Module Title	Cultivation, Collection, Processing and Storage of Drugs of Natural Origin
Subject /Course	Introduction to Pharmacognosy
Subject/Course ID	BP105T
Semester	I
Course coordinator	Dr. Navjot Kaur
Mobile No.	9781232678
Email id	saini.navjotkaur@gmail.com

Learning Outcome of Module 02

LO	Learning Outcome	Course Outcome
LO1	Understand the cultivation, collection, processing, and storage methods of medicinal plants following WHO guidelines.	BP105.2
LO2	Explain the factors affecting the quality and yield of medicinal plants during cultivation and storage.	BP105.2
LO3	Describe the role of plant hormones, polyploidy, mutation, and hybridization in medicinal plant improvement.	BP105.4
LO4	Differentiate between in-situ and ex-situ conservation strategies for medicinal plants.	BP105.2
LO5	Discuss the importance of eco-pharmacognosy in conserving endangered medicinal plants like Kutki and Chirata.	BP105.2

Content Table

GOOD AGRICULTURAL AND COLLECTION PRACTICES (GACP/GAP/GCP) FOR MEDICINAL PLANTS

Good Agricultural and Collection Practices (GACP), also referred to as GAP/GCP guidelines, are standards recommended by the World Health Organization for the cultivation, collection, harvesting, processing, and storage of medicinal plants to ensure their quality, safety, efficacy, and sustainability. WHO published the "WHO Guidelines on Good Agricultural and Collection Practices (GACP) for Medicinal Plants" in **2003**.

These guidelines help:

- Maintain consistent quality of crude drugs
- Prevent contamination and adulteration
- Ensure traceability and safety
- Promote sustainable cultivation and conservation
- Protect medicinal plant biodiversity

Objectives of GACP

- To produce high-quality medicinal plant materials
- To ensure safe and hygienic cultivation practices
- To minimize microbial, chemical, and environmental contamination
- To promote sustainable harvesting and biodiversity conservation
- To standardize cultivation and collection methods

Importance of WHO GACP Guidelines

- Ensures quality, purity, and safety of herbal drugs
- Reduces contamination and adulteration
- Improves international acceptance of herbal medicines
- Supports sustainable medicinal plant conservation
- Promotes standardized cultivation practices
- Protects endangered medicinal plants

Limitations of GACP

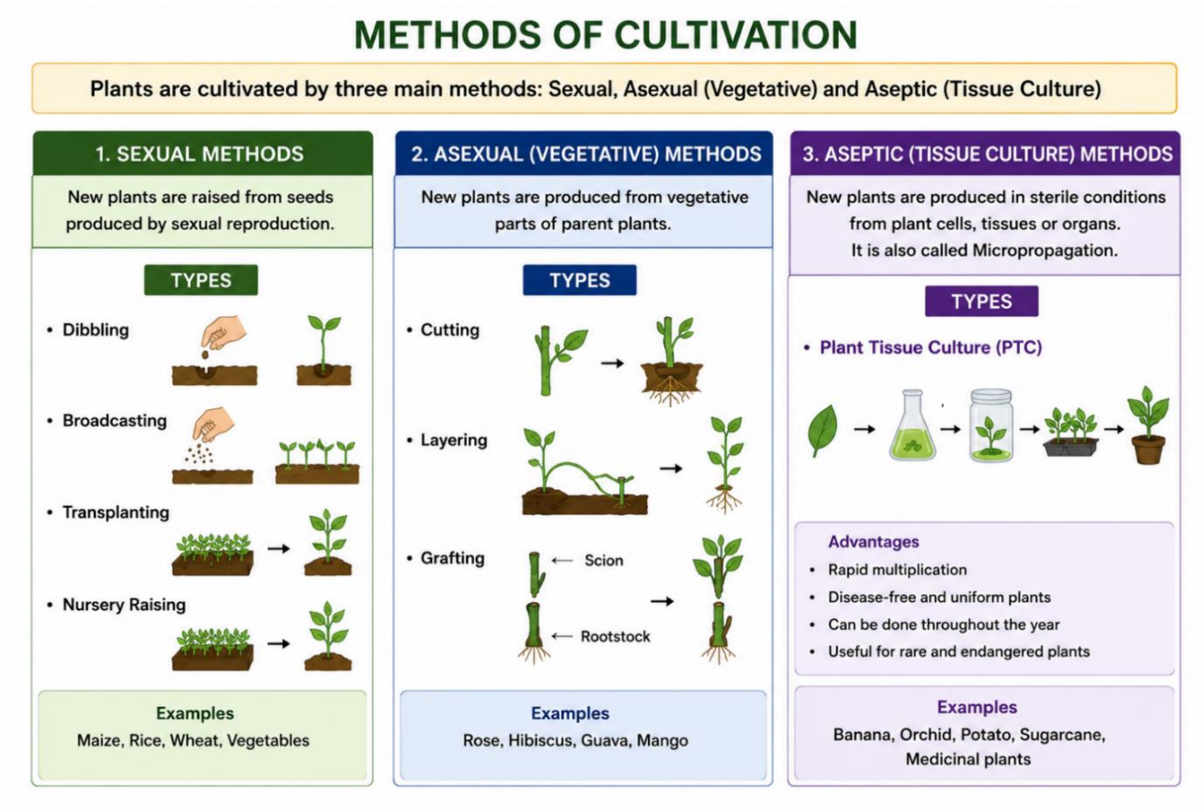
- Requires technical knowledge and training
- Increased cost of cultivation and monitoring
- Difficult implementation in remote forest areas
- Limited awareness among small-scale collectors

