughout South Asia, the Mediterranean regions and West Asia. They are frequently combined with rice, which has a similar cooking time. Rice and lentils are cooked together in *khichdi*, a popular dish in the Indian subcontinent (India and Pakistan); a similar dish, *kushari*, made in Egypt, is considered one of two national dishes. Lentils are used to prepare an inexpensive and nutritious soup all over Europe and North and South America, sometimes combined with some form of chicken or pork.

Dried lentils can also be sprouted by soaking in water for one day and keeping moist for several days, which changes their nutrition profile. Lentils with husk remain whole with moderate cooking; lentils without husk tend to disintegrate into a thick purée, which leads to quite different dishes.

Nutritional value

In a 100 g serving, raw lentils provide 353 calories and a rich source of numerous essential nutrients, particularly dietary fibre and protein supplying 122% and 52% of the Daily Value (DV), respectively, (table). Micronutrients in high content include folate (120% DV), thiamine (76% DV), phosphorus (64% DV) and iron (58% DV).

With 26% of total food content from protein, lentils have the third-highest level of protein, by weight, of any legume or nut, after soybeans and hemp. Red (or pink) lentils contain a lower concentration of fibre than green lentils (11% versus 31%).The low levels of readily digestible starch (5%), and high levels of slowly digested starch (30%), make lentils of potential value to people with diabetes. The remaining 65% of the starch is a resistant starch classified as RS1, as a high-content resistant starch, which is 32% amylose. A minimum of 10% in starch from lentils escapes digestion and absorption in the small intestine (therefore called "resistant starch").

Lentils also have anti-nutrient factors, such as trypsin inhibitors and a relatively high phytate content. Trypsin is an enzyme involved in digestion, and phytates reduce the bioavailability of dietary minerals. The phytates can be reduced by soaking the lentils in warm water overnight.

Production

Lentils are relatively tolerant to drought, and are grown throughout the world. FAOSTAT reported that the world production of lentils for calendar year 2013 was 4,975,621 metric tons, primarily coming from Canada, India and Turkey. About a quarter of the worldwide production of lentils is from India, most of which is consumed in the domestic market. Canada is the largest export producer of lentils in the world. The Palouse region of eastern Washington and the Idaho panhandle, with its commercial centre at Pullman, Washington, constitute the most important lentil-producing region in the United States.

1.5 SUMMARY

Wheat, paddy (rice) and maize are the three major staple food crops globally. Rice is the main grain crop of India. India ranks second in the world in production of rice. About 34% of the total cultivated area of the nation is under rice cultivation. Rice is cultivated in areas having annual average rainfall of 125 cm. Major rice cultivating areas are north eastern India, eastern and western coastal regions. West Bengal, Punjab and Uttar Pradesh are the major rice producing states. Wheat is the second major crop in India. Wheat is cultivated in areas with mean annual rainfall of 75 cm and fertile soil. Wheat has got an important role in 'Green Revolution'. The highest quantity of wheat in the country is in Uttar Pradesh, 35 % of wheat is produced only in Uttar Pradesh. Punjab and Haryana are the states where production of wheat is on a large scale. Maize is an important crop of rainy season. Maize is cultivated in different areas and in different climates but it is suitable where temperature is 35° C and rainfall is 75 cm. It is cultivated in hilly areas-of Jammu and Kashmir and Himachal Pradesh. Maize is cultivated throughout our country but it is cultivated more in Punjab, U.P., Bihar, M.P. and Rajasthan.

Among millets, pearl millet (bajra) and sorghum (jowar) are the two important crops grown globally. Pearl millet is the most widely grown type of millet. It has been grown in Africa and the Indian subcontinent since prehistoric times. Jowar is grown where the climate is hot and dry. In India, it is cultivated in Maharashtra, Karnataka, Andhra Pradesh, and Tamil Nadu.

Legumes are important source of human food - next to the cereals. The term pulse is used for the seeds of leguminous plants. Legumes supply proteins and form chief source in vegetarian food. Leguminous plants fix nitrogen in root nodules - produced with the help of nitrogen fixing bacteria. Seeds, pods, leaves and the shoots also contain a high proportion of protein e.g. pigeonpea, black gram, green gram, the major legumes of Indian origin.

1.6 GLOSSARY

Aleurone: (Aleurone layer). The outermost cell layer of the endosperm, usually only one cell thick in wheat and the only endosperm tissue alive at maturity. The cells of this layer are responsible for the de-novo synthesis of enzymes needed at germination.
Caryopsis: The fruit, of grasses, in which the ripened ovary wall, the pericarp, is fused to the seed coats, the testa, at maturity.
Cereals: are grasses (members of the monocot family Poaceae, also known as Gramineae) cultivated for the edible components of their grain composed of the endosperm, germ, and bran.
Diploid: with two full sets of chromosomes in the nucleus of a cell; having two complements of haploid chromosomes, that are the two complete sets of chromosomes, one from each of the parental gamete. This is expressed symbolically as 2n, where n = the gamete number of chromosomes.
Aromatic Rice: Brown or white rice with a natural aroma and flavor similar to that of roasted nuts or popcorn. Various types grown; cooks dry and separate or moist and tender.
Basmati rice: A very slender, long-grain, highly aromatic rice grown in India and Pakistan; it is aged for a year after harvesting to develop full flavor. Available in brown and white
Brown Rice: Kernels of rice from which only the hull has been removed. The light brown color is caused by the presence of bran layers, which are rich in minerals and vitamins. Cooked brown rice has a slightly chewy texture and a nut-like flavor.
Rice Bran: The outer layer on brown rice and an excellent source of thiamin, niacin, vitamin B-6, iron, phosphorus, magnesium, potassium and fibre.
Texmati: A registered trademark brand of aromatic rice grown in the United States.

Transgenic: An experimentally-produced organism whose DNA includes genetic material that has been introduced by scientists.

Transposon: A transposon is a mobile segment of DNA that serves as an agent of genetic change in maize.

Millets: Millets are a group of highly variable small-seeded grasses, widely grown around the world as cereal crops or grains for fodder and human food. Millets are important crops in the semiarid tropics of Asia and Africa (especially in India, Nigeria, and Niger), with 97% of millet production in developing countries. The crop is favoured due to its productivity and short growing season under dry, high-temperature conditions.

Legumes: A **legume** is a plant in the family Fabaceae, or the fruit or seed of such a plant. Legumes are grown agriculturally, primarily for their food grain seed (example beans and lentils, or generally pulse), for livestock forage and silage, and as soil-enhancing green manure. Legumes are notable in that most of them have symbiotic nitrogen-fixing bacteria in structures called root nodules. Well-known legumes include pigeon pea, peas, beans, lentils, peanuts, etc.

Pulse: A pulse, sometimes called a "grain legume", is an annual leguminous crop yielding from one to twelve seeds of variable size, shape, and colour within a pod. Pulses are used as food for humans and other animals. Included in the pulses are: dry beans like pinto beans, kidney beans and navy beans; dry peas; lentils; and others.

1.7 SELF ASSESSMENT QUESTIONS

1.7.1 Short answer type Questions:

1. The importance of cereal, millet and legume crops.
2. The cereal, millet and legume crops domesticated or originated in Indian sub-continent.
3. The impact of cereal, millet and legume crops on the global and Indian economy.
4. Important cereal, millet and legume crops and the regions or the state in India each one is grown.
5. The staple food of north Indian people.
6. The health benefits of millets.
7. Different types of common bean.
8. Different kinds of chick peas. The chick pea type predominantly grown in India.

1.7.2 Multiple choice questions:

1.Which of the following wheats have the highest gluten content and are used for making bread, rolls and all-purpose flour-

(a) Soft red winter (b) Soft white wheat

(c) Hard white (d) Hard red spring

2. Genes for the 'dwarfing' trait, first used by-

(a) Indian scientists (b) Japanese scientists

(c) Mexican scientists (d) Canadian scientists

3. Einkorn wheat (*T. monococcum*) is diploid (AA) with two complements of-
(a) 7 chromosomes (b) 14 chromosomes
(c) 10 chromosomes (d) 21 chromosomes

4. Tetraploid purple wheats grown in the highlands of Ethiopia are rich in antioxidants
(a) Starch (b) Antioxidants
(c) Protein (d) Vitamin A

5. Genetic evidence has shown that the Asian rice originates in the
(a) NEH Region of India (b) Jeypore tract of Odisha
(c) NW Himalayas of India (d) Pearl River valley region of China

6. The genetically engineered "golden rice" is a rich source of-
(a) Starch (b) Protein
(c) Vitamin A (d) Antioxidant

7. An aromatic cultivar of rice from America is sold under the trade name
(a) Texmati (b) Basmati
(c) Kalanamak (d) Sona Msuri

8. The transposon theory of "jumping genes"is related to-
(a) Wheat (b) Maize
(c) Rice (d) Jowar

9. Which among the followings are the world top producers of jowar (*Sorghum bicolor)*-
(a) Mexico (b) USA
(c) Nigeria (d) India

10. The highest pearl millet producing state in India is-
(a) Madhya Pradesh (b) Gujarat
(c) Rajasthan (d) Andhra Pradesh

11. The centre of origin of pigeon pea is-
(a) India (b) China
(c) South Africa (d) Ethiopia

12. The legume crop Gregor J. Mendel chose for his experiments is-
(a) Common bean (b) Chickpea
(c) Pigeon pea (d) Pea

13. An international crop research institute (IARC) in India that works on sorghum, bajra, chickpea, pigeon pea and groundnut is
(a) ICRISAT (b) IRRI

(c) CIMMYT (d) CIAT

14. The legume crop originated and domesticated in Indian sub-continent is?
(a) Mung bean (b) Chickpea
(c) Lentil (d) Common bean

15. The world leader in chickpea production is-
(a) Australia (b) India
(c) Turkey (d) Pakistan

1.7.2 Answer Key: 1-(d), 2-(b), 3-(a), 4-(b), 5-(d), 6-(c), 7-(a), 8-(b), 9-(c), 10-(c), 11-(a), 12-(d), 13-(a), 14-(a), 15-(b)

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1.10 TERMINAL QUESTIONS

1. Which plant family the major food crops of the world belong?
2. Where the wheat was first domesticated?
3. Describe different types of wheat. Which wheat is widely cultivated?
4. Which country is the larger exporter of wheat globally?
5. Name the two cultivated species of rice.
6. Where the rice was first originated?
7. Name the three countries which are the world's largest producers of rice.
8. Where are the global rice germplasm accessions are maintained?
9. Which year the draft genomes for the two most common rice cultivars, *indica* and *japonica*, published?
10. Describe different forms of maize. Name various subspecies of maize related to the amount of starch each has.
11. What do you understand by "jumping genes"? Describe its significance in context of maize.
12. Describe the teosinte theory of maize.
13. Which part of the world pearl millet or bajra is most extensively cultivated?
14. Name the international institute located in India that has successfully bred bajra and sorghum varieties grown globally.
15. Where was pigeon pea originated? Which part of the world it is presently cultivated?
16. Name various Indian dishes in which fresh peas are used.
17. Name two most important Asian *Vigna* species used as pulses.
18. Which countries in the world are the top dry bean and green bean producers, respectively?
19. Which institute led the sequencing of the chickpea genome?
20. Which countries lead the lentil production in the world?

UNIT-2 FRUITS, VEGETABLES, FIBRE-YIELDING AND TIMBER-YIELDING FOREST SPECIES

2.1 OBJECTIVES

The major objectives of the present chapter are:

- To study origin, domestication, genetics, cultivation and production of fruits, vegetables, fibre-yielding plants and timber yielding forest species.
- To establish link between biology and anthropology and exploiting ways humans use fruits, vegetables, fibre-yielding plants and timber yielding forest species for food and other purposes.

2.2 INTRODUCTION

Fruits and vegetables provide health benefits and are important for the prevention of illnesses. Fruits and vegetables contain a variety of nutrients including vitamins, minerals and antioxidants. Eating the recommended amount of fruits and vegetables each day can reduce the risk of chronic diseases. The healthiest choices are fresh fruits or frozen without added sweeteners. Fruit is naturally low in fat, sodium and calories, and rich in potassium, fibre, vitamin C and folate. Some high-potassium fruits include oranges and bananas. Fibre in fruit helps to protect against heart disease and lower cholesterol. Vitamin C in foods like citrus helps in wound healing and keeps gums and teeth healthy. Vegetables are rich in vitamin A, vitamin C, folate, fibre and potassium. Folate helps the body in formation of red blood cells. It is especially important for pregnant women to consume folate-rich foods such as bell peppers, tomatoes and spinach to prevent neural-tube defects in babies. Vitamin A-rich foods help keep your skin and eyes healthy and protect against infections. A few important fruits, mango, apple, banana, citrus and litchi are described here in the present chapter, beside the vegetables in all four categories, root, stem, leaf and fruits.

Fibre crops are field crops grown for their fibres, which are traditionally used to make paper, cloth, or rope. Botanically, the fibres harvested from many plants are bast fibres; the fibres come from the phloem tissue of the plant. The other fibre crop fibres are seed padding, leaf fibre, or other parts of the plant. Jute is bast (stem-skin) fibre; cotton and the coir, the fibre from coconut husk are seed fibres. Cotton, jute and coconut are described in this chapter.

There are over 150 species of timber which are produced in India of which Teak, Shisham, Sal, Chir-pine and deodar are important timber-yielding forest species described in this chapter.

2.3 GENERAL ACCOUNT OF FRUITS

2.3.1-Mango

Mango is one of the juicy and delicious popular fruit grown in the tropics belonging to the genus *Mangifera* in the family *Anacardiaceae*. Mango, more popularly known as the "King of the fruits" is nutritionally rich with unique flavour, fragrance, taste, and heath promoting qualities, making it number one among new functional foods, often labelled as "super fruits."

Description

The mango is native to *South Asia* from where it has been distributed worldwide to become one of the most cultivated fruits in the tropics. The centre of diversity of the *Mangifera* genus is in India. While other *Mangifera* species (e.g. horse mango, *Mangifera foetida*) are also grown on a more localized basis. *Mangifera indica*- the "common mango" or "Indian mango"- is the only mango tree commonly cultivated in many tropical and subtropical regions. It is the national fruit of India, Pakistan, and the Philippines, and the national tree of Bangladesh. Mango also has cultural significance.

Mango trees grow up to 35–40 m tall, with a crown radius of 10 m. After flowering its fruits generally grow at the end of a long, string like peduncle, with sometimes more than one fruit to a peduncle. The ripe fruit varies in size and colour. Each fruit measures 5 to 15 cm in length and about 4 to 10 cm in width, and has typical "mango" shape, or sometimes oval or round. Its weight ranges from 150 g to around 750 g. Outer skin (pericarp) is smooth and is green in unripe mangoes but turns in ripe fruits into golden yellow, crimson red, yellow or orange-red depending upon the cultivar type. Fresh mango season lasts from April until August.

Cultivation

Mangoes have been cultivated in South Asia for thousands of years and reached East Asia between the fifth and fourth centuries BC. By the 10th century AD, cultivation had begun in East Africa. The mango is now cultivated in most frost-free tropical and warmer subtropical climates; almost half of the world's mangoes are cultivated in India alone, with the second-largest source being China. Though India is the largest producer of mangoes, it accounts for less than 1% of the international mango trade; India consumes most of its own production. Many of the 1,000+ mango cultivars are easily cultivated using grafted saplings. Dwarf or semi dwarf varieties serve as ornamental plants and can be grown in containers.

Food and other uses

Mangoes are generally sweet, although the taste and texture of the flesh varies across cultivars; some have a soft, pulpy texture similar to an overripe plum, while others are firmer, like a cantaloupe or avocado, and some may have a fibrous texture. The skin of unripe, pickled, or cooked mango can be consumed, but has the potential to cause contact dermatitis of the lips, gingiva, or tongue in susceptible people.

Mangoes are widely used in cuisine. Sour, unripe mangoes are used in chutneys, pickles, side dishes, or may be eaten raw with salt, chilli, or soy sauce. A summer drink called *aam panna* comes from mangoes. Mango pulp made into jelly or cooked with red gram *dhal* and green chillies may be served with cooked rice. Mango lassi is popular throughout South Asia, prepared by mixing ripe mangoes or mango pulp with buttermilk and sugar. Ripe mangoes are also used to make curries. *Aamras* is a popular thick juice made of mangoes with sugar or milk, and is consumed with *chapatis* or *pooris*. The pulp from ripe mangoes is also used to make jam.

Mangoes are used as preserve food such as *moramba*, *amchur* (dried and powdered unripe mango), and pickles, including a spicy mustard-oil pickle and alcohol. Mango is used to make juices, smoothies, ice cream, fruit bars, pies, and sweet chili sauce or a sweet and spicy chilli paste. In other parts of Southeast Asia, mangoes are pickled with fish sauce and rice vinegar. Mango with condensed milk may be used as a topping for shaved ice.

Nutritional value

The energy value per 100 g serving of the common mango is 60 kcal, and that of the apple mango is slightly higher (79 kcal per 100g). Fresh mango contains a variety of nutrients, but only vitamin C and folate are in significant amounts of the Daily Value as 44% and 11%, respectively. Numerous phytochemicals are present in mango peel and pulp. Mango peel pigments include carotenoids, such as the provitamin A compound, beta-carotene, lutein and alpha-carotene, and polyphenols. Mango contains a unique xanthonoid called mangiferin. Up to 25 different carotenoids have been isolated from mango pulp, the densest of which was beta-carotene, which accounts for the yellow-orange pigmentation of most mango cultivars.

The flavour of mango fruits is constituted by several volatile organic chemicals mainly belonging to terpene, furanone, lactone, and ester classes. Different varieties or cultivars of mangoes can have flavour made up of different volatile chemicals or same volatile chemicals in different quantities. In India, 'Alphonso' is one of the most popular cultivars. In 'Alphonso' mango, the lactones and furanones are synthesized during ripening; whereas terpenes and the other flavourants are present in both the developing (immature) and ripening fruits. In contrast to the huge amount of information available on the chemical composition of mango flavour, the biosynthesis of these chemicals has not been studied in depth; only a handful of genes encoding the enzymes of flavour biosynthetic pathways have been characterized to date.

2.3.2-Apple

The apple tree (*Malus domestica*), is a deciduous tree in the family Rosaceae. Apple trees prosper in areas with warm summers and dry climates. They cannot be grown north of the Arctic Circle. While the fruit-bearing trees are mainly grown in the northern hemisphere, some are now being grown in Australia and New Zealand as well.

Origin and domestication

The tree originated in Central Asia, where its wild ancestor, *Malus sieversii*, is still found today. Apples have been grown for thousands of years in Asia and Europe, and were brought to North America by European colonists. Apples have religious and mythological significance in many cultures, including Norse, Greek and European Christian traditions.

The original wild ancestor of *Malus domestica* was *Malus sieversii*, found growing wild in the mountains of Central Asia in southern Kazakhstan, Kyrgyzstan, Tajikistan, and Xinjiang, China. Significant exchange with *Malus sylvestris*, the crabapple, resulted in current populations of apples being more related to crabapples than to the more morphologically similar progenitor *Malus sieversii*. In strains without recent admixture the contribution of the latter predominates.

Production

About 80 million tons of apples were grown worldwide in 2013, and China produced almost half of this total. The United States is the second-leading producer, with more than 6% of world production. Turkey is third, followed by Italy, India and Poland. Apples are often eaten raw, but can also be found in many prepared foods (especially desserts) and drinks. Many beneficial health effects are thought to result from eating apples; however, two types of allergies are attributed to various proteins found in the fruit.

Cultivars

There are more than 7,500 known cultivars of apples. Cultivars vary in their yield and the ultimate size of the tree, even when grown on the same rootstock. Different cultivars are available for temperate and subtropical climates. Most of these cultivars are bred for eating fresh (dessert apples), though some are cultivated specifically for cooking (cooking apples) or producing cider. Red Delicious trees are the most popular variety in apple growing regions worldwide. Most North Americans and Europeans favour sweet, subacid apples, but tart apples have a strong minority following. Extremely sweet apples with barely any acid flavour are popular in Asia and especially Indian Subcontinent.

Genome

In 2010, an Italian-led consortium announced they had decoded the complete genome of the apple in collaboration with horticultural genomicists at Washington State University, using the Golden delicious variety. It had about 57,000 genes, the highest number of any plant genome studied to date and more genes than the human genome (about 30,000). This new understanding of the apple genome will help scientists in identifying genes and gene variants that contribute to resistance to disease and drought, and other desirable characteristics. Decoding the genome also provided proof that *Malus sieversii* was the wild ancestor of the domestic apple-an issue that had been long-debated in the scientific community.

2.3.3-Banana

The banana is an edible fruit, botanically a berry, produced by several kinds of large herbaceous flowering plants in the genus *Musa*. Banana is, in fact, not a tree but a high herb that grows up to 15 metres. It is believed that there are almost 1000 varieties of bananas in the world, subdivided in 50 groups. The most commonly known banana is the Cavendish variety, which is the one produced for export markets.

Origin and domestication

It is believed that the earliest written reference to banana is in Sanskrit and dates back to around 500 BC. Bananas are suspected to be the first fruit in the earth by some horticulturists. Their origin is placed in Southeast Asia, in the jungles of Malaysia, Indonesia or Philippines, where many varieties of wild bananas still grow today. Africans are credited to have given the present name, since the word banana would be derived from the Arab for 'finger'. They started to be traded internationally by the end of fourteenth century. The development of railroads and technological advances in refrigerated maritime transport subsequently enabled bananas to become the most important world traded fruit.

Taxonomy

The classification of cultivated bananas has long been a problematic issue for taxonomists. Linnaeus originally placed bananas into two species based only on their uses as food: *M. sapientum* for dessert bananas and *M. paradisiaca* for plantains (less sweet). Subsequently further species names were added. However, this approach proved inadequate to address the sheer number of cultivars existing in the primary centre of diversity of the genus, Southeast Asia. Many of these cultivars were given names which proved to be synonyms.

The currently accepted scientific names for most groups of cultivated bananas are *M. acuminata* Colla and *M. balbisiana* Colla for the ancestral species, and *M. paradisiaca* L. for the hybrid *M. acuminata* × *M. balbisiana*. Almost all modern edible parthenocarpic (seedless) bananas come from two wild species - *M. acuminata* and *M. balbisiana*. The scientific names of most cultivated bananas are *M. acuminata*, *M. balbisiana*, and *M. paradisiaca* for the hybrid *M. acuminata* × *M. balbisiana*, depending on their genomic constitution. The old scientific name *M. sapientum* is no longer used.

Generally, modern classifications of banana cultivars follow Simmonds and Shepherd's system. Cultivars are placed in groups based on the number of chromosomes they have and which species they are derived from. Thus the Latundan banana is placed in the AAB Group, showing that it is a triploid derived from both *M. acuminata* (A) and *M. balbisiana* (B). In 2012, a team of scientists announced they had achieved a draft sequence of the genome of *M. acuminata*.

Cultivation, production and export

Bananas are grown in more than 150 countries, producing 105 million tonnes of fruit per year. The bananas grown for local consumption are generally grown in traditional, extensive systems. Dessert bananas account for 43 million tonnes per year and are of huge economic importance for many countries in the South. Cooking bananas (plantains and others) account for 45 million tonnes. Locally consumed bananas, which are a staple food in many tropical countries, play a major role in terms of food security.

The banana plant is the largest herbaceous flowering plant. All the above-ground parts of a banana plant grow from a structure usually called a "corm". Plants are normally tall and fairly sturdy, the trunk is actually a "false stem" or pseudostem. Cultivated bananas are parthenocarpic, i.e. the flesh of the fruit swells and ripens without its seeds being fertilized and developing. Lacking viable seeds, propagation typically involves farmers removing and transplanting part of the underground stem. Usually this is done by carefully removing a sucker with some roots intact.

Cavendish bananas are the main commercial banana cultivars sold in the world market, belonging to the triploid AAA group of *M. acuminata*. Ease of transport and shelf life rather than superior taste make the Dwarf Cavendish the main export banana. Bananas must be transported over long distances from the tropics to world markets. The 2012 statistics show that India led the world in banana production, producing around 18% of the worldwide crop of 139 million metric tonnes. Philippines was the next largest producer with around 7% of the worldwide crop. Its national data does distinguish between bananas and plantains, and shows that the latter made up over 95% of production. Ten countries produced around two thirds of the total world production.

Nutritional value and uses

Bananas and plantains constitute a major staple food crop for millions of people in developing countries. Bananas are an excellent source of vitamin B_6 and contain moderate amounts of vitamin C, manganese and dietary fibre. Ripe bananas were found to contain serotonin, dopamine and norepinephrine.

The banana plant has long been a source of fibre for high quality textiles. In Japan, banana cultivation for clothing and household use dates back to at least the 13th century. Banana fibre is also used in the production of banana paper. Banana paper is made from two different parts: the bark of the banana plant mainly used for artistic purposes, or from the fibres of the stem and non-usable fruits. The paper is either hand-made or by industrial process.

2.3.4-Citrus

Citrus is a common term and genus (*Citrus*) of flowering plants in the family Rutaceae.

Origin and domestication

The most recent research indicates an origin of *Citrus* in Australia, New Caledonia and New Guinea. Some researchers believe that the origin is in the part of Southeast Asia bordered by Northeast India, Burma (Myanmar) and the Yunnan province of China, and it is in this region that some commercial species such as oranges, mandarins, and lemons originated. Citrus fruit has been cultivated in an ever-widening area since ancient times; the best-known examples are the oranges, lemons, grapefruit, and limes.

Taxonomy

The taxonomy and systematics of the genus are complex and the precise number of natural species is unclear, as many of the named species are hybrids clonally propagated through seeds (by apomixis), and there is genetic evidence that even some wild, true-breeding species are of hybrid origin. Most cultivated *Citrus* seem to be natural or artificial hybrids of four core ancestral species-the citron (*C. medica* L.), pummelo (*C. maxima* or *C.grandis)*, mandarine (*C. reticulata*), and papeda (*Citrus* subg *Papeda*). Natural and cultivated citrus hybrids include commercially important fruit such as oranges, grapefruit, lemons, limes, and some tangerines.

Apart from these four core citrus species, there are Australian limes and the recently-discovered Mangshanyegan, Kumquats and *Clymenia sp.* are now generally considered to belong within the Citrus genus. Trifoliate orange, which is often used as commercial rootstock, is an out-group and may or may not be categorized as a citrus.

Citrus trees hybridise very readily - depending on the pollen source. Thus all commercial citrus cultivation uses trees produced by grafting the desired fruiting cultivars onto rootstocks selected for disease resistance and hardiness.

Description

The colour of citrus fruits only develops in climates with a (diurnal) cool winter. In tropical regions with no winter at all, citrus fruits remain green until maturity, hence the tropical "green oranges". The Persian lime in particular is extremely sensitive to cool conditions, thus it is not usually exposed to cool enough conditions to develop a mature colour. If they are left in a cool place over winter, the fruits will change colour to yellow.

The terms "ripe" and "mature" are usually used synonymously, but they mean different things. A mature fruit is one that has completed its growth phase. Ripening is the changes that occur within the fruit after it is mature to the beginning of decay. These changes usually involve starches converting to sugars, a decrease in acids and a softening and change in the fruit's colour.

Citrus trees are not generally frost hardy. Mandarin oranges (*C. reticulata*) tend to be the hardiest of the common *Citrus* species and can withstand short periods down to as cold as -10°C, but realistically temperatures not falling below -2°C are required for successful cultivation. Tangerines can be grown outside even in regions with more marked sub-freezing temperatures in winter, although this may affect fruit quality. The related trifoliate orange (*C. trifoliata*) can survive below -20 °C; its fruit are astringent and inedible unless cooked but a few better-tasting cultivars and hybrids have been developed.

Cultivation

Major commercial citrus growing areas include southern China, the Mediterranean Basin (including southern Spain), South Africa, Australia, the southern most United States, Mexico and parts of South America. In the United States, Florida, California, Arizona, and Texas are major producers, while smaller plantings are present in other Sun Belt states and in Hawaii. According to UN 2007 data, Brazil, China, the United States, Mexico, India, and Spain are the world's largest citrus-producing countries.

Uses

Many citrus fruits, such as oranges, tangerines, grapefruits, and clementines, are generally eaten fresh. They are typically peeled and can be easily split into segments. Grapefruit is more commonly halved and eaten out of the skin with a spoon. Orange and grapefruit juices are also very popular breakfast beverages. More acidic citrus, such as lemons and limes, are generally not eaten on their own. Lemons and limes are also used as garnishes or in cooked dishes.

A variety of flavours can be derived from different parts and treatments of citrus fruits. Citrus juices, rinds, or slices are used in a variety of mixed drinks. The colourful outer skin of some citrus fruits, known as zest, is used as flavouring in cooking; the white inner portion of the peel, the pith, is usually avoided due to its bitterness.

Oranges were historically used for their high content of vitamin C, which prevents scurvy. Pectin is a structural heteropolysaccharide contained in the primary cell walls of plants. Limes and lemons as well as oranges and grapefruits are among the highest in this level. After consumption, the peel is sometimes used as a facial cleanser. Before the development of fermentation-based processes, lemons were the primary commercial source of citric acid.

2.3.5-Litchi

The litchi (*Litchi chinensis*) is the sole member of the genus *Litchi* in the family, Sapindaceae. It is a tropical and subtropical fruit tree native to the Guangdong and Fujian provinces of China, and now cultivated in many parts of the world. The fresh fruit has a "delicate, whitish pulp" with a floral smell and a fragrant, sweet flavour. Since this perfume-like flavour is lost in the process of canning, the fruit is usually eaten fresh.

Description

L. chinensis is an evergreen tree that is frequently less than 19 m tall. The litchi bears fleshy fruits that are up to 5 cm long and 4 cm wide. Fruits mature in 80–112 days, depending on climate, location, and cultivar. Fruits vary in shape from round to ovoid to heart-shaped. The fleshy, edible portion of the fruit is an aril, surrounding one dark brown inedible seed that is 1 to 3.3 cm long and 0.6 to 1.2 cm wide. Some cultivars produce a high percentage of fruits with shrivelled aborted seeds known as 'chicken tongues'. These fruit typically have a higher price, due to having more edible flesh.

Cultivation and production

China is the main producer of litchi, followed by India, with production occurring among other countries in Southeast Asia, the Indian subcontinent and South Africa.

Cultivation of litchi began in the region of southern China, Malaysia, and northern Vietnam. Wild trees still grow in rainforests in Guangdong province and on Hainan Island. Unofficial records in China refer to litchi as far back as 2000 BC. There are numerous litchi cultivars, with considerable confusion regarding their naming and identification. The same cultivar grown in different climates can produce very different fruit. Cultivars can also have different synonyms in various parts of the world. Different cultivars of litchi are popular in the varying growing regions and countries. India grows more than a dozen named cultivars, including Shahi (Highest Pulp %), Dehradun, Early Large Red, Kalkattia, Rose Scented.

Nutritional value

Fresh whole litchi contains a total 72 mg of vitamin C per 100 g of fruit, an amount representing 86% of the Daily Value (DV). On average, consuming nine peeled litchi fruits would meet an adult's daily vitamin C requirement but otherwise would supply little nutrient content. Litchi are low in saturated fat and sodium. Litchi has moderate amounts of polyphenols, shown in one French study to be higher than several other fruits analyzed, such as grapes and apples.

2.4 GENERAL ACCOUNT OF VEGETABLES

2.4.1-Root Vegetables

Root vegetables are underground plant parts used as vegetables. They are called root vegetables, but include both true roots such as tuberous roots and taproots, as well as non-roots such as tubers, rhizomes, corms, bulbs, and hypocotyls.

Root vegetables are generally storage organs, enlarged to store energy in the form of carbohydrates. They differ in the concentration and the balance between sugars, starches, and other types of carbohydrate. Of particular economic importance are those with a high carbohydrate concentration in the form of starch. Starchy root vegetables are important staple foods, particularly in tropical regions, overshadowing cereals throughout much of West Africa, Central Africa and Oceania, where they are used directly or mashed to make fufu or poi. Yams, beets, parsnips, turnips, rutabagas, carrots, yuca, kohlrabi, onions, garlic, celery root (or celeriac), horseradish, daikon, turmeric, jicama, Jerusalem artichokes, radishes, and ginger are all considered roots.

Because root vegetables grow underground, they absorb a great amount of nutrients from the soil. They are packed with a high concentration of antioxidants, Vitamins C, B, A, and iron, helping to cleanse your system. They are also filled with slow-burning carbohydrates and fibre, which make you feel full, and help regulate your blood sugar and digestive system. This factor, plus the high-octane nutrients and low calories, make roots excellent for people who are trying to lose weight, or simply stay healthy.

Adding up all of the nutrient qualities, root vegetables are disease-fighting, immunity and energy-boosting, and are also extremely versatile in cooking.

The following list classifies root vegetables according to anatomy.

True root: Storage roots are very common all over the world. There are more than 50 types of storage roots (categorised in bulb, rhizome, tubers).

1-**Taproot** (some types may incorporate substantial hypocotyl tissue)

- *Arracacia xanthorrhiza* (arracacha)
- *Beta vulgaris* (beet and mangelwurzel)
- *Brassica* spp. (rutabaga and turnip)
- *Bunium persicum* (black cumin)
- Burdock (*Arctium, family Asteraceae*)
- Carrot (*Daucus carota subsp. sativus*)
- Celeriac - (*Apium graveolens rapaceum*)
- Daikon - the large East Asian white radish (*Raphanus sativus var. longipinnatus*)
- Dandelion - (*Taraxacum*) spp.
- *Lepidium meyenii* (maca)
- *Microseris scapigera* (yam daisy)
- *Pachyrhizus* spp. (jicama and ahipa)
- Parsnip (*Pastinaca sativa*)
- *Petroselinum* spp. (parsley root)
- Radish - (*Raphanus sativus*)
- *Scorzonera hispanica* (black salsify)
- *Sium sisarum* (skirret)
- *Tragopogon* spp. (salsify)
- *Vigna lanceolata* (bush potato)

2-**Tuberous root**

- *Amorphophallus galbra* (Yellow lily yam)
- *Conopodium majus* (pignut or earthnut)
- *Dioscorea opposita* (nagaimo, Chinese yam, Korean yam)
- *Hornstedtia scottiana* (Native ginger)
- *Ipomoea batatas* (sweet potato)
- *Ipomoea costata* (desert yam)
- *Manihot esculenta* (cassava or yuca or manioc)
- *Mirabilis extensa* (mauka or chago)
- *Psoralea esculenta* (breadroot, tipsin, or prairie turnip)
- *Smallanthus sonchifolius* (yacón)

Modified plant stem

1-**Corm**

- *Amorphophallus konjac* (konjac)
- *Colocasia esculenta* (taro)
- *Eleocharis dulcis* (Chinese water chestnut)

- *Ensete* spp. (enset)
- *Nelumbo nucifera*
- *Nymphaea* spp. (waterlily)
- *Pteridium esculentum*
- *Sagittaria* spp. (arrowhead or wapatoo)
- *Typha spp.*
- *Xanthosoma* spp. (malanga, cocoyam, tannia, and other names)

2- **Rhizome**

- *Curcuma longa* (turmeric)
- *Panax ginseng* (ginseng)
- *Arthropodium* spp. (rengarenga, vanilla lily, and others)
- *Canna* spp. (canna)
- *Cordyline fruticosa* (ti)
- *Maranta arundinacea* (arrowroot)
- *Nelumbo nucifera* (lotus root)
- *Typha* spp. (cattail or bulrush)
- *Zingiber officinale* (ginger, galangal)

3-**Tuber**

- *Apios americana* (hog potato or groundnut)
- *Cyperus esculentus* (tigernut or chufa)
- *Dioscorea* spp. (yams, ube)
- *Helianthus tuberosus* (Jerusalem artichoke or sunchoke)
- *Hemerocallis* spp. (daylily)
- *Lathyrus tuberosus* (earthnut pea)
- *Oxalis tuberosa* (oca or New Zealand yam)
- *Plectranthus edulis* and *P. esculentus* (kembili, dazo, and others)
- *Solanum tuberosum* (potato)
- *Stachys affinis* (Chinese artichoke or crosne)
- *Tropaeolum tuberosum* (mashua or añu)
- *Ullucus tuberosus* (ulluco)

4-Bulb

- *Allium* spp. (garlic, onion, shallot, etc.)

2.4.2-Stem Vegetables

Stem vegetables are plant stems used as vegetables. Although many leaf vegetables, root vegetables, and inflorescence vegetables in fact contain substantial amounts of stem tissue, the term is used here only for those vegetables composed primarily of above-ground stems.

Important crops found in category of stem vegetables include: 1) Asparagus, 2) Bamboo, 3) Blanched celery, 4) Celery, 5) Celtuce, 6) Florence fennel, 7) Good King Henr, 8) Kohlrabi, 9) Lotus, 10) Moso bamboo, 11) Oldhams bamboo, 12) Rhubarb, 13) Sago palm,

14) Sea kale, etc. A few examples of stem vegetables with edible above ground stems are as follows:

Crop name	Scientific name	Family	Collective name for members of the family, other information
Asparagus	*Asparagus officinalis*	Asparagaceae	Asparagus family (formerly under Liliaceae); the edible part is the young shoot commonly called "spear," best consumed when the tip is still tightly closed.
Bamboos	Various species	Poaceae/ Gramineae	Grass family; the edible part is the young, newly emerged shoot.
Kohlrabi	*Brassica oleracea var. gongylodes*	Brassicaceae/ Cruciferae	Mustard family, also called Cole Crops and Crucifers; the main consumable plant part is the basal stem which forms a spherical structure.
Potato vine, kangkong	*Ipomoea aquatica*	Convolvulaceae	Morning Glory/Bindweed family; both stems and leaves are eaten cooked or blanched.

2.4.3-Leafy Vegetables

Humans have used leaves as food since time immemorial. Different types of leaves, depending from the place and the season, were part of the human diet since prehistoric times. With the passing of the centuries many of those traditional leaf vegetables have been replaced by leaves that are more tender, have a more neutral taste or that are considered more refined. The leaves that were part of ancient traditional diets are still to be found in the wild, sometimes at the edge of cultivated fields, or near abandoned homesteads.

Below is the list of vegetables which are grown primarily for the consumption of their leafy parts, either raw or cooked. Many plants with leaves that are consumed in small quantities as a spice like oregano, or for medicinal purposes like lime, or used in infusions like tea, are not included in this list.

Species	Common name	Observations
Amaranthus cruentus	Purple amaranth	Thai: *phak khom daeng*. Vietnamese: *rau dền*. Amaranthus species are edible and have a pleasant taste, but contain a certain proportion of oxalic acid and should preferably be eaten after boiling and disposing of the water.
Amaranthus	Amaranth	Amarant hybrids, often from hydroponic cultivation, are

tricolor		popular in China and other Asian countries. They are usually eaten blanched.
Apium graveolens	Celery	Generally the stalk is preferred, but the leaves are a staple in many soups. Some people have celery allergy which can cause potentially fatal anaphylactic shock.
Brassica napus	Rutabaga	*Sag*, popular in Indian and Nepalese cuisine, usually stir-fried with salt, garlic and spices.
Brassica nigra	Black Mustard	Black mustard is commonly found in neglected gardens, on roadsides, in abandoned fields, and in areas where waste is disposed of. The plant is native to Asia and Europe, but now grows over much of southern Canada and almost all of the United States. This is the chief mustard used in condiments and as such is normally associated with hot-dogs. To make the mustard condiment, the seeds must be ground fine and then mixed with flour and a small portion of water and vinegar. The plant can be cultivated for its young leaves which are used in a salad or as a pot herb.
Brassica oleracea var. Acephala	Kale	Kale is a type of cabbage that has flat or curly leaves and stem colors ranging from dark green to burgundy. Kale contains many nutrients including calcium, iron, and vitamins A, C, and K. Young leaves can be harvested to use fresh in salads or allowed to mature and used as a cooked green. Kale can be found throughout the summer months, but is especially good after a frost.
Brassica rapa	Turnip	Leaves popular in the southern United States, Galicia, Spain (*Grelos*).
Celosia argentea var. Argentea	Wild Coxcomb	Known as "Lagos spinach", it is one of the main boiled greens in West Africa.
Chenopodium album	Lamb's Quarters	Popular type of *Palak* in Northern India. Also used to stuff paratha.
Chenopodium ambrosioides	American Wormseed	*Chenopodium* species are edible, but many species are mediocre as a leaf vegetable.
Chenopodium bonus-henricus	Good King Henry	One of the finest *Chenopodium* species.
Chenopodium quinoa subsp. quinoa	Quinoa	It has its origin in the Andean region.
Coriandrum sativum	Cilantro, Coriander	Used mainly for garnishing or in small quantities.
Crambe maritima	Sea kale	It was popular as a blanched vegetable in the early 19th Century, but its use declined

Crotalaria longirostrata	Chipilín	A common leafy vegetable in the local cuisines of southern Mexico.
Cyclanthera pedata	Caigua	Traditional green in Central America and South America.
Diplazium esculentum	Vegetable fern	Probably the most commonly consumed fern.
Gynura crepioides	Okinawan Spinach	Grown commercially as a vegetable in China
Hibiscus sabdariffa	Roselle	Telugu: *Gongura*. Roselle leaves are edible and have a pleasant taste. This plant is having good medicinal values. In some areas it is used as substitute of Jute.
Ipomoea aquatica Forssk.	Water Spinach	Popular leafy green in Southeast Asia.
Lablab purpureus	Lablab	The leaves are used as greens, but have to be cooked like spinach and the water has to be discarded.
Lactuca sativa	Lettuce	The wild varieties differ much from the average cultivated salad lettuce.
Lactuca serriola	Prickly Lettuce	Prickly lettuce is a common edible weed that is native to Europe, but can now be found from coast to coast in the United States. The name comes from the small prickles that can be found on the lower part of the stem and the midrib of the leaves. The plant is found in fields, places of waste, and roadsides. The leaves of the plant reach out towards the sun and for this reason the plant is sometimes called the Compass Plant. Prickly Lettuce can grow to be from two to five feet tall but should be harvested early on when it is a few inches high. The young leaves of the plant are very tender and make an excellent salad green. As a potherb, the plant needs little cooking and is commonly made with a sauce of melted butter or vinegar. Prickly lettuce should be harvested in spring or early summer.
Lepidium sativum	Garden cress	Used in soups, sandwiches and salads for its tangy flavour.
Manihot esculenta subsp. esculenta	Cassava	Should be always eaten boiled after disposing of the water. In some countries cassava leaves are regarded as a poor man's food and only eaten when there is nothing else..
Mentha arvensis piperascens	Japanese mint	All *Mentha* species are edible, but generally used in small quantities as garnishing or in salads
Nasturtium	Watercress	One of the most popular salad greens in certain areas, but

officinale		watercress crops grown in the presence of animal waste can be a haven for parasites such as the liver fluke *Fasciola hepatica*.
Oxalis deppei	Iron Cross	Popular as a vegetable in Mexico for its sharp, lemony taste˙
Pisonia grandis	Tree lettuce	The leaves are traditionally used as a leaf vegetable in some countries.˙ Traditionally eaten by Maldivians in *Mas huni*.˙
Psoralea esculenta	Prairie turnip	The prairie turnip is a legume that was often used by American Indians located in the Great Plains. Roots of the legumes provide a valuable source of protein, minerals, and carbohydrates. Most turnips have white skin and the portion of the plant that is seen above the ground is purple, red, or green in color. The root below the surface is known as the taproot and is usually around 5-20 centimeters in diameter.˙
Rumex acetosa	Sorrel	Many species of Rumex are edible, but they contain a relatively high proportion of oxalic acid. Raw leaves should be eaten sparingly and leaves should preferably be used after boiling and disposing of the water.
Sauropus androgynus	*Katuk*	A traditional vegetable in some tropical countries that should be consumed in moderate quantities due to the presence of papaverine
Senna occidentalis	*Digutiyara*	Traditionally eaten in the Maldives in *Mas huni*. Leaves are finely chopped.
Senna siamea	Cassod Tree	Used in Thai cuisine in a curry named *Kaeng khilek*. Leaves are boiled and strained and the water discarded.˙
Spinacia oleracea	Spinach	Spinach contains a certain proportion of oxalic acid. Raw leaves should be eaten sparingly. In dishes that include large quantities, leaves should preferably be used after boiling and disposing of the water.

2.4.4-Fruit Vegetables

Vegetable-like fruits are vegetables formed from the fruits of the plants that bear them. The major fruit vegetables include:

1-*Chili peppers*

The chili pepper is the fruit of plants from the genus *Capsicum,* members of the family, Solanaceae. The substances that give chili peppers their intensity when ingested or applied topically are capsaicin (8-methyl-*N*-vanillyl-6-nonenamide) and several related chemicals, collectively called capsaicinoids.

Chili peppers originated in the Americas. After the Columbian Exchange, many cultivars of chili pepper spread across the world, used in both food and medicine. Chilies were brought to Asia by Portuguese navigators during the 16th century.

India is the world's largest producer, consumer and exporter of chili peppers. Guntur in the South Indian state of Andhra Pradesh produces 30% of all the chilies produced in India. Andhra Pradesh as a whole contributes 75% of India's chili exports.

The chili pepper features heavily in the cuisine of the Goan region of India, which was the site of a Portuguese colony (e.g., vindaloo, an Indian interpretation of a Portuguese dish). Chili peppers journeyed from India, through Central Asia and Turkey, to Hungary, where they became the national spice in the form of paprika.

The five domesticated species of chili peppers are as follows:

- *Capsicum annuum*, which includes many common varieties such as bell peppers, wax, cayenne, jalapeños, and the chiltepin
- *Capsicum frutescens*, which includes malagueta, tabasco and Thai peppers, piri piri, and Malawian Kambuzi
- *Capsicum chinense*, which includes the hottest peppers such as the naga, habanero, Datil and Scotch bonnet
- *Capsicum pubescens*, which includes the South American rocoto peppers
- *Capsicum baccatum*, which includes the South American aji peppers

Though there are only a few commonly used species, there are many cultivars and methods of preparing chili peppers that have different names for culinary use.

2-***Egg plants***

Egg plant (*Solanum melongena*) or aubergine is a species of nightshade grown for its edible fruit. It is known in South Asia, Southeast Asia and South Africa as brinjal. The fruit is widely used in cooking. As a member of the genus *Solanum*, it is related to both the tomato and the potato. It was originally domesticated from the wild nightshade species, the thorn or bitter apple, *S. incanum*, probably with two independent domestications, one in the region of South Asia, and one in East Asia.

Botanically classified as a berry, the fruit contains numerous small, soft seeds which, though edible, taste bitter because they contain nicotinoid alkaloids. Eggplant has been cultivated in southern and eastern Asia since prehistory. Different varieties of the plant produce fruit of different size, shape, and colour, though typically purple.

Egg plant is used in the cuisine of many countries. Eggplant is widely used in its native Indian cuisine, for example in *sambhar*, *dalma* (a *dal* preparation with vegetables, native to Odisha), chutney, curry, and *achaar*. Owing to its versatile nature and wide use in both everyday and festive Indian food, it is often described (under the name "baingan" or "brinjal") as the "king of vegetables". Roasted, skinned, mashed, mixed with onions, tomatoes and spices and then slow cooked gives the South Asian dish *Baingan bharta* or *gojju*. Another version of the dish, *begun-pora* (eggplant charred or burnt), is very popular in Bangladesh and the east Indian states of Odisha and West Bengal where the pulp of the vegetable is mixed with raw chopped shallot, green chillies, salt, fresh coriander and mustard oil. Sometimes fried tomatoes and deep-fried potatoes are also added, creating a dish called *begun bhorta*. In a dish called *bharli vangi*, brinjal is stuffed with ground coconut, peanuts, and masala, and then cooked in oil.

According to FAO in 2012, production of eggplant is highly concentrated, with 90% of output coming from five countries. China is the top producer (58% of world output) and India is second (25%), followed by Iran, Egypt and Turkey. More than 1,600,000 ha are devoted to the cultivation of eggplant in the world. Nutritionally, raw eggplant is low in fat, protein, dietary fibre and carbohydrates. It also provides low amount of essential nutrients, with only manganese having a moderate percentage (11%) of the Daily Value. Minor changes in nutrient composition occur with season and environment (open field or greenhouse) of cultivation and genotype.

Bt brinjal is a transgenic eggplant that contains a gene from the soil bacterium *Bacillus thuringiensis*. This variety was designed to give the plant resistance to lepidopteran insects like the brinjal fruit and shoot borer (*Leucinodes orbonalis*) and fruit borer (*Helicoverpa armigera*). On 9 February 2010, the Environment Ministry of India imposed a moratorium on the cultivation of Bt brinjal after protests against regulatory approval of cultivated Bt brinjal in 2009, stating the moratorium would last "for as long as it is needed to establish public trust and confidence". This decision was deemed controversial, as it deviated from previous science-based, objective successes of other genetically-modified crops in India.

3- *Pod vegetables*

Pod vegetables are a type of fruit vegetables where pods are eaten, much of the time as they are still green. Such plants as green beans in the family Fabaceae, or okras in the family Malvaceae are pod vegetables.

4- Squashes and pumpkins

Squashes and pumpkins are members of the gourd family. Summer squashes and pumpkins originated in Mexico and Central America. Most winter squashes originated in or near the Andes in northern Argentina.

Summer squashes–zucchini, patty pans and cocozelles (Italian for vegetable marrows)–have whitish or yellow flesh. They are the quickest to harvest–picked in summer while immature and as soon they are big enough to use. Winter squashes have orange flesh. They take longer to mature than summer squashes. Harvest winter squashes when their skins are extremely hard and their stems have started to dry out.

Pumpkins–which are simply very large hard-skinned squashes that are usually orange–are the longest to harvest mostly because they are commonly carved at Halloween and pureed for Thanksgiving pie (dish). Like other winter squashes they are picked when their skins are extremely hard and their stems are dry.

5-*Tomatoes*

The tomato is the edible, often red berry-type fruit of the nightshade *Solanum lycopersicum (*Syn. *Lycopersicon esculentum),* commonly known as a tomato plant. The tomato is consumed in diverse ways, including raw, as an ingredient in many dishes, sauces, salads, and drinks. The species originated in the South American Andes and its use as a food originated in Mexico, and spread throughout the world following the Spanish colonization of the Americas. Its many varieties are now widely grown, sometimes in greenhouses in cooler climates. The plants typically grow to 1–3 meters (3–10 ft) in height and have a weak stem that often sprawls over the ground and vines over other plants. It is a perennial in its native habitat, although often grown outdoors in temperate climates as an annual. An average common tomato weighs approximately 100 g.

The tomato is now grown worldwide for its edible fruits, with thousands of cultivars having been selected with varying fruit types, and for optimum growth in differing growing conditions. Cultivated tomatoes vary in size, from tomberries, about 5 mm in diameter, through cherry tomatoes, about the same 1-2 cm size as the wild tomato, up to beefsteak tomatoes 10 cm or more in diameter. The most widely grown commercial tomatoes tend to be in the 5–6 cm diameter range. Most cultivars produce red fruit, but a number of cultivars with yellow, orange, pink, purple, green, black, or white fruit are also available. Multicoloured and striped fruit can also be quite striking. Tomatoes grown for canning and sauces are often elongated, 7-9 cm long and 4-5 cm diameter; they are known as plum tomatoes, and have a lower water content

There are around 7,500 tomato varieties grown for various purposes. Heirloom tomatoes are becoming increasingly popular, particularly among home gardeners and organic producers, since they tend to produce more interesting and flavourful crops at the cost of disease resistance and productivity. In 1973, Israeli scientists developed the world's first long shelf-life commercial tomato varieties.

Tomatoes are now eaten freely throughout the world. They contain the carotene lycopene, one of the most powerful natural antioxidants. In some studies, lycopene, especially in cooked tomatoes, has been found to help prevent prostate cancer, but other research contradicts this claim. Lycopene has also been shown to improve the skin's ability to protect against harmful UV rays. Natural genetic variation in tomatoes and their wild relatives has given a genetic plethora of genes that produce lycopene, carotene, anthocyanin, and other antioxidants. Tomato varieties are available with double the normal vitamin C, high levels of anthocyanin (resulting in blue tomatoes), and two to four times normal amount of lycopene (numerous available cultivars with the high crimson gene).

Active breeding programs are ongoing by individuals, universities, corporations, and organizations. The Tomato Genetic Resource Centre, Germplasm Resources Information Network, AVRDC, Taiwan and numerous seed banks around the world store seed representing genetic variations of value to modern agriculture. These seed stocks are available for legitimate breeding and research efforts. While individual breeding efforts can produce useful results, the bulk of tomato breeding work is at universities and major agriculture-related corporations.

2.5 GENERAL ACCOUNT OF FIBRE-YIELDING PLANTS

2.5.1- Cotton

Cotton (*Gossypium* spp.) is a type of flowering plant that belongs to the family Malvaceae. Cultivation of cotton started approximately 7000 years ago in Mexico (New world) and in India and Pakistan (Old world). Out of roughly 43 species of cotton, only four are cultivated on a large scale. Cotton grows in tropical and subtropical parts of Asia, Africa, Australia and America. The greatest diversity of wild cotton species is found in Mexico, followed by Australia and Africa. Cotton was independently domesticated in the Old and New Worlds. People cultivate cotton because of the seed that represent valuable source of fibres and oil. Each year, around 25 million tons of cotton are produced in the 70 countries around the world. International cotton trade is 12 billion dollars worth business. China is the greatest manufacturer of cotton in the world. The fibre is almost pure cellulose.

The use of cotton for fabric is known to date to prehistoric times; fragments of cotton fabric dated from 5000 BC have been excavated in Mexico and the Indus Valley Civilization in Ancient India. Although cultivated since antiquity, it was the invention of the cotton gin that lowered the cost of production that led to its widespread use, and it is the most widely used natural fibre cloth in clothing today.

Cotton types

There are four commercially grown species of cotton, all domesticated in antiquity:

- *Gossypium hirsutum* – upland cotton, native to Central America, Mexico, the Caribbean and southern Florida (90% of world production)
- *Gossypium barbadense* – known as extra-long staple cotton, native to tropical South America (8% of world production)
- *Gossypium arboreum* – tree cotton, native to India and Pakistan (less than 2%)
- *Gossypium herbaceum* – Levant cotton, native to southern Africa and the Arabian Peninsula (less than 2%)

History of cultivation

The two New World cotton species account for the vast majority of modern cotton production, but the two Old World species were widely used before the 1900s. While cotton fibres occur naturally in colours of white, brown, pink and green, fears of contaminating the genetics of white cotton have led many cotton-growing locations to ban the growing of coloured cotton varieties, which remain a specialty product.

Historically cotton cultivation, in Old World, became more widespread during the Indus Valley Civilization, which covered parts of modern eastern Pakistan and north-western India.

Between 2000 and 1000 BC cotton became widespread across much of India. Cotton fabrics discovered in Mexico have been dated to around 5800 BC, although it is difficult to know for certain due to fibre decay.

India's cotton-processing sector gradually declined during British expansion in India and the establishment of colonial rule during the late 18th and early 19th centuries. Indian markets were increasingly forced to supply only raw cotton and were forced, by British-imposed law, to purchase manufactured textiles from Britain. The advent of the Industrial Revolution in Britain provided a great boost to cotton manufacture, as textiles emerged as Britain's leading export. From the late 18th century on, the British city of Manchester acquired the nickname *"Cottonopolis"* due to the cotton industry's omnipresence within the city, and Manchester's role as the heart of the global cotton trade.

Cultivation

Successful cultivation of cotton requires a long frost-free period, plenty of sunshine, and a moderate rainfall, usually from 600 to 1,200 mm. Soils usually need to be fairly heavy, although the level of nutrients does not need to be exceptional. In general, these conditions are met within the seasonally dry tropics and subtropics in the Northern and Southern hemispheres, but a large proportion of the cotton grown today is cultivated in areas with less rainfall that obtain the water from irrigation.

Genetically modified cotton

Genetically modified (GM) cotton was developed to reduce the heavy reliance on pesticides. GM cotton acreage in India grew at a rapid rate, increasing from 50,000 hectares in 2002 to 10.6 million hectares in 2011. The GM cotton was grown on 88% of the cotton area. This made India the country with the largest area of GM cotton in the world. Cotton has been genetically modified for resistance to glyphosate a broad-spectrum herbicide discovered by Monsanto which also sells some of the Bt cotton seeds to farmers. There are also a number of other cotton seed companies selling GM cotton around the world. About 62% of the GM cotton grown from 1996 to 2011 was insect resistant, 24% stacked product and 14% herbicide resistant.

Production and International trade

The largest producers of cotton, currently, are China and India, with annual production of about 34 million bales and 27 million bales, respectively; most of this production is consumed by their respective textile industries. The largest exporters of raw cotton are the United States, with sales of $4.9 billion, and Africa, with sales of $2.1 billion. The total international trade is estimated to be $12 billion.

In India, the states of Maharashtra (26.63%), Gujarat (17.96%) and Andhra Pradesh (13.75%) and also Madhya Pradesh are the leading cotton producing states, these states have a predominantly tropical wet and dry climate. In Pakistan, cotton is grown predominantly in the provinces of Punjab, and Sindh. The leading area of cotton production is the south Punjab, comprising the areas around. In the United States, the state of Texas led in total production as of 2004, while the state of California had the highest yield per acre.

Uses

Cotton is used to make a number of textile products. These include terrycloth for highly absorbent bath towels and robes; denim for blue jeans; cambric, popularly used in the manufacture of blue work shirts (from which we get the term "blue-collar"); and corduroy, seersucker, and cotton twill. Socks, underwear, and most T-shirts are made from cotton. Bed sheets often are made from cotton. Cotton also is used to make yarn used in crochet and knitting. Fabric also can be made from recycled or recovered cotton that otherwise would be thrown away during the spinning, weaving, or cutting process. While many fabrics are made completely of cotton, some materials blend cotton with other fibres, including rayon and synthetic fibres such as polyester. It can either be used in knitted or woven fabrics, as it can be blended with elastine to make a stretchier thread for knitted fabrics, and apparel such as stretch jeans.

In addition to the textile industry, cotton is used in fishing nets, coffee filters, tents, explosives manufacture, cotton paper, and in bookbinding. The name Egyptian cotton is broadly associated with quality products, however only a small percentage of Egyptian cotton production is actually of superior quality. Most products bearing the name are not made with the finest cottons from Egypt.

Cotton genome

A public genome sequencing effort of cotton was initiated in 2007 by a consortium of public researchers. They agreed on a strategy to sequence the genome of cultivated, tetraploid cotton. "Tetraploid" means that cultivated cotton actually has two separate genomes within its nucleus, referred to as the A and D genomes. The sequencing consortium first agreed to sequence the D-genome relative of cultivated cotton (*G. raimondii*, a wild Central American cotton species) because of its small size and limited number of repetitive elements. It is nearly one-third the number of bases of tetraploid cotton (AD), and each chromosome is only present once. The A genome of *G. arboreum* would be sequenced next. Its genome is roughly twice the size of *G. raimondii*'s. The public sector effort continues with the goal to create a high-quality, draft genome sequence from reads generated by all sources.

2.5.2- Jute

Jute, popularly called the 'Golden Fibre', is a plant that yields a fibre used for sacking and cordage. Jute is a long, soft, shiny vegetable fibre that can be spun into coarse, strong threads. It is produced from plants in the genus *Corchorus*, which was once classified with the family Tiliaceae, more recently with Malvaceae, and has now been reclassified as belonging to the family Sparrmanniaceae. The primary source of the fibre is *Corchorus olitorius*, but it is considered inferior to *Corchorus capsularis*.

Cultivation

Jute is one of the most affordable natural fibres and is second only to cotton in amount produced and variety of uses of vegetable fibres. Jute fibres are composed primarily of the plant materials cellulose and lignin. It falls into the bast fibre category (fibre collected from bast, the phloem of the plant, sometimes called the "skin”). The industrial term for jute fibre is *raw jute*. The fibers are off-white to brown, and 1- 4 m long.

Jute needs a plain alluvial soil and standing water. The suitable climate for growing jute (warm and wet) is offered by the monsoon climate, during the monsoon season. Temperatures from 20˚C to 40˚C and relative humidity of 70%–80% are favourable for successful cultivation. Jute requires 5–8 cm of rainfall weekly, and more during the sowing time. Soft water is necessary for the jute production.

White jute (*Corchorus capsularis*): Historical documents (including *Ain-e-Akbari* by Abul Fazal in 1590) state that the poor villagers of India used to wear clothes made of jute. Simple handlooms and hand spinning wheels were used by the weavers, who used to spin cotton yarns as well. History also states that Indians, especially Bengalis, used ropes and twines made of white jute (*Corchorus capsularis)* from ancient times for household and other uses. It is highly functional in carrying grains or other agricultural products.

Tossa jute (*Corchorus olitorius*): Tossa jute (*Corchorus olitorius*) is a variety thought to be native to India, and is also the world's top producer. It is grown for both fibre and culinary purposes. It is used as a herb in Middle Eastern and African countries, where the leaves are used as an ingredient in a mucilaginous potherb. It is high in protein, vitamin C, beta-carotene, calcium, and iron.

History

For centuries, jute has been an integral part of the culture of East Bengal, in the entire southwest of Bangladesh. Since the seventeenth century the British East India Company started trading in Jute. During the reign of the British Empire Jute was also used in the military. British jute barons grew rich processing jute and selling manufactured products made from jute. Dundee Jute Barons and the British East India Company set up many jute mills in Bengal and by 1895 jute industries in Bengal overtook the Scottish jute trade.

Production

Jute production is concentrated mostly in India's states of Assam, Bihar, and West Bengal, and Bangladesh. India is the world's largest producer of jute. However, India, Pakistan, and China import significant quantities of jute fibre and products from Bangladesh, as does the United Kingdom, Japan, United States, France, Spain, Côte d'Ivoire, Germany and Brazil.

Uses

Jute is in great demand due to its cheapness, softness, length, lustre and uniformity of its fibre. It is also called the 'golden fibre' due to its versatile nature. It is called the 'brown paper bag' as it is also used to store rice, wheat, grains, etc.

Jute is the second most important vegetable fibre after cotton due to its versatility. Jute is used chiefly to make cloth for wrapping bales of raw cotton, and to make sacks and coarse cloth. The fibres are also woven into curtains, chair coverings, carpets, area rugs, hessian cloth, and backing for linoleum.

Diversified byproducts from jute can be used in cosmetics, medicine, paints, and other products.

2.5.3-Coconut

Coconut tree (*Cocos nucifera*) is a plant that belongs to the family Arecaceae. The term coconut can refer to the entire coconut palm, the seed, or the fruit, which, botanically, is a drupe, not a nut. There are over 150 species of coconuts that can be found in 80 different countries throughout the world. Coconut tree grows only in the tropical climate. This plant live on the sandy soil, requires a lot of sunlight and regular rainfalls. Coconut tree does not tolerate low temperatures and low percent of humidity. Cultivated plants are prone to insect attacks which can decrease production of fruit worth of hundreds of million dollars.

Description

The coconut is known for its great versatility as seen in the many uses of its different parts and found throughout the tropics and subtropics. Coconuts are part of the daily diets of many people. Coconuts are different from any other fruits because they contain a large quantity of "water" and when immature they are known as tender-nuts or jelly-nuts and may be harvested for drinking. When mature, they still contain some water and can be used as seednuts or processed to give oil from the kernel, charcoal from the hard shell and coir from the fibrous husk. The endosperm is initially in its nuclear phase suspended within the coconut water. As development continues, cellular layers of endosperm deposit along the walls of the coconut, becoming the edible coconut "flesh". When dried, the coconut flesh is called copra. The oil and milk derived from it are commonly used in cooking and frying; coconut oil is also widely used in soaps and cosmetics. The clear liquid coconut water within is potable. The husks and leaves can be used as material to make a variety of products for furnishing and decorating. The coconut also has cultural and religious significance in many societies that use it.

Cocos nucifera is a large palm, growing up to 30 m tall. Coconuts are generally classified into two general types: tall and dwarf. On very fertile land, a tall coconut palm tree can yield up to 75 fruits per year, but more often yields less than 30, mainly due to poor cultural practices.

Botanically, the coconut fruit is a drupe, not a true nut. Like other fruits, it has three layers: the exocarp, mesocarp, and endocarp. The exocarp and mesocarp make up the "husk" of the coconut. Coconuts sold in the shops of nontropical countries often have had the exocarp (outermost layer) removed. The mesocarp is composed of a fibre, called coir, which has many traditional and commercial uses. The shell has three germination pores (stoma) or "eyes" that are clearly visible on its outside surface once the husk is removed. A full-sized coconut weighs about 1.44 kg. It takes around 6,000 full-grown coconuts to produce a tonne of copra. The palm produces both the female and male flowers on the same inflorescence; thus, the palm is monoecious. Other sources use the term polygamomonoecious. The female flower is much larger than the male flower. Flowering occurs continuously. Coconut palms are believed to be largely cross-pollinated, although some dwarf varieties are self-pollinating.

Origin, domestication and dispersal

The origin of the plant is the subject of debate. It has been hypothesized that the coconut originated in the Americas. However, more evidence exists for an Indo-Pacific origin either around Melanesia and Malesia or the Indian Ocean. The oldest fossils known of the modern coconut dating from the Eocene period from around 37 to 55 million years ago were found in Australia and India. However, older palm fossils such as some of nipa fruit have been found in the Americas.

Among modern *C. nucifera*, two major types or variants: a thick-husked, angular fruit and a thin-husked, spherical fruit with a higher proportion of endosperm reflect a trend of cultivation in *C. nucifera*. Variants of *C. nucifera* are also categorized as Tall (var. *typical*) or Dwarf (var. *nana*). The two groups are genetically distinct, with the Dwarf variety showing a greater degree of artificial selection for ornamental traits and for early germination and fruiting. The Tall variety is outcrossing while Dwarf palms are incrossing, which has led to a much greater degree of genetic diversity within the Tall group. It is believed that the Dwarf subgroup mutated from the Tall group under human selection pressure.

The coconut has spread across much of the tropics, probably aided in many cases by seafaring people. Coconut fruit in the wild are light, buoyant and highly water resistant, and evolved to disperse significant distances via marine currents.

Cultivation and production

The coconut palm thrives on sandy soils and is highly tolerant of salinity. It prefers areas with abundant sunlight and regular rainfall (1500 mm to 2500 mm annually), which makes colonizing shorelines of the tropics relatively straightforward. Coconuts also need high humidity (70–80%) for optimum growth, which is why they are rarely seen in areas with low humidity, like the south-eastern Mediterranean or Andalusia (Spain), even where temperatures are high enough (regularly above 24 °C or 75.2 °F). However, they can be found in humid areas with low annual precipitation such as in Karachi, Pakistan, which receives only about 250 mm (9.8 in) of rainfall per year, but is consistently warm and humid. Coconut palms require warm conditions for successful growth, and are intolerant of cold.

Coconut palms are grown in more than 90 countries of the world, with a total production of 62 million tonnes per year. Most of the world production is in tropical Asia. The extent of cultivation in the tropics is threatening a number of habitats, such as mangroves. In some parts of the world (Thailand and Malaysia), trained pig-tailed macaques are used to harvest coconuts. Training schools for pig-tailed macaques still exist both in southern Thailand and in the Malaysian state of Kelantan. Competitions are held each year to find the fastest harvester.

Traditional areas of coconut cultivation in India are the states of Kerala, Tamil Nadu, Karnataka, Puducherry, Andhra Pradesh, Goa, Maharashtra, Odisha, West Bengal and the islands of Lakshadweep and Andaman and Nicobar. Four southern states combined account for almost 92% of the total production in the country: Kerala (45.22%), Tamil Nadu (26.56%), Karnataka (10.85%), and Andhra Pradesh (8.93%). Other states, such as Goa, Maharashtra, Odisha, West Bengal, and those in the northeast (Tripura and Assam) account for the remaining 8.44%. Kerala, which has the largest number of coconut trees, is famous for its coconut-based products—coconut water, copra, coconut oil, coconut cake (also called coconut meal, copra cake, or copra meal), coconut toddy, coconut shell-based products, coconut wood-based products, coconut leaves, and coir pith.

Uses

The coconut palm is grown throughout the tropics for decoration, as well as for its many culinary and nonculinary uses; virtually every part of the coconut palm can be used by humans in some manner and has significant economic value and is commonly called the "tree of life".

The culinary uses will be discussed in Unit 3 (under oilseed crops). In this section the use of coconut as coir (fibre) will only be described.

Coir (the fibre from the husk of the coconut) is used in ropes, mats, door mats, brushes, sacks, caulking for boats, and as stuffing fibre for mattresses. It is used in horticulture in potting compost, especially in orchid mix. Red coir is used in floor mats and doormats, brushes, mattresses, floor tiles and sacking. A small amount is also made into twine. Pads of curled brown coir fibre, made by needle-felting (a machine technique that mats the fibres together), are shaped and cut to fill mattresses and for use in erosion control on river banks and hillsides. A major proportion of brown coir pads are sprayed with rubber latex which bonds the fibres together (rubberised coir) to be used as upholstery padding for the automobile industry in Europe. The material is also used for insulation and packaging. The major use of white coir is in rope manufacture.

2.6 GENERAL ACCOUNT OF TIMBER-YIELD FOREST SPECIES

2.6.1-Teak

Teak is a tropical hardwood species of tree known as *Tectona grandis*. The species is placed in the family Lamiaceae. It is also known as C.P.Teak , Nagpur Teak in English. It is sometimes known as the "Burmese Teak". *Tectona grandis* is a large, deciduous tree that is dominant in mixed hardwood forests. It has small, fragrant white flowers and papery leaves that are often hairy on the lower surface. Teak wood has a leather-like smell when it is freshly milled. Teak timber is particularly valued for its durability and water resistance, and is used for boat building, exterior construction, veneer, furniture, carving, turnings, and other small wood projects.

Origin and distribution

The tree is native to south and southeast Asia, mainly India, Sri Lanka, Indonesia, Malaysia, Thailand and Burma, but is naturalized and cultivated in many countries in Africa and the Caribbean. Burma accounts for nearly one third of the world's total teak production. The other two species, *T. hamiltoniana* and *T. philippinensis*, are endemics with relatively small native distributions in Myanmar and the Philippines, respectively.

Description

Teak is a beautiful wood, valued not only for its grain quality and hue, but also for its strength and resistance to rot and mould. Teak wood has a multitude of uses, such as, the manufacture of outdoor furniture, the best available parquet flooring, sail boat decks and even for electrical insulation in harsh, dry desert conditions.

Teak can grow up to 50 m high with a girth of well over 1 m. A mature tree will have a rounded crown and, under favourable conditions, a tall clean cylindrical trunk, which is often buttressed at the base. The trees typically enjoy deep soils that are well drained and rich in calcium. They will flourish where there is an average yearly temperature of 27^oC and generous rainfall; although a 3 to 4 month dry season is necessary. Teak is one of the world's most valuable hardwood varieties. The rare beauty of teak, with its golden brown lustre, decorative grain and unique properties have made it one of the most demanded exotic woods of the world.

Uses

On land teak has a multitude of uses, doors, window frames, sculptures, exterior joinery, interior and exterior furniture. Teak flooring in a variety of sizes and designs enhances the beauty and the value of any room. The chemical industry recognises many applications for teak because of its durability and resistance to harsh chemicals. Teak has been used extensively in the oil fields of the Middle East as it is the only wood in the world that can withstand the harsh, dry desert conditions and not conduct electrical sparks that could cause a deadly explosion. Another outstanding feature of teak is its ability to withstand all types of climatic conditions. Teak is extremely resistant to rot and has resins (techno-quinine) that naturally repel termites.

Teak's high oil content, high tensile strength and tight grain makes it particularly suitable for outdoor furniture applications. Teak is used extensively in India to make doors and window frames, furniture, and columns and beams in old type houses. It is very resistant to termite attacks and damage caused by other insects. Mature teak fetches a very good price. It is grown extensively by forest departments of different states in forest areas.

Leaves of the teak wood tree are used in making Pellakai gatti (jackfruit dumpling), where batter is poured into a Teak leaf and is steamed. This type of usage is found in the coastal district of Udupi in the Tulunadu region in South India.

Teak has been used as a boatbuilding material for over 2000 years. In addition to relatively high strength, teak is also highly resistant to rot, fungi and mildew. In addition, teak has a relatively low shrinkage ratio, which makes it excellent for applications where it undergoes periodic changes in moisture.

The oldest and biggest teak in the world is in Uttaradit Province, Thailand. It is more than 1,500 years old. The tree is 47 metres tall, and the circumference of the trunk is 10.23 metres.

2.6.2-Shisham

Shisham (Indian rosewood, *Delbergia sissoo*) is a medium to large deciduous tree, native to India, with a light crown which reproduces by seeds and suckers. It belongs to family Fabaceae.

Description

It can grow up to a maximum of 25 m in height and 2m to 3m in diameter, but is usually smaller. It has been established in irrigated plantations, along roadsides and canals, and around farms and orchards as windbreaks. *Dalbergia sissoo* is best known internationally as a premier timber species of the rosewood genus. However, *sissoo* is also an important fuelwood, shade, shelter and fodder tree. With its multiple products, tolerance of light frosts and long dry seasons, this species deserves greater consideration for agroforestry applications.

Shisham is among the finest cabinet, furniture and veneer timbers. The heartwood is golden to dark brown, and sapwood white to pale brownish white. The heartwood is extremely durable and is resistant to dry-wood termites. Young branches and foliage form an excellent fodder with dry-matter content.

Uses

It is used for high-quality furniture, cabinets, decorative veneer, marine and aircraft grade plywood, ornamental turnery, carving, engraving, tool handles and sporting goods. Its root wood is used for tobacco pipes.

Oil obtained from the seeds is used to cure skin diseases. The powdered wood, applied externally as a paste, is reportedly used to treat leprosy and skin diseases. The roots contain tectoridin, which is used medicinally.

The calorific value of both the sapwood and heartwood is 'excellent', being reported to be 4,908 kcal/kg and 5,181 kcal/kg respectively. As a fuel wood it is grown on a 10 to 15-year rotation. The tree has excellent coppicing ability, although a loss of vigour after two or three rotations has been reported. *Shisham* wood makes excellent charcoal for heating and cooking.

Propagation

Propagation takes place most commonly by root suckers and also by seeds. The seeds remain viable for only a few months. Seeds should be soaked in water for 48 hours before sowing and 60% – 80% germination can be expected in 1–3 weeks. Seedlings require partial sun or full sun.

2.6.3-Sal

Sal *(Shorea robusta*) is a tall handsome tree providing very good quality timber and belongs to the Dipterocarpaceae family. Sal is a gregarious species and it forms the dominant composition in the forests where it occurs. It grows well in a well-drained, moist, sandy loam soil. It is a moderate to slow growing species and can attain a height upto 35 m and a girth of about 2 to 2.5 m in about 100 years under favourable conditions.

Distribution and description

Sal trees are found from Burma in the East, to Assam, Bengal, Nepal, the Deccan Plateau, going up to the foothills of the Shivaliks on the left bank of the Yamuna river. In Haryana, Sal can be found in the Morni Hills and the Kalesar forest. Sal grows well in low height plains to foothills viz. Shivaliks from 200 to 1200 meters above mean sea level. But Sal growing in Nepal and Singhbhum district of Bihar are considered to be the best variety.

The bole of Sal tree is erect and cylindrical. Sal tree is seldom completely leafless. In dry regions, however, it tends to shed practically all leaves for a short period from February to April. Fresh leaves appear during April to May depending upon the local climate.

The sap wood in Sal is of small thickness. It is whitish in colour and less durable. Heart wood is pale when freshly cut and tends to grow dark brown on exposure. It is coarse grained, hard and of fibrous structure. Annual rings are visible in young trees or on freshly cut wood. Its pores are of moderate size. These are filled with a kind of resin which makes the wood naturally durable.

Uses

Sal wood is one of the three naturally lasting timbers of the Asian subcontinent, the other two being Teak and Deodar. It weighs nearly 25 to 30 kg to a cubic foot. It is difficult to plane and more so to drive a nail in to it. It is accordingly considered most suitable for railway sleepers, piles, beams and other load bearing parts of bridge structures, wheels and bodies of carts and other similar load carriers, including motor trucks, super structure of house tops, etc. In fact Sal wood is most suitable for all such applications where strength and elasticity are foremost requirements, and where polishing is not very essential.

Sal tree when tapped yields white opaline resin which is burnt as incense in Hindu homes during religious ceremonies. It is also used for caulking boats and ships. The seeds are used for fat extraction. The oilcake, though rich in tannins (5-8%), has been used in proportions of up to 20% in concentrates for cattle without detrimental effects. As the protein remains completely undigested, the oilcake yields energy only. Sal seed cake can constitute up to 10% of poultry and pig rations without changes in performance. A kind of oil is also obtained from sal fruit which is used for burning in earthen lamps.

Religious significance

The Sal tree worshipped among Buddhists and Hindus in India and the adjoining countries. The legend has it that the famous Lumbini tract where Lord Buddha had sat for meditation and acquired salvation constituted a thick forest of Sal trees.

Regeneration

The healthy forests of Sal in their original habitat like Singhbhum (Bihar) and Doon valley (Uttarakhand) regenerate on their own. In less favourable areas these need continuous assistance for regeneration. These causes and remedies for the difficulty of Sal regeneration are an important subject of research at the National Institute of Forestry and Environment, Dehradun. They are also conducting studies into the insects and bacteria afflicting the healthy growth of Sal trees.

2.6.4-Chir-Pine

Pinus roxburghii (known as chir pine) is a species of pine native to the Himalayas, and was named after William Roxburgh. *P. roxburghii* is a large evergreen tree, which is sometimes deciduous in dry locations or dry seasons. The geographical range of occurrence of *P. roxburghii* extends from northern Pakistan, across northern India and Nepal to Bhutan. It generally occurs at lower altitudes than other pines in the Himalaya, from 500–2,000 m, occasionally up to 2,300 m. The other Himalayan pines are *Pinus wallichiana* (blue pine), *Pinus bhutanica* (Bhutan white pine), *Pinus armandii* (Chinese white pine), *Pinus gerardiana* (chilgoza pine) and *Pinus densata* (Sikang pine).

Description

P. roxburghii commonly attains a height of 45-55 m, with a diameter at breast height of 110-120 cm. The branches are very large, whorled and the crown is elongated up until reasonable maturity. As the tree matures, the crown becomes either pyramid-shaped, spreading, rounded or umbrella-shaped, with a large branch system. *P. roxburghii* is a long-lived tree. The bark is red-brown, thick and deeply fissured at the base of the trunk, thinner and flaky in the upper crown. The leaves are needle-like, in fascicles of three, very slender, 20–35 cm long, and distinctly yellowish green. The cones are ovoid conic, 12–24 cm long and 5–8 cm broad at the base when closed, green at first, ripening glossy chestnut-brown when 24 months old. They open slowly over the next year or so, or after being heated by a forest fire, to release the seeds, opening to 9–18 cm broad. The seeds are 8–9 mm long, with a 40 mm wing, and are wind-dispersed.

Uses

Chir pine is widely planted for timber in its native area, being one of the most important trees in forestry in northern Pakistan, India and Nepal. For local building purposes, the wood of this tree is the least preferred, as it is the weakest and most prone to decay when compared with other conifers. Old trees which die from fire or drought, undergo some metamorphosis in their wood due to the crystallization of the resin inside the heart wood. This makes the wood become brightly coloured and very aromatic with a brittle, glassy feel. This form of wood is very easy to ignite. Every autumn, the dried needles of this tree form a dense carpet on the forest floor, which the locals gather in large bundles to serve as bedding for their cattle, for the year round. The green needles are also used to make tiny hand brooms.

It is also tapped commercially for resin. On distillation, the resin yields an essential oil, commonly known as turpentine, and non-volatile rosin. The proportion of rosin and turpentine oil in chir pine is 75% and 22%, respectively, with 3% losses, etc. The turpentine is chiefly used as a solvent in pharmaceutical preparations, perfume industry, in manufacture of synthetic pine oil, disinfectants, insecticides and denaturants. It is one of the most important basic raw materials for the synthesis of terpene chemicals which are used in a wide variety of industries such as adhesives, paper and rubber, etc.

Chir pine rosin is principally used in paper, soap, cosmetics, paint, varnish, rubber and polish industries. Besides these, other uses include manufacture of linoleum, explosives, insecticides and disinfectants, as a flux in soldering, in brewing and in mineral beneficiation as a frothing agent.

Presently, India imports resin which is far superior in quality as well as cheaper than the indigenous one. Quality of resin depends on the pinene content. Imported resin contains 75–95% pinenes, whereas chir pine resin contains only about 25% pinenes.

2.6.5-Deodar

Deodar *(Cedrus deodara)* is a species of cedar native to the western Himalayas in eastern Afghanistan; northern Pakistan; north-western Indian Himalayas; south-westernmost Tibet (in China) and western Nepal, occurring at 1,500–3,200 m altitude. It is a large evergreen coniferous tree reaching 40–50 m tall, exceptionally 60 m with a trunk up to 3 m in diameter. It has a conic crown with level branches and drooping branchlets. The leaves are needle-like, mostly 2.5–5 cm long, occasionally up to 7 cm long, slender (1 mm thick), borne singly on long shoots, and in dense clusters of 20–30 on short shoots; they vary from bright green to blue-green in colour. The female cones are barrel-shaped, 7–13 cm long and 5–9 cm broad, and disintegrate when mature (in 12 months) to release the winged seeds. The male cones are 4–6 cm long, and shed their pollen in autumn.

Cultural significance

Among Hindus, as the etymology of deodar suggests, it is worshiped as a divine tree. Deva, the first half of the Sanskrit term, means *divine*, *deity*, or *deus*. Dāru, the second part, is cognate with (related to) the words *durum*, *druid*, *tree*, and *true*.

Forests full of Deodar trees were the favourite living place of ancient Indian sages and their families who were devoted to the Hindu God Shiva. To please Lord Shiva, the sages used to perform very difficult tapasya (meditation) practices in deodar forests. Also the ancient Hindu epics and Shaivite texts regularly mention *Darukavana*, meaning a forest of deodars, as a sacred place.

Cultivation and uses

It is widely grown as an ornamental tree, often planted in parks and large gardens for its drooping foliage. General cultivation is limited to areas with mild winters, with trees frequently killed by temperatures below about −25 °C, limiting it to USDA zone 7 and warmer for reliable growth. The most cold-tolerant trees originate in the northwest of the species' range in Kashmir and Paktia Province, Afghanistan.

Deodar is in great demand as building material because of its durability, rot-resistant character and fine, close grain, which is capable of taking a high polish. Its historical use to construct religious temples and in landscaping around temples is well recorded. Its rot-resistant character also makes it an ideal wood for constructing the well-known houseboats of Srinagar, Kashmir. In Pakistan and India, during the British colonial period, deodar wood was used extensively for construction of barracks, public buildings, bridges, canals and railway cars. Despite its durability, it is not a strong timber, and its brittle nature makes it unsuitable for delicate work where strength is required, such as chair-making.

The use of *C. deodara* in Ayurvedic medicines is well recorded. The inner wood is aromatic and used to make incense. Inner wood is distilled into essential oil. As insects avoid this tree, the essential oil is used as insect repellent on the feet of horses, cattle and camels. It also has anti-fungal properties and has some potential for control of fungal deterioration of spices during storage. The outer bark and stem are astringent. Due to its anti fungal and insect repellent properties, rooms made of Deodar wood are used to store meat and food grains like oats and wheat in Shimla, Kullu and Kinnaur district of Himachal Pradesh. In Himachal people suffering from asthma or other respiratory problems are advised to sit under a Deodar tree early in the morning.

Cedar oil is often used for its aromatic properties, especially in aromatherapy. It has a characteristic woody odour which may change somewhat in the course of drying out. The crude oils are often yellowish or darker in colour. Its applications cover soap perfumes, household sprays, floor polishes and insecticides and are also used in microscope work as a clearing oil.

The bark of *Cedrus deodara* contains large amounts of taxifolin. The wood contains cedeodarin (6-methyltaxifolin), dihydromyricetin (ampelopsin), cedrin (6-methyldihydromyricetin), cedrinoside and deodarin (3′,4′,5,6-tetrahydroxy-8-methyl dihydroflavonol). The main components of the needle essential oil include α-terpineol (30.2%), linalool (24.47%), limonene (17.01%), anethole (14.57%), caryophyllene (3.14%) and eugenol (2.14%). The deodar cedar also contains lignans and the phenolic sesquiterpene himasecolone together with isopimaric acid.

2.7 SUMMARY

Fruit and vegetables should be an important part of your daily diet. They are naturally good and contain vitamins and minerals that can help to keep you healthy. They can also help protect against some diseases. Fruits and vegetables contain many vitamins and minerals that are good for your health. These include vitamins A (beta-carotene), C and E, magnesium, zinc, phosphorous and folic acid. Folic acid may reduce blood levels of homocysteine, a substance that may be a risk factor for coronary heart disease. Fruits and vegetables are low in fat, salt and sugar. They are a good source of dietary fibre. As part of a well-balanced, regular diet and a healthy, active lifestyle, a high intake of fruit and vegetables can help you to: Reduce obesity and maintain a healthy weight; Lower your cholesterol, and Lower your blood pressure. Fruits are usually eaten raw and come in a wide variety of colours, shapes and flavours. Mango, apple, banana, citrus, litchi are important fruit species from Indian context. Similarly cucurbits, okra, brinjal, tubers, yams, many leafy vegetables, etc. are important vegetables in Indian context. Fruits and vegetables work as excellent substitutes in different recipes.

Fibre crops are plants that are intentionally grown or otherwise managed for the production of fibres or fibrous materials with varied uses but not for dietary purposes. Jute is one of the most affordable natural fibers and is second only to cotton in amount produced and variety of uses of vegetable fibers. Coir, the fibre from the coconut husk also has varied uses.

India is blessed with a variety of timber-yielding tree species. Important among these are teak, Sal, Shisham, Chir-pine and deodar. Teak is moderately hard, durable and fire-resistant. It can be easily seasoned and worked. It is among the most valuable timber trees of the world and its use is limited to superior work only. Sal is hard, fibrous and close-grained. It is durable underground and water and used for railway sleepers, shipbuilding, and bridges.
Moderately hard, teak is durable and fire-resistant. It can be easily seasoned and worked. It takes up a good polish and is not attacked by white ants and dry rot. It does not corrode iron fastenings and it shrinks little. It is among the most valuable timber trees of the world and its

use is limited to superior work only. Shisham wood is strong and tough. It can be easily seasoned. It is used for high quality furniture, plywoods, bridge piles, sport goods, railway sleepers and so forth. It is a very good material for decorative works and carvings. Chir-pine wood is hard and tough. It decays easily if it comes into contact with soil. It is also tapped commercially for resin. Deodar is the most important timber tree providing soft wood. It can be easily worked and it is moderately strong. It possesses distinct annual rings. It is used for making cheap furniture, railway carriages, railway sleepers, packing boxes, structural work and so forth.

2.8 GLOSSARY

Achene: An achene is a kind of dry, indehiscent one-seeded fruit with a leathery pericarp that is easily separated from the seed coat.
Fruit: The edible part of a plant, shrub, or tree also developed from a flower and consisting of one or more seeds and the mass of juicy flesh that is used as food.
Grapefruit: A tropical citrus fruit that is characterized by its slightly bitter taste. Grapefruit is usually about the size of a softball and larger, has a skin that is usually yellow in color and very fleshy that ranges in color from yellowish-white to deep ruby red. Like other citrus fruits, grapefruit is an excellent source of vitamin C.
Kaffir Lime: A variety of lime that is small, round and then pointed at the end with a gnarled outer skin that emits a sharp lemon-like aroma. The Kaffir lime is not measured to be a direct member of the lime species. Instead it is categorized as one of the subspecies of citrus fruits, which are linked to the lime family. Since the flesh of the Kaffir is not edible, it is the grated peel and leaves most commonly used for foods. The rind and leaves of the lime are second-hand in recipes for curry pastes, soups, fish, shellfish, meat, poultry, vegetables, marinades, and chutneys, adding a distinct citrus smell and flavour
Lemon: An oval or round shaped bright yellow citrus fruit that is sought for its tart flavored, highly acidic juice and skin. This type is most often available are the common lemon and also the Meyer lemon. The common lemon is larger in size and very bright yellow in color and has either a smooth skin or a rough, somewhat knobby skin. The smooth skinned lemons are good for cooking or juicing while the rough skinned lemons are best for grating.
Lime: In botany, small shrub like tree (*Citrus aurantifolia*) of the family Rutaceae (rue family), one of the citrus fruit trees are similar to the lemon but more spreading and very irregular in growth. The true lime, a natural hybrid of the citron and papeda, is native to SE Asia and was introduced into S Europe, the West Indies, Mexico, Florida, and California.
Mesocarp: Mesocarp in a botanical term for the succulent and fleshy middle layer of the pericarp of drupaceous fruit, between the exocarp and very endocarp; it is usually the part of the fruit, which is eaten. The term may also refer to any fruit which is fleshy throughout.
Nuts: An edible dry fruit and seed enclosed with a hard shell that protects the kernel or meat inside. Usually, the shell is removed and discarded and only the kernel, known as the nut, inside is the item to be eaten. Nuts are available shelled and unshelled as well and the shelled nuts are available blanched or unbalanced, whole or chopped, halved, minced, raw, oil

roasted, dry-roasted, salted, unsalted, and also coated with a flavoring. Nuts are also available ground as powders and butters. Some common varieties of foods referred to as nuts include: almonds, cashews, chestnuts, hazelnuts, hickory nuts, macadamias, peanuts, pecans, pine nuts, soy nuts, sunflower seeds, and also walnuts.

Stone fruits: Fruits also known as drupes - with one or more seeds surrounded by fleshy, normally edible tissue. They are often in the genus Prunes. Example: apricots, plums, cherries and mangoes.

Broccoli: Broccoli is closely related to cabbage - and it's another one of those 'greens' we're always being told to eat up. The part of a broccoli plant we normally eat is the lovely flower head - the flowers are usually green but sometimes purple. Steamed broccoli is tasty in a salad or stir-fry.

Brussels sprout: Brussels sprouts are like mini cabbages! They grow out of the ground in knobbly rows on a long tough stalk. They contain loads of vitamin C. Can you guess which country Brussels sprouts originally came from? Well, Brussels is the capital city of Belgium.

Courgette: A courgette is a type of squash and if it isn't picked early, it grows into a marrow! Courgettes grow on bushes. They look quite like cucumbers and have very soft seeds. They can be cooked with onions, tomatoes, aubergines and peppers to make ratatouille. The American name for a courgette is 'zucchini'.

Leek: These are in the same family as onion and garlic – they are Allium vegetables. Leeks need to be washed well to remove any dirt and grit between the white sections. You can boil or steam leeks to add to a recipe or stir-fry them with other vegetables. They are in season in the UK. Over the winter months and are a good source of fibre.

Yam: The skin of a yam is thick and rough like the bark of a tree! Yams are a bit like potatoes but their flesh can be white, yellow or even purple. They come from hot countries in the Caribbean and Africa, where people often mash them up and eat them in spicy stews and soups. A yam can grow to be heavier than a human adult.

Natural fibres: Natural fibres can be defined as substances produced by plants and animals that can be spun into filament, thread or rope and in a next step be woven, knitted, matted or bound.

Textile fibre: A textile or cloth is a flexible woven material consisting of a network of natural or artificial fibres often referred to as thread or yarn. Yarn is produced by spinning raw fibres of wool, flax, cotton, or other material to produce long strands.

Plant Fibre: Plant fibre is a material for many useful recipes, including Bandages. Plant Fibre is obtained by cutting vines in caves, cutting Giant Flowers from the Giant Flower Biome, cutting thick growth in Jungle Biomes, and at a lower drop rate, by harvesting crops

2.9 SELF ASSESSMENT QUESTIONS

2.9.1 Multiple choice questions:

1. Beside India, mango is a national fruit of-

(a) China (b) Myanmar

(c) Pakistan (d) Indonesia

2- The world leader in apple production is:
(a) India (b) China
(c) USA (d) Turkey

3- Which of the following *Musa* species is a hybrid
(a) *M. acuminata* (b) *M. Sapientum*
(c) *M. balbisiana* (d) *M. Paradisiacal*

4- The most recently discovered Australian lime is-
(a) *Clymenia sp.* (b) *Citrus reticulate*
(c) *C. maxima* (d) *Citrus* subg *Papeda*

5- Litchi is native to:
(a) India (b) China
(c) Malaysia (d) Indonesia

6- Onion is a modified stem and belongs to:
(a) Rhizome (b) Corm
(c) Bulb (d) Tuber

7- The chili peppers originated in:
(a) Americas (b) Near East
(c) Europe (d) Africa

8- Bamboos belong to-
(a) Root vegetables (b) Stem vegetables
(c) Leaf vegetables (d) Fruit vegetables

9- Tomato originated in
(a) South America (b) North America
(c) Asia (d) Europe

10- Of the four commercially grown species, cotton species native to India is:
(a) *Gossypium hirsutum* (b) *Gossypium barbadense*
(c) *Gossypium arboreum* (d) *Gossypium herbaceum*

11- 'Golden Fibre' is a popular name of-
(a) Cotton (b) Jute
(c) Coconut (d) Flax

12- Teak is native to-
(a) South and South-east Asia (b) Africa
(c) Australia (d) South America

13-The famous Lumbini tract where Lord Buddha had sat for meditation and acquired salvation constituted a thick forest of-

(a) Teak (b) Chir Pine

(c) Sal (d) Deodar

14- The chilgoza pine is the other Himalayan pines are (blue pine), *Pinus bhutanica* (Bhutan white pine), (Chinese white pine), (chilgoza pine) and (Sikang pine).

(a) *Pinus wallichiana* (b) *Pinus armandii*

(c) *Pinus gerardiana* (d) *Pinus densata*

15- Favourite living place of ancient Indian sages and their families who were devoted to the Hindu god Shiva were the forest tress of-

(a) Deodar (b) Teak

(c) Sal (d) Chir Pine

2.9.1 Answer Key: 1-(c), 2-(b), 3-(d), 4-(a), 5-(b), 6-(c), 7-(a), 8-(b), 9-(a), 10-(c), 11-(b), 12-(a), 13-(c), 14-(c), 15-(a)

2.9.2 Short Answer type Questions:

1. Is tomato a fruit or vegetable?
2. What is a natural fibre?
3. What is a textile fibre?
4. What are the three stages in the making of textile materials?
5. Various uses of chir pine.
6. The religious significance of sal and deodar trees.

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2.12 TERMINAL QUESTIONS

1. Beside India, which other countries mango is a national fruit?
2. Describe widespread uses of mango in Indian cuisines.
3. Name the wild ancestor of apple.
4. Write a note on global production of apple.
5. Write the difference between banana and plantain.
6. Name scientific names of different banana species depending on their genomic constitution.
7. Name the most important commercial banana cultivar sold in world market.
8. Describe in brief the taxonomy and systematics of the genus *Citrus*.
9. Describe the major citrus growing areas in the world
10. Describe the origin of litchi.
11. Give a general account of root, stem, fruit and leafy vegetables with special reference to India.
12. Define Bt brinjal. Why its commercial cultivation raises controversy in India?
13. Name the commercially grown species of cotton and write a note on its domestication.
14. Define GM cotton. Which country in the world is the largest producer of GM cotton?
15. Describe the cultural significance of jute in India.
16. Describe the importance of coconut as a fibre crop.
17. Give a general account of timber yielding plants of India.
18. Deodar tree is native to which part of the world? What is its cultural significance?

UNIT-3 MEDICINAL PLANTS, OILS AND BEVERAGES

3.1 OBJECTIVES

The major objectives of the present chapter are:

- To study origin, domestication, genetics, cultivation and production of medicinal plants, oils and beverages.
- To establish link between biology and anthropology and exploiting ways humans use medicinal plants, oils and beverages for medicinal, food and other purposes.

3.2 INTRODUCTION

Before there was modern-day medicine and its pharmacopeia of synthetic drugs, there were plants, and ancient civilizations knew how to use them strategically to treat common ailments and even life-threatening diseases. The ancient Egyptian Ebers Papyrus details 700 medicinal herbs and how to use them. The Greek Corpus Hippocraticum from the 16th century BC also details the use of herbal medicine. Later, during the 1800s and early 1900s, the knowledge of herbal medicine was passed down from one generation to the next. Typically, the woman of the house was well versed in the use of herbs for healing, and would act as the family's physician not only to treat illnesses but also to prepare various herbal wellness tonics and other remedies. Today, the World Health Organization (WHO) estimates that 80 percent of the world's population still uses traditional remedies, including plants, as their primary health care tools. Medicinal and other uses of *Aconitum*, *Atropa*, *Cinchona*, *Rauwolfia* and *Ephedra* are described here.

Oil-bearing crops or oil crops include both annual (usually called oilseeds) and perennial plants whose seeds, fruits or mesocarp and nuts are valued mainly for the edible or industrial oils that are extracted from them. Dessert and table nuts, although rich in oil, are listed under "Nuts". The important oil crops included in this chapter are castor, coconut, linseed, mustard and groundnut. Only 5-6 percent of the world production of oil crops is used for seed (oilseeds) and animal feed, while about 8 percent is used for food. The remaining 86 percent is processed into oil. The fat content of oil crops varies widely. Fat content ranges from as low as 10-15 percent of the weight of coconuts to over 50 percent of the weight of groundnut, mustard or castor seeds. Carbohydrates, mainly polysaccharides, range from 15 to 30 percent in the oilseeds, but are generally lower in other oil-bearing crops. The protein content is also high in some oilseeds.

The beverages are liquids, specifically prepared for human consumption. In addition to basic needs, beverages form a part of the culture of human society. Important beverage crops included in this chapter are tea, coffee and cocoa.

3.3 MEDICINAL PLANTS

3.3.1-*Aconitum*

Aconitum, also known as aconite, monkshood, wolf's bane, leopard's bane, mouse bane, women's bane, devil's helmet, Queen of all Poisons, or blue rocket, is a genus of over 250 species of flowering plants belonging to the family Ranunculaceae. These herbaceous perennial plants are chiefly native to the mountain meadows of the northern hemisphere. Most species are extremely poisonous and must be dealt carefully. The name may reflect that toxins extracted from the plant were historically used to kill wolves, hence the name *wolf's bane*. It has been noted that the symptoms of aconite poisoning in humans bear some passing similarity to those of rabies: frothy saliva, impaired vision, vertigo, and finally a coma.

Origin and cultivation

Aconitum napellus is endemic to western and central Europe. Plants native to Asia and North America formerly listed as *A. napellus* are now regarded as separate species. *A. napellus* is grown in gardens in temperate zones for their spiky inflorescences that are showy in early-midsummer, and their attractive foliage. There are white and rose coloured forms in cultivation too. The cultivar 'Spark's Variety' has gained the Royal Horticultural Society's Award of Garden Merit. Nine subspecies of *A. napellus* are accepted by the *Flora Europaea*.

Uses and toxicology

Several species of *Aconitum* have been used as arrow poisons. The Minaro in Ladakh use *A. napellus* on their arrows to hunt ibex, while the Ainu in Japan used a species of *Aconitum* to hunt bear. The Chinese also used *Aconitum* poisons both for hunting and for warfare. Aconitum poisons were used by the Aleuts of Alaska's Aleutian Islands for hunting whales. Usually, one man in a kayak armed with a poison-tipped lance would hunt the whale, paralyzing it with the poison and causing it to drown.

Like other species in the genus, *A. napellus* contains several poisonous compounds, including enough cardiac poison that it was used on spears and arrows for hunting and battle in ancient times. *A. napellus* has a long history of use as a poison, with cases going back thousands of years. During the ancient Roman period of European history, the plant was often used to eliminate criminals and enemies, and by the end of the period it was banned and anyone growing *A. napellus* could have been legally sentenced to death. Aconites have been used more recently in murder plots; they contain the chemical alkaloids aconitine, mesaconitine, hypaconitine and jesaconitine, which are highly toxic.

Marked symptoms may appear almost immediately, usually not later than one hour, and with large doses death is almost instantaneous. The initial signs are gastrointestinal including nausea, vomiting, and diarrhoea. This is followed by a sensation of burning, tingling, and numbness in the mouth and face, and of burning in the abdomen. In severe poisonings pronounced motor weakness occurs and cutaneous sensations of tingling and numbness spread to the limbs. Cardiovascular features include hypotension, sinus bradycardia, and ventricular arrhythmias. Other features may include sweating, dizziness, difficulty in breathing, headache, and confusion. The main causes of death are ventricular arrhythmias and asystole, paralysis of the heart or of the respiratory centre. Aconite has long been used in traditional Chinese medicine and Ayurveda (Hindu traditional medicine).

3.3.2-*Atropa*

Atropa is a genus of flowering plants belonging to the family, Solanaceae. Its best-known member is the deadly Nightshade (*A. belladonna*). *A. belladonna*, commonly known as belladonna or deadly nightshade, is a perennial herbaceous plant, native to Europe, North Africa, Western Asia, and some parts of Canada and the United States. The foliage and berries are extremely toxic, containing tropane alkaloids. These toxins include scopolamine and hyoscyamine, which cause a bizarre delirium and hallucinations, and are also used as pharmaceutical anticholinergics. The drug atropine is derived from the plant.

Uses and toxicity

It has a long history of use as a medicine, cosmetic, and poison. Before the Middle Ages, it was used as an anaesthetic for surgery; the ancient Romans used it as a poison; and, predating this, it was used to make poison-tipped arrows. The genus name *Atropa* comes from Atropos, one of the three Fates in Greek mythology, and the name "belladonna" is derived from Italian and means "beautiful lady" because the herb was used in eye-drops by women to dilate the pupils of the eyes to make them appear seductive.

The active agents in belladonna, atropine, hyoscine (scopolamine), and hyoscyamine, have anticholinergic properties. The symptoms of belladonna poisoning include dilated pupils, sensitivity to light, blurred vision, tachycardia, loss of balance, staggering, headache, rash, flushing, severely dry mouth and throat, slurred speech, urinary retention, constipation, confusion, hallucinations, delirium, and convulsions. The antidote for belladonna poisoning is physostigmine or pilocarpine, the same as for atropine.

A. belladonna is also toxic to many domestic animals, causing narcosis and paralysis. However, cattle and rabbits eat the plant seemingly without suffering harmful effects. In humans, its anticholinergic properties will cause the disruption of cognitive capacities, such as memory and learning.

Belladonna has been used in herbal medicine for centuries as a pain reliever, muscle relaxer, and anti-inflammatory, and to treat menstrual problems, peptic ulcer disease, histaminic reaction, and motion sickness. Belladonna tinctures, decoctions, and powders, as well as alkaloid salt mixtures, are still produced for pharmaceutical use. The alkaloids are compounded with phenobarbital and/or kaolin and pectin for use in various functional gastrointestinal disorders. The combination of belladonna and opium, in powder, tincture, or alkaloid form, is particularly useful by mouth or as a suppository for diarrhoea and some forms of visceral pain; it can be made by a compounding pharmacist, and may be available as a manufactured fixed combination product in some countries.

Scopolamine is used as the hydrobromide salt for GI complaints and motion sickness, and to potentiate the analgesic and anxiolytic effects of opioid analgesics. It was formerly used in a painkiller called "twilight sleep" in childbirth.

Scientific evidence to recommend the use of *A. belladonna* in its natural form for any condition is insufficient, although some of its components, in particular *l*-atropine, which was purified from belladonna in the 1830s, have accepted medical uses. Belladonna preparations are used in homeopathy as alleged treatments for various conditions. *A. belladonna* and related plants, such as jimson weed (*Datura stramonium*), have occasionally been used as recreational drugs because of the vivid hallucinations and delirium they produce.

3.3.3-*Cinchona*

Cinchona, common name quina, is a genus of about 25 recognized species in the family Rubiaceae, native to the tropical Andes forests of western South America. A few species are reportedly naturalized in Central America, Jamaica, French Polynesia, Sulawesi, Saint Helena in the South Atlantic, and São Tome & Principe off the coast of tropical Africa. A few species are used as medicinal plants, known as sources for quinine and other compounds.

Taxonomy

The name of the genus is due to Linnaeus, who named the tree in 1742 after the Second Countess of Chinchón, the wife of a viceroy of Peru, who, in 1638 (according to accounts at the time, now disparaged) was introduced by native Quechua healers to the medicinal properties of cinchona bark. Stories of the medicinal properties of this bark, however, are perhaps noted in journals as far back as the 1560s-1570s. It is the national tree of Ecuador and Peru.

Cultivation and medicinal uses

The medicinal properties of the cinchona tree were originally discovered by the Quechua peoples of Peru, Bolivia, and Ecuador, and long cultivated by them as a muscle relaxant to abate shivering due to low body temperatures, and symptoms of Malaria. The Countess of Chinchon contracted malaria and native people persuaded her to immerse in a small pond beneath a tree; the water was bitter (due to the quinine contents). After a few days the Countess was cured of malaria. When the scientific botanical classification was determined, the tree was named after the Chinchon Countess, *Chinchona*. Later the Jesuit Brother Agostino Salumbrino (1561–1642), an apothecary by training who lived in Loja (Ecuador) and Lima, observed the Quechua using the quinine-containing bark of the cinchona tree for the purpose of curing malaria. While its effect in treating malaria (and related malaria-induced shivering) was entirely unrelated to the plant's efficacy in controlling shivering from cold, it was nevertheless the correct medicine for malaria. The use of the "fever tree" bark was introduced into European medicine by Jesuit missionaries (Jesuit's bark). Jesuit Bernabé

Cobo (1582–1657), who explored Mexico and Peru, is credited with taking cinchona bark to Europe. He brought the bark from Lima to Spain, and afterwards to Rome and other parts of Italy, in 1632. To maintain their monopoly on cinchona bark, Peru and surrounding countries began outlawing the export of cinchona seeds and saplings beginning in the early 19th century.

In the 19th century, the plant's seeds and cuttings were smuggled out for new cultivation at cinchona plantations in colonial regions of tropical Asia, notably by the British to the British Raj and Ceylon (present day India and Sri Lanka), and by the Dutch to Java in the Dutch East Indies (present day Indonesia).

Chemistry

As a medicinal herb, cinchona bark is stripped from the tree, dried, and powdered for medicinal uses. The bark is medicinally active, containing a variety of alkaloids including the antimalarial compound quinine and the antiarrhythmic quinidine. Although the use of the bark has been largely superseded by more effective modern medicines, cinchona is the only economically practical source of quinine, a drug that is still recommended for the treatment of Malaria.

English King Charles II called upon Robert Talbor, who had become famous for his miraculous malaria cure. Because at that time the bark was in religious controversy, Talbor gave the king the bitter bark decoction in great secrecy. The treatment gave the king complete relief from the malaria fever. In return, Talbor was offered membership of the prestigious Royal College of Physicians. In 1679, Talbor was called by the King of France, Louis XIV, whose son was suffering from malaria fever. After a successful treatment, Talbor was rewarded by the king with 3,000 gold coins and a lifetime pension for this prescription. Talbor, however, was asked to keep the entire episode secret. After Talbor's death, the French king found this formula: seven grams of rose leaves, two ounces of lemon juice and a strong decoction of the cinchona bark served with wine. Wine was used because some alkaloids of the cinchona bark are not soluble in water, but are soluble in the ethanol in wine.

The birth of homeopathy was based on cinchona bark testing. The founder of homeopathy, Samuel Hahnemann, when translating William Cullen's *Materia medica*, noticed Cullen had written that Peruvian bark was known to cure intermittent fevers. Hahnemann took daily a large, rather than homeopathic, dose of Peruvian bark. After two weeks, he said he felt malaria-like symptoms. This idea of "like cures like" was the starting point of his writings on homeopathy. Hahnemann's symptoms are believed to be the result of a hypersensitivity to cinchona bark on his part.

The bark was very valuable to Europeans in expanding their access to and exploitation of resources in far-off colonies, and at home. Bark gathering was often environmentally destructive, destroying huge expanses of trees for their bark, with difficult conditions for low wages that did not allow the indigenous bark gatherers to settle debts even upon death.

British expedition to South America led by Clements Markham brought back smuggled cinchona seeds and plants, which were introduced in several areas of the British Raj in India and Sri Lanka. In Sri Lanka, it was planted in the Hakgala Botanical Garden in January 1861. James Taylor, the pioneer of tea planting in Sri Lanka, was one of the pioneers of cinchona cultivation. By 1883, about 64,000 acres were in cultivation in Sri Lanka, with exports reaching a peak of 15 million pounds in 1886. It was also cultivated by British in 1862 in the hilly terrain of Darjeeling District of West Bengal, India. There is a factory and plantation named after Cinchona at Mungpoo, Darjeeling, West Bengal. The factory is called a Govt. Quinine Factory. Cultivation of Cinchona continues at places like Mungpoo, Munsong, Latpanchar, and Rongo under the supervision of the government of West Bengal's Directorate of Cinchona & Other Medicinal Plants.

There are at least 31 species acknowledged by botanists, and the list is growing, on account of the tendency of the various trees to hybridize. Resolution of other species is awaiting results of DNA studies. Several species formerly in the genus are now placed in *Cascarilla*.

3.3.4-*Rauwolfia*

Rauvolfia (also spelled *Rauwolfia*) is a genus of evergreen trees and shrubs in the dogbane family, Apocynaceae. The genus is named to honour Leonhard Rauwolf. The genus can mainly be found in tropical regions of Africa, Asia, Latin America, and various oceanic islands with over 75 species reported. *R. serpentina* (L.) Benth. *ex* Kurz, , or Indian snakeroot or *sarpagandha*, is native to the Indian Subcontinent and East Asia (from India to Indonesia).

Chemical constituents

Rauvolfia serpentina plant contains more than 50 different alkaloids which belong to the monoterpenoid indole alkaloid family. The major alkaloids are ajmaline, ajmalicine, ajmalimine, deserpidine, indobine, indobinine, reserpine, reserpiline, rescinnamine, rescinnamidine, serpentine, serpentinine and yohimbine.

Medicinal uses

The plant is known for curing various disorders because of the presence of alkaloids, carbohydrates, flavonoids, glycosides, phlobatannins, phenols, resins, saponins, tannins and terpenes.

The extract of the plant has also been used for millennia in India - Alexander the Great administered this plant to cure his general Ptolemy I Soter of a poisoned arrow. It was reported that Mahatma Gandhi took it as a tranquilizer during his lifetime. It has been used for millennia to treat insect stings and the bites of venomous reptiles. A compound which it contains called reserpine, was used in an attempt to treat high blood pressure and mental disorders including schizophrenia, and had a brief period of popularity for that purpose in the

West from 1954 to 1957. *R. serpentina* is also known for its antimicrobial, antifungal, anti-inflammatory, antiproliferative, antidiuretic and anticholinergic activities.

Recent research has proved that *R. serpentina* exhibits profound activity toward drug-resistant tumour cells. It is one of the 50 fundamental herbs used in traditional Chinese medicine. Reserpine is an alkaloid first isolated from *R. serpentina* and was widely used as an antihypertensive drug. It had drastic psychological side effects and has been replaced as a first-line antihypertensive drug by other compounds that lack such adverse effects, although combination drugs that include it are still available in some countries as second-line antihypertensive drugs.

Other plants of this genus are also used medicinally, both in conventional western medicine and in Ayurveda, Unani, and folk medicine. Alkaloids in plants reduce blood pressure, depress activity of the central nervous system and act as hypnotics. *R. serpentina* is declining in the wild due to collection for its medicinal uses.

3.3.5-*Ephedra*

Ephedra is a medicinal preparation from the plant *Ephedra sinica*. Several additional species belonging to the genus *Ephedra* have traditionally been used for a variety of medicinal purposes, and are a possible candidate for the Soma plant of Indo-Iranian religion. It has been used in traditional Chinese medicine for more than 2,000 years. Native Americans and Mormon pioneers drank a tea brewed from other *Ephedra* species, called "Mormon tea" and "Indian tea". In recent years, ephedra-containing dietary supplements have been found to be unsafe, with reports of serious side effects and ephedra-related deaths.

Biochemistry and effects

A wide variety of alkaloid and non-alkaloid compounds have been identified in various species of *Ephedra*. Of the six ephedrine-type ingredients found in *Ephedra* (at concentrations of 0.02-3.4%), the most common are ephedrine and pseudoephedrine. The stimulant and thermogenic effects of *Ephedra sinica* and other *Ephedra* species are due to the presence of the alkaloids ephedrine and pseudoephedrine. These compounds stimulate the brain, increase heart rate, constrict blood vessels (increasing blood pressure), and expand bronchial tubes (making breathing easier). Their thermogenic properties cause an increase in metabolism, as evidenced by an increase in body heat.

Uses in sports

Ephedra is widely used by athletes as a performance-enhancing drug, despite a lack of evidence that it improves athletic performance. Ephedra may also be used as a precursor in the illicit manufacture of methamphetamine. Ephedra has been used as a weight-loss aid, sometimes in combination with aspirin and caffeine. However, several reports have documented a number of adverse events attributable to unregulated ephedra supplements. Adverse effects of ephedra consumption may include severe skin reactions, irritability, nervousness, dizziness, trembling, headache, insomnia, profuse perspiration, dehydration, itchy scalp and skin, vomiting, and hyperthermia. More serious potential side effects include irregular heartbeat, seizures, heart attack, stroke, and death.

Ephedrine is listed as a banned substance by both the International Olympic Committee and the World Anti-Doping Agency. Nonetheless, ephedra remains widely used by athletes; a 2006 survey of collegiate hockey players found that nearly half had used ephedra believing it enhanced their athletic performance.

In the 1994 FIFA World Cup, the Argentine footballer Diego Armando Maradona tested positive for ephedrine. The Japanese motorcycle racer Noriyuki Haga tested positive for ephedrine in 2000, being disqualified from two races and banned from two more as a result. NFL punter Todd Sauerbrun of the Denver Broncos was suspended for the first month of the 2006 season after testing positive for ephedrine.

3.4 OIL-YIELDING PLANTS

3.4.1-Castor

Castor (*Ricinus communis*), the castor oil plant, is a species of flowering plant belonging to the family Euphorbiaceae. *R.communis* is the sole species in the monotypic genus, *Ricinus*, and subtribe, Ricininae. The evolution of castor and its relation to other species are currently being studied using modern genetic tools. Although *R. communis* is indigenous to the southeastern Mediterranean Basin, Eastern Africa, and India, today it is widespread throughout tropical regions. In areas with a suitable climate, castor establishes itself easily where it can become an invasive plant and can often be found on wasteland.

Biology

R. communis can vary greatly in its growth habit and appearance. The variability has been increased by breeders who have selected a range of cultivars for leaf and flower colours, and for oil production. It is a fast-growing, suckering perennial shrub that can reach the size of a small tree (around 12 m), but it is not cold hardy.

Uses

Castor seed is the source of castor oil, which has a wide variety of uses. The seeds contain between 40% and 60% oil that is rich in triglycerides, mainly ricinolein. The seed also contains ricin, a water-soluble toxin, which is also present in lower concentrations throughout the plant.

Castor oil has many uses in medicine and other applications. An alcoholic extract of the leaf was shown, in lab rats, to protect the liver from damage from certain poisons. Methanolic extracts of the leaves of *R. communis* were used in antimicrobial testing against eight pathogenic bacteria in rats and showed antimicrobial properties. A water extract of the root bark showed analgesic activity in rats. Antihistamine and anti-inflammatory properties were found in ethanolic extract of *Ricinus communis* root bark. Extract of *R. communis* exhibited acaricidal and insecticidal activities against the adult of *Haemaphysalis bispinosa* Neumann (Acarina: Ixodidae) and hematophagous fly *Hippobosca maculata* Leach (Diptera: Hippoboscidae). The Bodo tribals of Bodoland, Assam (India), use the leaves of this plant to feed and rear the larvae of muga and endi silkworms.

Castor oil is an effective motor lubricant and has been used in internal combustion engines, including those of World War I airplanes, some racing cars and some model airplanes. It has historically been popular for lubricating two-stroke engines due to high resistance to heat compared to petroleum-based oils. In Brazil, castor oil (locally known as mamona oil) is now being used to produce biodiesel. In rural areas, the abundant seeds are used by children for slingshot balls, as they have the right weight, size, and hardness.

Castor oil was traditionally used on the skin to prevent dryness. This is now used as a base for many cosmetics. Castor oil in a processed form, called Polyglycerol polyricinoleate—or PGPR, is currently being used in chocolate bar manufacturing as a less expensive substitute for cocoa butter. Selections have been made by breeders for use as ornamental plants and for commercial production of castor oil. Commercially available cold-pressed castor oil is not toxic to humans in normal doses, either internal or externally.

3.4.2-Coconut

Coconut tree (*Cocos nucifera*) is a plant that belongs to the family Arecaceae. The term coconut can refer to the entire coconut palm, the seed, or the fruit, which, botanically, is a drupe, not a nut. There are over 150 species of coconuts that can be found in 80 different countries throughout the world. Coconut tree grows only in the tropical climate. This plant live on the sandy soil, requires a lot of sunlight and regular rainfalls. Coconut tree does not tolerate low temperatures and low percent of humidity. Cultivated plants are prone to insect attacks which can decrease production of fruit worth of hundreds of million dollars.

The origin, domestication, cultivation, production, religious importance and its uses as coir have been described in Unit 2. The culinary uses and nutritional value are being described here.

Culinary uses and nutritional value

The various parts of the coconut have a number of culinary uses. The seed provides oil for frying, cooking, and making margarine. The white, fleshy part of the seed, the coconut meat, is used fresh or dried in cooking, especially in confections and desserts such as macaroons. Desiccated coconut or coconut milk made from it is frequently added to curries and other savory dishes. Coconut flour has also been developed for use in baking, to combat malnutrition. Coconut chips have been sold in the tourist regions of Hawaii and the Caribbean. Coconut butter is often used to describe solidified coconut oil, but has also been adopted as a name by certain specialty products made of coconut milk solids or puréed coconut meat and oil. Dried coconut is also used as the filling for many chocolate bars. Some dried coconut is purely coconut but others are manufactured with other ingredients, such as sugar, propylene glycol, salt, and sodium metabisulfite.

Per 100 gram serving with 354 calories, raw coconut meat supplies a high amount of total fat (33 grams), especially saturated fat (89% of total fat) and carbohydrates (24 grams). Micronutrients in significant content include the dietary minerals, manganese, iron, phosphorus and zinc.

Coconut water serves as a suspension for the endosperm of the coconut during its nuclear phase of development. Later, the endosperm matures and deposits onto the coconut rind during the cellular phase. It is consumed throughout the humid tropics, and has been introduced into the retail market as a processed sports drink. Mature fruits have significantly less liquid than young, immature coconuts, barring spoilage. Coconut water can be fermented to produce coconut vinegar. Per 100 gram (100 ml) serving, coconut water contains 19 calories and no significant content of essential nutrients.

Coconut milk, not to be confused with coconut water, is obtained primarily by extracting juice by pressing the grated coconut white kernel or by passing hot water or milk through grated coconut, which extracts the oil and aromatic compounds. It has a fat content of around 23%. When refrigerated and left to set, coconut cream will rise to the top and separate from the milk. The milk can be used to produce virgin coconut oil by controlled heating and removal of the oil fraction. A protein-rich powder can be processed from coconut milk following centrifugation, separation and spray drying.

Another byproduct of the coconut is coconut oil. It is commonly used in cooking, especially for frying. It can be used in liquid form as would other vegetable oils, or in solid form as would butter or lard.

In southern India, most common way of cooking vegetables is to add grated coconut and then steam them with spices fried in oil. People from southern India also make chutney, which involves grinding the coconut with salt, chillies, and whole spices. Coconut ground with spices is also mixed in *sambar* and other various lunch dishes for extra taste. Coconut meat can be eaten as a snack sweetened with jaggery or molasses. In Karnataka sweets are prepared using coconut and dry coconut "copra".

3.4.3-Linseed

Flax (also known as linseed), with the binomial name *Linum usitatissimum*, is a member of the genus *Linum* in the family Linaceae. It is a food and fibre crop that is grown in cooler regions of the world. The textiles made from flax are known in the West as linen, and traditionally used for bed sheets, underclothes and table linen. The oil is known as linseed oil. In addition to referring to the plant itself, the word "flax" may refer to the unspun fibres of the flax plant. The plant species is known only as a cultivated plant, and appears to have been domesticated just once from the wild species *L. bienne*, called pale flax.

Several other species in the genus *Linum* are similar in appearance to *L. usitatissimum*, cultivated flax, including some that have similar blue flowers, and others with white, yellow, or red flowers. Some of these are perennial plants, unlike *L. usitatissimum*, which is an annual plant.

Origin and domestication

Flax was first domesticated in the Fertile Crescent region. Use of the crop steadily spread, reaching places as far as Switzerland and Germany by 5,000 years ago (3,000 BC). In China and India domesticated flax was cultivated by at least 5,000 years ago (3,000 BC).

History

Flax was extensively cultivated in ancient Egypt, where temple walls had paintings of flowering flax and mummies were entombed in linen. Egyptian priests only wore linen, as flax was considered a symbol of purity. Phoenicians traded Egyptian linen throughout the Mediterranean, and the Romans used it for their sails. As the Roman Empire declined, so did flax production, but Charlemagne revived the crop in the 8th century CE with laws designed to publicize the hygiene of linen textiles and the health of linseed oil. Eventually, Flanders became the major centre of the linen industry in the European Middle Ages. In North America, flax was introduced by the colonists and it flourished there. But by the early 20th century cheap cotton and rising farm wages had caused production of flax to become concentrated in northern Russia, which came to provide 90% of the world's output. Since then flax has lost its importance as a commercial crop, due to the easy availability of more durable fibres.

Uses

Flax is grown for its oil, used as a nutritional supplement, and as an ingredient in many wood-finishing products. Flax is also grown as an ornamental plant in gardens. Flax fibres are used to make linen. The Latin species name *usitatissimum* means *most useful*.

Flax fibres are taken from the stem of the plant and are two to three times as strong as those of cotton. As well, flax fibres are naturally smooth and straight. Europe and North America depended on flax for vegetable-based cloth until the nineteenth century, when cotton overtook flax as the most common plant used for making rag-based paper. Flax is grown on the Canadian Prairies for linseed oil, which is used as a drying oil in paints and varnish and in products such as linoleum and printing inks.