CULTIVATION

It involves convergence of various pharmaceutical and environmental factors like rainfall, irrigation, fertilizers, pests, humidity, light and temperature. When all these factors are precisely controlled to grow plants, the process is known as **Cultivation.**

Methods of Plant Propagation

Medicinal plants can be propagated by two usual methods as applicable to nonmedicinal plants or crops.



These methods are referred as sexual method and asexual method.

Sexual Method (Seed Propagation)

In the sexual method of propagation, new plants are produced from seeds, and the resulting plants are known as **seedlings**. Seed propagation is the most common and economical method used for the cultivation of many medicinal plants. Depending on the size, viability, and germination characteristics of the seeds, different sowing methods are employed.

Methods of Sowing Seeds

i. Broadcasting

Broadcasting is used for very small seeds. In this method, seeds are uniformly scattered over well-prepared soil and lightly covered by raking. Deep sowing should be avoided as it may hinder germination. After emergence, excess seedlings are thinned to maintain proper spacing. Examples include Isabgol, linseed, and sesame.

ii. Dibbling

Dibbling involves placing seeds in holes made at suitable distances in the field. The number of seeds sown per hole depends on seed viability, plant size, and cultivation requirements. For example, fennel is usually sown by placing four to five fruits in each hole, whereas castor requires only two to three seeds. In papaya, five to six seeds are sown per hole because only female plants are desirable for cultivation; after sex determination, healthy female plants are retained and the remaining plants are removed.

iii. Nursery Beds and Transplantation

In many medicinal plants, seeds are first sown in nursery beds and the seedlings are later transplanted to the main field. This method is particularly useful for seeds that are very small, expensive, slow-germinating, or have poor germination rates. Examples include cinchona, cardamom, clove, digitalis, and capsicum.

Nursery cultivation offers several advantages, such as better irrigation, disease management, and efficient use of fertilizers during the early stages of growth. Depending on the soil type and water requirements, different types of nursery beds may be used:

- Flat bed method
- Raised bed method
- Ridge and furrow method
- Ring and basin method

The choice of nursery bed depends on the specific requirements of the crop and local environmental conditions.

Special Treatment and Storage of Seeds

To improve germination, seeds are often subjected to pre-sowing treatments. Slow-germinating seeds may be soaked in water for 24 hours, as in castor. Some seeds require chemical scarification, such as treatment with sulphuric acid (e.g., henbane), while others undergo mechanical scarification by scratching or partially removing the seed coat, as in Indian senna. Plant growth regulators such as gibberellins and auxins may also be used to stimulate germination.

Seeds selected for propagation should be healthy, disease-free, and possess a high germination percentage. Their viability can be evaluated by tests such as the rolled towel test and excised embryo test. Scarification is often employed to increase seed coat permeability to water and gases, thereby promoting germination.

When seeds are not intended for immediate sowing, they should be stored in a cool, dry place to maintain viability. Prolonged storage should be avoided as it may reduce germination capacity. Various chemical stimulants, including gibberellic acid (GA_3), cytokinins, ethylene, thiourea, potassium nitrate, and sodium hypochlorite, are commonly used to overcome seed dormancy. GA_3 promotes germination and seedling growth in dormant seeds, potassium nitrate enhances germination in freshly harvested dormant seeds, and thiourea is particularly useful for seeds that fail to germinate under dark conditions or at elevated temperatures.