Nutritional value

Flax seeds come in two basic varieties: 1. brown; and 2. yellow or golden (also known as golden linseeds). Most types have similar nutritional characteristics and equal numbers of short-chain omega-3 fatty acids. The exception is a type of yellow flax called solin (trade name Linola), which has a completely different oil profile and is very low in omega-3 FAs. Flax seeds produce a vegetable oil known as flax seed oil or linseed oil, which is one of the oldest commercial oils. It is an edible oil obtained by expeller pressing, sometimes followed by solvent extraction. Solvent-processed flax seed oil has been used for many centuries as a drying oil in painting and varnishing. Although brown flax can be consumed as readily as yellow, and has been for thousands of years, its better-known uses are in paints, for fibre, and for cattle feed.

In a 100 gram serving, flax seeds supply 534 calories and contain high levels (> 19% of the Daily Value, DV) of protein, dietary fibre, several B vitamins and dietary minerals . Flax seeds are especially rich in thiamin, magnesium and phosphorus (DVs above 90%).

As a percentage of total fat, flaxseeds contain 54% omega-3 fatty acids (mostly ALA), 18% omega-9 fatty acids (oleic acid) and 6% omega-6 fatty acids (linoleic acid); the seeds contain 9% saturated fat, including 5% as palmitic acid. Flaxseed oil contains 53% 18:3 omega-3 fatty acids (mostly ALA) and 13% 18:2 omega-6 fatty acids.

L. usitatissimum seeds have been used in the traditional Austrian medicine internally (directly soaked or as tea) and externally (as compresses or oil extracts) for treatment of disorders of the respiratory tract, eyes, infections, cold, flu, fever, rheumatism and gout.

Production

The largest producer of flax is Canada followed by China, Russia and India, among top 10 others. Flax is harvested for fibre production after approximately 100 days or a month after the plant flowers and two weeks after the seed capsules form. The base of the plant will begin to turn yellow. If the plant is still green, the seed will not be useful, and the fibre will be underdeveloped. The fibre degrades once the plant is brown.

Harvesting

Flax grown for seed is allowed to mature until the seed capsules are yellow and just starting to split; it is then harvested in various ways. A combine harvester may either cut only the heads of the plants, or the whole plant. These are then dried to extract the seed. The amount of weeds in the straw affects its marketability, and this coupled with market prices determines whether the farmer chooses to harvest the flax straw. If the flax straw is not harvested, it is typically burned, since the stalks are quite tough and decompose slowly (*i.e.*, not in a single season). Still being somewhat in a windrow from the harvesting process, the straw would often clog up tillage and planting equipment. Flax straw that is not of sufficient quality for fibre uses can be baled to build shelters for farm animals, or sold as bio-fuel, or removed from the field in the spring. There are two ways to harvest flax fibre, one involving mechanized equipment (combines), and a second method, more manual and targeted towards maximizing the fibre length.

3.4.4-Groundnut

The peanut or groundnut (*Arachis hypogaea*) is a species in the family Fabaceae. The peanut was probably first domesticated and cultivated in the valleys of Paraguay. It is an annual herbaceous plant growing 30 to 50 cm tall. The flowers are a typical pea flower in shape, 2 to

4 cm across, yellow with reddish veining. The specific name, *hypogaea* means "under the earth"; after pollination, the flower stalk elongates, causing it to bend until the ovary touches the ground. Continued stalk growth then pushes the ovary underground where the mature fruit develops into a legume pod, the peanut - a classical example of geocarpy. Pods are 3 to 7 cm long, normally containing 1 to 4 seeds. Because, in botanical terms, "nut" specifically refers to indehiscent fruit, the peanut is not technically a nut, but rather a legume.

Origin and domestication

The domesticated peanut is an amphidiploid or allotetraploid, meaning that it has two sets of chromosomes from two different species, thought to be *A. duranensis* and *A. ipaensis*. These probably combined in the wild to form the tetraploid species *A. monticola*, which gave rise to the domesticated peanut. This domestication might have taken place in Paraguay or Bolivia, where the wildest strains grow today. Many pre-Columbian cultures, such as the Moche, depicted peanuts in their art. Archaeologists have dated the oldest specimens to about 7,600 years, found in Peru. Although the peanut was mainly a garden crop for much of the colonial period of North America, it was mostly used as animal feed stock until the 1930s.

Production

China leads in production of peanuts, having a share of about 42% of overall world production, followed by India (12%) and the United States of America (8%). Thousands of peanut cultivars are grown, with four major cultivar groups being the most popular: Spanish, Runner, Virginia, and Valencia. There are also Tennessee red and white groups. Certain cultivar groups are preferred for particular uses because of differences in flavour, oil content, size, shape, and disease resistance. For many uses, the different cultivars are interchangeable. Most peanuts marketed in the shell are of the Virginia type, along with some Valencias selected for large size and the attractive appearance of the shell. Spanish peanuts are used mostly for peanut candy, salted nuts, and peanut butter. Most Runners are used to make peanut butter. The various types are distinguished by branching habit and branch length. There are numerous varieties of each type of peanut. There are two main growth forms, bunch and runner. Bunch types grow upright, while runner types grow near the ground. Each year, new cultivars of peanuts are bred and introduced.

Uses

Peanuts can be eaten raw, used in recipes, made into oils, textile materials, and peanut butter, as well as many other uses. In general, peanut products are considered safe for human use, although there are insufficient studies about peanut aflatoxins and uses for cosmetics. Popular confections made from peanuts include salted peanuts, peanut butter (sandwiches, peanut candy bars, peanut butter cookies, and cups), peanut brittle, and shelled nuts (plain/roasted). Salted peanuts are usually roasted in oil and packed in retail-size plastic bags or hermetically sealed cans.

Peanuts are used to help fight malnutrition. Peanuts can be used like other legumes and grains to make a lactose-free milk-like beverage, peanut milk. Peanut milk is promoted in Africa as a way to reduce malnutrition among children. Low-grade or culled peanuts not suitable for the edible market are used in the production of peanut oil for manufacturing. The protein cake (oilcake meal) residue from oil processing is used as an animal feed and as a soil fertilizer. Raw peanuts are also widely sold as a garden bird feed. Peanuts also have a variety of industrial end uses. Paint, varnish, lubricating oil, leather dressings, furniture polish, insecticides, and nitroglycerine are made from peanut oil. Soap is made from saponified oil, and many cosmetics contain peanut oil and its derivatives. The protein portion is used in the manufacture of some textile fibres. Peanut shells are used in the manufacture of plastic, wallboard, abrasives, fuel, cellulose (used in rayon and paper) and mucilage (glue). Rudolf Diesel ran some of the first engines that bear his name on peanut oil and it is still seen as a potentially useful fuel.

Nutritional value

Peanuts are rich in essential nutrients. In a 100 g serving, peanuts provide 570 calories and are an excellent source (defined as more than 20% of the Daily Value, DV) of several B vitamins, vitamin E, several dietary minerals, such as manganese (95% DV), magnesium (52% DV) and phosphorus (48% DV), and dietary fibre. They also contain about 25 g protein per 100 g serving, a higher proportion than in many tree nuts.

Recent research on peanuts has found polyphenols and other phytochemicals that are under basic research for their potential to provide health benefits. New research shows peanuts, especially the skins, to have comparable polyphenol content of many fruits. Peanut skins are a significant source of resveratrol, a phenolic under research for a variety of potential effects in humans.

A common cooking and salad oil, peanut oil is 46% monounsaturated fats (primarily oleic acid), 32% polyunsaturated fats (primarily linoleic acid) and 17% saturated fats (primarily palmitic acid). Extractable from whole peanuts using a simple water and centrifugation method, the oil is being considered by NASA's Advanced Life Support program for future long-duration human space missions.

Peanuts may be contaminated with the mold *Aspergillus flavus* which produces a carcinogenic substance called aflatoxin. Lower quality specimens, particularly where mold is evident, are more likely to be contaminated.

International trade

Although India and China are the world's largest producers of peanuts, they account for a small part of international trade because most of their production is consumed domestically as peanut oil. Exports of peanuts from India and China are equivalent to less than 4% of world trade. The major producers/exporters of peanuts are the United States, Argentina, Sudan, Senegal, and Brazil. These five countries account for 71% of total world exports. In recent years, the United States has been the leading exporter of peanuts. The major peanut importers are the European Union (EU), Canada, and Japan. These three areas account for 78% of the world's imports.

3.4.5-Mustard

Mustard and rapeseed (canola) is the third largest vegetable oil traded in the world, next to soybean and palm oil. A genetically modified variety of rapeseed (*Brassica spp.)* that was developed by Canadian plant breeders specifically for its nutritional qualities and its low level of saturated fat is known as Canola, which is a short form of "Canadian oil".

Description

Brassica species are cultivated since historic times, particularly in Asian countries. According to ancient Indian literature, cultivation of *Brassica rapa* was practiced since 1500 BC and seed of *Brassica juncea* (Indian mustard) was reported to have found in archaeological sites. On the other hand, the Chinese word for rapeseed was first recorded 2500 years ago, and the oldest archaeological discoveries reported to be dated back to 5000 BC.

Rapeseed oil reported to be used as a marine and industrial lubricant during World War II and consequently, the market for rapeseed oil plummeted in the post war period. Production of rapeseed has been rising rather steeply during the past two decades and has outpaced the production of other oilseeds including peanut, cottonseed and sunflower.

Seed: Rapeseed and mustard is grown for its oil rich seeds. Apart from extracting oil, seeds are also used directly in the preparation of almost all Indian curries particularly in a process called "tadka"
Oil: Well-developed rapeseed seed contains 40 to 44% of edible oil.
Meal: Seed extract after recovering oil is used as a feed.
Recovery on average: Oil to Seeds– 33%; Cake to Seeds– 67%

Cultivation

Rapeseed and mustard can be cultivated in both tropical as well as temperate climates. Its growth is most vigorous in temperatures between 10°C and 30°C with an optimum temperature of around 20°C. Seed oil formation is optimum at a temperature of 10°C to 15°C. The crop is very sensitive to high temperatures as well as for frost at the time of flowering. Crop growth is healthy at a rainfall of 350-550 mm.

Rapeseed and mustard are normally cultivated as a rabi crop in India as it requires relatively cooler temperatures for seed setting and oil formation. Sowing normally starts in the month of November and the crop season spreads up to April.

Production

World output of rapeseed and mustard has been increasing persistently and rather steeply during the past 15 years. The output has doubled from about 36 million tonnes in 2001-02 to 70 million tonnes in 2013-14. Production from European Union and Canada has risen steadily and reached to nearly 30% and 26% respectively of total world production. On the other hand, output from China has remained largely stable at around 12-13 million tonnes and consequently its share has declined to about 20% from about 31% a decade ago.

The steep rise in production from Canada was primarily on account of significant expansion in area, which could have apparently been driven by a sharp rise in exports from Canada. While the production and consumption doubled during the past decade, trade has gone up by three times. During this period, exports from Canada rose by nearly four times.

Similar to production, world consumption pattern of rapeseed and mustard also doubled during the past 15 years primarily driven by the European Union, China and Canada. The European Union registered growth followed by Canada and China. Consequently, imports by China and the EU rose the steepest pushing them to top two positions replacing Japan and Mexico.

India is the fourth largest producer of rapeseed & mustard. Production trends over the past two decades indicated that there was a significant shift in production levels from about 5-6 million tonnes until 2002-03 to around 7-8 million tonnes during the past one decade. The jump in production was primarily on account of sharp rise in yields. In addition, there was a significant expansion in area under rapeseed during the same period.

Rajasthan occupies the first place both in terms of cultivated area and production accounting for over 45% followed by Madhya Pradesh with 13%. Haryana and Uttar Pradesh occupy the third place contributing for 11% of total production each. Thus, the top four states produce about 80% of total rapeseed & mustard production in the country.

3.5 BEVERAGES

3.5.1-Tea

Tea is an aromatic beverage commonly prepared by pouring hot or boiling water over cured leaves of the *Camellia sinensis*, an evergreen shrub native to Asia. After water, it is the most widely consumed drink in the world. Some teas, like Darjeeling and Chinese greens, have a cooling, slightly bitter, and astringent flavour, while others have vastly different profiles that include sweet, nutty, floral, or grassy notes.

Origin and history

Tea originated in China, possibly as a medicinal drink. It came to the West via Portuguese priests and merchants, who introduced it during the 16th century. Drinking tea became fashionable among Britons during the 17th century, who started large scale production and commercialization of the plant in India to bypass a Chinese monopoly at that time.

Tea plants are native to East Asia, and probably originated around the meeting points of the lands of northern Burma (Myanmar) and south-western China. Chinese legends attribute the invention of tea to Shennong in 2737 BC. A Chinese inventor was the first person to invent a tea shredder. The first recorded drinking of tea is in China, with the earliest records of tea consumption dating to the 10th century BC. In India, it has been drunk for medicinal purposes for a long but uncertain period, but apart from the Himalayan region seems not to have been used as a beverage until the British introduced Chinese tea there.

The first European to successfully transplant tea to the Himalayas, Robert Fortune, was sent by the East India Company on a mission to China in 1848 to bring the tea plant back to Great Britain. He began his journey in high secrecy as his mission occurred in the lull between the Anglo-Chinese First Opium War (1839–1842) and Second Opium War (1856–1860), at a time when westerners were not held in high regard.

Tea was introduced into India by the British. The British brought Chinese seeds into North-eastern India, but the plants failed; they later discovered that a different variety of tea was endemic to Assam and the northeastern region of India and that it was used by a local tribe Siphung. Using the Chinese planting and cultivation techniques, the British launched a tea industry by offering land in Assam to any European who agreed to cultivate it for export. Tea was originally consumed only by anglicized Indians; it became widely popular in India in the 1950s because of a successful advertising campaign by the India Tea Board.

Cultivation

C. sinensis is an evergreen plant that grows mainly in tropical and subtropical climates. Some varieties can also tolerate marine climates and are cultivated as far north as Cornwall in the United Kingdom, Perthshire in Scotland, Washington state in the United States and Vancouver Island in Canada. In the Southern Hemisphere, tea is grown as far south as Hobart on the Australian island of Tasmania and Waikato in New Zealand.

Tea plants are propagated from seed and cuttings; about 4 to 12 years are needed for a plant to bear seed and about three years before a new plant is ready for harvesting. In addition to a zone 8 climate or warmer, tea plants require at least 127 cm of rainfall a year and prefer acidic soils. Many high-quality tea plants are cultivated at elevations of up to 1,500 m above sea level. While at these heights the plants grow more slowly, they acquire a better flavour.

Two principal varieties are used: *C. sinensis* var. *sinensis*, which is used for most Chinese, Formosan and Japanese teas, and *C. s.* var. *assamica*, used in most Indian teas (but not Darjeeling). Within these botanical varieties, many strains and modern clonal varieties are known. Leaf size is the chief criterion for the classification of tea plants, with three primary classifications being, Assam type, characterised by the largest leaves; China type, characterised by the smallest leaves; and Cambodian type, characterised by leaves of intermediate size.

A tea plant will grow into a tree of up to 16 m if left undisturbed, but cultivated plants are generally pruned to waist height for ease of plucking. Also, the short plants bear more new shoots which provide new and tender leaves and increase the quality of the tea. Only the top 1–2 inch of the mature plant are picked. These buds and leaves are called 'flushes'. A plant will grow a new flush every seven to 15 days during the growing season. Leaves that are slow in development tend to produce better-flavoured teas.

Types of tea

Tea is generally divided into categories based on how it is processed. At least six different types are produced: White- Wilted and unoxidized; Yellow-Unwilted and unoxidized, but allowed to yellow; Green-Unwilted and unoxidized; Oolong-Wilted, bruised, and partially oxidized; Black: Wilted, sometimes crushed, and fully oxidized (called 'red tea' in China), and Post-Fermented: Green tea that has been allowed to ferment/compost ('black tea' for the Chinese). The most common are white, green, oolong, and black.

Processing

After picking, the leaves of *C. sinensis* soon begin to wilt and oxidize unless immediately dried. An enzymatic oxidation process triggered by the plant's intracellular enzymes causes the leaves to turn progressively darker as their chlorophyll breaks down and tannins are released. This darkening is stopped at a predetermined stage by heating, which deactivates the enzymes responsible. In the production of black teas, halting by heating is carried out simultaneously with drying.

Although single-estate teas are available, almost all tea in bags and most loose tea sold in the West are blended. Such teas may combine others from the same cultivation area or several different ones. The aim is to obtain consistency, better taste, higher price, or some combination of the three.

Tea easily retains odours, which can cause problems in processing, transportation, and storage. This same sensitivity also allows for special processing (such as tea infused with smoke during drying) and a wide range of scented and flavoured variants, such as bergamot (found in Earl Grey), vanilla, and spearmint.

Nutrients and phytochemicals

Caffeine constitutes about 3% of tea's dry weight, translating to between 30 mg and 90 mg per 250 ml cup depending on type, brand, and brewing method. A study found that the caffeine content of 1 g of black tea ranged from 22 to 28 mg, while the caffeine content of 1 g of green tea ranged from 11 to 20 mg, reflecting a significant difference. Tea also contains small amounts of theobromine and theophylline, which are stimulants and xanthines similar to caffeine.

Tea leaves contain diverse polyphenols, including flavonoids, epigallocatechin gallate (commonly noted as EGCG) and other catechins. It has been suggested that green and black tea may protect against cancer or other diseases such as obesity or Alzheimer's disease, but the compounds found in green tea have not been conclusively demonstrated to have any effect on human diseases. One human study demonstrated that regular consumption of black tea over four weeks had no beneficial effect in lowering blood cholesterol levels.

Tea culture

Tea may be consumed early in the day to heighten calm alertness; it contains L-theanine, theophylline, and bound caffeine (sometimes called *theine*). Decaffeinated brands are also sold. While herbal teas are also referred to as tea, most of them do not contain leaves from the tea plant. While tea is the second most consumed beverage on Earth after water, in many cultures it is also consumed at elevated social events, such as afternoon tea and the tea party.

In India, tea is one of the most popular hot beverages. It is consumed daily in almost all homes, offered to guests, consumed in high amounts in domestic and official surroundings, and is made with the addition of milk with or without spices. In the United States, 80% of tea is consumed as iced tea. Switzerland has its own unique blend of iced tea. In the United Kingdom, it is consumed daily and often by a majority of people across the country, and indeed is perceived as one of Britain's cultural beverages.

Popular varieties of black tea include Assam, Iran, Nepal, Darjeeling, Nilgiri, Turkish, Keemun, and Ceylon teas. In India, black tea is often boiled for fifteen minutes or longer to make Masala chai, as a strong brew is preferred. Tea should be strained while serving.

In regions of the world that prefer mild beverages, such as the West and Far East, green tea should be steeped in water around 80 to 85 °C, the higher the quality of the leaves the lower the temperature. Regions such as North Africa or Central Asia prefer a bitter tea, and hotter water is used. In Morocco, green tea is steeped in boiling water for 15 minutes. High-quality green and white teas can have new water added as many as five or more times, depending on variety, at increasingly higher temperatures.

Flowering tea or blooming tea should be brewed at 100 °C in clear glass tea wares for up to three minutes.

Tea is the most popular manufactured drink consumed in the world, equalling all others – including coffee, chocolate, soft drinks, and alcohol – combined. Most tea consumed outside East Asia is produced on large plantations in the hilly regions of India and Sri Lanka, and is destined to be sold to large businesses. India is the world's largest tea-drinking nation although the per capita consumption of tea remains a modest 750 grams per person every year. Turkey, with 2.5 kg of tea consumed per person per year, is the world's greatest per capita consumer.

Production

In 2003, world tea production was 3.21 million tonnes annually. In 2010, world tea production reached over 4.52 million tonnes after having increased by 5.7% between 2009 and 2010. Production rose by 3.1% between 2010 and 2011. The largest producers of tea are the People's Republic of China, India, Kenya, Sri Lanka, and Turkey.

International trade

According to the FAO in 2007, the largest importer of tea, by weight, was the Russian Federation, followed by the United Kingdom, Pakistan, and the United States. Kenya, China, India and Sri Lanka were the largest exporters of tea in 2007. The largest exporter of black tea is Kenya, largest producer (and consumer) India.

3.5.2-Coffee

All coffee plants belong to family Rubiaceae. Several species of the genus *Coffea* produce the berries from which coffee is extracted. The two main species commercially cultivated are *C. canephora* (predominantly a form known as 'robusta') and *C. arabica*. *C. arabica*, the most highly regarded species, is native to the southwestern highlands of Ethiopia and the Boma Plateau in southeastern Sudan and possibly Mount Marsabit in northern Kenya. *C. canephora* is native to western and central Subsaharan Africa, from Guinea to the Uganda and southern Sudan. Less popular species are *C. liberica*, *C. stenophylla*, *C. mauritiana*, and *C. racemosa*.

Biology

Coffee are evergreen shrubs or trees that may grow 5 m tall when unpruned. The flowers are followed by oval berries of about 1.5 cm. When immature they are green, and they ripen to yellow, then crimson, before turning black on drying. Each berry usually contains two seeds, but 5–10% of the berries have only one; these are called peaberries. *Arabica* berries ripen in six to eight months, while *robusta* take nine to eleven months.

C. arabica is predominantly self-pollinating, and as a result the seedlings are generally uniform and vary little from their parents. In contrast, *C. canephora*, and *C. liberica* are self-incompatible and require outcrossing. This means that useful forms and hybrids must be propagated vegetatively. Cuttings, grafting, and budding are the usual methods of vegetative propagation. On the other hand, there is great scope for experimentation in search of potential new strains.

Cultivation

Coffee is a brewed drink prepared from roasted coffee beans, which are the seeds of "berries" from the *Coffea* plant. Coffee plants are cultivated in over 70 countries, primarily in the equatorial regions of the Americas, Southeast Asia, India and Africa. The two most commonly grown are the highly regarded *arabica*, and the less sophisticated but stronger and more hardy *robusta*. The latter is resistant to the coffee leaf rust, *Hemileia vastatrix*, but has a more bitter taste. Once ripe, coffee beans are picked, processed, and dried. Green (unroasted) coffee beans are one of the most traded agricultural commodities in the world. Once traded, the beans are roasted to varying degrees, depending on the desired flavour, before being ground and brewed to create coffee.

Uses

Coffee is slightly acidic (pH 5.0–5.1) and can have a stimulating effect on humans because of its caffeine content. Coffee is one of the most popular drinks in the world. It can be prepared and presented in a variety of ways (e.g., espresso, cappucino, cafe latte, etc.). It is usually served hot, although iced coffee is also served. The effect of coffee on human health has been a subject of many studies; however, results have varied in terms of coffee's relative benefit. The majority of recent research suggests that moderate coffee consumption is benign or mildly beneficial in healthy adults. However, the diterpenes in coffee may increase the risk of heart disease.

Coffee cultivation first took place in Southern Arabia. The earliest credible evidence of coffee-drinking appears in the middle of the 15^{th} century in the Sufi shrines of Yemen. Coffee is a major export commodity. It has become a vital cash crop for many developing countries. Over one hundred million people in developing countries have become dependent on coffee as their primary source of income. It has become the primary export and backbone for African countries like Uganda, Burundi, Rwanda, and Ethiopia, as well as many Central American countries. Further, green (unroasted) coffee is one of the most traded agricultural commodities in the world.

About three-quarters of coffee cultivated worldwide is *C. arabica*. *Robusta* coffee is used as an inexpensive substitute for *arabica* in many commercial coffee blends. Good quality *robusta* beans are used in traditional Italian espresso blends to provide a full-bodied taste and a better foam head (known as *crema*). However, *C. canephora* is less susceptible to disease than *C. arabica* and can be cultivated in lower altitudes and warmer climates where *C. arabica* will not thrive. The spread of the devastating coffee leaf rust (*H. vastatrix*), to which *C. arabica* is vulnerable, hastened the uptake of the resistant *robusta*. Coffee leaf rust is found in virtually all countries that produce coffee.

Production

In 2011 Brazil was the world leader in production of green coffee, followed by Vietnam, Indonesia and Colombia. Arabica coffee seeds are cultivated in Latin America, eastern Africa, Arabia, or Asia. Robusta coffee seeds are grown in western and central Africa, throughout Southeast Asia, and to some extent in Brazil.

Seeds from different countries or regions can usually be distinguished by differences in flavour, aroma, body, and acidity. These taste characteristics are dependent not only on the coffee's growing region, but also on genetic subspecies (varietals) and processing. Varietals are generally known by the region in which they are grown, such as Colombian, Java and Kona.

Processing

Coffee berries and their seeds undergo several processes before they become the familiar roasted coffee. Berries have been traditionally selectively picked by hand; a labour-intensive method, it involves the selection of only the berries at the peak of ripeness. More commonly, crops are strip picked, where all berries are harvested simultaneously regardless of ripeness by person or machine. After picking, green coffee is processed by one of two methods-the dry process method, simpler and less labour-intensive as the berries can be strip picked, and the wet process method, which incorporates fermentation into the process and yields a mild coffee.

A number of products are sold for the convenience of consumers who do not want to prepare their own coffee. Instant coffee is dried into soluble powder or freeze-dried into granules that can be quickly dissolved in hot water. Originally invented in 1907, it rapidly gained in popularity in many countries in the post-war period, with Nescafé being the most popular product. Many consumers determined that the convenience in preparing a cup of instant coffee more than made up for a perceived inferior taste. Paralleling (and complementing) the rapid rise of instant coffee was the coffee vending machine, invented in 1947 and multiplying rapidly through the 1950s.

International trade

Brazil remains the largest coffee exporting nation, however Vietnam tripled its exports between 1995 and 1999 and became a major producer of *robusta* seeds. Indonesia is the third-largest coffee exporter overall and the largest producer of washed *arabica* coffee. Organic Honduran coffee is a rapidly growing emerging commodity owing to the Honduran climate and rich soil.

Phytochemistry

The primary psychoactive chemical in coffee is caffeine, an adenosine antagonist that is known for its stimulant effects. Coffee also contains the monoamine oxidase inhibitors β-carboline and harmane, which may contribute to its psychoactivity. In a healthy liver, caffeine is mostly broken down by the hepatic microsomal enzymatic system. The excreted metabolites are mostly paraxanthines-theobromine and theophylline—and a small amount of unchanged caffeine. Therefore, the metabolism of caffeine depends on the state of this enzymatic system of the liver.

Extensive scientific research has been conducted to examine the relationship between coffee consumption and an array of medical conditions. The consensus in the medical community is that moderate regular coffee drinking in healthy individuals is either essentially benign or mildly beneficial. Coffee is no longer thought to be a risk factor for coronary heart disease. A 2012 meta-analysis concluded that people who drank moderate amounts of coffee had a lower rate of heart failure, with the biggest effect found for those who drank more than four cups a day. Moreover, in one study, habitual coffee consumption was associated with improved vascular function.

Polyphenols in coffee have been shown to affect free radicals in vitro, but there is no evidence that this effect occurs in humans. Polyphenol levels vary depending on how beans are roasted as well as for how long. As interpreted by the Linus Pauling Institute and the European Food Safety Authority, dietary polyphenols, such as those ingested by consuming coffee, have little or no direct antioxidant value following ingestion.

3.5.3-Cocoa

The cocoa bean, also cacao bean or simply cocoa or cacao, is the dried and fully fermented fatty seed of *Theobroma cacao*, from which cocoa solids and cocoa butter are extracted. They are the basis of chocolate, as well as many Mesoamerican foods such as mole sauce and tejate.

Description

A cocoa pod (fruit) has a rough and leathery rind about 2 to 3 cm thick. It is filled with sweet, mucilaginous pulp with a lemonade like taste enclosing 30 to 50 large seeds that are fairly soft and a pale lavender to dark brownish purple colour. Due to heat build up in the fermentation process, cacao beans lose most of the purplish hue and become mostly brown in color, with an adhered skin which includes the dried remains of the fruity pulp. This skin is released easily after roasting by winnowing. White seeds are found in some rare varieties, usually mixed with purples, and are considered of higher value. Historically, white cacao was cultivated by the Rama people of Nicaragua.

Origin and cultivation

The cacao tree is native to the Americas. It may have originated in the foothills of the Andes in the Amazon and Orinoco basins of South America, current day Colombia and Venezuela, where today, examples of wild cacao still can be found. Cacao trees will grow in a limited geographical zone, of approximately 20 degrees to the north and south of the Equator. Nearly 70% of the world crop today is grown in West Africa. Cocoa was an important commodity in pre-Columbian Mesoamerica. Chocolate was introduced to Europe by the Spaniards, and became a popular beverage by the mid 17th century. They also introduced the cacao tree into the West Indies and the Philippines. It was also introduced into the rest of Asia and into West Africa by Europeans.

More than 3,000,000 tonnes of cocoa are produced each year. The production increased by 131.7% in 30 years, representing a compound annual growth rate of 2.9%. There are three main varieties of cocoa plant: Forastero, Criollo, and Trinitario. The first is the most widely used, comprising 95% of the world production of cocoa. Overall, the highest quality cocoa beans come from the Criollo variety, which is considered a delicacy. Trinitario is a hybrid between Criollo and Forastero varieties. It is considered to be of much higher quality than the latter, but has higher yields and is more resistant to disease than the former.

Uses

Cocoa and its products (including chocolate) are used worldwide. Per capita consumption is poorly understood, with numerous countries claiming the highest: various reports state that Switzerland, Belgium, and the UK have the highest consumption.

Production

There were 3.54 million tonnes of cocoa beans produced in the 2008–2009 growing year, which runs from October to September. Of this total, African nations produced 2.45 million tonnes (69%), Asia and Oceania produced 0.61 million tonnes (17%) and the Americas produced 0.48 million tonnes (14%). Two African nations, Côte d'Ivoire and Ghana, produce more than half of the world's cocoa, with 1.23 and 0.73 million tonnes respectively (35% and 21%, respectively). Indonesia is the world’s second largest producer of cocoa.

A typical pod contains 20 to 50 beans and about 400 dried beans are required to make one pound - or 880 per kilogram - of chocolate. Cocoa pods weigh an average of 400 grams and each one yields 35 to 40 grams dried beans (this yield is 40–44% of the total weight in the pod). It is estimated one person can separate the beans from 2000 pods per day.

The wet beans are then transported to a facility so they can be fermented and dried. The beans should be dry for shipment (usually by sea). Traditionally exported in jute bags, over the last decade, beans are increasingly shipped in 'Mega-Bulk' bulk parcels of several thousand tonnes at a time on ships, or in smaller lots of around 25 tonnes in 20 foot containers. Shipping in bulk significantly reduces handling costs; shipment in bags, however, either in a ship's hold or in containers, is still common.

Processing

To make 1 kg of chocolate, about 300 to 600 beans are processed, depending on the desired cocoa content. In a factory, the beans are roasted. Next they are cracked and then de-shelled by a "winnower". The resulting pieces of beans are called nibs. They are sometimes sold in small packages at specialty stores and markets to be used in cooking, snacking, and chocolate dishes. Since nibs are directly from the cocoa tree, they contain high amounts of theobromine. Most nibs are ground, using various methods, into a thick creamy paste, known as chocolate liquor or cocoa paste. This "liquor" is then further processed into chocolate by mixing in (more) cocoa butter and sugar (and sometimes vanilla and lecithin as an emulsifier), and then refined, conched and tempered. Alternatively, it can be separated into cocoa powder and cocoa butter using a hydraulic press or the Broma process. This process produces around 50% cocoa butter and 50% cocoa powder. Standard cocoa powder has a fat content of approximately 10–12 percent. Cocoa butter is used in chocolate bar manufacture, other confectionery, soaps, and cosmetics.

Nutritional value

In general cocoa is considered to be a rich source of antioxidants such as procyanidins and flavanoids, which may impart anti aging properties. Cocoa also contains a high level of flavonoids, specifically epicatechin, which may have beneficial cardiovascular effects on health. The stimulant activity of cocoa comes from the compound theobromine which is less diuretic as compared to theophylline found in tea. Prolonged intake of flavanol-rich cocoa has been linked to cardiovascular health benefits, though it should be noted that this refers to raw cocoa and to a lesser extent, dark chocolate, since flavonoids degrade during cooking and alkalizing processes.

A 15-year study of elderly men published in 2006 found a 50 percent reduction in *cardiovascular* mortality and a 47 percent reduction in *all-cause* mortality for the men regularly consuming the most cocoa, compared to those consuming the least cocoa from all sources. It is believed that the improved blood flow after consumption of flavanol-rich cocoa may help to achieve health benefits in hearts and other organs. In particular, the benefits may extend to the brain and have important implications for learning and memory.

International trade

There are Fair trade cocoa producer groups in Belize, Bolivia, Cameroon, The Congo, Costa Rica, Dominican Republic, Ecuador, Ghana, Haiti, India, Côte d'Ivoire, Nicaragua, Panama, Peru, Sierra Leone and Sao Tome & Principe. As of 2014, less than 1% of the chocolate market was Fair Trade. Cadbury, one of the world's largest chocolate companies, has begun certifying its Dairy Milk bars as Fair Trade.

Cocoa beans, cocoa butter and cocoa powder are traded on two world exchanges: ICE Futures U.S. and NYSE Liffe Futures and Options. The London market is based on West African cocoa and New York on cocoa predominantly from Southeast Asia. Cocoa is the world's smallest soft commodity market.

The future price of cocoa butter and cocoa powder is determined by multiplying the bean price by a ratio. The combined butter and powder ratio has tended to be around 3.5. If the combined ratio falls below 3.2 or so, production ceases to be economically viable and some factories cease extraction of butter and powder and trade exclusively in cocoa liquor.

Cocoa beans can be held in storage for several years in bags or in bulk, during which the ownership can change several times, as the cocoa is traded much the same as metal or other commodities, to gain profit for the owner.

3.6 SUMMARY

Aconitum spp. are considered as the queen of all poisons is a genus of over 250 species. Most species are extremely poisonous and must be dealt carefully. ***Atropa belladonna*** (Deadly Nightshade) is also known for its toxic properties. It has been used as a poison and a recreational drug. The cinchona - a large shrub or small tree of South American origin- its bark, also known as Peruvian Bark or Jesuit’s Bark, is renowned for its medicinal properties. It produces a number of alkaloids, of which the most valuable is quinine, a drug used to treat malaria, which according to a report of the Commissions of Medical Officers of the Government in India, possesses “more than any other that can be named, the confidence of medical practitioners [in India]”. Rauwolfia alkaloids belong to the general class of medicines called antihypertensives. They are used to treat high blood pressure (hypertension). Rauwolfia alkaloids may also be used to treat other conditions as determined by your doctor. Ephedra is used for weight loss and obesity and to enhance athletic performance. It is also used for allergies and hay fever; nasal congestion; and respiratory tract conditions such as bronchospasm, asthma, and bronchitis. It is also used for colds, flu, swine flu, fever, chills, headache, inability to sweat, joint and bone pain, and as a “water pill” to increase urine flow in people who retain fluids

Castor (*Ricinus communis*), is the sole species in the monotypic genus, *Ricinus*. Castor seed is the source of castor oil, which has a wide variety of uses. Methanolic extracts of the leaves of *Ricinus communis* has antimicrobial properties. Antihistamine and anti-inflammatory properties were found in ethanolic extract of *Ricinus communis* root bark. Coconut (*Cocos nucifera*) is the only accepted species in the genus *Cocos*. The term coconut can refer to the entire coconut palm, the seed, or the fruit, which, botanically, is a drupe, not a nut. The popularity of coconut is because of a variety of coconut-derived ingredients—from coconut oil to coconut flour and coconut milk—increasingly being used in home kitchens, restaurants and packaged foods besides the coir, a natural fibre extracted from the husk of coconut and used in products such as floor mats, doormats, brushes, mattresses, etc. Linseed (*Linum usitatissimum*) is a food and fibre crop that is grown in cooler regions of the world. The textiles made from flax are known as linen, and traditionally used for bed sheets, underclothes and table linen. The oil is known as linseed oil. In addition to referring to the plant itself, the word "flax" may refer to the unspun fibres of the flax plant. Mustard is an annual herb cultivated as oil seed crop or as vegetable or as fodder, of which, 3 species are known for its condiment value. They are pale yellow or white mustard (*Brassica hirta*), brown mustard (*Brassica juncea*) and black mustard (*Brassica nigra*). The major processed products are mustard powder used in the manufacture of mayonnaise, dried or dehydrated mustard leaves, whole mustard seeds etc. Whole mustard is used as a flavouring agent in Indian cooking, whereas ground mustard provides flavour and consistency in Bengali fish curries. Peanut, also known as groundnut (*Arachis hypogaea*) is a crop of global importance. It is widely grown in the tropics and subtropics, being important to both smallholder and large commercial producers. It is classified as both a grain legume, and, because of its high oil content, an oil crop.

The market for beverages is broadly divided in many countries into those products that are bought to quench thirst, and those that are consumed on special occasions including festivals. The former group are mostly nonalcoholic and include tea, coffee, and cocoa. Competition from medium/large-scale producers is most acute for small-scale producers in beverage manufacture. Many large-scale producers promote their products by implying status in their consumption and spend considerable amounts on advertising and packaging. They may also have established sophisticated distribution systems and specific agreements with wholesalers and retailers. Thus beverage manufacture is one of the most difficult for small-scale producers to establish and succeed in.

3.7 GLOSSARY

Analgesic: A drug characterized by its ability to relieve pain.

Antioxidant: An agent that inhibits oxidation. May reduce risks of contracting certain diseases.

Astringent: A drug characterized for its ability to draw together skin or mucous membranes.

Laxative: A substance that, when ingested, has the property of loosening the bowels.

Resin: A vegetable product obtained from secretions of fir and juniper plants used in making varnish and adhesives.

Tannins: An astringent substance found in some plants possessing the property of turning animal hide into leather.

Tincture: An infusion.

Canola oil: Rapeseed oil, specifically that prepared from rapeseed plants bred to be low in erucic acid.

Castor oil: A fixed oil obtained from the seed of *Ricinus communis;* used as a bland topical emollient and also occasionally as a strong cathartic.

Peanut oil: (Ground nut oil), a clear oil with some applications as a salad dressing, and, due to its high smoke point, especially used for frying.

Coconut oil: Cooking oil, with medical and industrial applications as well. Extracted from the kernel or meat of the fruit of the coconut palm. Common in the tropics and unusual in composition, with medium chain fatty acids dominant.[6]

Flaxseed oil: (called linseed oil when used as a drying oil), from the seeds of *Linum usitatissimum*. High in omega-3 and lignans, which can be used medicinally. A good dietary equivalent to fish oil.[60] Easily turns rancid.[61

Mustard oil : (pressed), used in India as a cooking oil. Also used as a massage oil.

Aged coffee: Certain coffees from the Asia/Pacific region benefit from prolonged storage prior to roasting. After ageing for three to five years, these coffees develop a unique cedar-spice flavour and are used in select Starbucks blends, including Starbucks® Christmas Blend.

Arabica: One of the two major commercially significant species of coffee. The only one purchased by Starbucks.

Berry: A flavour and aroma reminiscent of blackberries or blueberries. Some of the best coffees of East Africa and the Arabian Peninsula have these characteristics.

Blend: A coffee such as Caffè Verona® that combines coffees from different origin countries to achieve a taste that no single origin coffee can offer

Organic coffees: Coffee grown without the use of synthetic pesticides, herbicides or chemical fertilisers can be certified organic. They must also be processed in mills and roasting facilities that are certified organic.

Processing: The method in which the fruit of the coffee cherry is separated from the green coffee bean

Robusta: One of the two major commercially significant species of coffee. Grown at lower altitudes than arabicas. The flavour is less refined and the caffeine content is higher. Starbucks does not purchase robusta coffees

Astringent: A tea tasting term which describes a liquor which is pungent but inclined to be acidic

Black Tea: The most commonly consumed tea in the world accounting for approximately 80% of all consumption. In the United States well over 90% of the tea consumed is black. One of three major types of tea, the others being Green and Oolong. Black teas are the most processed of all teas in that they are oxidized or fermented.

Caffeine: A component of tea which stimulates the nervous system. A cup of tea averages 40 milligrams of caffeine versus approximately 110 in a cup of coffee

Darjeeling tea: A very high quality black tea grown in the Himalayan Mountains in Northern India. Called the champagne of teas

Fermentation: A term used to describe the processing of Oolong and Black teas. The actual chemical transformation which takes place is actually oxidation.

Green tea: Tea which undergoes minimal processing and most resembles the original green leaf.

Imperial Tea: A rolled Green Tea from Ceylon, China, or India made from older leaves. It has a g: Developed in the 1930's and commercialized in the 50's, instant tea sacrifices nuances in fragrance and flavor for convenience

Organoleptic: The process used by most tea tasters to evaluate the quality of a tea using all the senses

Tea: The leaf and extracted liquor of the shrub Camellia sinensis. No other beverages merit the unqualified term tea

Cocoa: A texture and flavour reminiscent of unsweetened cocoa powder. It leaves a somewhat dry but very pleasant aftertaste in the mouth

Cocoa Bean: The seed of the cacao tree, which is only called a cocoa bean once it is removed from the pod in which it grows.

Cocoa Pod: The leathery oval pod that contains cocoa beans.

Conching: Part of the process by which chocolate is manufactured. Cocoa liquor, cocoa butter and sugar are blended and placed in large agitators, called ‘conches’ that stir the mixture under heat.

Forastero Cocoa Beans: The most commonly grown and used beans. These beans make up about 90 percent of the world’s production and are grown primarily in West Africa.

3.8 SELF ASSESSMENT QUESTIONS

3.8.1 Short answer type questions:

1. Distribution and diversity of *Aconitum* species.
2. Medicinal uses of Belladona.

3. Historical perspective of medicinal uses of *Cinchona.*
4. How is cinchona bark testing is related to the birth of Homeopathy?
5. Different alkaloids found in *Rauvolfia serpentine.*
6. Traditional uses of *Ephedra* for a variety of medicinal purposes.
7. Major oil yielding plant species.
8. Beside oil, coconut is and essential element of rituals in Hindu tradition. Illustrate.
9. Importance of linseed as a food and fibre crop.
10. Domestication and production of groundnut.
11. World output of rapeseed & mustards.
12. General account of beverages with special reference to tea, coffee and cocoa.

3.8.2 Multiple choice questions:

1. The "Queen of all Poisons" is-
(a) Atropa (b) Aconitum
(b) Ephedra (d) Cinchona

2. "Deadly Nightshade" is-
(a) Aconitum (b) Rauwolfia
(c) Atropa (d) Ephedra

3. *Cinchona* is native to-
(a) Africa (b) Asia
(c)Australia (d) South America

4. Performance enhancing drugs in sports is-
(a) Aconitum (b) Ephedra
(c) Atropa (d) Rauwolfia

5. Botanically, the coconut fruit is a-
(a) Drupe (b) Nut
(c) Berry (d) None of the above

6. Flax was domesticated in-
(a) Fertile Crescent region (b) Andean hills
(c) Ethiopia (d) India

7. The domesticated peanut is a-
(a) Diploid (b) Polyploid
(c) Tetraploid (d) Amphidiploid

8. The largest producers of peanut is-
(a) USA (b) India
(c) Argentina (d) Brazil

9. The Indian state occupying first place both in terms of cultivated area and production of mustard is –

(a) Madhya Pradesh (b) Haryana
(c) Rajasthan (d) Uttar Pradesh

10. The world leader in production of tea is-

(a) People's Republic of China (b) India
(c) Sri Lanka (d) Kenya

11. The world leader in production of green coffee is-

(a) Vietnam (b) Indonesia
(c) Brazil (d) Colombia

12. The largest producer of washed *arabica* coffee-

(a) Brazil (b) Honduras
(c) Vietnam (d) Indonesia

13. The cacao tree is native to the-

(a) Europe (b) Americas
(c) Africa (d) Asia

14. The highest cocoa beans are produced by-

(a) African nations (b) Asia
(c) Americas (d) Oceania

15. In general cocoa is considered to be a rich source of-

(a) Polysaccharides (b) Proteins
(c) Fats (d) Antioxidants

3.8.2: Answers Key: 1-(b), 2-(c), 3-(d), 4-(b), 5-(a), 6-(a), 7-(d), 8-(b), 9-(c), 10-(a). 11-(c), 12-(d), 13-(b), 14-(a), 15-(d)

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3.11-TERMINAL QUESTIONS

1. Describe in brief how aconite has long been used in traditional Chinese medicine and Ayurveda (Hindu traditional medicine).
2. Name the toxins *Atropa* contains. What drug is derived from *Atropa* plant.
3. Who originally discovered the medicinal properties of the cinchona tree and in what ways it was used.
4. Describe different variety of uses of castor oil.
5. Name the traditional areas of coconut cultivation in India. Which Indian state has the largest number of coconut trees? Also describe various coconut-based products.
6. Where was linseed domesticated? Describe where it is cultivated most globally.
7. Who are the major producers/exporters of peanuts in the world?
8. Describe the world production and consumption trend of rapeseed and mustard.
9. India is the world's largest tea-drinking nation. What is the per capita consumption of tea per person every year? Name the country that is the world's greatest per capita consumer.
10. Who are the world leaders in production of Arabica and Robusta coffee?.
11. Describe the health benefits of consuming cocoa.

UNIT-4 ETHNOBOTANY

4.1 OBJECTIVES

After going through this unit student will be able to-

- Define the ethnobotany and know about the scope
- Discuss the historic roots of ethnobotany
- Discuss Ethnic groups of India, their food and food plants
- explain Ethnobotany and conservation of natural resources
- What are Ethnomedicinal plants
- Which ones are Narcotic plants

4.2 INTRODUCTION

The term ethanobotany was coined by J.W. Harshberger, an American botanist at the University of Pensylvania, in 1895. Ethanobotany is the systematic study of the relationships between plants and people though initially it was used to describe the study of plants used by primitive and aboriginal people. In other words Ethanobotany means all the sources of the plants towards humankind and the other species growing on the planet. From the ancient time, people have used plants to provide them food, fodder, medicines, clothes, fibers, crafts, dyes, soaps and detergent, dyes, novel compounds, materials for construction.

Ethno (as in ethnic) refers to people, culture, a culture collective body of beliefs, aesthetic, knowledge, language and practice. Botany is the study of plants.

The scope of Ethnobotany is increasing day by day. To describe the field in broader sense ethnobotanists have given their definitions time to time.

Jones (1941) defined Ethnobotany as 'the study of interrelations of primitive man and plants'.

According to Schultes (1962), Ethnobotany is defined as the study of the relationships which exist between plants and people of a primitive society and their plant environment'.

Vartak and Gadgil (1980) suggested 'Ethnobotany is a branch of economic botany, a section of which deals with the role of plants in life and culture of aborigines and tribal people'.

Alcom (1984) states that Ethnobotany is the study of contextualized plant use.

Jain (1987) applied the term Ethnobotany as the total natural and traditional relationship and interaction between man and his surrounding plant wealth. Wickens (1990) defined Ethnobotany as the study of useful plants prior to their commercial exploitation and eventual domestication.

According to ford 1994, Ethanobotany is concerned with a wide range of interest of plants in cultural and ecological context.

Turner (1996) has given an appropriate definition that is "the Science of people's interaction with plants".

Ethanobotany is the use of plants in material or abstract form among ethnic communities or tribal people. Sometimes, it is regarded as ethnographical or anthropological or tribal botany. Ethanobotany is a combination of ethnography and botany. Ethnographers describe the people of a region including their race, language and their uses of plants.

Ethanobotany is an interdisciplinary science and undertakes a research on the relationship between plants and humans in the areas of: nutrition, education, archaeology, linguistics, healing, paleology, livelihood, medicine, agriculture etc. The scope of the subject has expanded greatly. Botanists, anthropologists, social scientists, and the practitioners of indigenous medicines are engaged in the study of people-plant interactions in natural environment.

4.3 CONCEPT AND HISTORY

The term Ethnobotany was coined by the early 20^{th} century botanist John William Harshberger. The roots of ethnobotanical science can be traced in the ancient Sanskrit, Arabic literatures, Greek, ethnographics, travelogues etc. Vast ethanobotanical knowledge exists in India from ancient time. A variety of uses of plants are mentioned in the ancient Indian Sanskrit literature, e.g. Rigveda, Atharvaveda, Upanishads, Mahabharata and Puranas etc. These include plants used in worships, as medicines, tools of agriculture, food, fuel etc. A list of some of the importance Indian treatises is presented in two vedic periods Rigveda and Athervaveda 148 medicinal plants are included in Charaka Samhita 400-450 medicinal plants are included.

Pent-s'ao, the treatise on herbs written by Emperor Shah Nung has references to 365 drugs. It has also been reported that hundreds of drugs including important species, i.e., henbane, pomegranate, opium, poppy, aloe and onion were commonly used by the Egyptians. Ethanobotany has developed in the recent past into an important scientific discipline. The central issues in the ethnobotanical studies involve the interaction between plants and people and foremost among these are the management of plant diversity by indigenous communities and the traditional use of medicinal plants.

4.4 ETHNIC GROUPS OF INDIA

Ethnic Groups in India:

India has been the most ethnically diverse nation on earth for many centuries, with over 200 tribes, sub tribes, and some other ethnic groups. Ethnic categories exist based on language, religion, geographical ancestry and other factors. The following list of ethnic groups give State wise brief general information on some specify groups.

Uttarakhand:

Bhotia, Gangwal, Jodh, Jaunsari, Khaseas (different from Khasia, found in Kumaon), Tharu.

Andhra Pradesh:

Andh tribe Bagata (Bagatha), Chenchu, Hill Reddis, Jatapau, Kanmara (Konda), Khond (Konod), Kolam, Kollavaru, Konda-Dhora, Konda-Kapus, Konda-Reddis, Koya, Lambadis (Sugalis), Pardhan, Paroja, Saora, Valmiki, Yenadis, Yerakulas.

Madhya Pradesh:
Panika Gond tribe, Abujhmaria, Agariya, Baiga (Panda), Bhaina, Bharias (Bhumia), Bhatra, Bhil, Bhumiya, Binjhal, Binghwar, Birhor, Dhurwa, Gudaba, Gond, Halwa, Hillmaria, Kamar (Kanwar), Khairwar, Khariya, Khond, Kol (Col), Korku, Mahto, Manjhi, Majhwar, Munda, Maria, Mina, Saharias, Saora (Sawara), Pao, Pardhan, Pardhi, Paroja, Nagesia, Oraon.

Arunachal Pradesh:
Abor (Adi), Aka (Hrusso), Apatani, Bagung, Bangni, Deuri, Digaru-Mishmi, Hill-miri, Idu-Mishmi, Kangbo, Khampti, Meyer, Miji, Miju, Mishing, Mishmi, Monpa, Na, Nishi, Nocte, Sherdukpen, Simpha, Sulung, Tagin, Tangsa, Tangkhul, Wanehu, Yabin.

Himachal Pradesh:
Bhat, Gaddi (Gadi), Johari, Kanaura.

Uttar Pradesh:
Dusadh, Bhoxa (Bhoksa), Kol, Bhil, Kharwal, Tharu (Tippera), Bhotia, etc.

Gujarat:
Chaudhri (Chandhra), Ravalia, Damor, Dhodia, Dubla, Gamit, Kathodia, Katkuri, Kokna, Kunbi, Paradhi, Patelia, Rathawa, Vasavas.

Bihar:
Asur, Bathudi, Bedia (Beria), Birhor, Gond, HO, Karmali, Kharia, Kherwar, Kora, Kurmi, Santhal, Sauriya Pahariya.

Jharkhand:
Baiga, Korwa, Lohra, Munda, Mahto, Mallar, Parhaya, Porja, Sauria Pahariya.

Chhatisgarh:
Kol (Munda), Majhi, Majhwar, Muria, Gond, Nagesia, Pao, Abujhmaria.

Jammu & Kashmir:
Amchi (Laddakh), Bakarwala (Gujjars), Gujjar.

Karnataka:
Badaga (Nilgiri Hills), Koli (Dhor-Koli), Koya, Marati, Mullukurumban, Wynaadan-chetty, Yerava.

Kerala:
Panyan, Pathiyar, Pulayan, Uridavan-Gowdatu, Adiyan, Hill Pulaya, Ilava, Irula, Kadai, Kanikkar, Karimpalan, Kundu Vadian, Kurichya (Kurichchan), Kuruman, Kurumba, Malaarayan, Malakkaran, Malapantaram, Malavettivam, Malayar, Muthuvan.

Maharashtra:
Bhil, Dhanka, Dhanwar, Dhodia, Dubla, Halba (Holwa), Kokna, Kolam, Kolimahadev, Koli Malhar, Korku, Maria, Pardhan, Pardhi, Pathawa, Thakur, Varii.

Orissa:
Bagata, Banjara, Bathudi, Bhatra, Bhuiya, Bhumia, Bhumij, Binjhal, Buijhwar, Gadaba, Gondaru, HO, Juang, Kharia, Kharivar, Kisan (Kuda), Kol, Kolha, Konda, Dhora, Kora, Koya Lodha, Mallar, Mirdha, Munda, Mundari, Porja Santal Sounti.

Rajasthan:
Bhil, Garasia, Kathodia, Katkari, Mina, Saharias.

Tamil Nadu:
Irula, Kadar, Kota, Kuruman, Kurumla, Malasar, Malayali, Mullukurumban, Panyan, Toda, Urali, Kurumba.

West Bengal:
Asur, Bathudi, Bhotia, Bhumij, Bishor, Chick Barak, Ho (Munda), Kharwar, Kora, Korwa, Lepcha, Lodha, Lohra, Mahali (Mahli), Male (Maler), Parhaya, Santhals, Sheipa, Toto.

Assam:
Bodo or Boro-Kachari, Chakma, Deori, Dimasa-Kachari, Garo, Hojong, Hmar, Hojai, Kachari including Sonwal, Khasi and Jaintia, Kuki, Barmons, Lalung (Bodorace), Mech, Mikir (Karbi) Mishings, Hill miris.

Manipur:
Amol, Anal, Angami, Chira, Chothe, Gangte, Hmar, Kubui, Kacha Naga, Koirao, Koireng, Kom, Lamgang, Mao, Maram, Maring, Mizo, Monsang, Moyon, Paite, Purum, Ralte, Sabte' Sema, Simte, Tangkhul, Thodou, Vaiphei and Zou.

Meghalaya:
The Garo, Khasi and Jaintia, Banai, Baro, Bhoi, Biate, Dalu, Hajong, Koch, Lyngam, Man, Rabha and War Jaintia.

Mizoram:
Miza (Hmar, Lushai, Paite, Pawi, Ralti), Lakheri, Kuki, Thode, Chakma, Chowngthu, Abzia (Mora), (Chawhto, Nagenta, Khanlthting, Khaingte, Pautu, Rawite, Renthlet, Tlau, Vongachhia, Zawngte).

Nagaland:
Nagas (16 scheduled tribes) including Angami, AO, Chakhesang, Chang, Chirr, Konyak, Khei, Mnungan, Lotha, Makware, Phom, Rengma, Sangtam, Sema, Tikhir, Yimchungrel, Zeliang'

Sikkim:
Bhotia and Lepcha.

Andman & Nicobar Island:
Andmanese, a small tribe of Negrito race of a few dozen persons, Jarawa (Jorawa), Nicobarese,
Onge Sentinelese, Shompen (Great Nicobar).

4.5 IMPORTANCE OF ETHANOBOTANY

The Significance of ethanobotany is manifold. Since humans came into existence we have been using plants as medicines and food. Ethanobotanist study how people in different areas and different cultures have used plants throughout history. This area of study has become more popular as people around the world have become more interested in the medicinal qualities of plants. Beginning in the twentieth century, the field of ethanobotany experienced a shift from the raw compilation of data to a greater methodological and conceptual reorientation. The study of indigenous food production and local medicinal knowledge may have practical implications for developing sustainable agriculture and discovering new medicines. Ethanobotany also encourages an awareness of the link between biodiversity and cultural diversity, as well as a sophisticated understanding of the mutual influences (both destructive and beneficial) of plants and humans. Ethanobotany, in totality, is virtually a new field of research, and if this field is investigated thoroughly and systematically, it will yield results of great value to the ethanologists, archaeologists, anthropologist, plant-geographers and pharmacologists etc. The knowledge of ethanobotany plays a vital role in the primary health care and economy of the tribals and aboriginal populations of our country and has potential for the discovery of new herbal drugs and new sources of nutraceuticals etc. The agricultural practices are not technologically advanced and most tribal groups in north-east part of India resort to shifting cultivation widely known as Jhum. Jhuming or shifting cultivation involves felling of forest trees, clearing of shrubs and undergrowth in limited area and turning of soil for sowing crops. Ethanobotany contributes to an understanding of agriculture in two ways:

1-By explaining and describing the many different ways the same crop can be raised, whether for economic gain, a desire for sustained yield, or other culturally specific purposes.

2-By revealing ways to create genetically altered plants are almost the exclusive source of drugs for the majority of World population even today. Plant products constitute approximately 25% of the total prescribed medicines even in developed countries like U.S.A. Use of plants in folk medicine is very Prevalent in Central India (Jain, 1963, Jain and Tarafder, 1963). The record of use of herbal medicines in India is very ancient. India with diverse ethnic groups and rich biodiversity has a century old heritage of medicinal phototherapy for the treatment of various diseases and promotion of health.

The Botanists collects the information regarding the traditional uses of many plant species which are unknown to modern society from tribals. Anthropologists have to deal with the cultural aspects of the life of tribal people.

The ethno botanical studies throw light on certain unknown useful plants and new uses of many known plants which can be exploited for developing new sources for some plant products and agro based industries such as, food processing, fibres and floss, cordage and basketry, extraction of edible and non edible oils, gum, resins, tannin, dye extraction for the upliftment of tribal communities.

The study of ethno botany provides valuable information to the scientists, planners and administrators for the preparation of action plan for the economic emancipation of tribals and Eco development of tribal areas.

4.6 ETHNOBOTANY AND CONSERVATION OF NATURAL RESOURCES

The importance of Ethanobotany is that it has an important role to play in conservation of nature and culture, and in particular, the biological diversity and the diversity of traditional human cultures. Indigenous knowledge of food and medicinal plants can add value in the overall conservation and sustainable management of natural habitats and ecosystem. The indigenous knowledge which is transmitted from their ancestors is being well maintained as guarded secret. Local knowledge provides new insights and opportunities for sustainable and multipurpose use of resources and offers contemporary strategies for preserving cultural and ecological diversity. In recent years conservationists have realized that the maintenance of protected areas is closely linked to rural development. Indigenous people (particularly those that depend on forests) regularly face the threat of biodiversity loss, a factor that may affect their quality of life due to land degradation and deforestation. It is important that local indigenous peoples be given opportunity to conserve their own culture. Local people should be part of a conservation programme. *In-situ*, *ex-situ*, cryopreservation etc are discussed below-

1-In situ conservation: The conservation of genetic resources through their maintenance within natural or even human made ecosystems in which they occur, is called in-situ conservation. It is the process of protecting an endangered plant or animal species in its natural habitat. This method preserves both the population and the evolutionary process that enable the population to adapt by managing organisms in their normal state or within their normal range. For example, large ecosystems may be left intact as protected reserve areas with minimal intrusion or alteration by humans. In India, ecologically unique and biodiversity-rich regions are legally protected as biosphere reserves, national parks, Sanctuaries, nature reserves, reserved forests. India now has 14 biosphere reserves, 90 national parks and 448 wildlife sanctuaries.

2- Ex-situ conservation is the conservation of plants away from their areas of natural occurrence. The knowledge of ethanobotany is important to manage plants in the landscape for better watershed management. For watershed development and management, the contribution of local people's knowledge, consortium approach and adoption of new technology are important to achieve desired result for insuring sustainable utilization of natural resources in a given watershed. The watershed approach enables planners to harmonize the use of soil, water and vegetation in a way that conserves these resources and maximize their productivity. The impact of resource conservation in a Shivalik micro watershed was studied 10 years after imposition of protection. The main activity taken up in the micro watershed was the construction of an earth fill dam in 1992 at the outlet to runoff water from a contributing area of 59.6 ha consisting of sparse vegetation. Ex-situ conservation and maintenance of samples of living organisms outside their natural habitat, in the form of whole plants, seed, pollen, vegetative propagules, tissue or cell cultures. This involves conservation of genetic resources, as well as wild and cultivated or species, and draws on a diverse body of techniques and facilities. Botanical gardens play a key role in ex-situ conservation of medicinal plants. In India, we have a network of 140 botanical gardens which includes 33 botanic gardens attached to the Universities. Some of these are meant for medicinal plants and there are exclusive herbal gardens (National Botanic Gardens, now NBRA- National Botanical Research Institute) at Lucknow and Tropical Botanic Garden and Research Institute at Palode (TBGRI- near Tiruvananthapuram) have medicinal plants wings.

Ex-situ conservation provides excellent research opportunities on the components of biological diversity.

3-Cryopreservation is the process of freezing biological material at extreme temperatures; most common-196^{0}C / -321^{0}F in liquid nitrogen (N_2). The objective of cryopreservation is to minimize damage to biological materials, including tissues, mammalian cells, bacteria, fungi, plant cells, and viruses, during low temperature freezing and storage. Cryopreservation technology is important to preserve the genetic diversity of a particular plant or genetic stock for its use at any time in future.

In India, 4.5 % of total geographical area constitutes protected area network, comprising eight designated biospheres, 87 national parks, and 447 wildlife sanctuaries. These protected areas harbour large varieties of medicinal plants.

The Himalayan region is blessed with an immense amount of natural resources such as forest, water and wildlife. The local inhabitants have been dependent upon indigenous plant resources for their daily needs. The people of the Himalayan region are well aware of valuable species of medicinal and aromatic plants. These are now under stress due to over-extraction. Conservation of these valuable resources is now crucial. The wise use, development and conservation of our natural resources is every individuals duty.

4.7 PLANTS OF ETHNOBOTANICAL IMPORTANCE

India has about 563 tribal communities having past traditional knowledge through their long association with the forests. They have collected valuable knowledge on the use of wild plants in their daily life for food, fuel, fodder, clothing, health-care and other purposes. Many native people also use plants in ceremonial or spiritual rituals. Most of the traditional knowledge about plants and their uses in fast disappearing as a consequence of socio-economic and land use changes. The ethnobotanical studies through light on certain unknown useful plants and new uses of many known plants which can be exploited for developing new sources for some plant products and agro based industries. Botanical Survey of India initiated recording and documenting this ethnobotanical data of all tribes belonging to the states of Bihar, Goa, Karnataka, Orissa, Rajasthan, Himachal Pradesh, Chattisgarh, Uttarakhand, Andaman and Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Assam, Jammu and Kashmir, Madhya Pradesh, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal for critical studies leading to sustainable utilisation of bioresources, documentations of traditional knowledge system.

The tribals and natural populations living in different parts of India use plant species of forest floras for food, fodder, fibres house building, fuels, medicines, beverages, oils, gums, resins, dyes, basketry, timber and wood works, musical instruments, fish poisons, religious ceremonies, narcotics etc. About 5000 plant species have been recorded so far which are used by tribals and aboriginal communities in different states.

Food plants of tribal people

Indigenous people are those who retain knowledge of the land and food resources rooted in historical continuity within their region. The food systems of Indigenous people often included "traditional foods", that is, which indigenous people have access to locally, without having to purchase them, and within traditional knowledge and the natural environment from farming or wild harvesting. Tribals take shelter from forest and utilize wild edible plants both raw and cooked. Forest plays an important role in enhancing livelihood requirements for rural community. Over 50 million tribal people in India belong to 550 communities of 227 ethnic groups (1-3) and about 60 % of the rural communities directly rely on forest for their day-to-day requirement. The flower and fruits are generally eaten raw where as tubers, seeds and leaves are cooked. There is an enormously larger number of plants that are potentially edible (about 30,000 species), including about 7,000 species that are being utilized locally by indigenous peoples as nutritious sources of food.

Tribal people through their hereditary traditional knowledge know about the useful and harmful effects of plant food. The foods, habits of people are developed on the basis of experience and survival through successive generations.

Earliest food gathering man gathered fruit, nuts, moss, tubers, mushroom, morels and stems in season. Now they are fully aware how to exclude the substances from the wild plants and preparing recipes for their meager meals. A list of some wild plants used as food is given below:

1-*Annona squamosa* Verna. Sharifa, family- Annonaceae. The fresh flowers are eaten, the ripe fruits are eaten and the under-ripe fruits are roasted and eaten.
2- *Bauhinia purpurea*, *B.variegata* and *B.diffusa,* Verna, Kachnar, Family- Caesalpiniaceae. The tender leaves, buds and flowers are eaten as vegetable.
3-*Bombax ceiba*, verna. Semal, Family-Bombacaceae. The flowers and young fruits are eaten as vegetable.
4- *Cassia fistula*. Verna. Amaltas, Family-Caesalpiniaceae. The flower buds and the flowers are used as vegetable by tribals.
5- *Emblica officinalis*. Verna. Amla. Family- Euphorbiaceae. The fruits are eaten raw or cooked.
6- *Ficus religiosa.* Verna. Peepal, family- Moraceae. The leaf buds are used as vegetable.
7- *Holostemnia annulare.* Verna. Dudhi, family- Asclepiadaceae. The leaves are used with pulses to make curry.
8- *Indigofera pulchella*, verna. Jirhul, family- papilionaceae. The pink flowers are eaten as vegetable.
9- *Leucas cephalotes*, verna. Durup, family-Lamiaceae. The leaves are used as vegetable.
10- *Madhuca latifolia*, verna. Mahua, family-Sapotaceae. The flowers are eaten fresh and dry. The fruits are eaten as vegetable. A spirit prepared from flowers is considered as tonic and nutritive.
11- *Moringa oleifera.* Verna. Sainjana, Family- Moringaceae. The pods and flowers are used as vegetable.
12- *Randia dumetorum*. Verna. Maurea, Family- Rubiaceae. The leaves are used as vegetable, and the ripe seeds are edible.
13- *Shorea robusta*, verna. Sal, Sakna, Sarjan, Daru, Family-Dipterocarpaceae. The seeds are eaten by the poor as a famine food.
14- *Terminalia cremulate.* Verna-Asan, Family- Combretaceae. The hard gumming exudates from the stem is called 'asan-latha' is eaten and considered delicious.
15- *Dioscorea bulbifera.* Verna- Gethi kanda. The yam is cut into slices, boiled and kept in running water and eaten.

Some less known ethnic plants which are used by tribals for food, ethno medicine and narcotic purposes are listed here.

Plant Species	**Common Name**	**Family**	**Plant parts used**	**Tribal areas**
Vegetables				
Amaranthus spinosus	Kanta chaulai	Amaranthaceae	Young shoots	
Amaranthus viridis	Jangali Chaulai	Amaranthaceae	Young shoots	
Aspragus racemosus	Shatavari, or Shatamull	Liliaceae	Tuberous roots and tender shoots	North Bengal
Bambusa		Poaceae	Young shoots	Meghalaya &

khasiana				Manipur
Bambusa tulda	Jati	Poaceae	Young shoots	Meghalaya & Manipur
Bambusa vulgaris	Baans	Poaceae	Young shoots	Meghalaya & Manipur
Bauhinia purpurea	Kaniar	Caesalpiniaceae	Flower buds	Sikkim, Darjeeling
Begonia palmata	Begonia	Caesalpiniaceae	Tender shoots and leaves	N-E India
Boerhaavia diffusa	Punurnava	Nyctaginaceae	Leaves	
Bombax ceiba	Simal	Bombacaceae	Flwer buds and fleshy calyx	Assam, Manipur, Meghalaya
Buddleja asiatica	Neemda, Dhaula	Loganiaceae	Leaves (eaten raw)	Arunachal Pradesh
Calamus erectus and *C.tenuis*	Jeng bet (in Assam)	Arecaceae	Young shoots	Arunachal Pradesh, Assam
Chenopodium album	Bathua	Chenopodiaceae	Young shoot India	N-E India, Central
Chlorophytum arundinaceum	Safed musli	Liliaceae	Whole plant	N-E India
Clerodendron spp		Verbenaceae	Tender shoot & leaves	N-E India
Colocasia esculenta	Arvi	Araceae	Tender leaves & corm	All over India
Commelina bengalensis	Kana	Commelinaceae	Young leaves	N-E India
Costus spaciosus	keukand	Zingiberaceae	Flowers and rhizome	Sikkim, Manipur
Cyathea gigantean (Tree fern)		Cyathiaceae	Pith	Nishi & Shulung of Arunachal Pradesh
Debregeasia longifolia	tusara, sausaru	Urticaceae	leaves	Uttarakhand
Dioscoria spp.	Yam	Dioscoriaceae	Tubers and Bulbils	Uttarakhand
Diplazium esculentum		Athyriaceae (fern)	Young fronds	N.E. India
Elatostema platiphyllum		Urticaceae	leaves	Assam, Arunanchal States
Fagopyrum	Ban ogal	Polygonaceae	leaves	N.E.India,

dibotrys (Syn. F.cymosum				Uttarakhand, J&K, Shimla
Fagopyrum esculentum	Kuktu	Polygonaceae	Leaves and seeds	N.E.India, Uttarakhand, J&K, Shimla
Girardinia palmate		Urticaceae	Tender shoots	Sikkim, Darjeeling
Ipomoea aquatic	Nali	Convolvulaceae	Tender shoots	N.E.India, Uttarakhand, U.P., M.P., Bihar
Lassia spinosa	Invider kand	Araceae	rhizomes	Assam, Nagaland
Meliosma pinnata		Salriaceae	Young leaves & shoots	Napalese in Sikkim
Moringa oleifera	Senjana	Moringaceae	Young leaves and fruits	All tribals in India use it Sikkim, Assam
Musa balbisiana	Banana	Musaceae	Young fruits and inforescence	Sikkim, Assam, Darjeeling
Natsiatum herpeticum		Icacinaceae	Leaves & young shoots	Sikkim, Assam, Darjeeling
Oenothera javanica		Apiaceae	Young shoots	Sikkim, Arunachal
Plantago erosa (Syn. P. major)	Lahuriya	Plantaginaceae	Tender shoots	Arunachal, Manipur
Portulaca oleracea	Lunia	Portulacaceae	Leaves & shoots	All over India
Pueraria tuberose	Vidarikand	Fabaceae	Tubers & young shoots	Sikkim
Rhus javanicus	Tatri	Anacardiaceae	Tender shoots	Sikkim, Darjeeling, Manipur
Rumex hastatus	Amlora, Chulmora	Polygonaceae	leaves	N.E. India, Bihar, U.P., Uttarakhand
Solanum indicum	Badikateri, Jangli bhata	Solanaceae	Fruits	N.E. India
Sterculia indica		Sterculiaceae	Tender shoots	N.E. India
Urtica ardens	Himalayan Nettle (in English)	Urticaceae	Young leaves & shoots	Sikkim, Manipur
Vaccinum vacciniaceum		Vacciniaceae	Leaves & flower	Manipur, Sikkim
Zanthoxylum acanthopodium	Darmar, tejphal	Rubiaceae	Tender shoots & leaves	Manipur, Meghalaya,

				Manipur, Arunachal Pradesh
Fruit and Seeds				
Aegle marmelos	Bael	Rutaceae	Pulp of ripe fruits	N.E. India, Bihar, U.P., Uttarakhand, M.P., Orissa, Bihar
Aglaia edulis		Meliaceae	Aril	Sikkim, Darjeeling
Ampelocissus barbata	Jarila-lahari	Vitaceae	Ripe fruits	Sikkim, Manipur
Aporusa octandra		Euphorbiaceae	Ripe fruits	Sikkim, Manipur, Arunachal, Meghalaya
Artocarpus chama	Chaplasp	Moraceae	Ripe fruits	N.E. India, U.P., Bihar, Uttarakhand
Bauhinia purpurea	Kaniar	Caesalpinaceae	Seeds	Sikkim, Darjeeling
Castanopsis indica	Chestnut, Hinguri	Fagaceae	Fruits and seeds	Assam, Meghalaya
Clausena dentata		Rutaceae	Ripe fruits	Sikkim
Daphiniphyllum himalayense		Daphniphyllaceae	Ripe fruits	Arunachal Pradesh
Dandrocalamus hamiltonii	Kaghsi bans	Poaceae	Seeds used as rice	Arunachal, Assam, Sikkim, Darjeeling
Duchesnea indica (Syn. Fragaria indica)	Kiphaliya	Rosaceae	Fruits	Khasia, Manipur, Arunachal
Echinochloa coloum	Jungle rice	Poaceae	Grains	Arunachal, Mehgalaya
Elaeagnus caudate	Wild Olive	Elaeagnaceae	Ripe fruits	N-E.India
Elaeagnus pyriformis		Elaeagnaceae	Ripe fruits	N-E.India
Emblica officinalis	Amla	Euphorbiaceae	Fruits	N-E.India, U.P., Bihar, M.P.
Evodia fraxinifolia		Rutaceae	fruits	Sikkim, Manipur
Fagopyrum esculentum	Kotu, kuktu	Polygonaceae	seeds	N-E.India
Fagopyrum dibotrys	Ban ogal	Polygonaceae	Made into flour	Uttarakhand
Ficus hispida	gobla,	Moraceae	Ripe fruits	Sikkim, Manipur,

	kagsha			Assam
Garcinia anomala		Clusiaceae	fruits	Manipur
Garcinia pedumeulata	Amalvet	Clusiaceae	fruits	Assam, Manipur
Gnetum gnemon		Gnetaceae	Seeds	Assam, Manipur
Hodgsonia macrocarpa	Lard fruit	Cucurbitaceae	Roasted seeds	N-E.India
Knema lincifolia		Myristicaceae	fruits	Manipur, Meghalaya
Litsea cubeba	Mountain Pepper	Lauraceae	fruits	Sikkim, Darjeeling
Mangifera sylvatica	Himalayan Mango, Pickling Mango	Anacardiaceae	fruits	Sikkim, Darjeeling
Melia dubia	Malabar Neem, kadukhajur	Meliaceae	fruits	Sikkim, Darjeeling
Microcos paniculata	Shiral	Teliaceae	fruits	Manipur, Maghalaya, Uttarakhand
Morus australis	Contorted mulberry	Moraceae	fruits	N-E.India, Uttarakhand
Musa balbisiana(Syn. M.sikkimensis)	Bhimkol	Musaceae	fruits	Sikkim, Darjeeling
Myrica esculenta	kaphal	Myricaceae	fruits	Sikkim, Darjeeling
Phoenix acaulis	Chota khajur	Aracaceae	Ripe fruits	Sikkim
Prunus cerasoides	Padam	Rosaceae	Ripe fruits	Arunachal, Manipur, Uttarakhand, H.P.
Pyrus pashia	Mehal Mole, Kainath	Rosaceae	fruits	Meghalaya, Manipur
Rhus javanica	Tatri	Anacardiaceae	Fruits	Sikkim, Darjeeling, Manipur
Rubus biflorus		Rosaceae	Fruits	Sikkim, Manipur
Rubus ellipticus	Lalanchu, Hinsal	Rosaceae	fruits	Sikkim, Manipur
Saurauria nepalensis		Saurauriaceae	Fruits	Arunachal, Sikkim, Meghalaya
Sterculia villosa	Katira	Sterculiaceae	Roasted seeds	N-E.India

Syzygium claviflorum	Grey Satinash	Myrtaceae	Ripe fruits	Sikkim, Darjeeling
Tetrastigma bracteolatum		Vitaceae	Ripe fruits	Sikkim, Manipur
Viburmum cotinifolium		Caprifoliaceae	Ripe fruits	Sikkim
Zizyphus apetata		Rhamnaceae	Ripe fruits	Sikkim
Ethnomedicinal plants				
Acorus calamus	Bach	Araceae	Root and rhizome paste used as antiseptic, paste is used in snake bite, Leprosy	Tharu in Kheri district Nagaland, Arunachal, Sikkim
Aconitum ferox	Bachang, Meetha vish	Ranunculaceae	Corm and root powder is given to animals to cure sickness	Nagaland, Arunachal
Alpinia galanga	bara-kulanjan	Zingiberaceae	Rhizome powder is given orally for rheumatism, piles and respiratory troubles in children	Manipur Nagaland, Arunachal
Amomum aromaticum	Morang ilachi	Zingiberaceae	Paste of rhizome and seed given for abortion and as purgative	Arunachal, Meghalaya
Begonia palmata		Begoniaceae	Plant extract is cure for stomach ache and diarrhoea	Nagaland
Berginia ciliata	Pashanbheda	Saxifragaceae	Plant extract is cures cough and cold, paste of plant stops bleeding	Arunachal, Sikkim
Clerodendron colebrookianum		Verbenaceae	Leaf paste is applied in rheumatism and	Assam, Nagaland

			gout, plant decoction is a cure for Malaria	
Coptis teeta	mameera	Ranunculaceae	Plant decoction is used in cough, cold and fever, backache and Malaria	Arunachal
Costus speciosus	Keukand, Keu, Kust	Zingiberaceae	Rhizome decoction given in kidney stone, burning pain during urination	Nagaland, Manipur
Croton roxburghii	Bhutala	Euphorbiaceae	Seeds are purgative, seed oil is insecticide, plant juice is antidote to snake poison	Nagaland, Manipur, Arunachal
Curcuma angustifolia	Tikhur	Zingiberaceae	Rhoizome juice is rubbed on swollen parts and paste applied on bone fracture	Nagaland
Eclipta prostrata	Bhringaraj	Asteraceae	Aqueous extract of plant given in body swelling	Tharus of U.P.
Eryngium foetidum	Ban dhania	Apiaceae	Plant juice is used for headache, fever and as tonic	Nagaland
Euphorbia acaulis		Euphorbiaceae	Paste of root stock boiled with linseed oil is applied on rheumatism	Tharus of U.P.
Geranium nepalense	ratanjot	Geraniaceae	Powder of whole plant is given in stomach disorders	Nagaland, Sikkim, Darjeeling
Helictres isora (Vsn. Marorphali)	Maror phali	Sterculiaceae	Seed extract is given in dysentery	Tharu of U.P.
Hedychium spp.		Zingiberaceae	Decoction of	Arunachal,

			rhizome is cure for bronchitis, tonsillitis, throat and stomach trouble	Manipur
Hydnocarpus kurzii		Flacourtiaceae	Seed oil is a cure for leprosy	Nagaland, Manipur
Helminthostachys zeylanica	Kamraj	Ophioglossaceae	Rhizome decoction is given in impotency and leaf juice cures tongue blisters	U.P.(Tharu)
Picrorhiza kurroa (Kutki)	Kutki	Scrophulariaceae	Root decoction is given in diarrhoea, cough, influenza, fever. It is effective in liver and spleen disorders	Arunachal, Sikkim, Dharchula in Pithoragarh (Uttarakhand)
Piper spp.		Piperaceae	Paste of stem and black pepper is given for sterilization of woman, and leaf juice cures eye troubles	Assam, Darjeeling, Sikkim, Meghalaya
Podophyllum hexandrum		Podophyllaceae	Decoction of roots and rhizome is given for tumor and skin diseases and as purgative	Arunachal
Rubia cardifolia	Majith	Rubiaceae	Root and stem decoction is given for stomach ailment, chest trouble, jaundice and irregular menstruation and cancer	Meghalaya, Darjeeling, Nagaland, Pithoragarh (Uttarakhand)
Solanum viarum		Solanaceae	Seed powder mixed with mustard oil is	Assam, Meghalaya, Nagaland, U.P. (by

			inhaled to relieve headache, cold, blocked nose and insanity	Tharu)
Solanum torvum	Bhurat, Bhankatiya	Solanaceae	Leaf decoction is given in snake bite, and fruits given in cough and tonsil complaints	Khasi, Jantia, Manipur
Stephania glabra	Rajapatha, Gindaru, Ganeeth	Manispermaceae	Tuber powder along with honey is given in Asthma and stomach tumor. Juice of tuber is dropped in eyes to cure eye diseases	Nagaland
Swertia chirayeta	Chirayata	Gentianaceae	Plant powder is given in stomache and root decoction in fever and influenza	Nagaland, Sikkim, Uttarakhand
Taraxacum officinalis	Dudhi, Baran	Asteraceae	Given in malaria and urinary complaints	Arunachal

4.8 AREAS OF ETHANOBOTANICAL STUDIES

Ethnobotanists engage in a broad array of research questions and practices, which do not lend themselves to easy categorization. However, the following headings attempt to describe some of the key areas of modern ethnobotanical study.

1-Archaeoethnobotany: Archaeoethnobotany involves three subjects namely, archaeology, ethnology, and botany. This interdiscipline of ethanobotany studies the identification of plant materials from archaeological sites for studies on migration of human cultures, and origin, dispersal and domestication of crops, etc, (Smith J., 1965).

2- Ethnoecology: Ethnoecology is the scientific study of the past and present interrelationships between human societies, and their living and non-living environment. It seeks valid, reliable understanding of how humans have interacted with the environment and how these intricate relationships have been sustained over time.

3- Ethnomedicine: includes research that deals with medicines derived from plants, animals, minerals, etc., and used in the treatment of various diseases and ailments, based on indigenous phurmacopoeia, folklore and herbal charms (Weiner, 1971). Ethnomedicine is a sub-field of medical anthropology that deals with the study of traditional medicines—not only those with relevant written sources (e.g., Traditional Chinese Medicine and Ayurveda), but also those whose knowledge and practices have been orally transmitted over the centuries.

4- Ethnogynaecology: is an emerging discipline that deals with various diseases among women in tribal societies, related to sterility, conception, abortion, etc., and the use of abortifacients (Tarafder, 1983).

5- Ethnomusicology: is defined as "the study and cultural aspects of music and dance in local and global contexts". It also includes the study of musical instruments they make and use, which are often made of plant materials.

6- Ethnomycology: is the study of mushrooms and other fungi by common people, as food or medicine, or in crafts, stories, or rituals.

7-Ethnonarcotics: deals with study of the use of narcotics, snuffs, hallucinogens, etc, in primitive human societies.

8-Ethnopharmacology: is the scientific study correlating ethnic groups, their health, and how it relates to their physical habits and methodology n creating and using medicines. This is a key field that often explains the effectiveness of herbal medicine, stimulants, analgesics, inebriants or psychoactive species. Both ethnomedicine and ethnopharmacology overlap significantly with ethnobotany.

9-Ethnotaxonomy: The term ethnobotany refers the naming and classification of plants and their cultivars, and animals and their races by human societies in their language. Ethnotaxonomy studies the ethnic concepts of classification of plants based on habit, habitat, colour, odour, usage or some other parameters.

10-Ethnotoxicology: Study of use of various plants as fish poison (Ichthyotoxic), arrow poisons etc., in human societies. The adivasis possess immense knowledge on procurement of wild food using poisonous crude drugs.

11- Paleoethnobotany: deals with the identification of fossolized plant materials and remains for studies on ancient plant economy, palaeoethnobotanical history of crops and changing patterns. On the use of plant life by human culture (Stewart, 1976). Major research themes are recovery and identification of plant remains, the use of wild plants, the origins of agriculture and domestication, and the co-evolution of human-plant interactions.

4.9 NARCOTIC PLANTS

The term "narcotic," derived from the Greek word for stupor, originally referred to a variety of substances that dulled the senses and relieved pain. Term originally applied to all compounds that produce insensibility to external stimuli through depression of the central nervous system, but now applied primarily to the drugs known as opiates—compounds extracted from the opium poppy and their chemical derivatives. Also classed as narcotics are the opioids, chemical compounds that are wholly synthesized, but which resemble the opiates in their actions.

Many narcotic plants contain substances that have medicinal properties and are used primarily as pain relievers. Alkaloids are the principal active constituents of narcotic plants. Many of these plants are highly toxic, and the drugs obtained from them cause narcomania when frequently used.

Narcotics have a high potential for abuse. As abused drugs they are sniffed, smoked, or self-administered by the more direct routes of subcutaneous ("skin-popping") and intravenous ("mainlining") injection. Drug effects depend heavily on the dose, route of administration, and previous exposure to the drug. Aside from their medical use, narcotics produce a general sense of well-being by reducing tension, anxiety, and aggression. These effects are helpful in a therapeutic setting but contribute to their abuse

The uses of narcotics, snuffs, hallucinogens, etc, in primitive human societies have been noticed since the beginning of recorded history. There are such types of plant given below-

1-**Betel palm** (Areca catechu L.) is a tree like plants in the genus Areca and family Palmaceae.

The betel palm is cultivated for its seeds, which together with lime get wrapped in betel leaves, used by natives for chewing (the mixture is called "moma"). Betel is the fourth most common psychoactive drug in the World, following caffeine, alcohol and nicotine. The seeds contain alkaloids such as arecaidine and arecoline, which when chewed, are intoxicating and slightly addictive. Areca palms are grown in India, Indonesia, Bangladesh, Taiwan, Malaysia and many other Asian countries for their seeds**.** Betel chewing releases a number of addictive alkaloids that cause sensations of mild euphoria, and regular users often have red-stained teeth and lips. In Ayurvedic medicine betel nut is used as a diuretic, digestive, anthelmintic, astringent, and cardiotonic. Betel nuts are also used as an offerings to Hindu deities. Excessive use of this plant causes profuse salivation, vomiting and stupor. Betel chewing can also cause a number of serious health problems, including oral and esophageal cancer.

2-Jimson weed (Datura L.) is an annual with unpleasant smell, reaching up to 50 cm in height. The species belongs to the genus Datura, family Solanaceae. It is a large herbaceous, rarely arborescent plant. The seeds represent a thorned many-seeded capsule, the size of walnut. The plant contains chemicals such as atropine, hyoscyamine, and scopolamine. These chemicals interfere with one of the chemical messengers (acetylcholine) in the brain and nerves. Due to its easy availability and strong anticholinergic properties, teens are using jimson weed as a drug. Despite serious safety concerns, jimson weed is used to treat asthma, flu (influenza), cough, swine flu, and nerve diseases.

3-**Hemp** (Cannabis L.) is a genus of bast-fiber annuals of the family Cannabaceae. Cannabis contains psychoactive substances, cannabinoids, including tetrahydrocannabidinol (THC); it is used as raw material for popular psychotropic substances (hashish, marijuana etc). According to the modern classification, genus Cannabis includes one species with two subspecies: *Cannabis sativa* subsp. *sativa* — Common hemp, *Cannabis sativa* subsp. *indica* — Indian hemp. There was a third species earlier, called Ruderal hemp, but now it doesn't have an independent rank and considered to be a synonym of Cannabis sativa subsp. sativa. Hemp is used to make a variety of commercial and Industrial products including rope, clothes, food, textiles, paper, plastics, insulation and biofuel. Known for its characteristic leaves, the plant is used in religious practices in India.

4-**Poppy** (Papaver L.): A poppy is a flowering plant in the subfamily Papaveroideae of the family Papaveraceae. One species of poppy, *papaver somniferum*, is the source of the crude drug opium which contains powerful medicinal alkaloids such as morphine and has been used since ancient time as an analgesic and narcotic medicinal and recreational drug. Poppies are herbaceous plants, often grown for their colorful flowers. The seeds of the poppy are widely used as the popular "Poppy-seed" found in and on many food items such as cakes, bagles, muffins. Poppy extracts have traditionally been used to relax smooth muscle tone, making them potentially useful in the treatment of diarrhea and abdominal cramping.

5-Tobacco- *Nicotiana tobacum*, tobacco, is a stout herbaceous plant in the Solanaceae (nightshade family) that originated in the tropical America (South America, Mexico and the West Indies) and now cultivated worldwide as the Primary commercial source of tobacco. Tobacco contains the alkaloid nicotine, which is a stimulant, and harmala alkaloids. Dries tobacco leaves are mainly used for smoking in cigarettes, cigars. They can also be consumed as chewing, tobacco, snuff, dipping tobacco and snus. Tobacco causes cardiovascular diseases and lung disease.

6- Ephedra: Ephedra is a genus of gymnosperm shrubs, the only genus in its family, Ephedraceae and order, Ephedrales. The various species of Ephedra are widespread in many lands, native to Southwestern North America, Southern Europe, Northern Africa, Southwest and Central Asia, Northern China and Western South America. The whole *Ephedra sinica* plant has traditionally been used by indigenous people for a variety of medicinal purposes, including treatment of bronchial asthma, hay fever, colds, allergies, influenza, and hives in teas of tinctures. Dosages of Ephedra more than 32 mg/day have resulted in adverse reactions. Ephedra can cause a quickened heartbeat and elevated blood pressure. Side effects include heart palpitations, nausea and vomiting.

7-Sarpgandha: Rauwolfia serpentine (sarpagandha) also known as Black snakeroot or Indian snakeroot or devil pepper, is a species of flower in the family Apocynaceae. It is native to the Indian subcontinent and East Asia (from India to Indonesia). The herb is known to cure numerous disorders due to its constituents like alkaloids, carbohydrates, flavonoids, phlobatannins, glycosides, resins, phenols, tannins, saponins and terpenes. The root of Sarpagandha is used in medicines. Its roots contain the highest amount of active substances, which are beneficial as active substances, which are beneficial as anti-anxiety, sedative, antihypertensive and relaxing effects.

8. Quinine: *Cinchona officinalis* is a medicinal plant, one of several cinchona species used for the production of quinine. Cinchona is a genus of flowering plants in the family.

Rubiaceae containing at least 23 species of trees and shrubs. Quinine is an alkaloid which can reduce fever, work against malaria, pain and swelling. The bark of the cinchona family of trees contains quinine. Quinine may cause some unwanted effects such as Diarrhoea, vomiting, nausea, stomach cramps or pain.

9. Belladonna: A poisonous plant of the nightshade family, with purplish or reddish bell-shaped flowers and shiny black berries. The word belladonna is from the Italian word belladonna literally, fairlady (so called because it is said to have been used by women to dilate the pupils of the eyes and to create an artificial Pallor). Belladonna is a natural substance made from a toxic plant. Pharmacology a drug from the leaves and root of this plant, containing atropine and related alkaloids used in medicine to check secretions and spasms, to relieve pain or dizziness and as a cardiac and respiratory stimulant.

10. Aconite: Aconite is a genus of plants belonging to natural order Ranunculaceae, the Buttercup family, also known as monkshood (because of the shape of the flower), or wolfsbane (because of its use in hunting). Aconitine and other alkaloids found in aconite are highly toxic. Despite serious concerns about safety, some people takes aconite by mouth for facial paralysis, finger numbness, joint pain, gout, fever, skin diseases etc. Aconite has been used since ancient times, especially as an antidote.

4.10 SUMMARY

Ethanobotany is the systematic study of the relationships between plants and people. The term Ethanobotany was coined by J.W. Harshberger. Ethanobotanical studies involve the interaction between plants and people and the management of plant diversity by indigenous communities and the traditional use of plants. India has been the most ethnically diverse nation on earth for many centuries. Ethanobotany encourages an awareness of the link between biodiversity and cultural diversity. The study of ethanobotany provides valuable informations to the scientists, planners and administrators for the preparation of action plan for the economic emancipation of tribals and eco development of tribal areas. Ethanobotany has an important role in conservation of natural resources through in-situ, ex-situ, cryopreservation etc conservation programmes. The tribals living in different parts of India use plant species for food, fodder, fibres house building, medicines etc. Areas of Ethanobotanical studies are Archaeoethanobotany, Ethnomedicine, Palaoethanobotany etc. The use of narcotics, snuff, hallucinogens etc, in primitive human societies have been since the beginning of recorded history.

4.11 GLOSSARY

Ethanobotany: It is the study of human interaction with the plant world.
Ethanobiology: It is the study of the relationships between people, the life forms surrounding them, and the environment in which they live, in the past or present.

Ethanomycology: It is the study of folk knowledge of mushrooms and other fungi.
Ethanomedicine: It is study of traditional medicines, whether written, or remembered and transmitted via oral tradition.
Ethanopharmacology: It is the study of the uses, effects and modes of actions of naturally-occurring drug compounds.
Ethanomusicology: It is the study and cultural aspects of music and dance in local and global contexts.
Ethanoecology: It is the scientific study of the way different groups of people in different locations, understand ecosystems around them, the environments in which they live and their relationship with these.
Narcotic: anything that relieves pain or induces sleep, mental numbness, etc.
Indigenous: Existing, growing, or produced naturally in a region or country; belonging (to) as a native
Jhum cultivation: also known as the slash and burn agriculture, is the process of growing crops by first clearing the land of trees and vegetation and burning them thereafter.
Helminths: worm that is parasitic on the intestines of vertebrates especially roundworms and tapeworms and flukes
Tetrahydrocannabidinol (THC): A compound that produces psychoactive effects in humans.

4.12 SELF ASSESSMENT QUESTIONS

4.12.1 Multiple choice Questions:

1-The study of folk knowledge of mushrooms and other fungi
(a) Ethnotoxicology (b) Ethanarcotics
(c) Ethanomycology (d) Ethanomedicine

2- Which one of the following is not a narcotics plant?
(a) Hemp (b) Kutki
(c) Poppy (d) Datura

3-Botanical names of majith is
(a) *Rubia cordifolia* (b) *Picrorhiza kurroa*
(c) *Curcuma angustifolia* (d) *Ficus hispida*

4-Which one of the following ethnic group belongs to Uttarakhand -
(a) Khond (b) Johari
(c) Majhwar (d) Gangwal

5-*Aegle marmelos* belongs to family-
(a) Rubiaceae (b) Rutaceae
(c) Moraceae (d) Fabaceae

4.12.2. True or False

1- Nux-vomica is a anticancer drug.
2- Tobacco plant belongs to family Solanaceae
3-Botanical name of Amla is *Fagopyrum dibotrys.*
4-Jaunsari, the ethnic group belongs to Gujarat State.
5- Simal is the common name of *Bombax ceiba.*

4.12.1 Answer Key: 1-(c), 2-(b), 3-(a), 4-(d), 5-(b)
4.12.2 Answer Key: 1-False, 2-True, 3-False, 4-False, 5-True

4.13 REFERENCES

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4.15 TERMINAL QUESTIONS

1- Define Ethanobotany. Discuss its concept and History.
2- Describe in detail the ethnic groups of India.
3- Give a detailed note on conservation of natural resources.
4- Explain about the plants of ethanobotanical importance.
5- What are narcotic plants? Give a brief description about five narcotic plants.

BLOCK-2 GENETICS

UNIT-5 GENETIC INHERITANCE

5.1 OBJECTIVES

After reading this unit students will be able-

- To understand the genetic inheritance
- To understand about Mendel's experiment and laws of inheritance, and an insight into Mendelian or Classical Genetics.

5.2 INTRODUCTION

All living organism reproduce and reproduction results in the formation of offspring of their same kind. However, the resulting offspring need not always resemble to the parent. Several characteristics may differ among individual belonging to the same species. These differences are known as *variations.* The mechanism of transmission of characters from parents to offspring, resemblance as well as differences, is termed as *heredity.* The scientific study of heredity, variation and the environmental factor accountable for these variations is known as *genetics.*

The father of genetics is Gregor Mendel (1822-1844), a late 19th-century scientist and Austrian monk and a teacher in Augustinian Monastery at Brunn (in Czeckoslovakia, now called Brno). Mendel studied 'trait inheritance', patterns in the way traits (character) were handed down from parents to offspring. He discovered that individual traits are inherited as discrete *factors* which retain their physical identity in a hybrid. Later on these factors were called *genes*. The term 'gene' was given by Danish botanist Wilhelm Johannsen in 1990. Traits studied by Mendel were clear and discrete. Such discrete traits are known as *Mendelian characters.*

Every chromosome in a cell contains many genes and each gene is located at a particular site or *locus* in the chromosome. Chromosomes that carry same set of genes in the same sequence are called *homologous* for example human body cell contains 23 pairs of homologous chromosome.

Alleles are the alternative forms of a gene, which code for different versions of a particular inherited character. We can also define it as genes occupying corresponding positions on homologous chromosomes and controlling the same characteristic (e.g. height of plant) but producing different effects (tall or short). A dominant allele hides the expression of a recessive allele and it is represented by the uppercase letter. A recessive allele is the allele that expresses its effect only in homozygous state and in heterozygous condition its expression is masked by dominant allele. It is represented by lowercase letter.

Homozygous and Heterozygous

Each diploid parent has two allels for a trait- they may be:

1. Homozygous, when they possess two identical alleles for a trait.

Homozygous dominant (TT)

Homozygous recessive (tt)

2. Heterozygous, when they possess one of each allele for a particular trait (Tt).

Genotype and Phenotype

These terms are used in genetics to distinguish the physical appearance from the genetic constitution. Genotype is defined as the genetic constitution of an individual for any particular character or trait, usually expressed by symbol e.g. tt, Tt or TT etc. The physical appearance of an individual for any particular trait is defined as the phenotype. Phenotype of an individual is dependent on its genetic constitution.

5.3 MENDEL'S EXPERIMENT AND LAWS OF INHERITANCE

The laws of inheritance were derived by Gregor Mendel, a nineteenth-century Austrian monk conducting hybridization experiments in garden peas (*Pisum sativum*). Between 1856 and 1863, he cultivated and tested some 5,000 pea plants. He published the results of his experiment in 'Annual Proceedings of Natural History Society of Brunn'.From these experiments, he induced two generalizations which later known as *Mendel's Principles of Heredity* or *Mendelian inheritance*.

Mendel work remained hidden for about three decades (34 years) but in 1900 three workers rediscovered Mendel's work independently. These were *Hugo de Vries* (Holland) worked on evening primrose (*Oenothera), Karl Correns* (Germany) worked on maize (*Zea mays*) and *Tschermak* (Austria) worked on different flowering plants. All these workers after performing their experiment separately reached to the same conclusion and republished the original work of Mendel in 'Flora' (1901).

Regardless, the "re-discovery" made Mendelism an important but controversial theory. Its most vigorous promoter in Europe was William Bateson, who coined the terms "genetics" and "allele" to describe many of its view. The model of heredity was highly contested by other biologists because it implied that heredity was discontinuous, in opposition to the apparently continuous variation observable for many traits. Many biologists also dismissed the theory because they were not sure it would apply to all species. However, later work by biologists and statisticians such as R.A. Fisher showed that if multiple Mendelian factors were involved in the expression of an individual trait, they could produce the diverse results observed. Thomas Hunt Morgan and his assistants later integrated the theoretical model of Mendel with the chromosome theory of inheritance, in which the chromosomes of cells were thought to hold the actual hereditary material, and created what is now known as classical genetics, which was extremely successful and cemented Mendel's place in history.

Mendel's findings allowed other scientists to predict the expression of traits on the basis of mathematical probabilities. A large contribution to Mendel's success can be traced to his decision to start his crosses only with plants he demonstrated were true-breeding. He also only measured absolute (binary) characteristics, such as colour, shape, and position of the offspring, rather than quantitative characteristics. He expressed his results numerically and subjected them to statistical analysis. His method of data analysis and his large sample size gave credibility to his data. He also had the foresight to follow several successive generations (F2, F3) of pea plants and record their variations. Finally, he performed "test crosses" (backcrossing descendants of the initial hybridization to the initial true-breeding lines) to reveal the presence and proportion of recessive characters.

Mendel's Laws

Mendel discovered that, when he crossed purebred white flower and purple flower pea plants (the parental or P generation), the result was not a blend. Rather than being a mix of the two, the offspring (known as the F_1 generation) was purple-flowered. When Mendel self-fertilized the F_1 generation pea plants, he obtained a purple flower to white flower ratio in the F_2 generation of 3 to 1. The results of this cross are tabulated in the Punnett square below.

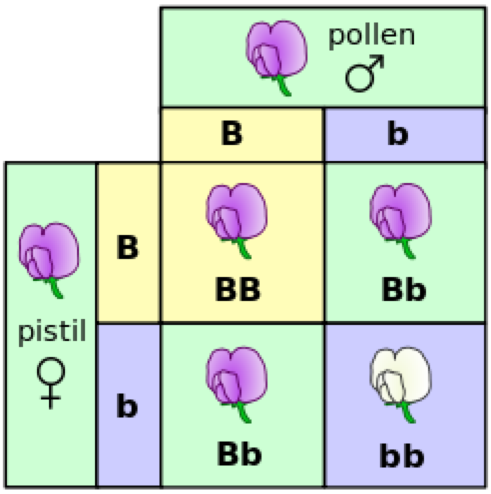

Fig.5.1 A Punnett square for one of Mendel's pea plant experiments

He then conceived the idea of heredity units, which he called "factors". Mendel found that there are alternative forms of factors - now called genes - that account for variations in inherited characteristics. For example, the gene for flower colour in pea plants exists in two forms, one for purple and the other for white. The alternative forms are now called alleles.

Mendel also hypothesized that allele pairs separate randomly, or segregate, from each other during the production of gametes: egg and sperm. Because allele pairs separate during gamete production, a sperm or egg carries only one allele for each inherited trait. When sperm and egg unite at fertilization, each contributes its allele, restoring the paired condition in the offspring. This is called the **Law of Segregation**. Mendel also found that each pair of alleles segregates independently of the other pairs of alleles during gamete formation. This is known as the **Law of Independent Assortment**.

The genotype of an individual is made up of the many alleles it possesses. An individual's physical appearance, or phenotype, is determined by its alleles as well as by its environment. The presence of an allele does not mean that the trait will be expressed in the individual that possesses it. If the two alleles of an inherited pair differ (the heterozygous condition), then one determines the organism’s appearance and is called the dominant allele; the other has no noticeable effect on the organism’s appearance and is called the recessive allele. Thus, in the

example above dominant purple flower allele will hide the phenotypic effects of the recessive white flower allele. This is known as the **Law of Dominance** but it is not a transmission law, dominance has to do with the expression of the genotype and not its transmission.
In the pea plant example above, the capital "P" represents the dominant allele for purple flowers and lowercase "p" represents the recessive allele for white flowers. Both parental plants were true-breeding, and one parental variety had two alleles for purple flowers (*PP*) while the other had two alleles for white flowers (*pp*). As a result of fertilization, the F_1 hybrids each inherited one allele for purple flowers and one for white. All the F_1 hybrids (*Pp*) had purple flowers, because the dominant *P* allele has its full effect in the heterozygote, while the recessive *p* allele has no effect on flower colour. For the F_2 plants, the ratio of plants with purple flowers to those with white flowers (3:1) is called the phenotypic ratio. The genotypic ratio, as seen in the Punnett square, is 1 *PP*: 2 *Pp* : 1 *pp*.

5.3.1-Principle of Segregation

Mendel followed the inheritance of 7 pea traits. Dominant traits, like round peas, appeared in the first-generation hybrids (F1), whereas recessive traits, like wrinkled peas, were masked. However, recessive traits reappeared in the second generation (F2). Each individual carries a pair of factors for each trait, and they separate from each other during fertilization. This is the basis of Mendel’s principle of segregation.

On the basis of monohybrid cross (a cross involving only one trait), Mendel formulated the law of Segregation, this law states that every individual contains a pair of alleles for each particular trait which segregate or separate during cell division (assuming diploidy) for any particular trait and that each parent passes a randomly selected copy (allele) to its offspring. The offspring then receives its own pair of alleles of the gene for that trait by inheriting sets of homologous chromosomes from the parent organisms. Interactions between alleles at a single locus are termed dominance and these influence how the offspring expresses that trait (e.g. the colour and height of a plant, or the color of an animal's fur). At the time of formation of gametes each member of the pair of genes separate from each other so that each gamete carries only one factor (gene) i.e. gametes are always pure (law of purity of gametes).

Definition: The Law of Segregation states that the two alleles for a heritable character segregate (separate from each other) during gamete formation and end up in different gametes.

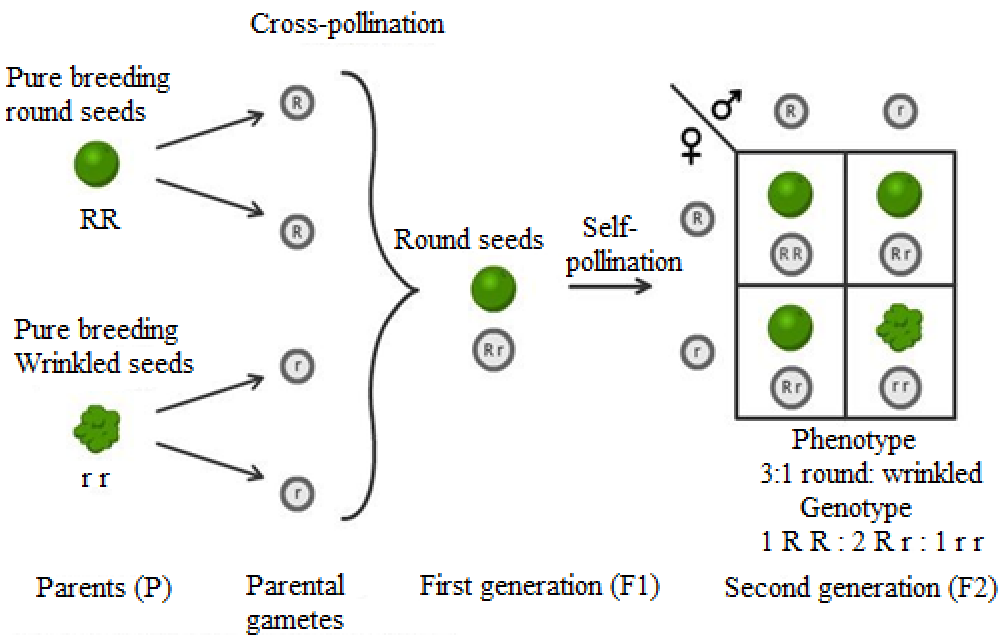

Fig. 5.2 Dominant and recessive phenotypes

5.3.2-Principle of Independent Assortment

The law in short stated that: In the inheritance of more than one pair of traits in a cross simultaneously, the factor responsible for each pair of traits are distributed to the gametes.

The Law of Independent Assortment, also known as "Inheritance Law", states that separate genes for separate traits are passed independently of one another from parents to offspring. That is, the biological selection of a particular gene in the gene pair for one trait to be passed to the offspring has nothing to do with the selection of the gene for any other trait. More precisely, the law states that alleles of different genes assort independently of one another during gamete formation. While Mendel's experiments with mixing one trait always resulted in a 3:1 ratio (Fig. 1) between dominant and recessive phenotypes, his experiments with mixing two traits (dihybrid cross) showed 9:3:3:1 ratios (Fig. 5.3). But the 9:3:3:1 table shows that each of the two genes is independently inherited with a 3:1 phenotypic ratio. Mendel concluded that different traits are inherited independently of each other, so that there is no relation, for example, between a pea seed shape (round or wrinkled) and seed colour (yellow or green). This is actually only true for genes that are not linked to each other.

A dihybrid cross shows Mendel's Law of Independent Assortment

In a dihybrid cross we are looking at the inheritance of two traits at the same time. Instead of looking at flower colour, we are going to look at two traits that affect the pea. Peas can either be round or wrinkled, and they can either be yellow or green. Round is dominant to wrinkled, so use **R** to represent round. Wrinkled is recessive and is represented by **r**. Always use the same letter so that you know you are specifying the same character. The dominant colour in peas is yellow, so we will use **Y** for yellow and **y** for green. Before Mendel could perform a dihybrid cross, he had to create a line that was true-breeding for both traits, so in this case the line with peas that always had round shape and were always yellow were genotype **RRYY**, and the line with peas that were always wrinkled and green were **rryy**. What do you expect in the F1 generation when you cross these two true-breeding lines? That is straight forward because the only gametes that the round yellow plants can make will have the **RY** genotype, and the only gametes that the wrinkled green plants can make will have the **ry** genotype. Therefore, all of their offspring will be heterozygous. The phenotype of the F1 will be all round and yellow because those are the dominant traits.

Then, Mendel allowed these F1 plants to self-fertilize. This is where things got a bit tricky. These heterozygotes can make four different types of gametes. Do you know what they are? Write them down before you look at Figure 2 below. The law of segregation applies to each character. In addition, the two characters are independent when gametes are formed. So, the heterozygous plants can make four types of gametes, with all of the possible allelic combinations. There are gametes that are parental, **RY** and **ry**. They are called *parental* because they were also made by the parents in the P1 generation. However, you also find unique combinations of gametes, **Ry** and **rY**. These are *recombinant* gametes. Because each heterozygous individual can make four types of gametes, this results in a Punnett square with sixteen possible combinations.

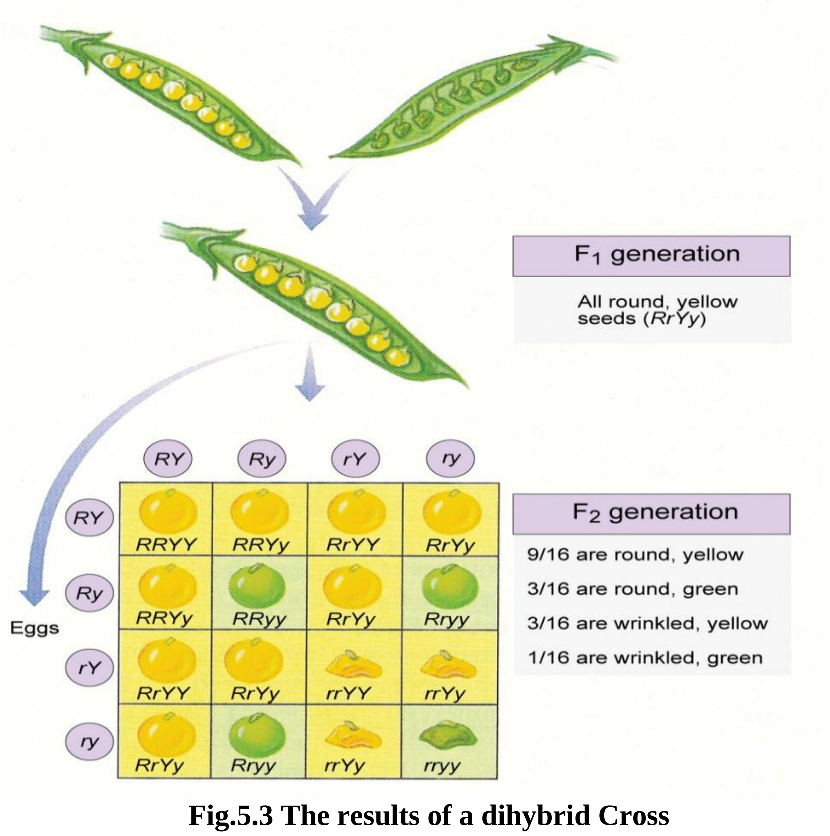

Fig.5.3 The results of a dihybrid Cross

Independent assortment occurs in eukaryotic organisms during meiotic metaphase I, and produces a gamete with a mixture of the organism's chromosomes. The physical basis of the independent assortment of chromosomes is the random orientation of each bivalent chromosome along the metaphase plate with respect to the other bivalent chromosomes.

Along with crossing over, independent assortment increases genetic diversity by producing novel genetic combinations.

Of the 46 chromosomes in a normal diploid human cell, half are maternally derived (from the mother's egg) and half are paternally derived (from the father's sperm). This occurs as sexual reproduction involves the fusion of two haploid gametes (the egg and sperm) to produce a new organism having the full complement of chromosomes. During gametogenesis the production of new gametes by an adult-the normal complement of 46 chromosomes needs to be halved to 23 to ensure that the resulting haploid gamete can join with another gamete to produce a diploid organism. An error in the number of chromosomes, such as those caused by a diploid gamete joining with a haploid gamete, is termed aneuploidy.

In independent assortment, the chromosomes that result are randomly sorted from all possible combinations of maternal and paternal chromosomes. Because gametes end up with a random mix instead of a pre-defined "set" from either parent, gametes are therefore considered assorted independently. As such, the gamete can end up with any combination of paternal or maternal chromosomes. Any of the possible combinations of gametes formed from maternal and paternal chromosomes will occur with equal frequency. For human gametes, with 23 pairs of chromosomes, the number of possibilities is 2^{23} or 8,388,608 possible combinations. The gametes will normally end up with 23 chromosomes, but the origin of any particular one will be randomly selected from paternal or maternal chromosomes. This contributes to the genetic variability of progeny.

5.3.3-Incomplete Dominance

Mendel's Law of Dominance states that recessive alleles will always be masked by dominant alleles. Therefore, a cross between a homozygous dominant and a homozygous recessive will always express the dominant phenotype, while still having a heterozygous genotype. Law of Dominance can be explained easily with the help of a mono hybrid cross experiment:- In a cross between two organisms pure for any pair (or pairs) of contrasting traits (characters), the character that appears in the F1 generation is called "dominant" and the one which is suppressed (not expressed) is called "recessive." Each character is controlled by a pair of dissimilar factors. Only one of the characters expresses. The one which expresses in the F1 generation is called Dominant. It is important to note however, that the law of dominance is significant and true but is not universally applicable.

According to the latest revisions, only two of these rules are considered to be laws. The third one is considered as a basic principle but not a genetic law of Mendel. Mendel explained inheritance in terms of discrete factors ‘genes’, that are passed along from generation to generation according to the rules of probability. Mendel's laws are valid for all sexually reproducing organisms, including garden peas and human beings. However, Mendel's laws stop short of explaining some patterns of genetic inheritance. For most sexually reproducing organisms, cases where Mendel's laws can strictly account for the patterns of inheritance are relatively rare. Often, the inheritance patterns are more complex.

Non-Mendelian Inheritance

The F_1 offspring of Mendel's pea crosses always looked like one of the two parental varieties. In this situation of "complete dominance," the dominant allele had the same phenotypic effect whether present in one or two copies. But for some characteristics, the F_1 hybrids have an appearance *in between* the phenotypes of the two parental varieties. A cross between two four o'clock (*Mirabilis jalapa*) plants shows this common exception to Mendel's principles. Some alleles are neither dominant nor recessive. The F_1 generation produced by a cross between red-flowered (RR) and white flowered (WW) *Mirabilis jalapa* plants consists of pink-colored flowers (RW). Which allele is dominant in this case? Neither one. This third phenotype results from flowers of the heterozygous having less red pigment than the red homozygous. Such conditions in which one allele is not completely dominant or semidominant or partial dominant over another are called **incomplete dominance**. In incomplete dominance, the heterozygous phenotype lies somewhere between the two homozygous phenotypes.

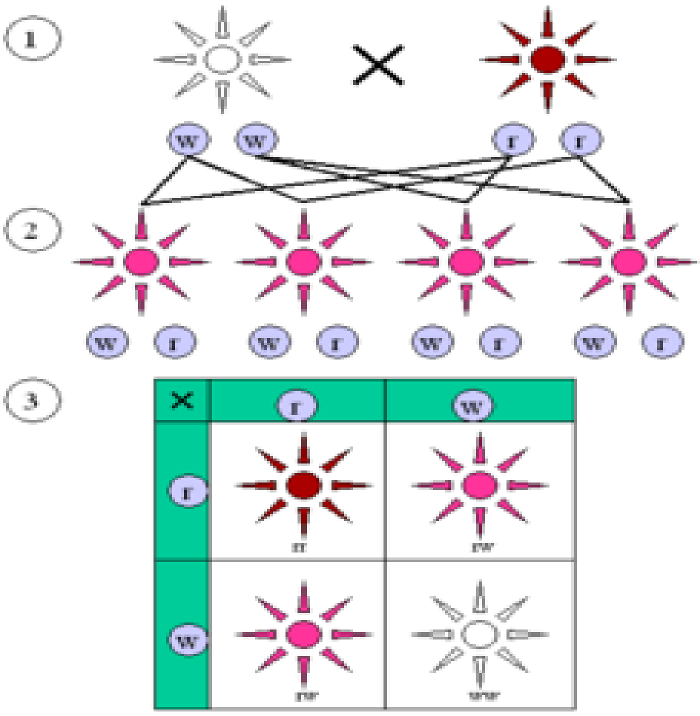

Fig.5.4. In four o'clock plants, the alleles for red and white flowers show incomplete dominance. As seen in the F_1 generation, heterozygous (*wr*) plants have "pink" flowers—a mix of "red" (rr) and "white" (ww) coloring. The F_2 generation shows a 1:2:1 ratio of red: pink:white

A similar situation arises from **codominance**, in which alleles that lack dominant and recessive relationships, and are both observed phenotypically to same degree. For example, in certain varieties of chicken, the allele for black feathers is codominant with the allele for white feathers. Heterozygous chickens have a color described as "erminette," speckled with black and white feathers. Unlike the blending of red and white colours in heterozygous four o'clocks, black and white colours appear separately in chickens. Many human genes, including one for a protein that controls cholesterol levels in the blood, show codominance, too. People with the heterozygous form of this gene produce two different forms of the protein, each with a different effect on cholesterol levels.

In Mendelian inheritance, genes have only two alleles, such as *A* and *a*. In nature, such genes exist in several different forms and are therefore said to have **multiple alleles**. A gene with more than two alleles is said to have multiple alleles. An individual, of course, usually has only two copies of each gene, but many different alleles are often found within a population. One of the best-known examples is coat color in rabbits. A rabbit's coat color is determined by a single gene that has at least four different alleles. The four known alleles display a pattern of simple dominance that can produce four coat colors. Many other genes have multiple alleles, including the human genes for ABO blood type.

Furthermore, many traits are produced by the interaction of several genes. Traits controlled by two or more genes are said to be **polygenic traits**. *Polygenic* means "many genes." For example, at least three genes are involved in making the reddish-brown pigment in the eyes of fruit flies. Polygenic traits often show a wide range of phenotypes. The variety of skin color in humans comes about partly because more than four different genes probably control this trait.

5.4 SUMMARY

Inheritance is the process by which genetic informations are passed from parent to child. This is why members of the same family tend to have similar characteristics. Most of our cells contain two sets of 23 chromosomes (they are diploid). An exception to this rule are the sex cells (egg and sperm), also known as gametes, which only have one set of chromosomes each (they are haploid). However, in sexual reproduction the sperm cell combines with the egg cell to form the first cell of the new organism in a process called fertilization. This cell (the fertilized egg) has two sets of 23 chromosomes (diploid) and the complete set of instructions needed to make more cells, and eventually a whole person. Each of the cells in the new person contains genetic material from the two parents. This passing down of genetic material is evident if you examine the characteristics of members of the same family, from average height to hair and eye colour to nose and ear shape, as they are usually similar. If there is a mutation in the genetic material, this can also be passed on from parent to child. This is why diseases run in families.

Mendelian inheritance is inheritance of biological features that follows the laws proposed by Gregor Johann Mendel in 1865 and 1866 and re-discovered in 1900. It was initially very controversial. When Mendel's theories were integrated with the Boveri-Sutton chromosome theory of inheritance by Thomas Hunt Morgan in 1915, they became the core of classical genetics.

5.5 GLOSSARY

Gene: A unit of heredity composed of DNA occupying a fixed position on a chromosome (some viral genes are composed of RNA). A gene may determine a characteristic of an individual by specifying a polypeptide chain that forms a protein or part of a protein (**structural gene**); or encode an RNA molecule; or regulate the operation of other genes or repress such operation.

Allele: An **allele** is one of a pair of genes that appear at a particular location on a particular chromosome and control the same characteristic, such as blood type or colorblindness. **Alleles** are also called alleleomorphs. Your blood type is determined by the **alleles** you inherited from your parents.

Genetic inheritance: Inheritance is the process by which genetic information is passed on from parent to child. This is why members of the same family tend to have similar characteristics. Each cell in the body contains 23 pairs of chromosomes. One chromosome from each pair is **inherited** from your mother and one is **inherited** from your father. The chromosomes contain the **genes inherit** from parents. There may be different forms of the same **gene** – called alleles.

Heredity: Heredity is the passing of traits from parents to their offspring, either through asexual reproduction or sexual reproduction. This is the process by which an offspring cell or organism acquires or becomes predisposed to the characteristics of its parent cell or organism.

Mendel's Law of Segregation: The characteristics of the offspring are derived from both maternal and paternal factors. Every individual has a pair of genes governing a particular characteristic (e.g. the color of the eyes). During the formation of sex cells each pair is separated (segregated) so that each sex cell (egg or sperm) carries only one form of each gene. The offspring thus receives one from each parent and this pair of genes determines how the caracteristic is expressed (e.g. whether the child's eyes are blue or brown).

Mendel's Law of Independent Assortment: When considering more than one gene, Mendel noted that two characteristics do not always appear together. For instance a mother with blonde hair and blue eyes may have a blonde-haired child with brown eyes. Thus different characteristics can be independently inherited.

Mendel’s Law of Dominance: A principle in genetics proved subsequently to be subject to many limitations: because one of each pair of hereditary units dominates the other in expression, characters are inherited alternatively on an all-or-nothing basis also called law of dominance.

5.6 SELF ASSESSMENT QUESTIONS

5.6.1 Multiple choice questions:

1- Gregor Mendel was:

(a) An English scientist who carried out research with Charles Darwin

(b) An early 20th century Dutch biologist who carried out genetics research

(c) An Austrian monk

(d) An American geneticist

2- An allele is-
(a) One of four possible forms of a gene (b) A heterozygous genotype
(c) A homozygous genotype. (d) One of several possible forms of a gene

3- In a two allele, one locus diploid system, True Breeding individuals are-
(a) Homozygous at one locus (b) Heterozygous at one locus
(c) Always dominant (d) Always recessive

4- Phenotype of an individual refers to the-
(a) Actual allele signal (b) Actual physical appearance
(c) Genetic makeup (d) Recessive allele

5- The idea that different pairs of alleles are passed to offspring independently is Mendel's principle of:
(a) Segregation (b) Unit inheritance
(c) Independent assortment (d) Blended inheritance

6- The idea that for any particular trait, the pair of alleles of each parent separate and only one allele from each parent passes to an offspring is Mendel's principle of:
(a) Independent assortment (b) Blended inheritance
(c) Unit inheritance (d) Segregation

7- Which of the following statements is true about Gregor Mendel?
(a) His ideas about genetics apply equally to plants and animals
(b) His ideas about genetics were useful to Darwin in his development of his theory of evolution
(c) His ideas about genetics do not apply equally to plants and animals.
(d) His discoveries concerning genetic inheritance were generally accepted by the scientific community when he published them during the mid 19th century.