The sexual method of propagation enjoys following advantages:

- Seedlings are longlived (in case of perennial drugs) and bear more heavily (in case of fruits). Plants are more sturdier.
- Seedlings are comparatively cheaper and easy to raise.
- Propagation from seed has been responsible for production of some chanceseedlings of highly superior merits which may be of great importance to specific products, such as orange, papaya, etc.
- In case of plants where other vegetative methods cannot be utilized, propagation from seeds is the only method of choice.

Sexual method suffers from following **limitations**

- Generally, seedling trees are not uniform in their growth and yielding capacity, as compared to grafted trees.
- They require more time to bear, as compared to grafted plants.
- The cost of harvesting, spraying of pesticides, etc. is more as compared to grafted trees.
- It is not possible to avail of modifying influence of root stocks on scion, as in case of vegetatively propagated trees.

Asexual/ Vegetative Propagation

Vegetative propagation is an asexual method of plant reproduction in which a new plant develops from vegetative parts such as stems, roots, leaves, bulbs, or rhizomes instead of seeds. The separated plant part is placed under suitable environmental conditions, where it develops roots and shoots to form an independent plant. Vegetative propagation is widely used for medicinal plants because it produces genetically identical plants and ensures uniformity in quality and yield.

Vegetative propagation can be classified into three types:

A. Natural Vegetative Propagation

In natural vegetative propagation, new plants arise naturally from modified vegetative organs. These structures are planted in well-prepared soil, where they develop into mature plants.

Vegetative Structure	**Examples**
Bulbs	Squill, Garlic
Tubers	Aconite, Jalap, Potato
Rhizomes	Ginger, Turmeric
Stolons	Liquorice

B. Artificial Vegetative Propagation

Artificial vegetative propagation involves the use of specialized techniques to produce new plants from vegetative parts. These methods are commonly employed for rapid multiplication and preservation of desirable plant characteristics.

1. Cuttings

A portion of the stem, root, or leaf is detached from the parent plant and induced to develop into a new plant.

- Stem Cuttings
- Softwood cuttings: Berberry
- Semi-hardwood cuttings: Citrus, Camellia
- Hardwood cuttings: Orange, Rose, Bougainvillea

Root Cuttings

- Brahmi

Leaf Cuttings

- Bryophyllum

2. Layering

In layering, roots are induced on a stem while it remains attached to the parent plant. After root formation, the rooted portion is separated and planted.

- Simple layering: Guava, Lemon
- Serpentine layering: Jasmine, Clematis
- Air layering (Gootee): Ficus, Mango, Bougainvillea, Cashew nut
- Mound layering
- Trench layering
- Tip layering

3. Grafting

Grafting involves joining a scion (shoot portion) of one plant to the rootstock of another so that they grow as a single plant.

- Whip grafting: Apple, Rose

- Tongue grafting
- Side grafting: Sapota, Cashew nut
- Approach grafting: Guava, Sapota
- Stone grafting: Mango

Asexual propagation enjoys following **advantages**:

- There is no variation between the plant grown and plant from which it is grown. As such, the plants are uniform in growth and yielding capacity. In case of fruit trees, uniformity in fruit quality makes harvesting and marketing easy.
- Seedless varieties of fruits can only be propagated vegetatively e.g. grapes, pomegranates and lemon.
- Plants start bearing earlier as compared to seedling trees.
- Budding or grafting encourages diseaseresistant varieties of plants.
- Modifying influence of rootstocks on scion can be availed of.
- Inferior or unsuitable varieties can be overlooked.

It suffers from following **disadvantages**:

- In comparison to seedling trees, these are not vigorous in growth and are not longlived.
- No new varieties can be evolved by this method.

C. Aseptic Micropropagation (Tissue Culture)

Micropropagation is a modern method of vegetative propagation carried out under sterile (aseptic) laboratory conditions. Small plant parts such as single cells, callus tissues, seeds, embryos, shoot tips, root tips, or pollen grains are cultured on a nutrient medium containing appropriate growth regulators. Under controlled environmental conditions, these explants develop into complete plants. Tissue culture enables rapid multiplication of disease-free and genetically uniform medicinal plants and is widely used for the large-scale production of valuable species.