8- Mendel believed that the characteristics of pea plants are determined by the:
(a) Inheritance of units or factors from both parents
(b) Inheritance of units or factors from one parent
(c) Relative health of the parent plants at the time of pollination
(d) None of the above

9- Genes are part of chromosome. Chromosomes are found in:
(a) Only in egg cells (b) In every cell of an organism
(c) Only in sperm cells (d) All of above

10- Chromosomes determine a person’s:
(a) Sex (b) Height
(c) Age (d) Marital status

5.6.1- Answer Keys: 1-(c), 2-(d), 3-(a), 4-(b), 5-(c), 6-(d), 7-(a), 8-(a), 9-(b), 10-(a)

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5.9 TERMINAL QUESTIONS

5.9.1 Short answer type Questions:

1. Why do children look like their parents?
2. Why do some children look more like their mother and others look more like their father?
3. How is the similarity between children and parents controlled?
4. What controls the development of an organism?
5. What is a gene and where is it located?
6. Do all organisms have the same number of genes?
7. Is the number of genes proportional to size of the organism?
8. Do all genes get expressed?
9. How are genes regulated?
10. What do genes do in an organism’s development?

5.9.2 Long answer type Questions:

1. What two experimental innovations did Mendel use that allowed him to discover the laws of genetics?
2. What did Mendel conclude from his experiments?
3. Why Mendel’s First Law of Genetics is called the “Law of Segregation”?
4. Why Mendel’s Second Law of Genetics is called the “Law of Independent Assortment”?

5. Why a red 4 o'clock plant was crossed with a white 4 o'clock plant, they produced pink 4 o'clock plants. Explain why?
6. How can you account for the fact that in some cases organisms of the same phenotype are not of the same genotype? How can you account for cases of organisms with the same genotype but different phenotypes?
7. What causes biologists to suspect that chromosomes are involved in the transmission of the hereditary material?
8. What are genes?
9. What is the relationship between the gene and the appearance of an organism (Genotype vs. Phenotype)?
10. How does a cell divide into two cells?

UNIT-6 LINKAGE AND CROSSING OVER

6.1 OBJECTIVES

After reading this unit students will be able-

- to Define linkage and crossing over
- to understand the Insight into linkage mapping critical for identifying the location of genes of interest.

6.2 INTRODUCTION

Mendel's Second Law, or the law of the independent assortment, is valid for genes located in different chromosomes. These genes segregate independently during meiosis. However, Mendel's Second Law is not valid for phenotypical features conditioned by genes located in the same chromosome (genes under linkage), since these genes, known as linked genes, do not separate during meiosis (except for the phenomenon of crossing over). The fruit fly, or drosophila, has been suitable for studying genetics because it presents many distinct traits but only has four chromosomes (one sex chromosome and three autosomes).

6.3 LINKAGE

Genetic linkage is the tendency of alleles that are located close together on a chromosome to be inherited together during meiosis. Genes whose loci are nearer to each other are less likely to be separated onto different chromatids during chromosomal crossover, and are therefore said to be genetically *linked*. In other words, the nearer two genes are on a chromosome, the lower is the chance of a swap occurring between them, and the more likely they are to be inherited together.

Significance of linkage

(i) Linkage plays an important role in determining the nature and scope of hybridization and selection programmes.

(ii) Linkage reduces the chances of recombination of genes and thus helps to hold parental characteristics together. It thus helps organism to maintain its parental, racial and other characters. For this reason plant and animal breeders find it difficult to combine various characters.

6.3.1-Complete Linkage

The genes located on the same chromosome do not separate and are inherited together over the generations due to the absence of crossing over. Complete linkage allows the combination of parental traits to be inherited as such. It is rare but has been reported in male Drosophila and some other heterogametic organisms.

Example 1:

A red eyed normal winged (wild type) pure breeding female Drosophila is crossed to homozygous recessive purple eyed and vestigial winged male. The progeny or F_1 generation individuals are heterozygous red eyed and normal winged. When F_1 males are test crossed to homozygous recessive female (purple eyed and vestigial winged), only two types of individuals are produced— red eyed normal winged and purple eye vestigial winged in the ratio of 1 : 1 (parental phenotypes only). Similarly during inbreeding of F_1 individuals, recombinant types are absent. In practice, this 1: 1 test ratio is never achieved because total linkage is rare.

Example 2:

In Drosophila, genes of grey body and long wings are dominant over black body and vestigial (short) wings. If pure breeding grey bodied long winged Drosophila (GL/ GL) flies are crossed with black bodied vestigial winged flies (gl/gl), the F_2 shows a 3 : 1 ratio of parental phenotypes (3 grey body long winged and one black body vestigial winged).

This is explained by assuming that genes of body colour and wing length are found on the same chromosome and are completely linked.

6.3.2-Incomplete Linkage

Genes present in the same chromosome have a tendency to separate due to crossing over and hence produce recombinant progeny besides the parental type. The number of recombinant individuals is usually less than the number expected in independent assortment. In independent assortment all the four types (two parental types and two recombinant types) are each 25%. In case of linkage, each of the two parental types is more than 25% while each of the recombinant types is less than 25%.

Example 1:

A red eyed normal winged or wild type dominant homozygous female Drosophila is crossed to homozygous recessive purple eyed and vestigial winged male. The progeny or F_1 individuals are heterozygous red eyed and normal winged. F_1 female flies are test crossed with homozygous recessive males. It does not yield the ratio of 1: 1: 1: 1. Instead the ratio comes out to be 9: 1: 1: 8. This shows that the two genes did not segregate independently of each other. The data obtained and reported is as follows:

Phenotype	Progeny	Observed	Expected if Complete Linkage	Expected if Independent Assortment
Parental Types				
	(a) Red eyed, normal winged	1339	1420	710
	(b) Purple eyed vestigial winged	1195	1420	710
Recombinant Types				
	(a) Red eyed, vestigial winged	152	Zero	710
	(b) Purple eyed, normal winged	152	Zero	710

Only 9.3% recombinant types were observed which is quite different from 50% recombinants in case of independent assortment. This shows that in the oocytes of the F_1 generation only some of the chromatids undergo cross-over while the majority is preserved intact. This produces 90.7% parental types in the progeny.

Example 2:

In Sweet Pea (*Lathyrus odoratus*) blue flower colour (B) is dominant over red flower colour (b) while the trait of long pollen (L) is dominant over round pollen (l). A Sweet Pea plant heterozygous for both blue flower colour and long pollen (BbLl) was crossed with double recessive red flowered plant with round pollen (bbll). It is similar to test cross. In case the genes of the two traits are unlinked, the progeny should have four phenotypes (Blue Long, Blue Round, Red Long, and Red Round) in the ratio of 1: 1: 1: 1 (25% each). In case the two genes are completely linked the progeny should have both the parental types (Blue Long and Red Round) in the ratio of 1: 1(50% each). Recombinants should not appear. However, in the above cross Bateson and Punnett (1906) found both parental and recombinant types but with different frequencies in the ratio of 7: 1: 1: 7. (7 + 7 Parental and 1 + 1 recombinant types).

Phenotype	Progeny	Observed frequency	Expected frequency if complete linkage	Expected fre-quency if Independent assortment
Parental Types	(i) Blue Long	43.7%	50%	25%
Recombinant Types	(ii) Red Round	43.7%	50%	25%
	(a) Blue Round	6.3%	0%	25%
	(b) Red Long	6.3%	0%	25%

Only 12.6% recombinant types were observed against the expected percentage of 50% in case of independent assortment. Therefore, the genes are linked but undergo recombination due to crossing over in some of the cases.

Example 3: Morgan and his students have found that linked genes show varied recombinations, some being more tightly linked than others, (i) In Drosophila, crossing of yellow bodied (Y) and white eyed (W) female with brown bodied (Y^+) red eyed (W^+) male produced F_1 to be brown bodied red eyed. On intercrossing of F_1 progeny, Morgan observed that the two genes did not segregate independently of each other and, therefore, the F_2 ratio deviated significantly from expected 9: 3: 3: 1 ratio. He found 98.7% to be parental and only 1.3% recombinants. (ii) In a second cross in Drosophila between white eyed and miniature winged (wwmm) female with wild type or red eyed normal winged males, all the F_1 were found to be of wild type, i.e., red eyed and normal winged. An F_1 female fly was then test crossed with white eyed and miniature winged male. 62.8% of the progeny was of parental types while 37.2% were recombinants.

6.3.3-Linkage Group

A linkage group is a linearly arranged group of linked genes which are normally inherited together except for crossing over.

It corresponds to a chromosome which bears a linear sequence of genes linked and inherited together. Because the two homologous chromosomes possess either similar or allelic genes on the same loci, they constitute the same linkage group. Therefore, the number of linkage groups present in an individual corresponds to number of chromosomes in its one genome (all the chromosomes if haploid or homologous pairs if diploid). It is known as principle of limitation of linkage groups.

Fruit-fly *Drosophila melanogaster* has four linkage groups (4 pairs of chromosomes), human beings 23 linkage groups (23 pairs of chromosomes), Pea seven linkage groups (7 pairs of chromosomes), *Neurospora* 7 linkage groups (7 chromosomes), Mucor 2 linkage groups (2 chromosomes), *Escherichia coli* one linkage group (one pro-chromosome or nucleoid) while Maize has 10 linkage groups (10 pairs of chromosomes).

The size of the linkage group depends upon the size of chromosome. The smaller chromosome will naturally have smaller linkage group while a longer one has longer linkage group. This is subject to the amount of heterochromatin present in the chromosome. Thus Y-chromosome of man possesses 231 genes while human chromosome 1 has 2969 genes.

6.4 CROSSING OVER

Ever know a large family with many children, all of whom are indistinguishable from each other? Unless they are all identical twins, you have not encountered such a family. Non-twin siblings typically have a range of physical differences, from subtle distinctions in features to looking unrelated. Even though they inherited equal chromosomes from the same two parents, the combination of genes is diversified due to crossing over.

Crossing over is the exchange of genes between two chromosomes, resulting in non-identical chromatids that comprise the genetic material of gametes (sperm and eggs). This process results in the millions of sperm or eggs that are produced by an organism, each being different from one another. In other words, every single sperm or egg cell in your body is completely unique.

Think of it like two traders meeting to exchange their goods, resulting in both leaving with a more diverse collection of wares than they had before. Thanks to this process, living things have high diversity within populations, allowing for better chances of adaptation to changing conditions and survival of the species.

Crossing over occurs during meiosis I and is the process where homologous chromosomes pair up with each other and exchange different segments of their genetic material to form recombinant chromosomes. It can also happen during mitotic division, which may result in loss of heterozygosity. Crossing over is essential for the normal segregation of chromosomes during meiosis. Crossing over also accounts for genetic variation, because due to the swapping of genetic material during crossing over, the chromatids held together by the centromere are no longer identical. So, when the chromosomes go on to meiosis II and separate, some of the daughter cells receive daughter chromosomes with recombined alleles. Due to this genetic recombination, the offspring have a different set of alleles and genes than their parents do.

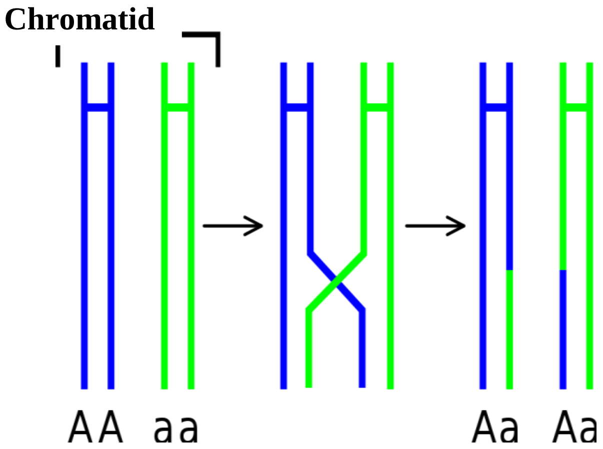

Fig. 6.1 Crossing over scheme

Chromosomal crossover (or **crossing over**) is the exchange of genetic material between homologous chromosomes that results in recombinant chromosomes during sexual reproduction. It is one of the final phases of genetic recombination, which occurs in the *pachytene* stage of prophase I of meiosis during a process called synapsis. Synapsis begins before the synaptonemal complex develops and is not completed until near the end of prophase I. Crossover usually occurs when matching regions on matching chromosomes break and then reconnect to the other chromosome.

Crossing over was described, in theory, by Thomas Hunt Morgan. He relied on the discovery of the Belgian Professor Frans Alfons Janssens of the University of Leuven who described the phenomenon in 1909 and had called it "chiasmatype". The term *chiasma* is linked if not identical to chromosomal crossover. Morgan immediately saw the great importance of Janssens' cytological interpretation of chiasmata to the experimental results of his research on the heredity of *Drosophila*. The physical basis of crossing over was first demonstrated by Harriet Creighton and Barbara McClintock in 1931.

Theories of Crossing Over

(i) Contact first theory (by Serebrovsky)

According to this theory the inner two chromatids of the homologous chromosomes undergoing crossing over first touch each other and then cross over. At the point of contact breakage occurs. The broken segments again unite to form new combinations.

(ii) The breakage-first theory (By Muller)

According to this theory the chromatids undergoing crossing over first of all break into two without any crossing-over and after that the broken segments reunite to form the new combinations.

(iii) Strain theory (by Darlington)

According to this theory the breakage in chromosomes or chromatids is due to strain caused by pairing and later the breakage parts again reunite.

Types of Crossing Over

(i) Single crossing over

In this type of crossing over only one chiasma is formed all along the length of a chromosome pair. Gametes formed by this type of crossing over are called single cross over gametes.

(ii) Double crossing over

In this type two chiasmata are formed along the entire length of the chromosome leading to breakage and rejoin of chromatids at two points. The gametes produced are called double cross over gametes.

(iii) Multiple crossing over

In this type more than two chiasmata are formed and thus crossing over occurs at more than two points on the same chromosome pair. It is a rare phenomenon.

Factors Influencing Crossing Over

1. Sex

In Drosophila, crossing over is completely suppressed in male but very high in female. Also there is a tendency of reduction of crossing over in male mammals.

2. Mutation

Gowen first discovered that mutation reduces crossing over in all the chromosomes of Drosophila.

3. Inversion

Inversion is an intersegmental change in the chromosome. In a given segment of chromosome crossing over is suppressed due to inversions.

4. Temperature

Plough has experimentally shown that when Drosophila is subjected to high and low temperature variations, the percentage of crossing over in certain parts of the chromosome is increased.

5. X-ray effect
Muller demonstrated that X-ray irradiations increase crossing over near centromere. Similarly Hanson has shown that radium increases crossing over.

6. Age
Bridges has demonstrated that the age also influences the rate of crossing over in Drosophila. When the female becomes older the rate of crossing over increases.

7. Nutrition
High calcium diet in young Drosophila decreases crossing over rate where as diet deficient of metallic ions increases crossing over.

8. The frequency of crossing over is less at the ends of the chromosome and also near the centromere in comparison to other parts.

Cytological Proof of Crossing Over

The first cytological evidence in support of genetic crossing over was provided by Curt Stern in 1931 on the basis of his experiments conducted with Drosophila. He used cytological markers in his studies. He selected a female fly in which one X-chromosome was broken into two segments.

Out of these two segments, one behaved as X-chromosome. The other X-chromosome had small portion of Y-chromosome attached to its one end. Thus, both the X-chromosomes in the female had distinct morphology and could be easily identified under microscope. In female fly, the broken X-chromosome had one mutant allele (carnation) for eye colour and another dominant allele (B) for bar eye shape.

The other X-chromosome with attached portion of Y chromosome had alleles for normal eye colour (red eye) and normal eye shape (oval eye). Thus, phenotype of female was barred. A cross of such females was made with carnation male (car+).

As a result of crossing over female flies produce four types of gametes, viz., two parental types or non-crossover types (car B and ++) and two recombinant types or crossover types (car+ and B+).

The male flies produce only two types of gametes (car + and Y), because crossing over does not take place in Drosophila male. A random union of two types of male gametes with four types of female gametes will produce males and females in equal number, means there will be four females and four males.

Stern examined the chromosomes of recombinant types, viz., red bar and carnation normal under microscope. He observed that in carnation normal females both the X-chromosomes were of equal length. In red bar flies, one X-chromosome was normal and other was fragmented.

The fragmented X-chromosome also had attached part of Y-chromosome. Such chromosome combination in red bar is possible only through exchange of segments between non-sister chromatids of homologous chromosomes. This has proved that genetic crossing over is the result of cytological crossing over. Similar proof of cytological crossing over was provided by Creighton and McClintock in maize.

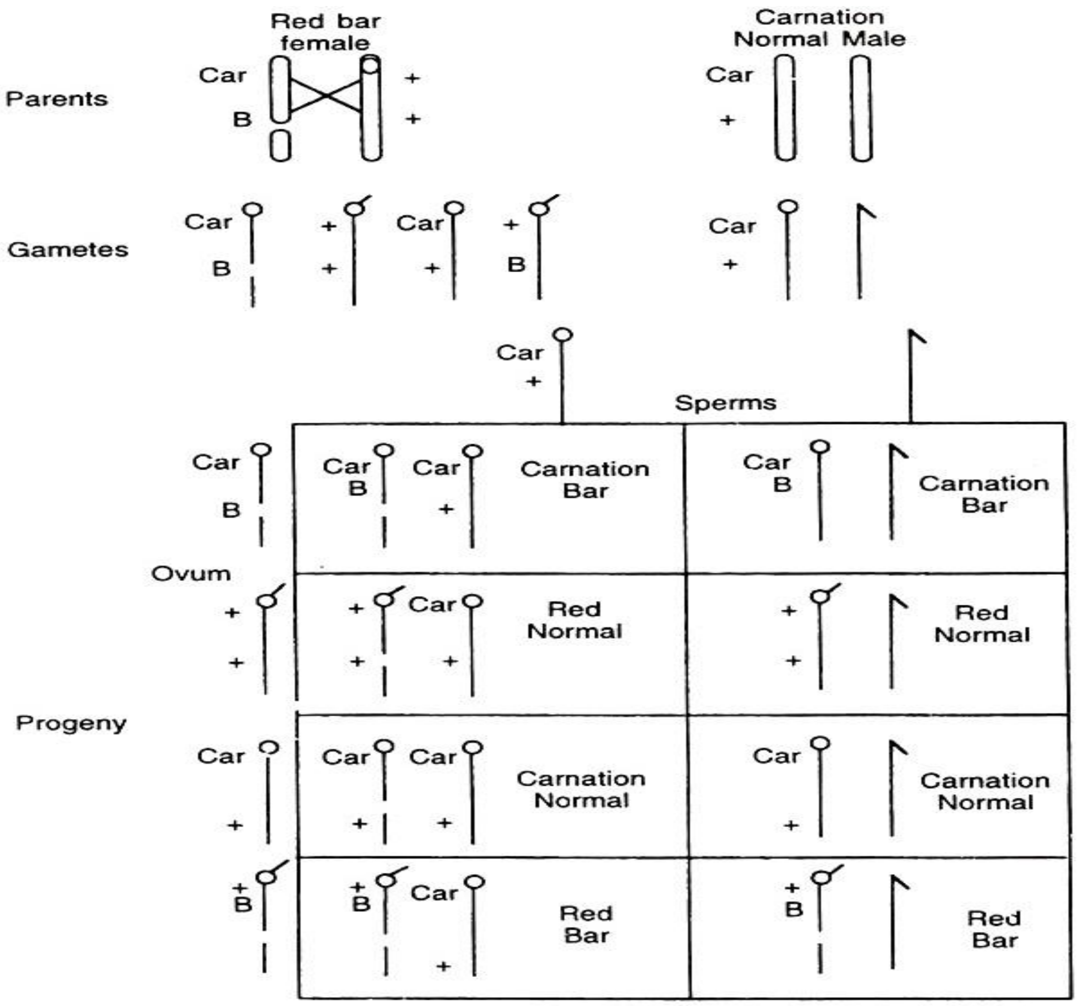

Fig.6.2, Cytological proof of crossing over in Drosophila

Significance of Crossing Over

1. Crossing over provides direct proof for the linear arrangement of genes,
2. Through crossing over segments of homologous chromosomes are interchanged and hence provide origin of new characters and genetic variations.
3. Crossing over has led to the construction of linkage map or genetic maps of chromosomes.

4. Linkage group and linear order of the genes help to reveal the mechanism of nature of genes.
5. Crossing over plays a very important role in the field of breeding to improve the varieties of plants and animals.

6.5 SUMMARY

Two genes are said to be under linkage, or linked, when they are located on the same chromosome. For example, research on the human genome discovered that the gene for factor III of clotting gene and the gene for factor V of clotting are located on the same chromosome (the human chromosome 1). However, the factor VII gene is not linked to those genes, since it is located on chromosome 13.
Linked alleles, for example, A-b and a-B, form the gametes A-b and a-B, which maintain the linkage of the alleles. This type of linkage is called complete linkage. However, in the first division of meiosis (meiosis I), the crossing over phenomenon may occur. Chromosomes from a pair of homologous chromosomes may exchange ends and certain once-linked alleles, for example, A-b and a-B, recombine to form different gametes, in this case, A-B and a-b. Crossing over a-B may happen when the arms of the chromatids of each homologous chromosomes are paired during meiosis. Matching portions of the ends of two non-sister chromatids (one from one homologous chromosome of the pair) break off and the pieces are exchanged, each of them becoming part of the arm of the other chromatid. For example, if the allele A is situated to one side of the arm relating to the point of breaking and the allele b is located on the other side, they will be separated and gametes A-B and a-b will be formed, instead of A-b and a-b. The percentage of recombinant gametes compared to normal gametes depends on the crossing over rate, which in turn depends on how far apart the given alleles are in the chromosome.

6.6 GLOSSARY

Crossing over: The exchange of segments between non-sister chromatids of homologous chromosomes during meiosis is called crossing over.
Recombination frequency: The proportion of recombinant types between two gene pairs as compared to the sum of all combinations is called cross over or recombination frequency.
Gene map: The recombination frequency is directly proportional to the distance between the linked gene loci. Genes can be mapped on a chromosome on the basis of their recombination frequencies. I% of recombination frequency is equal to I unit map distance.
Linkage map: A linkage map is a chromosome map of a species that shows the position of its known genes or markers relative to each other, rather than as specific physical points on each chromosome.
Centimorgan: A centimorgan, or recombination unit, by convention is the distance between two linked genes that corresponds to 1% of the recombination frequency of these genes.

6.7 SELF ASSESSMENT QUESTIONS

6.7.1 Multiple choice questions:

1- Who coined the term linkage-

(a) Mendel (b) Correns

(c) De Vries (d) Morgan

2- Mendel did not observe linkage due to-

(a) Crossing over (b) Synapsis

(c) Mutation (d) Independent assortment

3- The phenomenon of linkage was first observed in the plan-

(a) *Datura* (b) *Mirabilis jalapa*

(c) *Lathyrus odoratus* (d) *Pisum sativum*

4- How many linkage groups of chromosomes will be present in case of maize, if all its genes are mapped?

(a) 5 (b) 10

(c) 15 (d) 100

5- Crossing over is more frequent in-

(a) Males (b) Females

(c) Both (d) None of the above

6- Crossing over in diploid organism is responsible for-

(a) Dominance of genes (b) Segregation of alleles

(c) Recombination of linked genes (d) Linkage between genes

7- Complete linkage have been reported in-

(a) Maize (b) Human female

(c) Male Drosophila (d) Female Drosophila

8- Crossing over occurs during-

(a) Pachytene (b) Diplotene

(c) Diakinesis (d) Zygotene

9- Linkage prevents-

(a) Homozygous condition (b) Heterozygous condition

(c) Segregation of alleles (d) Hybrid formation

10- Coupling and repulsion phenomenon is concerned with

(a) Crossing over (b) Linkage

(c) Mutation (d) All of these

6.7.1 Answer Keys: 1-(d), 2(d), 3(c), 4-(b), 5-(b), 6-(c), 7-(c), 8-(a), 9-(c), 10-(b)

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6.10 TERMINAL QUESTIONS

6.10.1 Short answer type Questions:

1. Define crossing over. Give its significance.
2. What are linked genes? How can linked gene be separated?
3. Two genes A and B are linked. The other homologous chromosome contains their a and b allele. Give combination of alleles in gametes with and without crossing over.
4. Differentiate between parental and non-parental combinations.
5. Define recombination frequency.
6. What is gene map? How is it formed?
7. What is the importance of crossing over?
8. Define linkage map.
9. What is genetic map unit (m.u.), or a centimorgan?
10. What is Robust method of detection of linkage?

6.10.2 Long answer type Questions:

1. What is gene linkage? Demonstrate it with examples.
2. Write note on linkage groups.
3. What is crossing over? How is meiosis related to this phenomenon?
4. What is linkage map? How are they constructed? Explain.
5. Give different methods for detection of linkage map.
6. Why is Mendel’s Second Law not always valid for two or more phenotypical traits of an individual?
7. Why is drosophila a convenient animal for studying linked genes?
8. In genetic recombination by crossing over, what is the difference between parental gametes and recombinant gametes?
9. Why does the recombination frequency of genes vary depending on the distance between them in the chromosome?
10. How can the concept of recombination frequency be used in genetic mapping?
11. Is crossing over important for the diversity of biological evolution?

UNIT-7 POLYPLOIDY AND MUTATION

7.1 OBJECTIVES

After reading this unit students will be able-

- To understand the ploidy systems, mechanism of polyploidy, and its advantages and disadvantages.
- To discuss about various types of mutations.

7.2 INTRODUCTION

Ploidy is the number of sets of chromosomes in a cell. Usually a gamete (sperm or egg, which fuse into a single cell during the fertilization phase of sexual reproduction) carries a full set of chromosomes that includes a single copy of each chromosome, as aneuploidy generally leads to severe genetic disease in the offspring. The gametic or haploid number (n) is the number of chromosomes in a gamete. Two gametes form a diploid zygote with twice this number ($2n$, the zygotic or diploid number) i.e. two copies of autosomal chromosomes. For humans, a diploid species, $x = n = 23$. A typical human somatic cell contains 46 chromosomes: 2 complete haploid sets, which make up 23 homologous chromosome pairs.

Because chromosome number is generally reduced only by the specialized process of meiosis, the somatic cells of the body inherit and maintain the chromosome number of the zygote. However, in many situations somatic cells double their copy number by means of endoreduplication as an aspect of cellular differentiation. For example, the hearts of two-year-old children contain 85% diploid and 15% tetraploid nuclei, but by 12 years of age the proportions become approximately equal, and adults examined contained 27% diploid, 71% tetraploid and 2% octaploid nuclei. Cells are described according to the number of sets present (the ploidy level). The generic term polyploid is frequently used to describe cells with three or more sets of chromosomes (triploid or higher ploidy).

A mutation is a permanent change in the sequence of DNA. In order for an observable effect, mutations must occur in gene exons or regulatory elements. Changes in the non-coding regions of DNA (introns and junk DNA) generally do not affect function. Mutations can be caused by external (exogenous) or endogenous (native) factors, or they may be caused by errors in the cellular machinery. Physical or chemical agents that induce mutations in DNA are called mutagens and are said to be mutagenic. *Exogenous factors*: environmental factors such as sunlight, radiation, and smoking can cause mutations. *Endogenous factors*: errors during DNA replication can lead to genetic changes as can toxic by-products of cellular metabolism. Mutations can be advantageous and lead to an evolutionary advantage of a certain genotype. Mutations can also be deleterious, causing disease, developmental delays, structural abnormalities, or other effects. There are several classes of mutations, viz. deletion, frameshift, insertion, missense, nonsense, point, silent, splice site, translocation etc.
The present chapter discusses about the ploidy systems and mutations in plants and animals.

7.3 POLYPLOIDY

Polyploidy is the state where all cells have multiple sets of chromosomes beyond the basic set, usually 3 or more. Specific terms are triploid (3 sets), tetraploid (4 sets), pentaploid (5 sets), hexaploid (6 sets), heptaploid or septaploid (7 sets) octoploid (8 sets), nonaploid (9 sets), decaploid (10 sets), undecaploid (11 sets), dodecaploid (12 sets), tridecaploid (13 sets), tetradecaploid (14 sets), etc. Some higher ploidies include hexadecaploid (16 sets), dotriacontaploid (32 sets), and tetrahexacontaploid (64 sets), though Greek terminology may be set aside for readability in cases of higher ploidy (such as "16-ploid"). Polytene chromosomes of plants and fruit flies can be 1024-ploid. Ploidy of systems such as the salivary gland, elaiosome, endosperm, and trophoblast can exceed this, up to 1048576-ploid in the silk glands of the commercial silkworm *Bombyx mori*.

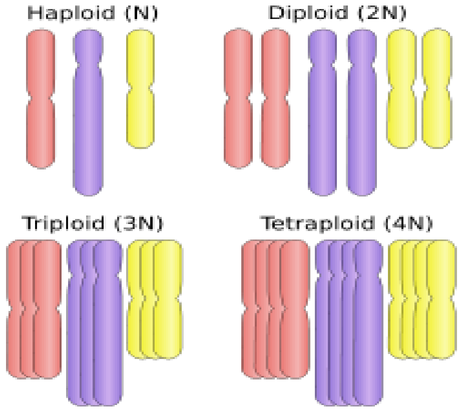

Fig.7.1 Haploid (single), diploid (double), triploid (triple), and tetraploid (quadruple) sets of chromosomes. Triploid and tetraploid chromosomes are examples of polyploidy

The chromosome sets may be from the same species or from closely related species. In the latter case, these are known as allopolyploids (or amphidiploids, which are allopolyploids that behave as if they were normal diploids). Allopolyploids are formed from the hybridization of two separate species. In plants, this probably most often occurs from the pairing of meiotically unreduced gametes, and not by diploid–diploid hybridization followed by chromosome doubling. The so-called *Brassica* triangle is an example of allopolyploidy, where three different parent species have hybridized in all possible pair combinations to produce three new species.

Polyploidy occurs commonly in plants, but rarely in animals. Even in diploid organisms, many somatic cells are polyploid due to a process called endoreduplication where duplication of the genome occurs without mitosis (cell division).

The extreme in polyploidy occurs in the fern genus *Ophioglossum*, the adder's-tongues, in which polyploidy results in chromosome counts in the hundreds, or, in at least one case, well over one thousand.

It is also possible for polyploid organisms to revert to lower ploidy by means of haploidisation.

Mechanisms of Polyploidy

How does an organism become polyploid? Polyploids arise when a rare mitotic or meiotic catastrophe, such as nondisjunction, causes the formation of gametes that have a complete set of duplicate chromosomes. Diploid gametes are frequently formed in this way. When a diploid gamete fuses with a haploid gamete, a triploid zygote forms, although these triploids are generally unstable and can often be sterile. If a diploid gamete fuses with another diploid gamete, however, this gives rise to a tetraploid zygote, which is potentially stable. Many types of polyploids are found in nature, including tetraploids (four sets of chromosomes), hexaploids (six sets of chromosomes), and other chromosome-pair multiples.

Researchers usually make a distinction between polyploids that arise within a species and those that arise due to the hybridization of two distinct species. The former are known as autopolyploids, while the latter are referred to as allopolyploids. Autopolyploids are essentially homozygous at every locus in the genome. However, allopolyploids may have varying degrees of heterozygosity depending on the divergence of the parental genomes. Heterozygosity is apparent in the gametes that polyploids produce. Allopolyploids can generally be distinguished from autopolyploids because they produce a more diverse set of gametes.

Different species exhibit different levels of tolerance for polyploidy. For example, polyploids form at relatively high frequency in flowering plants (1 per 100,000 individuals), suggesting that plants have a remarkably high tolerance for polyploidy. This is also the case for some species of fish and frogs. However, higher vertebrates do not appear to tolerate polyploidy very well; in fact, it is believed that 10% of spontaneous abortions in humans are due to the formation of polyploid zygotes.

Advantages of Polyploidy

Due to the high incidence of polyploidy in some taxa, such as plants, fish, and frogs, there clearly must be some advantages to being polyploid. A common example in plants is the observation of hybrid vigor, or heterosis, whereby the polyploid offspring of two diploid progenitors is more vigorous and healthy than either of the two diploid parents. There are several possible explanations for this observation. One is that the enforced pairing of homologous chromosomes within an allotetraploid prevents recombination between the genomes of the original progenitors, effectively maintaining heterozygosity throughout generations. This heterozygosity prevents the accumulation of recessive mutations in the genomes of later generations, thereby maintaining hybrid vigour. Another important factor is gene redundancy. Because the polyploid offspring now have twice as many copies of any particular gene, the offspring are shielded from the deleterious effects of recessive mutations. This is particularly important during the gametophyte life stage. One might envision that, during the haploid stage of the life cycle, any allele that is recessive for a deleterious mutation will not be masked by the presence of a dominant, normally functioning allele, allowing the mutation to cause developmental failure in the pollen or the egg sac. Conversely, a diploid gamete permits the masking of this deleterious allele by the presence of the dominant normal allele, thus protecting the pollen or egg sac from developmental dysfunction. This protective effect of polyploidy might be important when small, isolated populations are forced to inbreed.

Another advantage conferred by gene redundancy is the ability to diversify gene function over time. In other words, extra copies of genes that are not required for normal organism function might end up being used in new and entirely different ways, leading to new opportunities in evolutionary selection.

Interestingly, polyploidy can affect sexuality in ways that provide selective advantages. One way is by disrupting certain self-incompatibility systems, thereby allowing self-fertilization. This might be the result of the interactions between parental genomes in allopolyploids. Another way is by favoring the onset of asexual reproduction, which is associated with polyploidy in both plants and animals. This switch in reproductive strategies may improve fitness in static environments.

Disadvantages of Polyploidy

For all the advantages that polyploidy can confer to an organism, there are also a great number of disadvantages, both observed and hypothesized. One of these disadvantages relates to the relative changes between the size of the genome and the volume of the cell. Cell volume is proportional to the amount of DNA in the cell nucleus. For example, doubling a cell's genome is expected to double the volume of space occupied by the chromosomes in the nucleus, but it causes only a 1.6-fold increase in the surface area of the nuclear envelope. This can disrupt the balance of factors that normally mediate interactions between the chromosomes and nuclear components, including envelope-bound proteins. The peripheral positioning of telomeric and centromeric heterochromatin may be disturbed as well, because there is less relative surface space on the nuclear envelope to accommodate this positioning.

Polyploidy can also be problematic for the normal completion of mitosis and meiosis. For one, polyploidy increases the occurrence of spindle irregularities, which can lead to the chaotic segregation of chromatids and to the production of aneuploid cells in animals and yeast. Aneuploid cells, which have abnormal numbers of chromosomes, are more readily produced in meioses involving three or more sets of chromosomes than in diploid cells. Autopolyploids have the potential to form multiple arrangements of homologous chromosomes at meiotic metaphase I, which can result in abnormal segregation patterns, such as 3:1 or 2:1 plus one laggard. (Laggard chromosomes do not attach properly to the spindle apparatus and thus randomly segregate to daughter cells.) These abnormal segregation patterns cannot be resolved into balanced products, and random segregation of multiple chromosome types produces mostly aneuploid gametes. Chromosome pairing at meiosis I is more constrained in allopolyploids than in autopolyploids, but the stable maintenance of the two parental chromosomal complements also requires the formation of balanced gametes.

Another disadvantage of polyploidy includes potential changes in gene expression. It is generally assumed that an increase in the copy number of all chromosomes would affect all genes equally and should result in a uniform increase in gene expression. Possible exceptions would include genes that respond to regulating factors that do not change proportionally with ploidy. We now have experimental evidence for such exceptions in several systems. In one interesting example, investigators compared the mRNA levels per genome for 18 genes in 1X, 2X, 3X, and 4X maize. While expression of most genes increased with ploidy, some genes demonstrated unexpected deviations from expected expression levels. For example, *sucrose synthase* showed the expected proportional expression in 2X and 4X tissues, but its expression was three and six times higher, respectively, in 1X and 3X tissues. Two other genes showed similar, if less extreme, trends. Altogether, about 10% of these genes demonstrated sensitivity to odd-numbered ploidy.

Epigenetic instability can pose yet another challenge for polyploids. Epigenetics refers to changes in phenotype and gene expression that are not caused by changes in DNA sequence.

Evolutionary Potential of Polyploid Organisms

At first sight, the epigenetic changes observed in polyploids would seem to be deleterious because of their disruptive effects on regulatory patterns established by selection. However, these epigenetic changes might instead increase diversity and plasticity by allowing for rapid adaptation in polyploids. One example may be the widespread dispersal of the invasive allopolyploid *Spartina angelica*. However, it is not clear whether the success of this species can be attributed to fixed heterosis or to the increased variability that results from epigenetic remodeling. Polyploidy is also believed to play a role in the rapid adaptation of some allopolyploid arctic flora, probably because their genomes confer hybrid vigor and buffer against the effects of inbreeding. However, fertility barriers between species often need to be overcome in order to form successful allopolyploids, and these barriers may have an epigenetic basis.

7.4 MUTATION

In biology, a mutation is a permanent change of the nucleotide sequence of the genome of an organism, virus, or extrachromosomal DNA or other genetic elements. Mutations result from damage to DNA which is not repaired or to RNA genomes (typically caused by radiation or chemical mutagens), errors in the process of replication, or from the insertion or deletion of segments of DNA by mobile genetic elements. Mutations may or may not produce discernible changes in the observable characteristics (phenotype) of an organism. Mutations play a part in both normal and abnormal biological processes including: evolution, cancer, and the development of the immune system, including functional diversity.

Mutation can result in several different types of change in sequences. Mutations in genes can either have no effect, alter the product of a gene, or prevent the gene from functioning properly or completely. Mutations can also occur in nongenic regions. One study on genetic variations between different species of *Drosophila* suggests that, if a mutation changes a protein produced by a gene, the result is likely to be harmful, with an estimated 70 percent of amino acid polymorphisms that have damaging effects, and the remainder being either neutral or weakly beneficial. Due to the damaging effects that mutations can have on genes, organisms have mechanisms such as DNA repair to prevent or correct (revert the mutated sequence back to its original state) mutations.

Mutations can involve the duplication of large sections of DNA, usually through genetic recombination. These duplications are a major source of raw material for evolving new genes, with tens to hundreds of genes duplicated in animal genomes every million years. Most genes belong to larger families of genes of shared ancestry. Novel genes are produced by several methods, commonly through the duplication and mutation of an ancestral gene, or by recombining parts of different genes to form new combinations with new functions.

Here, domains act as modules, each with a particular and independent function, that can be mixed together to produce genes encoding new proteins with novel properties. For example, the human eye uses four genes to make structures that sense light: three for colour vision and one for night vision; all four arose from a single ancestral gene. Another advantage of duplicating a gene (or even an entire genome) is that this increases redundancy; this allows one gene in the pair to acquire a new function while the other copy performs the original function. Other types of mutation occasionally create new genes from previously noncoding DNA.

Changes in chromosome number may involve even larger mutations, where segments of the DNA within chromosomes break and then rearrange. For example, in the Homininae, two chromosomes fused to produce human chromosome 2; this fusion did not occur in the lineage of the other apes, and they retain these separate chromosomes. In evolution, the most important role of such chromosomal rearrangements may be to accelerate the divergence of a population into new species by making populations less likely to interbreed, thereby preserving genetic differences between these populations.

Sequences of DNA that can move about the genome, such as transposons, make up a major fraction of the genetic material of plants and animals, and may have been important in the evolution of genomes. For example, more than a million copies of the Alu sequence are present in the human genome, and these sequences have now been recruited to perform functions such as regulating gene expression. Another effect of these mobile DNA sequences is that when they move within a genome, they can mutate or delete existing genes and thereby produce genetic diversity.

Nonlethal mutations accumulate within the gene pool and increase the amount of genetic variation. The abundance of some genetic changes within the gene pool can be reduced by natural selection, while other "more favorable" mutations may accumulate and result in adaptive changes.

For example, a butterfly may produce offspring with new mutations. The majority of these mutations will have no effect; but one might change the colour of one of the butterfly's offspring, making it harder (or easier) for predators to see. If this colour change is advantageous, the chance of this butterfly's surviving and producing its own offspring are a little better, and over time the number of butterflies with this mutation may form a larger percentage of the population.

Neutral mutations are defined as mutations whose effects do not influence the fitness of an individual. These can accumulate over time due to genetic drift. It is believed that the overwhelming majority of mutations have no significant effect on an organism's fitness. Also, DNA repair mechanisms are able to mend most changes before they become permanent mutations, and many organisms have mechanisms for eliminating otherwise-permanently mutated somatic cells.
Beneficial mutations can improve reproductive success.

7.4.1-Spontaneous Mutation

Spontaneous mutations on the molecular level can be caused by:

- **Tautomerism** — A base is changed by the repositioning of a hydrogen atom, altering the hydrogen bonding pattern of that base, resulting in incorrect base pairing during replication.
- **Depurination** — Loss of a purine base (A or G) to form an apurinic site (AP site).
- **Deamination** — Hydrolysis changes a normal base to an atypical base containing a keto group in place of the original amine group. Examples include C → U and A → HX (hypoxanthine), which can be corrected by DNA repair mechanisms; and 5MeC (5-methylcytosine) → T, which is less likely to be detected as a mutation because thymine is a normal DNA base.
- **Slipped strand mispairing** — Denaturation of the new strand from the template during replication, followed by renaturation in a different spot ("slipping"). This can lead to insertions or deletions.

Error-prone replication bypass

There is increasing evidence that the majority of spontaneously arising mutations are due to error-prone replication (translesion synthesis) past a DNA damage in the template strand. Naturally occurring oxidative DNA damages arise at least 10,000 times per cell per day in humans and 50,000 times or more per cell per day in rats. In mice, the majority of mutations are caused by translesion synthesis. Likewise, in yeast, it was found that more than 60% of the spontaneous single base pair substitutions and deletions were caused by translesion synthesis.

Errors introduced during DNA repair

Although naturally occurring double-strand breaks occur at a relatively low frequency in DNA, their repair often causes mutation. Non-homologous end joining (NHEJ) is a major pathway for repairing double-strand breaks. NHEJ involves removal of a few nucleotides to allow somewhat inaccurate alignment of the two ends for rejoining followed by addition of nucleotides to fill in gaps. As a consequence, NHEJ often introduces mutations

7.4.2-Induced Mutation

Induced mutations on the molecular level can be caused by:

1-Chemicals

- Hydroxylamine NH_2OH
- Base analogs (e.g., BrdU)
- Alkylating agents (e.g., *N*-ethyl-*N*-nitrosourea) These agents can mutate both replicating and non-replicating DNA. In contrast, a base analog can mutate the DNA only when the analog is incorporated in replicating the DNA. Each of these classes of chemical mutagens has certain effects that then lead to transitions, transversions, or deletions.
- Agents that form DNA adducts (e.g., ochratoxin A metabolites)
- DNA intercalating agents (e.g., ethidium bromide)
- DNA crosslinkers
- Oxidative damage
- Nitrous acid converts amine groups on A and C to diazo groups, altering their hydrogen bonding patterns, which leads to incorrect base pairing during replication.

2-Radiation

- Ultraviolet radiation (nonionizing radiation). Two nucleotide bases in DNA — cytosine and thymine — are most vulnerable to radiation that can change their properties. UV light can induce adjacent pyrimidine bases in a DNA strand to become covalently joined as a pyrimidine dimer. UV radiation, in particular longer-wave UVA, can also cause oxidative damage to DNA.

7.5 SUMMARY

Polyploids - organisms that have multiple sets of chromosomes - are common in certain plant and animal taxa, and can be surprisingly stable. The evidence that has emerged from genome analyses also indicates that many other eukaryotic genomes have a polyploid ancestry, suggesting that both humans and most other eukaryotes have either benefited from or endured polyploidy. Studies of polyploids soon after their formation have revealed genetic and epigenetic interactions between redundant genes. These interactions can be related to the phenotypes and evolutionary fates of polyploids

Diploid organisms carry two copies (alleles) of each gene, whereas haploid organisms carry only one copy. Mutations are alterations in DNA sequences that result in changes in the structure of a gene. Both small and large DNA alterations can occur spontaneously. Treatment with ionizing radiation or various chemical agents increases the frequency of mutations. Recessive mutations lead to a loss of function, which is masked if a normal copy of the gene is present. For the mutant phenotype to occur, both alleles must carry the mutation. Dominant mutations lead to a mutant phenotype in the presence of a normal copy of the gene. The phenotypes associated with dominant mutations may represent either a loss or a gain of function.

In meiosis, a diploid cell undergoes one DNA replication and two cell divisions, yielding four haploid cells. The members of each pair of homologous chromosomes segregate independently during meiosis, leading to the random reassortment of maternal and paternal alleles in the gametes. Dominant and recessive mutations exhibit characteristic segregation patterns in genetic crosses.

7.6 GLOSSARY

Polyploidy: Polyploidy is the heritable condition of possessing more than two complete sets of chromosomes. Polyploids are common among plants, as well as among certain groups of fish and amphibians. For instance, some salamanders, frogs, and leeches are polyploids. Many of these polyploid organisms are fit and well-adapted to their environments. In fact, recent findings in genome research indicate that many species that are currently diploid, including humans, were derived from polyploid ancestors. These species that have experienced ancient genome duplications and then genome reduction are referred to as paleopolyploids. This article discusses the mechanisms underlying polyploidy, and both the advantages and disadvantages of having multiple sets of chromosomes.

Polyploid types are labeled according to the number of chromosome sets in the nucleus. The letter *x* is used to represent the number of chromosomes in a single set.

- **triploid** (three sets; 3*x*), for example seedless watermelons, common in the phylum Tardigrada.
- **tetraploid** (four sets; 4*x*), for example Salmonidae fish, the cotton *Gossypium hirsutum* .
- **pentaploid** (five sets; 5*x*), for example Kenai Birch (*Betula papyrifera* var. *kenaica*)
- **hexaploid** (six sets; 6*x*), for example wheat, kiwifruit.
- **heptaploid** or **septaploid** (seven sets; 7*x*)
- **octaploid** or **octoploid**, (eight sets; 8*x*), for example *Acipenser* (genus of sturgeon fish), dahlias.
- **decaploid** (ten sets; 10*x*), for example certain strawberries.
- **dodecaploid** (twelve sets; 12*x*), for example the plant *Celosia argentea* or the invasive one *Spartina anglica* or the amphibian *Xenopus ruwenzoriensis*.

Euploidy: Changes in chromosome number can occur by the addition of all or part of a chromosome (aneuploidy), the loss of an entire set of chromosomes (monoploidy) or the gain of one or more complete sets of chromosomes (euploidy). Each of these conditions is a variation on the normal diploid number of chromosomes.

Mutation: **A** sudden departure from the parent type in one or more heritable characteristics, caused by a change in a gene or a chromosome. Various types of mutations include:

Deletion: Genetic material is removed or deleted. A few bases can be deleted (as shown on the left) or it can be complete or partial loss of a chromosome.

Frameshift: The insertion or deletion of a number of bases that is not a multiple of 3. This alters the reading frame of the gene and frequently results in a premature stop codon and protein truncation.

Insertion: When genetic material is put into another region of DNA. This may be the insertion of 1 or more bases, or it can be part of one chromosome being inserted into another, non-homologous chromosome.

Missense: A change in DNA sequence that changes the codon to a different amino acid. Not all missense mutations are deleterious, some changes can have no effect. Because of the ambiguity of missense mutations, it is often difficult to interpret the consequences of these mutations in causing disease.

Nonsense: A change in the genetic code that results in the coding for a stop codon rather than an amino acid. The shortened protein is generally non-function or its function is impeded.

Point: A single base change in DNA sequence. A point mutation may be silent, missense, or nonsense.

Silent: A change in the genetic sequence that does not change the protein sequence. This can occur because of redundancy in the genetic code where an amino acid may be encoded for by multiple codons.

Splice Site: A change in the genetic sequence that occurs at the boundary of the exons and introns. The consensus sequences at these boundaries signal where to cut out introns and rejoin exons in the mRNA. A change in these sequences can eliminate splicing at that site which would change the reading frame and protein sequence.

Translocation: A structural abnormality of chromosomes where genetic material is exchanged between two or more non-homologous chromosomes.

7.7 SELF ASSESSMENT QUESTIONS

7.7.1 Multiple choice questions:

1- Which one of the following corresponds to polyploidy in man-

(a) 66 autosomes + 2x chromosomes + 1y chromosome

(b) 21 autosomes + 1x chromosome + 1y chromosome

(c) 44 autosomes + 2x chromosomes + 2y chromosomes

(d) 43 autosomes + 1x chromosome + 2y chromosomes

2- During ploidy there is a change in the-

(a) Number of chromosomes (b) Number of genes

(c) Arrangement of genes (d) Arrangement of chromosomes

3- The term genome refers to the-

(a) Haploid set of chromosomes (b) Diploid set of chromosomes

(c) Triploid set of chromosomes (d) Tetraploid set of chromosomes

4- This is commonly found in the plants-
(a) Haploidy (b) Diploidy
(c) Polyploidy (d) Trisomy

5- One of the following is not the kind of euploidy-
(a) Monoploidy (b) Diploidy
(c) Hyperploidy (d) Polyploidy

6- Point mutation involves-
(a) Deletion (b) Insertion
(c) Duplication (d) Change in single base pair

7- Gene mutation occurs at the time of-
(a) DNA repair (b) DNA replication
(c) Cell division (d) RNA transcription

8- X-ray causes mutation by-
(a) Deletion (b) Transition
(c) Transversion (d) Base substitution

9- In mutational events when adenine is replaced by guanine, it is case of-
(a) Transition (b) Transcription
(c) Transversion (d) Frame shift mutation

10- Muller was first to produce induced mutation in---- by exposing them to X-rays-
(a) *Paramecium* (b) *Arabidopsis*
(c) *Drosophila* (d) *Xenopus*

7.7.1 Answer Keys: 1-(c), 2-(a), 3-(a), 4-(c), 5-(c), 6-(a), 7-(b), 8-(c), 9-(a), 10-(c)

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7.10 TERMINAL QUESTIONS

7.10.1 Short answer type Questions:

1. Advantage and disadvantage of polyploidy.
2. Are mutations ever beneficial?
3. Can mutation be the mechanism for evolution?
4. Can any genetic information be gained from mutations?
5. Describe some common chromosomal mutations.
6. Why are mutations so important to living organisms?

7.10.2 Long answer type Questions:

1. What is gene mutation? Give its types.
2. What are mutagens? Give its types.
3. Describe the purpose and process of mutation breeding?
4. What are neutral mutations?

UNIT-8 SEX DETERMINATION AND SEX-LINKED INHERITANCE

8.1 OBJECTIVES

After reading this unit students will be able-

- To understand about various sex determination systems.
- To discuss about sex-linkage and sex-linked inheritance.

8.2 INTRODUCTION

Most animals and many plants show sexual dimorphism; in other words, an individual can be either male or female. In most of these cases, sex is determined by special sex chromosomes. In these organisms, there are two categories of chromosomes, sex chromosomes and autosomes (the chromosomes other than the sex chromosomes). The rules of inheritance considered so far, with the use of Mendel's analysis as an example, are the rules of autosomes. Most of the chromosomes in a genome are autosomes. The sex chromosomes are fewer in number, and, generally in diploid organisms, there is just one pair. The genes on the differential regions of the sex chromosomes show patterns of inheritance related to sex. The inheritance patterns of genes on the autosomes produce male and female progeny in the same phenotypic proportions, as typified by Mendel's data (for example, both sexes might show a 3:1 ratio). However, crosses following the inheritance of genes on the sex chromosomes often show male and female progeny with different phenotypic ratios. In fact, for studies of genes of unknown chromosomal location, this pattern is a diagnostic of location on the sex chromosomes.

The present chapter discusses about the sex chromosomes, different sex determination systems and sex-linked inheritance for various traits.

8.3 SEX DETERMINATION

A *sex-determination system* is a biological system that determines the development of sexual characteristics in an organism. Most organisms that create their offspring using sexual reproduction have two sexes. Occasionally, there are hermaphrodites in place of one or both sexes. There are also some species that are only one sex due to parthenogenesis, the act of a female reproducing without fertilization.

In many species, sex determination is genetic: males and females have different alleles or even different genes that specify their sexual morphology. In animals this is often accompanied by chromosomal differences, generally through combinations of XY, ZW, XO, ZO chromosomes, or haplodiploidy. The sexual differentiation is generally triggered by a main gene (a "sex locus"), with a multitude of other genes following in a domino effect.

In other cases, sex is determined by environmental variables (such as temperature) or social variables (e.g. the size of an organism relative to other members of its population). Environmental sex determination preceded the genetically determined systems of birds and mammals; it is thought that a temperature-dependent amniote was the common ancestor of amniotes with sex chromosomes. Some species do not have a fixed sex, and instead change sex based on certain cues. The details of some sex-determination systems are not yet fully understood.

Chromosomal determination

1- XX/XY sex chromosomes

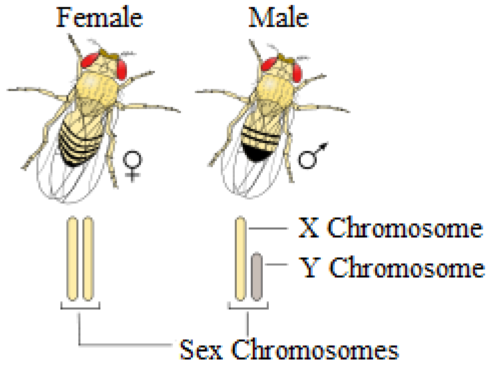

Fig.8.1 Drosophila sex-chromosomes

The **XX/XY sex-determination system** is the most familiar, as it is found in humans. In the system, females have two of the same kind of sex chromosome (XX), while males have two distinct sex chromosomes (XY). The XY sex chromosomes are different in shape and size from each other, unlike the autosomes, and are termed allosomes. Some species (including humans) have a gene SRY on the Y chromosome that determines maleness; others (such as the fruit fly) use the presence of two X chromosomes to determine femaleness. Because the fruit fly, as well as other species, use the number of Xs to determine sex, they are nonviable with an extra X. SRY-reliant species can have conditions such as XXY and still live. Human sex is determined by containing SRY or not. Once SRY is activated, cells create testosterone and anti-müllerian hormone to turn the genderless sex organs into male. With females, their cells excrete estrogen, driving the body down the female pathway. Not all organisms remain gender indifferent for a time after they're created; for example, fruit flies differentiate into specific sexes as soon as the egg is fertilized. In Y-centered sex determination, the SRY gene is not the only gene to have an influence on sex. Despite the fact that SRY seems to be the main gene in determining male characteristics, it requires the action of multiple genes to develop testes. In XY mice, lack of the gene DAX1 on the X chromosome results in sterility, but in humans it causes adrenal hypoplasia congenita. However, when an extra DAX1 gene is placed on the X, the result is a female, despite the existence of SRY. Also, even when there are normal sex chromosomes in XX females, duplication or expression of SOX9 causes testes to develop. Gradual sex reversal in developed mice can also occur when the gene FOXL2 is removed from females. Even though the gene DMRT1 is used by birds as their sex locus, species who have XY chromosomes also rely upon DMRT1, contained on chromosome 9, for sexual differentiation at some point in their formation.

The XX/XY system is also found in most other mammals, as well as some insects. Some fish also have variants of this, as well as the regular system. For example, while having an XY format, *Xiphophorus nezahualcoyotl* and *X. milleri* also have a second Y chromosome, known as Y', that creates XY' females and YY' males. At least one monotreme, the platypus, presents a particular sex determination scheme that in some ways resembles that of the ZW sex chromosomes of birds, and also lacks the SRY gene, whereas some rodents, such as several Arvicolinae (voles and lemmings), are also noted for their unusual sex determination systems. The platypus has ten sex chromosomes; males have an XYXYXYXYXY pattern while females have ten X chromosomes. Although it is an XY system, the platypus' sex chromosomes share no homology with eutherian sex chromosomes. Instead, homologous with eutherian sex chromosomes lie on the platypus chromosome 6, which means that the eutherian sex chromosomes were autosomes at the time that the monotremes diverged from the therian mammals (marsupials and eutherian mammals). However, homologous to the avian DMRT1 gene on platypus sex chromosomes X3 and X5 suggest that it is possible the sex-determining gene for the platypus is the same one that is involved in bird sex-determination. More research must be conducted in order to determine the exact sex determining gene of the platypus.

2-XX/X0 sex chromosomes

In this variant of the XY system, females have two copies of the sex chromosome (XX) but males have only one (X0). The *0* denotes the absence of a second sex chromosome. Generally in this method, the sex is determined by amount of genes expressed across the two chromosomes. This system is observed in a number of insects, including the grasshoppers and crickets of order Orthoptera and in cockroaches (order Blattodea). A small number of mammals also lack a Y chromosome. These include the Amami spiny rat (*Tokudaia osimensis*) and the Tokunoshima spiny rat (*Tokudaia tokunoshimensis*) and *Sorex araneus*, a shrew species. Transcaucasian mole voles (*Ellobius lutescens*) also have a form of XO determination, in which both genders lack a second sex chromosome. The mechanism of sex determination is not yet understood.

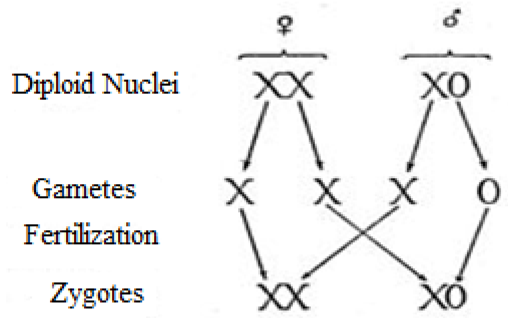

Fig. 8.2 Heredity of sex chromosomes in XO sex determination

The nematode *C. elegans* is male with one sex chromosome (X0); with a pair of chromosomes (XX) it is a hermaphrodite. Its main sex gene is XOL, which encodes XOL-1 and also controls the expression of the genes TRA-2 and HER-1. These genes reduce male gene activation and increase it, respectively.

3- ZZ/ZW sex chromosomes

The *ZW sex-determination system* is found in birds, some reptiles, and some insects and other organisms. The ZW sex-determination system is reversed compared to the XY system: females have two different kinds of chromosomes (ZW), and males have two of the same kind of chromosomes (ZZ). In the chicken, this was found to be dependent on the expression of DMRT1. In birds, the genes FET1 and ASW are found on the W chromosome for females, similar to how the Y chromosome contains SRY. However, not all species depend upon the W for their sex. For example, there are moths and butterflies that are ZW, but some have been found female with ZO, as well as female with ZZW. Also, while mammals inactivate one of their extra X chromosomes when female, it appears that in the case of Lepidoptera, the males produce double the normal amount of enzymes, due to having two Z's. Because the use of ZW sex determination is varied, it is still unknown how exactly most species determine their sex. However, reportedly, the silkworm *Bombyx mori* uses a single female-specific piRNA as the primary determiner of sex. Despite the similarities between ZW and XY, the sex chromosomes do not line up correctly and evolved separately. In the case of the chicken, their Z chromosome is more similar to human’s autosome 9. The chicken's Z chromosome also seems to be related to the X chromosomes of the platypus. When a ZW species, such as the Komodo dragon, reproduces parthenogenetically, usually only males are produced. This is due to the fact that the haploid eggs double their chromosomes, resulting in ZZ or WW. The ZZ become males, but the WW are not viable and are not brought to term.

4- UV Sex Chromosomes

In some Bryophyte and some algae species, the gametophyte stage of the life cycle, rather than being hermaphrodite, occurs as separate male or female individuals that produce male and female gametes, respectively. When meiosis occurs in the sporophyte generation of the life cycle, the sex chromosomes known as U and V assort in spores that carry either the U chromosome and give rise to female gametophytes, or the V chromosome and give rise to male gametophytes.

5- Haplodiploidy

Haplodiploidy is found in insects belonging to Hymenoptera, such as ants and bees. Unfertilized eggs develop into haploid individuals, which are the males. Diploid individuals are generally female but may be sterile males. Males cannot have sons or fathers. If a queen bee mates with one drone, her daughters share ¾ of their genes with each other, not ½ as in the XY and ZW systems. This is believed to be significant for the development of eusociality, as it increases the significance of kin selection, but it is debated. Most females in the Hymenoptera order can decide the sex of their offspring by holding received sperm in their spermatheca and either releasing it into their oviduct or not. This allows them to create more workers, depending on the status of the colony.

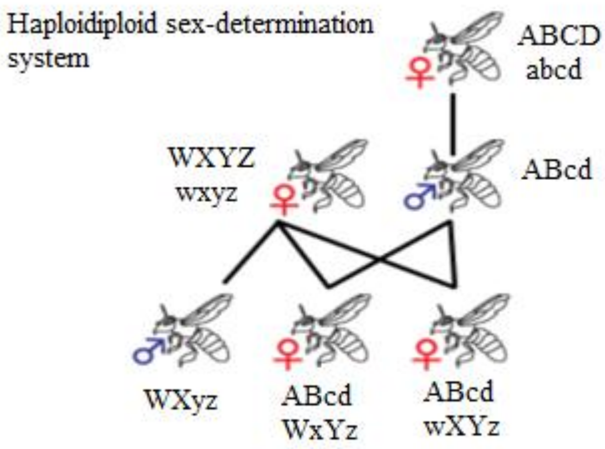

Fig.8.3 Haplodiploid sex chromosomes

Non-Genetic Sex-Determination Systems

1-Temperature-dependent sex determination

In some species of reptiles, including alligators, some turtles, and the tuatara, sex is determined by the temperature at which the egg is incubated during a temperature-sensitive period. There are no examples of temperature-dependent sex determination (TSD) in birds. Megapodes had formerly been thought to exhibit this phenomenon, but actually exhibit temperature-dependent embryo mortality. For some species with TSD, sex determination is achieved by exposure to hotter temperatures resulting in the offspring being one sex and cooler temperatures resulting in the other. For others species using TSD, it is exposure to temperatures on both extremes that results in offspring of one sex, and exposure to moderate temperatures that results in offspring of the opposite sex. These systems are known as Pattern I and Pattern II, respectively. The specific temperatures required to produce each sex are known as the female-promoting temperature and the male-promoting temperature. When the temperature stays near the threshold during the temperature sensitive period, the sex ratio is varied between the two sexes. Some species' temperature standards are based on when a particular enzyme is created. These species that rely upon temperature for their sex determination do not have the SRY gene, but have other genes such as DAX1, DMRT1, and SOX9 that are expressed or not expressed depending on the temperature. The sex of some species, such as the Nile tilapia, Australian skink lizard, and Australian dragon lizard, is initially determined by chromosomes, but can later be changed by the temperature of incubation.

It is unknown how exactly temperature-dependent sex determination evolved. It could have evolved through certain sexes being more suited to certain areas that fit the temperature requirements. For example, a warmer area could be more suitable for nesting, so more females are produced to increase the amount that nest next season.

Other sex-determination systems

Although temperature-dependent sex determination is relatively common, there are many other environmental systems. Some species, such as some snails, practice sex change: adults start out male, then become female. In tropical clown fish, the dominant individual in a group becomes female while the other ones are male, and bluehead wrasses (*Thalassoma bifasciatum*) are the reverse. In the marine worm (*Bonellia viridis*), larvae become males if they make physical contact with a female, and females if they end up on the bare sea floor. This is triggered by the presence of a chemical produced by the females, bonellin. Some species, however, have no sex-determination system. Hermaphrodite species include the common earthworm and certain species of snails. A few species of fish, reptiles, and insects reproduce by parthenogenesis and are female altogether. There are some reptiles, such as the boa constrictor and Komodo dragon that can reproduce both sexually and asexually, depending on whether a mate is available.

Evolution of Sex-Determination Systems

Origin of sex chromosomes

The accepted hypothesis of XY and ZW sex chromosome evolution is that they evolved at the same time, in two different branches. However, there is some evidence to suggest that there could have been transitions between ZW and XY, such as in *Xiphophorus maculatus*, which have both ZW and XY systems in the same population, despite the fact that ZW and XY have different gene locations. A recent theoretical model raises the possibility of both transitions between the XY/XX and ZZ/ZW system and environmental sex determination. The platypus' genes also back up the possible evolutionary link between XY and ZW, because they have the DMRT1 gene possessed by birds on their X chromosomes. Regardless, XY and ZW follow a similar route. All sex chromosomes started out as an original autosome of an original amniote that relied upon temperature to determine the sex of offspring. After the mammals separated, the branch further split into Lepidosauria and Archosauromorpha. These two groups both evolved the ZW system separately, as evidenced by the existence of different sex chromosomal locations. In mammals, one of the autosome pair, now Y, mutated its SOX3 gene into the SRY gene, causing that chromosome to designate sex. After this mutation, the SRY-containing chromosome inverted and was no longer completely homologous with its partner. The regions of the X and Y chromosomes that are still homologous to one another are known as the pseudoautosomal region. Once it inverted, the Y chromosome became unable to remedy deleterious mutations, and thus degenerated. There is some concern that the Y chromosome will shrink further and stop functioning in 10 million years, but other evidence has shown that the Y chromosome has been strictly conserved after its initial rapid gene loss.

There are some species, such as the medaka fish, that evolved sex chromosomes separately; their Y chromosome never inverted and can still swap genes with the X. These species are still in an early phase of evolution with regard to their sex chromosomes. Because the Y does not have male-specific genes and can interact with the X, XY and YY females can be formed as well as XX males.

8.4 SEX LINKED INHERITANCE

The inheritance of a trait (phenotype) that is determined by a gene located on one of the sex chromosomes. Genetic studies of many species have been facilitated by focusing on such traits because of their characteristic patterns of familial transmission and the ability to localize their genes to a specific chromosome. As the ability to map a gene to any of an organisms chromosome has improved markedly, reliance on the specific pattern of inheritance has waned.

The expectations of sex-linked inheritance in any species depend on how the chromosomes determine sex. For example, in humans, males are heterogametic, having one X chromosome and one Y chromosome, whereas females are homogametic, having two X chromosomes. In human males, the entire X chromosome is active (not all genes are active in every cell), whereas one of a female's X chromosomes is largely inactive. Random inactivation of one X chromosome occurs during the early stages of female embryogenesis, and every cell that descends from a particular embryonic cell has the same X chromosome inactivated. The result is dosage compensation for X-linked genes between the sexes. A specific gene on the long arm of the X chromosome, called XIST at band q13, is a strong candidate for the gene that controls X inactivation. This pattern of sex determination occurs in most vertebrates, but in birds and many insects and fish the male is the homogametic sex.

In general terms, traits determined by genes on sex chromosomes are not different from traits determined by autosomal genes. Sex-linked traits are distinguishable by their mode of transmission through successive generations of a family. In humans it is preferable to speak in terms of X-linked or Y-linked inheritance.

Red-green color blindness was the first human trait proven to be due to a gene on a specific chromosome. The characteristics of this pattern of inheritance are readily evident. Males are more noticeably or severely affected than females; in the case of red-green color blindness, women who have one copy of the mutant gene (that is, are heterozygous or carriers) are not at all affected. Among offspring of carrier mothers, on average one-half of their sons are affected, whereas one-half of their daughters are carriers. Affected fathers cannot pass their mutant X chromosome to their sons, but do pass it to all of their daughters, who thereby are carriers. A number of other well-known human conditions behave in this manner, including the two forms of hemophilia, Duchenne muscular dystrophy, and glucose-6-phosphate dehydrogenase deficiency that predisposes to hemolytic anemia.

Refined cytogenetic and molecular techniques have supplemented family studies as a method for characterizing sex-linked inheritance and for mapping genes to sex chromosomes in many species. Over 400 human traits and diseases seem to be encoded by genes on the X chromosome, and over 200 genes have been mapped. Among mammals, genes on the X chromosome are highly conserved. Thus, identifying a sex-linked trait in mice is strong evidence that a similar trait, and underlying gene, exists on the human X chromosome.

Sex chromosomes and sex-linked inheritance

Most animals and many plants show sexual dimorphism; in other words, an individual can be either male or female. In most of these cases, sex is determined by special sex chromosomes. In these organisms, there are two categories of chromosomes, ***sex chromosomes*** and ***autosomes*** (the chromosomes other than the sex chromosomes). The rules of inheritance considered so far, with the use of Mendel's analysis as an example, are the rules of autosomes. Most of the chromosomes in a genome are autosomes. The sex chromosomes are fewer in number, and, generally in diploid organisms, there is just one pair.

Let us look at the human situation as an example. Human body cells have 46 chromosomes: 22 homologous pairs of autosomes plus 2 sex chromosomes. In females, there is a pair of identical sex chromosomes called the X chromosomes. In males, there is a nonidentical pair, consisting of one X and one Y. The Y chromosome is considerably shorter than the X. At meiosis in females, the two X chromosomes pair and segregate like autosomes so that each egg receives one X chromosome. Hence the female is said to be the homogametic sex. At meiosis in males, the X and the Y pair over a short region, which ensures that the X and Y separate so that half the sperm cells receive X and the other half receive Y. Therefore the male is called the heterogametic sex.

The fruit fly *Drosophila melanogaster* has been one of the most important research organisms in genetics; its short, simple life cycle contributes to its usefulness in this regard. Fruit flies also have XX females and XY males. However, the mechanism of sex determination in *Drosophila* differs from that in mammals. In *Drosophila*, the number of X chromosomes determines sex: two X's result in a female and one X results in a male. In mammals, the presence of the Y determines maleness and the absence of a Y determines femaleness. This difference is demonstrated by the sexes of the abnormal chromosome types XXY and XO, as shown in Table below.

Chromosomal Determination of Sex in Drosophila and Humans

	Sex chromosomes			
Species	**XX**	**XY**	**XXY**	**XO**
Drosophila	♀	♂	♀	♂
Human	♀	♂	♂	♀

Vascular plants show a variety of sexual arrangements. ***Dioecious*** species are the ones showing animal-like sexual dimorphism, with female plants bearing flowers containing only ovaries and male plants bearing flowers containing only anthers. Some, but not all, dioecious plants have a non-identical pair of chromosomes associated with (and almost certainly determining) the sex of the plant. Of the species with nonidentical sex chromosomes, a large proportion has an XY system. For example, the dioecious plant *Melandrium album* has 22 chromosomes per cell: 20 autosomes plus 2 sex chromosomes, with XX females and XY males. Other dioecious plants have no visibly different pair of chromosomes; they may still have sex chromosomes but not visibly distinguishable types.

Cytogeneticists have divided the X and Y chromosomes of some species into homologous and nonhomologous regions. The latter are called *differential* regions. These differential regions contain genes that have no counterparts on the other sex chromosome. Genes in the differential regions are said to be hemizygous (“half zygous”) in males. Genes in the differential region of the X show an inheritance pattern called X linkage; those in the differential region of the Y show Y linkage. Genes in the homologous region show what might be called X-and-Y linkage. In general, genes on sex chromosomes are said to show sex linkage.
Differential and pairing regions of sex chromosomes of humans and of the plant *Melandrium album.* The regions were located by observing where the chromosomes paired up in meiosis and where they did not.

The genes on the differential regions of the sex chromosomes show patterns of inheritance related to sex. The inheritance patterns of genes on the autosomes produce male and female progeny in the same phenotypic proportions, as typified by Mendel’s data (for example, both sexes might show a 3:1 ratio). However, crosses following the inheritance of genes on the sex chromosomes often show male and female progeny with different phenotypic ratios. In fact, for studies of genes of unknown chromosomal location, this pattern is a diagnostic of location on the sex chromosomes. Let’s look at an example from *Drosophila.* The wild-type eye color of *Drosophila* is dull red, but pure lines with white eyes are available. This phenotypic difference is determined by two alleles of a gene located on the differential region of the X chromosome. When white-eyed males are crossed with red-eyed females, all the F_1 progeny have red eyes, showing that the allele for white is recessive. Crossing the red-eyed F_1 males and females produces a 3:1 F_2 ratio of red-eyed to white-eyed flies, but all the white-eyed flies are males. This inheritance pattern is explained by the alleles being located on the differential region of the X chromosome; in other words, by X-linkage. The reciprocal cross gives a different result. A reciprocal cross between white-eyed females and red-eyed males gives an F_1 in which all the females are red eyed, but all the males are white eyed. The F_2 consists of one-half red-eyed and one-half white-eyed flies of both sexes. Hence in sex linkage, we see examples not only of different ratios in different sexes, but also of differences between reciprocal crosses.

In *Drosophila,* eye color has nothing to do with sex determination, so we see that genes on the sex chromosomes are not necessarily related to sexual function. The same is true in humans, for whom pedigree analysis has revealed many X-linked genes, of which few could be construed as being connected to sexual function.

8.5 SUMMARY

The nature of the genetic basis of sex determination varies a great deal among the various forms of life. Most sexually reproducing species produce two different kinds of gametes. The relatively large and sessile form, an ovum or egg, usually accumulates nutriments in its cytoplasm for the early development of the offspring. The relatively mobile form, a sperm (or pollen grain in many plants), contributes little beyond a haploid chromosome set. Thus the primary form of sex differentiation determines which kind of gamete will be produced. The formation of gametes usually involves the concomitant differentiation of specialized organs, the gonads, to produce each kind of gamete. The ova-producing gonad is usually known as an archegonium or ovary (in flowering plants it is part of a larger organ, the pistil or carpel); the gonad producing the more mobile gametes is usually known as a testis in animals and an antheridium or stamen in plants. n most animals and many plants, individuals become specialized to produce only one kind of gamete. These individuals usually differ not only in which kind of gonad they possess but also in a number of other morphological and physiological differences, or secondary sex characteristics. The latter may define a phenotypic sex when present, even if the typical gonad for that sex is absent or nonfunctional. The form that usually produces ova is known as female; the one that usually produces sperm or pollen is known as male. Since some sexual processes do not involve gametes, the more universal application of the term “gender” refers to any donor of genetic material as male and the recipient as female. Sex differentiations are often accompanied by consistent chromosomal dimorphisms, leading to the presumption that the chromosomal differences are related to, and possibly responsible for, the sex differences. Indeed, the chromosomes that are not alike in the two sexes were given the name sex chromosomes. Some workers use the term “heterosomes” to distinguish them from the autosomes, which are the chromosomes that are morphologically identical in the two sexes. In most species, one of the sex chromosomes, the X chromosome, normally occurs as a pair in one gender but only singly in the other. The gender with two X chromosomes is known as the homogametic sex, because each of its gametes normally receives an X chromosome after meiosis. The gender with only one X chromosome generally also has a morphologically different sex chromosome, the Y chromosome. The X and Y chromosomes usually pair to some extent at meiosis, with the result that the XY is the heterogametic sex, with half its gametes containing an X and half containing a Y. Geneticists noted that the fundamental dimorphism of X and Y chromosomes lies in their genic contents: X chromosomes of the species share homologous loci, just as do pairs of autosomes, whereas the Y chromosome usually has few, if any, loci that are also represented on the X. Thus X and Y chromosomes are sometimes very similar in shape or size but are almost always very different in genetic materials.

The inheritance of a trait (phenotype) that is determined by a gene located on one of the sex chromosomes. Genetic studies of many species have been facilitated by focusing on such traits because of their characteristic patterns of familial transmission and the ability to localize their genes to a specific chromosome. As the ability to map a gene to any of an organism’s chromosomes has improved markedly, reliance on the specific pattern of inheritance has waned. The expectations of sex-linked inheritance in any species depend on how the chromosomes determine sex. For example, in humans, males are heterogametic, having one X chromosome and one Y chromosome, whereas females are homogametic, having two X chromosomes. In human males, the entire X chromosome is active (not all genes are active in every cell), whereas one of a female's X chromosomes is largely inactive. Random inactivation of one X chromosome occurs during the early stages of female embryogenesis, and every cell that descends from a particular embryonic cell has the same X chromosome inactivated. The result is dosage compensation for X-linked genes between the sexes. A specific gene on the long arm of the X chromosome, called XIST at band q13, is a strong candidate for the gene that controls X inactivation. This pattern of sex determination occurs in most vertebrates, but in birds and many insects and fish the male is the homogametic sex. In general terms, traits determined by genes on sex chromosomes are not different from traits determined by autosomal genes. Sex-linked traits are distinguishable by their mode of transmission through successive generations of a family. In humans it is preferable to speak in terms of X-linked or Y-linked inheritance. Refined cytogenetic and molecular techniques have supplemented family studies as a method for characterizing sex-linked inheritance and for mapping genes to sex chromosomes in many species. Over 400 human traits and diseases seem to be encoded by genes on the X chromosome, and over 200 genes have been mapped. Among mammals, genes on the X chromosome are highly conserved. Thus, identifying a sex-linked trait in mice is strong evidence that a similar trait, and underlying gene, exists on the human X chromosome.

8.6 GLOSSARY

Sex chromosome: A sex chromosome is a type of chromosome that participates in sex determination.

Sex-linked gene: A gene located on a sex chromosome, usually the X-chromosome**.**

Sex-linked trait: A trait associated with a **gene** that is carried only by the male or female parent.

Sex-linked inheritance: Pattern of inheritance that may result from a mutant gene located on either X or Y chromosomes.

Sex determination: The change in the fetus to a male or female configuration; the process by which the sex of an organism is fixed, associated, in animals, with the presence or absence of the Y chromosome.

Sex-linkage: Includes X-linked (much the most common) and Y-linked loci.

8.7 SELF ASSESSMENT QUESTIONS

8.7.1 Fill in the blanks:

1-A gamete without any sex chromosome is called--------- gamete.

2- ---------------- pattern of sex determination is found in Drosophila, man and many other organisms.
3- -------- type of sex-determination pattern is common in birds, butterflies and moths.
4-Presence of --------------- gene on Y chromosome is essential for starting the development of maleness in humans.
5- XXY set of chromosomes in Drosophila produces a---------- female.

8.7.2 Multiple choice questions:

1- **Sex chromosomes were discovered by-**
(a) Carl Correns (b) Nettie Stevens
(c) Morgan (d) Mendel

2- Sex-linked genetically inherited traits-
(a) Can appear in both males and females
(b) Are only found in males
(c) Are only found in females
(d) Result from premarital sexual relationships

3- Y-linked traits are inherited:
(a) Only by females (b) Only by males
(c) By both males and females (d) None of these

4- Harmful X-linked traits are:
(a) Inherited only from mothers
(b) More numerous than Y-linked ones
(c) Most likely to show up in the phenotype of daughters
(d) Most likely to show up in the phenotype of sons

5- What would be the sex of an XXY individual?
(a) Male (b) Female
(c) Hermaphrodite (d) Mosaic

6- Men with red-green color blindness inherited the genes for it from-
(a) Their mothers (b) Their fathers
(c) Either their mothers or fathers (d) Their grandmother

7- On which on the following chromosomes are sex-linked traits carried?
(a) 13 (b) Y
(c) 18 (d) X

8- The genotype of an individual with Turner syndrome is-
(a) XO (b) YO
(c) XXX (d) XXY

8.7.1 Answer Keys: 1. Nullo; 2. XX-XY; 3. ZZ-ZW; 4. SRY; 5. sterile
8.7.2 Answer Key: 1-(b), 2-(a), 3-(b), 4-(b), 5-(a), 6-(a), 7-(d), 8-(a)

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8.10 TERMINAL QUESTIONS

1. What is sex linked inheritance? Discuss its different types.
2. Discuss sex linkage in *Drosophila*.
3. Discuss genetics of colour blindness in man.
4. Discuss different pattern of sex determination.
5. Describe ZZ-ZW system of sex determination.
6. Write note on sex-limited traits.

BLOCK-3 PLANT BREEDING

UNIT-9 AIMS, OBJECTIVES AND BASIC TECHNIQUE OF PLANT BREEDING

9.1 OBJECTIVES

After reading this unit you will be able to know:

- Aim of plant breeding
- Objectives of plant breeding
- Techniques of plant breeding

9.2 INTRODUCTION

Plant breeding can be defined as a science as well as an art of improving the genetic makeup of plants in relation to their economic use. Recently plant breeding has been described as a technology of developing superior crop plants for various purposes.

> *"Plant breeding is the art and science of improving the heredity of plants for the benefit of mankind."*
> *"Plant breeding deals with the genetic improvement of crop plants also known as science of crop improvement*."
> *"Science of changing and improving the heredity of plants."*

9.3 AIM OF PLANT BREEDING

Plant breeding aims to improve the characteristics of plants so that they become more desirable agronomically and economically. The specific objectives may vary greatly depending on the crop under consideration.

History of plant breeding

Plant breeding started with sedentary agriculture and particularly the domestication of the first agricultural plants, a practice which is estimated to date back 9,000 to 11,000 years. Initially early farmers simply selected food plants with particular desirable characteristics, and employed these as progenitors for subsequent generations, resulting in an accumulation of valuable traits over time.

Gregor Mendel's experiments with plant hybridization led to his establishing law of inheritance. Once this work become well known, it formed the basis of the new science of genetics, which stimulated research by many plant scientists dedicated to improving crop production through plant breeding.

Modern plant breeding is applied genetics, but its scientific basis is broader, covering molecular biology, cytology, systematics, physiology, pathology, entomology, chemistry, and statistics (biometrics). It has also developed its own technology.

Some Indian Plant Breeders and their contributions

T.S. Venkatraman - An eminent sugarcane breeder, he transferred thick stem and high sugar contents from tropical noble cane to North Indian Canes. This process is known as noblization of sugarcane.

B.P. Pal - An eminent Wheat breeder, developed superior disease resistant N.P. varieties of wheat.

M.S. Swaminathan - Responsible for green revolution in India, developed high yielding varieties of Wheat and Rice.

Pushkarnath - Famous potato breeder.

N.G.P. Rao - An eminent sorghum breeder.

K. Ramaiah - A renowned rice breeder.

Ram Dhan Singh - Famous wheat breeder.

D.S. Athwal - Famous pearlmillet breeder.

Bosisen - An eminent maize breeder.

Dharampal Singh - An eminent oil-seed breeder.

C.T. Patel - Famous cotton breeder who developed world's first cotton hybrid in 1970.

V. Santhanam - Famous cotton breeder.

Steps of Plant Breeding

The following are the major activities of plant breeding:

1. Collection of variation
2. Selection
3. Evaluation
4. Release
5. Multiplication
6. Distribution of the new variety

9.4 OBJECTIVES OF PLANT BREEDING

1. Higher yield: The ultimate aim of plant breeding is to improve the yield of "*economic produce on economic part"***.** It may be grain yield, fodder yield, tuber yield, cane yield or oil yield depending upon the crop species.

2. Improved quality: The quality characters vary from crop to crop. e.g. grain size, colour, milling quality in barley, colour and size of fruits, nutritive and keeping quality in vegetables, protein content in pulses, oil content in oilseeds, fibre length, strength and fineness in cotton. The production of improved quality of crop plants, like: rice, barley, wheat, etc.

3. Abiotic resistance: Crop plants also suffer from abiotic factors such as drought, soil salinity, extreme temperatures, heat, wind, cold and frost, breeder has to develop resistant varieties for such environmental conditions.

4. Biotic resistance: Crop plants are attacked by various diseases and insects, resulting in considerable yield losses. Genetic resistance is the cheapest and the best method of minimizing such losses.

5. Change in maturity Duration/ Earliness: Earliness is the most desirable character which has several advantages. It requires less crop management period, less insecticidal sprays, permits new crop rotations and often extends the crop area. Maturity has been reduced from 270 days to 170 days in cotton, from 270 days to 120 days in pigeon pea, from 360 days to 270 days in sugarcane.

6. Dormancy: In some crops, seeds germinate even before harvesting in the standing crop if there are rains at the time of maturity, e.g., green gram, black gram, barley and Pea, etc. A period of dormancy has to be introduced in these crops to check loss due to germination. In some other cases, however, it may be desirable to remove dormancy.

7. Desirable Agronomic Characteristics: It includes plant height, branching, tillering capacity, growth habit, erect or trailing habit etc., is often desirable. For.eg. dwarfness in cereals is generally associated with lodging resistance and better fertilizer response. Tallness, high tillering and profuse branching are desirable characters in fodder crops.

8. Elimination of Toxic Substances: It is essential to develop varieties free from toxic compounds in some crops to make them safe for human consumption. For example, removal of neurotoxin in khesari-lentil (*Lathyruys sativus*) which leads to paralysis of lower limbs, erucic acid from *Brassica* which is harmful for human health, and gossypol from the seed of cotton is necessary to make them fit for human consumption. Removal of such toxic substances would increase the nutritional value of these crops.

9. Photo and Thermo insensitivity: Development of varities insensitive to light and temperature helps in crossing the cultivation boundaries of crop plants. Photo and thermo-insensitive varities of wheat and rice has permitted their cultivation in new 7 areas. Rice is now cultivated in Punjab, while wheat is a major *rabi* crop in West Bengal.

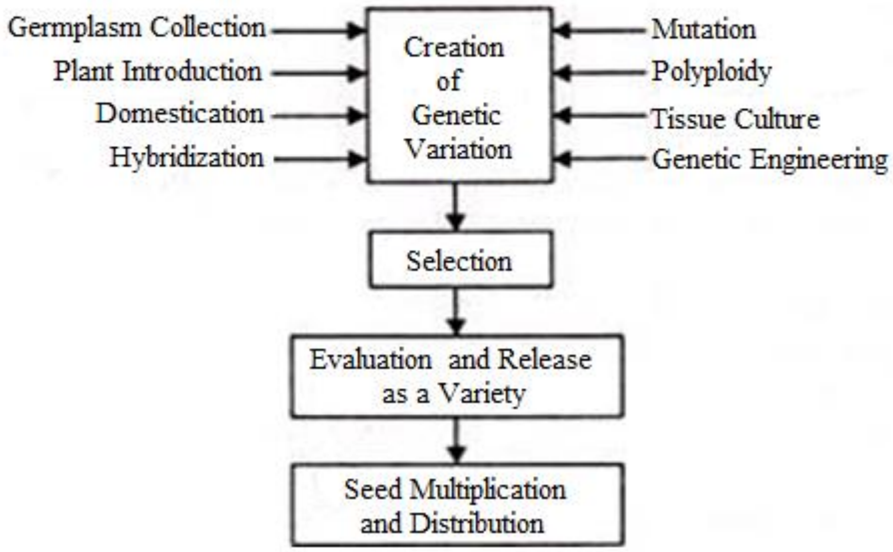
10. Wider adaptability: Adaptability refers to suitability of a variety for general cultivation over a wide range of environment conditions. Adaptability is an important objective in plant breeding because it helps in stabilizing the crop production over regions and seasons.

9.5 BASICS TECHNIQUES OF PLANT BREEDING

The various methods of breeding used for crop improvement are as follows:-

1. Domestication
2. Plant introduction
3. Hybridization
4. Polyploidy breeding
5. Mutation breeding
6. Tissue culture technique
7. Genetic engineering

1. Domestication: Domestication is the process of growing plants and keeping animals under human care and management. This is the very first step aimed at increasing food production. Domestication of plants is an artificial selection process conducted by humans to produce plants that have more desirable traits than wild plants, and which renders them dependent on artificial environments for their continued existence. The domestication of wheat provides an example of how natural selection and mutation can play a key role in the process. A large number of agricultural, horticultural and medicinal plants have been domesticated by humans since the beginning of civilization. Crop plants include a long list of food, vegetables, oilseeds, pulses, fodders, fibre and sugar yielding crops.



2- Plant Introduction

(a) It is the process of introducing plants or germplasms either from a foreign country or introducing plants or germplasm from one region to other regions of the same country.

(b) Plant introduction is followed by *acclimatisation*, i.e., the adaptation of an individual plant or a population of plants, under the changed climate. It is an ancient method of crop improvement.

(c) Introduction of plants from a foreign country is called *intercontinental* plant introduction**.**
For example:

(i) Groundnut has been introduced in India from Brazil,
(ii) Rubber has been introduced from South and Central America to India,
(iii) Mexican wheat varieties have been introduced from Mexico to India.

(d) Examples of introduced ornamental plants are innumerable, such as Jacaranda, Bougainvillea, Salvia, Cosmos, Dianthus, Antirrhinum etc.

(e) Introduction of plants from one state of a country to another state of the same country is called interstate plant introduction. For example, N.P. wheat varieties were introduced from Delhi to different states of India.

(f) Purposes of Plant Introduction
(i) For use in agriculture, forestry and industry.
(ii) For genetically improvement of economical crops.
(iii) For studying the origin, distribution, classification and evolution of the plants.

(g) Plant Introduction in India: Following agencies carry out plant introduction in India:
(i) Plant Introduction Division of IARI, New. Delhi,
(ii) Forest Research Institute, Dehradun.
(iii) Botanical Survey of India.
(iv) Some universities, gardens and agricultural departments also play an important role in introducing plants.

Types of plant introduction:

1. **Primary introduction:** Introduction that can be used for commercial cultivation as a variety without any change in the original genotype is referred to as primary introduction. Example- Sonora 64, Lerma Roja. It is also called as direct introduction.
2. **Secondary introduction:** Introduction that can be used as a variety after selection from the original genotype or used for transfer of some desirable gene to the cultivated variety is known as secondary introduction. Example- Kalyan Sona and Sonalika. It is also called as indirect introduction.

Disadvantages of Plant Introduction: Along with economically important plants, introduction of harmful crop diseases, insect pests and weeds also occurs sometimes.

(a) Diseases Introduced
(i) Late blight of potato (*Phytophthora infestans*)
(ii) Fire blight of apple and pear *(Erwinia amylovora*)

(b) Insect Pests Introduced:
(i) Potato tuber moth
(ii) Woolly aphis

(c)Weeds Introduced:
(i) *Argemone mexicana*, Lantana.
All introductions are subjected to quarantine, i.e., they are examined for the presence of insects, weeds and disease-causing organisms, and only those introductions that are free from the above are allowed to enter a country.

3. Hybridization

Hybridization may be defined as *"The mating or crossing of two plants or lines of dissimilar genotype."* The chief objective of hybridization is to create genetic variation. When two genotypically different plants are crossed, the genes from both the parents are brought together in F1 generation.
Segregation and recombination produce many new gene combinations in F2 and the later generations, i.e., segregating generations. The degree of variation produced in the segregating generations would, therefore, depend on the number of heterozygous genes in the F1. This will, in turn, depend upon the number of genes for which the two parents differ.
If the two parents are closely related, they are likely to differ for a few genes only. But if they are not related, or are only distantly related, they may differ for several, even a few hundred genes. However, it is most unlikely that the two parents will ever differ for all the genes. Therefore, when it is said that the F1 is 100 percent heterozygous, it has reference only to those genes for which two parents differ. The aim of hybridization may be transfer of one or few qualitative characters, improvement of one or more quantitative characters, or use of the F1 as a hybrid variety.

Technique of Hybridization: Before performing hybridisation, a plant breeder should have all the information about the time of flowering, the time when the anther and. stigma are ready for pollination, how long do the pollen grains remain viable, etc.

The actual technique consists of the following steps:

(i) The first step is the selection of parents from the available material possessing desired characters.
(ii) Second step is the selfing of plants to obtain homozygosity in desired characters. This step is not practiced in self pollinated crops because they are already homozygous.
(iii) Third step is emasculation. In this, the anthers are removed before they mature and have shed their pollens. Purpose of emasculation is to prevent self-pollination. It is not practiced in unisexual crops.
(iv) Bagging, tagging and labeling of males as well as females to be used in crosses, is done.
(v) Fifth step is the crossing, in which the pollen from bagged males are dusted on to the bagged female plant.

(vi) Lastly, seeds are collected from the crossed plants after maturity. Seeds are maintained separately and sown in the coming season to raise F generation.

Hybridization in Self-Pollinated Crops: Several methods, like pedigree method, bulk method and back-cross method are in practice.

(a) Pedigree Method: In this method, F1 hybrids possessing desirable characters are selected. The seeds from each plant are collected and grown separately to raise F2 generation. This process is repeated for a number of generations. Finally, the plants with desired characters are recommended for cultivation.

(b) Bulk Method: In this method, F1 hybrids rather than being grown separately are grown in bulk. Seeds, from F2 plants are also sown together and the process continued for 5-6 generations till homozygosity is obtained.

(c) Back-cross Method: F1 hybrids, in this method, are crossed by one of the above mentioned methods. This method is useful in the improvement of both self and cross-pollinated crops.

Hybridization in Cross-Pollinated Crops: Several methods like single cross, double cross, top cross and synthetic cross.

(a) Single Cross: It is a cross between two inbreeds. For example, A x B or C x D. The hybrids are distributed directly to farmers for cultivation.

(b) Double Cross: It is a cross between F1 hybrids of two different single crosses.

A × B → F_1 hybrid (AB)

C × D → F_1 hybrid (CD)

AB × CD → Double Cross hybrid (ABCD)

(c) Three-way Cross: It is a cross between F1 hybrid of a single cross and a third parent which is used as a male parent. For example,

Three Parents : A, B and C

A × B → F_1 (A × B) × C → [(A × B) C]

(d) Top Cross: It is a cross between an inbred and an open-pollinated variety.

Variety x Inbred

(e) Synthetic Cross: A number of inbreeds are crossed in order to combine different desirable characters into one variety.

Types of Hybridization: There are two types: (i) Inter-specific and (ii) Inter-generic.

(i) Inter-specific Hybridization: Here the plants of two different species belonging to the same genus are crossed together. It is also known as intra- generic hybridisation (within the same genus). All the disease, insect, drought and frost resistant varieties in wheat, tomato, sugarcane, etc., have been evolved by this method.

(a) Sugarcane: Two species of sugarcane are cultivated in India-*Saccharum officianarum* in Central and South India, while S. barberi is grown in northern India. Both these species are susceptible to red rot, lodging and drought.

Cultivated Species × Wild Species
↓
Hybrid

(50% characters of cultivated species, 50% characters of wild species)

It was found that the hybrid shows some bad features of wild species, like no sugar content. So bad characters have to be got rid of. For this, back crossing is carried out. In back crossing, hybrid is crossed with the cultivated species, which has the characters to more sugar content.

Hybrid (50% cultivated + 50% wild) × Cultivated Species (100% cultivated Hybrid)
↓
(75% cultivated + 25% wild)

So by continued backcrossing, canes with high sugar content have been obtained.

(b) Potato: *Solanum rybinii* is a wild diploid species of potato and is resistant to frost and virus infection. Another species *S. tuberosum* is cultivated and tetraploid species. The characters of wild species can be introduced into the cultivated one by hybridisation.

(ii) Inter-generic Hybridization: Crosses made between plants belonging to two different genera constitute inter- generic hybridisation.

(a) Cross between Sugarcane and Sorghum

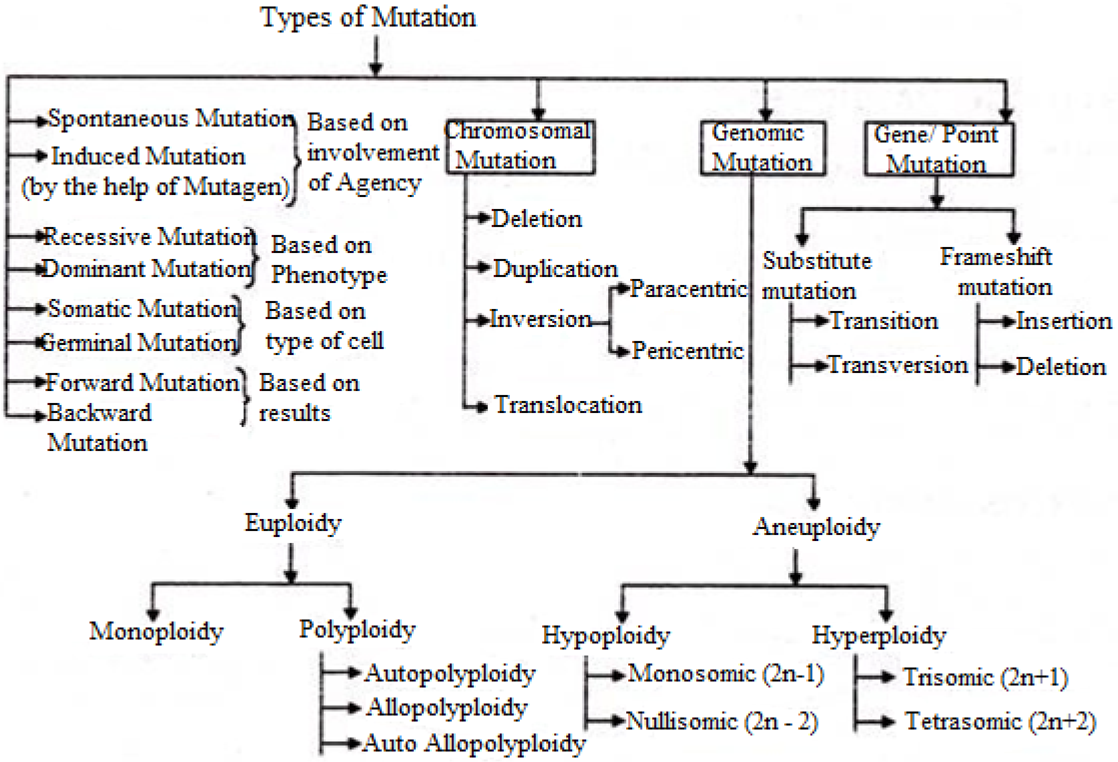
(b) Cross between Triticum and Secale: By crossing Triticum (wheat) with Secale, inter-generic hybrid Triticale has been evolved.

4. Mutation Breeding: "Mutation is a sudden and heritable change in a character of an organism."

1. A number of crop varieties have been developed through mutation breeding.
2. The first commercial success with induced mutations was reported in 1934 with the release of a new tobacco cultivar 'Chlorina' through X-ray irradiation. The Indian dwarf wheat's which contain the dwarfing gene was from a Japanese cultivar 'Norin- 10', which itself was a mutant.
3. Many varieties of barley contain artificially mutated genes which contribute to reduction in height, increase in yield, insensitivity to day length and resistance to mildew diseases. Sharbati Sonara and Pusa Lerma are two amber grain colour mutants of wheat produced from the red grained Sonara 64 and Lerma Rojo 64A, respectively. A mutant gene that induces semi-dwarfing in rice has been produced by X-ray treatment. Induced mutations have also become recently important in developing parents useful in hybridization programmes. Forty-five rice cultivars have been developed by the year 1982, either by direct radiation or by crossing with induced mutants.

4. Many crop plants are propagated vegetatively even though they can bear seed. Potato, tapioca and sugarcane are classical examples of such crops. In these, genetic improvement is carried out using sexual reproduction but the maintenance of the improved varieties is by cloning. For examples, potatoes are multiplied by tubers, apples by cuttings, and strawberries by runners.

5. Spontaneous mutations in somatic cells of a vegetatively propagated plant are commonly referred to as SPORTS. Such desirable sports occurring in well- adapted, asexually reproducing plants may result in quick improvements such as the colour sports in many apple varieties and superior shrub types in coffee plants.



6. The characters improved through mutation breeding include flowering time, flower shape, fruit shape, changes in oil content, and protein quality.

7. Some of the important limitations of the use of mutation breeding for crop improvement are:

(i) Most induced mutations are undesirable and have no value to the breeder. Many induced mutations are lethal.

(ii) The mutation rate is extremely low and a very large number of plants must be screened to identify the few individuals that may have desirable mutations. It is equally difficult to grow such useful mutants and include them in breeding programmes.

(iii) The stability of a mutant must be thoroughly tested as some mutants have a tendency to revert.

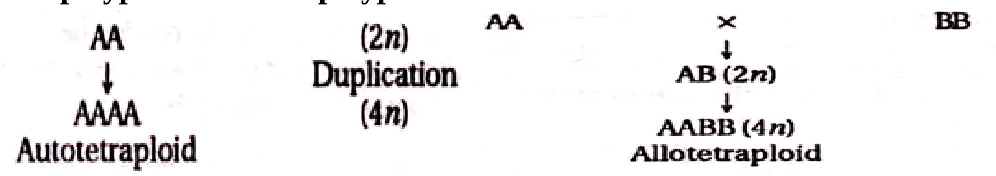
(iv) Most induced mutations are recessive; these have to be in double dose to be expressed phenotypically.

(v) Unless mutations are induced in gametes—especially in pollen—they will not be easily incorporated into the breeding line.

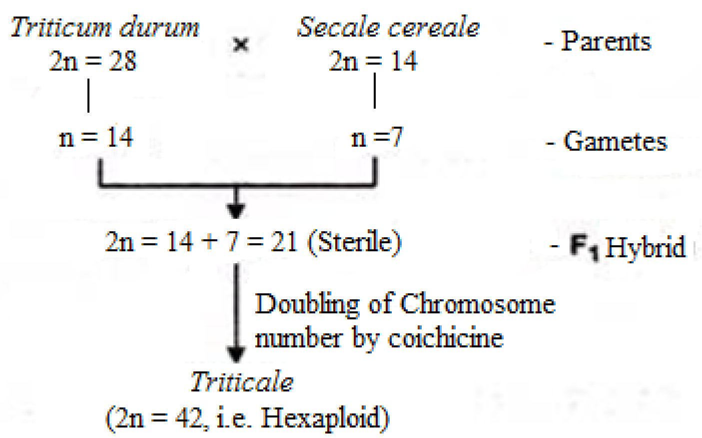
5. Polyploidy: Any organism in which the number of complete chromosome set is higher than the diploid number is called POLYPLOID and the phenomenon is known as polyploidy.

Characteristics of Polyploids: Polyploids are characterized by:
1. Leaves large, thick and deep green.
2. Increase in number of floral parts but poor flowering.
3. Formation of large pollen grains.
4. Fruits and seeds much larger.
5. Increase in cell size with more prominent nuclei.
6. Increase osmotic pressure of cell sap.
7. High conc. of Ca, Mg & K.

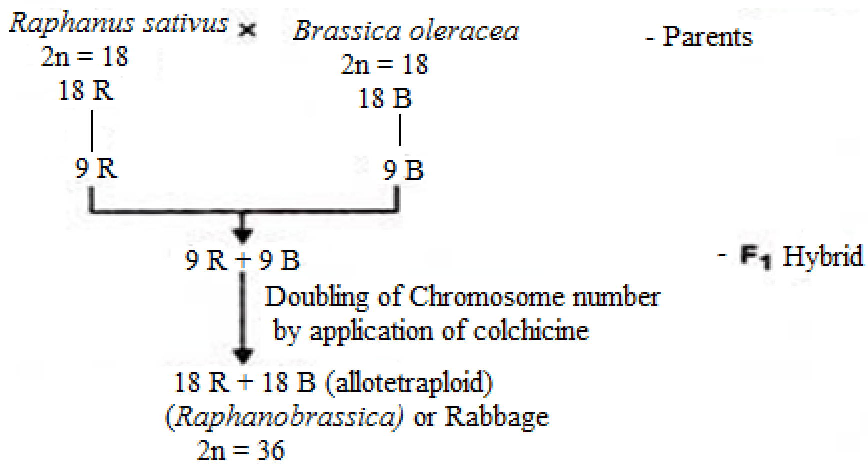
Types of Polyploids: There are two types of polyploids:
(i) **Euploids** are those forms in which the chromosome number has changed in such a way that an organism has an exact multiple of haploid number, such as triploids (3n), tetraploids (4n), pentaploids (5n), hexaploids (6n) and so on.
(ii**) Aneuploids or Heteroploids** are those forms in which the chromosome number has changed in such a way that an organism does not have an exact multiple of the haploid number. For example, 2n-1 (monosomics), 2n-2 (nullisomics), 2n+1 (trisomic), 2n+2 (tetrasomic), and likewise.
Euploidy has been used in plant breeding and improvement work. **Euploids are of two types: autopolyploids and allopolyploids.**



Induction of Polyploidy:
1. Polyploidy in plants can be induced by colchicine treatment.
2. Colchicine is an alkaloid obtained from the corms of Colchicum autumnale (Liliaceae).
3.Colchicine inhibits the formation of the spindle in the dividing cells and hence chromosomes do not separate at anaphase. Thus, a restitution nucleus (it is a nucleus in which the chromosomes have divided but could not separate into two daughter nuclei) is formed. Effect of colchicine is temporary. As a cell recovers from treatment, a new spindle is formed and the restitution nucleus undergoes normal mitosis as a polyploidy cell.
Origin of Triticale: It is a man-made cereal, an allopolyploid between Triticum (wheat) and Secale (rye). The released varieties of Triticale are hexaploid (2n = 42) and have been synthesized by doubling the chromosome complements of sterile hybrids between *T. turgidum* (durum wheat, 2n = 28) and S. cereale (rye, 2n = 14).



Origin of a new genus, allotetraploid: *Raphano brassica* (2n = 36) from diploid parents, viz, *Raphanus sativus* (2n = 18) and *Brassica oleracia* (2n = 18).



6. Selection: Selection is one of the oldest methods for crop improvement. It can be natural or artificial and is possible only if there exist variation in the crop.

(A) Natural Selection acts as a sieve in favour of the well adapted strains and varieties. Natural selection is a rule in nature and has resulted in evolution, according to which only the fittest can survive. All local varieties of crops are the result of natural selection. Many differences between species and sub-species have arisen due to this selection pressure. It is always operating in nature and is one of the natural factors which create variations in the already existing varieties of crops.

(B) Artificial selection involves picking out of the plants having desired combination of characters from a mixed population where the individuals differ in characters. The various methods of artificial selection are:

a. Mass Selection: It is practiced in those plants which are cross-pollinated like Zea, Brassica. In this method, plants are selected based on the phenotypic expression from the mixed population of a crop. Then, the seeds of these selected plants are obtained. All the seeds are mixed in a single lot and therefore, the method is known as mass selection. The seeds so obtained are used for raising the next crop. Again from these plants, selection is made as earlier. This process is continued till the plants show uniformity in the desired characters.

Merits:

(A) It is more of an art than a science because it needs no scientific knowledge.

(B) Simplest, easiest and quickest method of crop improvement.

(C) Pollination need not to be controlled to provide a new variety.

(D) To meet the need of the farmers, it is the only method for improving the local or wild varieties.

Demerits:

(A) Importance is given to phenotypic characters only.

(B) There is no control over pollination, which causes greater heterozygosity and as a result the desirable qualities gradually diminish.

(C) It is not possible to increase the yield because:

(a) Importance is given to material characters only.

(b) Environmental effects cannot be separated out.

(c) Pollination may be both by superior and inferior pollens.

(D) This method of crop improvement is not applicable to self-pollinated crops (due to less amount of heterozygosity).

(E) In cross pollinated crops variety produced is heterozygous i.e., mixture of different genotypes.

Procedure:

Step I. Seeds of desired plants with similar phenotypes (500-1000) are selected. harvested and thrashed together. **(I Year)**

Step II. Seeds selected in I year are grown in isolated plots compartments with standard varities as check for comparision. Best performers are selected and other are discarded **(II Year)**

Step III. Main yield trials are carried out to determine the performance and adaptation in comparison to standard varieties as check. **(III-V Year)**

Step IV. Trials on the selected seeds are conducted on the experimental forms of regional research stations or cultivators holding for three consecutive years to determine the adaptability of strains in different regions. In the eighth year variety is produced, named and distributed. **(VI-VIII Year)**

b. Pure Line Selection: It is practiced in self-pollinated crops such as wheat, barley, rice, legumes. Here also the selection is made on the basis of phenotypic expression. But the seeds of one plant are not mixed with the seeds of another. So, it involves testing the progeny of single individual plant separately. Selection is again made from the progenies arising from the seeds of a single individual. This method of selection from a single individual is continued till a true breeding type is obtained.

Merits:

1. This is the only method to improve the local varieties of self-pollinated crops. Best genotype for yield, disease resistance, insect resistance, earliness, quality etc. can be isolated from a heterogeneous or mixed population of an old variety.
2. This method is easier than hybridization (emasculation and crossing over)
3. The variety developed by this method is extremely in appearance and performance and, therefore, are more attractive.
4. This method is also used both in self and cross-pollinated crops for production of pure lines and inbreeds.

Demerits:

1. It is very lengthy and laborious process.
2. This method is applicable to self-pollinated crops. It cannot be used for development of varieties in cross-pollinated crops.
3. This method can isolate only superior genotypes from the mixed population. It cannot develop new genotypes.
4. Extremely homozygosity may result in low yield and other undesirable characters.
5. Due to high degree of homozygosity, variations among the varieties are also limited. Therefore, their adaptability to varied environmental condition is also poor.

Step I.	At the times of harvest large number of single plants (200-1000) are selected from the mixed population of ryot's field. Produce from individual plants are picked, separated and numbered.	**I Year**
Step II.	20 to 50 seeds of individual plants are grown in individual rows for observations. Defective rows (like susceptibility of diseases) are discarded and the superior, *i.e.*, the desired progenies of rows are harvested. Seeds from plants within each row are composited together and this composite produce of each row becomes an **experimental strain.**	**II Year**
Step III.	Preliminary yield trials are conducted by repeating step II. Desired progenies are selected on final visual observations and seeds are composited separately.	**III Year**
Step IV.	Selected plants of step III are tested in larger plots taking standard checks in replicated plots (These are main trials)	**IV to VI Year**
Step V.	Seeds selected in step IV are multiplied.	**VII Year**
Step VI.	Seed of superior strain is sent to progressive farmers in different regions for district yield trials on riot's field. On the basis of performance, one or two strains are selected, named, multiplied and distributed to the farmers for general cultivation in subsequent years.	**VIII to X Year**

Thus, a breeder by pure line selection renders a particular type, more or less homozygous. Unlike mass selection, here the progeny consists of a uniform population. Pure line lacks variability.

c. Clonal Selection: This method is practiced in vegetatively propagated crops such as banana, potato, onion, citrus, etc. Clones are plants propagated vegetatively from a single individual. The genotypic constitution of plants propagated in this way is not likely to change.

Here in, superior clones are selected on the basis of their phenotypic characters. The selection is always between clones and never within a clone, as all the individuals of a clone have the same genetic constitution.

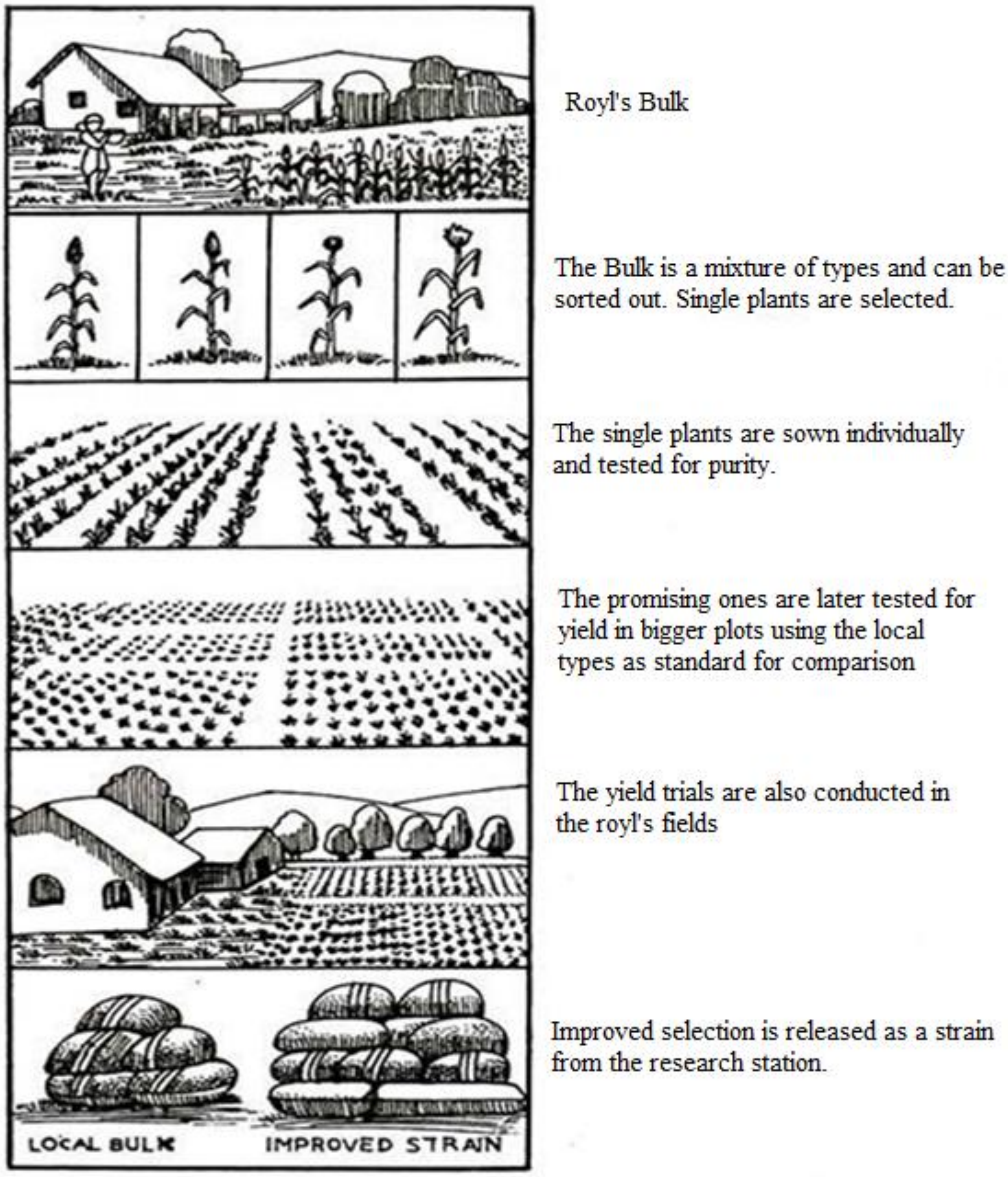


Fig.9.1 Diagram to illustrate the various steps involved in pure line selection

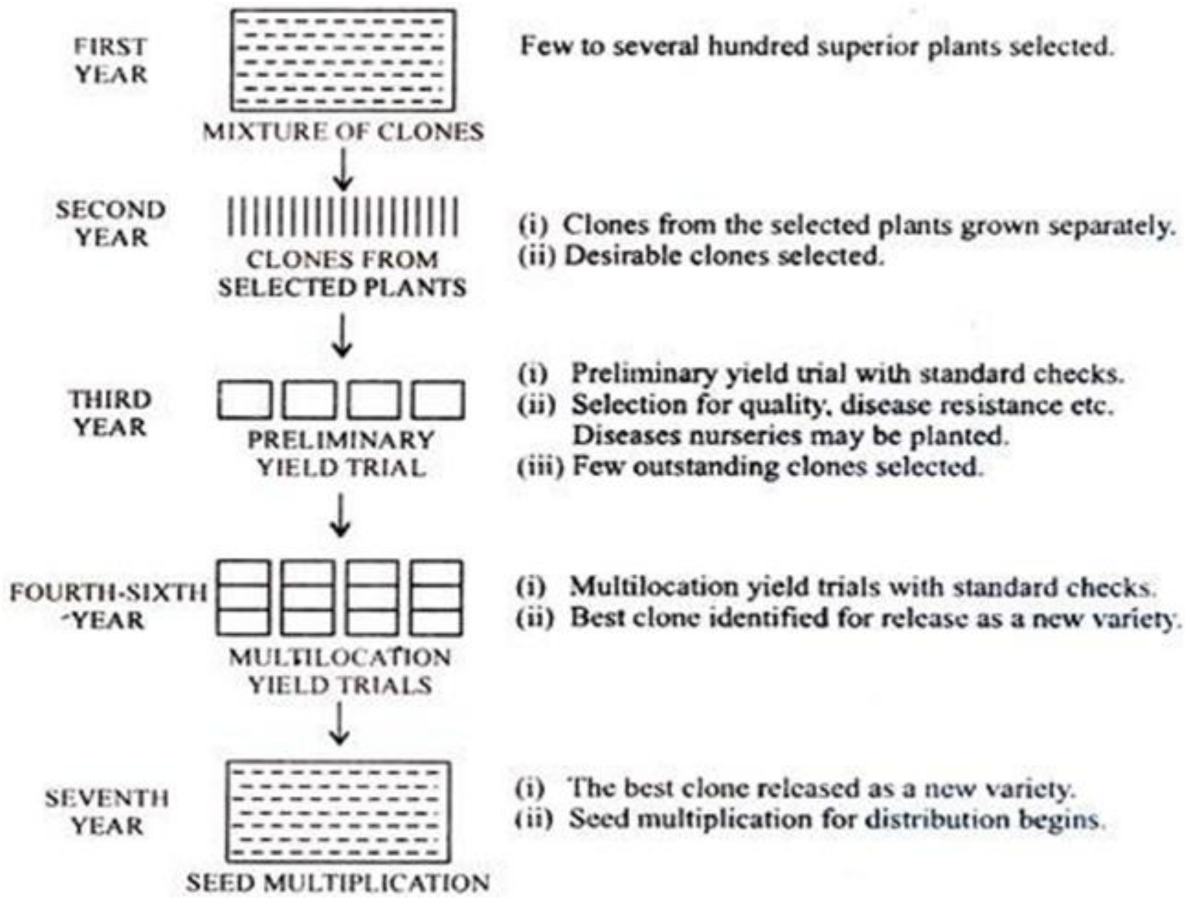


Fig.9.2 Procedure of clonal selection in asexually propagated crops. This method of selection applies to a crop in which one generation does not take more than one year.

Merits:

i. It is the only method to improve the clonal crops.
ii. It offers an opportunity to exploit desirable mutations in somatic parts of plants.
iii. It also helps to eliminate unproductive and undesirable types.
iv. This method is helpful in conserving hybrid vigour for several generations.
v. Varieties are as stable as pure lines and easy to maintain because there is no danger of deterioration due to segregation and recombination.

Demerits:

(i) In this method no new genetic variability can be created.
(ii) This method is applicable only to vegetatively propagated crops.

Achievements:

(i) New varieties of potato like Kufri red and Kufri safed; Pedda Nelum in mango- Pidi Monthan; Bombay green, high gate in Banana etc.

7. Plant Tissue Culture in Crop Improvement Programme: Lately, the tissue culture technology has played a very crucial role in crops improvement programme. Essentially the methodology of tissue culture consists of separating cells, tissues or organs of a plant and growing them aseptically in suitable containers on a nutrient medium under controlled conditions of temperature and light. The cultured parts (termed explants) require a source of energy (usually sucrose), salts, providing macro-and microelements, a few vitamins and generally the amino acid, glycine, in the nutrient medium. The amounts and the nature of salts used vary as there are several formulations developed by different scientists. Hormones and mixtures of substances such as yeast extract, coconut water, bean seed extract are included in the medium by some workers. An excised embryo or a shoot bud may develop into a whole plant. Pollinated ovaries have also been grown to mature fruits. Nevertheless, portions of organs or tissues generally give rise to an unorganized mass of cells called CALLUS.

In the early 1950’s Skoog and Miller showed that shoot or roots can be induced in the callus (organogenesis) by an appropriate balance of amounts of cytokinin and auxin in the medium. We now know that the type of growth response in tissue cultures depends on the source of the explants, composition of the medium and conditions in the culture room.

The following are the benefits of tissue culture in crop improvement:

1. Rapid multiplication of desired plants (Micro propagation)
2. Multiplication of rare plants which reproduce through seeds with great difficulty.
3. To rescue embryos which fail to reach maturity.
4. Multiplication of sterile hybrids.
5. Production of virus-free plants.
6. Protoplast fusion or somatic hybridization.
7. To shortern the period for development of new varieties of plants.
8. To induce weedicides resistance in plants.
9. Induction and selection of mutants.
10. Somoclonal variation and DNA recombinant technology.

There are a few other uses of plant tissue culture such as production of artificial seeds, and germplasm storage and exchange.

8. Genetic Engineering and Biotechnology in Plant Breeding:

“Genetic engineering is a term used for the directed manipulation of genes, i. e. The transfer of genes between organisms or changes in the sequence of a gene.”

The latest interest in crop improvement is not to involve whole genome (as in conventional plant breeding or in protoplast fusion). The objective of genetic engineering or recombinant DNA technology is to introduce one or more genes into an organism that normally does not possess them. This requires isolation of a fragment of DNA corresponding to a desirable character (or function), inserting it into a vector (such as the plasmid in a bacterium, *Agrobacterium tumifaciens*), and transferring it to a cell.

Genetic transformation is also possible through co-cultivation (incubating recipient protoplast with purified DNA), electroporation (by applying high electric potential for a few micro-seconds to change the porosity of protoplast to take up DNA) and by micro-injection of DNA into the cell by fine needles. Although the above account may sound simplistic and exciting, there are several obstacles in realizing the objectives.

Successful genetic engineering requires identification of the desired genes, their transfer to the cells of a target crop plant, their integration and expression. We know a good deal about genome organisation in a prokaryotic organism such as *E. Coli*. However, the genetic material of the eukaryotes is quite complex. Our present knowledge of the location and function of the specific genes in crop plants is so poor that genetic engineering is still very problematic. Each crop plant contains one to ten million genes. Detailed study of genome organisation is needed for major crops and their wild relatives.

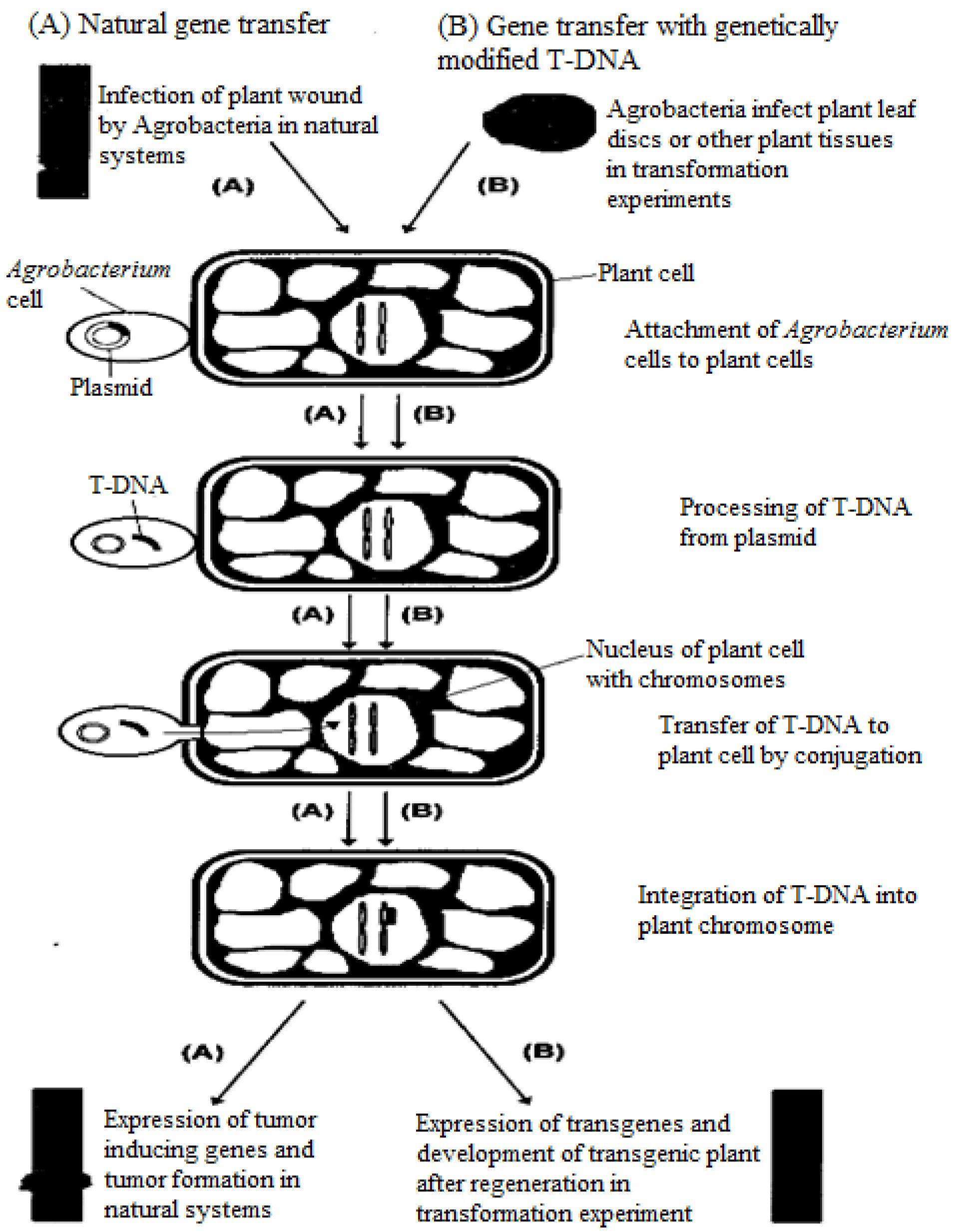


Fig. 9.3 (A) Natural gene transfer, (B) Gene transfer with genetically modified T-DNA

Gene transfer method: In the direct gene transfer methods, the foreign gene of interest is delivered into the host plant cell without the help of a vector. The following are some of the common methods of direct gene transfer in plants:

(a) Chemical mediated Gene transfer- Certain chemicals like polyethylene glycol (PEG) and dextran sulphate induce DNA uptake into plant protoplasts.
(b) Microinjection- Here the DNA is directly injected into plant protoplasts or cells using fine tipped glass needle or micropipette.
(c) Electroporation-In this case, a pulse of high voltage is applied for protoplasts/cells/tissues, which makes transient pores in the plasma membrane which facilitates the uptake of foreign DNA.
(d) Particle Gun- In this method, the foreign DNA is coated (precipitated) on to the surface of minute gold or tungsten particles (1-3 micrometer) and bombarded (shot) on to the target tissue or cells using a particle gun (also called as gene gun/shot gun/micro projectile gun).

Transgenic Breeding: Individuals which are developed through genetic engineering are called transgenic. A transgenic may be a plant, an animal or a microbe. Foreign genes present in a modified organism is called transgene. Transgenic plants contain transgenes. Using techniques of genetic engineering and biotechnology, useful genes can now be transferred into plants from a wide range of organisms including unrelated plant species, microbes, animals and from DNA synthesized in the laboratory. In the development of transgenic, sexual process is bypassed.

Transgenic plants have been developed in various field crops, such as wheat, barley, oat, maize sugarcane, rapeseed, soybean, peanut, cotton, tobacco, tomato, potato, sunflower etc. BT-cotton, a transgenic, is now successfully grown by farmers in India. BT-cotton is insect resistant and high yielding. Some of the most outstanding limitations of transgenic breeding are that polygenic characters cannot be manipulated, instable performance, low frequency and costly method of crop improvement. In-spite of many limitations and practical difficulties, genetic engineering offers immense possibilities for improving crops that were unthinkable before.

Improved Seed: The primary objective of plant breeding is to develop superior varieties of crops. The benefits from superior varieties can only be realized when they are grown commercially on a large scale. Seeds of improved varieties must be multiplied at a large scale in order to make them available to farmers for large scale cultivation. Here the word "seed" refers to seed or any other propagating material used for raising a crop. For example, grain produced for general consumption is not seed; only grain produced for raising a crop would be known as 'seed'.

On the other hand potato tubers produced for planting a new crop are known as seed potato. During multiplication of varieties for use as seed, it is essential that genetic purity of the variety must be maintained. If the genetic purity is not maintained, superiority of the variety is likely to be lost. In addition, for best results the farmer should use new pure seed every year in case of self-pollinated crops, and every year (hybrid varieties) or every few years (composite and synthetic varieties) in case of cross-pollinated crops. This would require maintenance of seeds of superior varieties in genetically pure state, which would be multiplied every year to supply new seed to the farmers.

The improved seed has four classes:
(1) Breeder seed
(2) Foundation seed
(3) Registered seed
(4) Certified seed
The seed produced by the breeder who developed the variety, or by the institution where the variety was developed is the breeder seed. Foundation seed is the progeny of the breeder seed and is used to produce registered seed or certified seed.
Certified seed is grown by various agencies and is certified for use as seed by the State Seed Certification Agency.

The requirements of good seed are:
(1) Genetic purity
(2) Physical purity
(3) Good germination
(4) Freedom from weed seeds
(5) Freedom from diseases, and
(6) An optimum moisture level
The minimum standards for certification vary to some extent from one crop to another. To ensure availability of pure seed of different crops to farmers, elaborate seed programmes (production and distribution) exist in most of the countries. Our country also has a well-organized seed production and distribution programme in the form of National Seeds Corporation (NSC), State Seeds Corporation (SSC) and State Seed Certification Agency (SSCA). These organizations are responsible for seed certification and its distribution.

9.5 SUMMARY

1. Plant breeding programs begin by selecting plants with superior characteristics.
2. In traditional breeding programs commercial cultivars are produced by a series of crossing and selections.
3. New cultivars can be produced by genetic engineering.
4. The commercial rights of plant breeders are protected by legislation.

9.6 GLOSSARY

Plant Breeding: A science, an art and a technology which deals with genetic improvement of crop plants in relation to their economic use for mankind, also called as crop improvement.
Breeding Techniques: Various breeding procedures which are used for genetic improvement of crop plants in relation to their economic use.
Domestication: The process of bringing wild plants under human management referred to as plant domestication.
Plant Introduction: Transposition of crop plants from the place of their cultivation to suchareas where they never grown.

Exotic Variety: A foreign variety which is directly recommended for cultivation.
Acclimatization: Adaptation of an introduced variety to the new environment.
Selection: The process that favours survival and further propagation of some plants having more desirable characters than others. It is of two types, *viz.*, natural and artificial.
Pureline Selection: Development of new variety through identification and isolation of a single best plant progeny.
Mass Selection: A method of crop improvement in which individual desirable plants are selected on the basis of phenotype from a mixed population, their seeds are bulked and used to grow the next generation (positive mass selection). Sometimes, only undesirable off type plants are removed from the field and rest are allowed to grow further (negative mass selection).
Clone: Progeny of a single plant obtained by asexual reproduction.
Clonal Selection: A procedure of selecting superior clones from the mixed population of asexually propagated crops such as sugarcane, potato etc.
Hybridization: Crossing between genetically dissimilar plants. It may involve two genotypes of the same species (intervarietal hybridization) or two species of the same genus (interspecific hybridization) or two genera of the same family (intergeneric hybridization).
Mutation: Sudden heritable change in the phenotype of an individual or permanent change in the number, kind and sequence of nucleotides in the genetic material.
Polyploidy: An organism or individual having more than two basic or monoploid sets of chromosomes is called polyploid and such condition is known as polyploidy.
Heteroploidy: Any changes in the chromosome number from the diploid state.
Euploidy: Numerical change in the entire genome.
Autopolyploids: Polyploids which originate by multiplication of chromosomes of a single species.
Allopolyploid: A polyploid individual which combines complete genomes from two or more species.
Interspecific Hybridization: Crossing between two different species of the same genus. Such crosses are called interspecific crosses.
Intergeneric Hybridization: Crossing between two different genera of the same family. Such crosses are called intergeneric crosses.
Biotechnology: A technology based on the knowledge of life process which is used for mass production of useful substance/products for industry, medicine and agriculture. Various branches of biotechnology are animal biotechnology, medical biotechnology, industrial biotechnology, environmental biotechnology and plant biotechnology.
Tissue culture: The growth of tissues of living organisms in a suitable culture medium (in vitro).
Explant: The plant part which is used for regeneration in culture medium.
Callus: A mass of unorganized regenerated cells in culture medium.
Somaclonal Variation: The variability generated by the use of tissue culture.
Genetic Engineering: Isolation, introduction and expression of foreign DNA in plants and animals.
Transgenic plants: Genetically engineered plants.

Protoplast: Naked cells without cell wall.
Transgenic Breeding: Genetic improvement of crop plants, domestic animals and useful micro - organisms through biotechnology.

9.7 SELF ASSESSMENT QUESTIONS

9.7.1 Very short type questions:

1. Which selection methods will be suitable for maintaining purity of a variety in a self pollinated crop?
2. Name two vegetatively grown crops where interspecific hybrids are used for Clonal Selection.
3. Triticale is which type of cross?
4. Name the method of rapid multiplication of desirable plants.
5. By which method genes are transferred into an organism?
6. Famous cotton breeder who developed world's first cotton hybrid in 1970.
7. Name the chemical, used to induce polyploidy.

9.7.2 Objective type questions:

1. Polyploidy is induced through
(a) Irradiation (b) Mutagenic chemicals
(c) Ethylene (d) Colchicine

2. The quickest method of plant breeding is
(a) introduction (b) Selection
(c) Hybridisation (d) Mutation Breeding

3. The new varieties of plants are produced by
(a) Introduction and mutation (b) Selection and hybridisation
(c) Mutation and Selection (d) Selection and Introduction

4. Pure line breed refers to
(a) heterozygosity only (b) homozygosity only
(c) homozygosity and self assortment (d) heterozygosity and linkage

5. Bagging is done to
(a) Aavoid cross pollination (b) Avoid self pollination
(c) Achieve desired pollination (d) Prevent contamination from foreign pollen

6. Which of the following is a cross pollinated crop
(a) Wheat (b) Rice
(c) Ground nut (d) Maize

9.7.3 Fill in the blanks:

1. ----------refers to unorganized mass of cells, which are generally parenchymatous in nature.
2. Triticale is a new variety of plant produced by cross breeding of ______________.
3. Commonly used technique in plant breeding is__________________.
4. No single plant progenies are grown during_______________.
5. _________refers to sudden heritable change in the phenotype of an individual.

9.7.4 True/False

1) Mass selection cannot be practiced in cross pollinated crops.
2) One of the disadvantages of all selection methods of plant breeding is that no variability can be introduced or generated due to recombination.
3) For transfer of a simple inherited trait, back cross method is normally used.
4) Hybrid varieties are never produced in self pollinated crops.
5) Explant is used for regeneration in culture medium.

9.7.1 Answer Key: **1.** Mass selection, **2.** Potato and sugarcane, **3.** Intergeneric, **4.** Micropropagation, **5.** Genetic Engineering, **6.** C.T. Patel, **7.** Colchicine

9.7.2 Answer Key: 1. (d), 2. (d), 3. (b), 4. (b), 5. (d), 6. (d)

9.7.3 Answer key: 1-callus, 2- Wheat plant and rye plant, 3- Hybridization, 4- Mass selection, 5- Mutation

9.7.4 Answer key: 1- False, 2- True, 3- True, 4- False, 5- True

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9.9 SUGGESTED READINGS

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- Cell Biology, Genetics and Plant Breeding by P.C.Trivedi
- Plant Breeding by Sandhu S.S.

9.10 TERMINAL QUESTIONS

9.10.1 Long Answer Type Questions

1. What is plant breeding? Describe briefly the various objective of Plant Breeding with suitable examples.

2. Discuss the various selection methods of plant breeding.

3. Write down the various steps involve in hybridization. What are the methods of hybridization in self-pollinated and cross-pollinated crops.

4. **a)** What do you understand by the plant introduction.
   b) What is the purpose of plant introduction.
   c) Agencies carry out plant introduction in India.
   d) Disadvantages of plant introduction.
5. Write on the following:
   a) Name of different techniques of plant breeding
   b) Steps of plant breeding
   c) Aim of plant breeding
   d) Domestication
   e) Callus
   f) Explant
   g) Transgenic
   h) Transgenes
   i) Transgenic breeding
   j) Examples of transgenic breeding.

9.10.2 Short Answer Type Questions

1. What is mutation breeding? What is its limitations for crop improvement?
2. What is polyploidy? Write its characteristics and types.
3. What is tissue culture? What are its advantages.
4. What is hybridization? Mention its different types.
5. What are direct gene transfer? What are the methods of direct gene transfer?
6. Give the contributions of the following scientists:
   a) T.S. Venkataraman
   b) B.P. Pal
   c) M.S. Swaminathan
   d) Gregor Mendel
   e) C.T. Patel.

UNIT-10 CROP IMPROVEMENT

10.1 OBJECTIVES

After reading this unit students will be able to:

- Study of plant breeding.
- Study of different breeding techniques.
- know Importance of different plant breeding methods.

10.2 INTRODUCTION

The main object of plant breeding is to produce the new and higher vigor, disease resistant crop varieties superior in all aspects as compared to the existing types. To achieve these objectives different crop methods are applied by plant breeders and agronomists. The process of plant breeding is assumed about 7,000 years ago with the beginning of human civilization. Domestication of wild species under human management is used as source of food. Since beginning the human beings used nomadic practices and it helped the movement of cultivated plant species. Various approaches viz. selection, hybridization, mutation etc. that are used for genetic improvement of crop plants are referred to as plant breeding methods or plant breeding procedures or plant breeding techniques. The choice of breeding methods mainly depends on the mode of pollination, mode of reproduction, gene action and breeding objectives of crop species.

Various breeding procedures that are more commonly used for the genetic improvement of various crop plants are known as general breeding methods. Such breeding methods include introduction (pureline selection, mass selection, progeny selection etc.), hybridization (pedigree, bulk and back cross methods), heterosis breeding, synthetic and composite breeding. Similarly, there are some other breeding methods, rarely used for improvement of crop plants are referred to as special breeding methods, including- mutation breeding, polyploidy breeding, wide crossing or distant hybridization and biotechnology.

10.3 CROP IMPROVEMENT METHODS

The main object of plant breeding is to produce the new and high vigor, disease resistant crop varieties superior in all aspects as compared to the existing types. To achieve these objects different crop improvement as below-

A. Selection
B. Hybridization
C. Plant Introduction and acclimatization, and
D. Mutation Breeding

All these methods have been dealt in this unit only in brief while a detailed account of each has been given in the text separately.

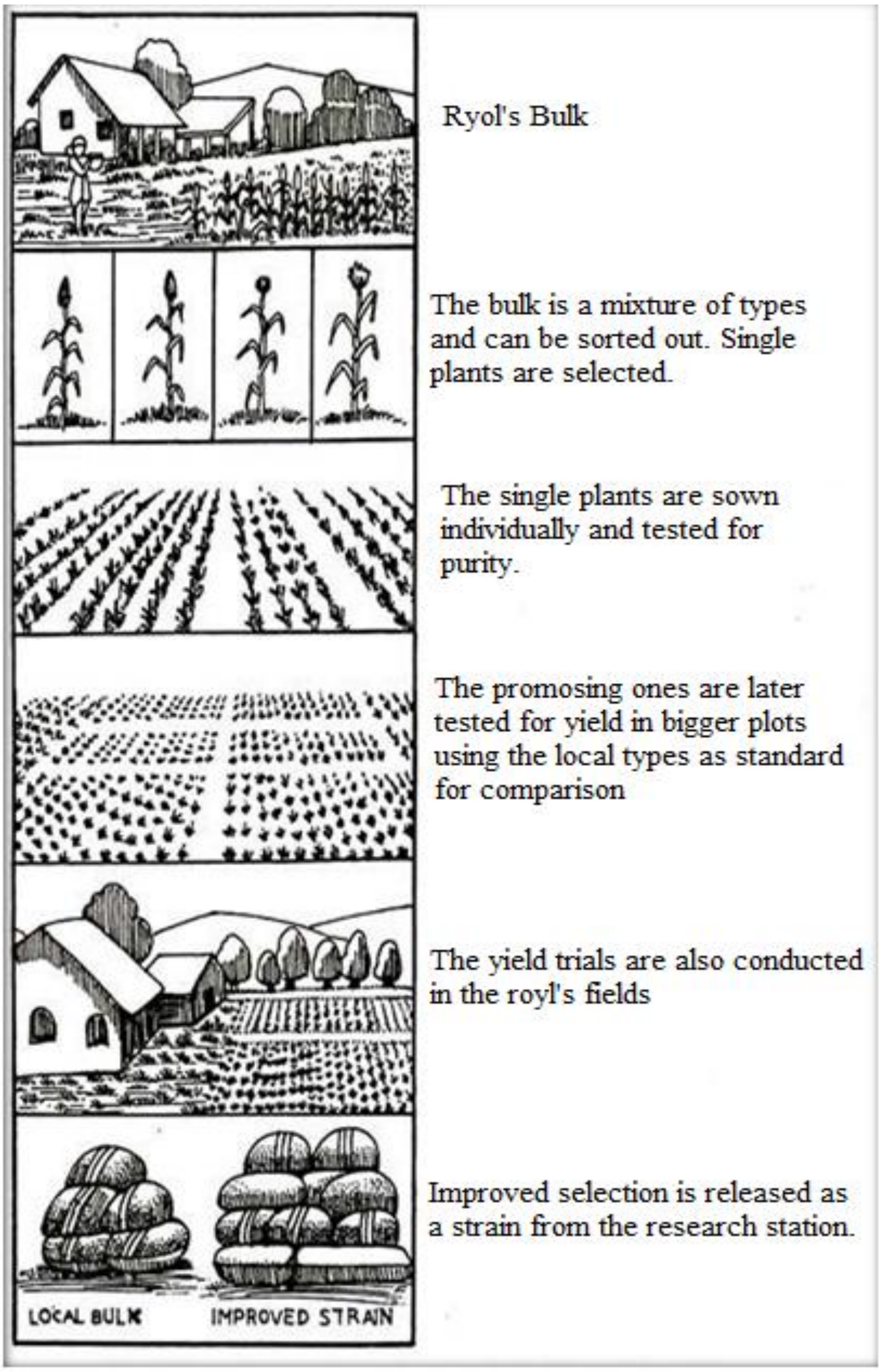


Fig.10.1 Schematic presentation of Crop Improvement Methods

A. Selection: Plant improvement is an ancient art or science started with the primitive man changing his mode of life from a nomad to agriculturists and might have the first crop from nature in wild form or he had never sown the seeds to ensure the first crop. So to obtain his first crop he unconsciously might have practiced the selection by selecting the best one. It is therefore, the oldest breeding method and is the basis of all crop improvements. It is the most common and popular method of crop improvement among the cultivators even today divided into two categories.

a. Natural selection and

b. Artificial selection

Fig.10.2 Presentation of different methods of plant breeding

a. Natural Selection: Natural selection as clear from its name that this selection is a rule in the nature that nature selects the best and fittest for future and discarded the inferior through evolution. According to natural law the fittest can survive and rest wipe out. This has given the cultivated crop and forms ecotypes in plants. Bases on climatic or regional specialties forms climatic or regional races are the basis of artificial selection and hybridization. Though this process local varieties of crops are produced. Sometimes many differences have arisen between species and sub- species due to selection pressure. It remains always operating in nature and is one of the natural factors resulted variations in the already existing varieties of crop in the nature. Besides natural selection, crop breeders and agriculturists also practiced artificial methods for selection and known as artificial selection.

b. Artificial Selection: The cultivators and plant breeders select special types of plants from the mixed population of crops for their own advantages. This type of selection is known as artificial selection and can be defined as “selection as to choose certain individual plants for the purpose of having better crop from a mixed population where the individuals differ in characters”.

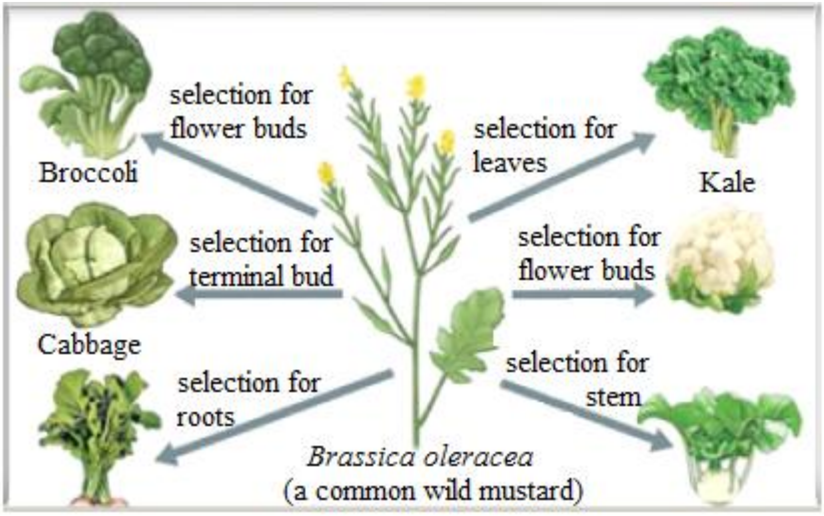


Fig. 10.3 Origin of different crops of Mustard family

Artificial selection is further categorized into two sub- divisions on the basis of nature of crop selection among a mixed population. It may be as below-

i. Mass selection

ii. Pure- line selection and

iii. Clonal selection.

In nature there is continuous selection by natural forces like temperature, soil, weather, pests, diseases**,** etc. The genotype which is more suited to a given environmental conditions leave behind others which are less adaptive in nature. The procedure selection involves the retention of superior phenotypic plants from mixed population. This can be done in different ways in different crops.

(i) Mass Selection: When a large number of plants of similar phenotypes are selected and their seeds are mixed together to constitute a new variety is called mass selection. The population obtained from the selected plants would be more uniform than the original or existing population. It is followed in both self- defective and cross- pollinated crops. Collecting and selecting the best, healthy and more vigorous plants or seeds from the mixed population of crop. All the selected plants are thrashed together and obtained a mixture of seeds. This mixture of seeds is a mass so, this method is known as mass selection. The mixture of seeds sown and raise a new crop. Again in the next year selection is made similarly by adopting the selection of best ones in the next year. This practice of selection is continued till the plants show uniformity in the desired characters and constitute a new variety. Mass selection cannot if the population is already uniform. Thus mass selection is based upon the presence of variability in the population. As a general rule it is known that greater the variability better are the results of selection. The new varieties developed by mass selection is more or less pure or similar in external features because the plants are selected on the basis of external or phenotypical characters which may be easily observed and used in identifications.

Thus by using this method a number of varieties had been obtained and some of the outstanding strains till recently were the products of this selection.

The purpose of mass selection in case of self- pollinated crops, mass selection procedure has following objectives-

a. Improvement of local varieties.
b. Purification of existing pureline varieties and
c. Production of new varieties from heterogenous local, land races.

Merits and Demerits:

1**.** In this method since a large number of plants are selected hence the variety is more stable in performance over different environment as it is more adopted than a single pureline selection. Thus the varieties developed through mass selection are more widely accepted than pureline.

2. This method is less labor consuming extensive and prolonged field trials are not necessary and hence reduces the time and cost needed for developing a new variety.

3. Mass selection retains considerable genetic variability and no another mass selections after few years improves the variety.

4. This method can be applied to cross pollinated crops.

5. This method utilized only the variability which is already exists in the population improvement is done only through selection. So the limitation is that it cannot generate new genetic variability.

Achievements

Mass selection is effective when the population has the following characters-

a. The characters should be highly heritable in nature.
b. High genetic variability for different traits.
c. The crop is strictly grown under low population density.

(ii) Pure-line Selection

Comparatively to mass selection in pureline selection a large number of plants are selected from a population of self- pollinated crops, harvested individually and their individual progenies are cultivated separately and are evaluated and the best progeny is released as a pureline variety. Thus a pureline consists of a progeny of a single self- fertilized homozygous plant and is used for developing a variety. This method of production of a variety from the pure- line is known as pure- line selection. It is used in the mixed population of self-pollinated crops. In this method the progeny of single individual plants tested separately. Usually large number of single plants are selected and then progeny compare and to save the single most valuable progeny as a new variety for future. Therefore, this method is not materially different from mass selection except that comparatively to mass selection, in this method fewer plants are selected and each selected plant is tested separately. Thus the variety developed through pure- line selection is genetically pure and more durable than the previous

one. This method is not only practiced for self- pollinated crops but also in cross- pollinated crops during hybridization for production of pure- lines to serve as the parents in crossing.
As referred previously that the pure- line is a progeny of a single homozygous self- pollinated plant. In self- pollinated crops pureline selection method has several applications as below-
a. It is more favorite method of improvement of local varieties which have considerable genetic variability.
b. Pure- line selection for introduced varieties.

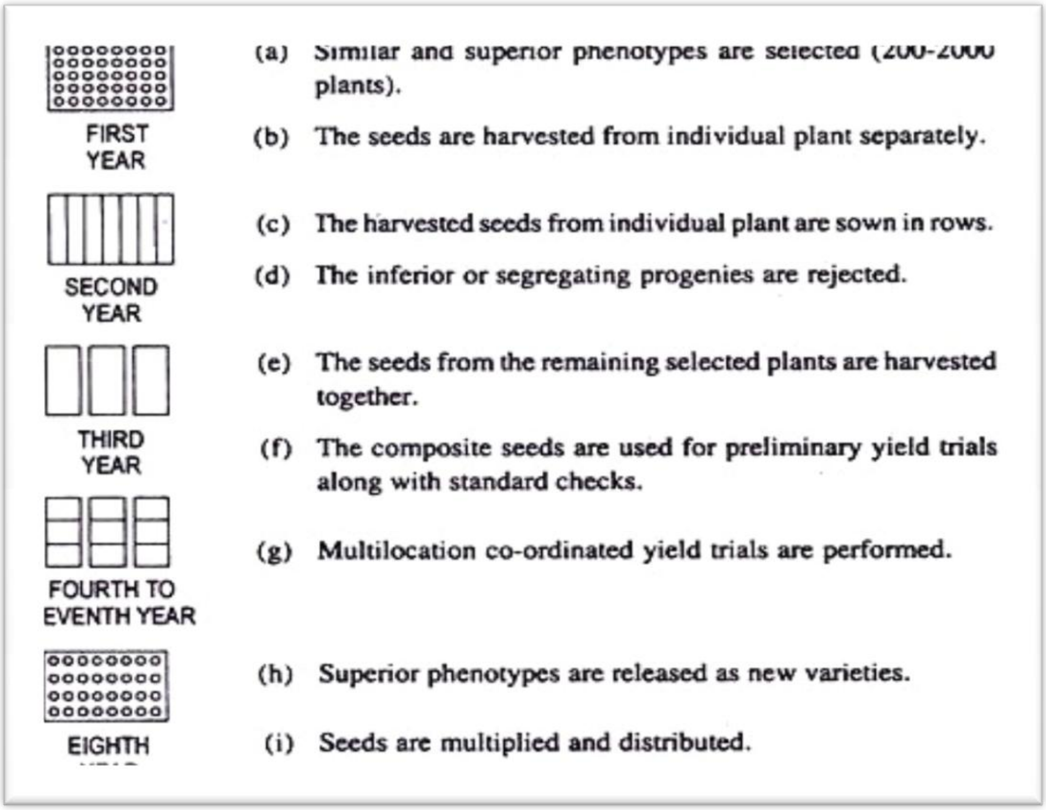


Fig.10.4. Presentation of Pure- line Selection Methodology

(iii) Clonal Selection

Clonal selection is generally practiced in vegetatively propagated crops such as potato, sweat potato, banana, sugarcane, mango, citrus, onion etc. In this case a group of plants obtained vegetatively from a single plant is known as a clone and the varieties are developing from the clones is known as clonal selection. After that on the basis of phenotypic characters the superior clones are selected. The fundamental basis of this selection is always between the clones and never within a clone because all the individuals of a clone has the same genetical constitution. These selected clones are multiplied vegetatively and compared with normal variety. The best ones are selected and multiplied and tried at different stations or areas continuously for three years. The best clones are given name and released as improved variety. Clonal selection is similar to pureline selection in vegetatively propagated crops, since vegetatively propagated pure- lines are the basis of improvement.

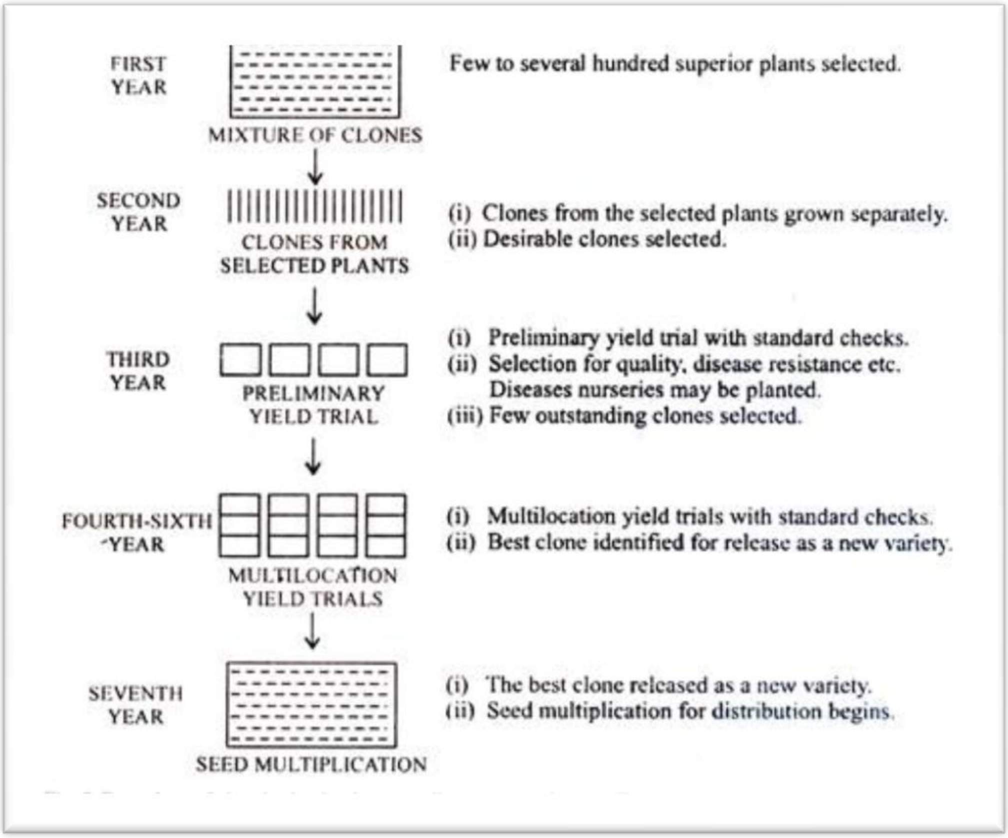


Fig.10.5 Presentation of Clonal Selection

Bud Selection

Bud selection is also a form of clonal selection where bud is the unit of selection. This method is applied in the improvement of fruit crops such as oranges and mangoes etc.

Hybridization

Hybridization is the best method among crop improvement. It is applicable for both type crops i.e. self and cross- pollinated ones, where two plants of different genetical constitution are crossed together. After domestication and crop selection, hybridization is the most potential breeding method for improvement of crop. Hybridization aims at to create new genetic variation of characters. It is the method of crossing of two pure- line plants of two dissimilar genotypes which will produce the F1 hybrids and then the subsequent generation will be segregating generations. The cross between two different varieties may be between two different species of the same species known as interspecific hybridization or may be between two different genera or intergenericis to create variation. The main object of hybridization new genes is not done yet variation is created by bringing new combination of genes already present in the parental stock. To select desirable characters, process of hybridization practiced between many plants, each possessing a separate combination of different characters. Out of them some may be selected possessing all the possible good characters together. To produce new variety and further selections practiced from these plants and thus ultimately by hybridization a variety containing as many economically valuable characters as possible may be produced.

Hybridization Process

To obtain improved variety there is a definite procedure of hybridization in which various steps are involved and they are briefly described below-

Hybridization between carefully chosen plants is now being used so extensively by plant between that the term breeding has become synonymous with the crossing of different varieties or species to evolve the desired types. Hybridization between cross- pollinated infact has been the only approach to transfer genes across different individuals. It is only with the development in tissue culture technology that somatic hybridization has also been used though on a limited scale, for this purpose.

Hybridization Procedure: To achieve the best results of hybridization techniques seven steps are involved as below-

1st step- Selection of Parents,
2nd step- Selfing of parents.
3rd step- Emasculation,
4th step- Bagging, tagging and labeling of males as well as females,
5th step- Crossing,
6th step- Collection of seeds from the crossed plants after maturity,
7th step- Handling of F_1 generations and
8th step- Raising the F_1 generation.

Selection of Parents

The first step of hybridization is selection of parents from the available material possessing all the desired characters second step of hybridization is the Selfing of parents to obtain homozygosity in desired characters so that they may easily be combined through hybridization. This step is not practiced in self- pollinated crops because they are already homozygous due to natural Selfing.

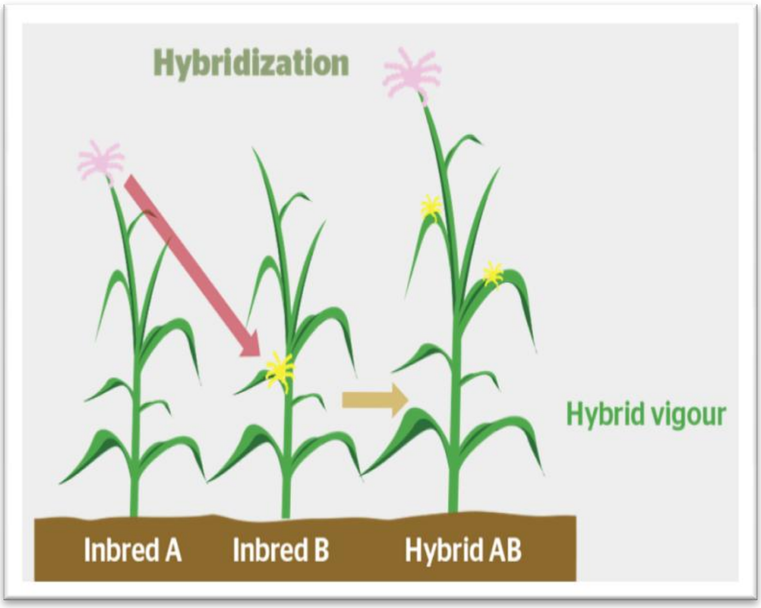


Fig. 10.6 Hybridization process

In the next step the anthers are removed or killed before maturation and have shed their pollens. This process is known as emasculation. The purpose of emasculation is only to prevent self- pollination. It is therefore, adopted only in those crops where there is self-pollinations, may be complete or up to some extent, it is not applied in unisexual crops. Bagging, logging and labeling of males as well as females is the fourth step of this process to be used in crosses.

To prevent natural cross pollination the females are bagged and males to prevent the contamination of pollen with foreign pollens and to collect the pollens for crossing.

The fifth step is the crossing, in which the pollens from already bagged males are collected and dusted on bagged females and labeled. The next or sixth step is the collection of seeds from the crossed plants after maturity. These seeds are sowing in the coming season to raise F_1 or first filial generation and hence maintain them separately. Plants obtained from this cross is known as **hybrids** and defined as **"Progenies of Cross".** The next step is the handling of F1 generation and subsequent generations for production of improved variety and last for raising the F1 generation.

Hybridization Methods:

Different selection methods of hybridization made by different selection methods for further selections from F1 to F5 generations, which are different for self and cross- pollinated crops as below-

For Cross- pollinated Crops-

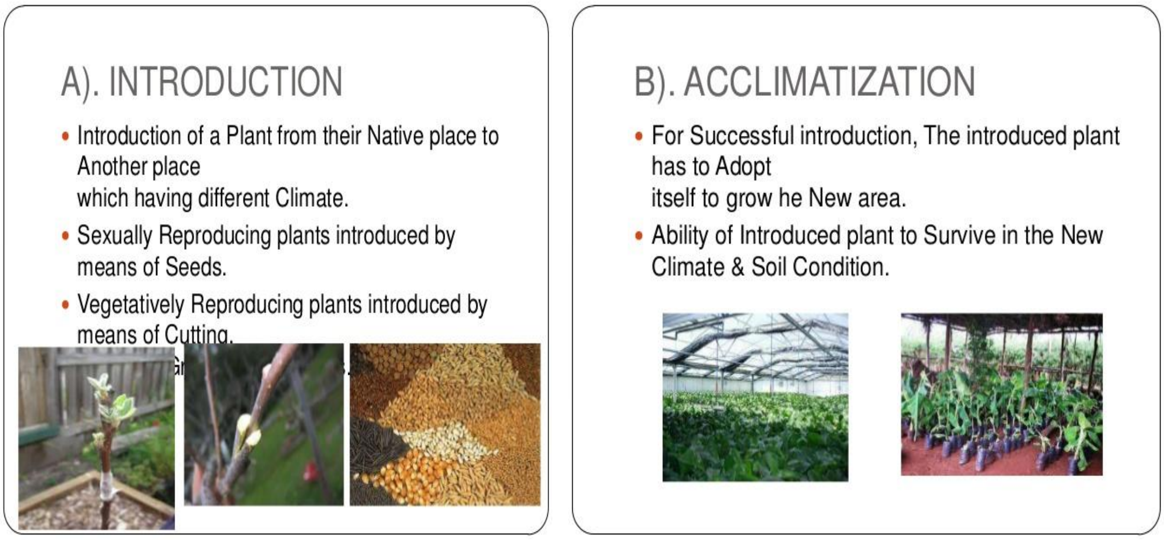
1. Single Cross (A x B),
2. Three Way Cross {(A x B) x C},
3. Double Cross {(A x B) - (C x D)}
4. Multiple Cross and
5. Synthetic Cross.

Self - Pollinated Crops-

1. Bulk Method,
2. Pedigree Method,
3. Backcross Method and
4. Multiple Cross Method.

All these methods have been given in details in the separate chapters of hybridization. The last and **eighth step is the testing, multiplication and distribution of the produced variety.** The testing of improved variety is done at various regional level research stations by research workers then multiplied by seed multiplication, farmers and final distributed to the farmers through Co- operative societies, panchayats and other agencies.

Hybridization has proved to be the best method of crop improvement and in the short period of 20th century is only due to this method is achieved in plant breeding and get great success



Introduction and Acclimatization: "Plant introduction and Acclimation" is the easiest and most rapid method of crop improvement in which the acclimatization follows the introduction and both the processes go by side. According to H.G. Chaudhary, "Plant introduction is the process of introducing plants from their growing locality to a new locality", or we can say that plants are transferred from one place to another having different climatic conditions. However,

Acclimatization is the segregation or adjustment of an individual plant or plant population controlled climate for a number of generations.

Introduction as a method of plant breeding involves the transfer of genotype or population from one environment of production to another. The plant material so introduced may reproduce its performance as such or may get adapted. This method is known as acclimatization, when new plant introduce into a new locality adapt itself according to new conditions.

To a new locality with different climate is termed as plant introduction, and further their adjustment under such changed climate of the new locality is known as acclimatization. Introduction of new crops as well as new varieties of crops may introduced either in the form of seeds or cuttings. In sexually propagated crops the cuttings are imported while in vegetatively propagated crops the cuttings are imported. The crops are generally introduced since in them there is greater frequency of gene recombinations owing to the frequent cross - pollinations and some of the combinations may be more favorably adopted in the environment. Introduction of crops may be done into a locality either from outside the country or from different regions within the country as per need and suitability. Infect, plant introduction within the country are very convenient but for introduction from another country followed a definite procedure as below-

1. The desired material is demanded from the concerned authority or agency of the foreign country through the plant introduction organization of the country.
2. After proper packing the material is sent by sea.

3. Before entering the country, this material is inspected at sea port by the plant protection authorities and
4. After certified fit according to quarantine rules, is permitted to enter in the country.
5. In the country it is handed over to the concerned institutions or workers.
6. Then it is grown under local climatic conditions and tested for acclimatization and presence of desired characters.
7. The material if proved fit for both, it is either utilized as such after selection or utilized as a material in hybridization for transferring the desired characters into the local varieties.

Hybridization method has been proved of great importance in crop improvement especially in recent years and used as a source of resistance material to some of our crop diseases. Most important among them is that rust resistance incorporated from foreign strains into Indian wheat variety.

Mutation Breeding: Sudden heritable variations in the plants other than those due to Mendelian segregation are known as mutation. These changes are due to rearrangement of genes or gene mutation or point mutation. When changes occurs in chromosomes size and structure, which is termed as chromosomal mutation, while changes in the chromosome number or ploidy. However, when changes occur in the plant body then it is known as somatic mutation. All these types cover up all types hereditary changes or changes in genotypes of the plants and give rise to inexhaustible variations which besides providing the new material for evolution are the basis of selection and production of new crop varieties in the plant breeding.

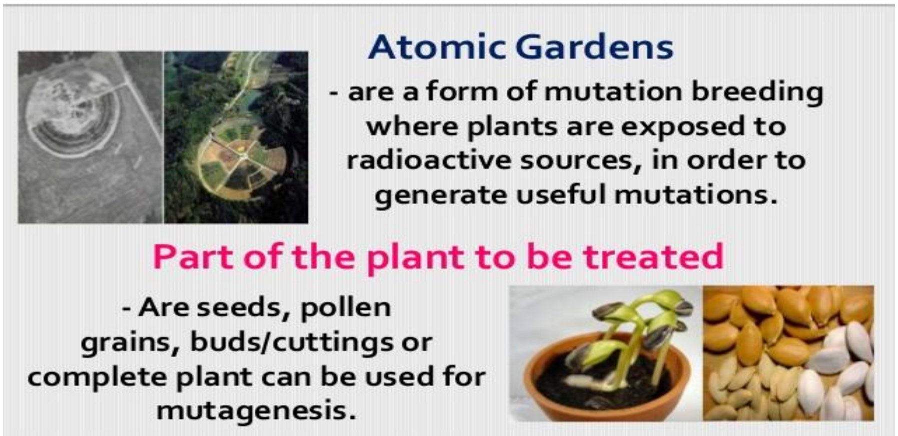


Fig.10.7 Different aspects of Mutation breeding

Certain chemicals, the agents responsible for mutation are known as mutagens. For this purpose two types radiations - ionic radiation i.e. x-rays, β-rays, γ- rays, radiation from radioactive isotopes, neutron, proton etc., Beside this, extreme temperature (Physical mutagens) and chemical mutagens- colchicine, Thiourea, HNO3 etc. are important mutagenic agents, Recently the plant breeder can change the genotype and phenotype of the plant according to his need for production of new desired strains by using this technique of mutation breeding. This is the recent and latest method of crop improvement and helps to produce rust resistance and increased baking quality in wheat, higher yield in mildew, resistance in barley, increased yield in cotton with superior fiber content. In mustard it helps to increase yield of seed and oil content. While in vegetatively propagated plants, selection from somatic mutation has led to improvements in dahlias, chrysanthemums, the ornamental plants, and crop plants like sugarcane and potato and fruit crops.

Table 1.Differences between Mass selection and Pure- Line selection

S.No.	Particulars	Mass Selection	Pure- line Selection
1.	Application	Used in both self and cross-pollinated species.	Used in self- pollinated species
2.	Genetic Constitution Variety	Homozygous but heterozygous in self-pollinated species. In cross pollinated species, hetero and homozygous.	Homozygous and homozygous.
3.	Basis of Selection	Selection is based on phenotype of plants	Selection is based on the progeny performance of plants.
4.	Component Lines	Mixture of several purelined in self- pollinated species. In cross pollinated species, mixture of several open genotypes pollinated.	It is a progeny of single homozygote
5.	Adaptation	Mass selected variety has wide adaptation	Pure- line variety has narrow genetic base.
6.	Produce of variety	Less uniform	Highly uniform
7.	Time Required	Release of new variety takes 6-7 years	Release of new variety takes 9-10 years
8.	Vulnerability	Low to new race of pathogen	High
9.	Genetic variation	Present	Absent

Table 2.Differences between Pure- line and Clonal Selection

S.No.	Particulars	Pure-line	Clonal
1.	Occurrence	In self-pollinated crops	In sexually propagated crops
2.	Genetic Constitution	Homogenous consisting Homozygous plants	Homogenous consisting of heterozygous plants
3.	Maintenance	Producing natural self-pollination	Produced by vegetative Propagation
4.	Type of progeny	Progenies of a single self-fertilized individual	Progenies of a single vegetatively propagated usually heterozygous individual
5.	Adaptation	Narrow	Wide
6.	Utilization	Utilized as improved variety and parents for hybridization also.	As variety and in hybridization

Conclusion:

The various above mentioned breeding methods have been developed on the basis of nature of crop propagation i.e. either it may reproduced sexually through self or cross- pollination or through vegetative propagation. The main basis of application of crop method to be used in a crop at any place depends on the amount of variation present in that particular crop in the past. The first method to improve the crops is selection, if no breeding work has been done so far in a crop. It may be mass, pure- line or clonal selection depending upon the type of propagation. Once if the variation is exhausted by selection then the next method of crop improvement is hybridization and selection from hybridization to meet the desired need. However, when recombination of hybridization may failed to obtain variation and improvement in a crop then to obtain the desired characters, plant introduction and acclimatization is adopted in which the desired material is introduced from outside and either utilized as such or incorporated in the local material. If all these methods did not succeeded to obtain any variation by any above methods, then at last the mutation breeding is employed in which inexhaustible variation is created artificially by inducing physical or chemical mutagens and utilized to produce new superior strain for future.

10.4 SUMMARY

Plant both domesticated as well as introduced, show considerable degrees of variations with respect to different characters. Some of these plants are superior whereas the others are inferior in performance. The process of selection of superior plants is an important method for the improvement of cultivated plants, which lead to the development of new varieties with more advantageous and superior characters. After selections i.e. mass selection, pure- line selection and clonal selection, the most frequently employed plant breeding technique is hybridization. The aim of hybridization is to bring together desired traits found in different plant lines into one line via cross pollination. Heterosis is an effective which is achieved by crossing highly inbred lines of crop plants, whereas, mutation refers to sudden heritable changes in the phenotype of an individual. Mutations do occur in nature either as spontaneous mutation or can be artificially introduced by various mutagenic agents known as induced mutation. Mutation breeding is the simple, quick and best way when a new character is to be induced in vegetatively propagated crops.

10.5 GLOSSARY

Acclimatization: The process by which a population adjusts and modifies itself to survive and reproduce normally under changed environmental or stress conditions.
Backcross: The cross of an F1 hybrid with either of the parents.
Breeding: The art and science of changing and improving heredity of living organisms.
Bud Selection: The form of clonal selection in which the bud is the unit of selection.

Clone: A group of plants produced through vegetative propagation from a single plant. It represents exact multiple copies of a genotype.
Colchicine: An alkaloid extracted from seed of colchicum autumnale that destroys spindle apparatus during mitosis and thus doubles chromosome number.
Emasculation: Manual removal of the anthers from a flower to make it ineffective for producing pollen.
Hybrid: The progeny of a cross between two or more individuals, plants or animals of unlike genetical condition.
Hybridization: A method of crop improvement in which two or more plants of unlike genetical constitution differing in one or more characters are crossed together.
Induced Mutation: The mutation which are artificially produced.
Mass Selection: The method of selecting plants on the basis of their phenotypic performance to bulk the seed in the form of new population.
Mutagen: An agent that can induce mutation.
Mutation: A sudden heritable change in a chromosome. It may involve change either in single gene or part of chromosome.
Pedigree Selection: A record of ancestry of an individual, family or strain.
Phenotype: External appearance of an organism as contrasted with its genetic makeup or genotype for particular character.
Pure- line: The progeny of a single homozygous individual produced through self-fertilization.
Male Sterility: The conditions in which the pollen is not produced or is non- functional for pollination.
Multiple Cross: A cross among many inbred with pollination between desired lines.
Three Way Cross: A cross between a single cross used as female and an inbred used as male i.e. (A x B x (C x D).
Single Cross: A cross between two inbred A x B
Variety: A group of similar plant within a species which are distinctly different for some structural features and performance from other varieties of the same species.

10.6 SELF- ASSESSMENT QUESTIONS

10.6.1 Fill in the blanks:

1. Mass selection is the simplest---------------- and ------------method of crop improvement.
2. Mass selection is used in --------------and -----------------------plants.
3. Most frequently employed plant breeding technique is ----------------------.
4. In pure- line selection the expected results is a set of genetically--------------- lines.
5. A cross {(A x B) - (C x D)} is known as-------------------Cross.
6. [(A x B) x C] represents-----------------Cross.

10.6.1 Answers Key: 1. common, oldest, 2. Self and cross-pollinated, 3.Hybridization, 4. Homozygous, 5. Double cross, 6. Three way cross.

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10.9 TERMINAL QUESTIONS

10.9.1 Long Answer Question:

1. What are the different methods of crop improvement and when and where are they used in particular crop?
2. Define artificial selection and what are its different types?
3. What are the different hybridization methods for self and cross - pollinated crops?
4. What do you mean by hybridization and what is its main purpose?
5. What do you mean by mutation breeding, what are its different kinds on the basis of origin, define briefly?
6. Define the following terms-
    a) Pure- line selection
    b) Clone
    c) Emasculation
    d) Hybrid
    e) Acclimatization and Introduction
7. What are the differences between mass selection and pure- line selection?
8. Write are the different steps applied in hybridization technique?
9. What type of selection methods are used for the improvement in vegetatively propagated crops?
10. Define the merits and demerits of mass selection?
11. Define the achievements of mass selection?

UNIT-11 MUTATIONAL BREEDING

11.1 OBJECTIVES

After reading this unit you will be able to know about:

- To increase yield
- To develop plants that is resistant to pests and diseases
- To improve quality
- To develop plants those have resistance to adverse conditions

11.2 INTRODUCTION

Mutations are sudden unpredictable heritable changes without any intermediate stage in characteristics of organism. In molecular terms, mutation is defined as the permanent and relatively rare change in the sequence of nucleotides. Mutations may be chromosomal, cytoplasmic or gene mutation (or point mutation).

Mutation was first discovered by Wright in 1791 in male lamb which had short legs. Later on mutation was discovered and studied in Oenothera by Hugo de Vries in 1900 Morgan in Drosophilla (white-eyed mutant) in 1910, and by several others in various organisms. However, the term "mutation" was coined by de Vries.

Mutations can be induced by some physical and chemical agents, called mutagens. Mutagens greatly enhance the frequency of mutations. Mutagenic action of X-ray was first discovered by Muller in 1927 and that of nitrogen mustards by Averbach and Robson in 1946. Based on their effect on survival, mutations are classified into four groups: lethal, sub-lethal, sub-vital, and vital. Mutation breeding utilizes vital mutations only.

Characteristics of Mutations:

1. Mutations are generally recessive, but dominant mutations also occur.

2. Mutations are generally harmful to the organism, but a small proportion (0.1 percent) of them is beneficial.
3. Mutations are random i.e., they may occur in any gene. However some genes show higher mutations rate than others.
4. Mutations are recurrent, that is the same mutations may occur again and again.
5. Induced mutations commonly show pleiotropy, often due to mutations in closely linked genes.

Types of Mutation:

1. Spontaneous mutation: Mutations occur in natural populations (without any treatment by man) at a low rate. These are known as spontaneous mutations. The frequency of natural mutations is generally one in ten lacs.

2. Induced mutation: Mutations may be artificially induced by a treatment with certain physical or chemical agents. Such mutations are known as induced mutations, and the agents used for producing them are termed as mutagen. The utilization of induced mutations for crop improvement is known as mutation breeding. Induced mutations have a great advantage over the spontaneous ones, they occur at a relatively higher frequency so that it is practical to work with them.

Induced mutations are of two types:-

1. **Macro- Mutations:** Mutations with distinct morphological changes in the phenotype are referred to as macro-mutations. Identification of such mutations is easy.
2. **Micro-Mutations:** Mutations with invisible phenotypic changes are called micro-mutations. Identification of such mutations is very difficult. Micro mutations are of economic value in plant breeding.

Effects of Mutation: Depending upon the effect on the survival of an individual, induced mutations are of 4 types:

1) **Lethal:** They kill each & every individual that carry them in appropriate genotype.
  Dominant lethal: It can’t survive.
  Recessive lethal: kill in homozygous state.

2) **Sub-lethal & Sub-Vital:-** Both mutation reduce viability but don’t kill all the individual carrying them in appropriate genotype.
  Sub lethal: kill more than 50%.
  Sub vital: kill less than 50%.

3) **Vital:** All mutants survive. Crop improvement can utilize only such mutations.

Mutagen: Agents used for induction of mutations are known as mutagens. The mutagens are classified into two groups, physical and chemical mutagens.

(a) Physical Mutagen

The mutations inducing radiation's are of two kinds.
i. Ionizing radiation
ii. Non-ionizing radiation

(i) Ionizing radiation: Alpha, Beta and gamma rays of radio active substances, Neutrons and X rays are examples of ionizing radiation. When ionizing radiations passes through matter, atoms, absorb energy from them and lose electrons. When an atom becomes ionized, molecule of which it is a part undergoes chemical change. If the molecule is a gene and if this changed gene duplicate its new pattern, the result of the change is a mutation.

X-rays: X-rays were first discovered by Roentgen in 1895. They are lightly ionizing and highly penetrating and are generated in X-rays machines. X-rays can break chromosomes and produce all types of mutations in nucleotides, *viz.* addition, deletion, inversion, transposition, transitions and transversions. X-rays were first used by Muller in 1927 for induction of mutation in *Drosophila*. In plants, Stadler in 1928 first used X-rays for induction of mutation in barley. Now X-rays are commonly used for induction of mutation in various crop plants. X-rays induce mutations by forming free radicals and ions.

(ii) Non-ionizing radiation: When compounds absorb energy from non-ionizing radiations, their electrons are raised to higher energy levels (excitation). It results in increased reactivity of the affected molecules leading to mutations. The only one non-ionizing radiation capable of inducing mutations is ultra violet light. UV radiation can be obtained from a mercury vapour lamp. UV rays have much longer wave lengths (about 2500 Angstroms).

UV rays: UV rays are non ionizing radiations, which are produced from mercury vapour lamps or tubes. They are also present in solar radiation. UV rays can penetrate one or more cell layers. Because of low penetrating capacity, they are commonly used for radiation of micro-organisms like bacteria and viruses. UV rays can also break chromosomes.

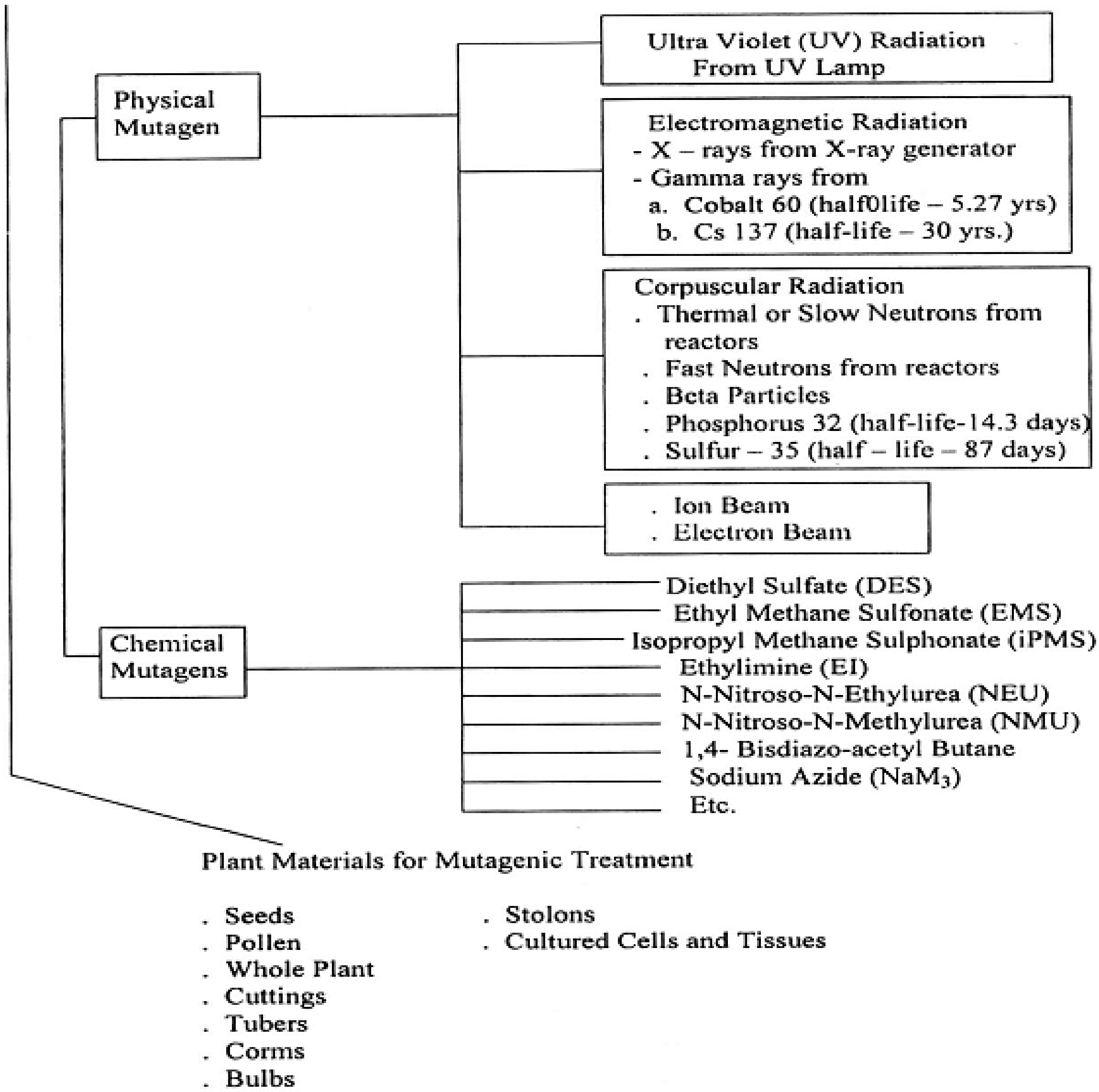
(b) Chemical Mutagens

1. Alkylating agents – This is the most powerful group of mutagens. They induce mutations especially transitions and transversion by adding an alkyl group (either ethyl or methyl) at various positions in DNA. Alkylation produces mutation by changing hydrogen bonding in various ways. eg., EMS (Ethyl Methane Sulphonate), MMS (Methyl Methane Sulphonate), ethylene imines (EI), sulphur mustard, nitrogen mustard, etc.

2. Acridine dyes- Dyes are very effective mutagens. eg., Ethidium Bromide, acriflavine, proflavine, acridine orange, acridine yellow.

3. Base analogue – Base analogue refer to chemical compounds which are very similar to DNA bases. They can cause mutation by wrong base pairing. eg. 5 Bromo uracil (5BU), 5 – Chloro uracil (5CU) and 2 amino purine (2AP).

4. Others – Other important chemical mutagens are:- Nitrous acid, hydoxylamine, sodium azide.



Gamma garden: The gamma garden of the Indian Agricultural Research Institute, New Delhi is a three-acre plot. In the centre of this field, there is a large source of radioactive cobalt (CO 60) and plants in pots are kept at varying distances from the source, irradiated and studied. It is used for irradiating whole plants during different stages and for varying durations.

Gamma rays are of shorter wavelength than X- rays and hence are penetrating. Gamma rays are commonly measured in terms of Roentgen units (r).

Mutagenesis

Treating a biological material with a mutagen in order to induce mutations is known as mutagenesis. Exposure of a biological material to radiation (x-rays, gamma rays etc.,) is known as irradiation.

Part of the plant to the treated Seeds, pollen grains, or vegetative propagules (buds and cuttings) may be used for mutagenesis. Chemical mutagens are best used with seeds.

Dose of the mutagen

Mutagen treatments reduce germination, growth rate, vigour and fertility (pollen as well as ovule). An optimum dose in the on which produces the maximum frequency of mutations and causes the minimum killing. LD 50 in that dose of a mutagen which would kill 50 percent of the treated individuals. LD 50 value varies with the crop species and with the mutagen used. A preliminary experiment is generally conducted to determine the suitable mutagen dose. Dose of the mutagen may be varied by varying the intensity or the treatment time. Intensity in the case of chemical mutagens may be varied by changing the concentration of mutagens.

Mutagen treatment

The selected plant part is exposed to the desired mutagen dose. The case of chemical mutagens, seeds are usually presoaked for a few hours, to initiate metabolic activities, exposed to the desired mutagen and then washed in running tap water to remove the mutagen present in them. The treated seeds are immediately planted in the field to raise the M1 generation. M2, M3, M4 etc are the subsequent generations derived from M1, M2, M3 etc., plants through selfing.

Stage at which mutation occurs:

Mutation can occur at any stage during the life cycle of a living organism.

1. Before the formation of gametes
2. In gametes
3. In zygotes
4. In normal body cell or somatic cell

Frequency of Mutation:

The frequency at which gene mutate is called mutation rate. The mutation rate depends upon the position and nature of the genes. The genes with relatively low mutation rate are known as stable genes and those with high mutation rate as unstable genes. General range of frequency of mutation is 1 in 20,000 to 1 in 2, 00,000.

Rate of mutation is influenced by:

1. Mutator gene (this gene increases the rate of mutation), supressor gene (this gene decreases the rate of mutation).
2. Virus can increase the mutation rate (e.g., *Zea mays*)
3. Environment (temperature, different radiations and chemicals)

Chromosomal Mutation:

The change in chromosome structure is known as chromosomal mutation. It is also known as chromosomal aberration. It may be due to the following reason:

(a) Deletion: Loss of part of chromosome.

(b) Duplication: Addition or increase in a part of chromosome

(c) Inversion: Reversal in order of genes in a part of chromosome. It is of two types:
(i) Paracentric inversion (inversion segment does not carry centromere)
(ii) Pericentric inversion (inversion segment with centromere).

(d) Translocation: Exchange of genes between non-homologous chromosomes.

Gene Mutation: The change of nitrogenous base sequence in DNA or gene is known as Gene or Point mutation. In other words, change in the chemical structure of gene at the molecular level is also known as gene mutation. Phenotypic changes which are produced by gene mutation are reversible, whereas due to structural and numerical changes in chromosome are irreversible.

Gene mutations are of two types:

1. Substitute mutation: The change of base pair or nucleotide pair in a DNA segment or cistron is called substitute mutation. It is of two types:

(a) Transition: Exchange of purine base by purine base or pyrimidine by pyrimidine base in a DNA segment or cistron is known as transition.

(b) Trans-version: The substitution of a purine base by pyrimidine base or vice-versa is known as trans-version.

2. Frame shift mutation: Insertion or deletion of single nitrogenous base in DNA chain is known as frame shift or gibberish mutation. For example, if the antisense strand of DNA is
TAG AAA GGG GCC AAG AGA
Its DNA transcript will be:
AUG UUU GCC GGG UUG UGG UGU
Translated message will be
Methionine – Phenyl alanine – Proline, – Glycin – Phenyl alanine – Serine.
If a single base 'G' is inserted in between G and U of first codon then a new protein will be produced.
AUG GUU UGG GGG GUU GUG GUC.
Methionine – Valine – Serine – Arginine – Valine – Leucine – Leucine.

11.3 MUTATION BREEDING

The genetic improvement of crop plants for various economic characters through the use of induced mutation is referred to as mutation breeding. It is one of the special methods of crop improvement. Mutation breeding is commonly used in self-pollinated and asexually propagated species. However, this method is rarely used for genetic improvement of cross pollinated species.

Procedure of mutation breeding

Step1. Choice of material

The best adapted variety of a crop should be chosen. Only one or two features of such variety have to be altered through mutagenesis depending upon the objectives. Suppose a variety is high yielding, but susceptible to a particular disease, the objectives of mutation breeding would be to induce resistance to that particular disease in the variety.

Step: 2.Choice of mutagen

It depends upon the plant parts to be treated. Generally, chemical mutagens are more preferred for seed treatment and radiations for the treatment of vegetative parts. The penetration of chemical mutagens can be enhanced dissolving the mutagen in solvents like dimethyl sulphoxide.

Step: 3. Mutagenic treatment

The procedure of mutagenic treatment takes three things into account: *viz.*

Plant species- Seeds, Pollens, Buds, Cuttings or Suckers.

Dose of mutagen –LD 50 refers to a dose of mutagen that kills 50% of the treated individuals

Duration of treatment- depends on the intensity of radiations or concentration. The seeds are water soaked before treatment. After treatment the seeds or cuttings are immediately planted and pollens are used for pollination. Plants obtained from treated seeds or cuttings are called M1 plants.

Step: 4 Handling of Treated Material:

Seed propagated species:-

M1 Generation

Several hundred (500 or more) treated seeds are space planted. All the M1populations are grown using wider spacings for easy identification. Generally the mutants are recessive. All the plants will be chimeras for the mutation present in heterozygous state. About 20 seeds from each M1 plant are harvested separately.

M2 Generation

About 2000 progeny rows are grown using wider spacings. Oligogenic mutants with distinct features are identified and selected. Only 1-3% of M2 rows may be expected to have beneficial mutations

M3 generation

Progeny rows form individual selected plants. Inferior mutant rows are eliminated. If the mutant progenies are homozygous, two or more M3 progenies containing the same mutation. Mutant M3 rows are harvested in bulk.

M4 generation

A preliminary yield trial is conducted with a promising mutant lines are selected for replicated multilocation trials.

M5-M8 generation

Selected lines are tested in coordinated Multilocation trials. The best performing line is released as a variety. In case of polygenic traits, identification of character is not possible through visual observations.
The material is tested in replicated trial and screening is done for the character under improvement using appropriate statistical methods.
Inferior plants are rejected in M3 and M4 generation based on screening tests and superior plants are bulked to raise next generation.
The homozygous progeny are tested in coordinated trial from M5 to M9 and the best line is released as a variety.
In India, over 200 varieties have been developed through mutation breeding.

Selection amongst Somaclonal Variation:

Genetic variation present among plant cells during tissue culture is called somaclonal variation. The term somaclonal variation is also used for the genetic variation present in plants regenerated from a single culture. This variation has been used to develop several useful varieties.
Some of the somaclonal variations are stable and useful, e.g., resistance to diseases and pests, stress tolerance, male sterility, early maturation, better yield, better quality, etc. Thus somaclonal variations have produced wheat tolerant to rust and high temperature, Rice to leaf ripper and Tungro virus, Potato to Phytophthora infestans (late blight of Potato), etc. Other useful variations include high protein content of Potato, short duration Sugarcane and increase shelf life of Tomato.

Achievements and Limitations of Mutation Breeding:

1. A number of crop varieties have been developed through mutation breeding.
2. The first commercial success with induced mutations was reported in 1934 with the release of a new tobacco cultivar ‘Chlorina’ through X-ray irradiation. The Indian dwarf wheat’s which contain the dwarfing gene was from a Japanese cultivar ‘Norin- 10’, which itself was a mutant.
3. Many varieties of barley contain artificially mutated genes which contribute to reduction in height, increase in yield, insensitivity to day length and resistance to mildew diseases. Sharbati Sonara and Pusa Lerma are two amber grain colour mutants of wheat produced from the red grained Sonara 64 and Lerma Rojo 64A, respectively. A mutant gene that induces semi-dwarfing in rice has been produced by X-ray treatment. Induced mutations have also become recently important in developing parents useful in hybridization programmes. Forty-five rice cultivars have been developed by the year 1982, either by direct radiation or by crossing with induced mutants.
4. Many crop plants are propagated vegetatively even though they can bear seed. Potato, tapioca and sugarcane are classical examples of such crops. In these, genetic improvement is carried out using sexual reproduction but the maintenance of the improved varieties is by cloning. For examples, potatoes are multiplied by tubers, apples by cuttings, and strawberries by runners.

5. Spontaneous mutations in somatic cells of a vegetatively propagated plant are commonly referred to as SPORTS. Such desirable sports occurring in well-adapted, asexually reproducing plants may result in quick improvements such as the colour sports in many apple varieties and superior shrub types in coffee plants.
6. The characters improved through mutation breeding include flowering time, flower shape, fruit shape, changes in oil content, and protein quality.
7. Some of the important limitations of the use of mutation breeding for crop improvement are:
(i) Most induced mutations are undesirable and have no value to the breeder. Many induced mutations are lethal.
(ii) The mutation rate is extremely low and a very large number of plants must be screened to identify the few individuals that may have desirable mutations. It is equally difficult to grow such useful mutants and include them in breeding programmes.
(iii) The stability of a mutant must be thoroughly tested as some mutants have a tendency to revert.
(iv) Most induced mutations are recessive; these have to be in double dose to be expressed phenotypically.
(v) Unless mutations are induced in gametes—especially in pollen—they will not be easily incorporated into the breeding line.

11.4 BREEDING FOR DISEASE RESISTANCE

Disease resistance is often defined as reduction of pathogen growth on or in the plant. It denotes less disease development in a genotype than that in the susceptible variety and is a relative attribute. Generally, the rate of reproduction is considerably reduced which limits the spread of disease. Plants are almost always resistant to certain pathogens but susceptible to other pathogens; resistance is usually pathogen species-specific or pathogen strain specific.

Types of Disease Resistance

Vertical resistance: Term coined by Vanderplank. It is qualitative resistance or race specific resistance governed by major genes and is characterized by phenotype specificity it is easily overcome by new races of the pathogen. Common in diseases caused by biotrophic pathogens e.g. rusts.

Horizontal resistance: Term coined by Vander plank Quantitative or durable resistance, controlled by polygenes and is host nonspecific. These genes provide the plants with defensive structures or toxic substances that slow down or stop the advance of the pathogen into the host tissues and reduce the damage caused by the pathogen, in diseases caused by non-biotrophic pathogens. The defenses in quantitative resistance develop slower and perhaps reach a lower level than those in the race specific resistance. It is durable resistance and never breaks down to new strains of disease, as does vertical resistance.

Plant breeders focus a significant part of their effort on selection and development of disease resistant plant lines. Plant diseases can also be partially controlled by use of pesticides, and by cultivation practices such as crop rotation, tillage, planting density, purchase of disease-free seeds and cleaning of equipment, but plant varieties with inherent (genetically determined) disease resistance are generally the first choice for disease control. Breeding for disease resistance has been underway since plants were first domesticated, but it requires continual effort. This is because pathogen populations are often under natural selection for increased virulence, new pathogens can be introduced to an area, cultivation methods can favor increased disease incidence over time, changes in cultivation practice can favor new diseases, and plant breeding for other traits can disrupt the disease resistance that was present in older plant varieties. A plant line with acceptable disease resistance against one pathogen may still lack resistance against other pathogens.

GENE-FOR-GENE Hypothesis

The concept of gene for gene hypothesis was first developed by Flor in 1956 based on his studies of host pathogen interaction in flax for rust caused by *Malampsora lini*. The gene for gene hypothesis states that for each gene controlling resistance in host, there is a corresponding gene controlling pathogenicity in the pathogen. The resistance of the host is governed by dominant genes and virulence of pathogen by recessive genes. The genotype of host and pathogen determine the disease reaction. When gene in host and pathogen is match for all the loci, then only the host will show susceptible reaction. If some gene loci remain unmatched, the host will show resistant reaction. Now gene-for-gene relationship has been reported in several other crop like potato, Sorghum, wheat etc. The gene for gene hypothesis is also known as "Flor Hypothesis".

Mechanisms of disease resistance:

Three different mechanisms operate in plants for disease resistance; *viz.*

1) Resistance to establishments of the pathogen in the host tissue,
2) Resistance to the growth and development of the pathogen already established in the host tissue,
3) Ability of a host to perform well despite the establishment of the pathogen in the host tissue.

The first two mechanisms are considered as true forms of resistance and the last is termed as tolerance.

Sources of resistance

In crop plants, there are four important sources of disease resistance. These are:

1. Cultivated varieties
2. Germplasm collections
3. Wild species
4. Induced mutation

1. Cultivated varieties: In some crops, resistance to disease may be found in cultivated varieties. For example, cotton variety MCU 5 VT tolerant to *Verticillium* wilt was isolated from the commercial variety MCU 5 of *Gossypium hirsutum.* Cultivated varieties are the best sources of disease resistance, because they possess good agronomic characters besides disease resistance.

2. Germplasm collections: Germplasm collections are the potential sources of disease and insect resistance in all the cultivated crops. In cotton, several germplasm lines resistant to bacterial blight and *Fusarium* wilt have been identified based on screening of large number of germplasm in India. Generally, germplasm lines have poor agronomic characters. Hence, their use in breeding programmes poses some problems.

3. Wild Species: Related wild species are also potential sources of disease resistance. However, utilization of wild sources poses many problems such as cross incompatibility, hybrid inviability, hybrid sterility and linkages of several undesirable traits with desirable ones. Therefore, wild related species are only used as source of resistance when the desired resistance is not found within the cultivated species. Wild species of crops like wheat, barley, potato, tomato, sugarbeet, tobacco, cotton etc., are good sources of resistance to various diseases. Many disease resistant genes have been transferred from wild species to cultivated species in these crops.

4. Mutations: Both spontaneous and induced mutations are good sources of disease resistance. Disease resistance has been achieved in several crops through the use of induced mutations. Some examples of disease resistance induced by mutagenic agents are; resistance to Victoria blight and crown rusts in oats, to strip rust in wheat, to mildew in barley, to flax rust in flax, and to leaf spot and stem rust in peanut.

Steps in Breeding for Disease Resistance

Identification of resistant breeding sources: Plants that may be less desirable in other ways, but which carry a useful disease resistance trait. Ancient known plant varieties and wild relatives, cultivated varieties and land races are very important to preserve because they are the most common sources of enhanced plant disease resistance. Others include mutations, somaclonal variation & unrelated species.

Breeding methods: Crossing of a desirable but disease-susceptible plant variety to another variety that is a source of resistance, to generate plant populations that mix and segregate for the traits of the parents. The methods of crossing include selection, introduction, marker assisted selection, genetic engineering; hybridization includes backcross, pedigree, bulk methods. Among these methods marker assisted selection & backcross methods are important.

Screening: This is carried out under field and glasshouse conditions. The glasshouse tests are conducted under controlled conditions. The procedure of field inoculation differs for various types of diseases:

(a) Soil borne diseases- For soil borne diseases like root rots, collar rots, wilts, etc., sick plots are created for testing resistance to such diseases.

(b) Air borne diseases- For air borne diseases such as rusts, smuts, mildews, blights, leaf spots, etc., spraying a suspension of spores.

(c) Seed borne diseases- Dry spores are dusted on seeds or seeds may be soaked in a suspension of pathogen spores.

Selection of disease-resistant individuals

Breeders are trying to sustain or improve numerous other plant traits related to plant yield and quality, including other disease resistance traits, while they are breeding for improved resistance to any particular pathogen. Each of the above steps can be difficult to successfully accomplish, and many highly refined methods in plant breeding and plant pathology are used to increase the effectiveness and reduce the cost of resistance breeding.

Method of Breeding for Disease Resistance

The method of breeding for disease resistance is essentially the same as those for other agronomic characters. The following breeding methods are commonly used,

1) Selection,
2) Introduction,
3) Mutation,
4) Hybridization,
5) Somaclonal Variation, and
6) Genetic engineering.

1. Introduction: This is easy and rapid method of developing disease resistant variety. The resistant variety may be introduced and after testing, if found suitable, can be released in the disease prone area. In 1860, the grape crop in France was completely destroyed by the attack of Phylloxera Vertifolia. Introduction of resistant root stocks to this pest from USA saved the grape crop from extinction in France.

2. Selection: When the source of resistance is a cultivated variety, mass selection and pure lines selection in self pollinated crops, mass and recurrent selection in cross pollinated species, and clonal selection in the vegetatively propagated crops will be ideal for isolating disease resistant plants. The resistant plants may be multiplied, screened for disease resistance and released a variety.

3. Hybridization: Hybridization is used when resistant genes are available either in the germplasm or in wild species of crop plants. After hybridization, the hybrid material is handled either by pedigree method or by backcross method. The pedigree method is used when the resistance is governed by polygene and the resistant variety is an adapted one which also contributes some desirable agronomic traits. The backcross method is used when resistance to governed by oligogenes. Induced mutations are also use for disease resistance.

Many disease resistant varieties have been developed in various crops through induced mutations.

4. Mutation: We have already considered briefly the usefulness of spontaneous as well as induced.

5. Somaclonal Variation: Disease resistant soma clonal variants can be obtained in the following two ways, firstly, plants regenerated from cultured cells or their progeny are subjected to disease test and resistant plants are isolated. Secondly, cultured cells are selected for resistance to the toxin or culture filterate produced by the pathogen and plants are regenerated from the selected cell. In most cases, these plants are also resistant to the disease in question. Cell selection strategy is most likely to be successful in cases where the toxin is involved in disease development.

6. Genetic Engineering: Genes expected to confer disease resistance are isolated, cloned and transferred into the crop in question. In case of viral pathogens, several transgenes have been evaluated, viz, virus coat protein gene, DNA copy of viral satellite RNA, defective viral genome, antisense constructs of critical viral genes, and ribozymes. Viral coat protein gene approach seems to be the most successful. A virus transgenic variety of squash is in commercial cultivation in U.S.A.

Advantages of breeding for disease resistance

1. Resistant varieties offer the cheapest means of disease control.
2. Resistant varieties obviate the use of fungicides, thus reduce environmental pollution
3. Effectiveness of resistant varieties is not affected by environmental conditions.
4. It safeguards against the inadvertent release of such varieties that are most susceptible than earlier varieties.

Problems in breeding for disease resistance

1. Resistance breakdown (vertifolia effect, boom & bust cycle)
2. Horizontal resistance being durable but difficulty relates to an accurate & reliable assessment of the level of resistance.
3. Sometimes there is negative correlation between yield & disease resistance e.g wheat leaf rust gene Lr34 causes a 5% reduction in grain yield.
4. For introgression of multiple resistances in varieties against several diseases requires meticulous planning and far greater effort than that required for single resistance.

Plant Breeding for Developing Resistance to Insect Pests:

Insects and pest infestation are two major causes for large destruction of crop plant and crop. Insect resistance in host crop plants is due to morphological, biochemical or physiological characters. Hairy leaves of many plants are associated with resistance to insect pests. For example, resistance to jassids in cotton and cereal leaf beetles in wheat. Solid stems in wheat lead to non-preference by the

stem saw fly and smooth leaved and nectar-less cotton varieties does not attract bollworms. Low nitrogen, sugar and high aspartic acid in maize develops resistance to maize stem borers.

Breeding methods for insect pests resistance include the same steps as for any other agronomic character like yield or quality as described above. Sources of resistance genes may be cultivated varieties, germplasm collections of the crop or wild relatives of the crop.

Plant Breeding for Improved Food Quality

It is estimated that more than 840 million people in the world do not have adequate food to meet their daily requirements. Three billion people suffer from protein, vitamins and micronutrient deficiencies or 'hidden hunger' because these people cannot afford to buy adequate vegetables, fruits, legumes, fish and meat. Their food does not contain essential micronutrients especially iron, iodine, zinc and vitamin A. This increases the risk for disease, reduces mental abilities and life span. Breeding of crops with higher levels of vitamins and minerals or higher protein and healthier fats is called biofortification. This is the most practical aspect to improve the health of the people.

Plant breeding is undertaken for improved nutritional quality of the plants. Following are the objectives of improving:

(1) Protein content and quality

(2) Oil content and quality

(3) Vitamin content and

(4) Micronutrient and mineral content.

Indian Agricultural Research Institute (IARI), New Delhi, has also developed many vegetable crops that are rich in minerals and vitamins. For example, vitamin A enriched carrots, pumpkin, spinach, vitamin C enriched bitter gourd, Bathua, tomato, mustard, calcium and iron enriched spinach and bathua; and protein enriched beans (broad lablab, French and garden peas).

Single Cell Protein (SCP):

As we know demand of food is increasing due to increase in human and animal population, the shift from grain to meat diets does not solve the problem as it takes 3-10 kg of grain to produce 1 kg of meat by animal farming. More than 25 percent of human population is suffering from hunger and malnutrition. One of the alternate sources of proteins for animal and human nutrition is single cell protein (SCP).

Microorganisms are used for the preparation of fermented foods (e.g., cheese, butter, idlis, etc.). Some microorganisms (e.g., blue green algae- Spirulina and mushrooms-fungi) are being used as human food. Now efforts are being made to produce microbial biomass using low cost substrates. Microbes like Spirulina can be grown on waste water from potato processing plants (containing starch), straw, molases, animal manure and even sewage, to produce food rich in proteins, minerals, fat, carbohydrates and vitamins. This biomass is used as food by humans.

The cells from microorganisms such as bacteria, yeasts, filamentous algae, treated in various ways and used as food, are called single cell protein (SCP). The term SCP does not indicate its actual meaning because the biomass is not only obtained from unicellular microorganisms but also from multicellular microorganisms.

Thus SCP is produced using bacteria, algae, fungi (yeasts, etc). The substrates used for SCP production range from C0 (used by algae) through industry effluents like whey (water of curd), etc. to low-cost organic materials like saw dust and paddy straw. Commercial production of SCP is mostly based on yeasts and some other fungi, e.g., Fusarium graminearum. In most cases, SCP has to be processed to remove the excess of nucleic acids. SCP is rich in high quality protein and is poor in fats. Both high quality of protein and low quantity of fats constitute good human food. It has been estimated that a 250 kg cow produces 200 g of protein per day. In the same period 250 g of a microorganism like Methylophilus methylotrophus because of its high content of biomass production and growth, can produce about 25 tonnes of protein.

Some Common Microbes as SCP producers:

(i) Cyanobacteria – Spirulina
(ii) Bacteria – Methylophilus methylotrophus
(iii) Yeasts – Candida utilis
(iv) Filamentous fungi – Fusarium graminearum

Advantages of SCP:

(i) It is rich in high quality protein and poor in fat content,
(ii) It reduces the pressure on agricultural production systems for the supply of the required proteins,
(iii) SCP production is based on industrial effluents so it helps to minimise environmental pollution,
(iv) SCP can be produced in laboratories throughout the year.

Role of Plant Breeding:

Plant breeding has played an important role in enhancing food production:
(i) Triticale is a man-made alloploid developed from Triticum turgidum and Secale cereale.
(ii) Lysine-rich maize varieties like Shakti, Rattan and Protina have been developed.
(iii) Through mutation breeding, more than 200 varieties of crops have been developed.
(iv) Disease resistance in plants has been introduced through breeding.
(v) All the sugarcane varieties that are cultivated today are interspecific hybrids.
(vi) Plant breeding has also given us improved varieties of crops like Sonora-64 of wheat and Taichung Native -1 of rice.

Practical Achievements

Disease resistant varieties have been developed in many crops all over the world. In India, disease resistant varieties have been evolved in wheat, barley, maize, rice, sorghum, sugarcane, cotton, pulses, oilseeds and many other crops. Almost all the currently released varieties of *arboretum* cotton are resistant to *Fusarium* wilt. Many varieties of wheat are resistant to rusts. In sugarcane, several varieties are resistant to red rot and wilt. In okra, a yellow mosaic virus resistant variety Parbhani Kranti has been released. In uplant cotton, variety MCU 5 VT is tolerant to *Verticillium* wilt.

11.5 SUMMARY

Mutation is a heritable change in the genetic material of living organisms and therefore a major driver of species diversity and evolution. Mutation may be spontaneous or induced, and mutants that are better fitted to their environment (natural or man-made) have a selective advantage. Mutation has been a major factor in bringing wild species into domestication and agriculture. Purposeful mutation in plant breeding has been a highly successful strategy. There are currently over 3,220 officially released mutant cultivars in over 210 plant species. Mutant traits can be produced for most if not all breeding goals and include yield, quality, stature, disease, pest resistance, tolerance to abiotic stresses, postharvest degradation, and novel end-user characters. This chapter reviews the current progress and assesses the future directions in mutation breeding for crop improvement with particular reference to physical mutagenesis. It provides a background to plant mutation breeding (impact and challenges), strategies involved, basic and advanced techniques, and provides a critical review of this approach compared with other methods for the genetic improvement of crops. The various mutagens (physical, chemical, and biological) are described. Currently, the vast majority of mutations used in plant breeding and crop production are derived from treatments of physical mutagens. Their effects (biological consequences) and their utility (advantages and disadvantages) are discussed. Furthermore, standard procedures are described for the optimization of mutagenesis and subsequent handling of mutated materials.

All agricultural crops are severely damaged when not protected against pathogens. A comparison of different means of protection has shown that the application of resistance is highly preferable. The great economic importance of this cost-effective and biologically safe means of protection is obvious in all types and areas of plant production. Durability of resistance is a highly variable phenomenon. Insight into the basis of durability is still insufficient. Biotechnology will increase the economic importance of breeding for resistance. It gives us new possibilities not only for the recombination of genetic information, but also for the analysis of host-pathogen relationships and for the improvement of durability of resistance. The significance of resistance and its durability for plant production in all countries and especially in developing countries, justifies that breeding for resistance be given top priority worldwide.

11.6 GLOSSARY

Mutation: Sudden heritable change in the phenotype of an individual or permanent change in the number, kind and sequence of nucleotides in the genetic material.

Spontaneous Mutations: Mutations that occur in nature.

Induced Mutations: Mutations that are induced (produced) by the treatment of mutagenic agents.

Macro-Mutation: Mutation with distinct morphological changes in the phenotype, usually observed in qualitative characters.

Gene: A macro molecule composed of DNA or in some viruses RNA.
Mutant: The product of mutation**.** It may be a genotype, a cell or a polypeptide.
Mutagen: Physical or chemical agents which greatly enhance the frequency of mutation.
Alkylating Agent: Chemical mutagens which cause mutation by adding alkyl group at various position in DNA.
Base Analogues: Chemical compounds which are similar to DNA bases such as 5 bromo uracil and 2 amino purine.
Ionizing Radiations: Radiations which produce ions in the medium through which they pass.
Ultraviolet Rays: Non ionizing radiations produced from mercury vapour lamps or tubes and used for induction of mutation in lower organisms.
X-rays: Sparsely ionizing radiations used for induction of mutation.
Vertical resistance: Resistance of a host to the particular race of a pathogen. Also called major gene resistance, oligogenic resistance and qualitative resistance.
Horizontal Resistance: Resistance of a host to all the prevalent races of a pathogen. Also called general resistance, polygenic resistance, minor gene resistance and nonspecific resistance.
Gene for Gene Hypothesis: This hypothesis states that for each gene controlling resistance in the host, there is a corresponding gene controlling pathogenecity in the pathogen. Also called flor hypothesis after the name of the scientist who developed this concept.
Parasite: An organism or virus which lives upon or within another living organism.
Pest: Any animal or higher plant which parasitizes crop plants, *e.g.* insects, nematodes, birds and parasitic weeds.
Disease: Disorders of crop plants caused by pathogens.
Pathogenicity: Ability of a pathogen to attack a host.
Pathogen: Various disease causing organisms such as fungi, bacteria, viruses and mycoplasmas.
Immune: Completely resistant plants.
Host: The plant attacked by a disease, insect or parasitic weed.
Virulent: A race of pathogen capable of attacking a host with specific resistance.
Avirulent: A pathogen race unable to attack a host with specific resistance.

11.7 SELF ASSESSMENT QUESTION

11.7.1 Very Short Answer Type Questions:

1. Write an alternate source of protein for animal and human nutrition.
2. Name the organism commercially used for the production of SCP.
3. Who discovered the mutation?
4. Name two physical mutagens.
5. What is the full form of IARI?
6. Name one special method of crop improvement.
7. In India how much varieties have been developed through mutation breeding?
8. Name two mutant varieties of wheat.

9. Who give the concept Gene-For-Gene hypothesis?
10. Name the cotton variety tolerant to *Verticillium* wilt.

11.7.2 Objective Type Questions:

1. Sonalika and Kalyan Sona are varieties of :
(a) Wheat (b) Rice
(c) Millet (d) Tobacco

2. Use of certain chemicals and radiation to change the base sequences of genes of crop plants is termed :
(a)Recombinant DNA technology (b) Transgenic mechanism
(c)Mutation breeding (d) Gene therapy

3. Point mutation involves :
(a) Deletion (b) Insertion
(c) Duplication (d) Change in single base pair

4. The action of UV radiation on DNA to induce mutation is the :
(a) Formation of thymine dimmers (b) Methylation of base pairs
(c) Deletion of base pairs (d) Addition of base pairs

5. X-rays causes mutation by :
(a) Deletion (b) Transition
(c) Transversion (d) Base substitution

6. Which of the following is not ionizing radiation:
(a) X-rays (b) UV rays
(c) Cosmic rays (d) Alpha rays

7. Breeding for disease resistance requires:
(a) A good source of resistance (b) Planned hybridization
(c) Disease test (d) All of these

8. Muller was first to produce induced mutations in______by exposing them X-rays.
(a) *Paramecium* (b) *Arabidopsis*
(c)*Drosophila* (d) *Xenopus*

9. In mutational event, when adenine is replaced by guanine, it is case of
(a) Transition (b) Transcription
(c) Transversion (d) Frame shift mutation

10. Plants can be made disease resistant by-------
(a) Heat treatment (b) Hormone treatment

(c) Colchicines treatment (d) Breeding with their wildly growing relatives

11.7.3 Fill in the blanks:

1. ________can be induced by some physical and chemical agents.
2. Mutation breeding utilizes____________only.
3. _______can break chromosomes and produce all types of mutations in nucleotides.
4. Spontaneous mutations in somatic cells of a vegetatively propagated plant are commonly referred to as_______.
5. The Gene-For-Gene hypothesis is also known as___________.

11.7.4 True/False

1. Resistant varieties offer the cheapest mean of disease control.
2. Insect and pest infestation are two minor causes for large destruction of crop plant and crop.
3. Micro-organisms are used for the preparation of fermented foods.
4. SCP can not be produced in laboratories throughout the year.
5. Disease resistance in plants has been introduced through breeding.

11.7.1 Answer key: 1-Single Cell Protein, 2-Spirulina, 3-Wright in 1791, 4-X-rays and UV rays, 5-Indian Agricultural Research Institute, 6-Mutation Breeding, 7-200, 8-Sharbati Sonara & Pusa Lerma, 9-By Flor in 1956, 10-MCU 5 VT

11.7.2 Answer key: 1-a, 2- c, 3- d, 4- a, 5- a, 6- b, 7- d, 8- c, 9- a, 10- d

11.7.3 Answer key: 1- Mutation, 2- Vital mutation, 3- X-rays, 4- SPORTS, 5- Flor hypothesis

11.7.4 Answer key: 1-True, 2- False, 3- True, 4- False, 5-True

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11.9 SUGGESTED READING

- General Plant Breeding by A.R. Dabholkar
- A text book of Plant breeding, by B.D. Singh, Kalyani publication, Ludhiana
- Cell Biology, Genetics and Plant Breeding by P.C.Trivedi
- Plant Breeding by Sandhu S.S.

11.10 TERMINAL QUESTIONS

11.10.1 Long Answer Type Questions:

1. What is mutation? What are the characteristics of mutation? Write its type and stages & frequency at which mutation occurs.
2. What do you mean by mutation breeding? What is the procedure of mutation breeding? Write its achievements and limitations in crop improvements.
3. What do you understand by breeding for disease resistance? Define vertical and horizontal resistance to plant disease.
4. Describe various sources of disease resistance in crop plants. Discuss their usefulness in resistance breeding. Also write the steps in breeding for disease resistance.
5. Explain briefly the various breeding methods used for breeding of disease resistant varieties. Write the advantages of breeding for disease resistance.
6. Write short note on the following :
   - **a)** Flor hypothesis
   - **b)** SCP

11.10.2 Short Answer Type Questions:

1. What is induced mutation? Write its type.
2. What is gene mutation? Give its type.
3. What is mutagen? Give its type.
4. Define the following terms :
   - **a)** Alkylating agents
   - **b)** Base analogues
   - **c)** Mutagenesis
   - **d)** Parasite
   - **e)** Pathogen
5. Write the role of plant breeding for improved food quality.
6. Write short note on the following :
   - **a)** Dose of mutagens
   - **b)** Mutagen treatment
   - **c)** Chromosomal mutation
   - **d)** Selection amongst somaclonal variation.

UNIT-12 CENTRES OF PLANT ORIGIN

12.1 OBJECTIVES

After reading this unit student will be able-

- To know the centers of plant origin.
- To study the centers of plant diversity.
- To differentiate between the centers of origin and diversity.
- To study the uses of centers of plant origin in relation to plant breeding

12.2 INTRODUCTION

Plant breeding is evolution in human hands where new forms of plants with respect to appearance, performance and adaptability are created. Evolution takes millions of years to modify the plants for survival under natural conditions but plant breeding aims to change plants in accordance with human needs. Over a short period of only few years, both these processes of modifying plants however, act as genetic differences among individuals to sort out the most successful ones under natural or human care. In contrast to the long history of evolution under natural selection, plant breeding literally started with the origin of agriculture about 10,000 years ago when initiated domesticating wild species as crop plants. The forces of natural selection acted on genetic variation to favor the most competitive plants as new species under the new sets of environments.

Fig. 12.1 Nikolai I. Vavilov

Nikolai I. Vavilov proposed that crop plants evolved from wild species in the areas showing diversity and termed them as primary centers of origin. It is known that with the movement of man, the crops moved to other areas from these areas. But in some areas, certain crop species show considerable diversity of forms although they did not originate there. Such areas are known as secondary centers of origin of these species.

The center of origin is also considered the center of diversity. Vavilov centers of origin are regions where a high diversity of crop wild relatives can be found, representing the natural relatives of domesticated crop plants. Later in 1935 Vavilov divided the centers into 12 centers known as Vavilov Centers or Chinese Centers of plants.

12.3 CENTERS OF ORIGIN OF PLANTS

What is a center of origin? What is a center of diversity? What is the difference between them? How they defined and used? The answers to that and other questions are answered in this review. “The center of origin” and “center of diversity” have been used interchangeable. Though the two concepts are related and highly intertwined there is a distinction between line of diversity is frequently used to identify the other, though the principle behind centers of origin and diversity applies to all organisms. They are most often used in relation to plants, particularly in plant breeding and studies of crop domestication.

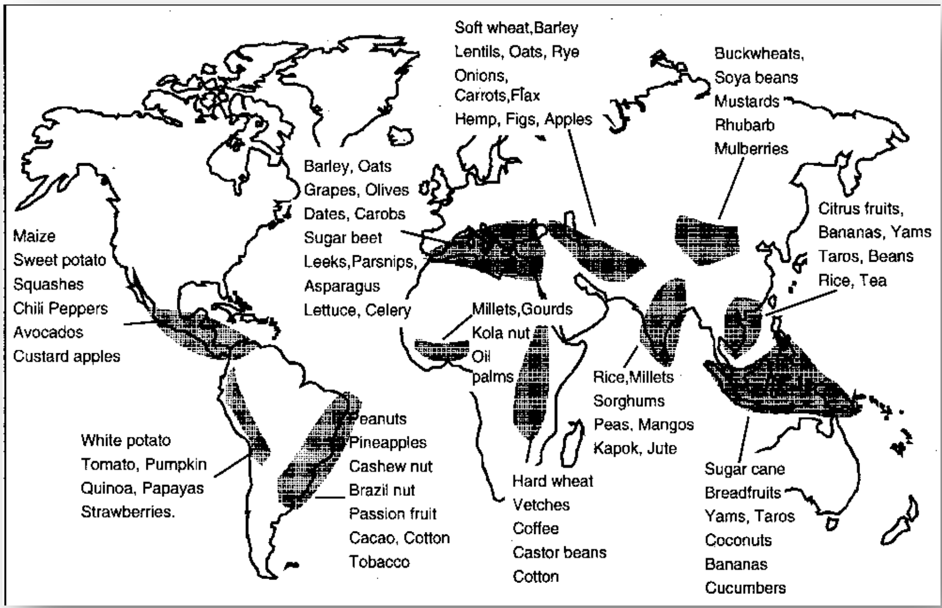

Fig. 12.2 Geographical regions of crop origin in the world

Definition: The center of diversity of a plant is defined as the geographic area wherein the plant exhibits the highest degree of variation. This variation manifests itself both at the population and genetic levels. That is the centers of diversity is where the highest number of cultivated types and wild relatives, as well as gene variants (alleles), exists. Based on the principle that it is only over time that genetic variation can be accumulated, the center of diversity often corresponds to the area where the plant has existed the largest variety.

The center of origin of a plant is that location where it is considered to have first appeared. The primary criterion is identifying a center of origin is the presence of wild relatives. The centers of origin and diversity are highly co-related, they do occasionally diverge. This happens when there is a high variation in cultivated crops, but no or few wild relatives. The variation occurs due to environmental forces and human intervention that may have conspired to increase a plant's diversity away from its site of origin. A plant species may also have more than one center of origin or diversity.

History: The center of origin was first proposed by the Russian Scientist Nikolai Vavilov (1887- 1943). Vavilov headed what was to be eventually named the Vavilov. All Union Institute of Plant Industry from 1920 to 1940. One of his mission was to collect crop relate germplasm for use in national plant breeding projects.

During his exploration, Vavilov observed that crop diversity tends to be concentrated around specific regions. He proposed that these concentrations of high variability indicated the regions

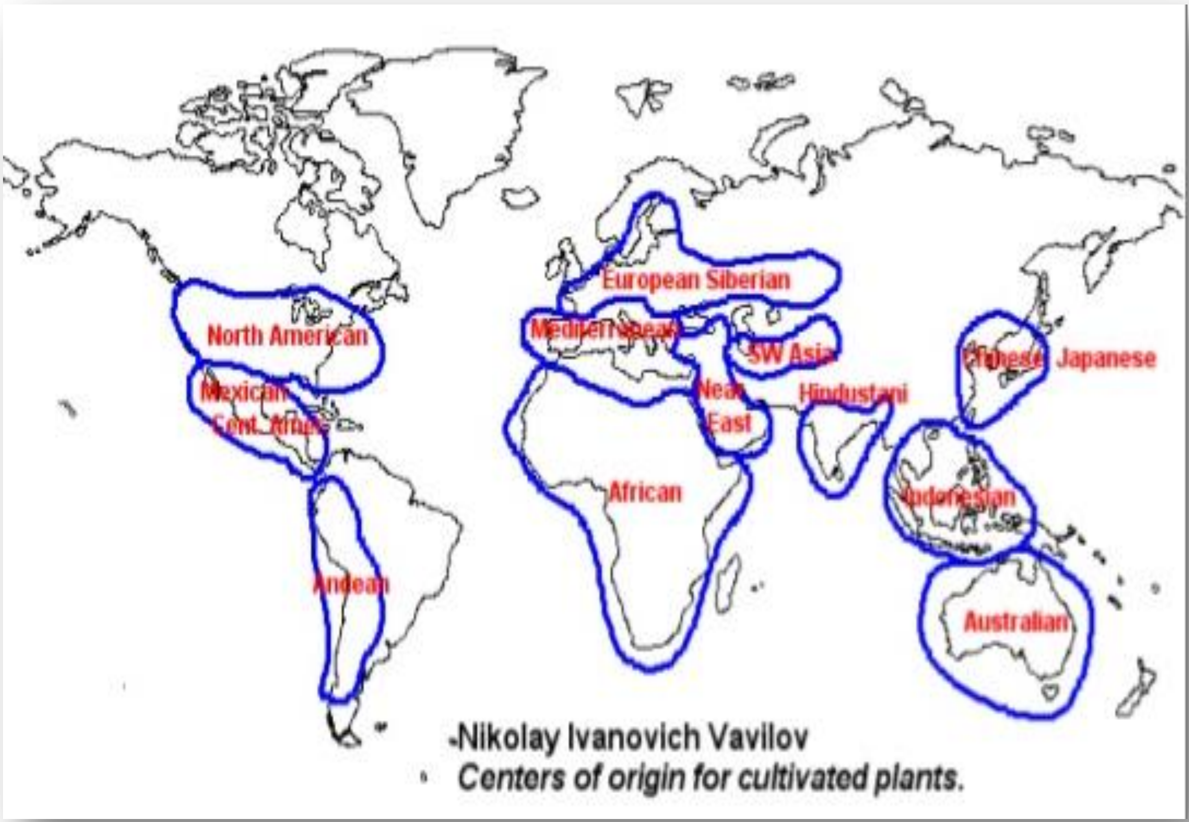

Fig.12.2 Nikolay Ivanovich Vavilov Centres of Origin for cultivated plants

where domestication of these crops began. This concept went against the prevailing view that cultivation of plants started randomly all over the world. In 1926, Vavilov published his theories in his **"Studies on the Origin of Cultivated Plants"**. He identified eight primary areas of diversity and origin of cultivated plants. These areas came to be known as the Vavilov Centers.

The ancient plant breeder's or the stone - age people domesticated all the major food and fiber plants that feed and cover the vast human population today. It is surprising that in some cases the present day cultivated plant forms are so strikingly different from their parental wild (natural), types that makes us to think about their progenitors and the transformation of characters. These transformations were accomplished by primitive plant breeders and not by modern scientists. Even in the early ages farmers were sedentary and tended to occupy a certain area for prolonged period of time than other people who are either nomadic or did not take to farming. During this period they developed new array of varieties of different crop plants to their special need adapted to specific nitches for different crops. After collection of best selected varieties the farmers would move out to other greener pastures and were growing. To carrying the plants from place to place, practiced by our ancestors has been the most important and crucial factors in the development of agriculture throughout the world. While shifting to new areas the shifting to new areas the varieties could come into contact with the distinct races of the same crop and occasional natural crossing between these races. This resulted in a marked increase in the genetic variation.

Alphonse de Candolle was the first botanist who attempted to locate the origin of crop plants. He published a book named “Origin of Cultivated Plants” in 1882 which was reprinted in1959. In his book he used the information on distribution of wild relatives, history, linguistic derivatives, archeology and patterns of variation. Nikolai Ivanovich Vavilov (N. I. Vavilov), the Russian explorer, geneticist and agronomist organized worldwide explorations of a large number of cultivated crops, vegetables, fruit trees, forages and fodder crops plantation crops and wild and related species of economic use and their samples were grown in the appropriate environments and studied for botanical and economic purposes.

N. I. Vavilov proposed that crop plants evolved from wild species in the areas showing diversity and termed as Primary Centers of Origin. From these areas these crops moved to other areas with the movements of man. But certain crop species show considerable diversity of forms in some areas although they did not originate there. Such areas are known as Secondary Centers of Origin of these species. Vavilov has suggested eight main centers of crop origin as below:

Table 1. Centre of Origin of crops according to Nikolai Ivanovski Vavilov

S.No.	**Centre**	**Main Centers**	**Crop Originate**
1.	Chinese	Central & Western China	Reddish, Apricot, Peach, Litchi, Citrus, Soybean
2.	Hindustan	Parts of India & Burma	Rice, Soybean, Cotton, Brinjal, legumes
3.	Central Asiatic	Pakistan, Afghanistan, Punjab, Kashmir, Parts of USSR	Wheat, Pea, Lentil, Apple, Spinach
4.	Near Eastern	Middle East countries	Barley, Wheat, linseed, Grape
5.	Mediterranean	Mediterranean sea	Wheat, Beans, Cabbage, Cauliflower, Sugar beet
6.	Abyssinian	Ethiopia & Eritrea	Coffee, Sesame, Lady’s finger
7.	Central America	Mexico & Neighbouring	Maize, Beans, Chili, Cotton, Pumpkin
8.	South America	Peru, Equator, Bolivia & Egyptian	Cotton, Tobacco, Sweet potato Papaya.

12.4 DOMESTICATION AND INTRODUCTION OF CROPS

Selection of best varieties of plants for future from such hybrid populations led to the development of new derivatives having higher potential and adaptation capacity. The plant breeders have been repeated such a cycle over thousands of years by millions of individuals in many parts of the world, resulting in the creation of an immensely rich heritage of germplasm of each species comprising not only the cultivated varieties but also the weedy and wild species which forms the base of plant genetic resources. The genetic variability has been introduced into plant populations primarily by the occasional movement of agricultural people from place to place or by natural but intermittent introgressive hybridization with weedy races and even with wild relatives of crop mixed with spontaneous mutation and the practice of wide scale growing of varietal mixture.

Collection of superior quality plant species from different parts of world the plant breeders practiced the technique of domestication of such plant species along with the animals etc. However, domestication refers to the process whereby a population of animals or plants becomes accustomed to human provision and control the plant domestication has been defined in various ways as below-

1. The process of bringing wild plants under human management is referred to as plant domestication.

2. The process of bringing wild plants under cultivation by humans is called plant domestication. These domesticated plants are grown on farms and become dependent upon humans for propagation. Domestication changes the physical characteristics of the plants under domestication.

3. The word domestication is used as a synonym of taming, though this word can apply to a single animal, while domestication concerns a population or a species as a whole.

4. Domestication is the process of hereditary recognition of wild plants into domestic and cultivated forms dependent upon the interest and need of people or strictly we can say that it shows the initial stage of human mastery of wild animals and plants.

Actually in certain situations plant breeding may lead to the domestication of wild plants. Domestication of plants is an artificial selection process conducted by humans to produce plants that have more desirable traits than wild plants and which renders them dependent on artificial environments for their continued existence.

Domestication has various purposes as -

The man has brought wild plants from nature under his control and domesticated them for various purposes. Primarily plants have been domesticated for five main purposes viz.

i) Plants domesticated for large - scale food production are generally known as crops including grains, vegetables and fruit crops.

ii) Clothes: Plants domesticated for large cloth productions are referred to as fiber clothes including cotton, jute, sun hemp etc.

iii) Shelter: Plants domesticated for large scale wood production are referred to as timber trees. Such plants are grown for use in house for window, doors and furniture.

iv) Aesthetic: Plants domesticated for decoration purposes are referred as ornamental plants. Such plants are grown in and around the home and are usually known as ornamental or home plants.

v) Medicine: Plants grown for large scale medicine production are called medicinal plants. These plants are used for treatment of various human and animal diseases.

Domestication and its effects:

Domestication is the first step of making the wild species to cultivated plants to bring the wild species under human management according to their need. This process is known as domestication, or in other words domestication of plants is the change of ideo type to adopt them better to manmade (artificial) environment. Due to natural selection or human selection the wild species get changed to cultivated species under domestication. While in nature there is continuous selection by natural forces like temperature, weather, soil, pests, diseases etc. The best suited genotypes acclimatized in the given environment and leaves behind others which are less adaptive in nature. Under domestication most of the characteristics of wild species have been also affected, which involves three processes like mutation or natural selection, hybridization and genetic recombination.

The concept of centres of diversity as centre of origin served as very useful purpose for the future explorers and collectors of plants and many of these areas still remain rich sources of variations. But Vavilov further observed that for some crops the centre of diversity did not include wild relatives of the crops as if these were not centers of origin. Wheat and barley exhibited enormous variation in Abyssinian Centre but no wild relatives were traced here suggesting their domestication in some other areas. Vavilov explained this pattern of distribution in the form of two types of centers.

Primary Centre: Geographical- areas where a crop originated, and had maximum diversity was termed as primary centre.

Secondary Centre: Vavilov believed that for some crops the wild progenitors migrated to other place from the centre of origin and were domesticated where these further developed into advanced and improved differential types through introgression of gene from new types of wild and weedy plant’s such regions of diversity were referred to as secondary centres of origin. The primary centre of maize is Mexico but a secondary centre of waxy maize has developed in China. Another example is the Ethiopian centre where rich variability for tetraploid wheat was reported but there was not a single wild species in Ethiopia.

The Process of Domestication: Generally it is believed that the main factors responsible for plant domestication are- i) natural selection ii) spontaneous (natural) mutation and iii) carefully controlled selective breeding for many of the collective changes associated with domestication. Natural selection and selective breeding have been played some important role in the domesticating throughout history.

Historically, domestication of wheat provides the examples of natural selection and mutation together can play a key role in the process. As the wild wheat fall to the ground to reseed itself when it is ripe, while the domesticated wheat stay on the stem when it is ripe. There is evidence that this importance and critical change came about as a result of a random mutation near the beginning of a cultivation of wheat only due to this mutation wheat harvested and became the seed for the next crop. This wheat was much more useful to farmers and became the basis for the various strains of domesticated wheat that have since been developed. The example of wheat has led some one to speculate that mutations may have been the basis for other early of instances of domestication.

Origin of Crop Plants-

1. Origin of Rice *(Oryza sativa*): Rice or *Oryza sativa* had originated in South and South - East Asia in 300 B. C. The cultivated forms of rice might have been originated from the wild species of rice namely *Oryza perennis*.

Fig.12.3 Domestication of *Oryza sativa*

After that rice moved to China and to Africa and America from India where during domestication three different forms have been originated viz. *indica japonica* and *indic*a *javonica*. Many morphological and physiological characters have occurred during domestication to acclimatize to changed habitats as from normal levels and open sun to shady swamps. Changes in leaf size and shape, grain character and other plant type characters differentiated *Oryza sativa* into three forms.

Species A (with 5 sets of chromosomes abcde) X Species B (with 5 sets of chromosomes a'b'c'd'e')

↓

Hybrid
2n = 20
(aa' bb' cc' dd' ee')

↓ Duplication of two chromosomes

Cultivate *Oryza sativa*
2n = 24 (a a' a")
(a a'a" b b'b" c c'c" d d'd" e e' e")

2. Origin of Wheat: The common wheat *Triticum aestivum* might have been originated about 6,000 years ago in Afghanistan and South Western Himalayas and then moved with man four species of wheat are cultivated e.g. *T. durum, T. eastivum. T. tergidium* and *T.dicoccum* which are allopolyploids. The plant type has get changed with the major changed character in non- brittle rachis during domestication**.**

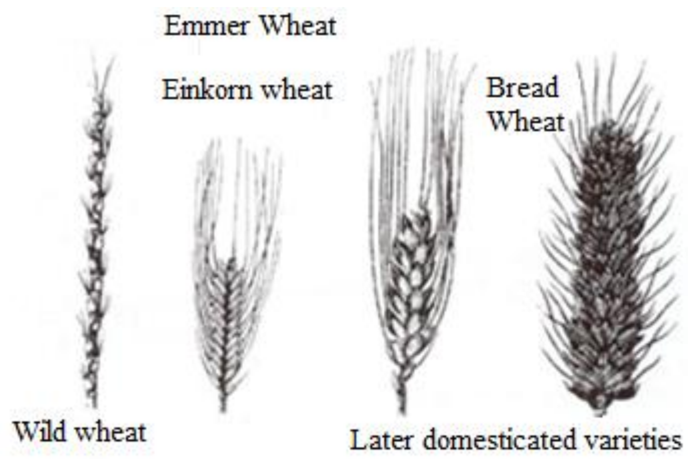

Fig. 12.5: Domestication of wheat

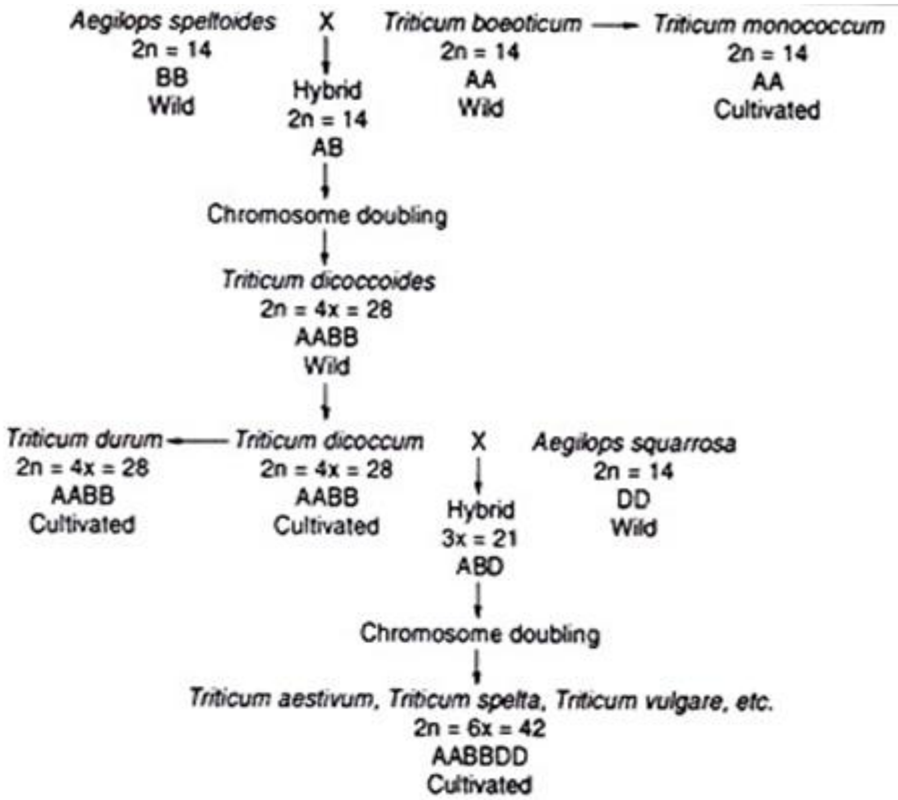

Fig. 12.6 Origin of tetraploid and haxaploid cultivated wheat from new ancestors

Origin of Cotton: Cotton or the Gossypium species is cultivated for fiber production. Out of four species of cotton under cultivation are diploid and rest two are tetraploids. The diploid species of cotton have been originated about 2000 B.C. during Indus civilization. Two species moved to Africa from India and there during domestication the tetraploid species have originated. During domestication the major character has been developed in the corboluted lint and its spinnability. *G. arborium*, G. *herbaceum*, are diploid species whereas G. *hirsutum*, *G. barbadense* are tetraploid species. While the new world cotton is an allopolyploid.

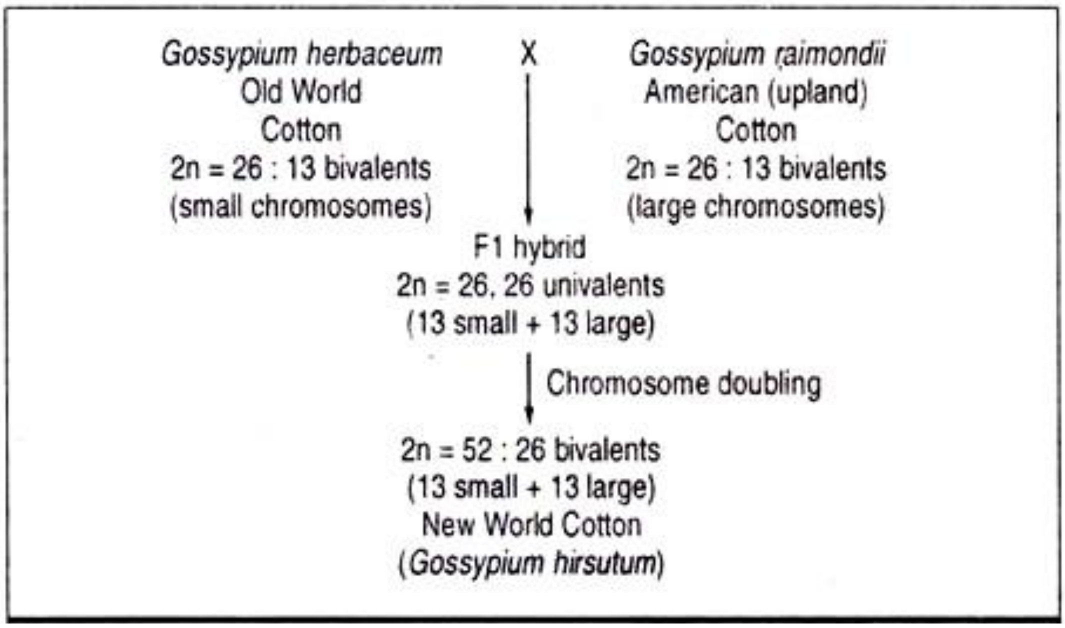

Fig.12.8: Origin of new world cotton from old world and American cotton

Origin of Tea: The centre of origin of tea might have been reported in central China and then differentiated into two types the small leaves china type and broad leaved Assam type. The China type tea *Camellia sinensis* further differentiated and domesticated in South China which has been introduced into India in the early part of 19^{th} Century and the Assam type tea *Camellia assamica* had the secondary Centre of origin in North East India.

Centre of Origin of Maize: Maize also known as corn, is a large grain plant first domesticated by indigenous people in Mexico. Maize was domesticated from its wild grass ancestor more than 8,700 years ago, according to biological evidence uncovered by researchers in Mexico'Central Balsas River Valley. This is the earliest dated evidence- by 1,200 years- for the presence and use of domesticated maize. Maize is the most widely grown grain crop throughout the America, with 332 million metric tons annually in the United States alone. Approximately 40% of the crop- 130 million tons is used for corn ethanol.

The studies carried out at the beginning of the century by Vavilov and others. Vavilov showed that the genetic diversity of cultivated plants are concentrated in certain regions of the world, which they called centres of Origin and diversity.

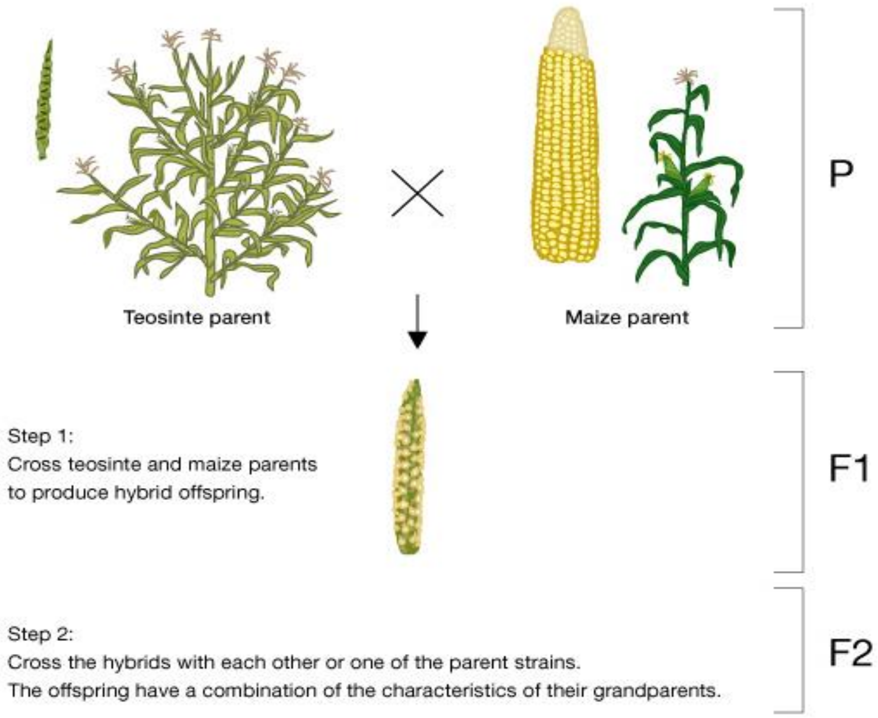

Fig.12.9 Origin of Maize

12.5 SUMMARY

The centre of origin of a plant is that location where it is considered to have first approved. The primary criterion in identifying a centre of origin. A centre of origin (or centre of diversity) is a geographical area where a group of organisms either domesticated or wild, fiber developed its distinctive properties. Nikolai I. Vavilov initially identified 8 of these later subdivided them into 12 in 1935. The study of centres of origin and diversity is helpful in plant breeding and genetic research. The genetic variation in these centres often serves as a rich reserve of genetic material for the improvement of cultivated crops. Genes for disease, pest and stress resistance, and natural quality are just some of the resource that can be found in these areas.

12.6 GLOSSARY

Acclimatization: Adaptation of a variety to new environment.
Biodiversity: Th**e** variability among the living organisms for all sources of soil, water, air or associated with other organisms.
Centre of Origin: The areas of origin of cultivated plant species.
Domestication: The process of bringing a wild species under human management.
Genome: The entire complement of genetic material of an organism or the haploid set of chromosome of any eukaryote.

Hybridization: Crossing between two different strains.
Introduction: Taking a variety into a new area.
Plant Breeding: Plant Science involved in changing the genotype of plants resulting in improved and more useful variety.
Transformation: A process involving introduction and expression of foreign gene (transgene) in the recipient plant.
Variation: The occurrence of difference among individuals due to genetic causes or environmental differences.
Variety: A strain released for commercial cultivation.

12.7 SELF ASSESSMENT QUESTION

12.7.1 Fill in the blanks-

1. The centre of origin of tea might have been reported in ____________.
2. The central China tea differentiated into two types ______China type and ______Assam type.
3. The botanical name of China tea is ___________.
4. The botanical name of Assam tea is _______.
5. Nikolai Vavilov has suggested _______ main centres of crop origin.
6. Rice (*Oryza sativa*) is originated in _______ and ____________.
7. The cultivated forms of rice might have been originated from the wild species of rice namely_______.
8. The common wheat *Triticum* might have been originated about _________ years ago in and ________ ____________ Himalaya.
9. In India ___________ species of wheat are cultivated.
10. The cultivated species of wheat in India are ________, ________, ________ and _______.
11. All the cultivated wheat species in India are ____________.
12. Domestication of plant is an __________ process conducted by____________.

12.7.1 Answers Key: 1. Central China, 2. small leaved, broad leaved, 3. *Camellia chinensis*, 4. *Camellia assamese*, 5.eight, 6. South & South East Asia, 7. *Oryza perennis*, 8. 6,000, Afghanistan and South Western**,** 9. Four, 10. *Triticum durum, T. eastivum, T. tergidium & T. dicoccum*, 11. Allopolyploids, 12. Artificial selection, Humans.

12.8 REFERENCES

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12.10 TERMINAL QUESTIONS

1. Define domestication and describe its main effects on various plant traits?
2. Describe briefly the purpose of plant domestication?
3. Describe briefly centres of origin of tea, maize and cotton?
4. Define primary and secondary centres of crop origin?
5. Describe the contribution of Vavilov for centres of crop origin?
6. Write short notes on center of origin of crop plants and domestication**?**
7. What do you mean by domestication? Discuss the origin of crop plants- rice, wheat, cotton, and tea.?
8. Define the purpose of introduction, its uses, merit and demerits?
9. Define the differences between center of origin and center of diversity of crops?
10. Write short note on Nikolai Ivanovski Vavilov?