Methods of Irrigation

Water is essential for any type of cultivation. After studying the availably and requirement of water for a specific crop, one has to design his own irrigation system at the reasonable cost. Following methods of irrigation are known traditionally in India. The cultivation has an option after giving due consideration to the merits and demerits of each.

- Hand watering: economical and easy to operate.
- Flood watering: easy to operate, results in wastage of water.
- Boom watering: easy to operate, but restricted utility.

- Drip irrigation: Scientific, systematic and easy to operate; costly. 5.Sprinkler irrigation: Costly, gives good results.

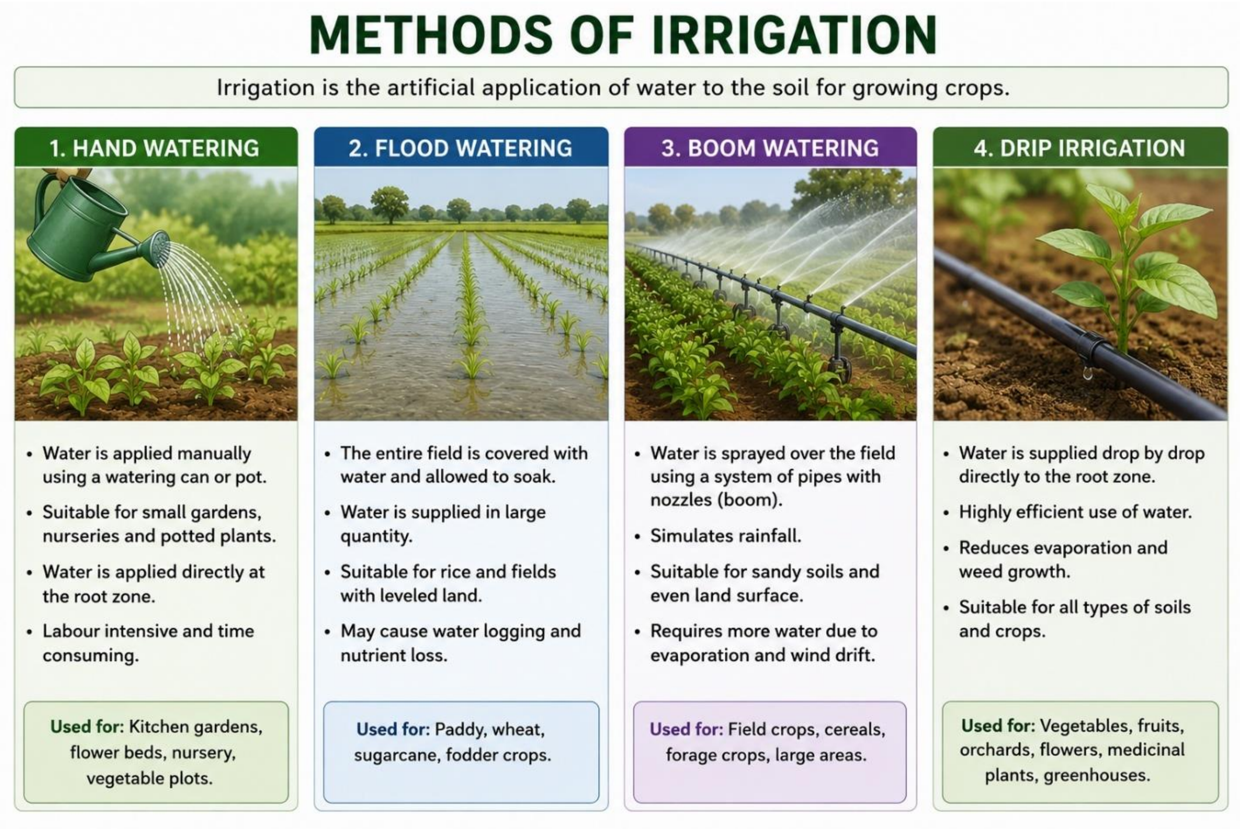


Figure 1: Methods of Irrigation

COLLECTION AND HARVESTING OF MEDICINAL PLANTS

The collection and harvesting of medicinal plants play a crucial role in ensuring the quality, safety, and efficacy of herbal drugs. Medicinal plant materials should be collected during the appropriate season and at the stage of growth when the concentration of biologically active constituents is at its maximum. The optimal harvesting time depends on the plant species, plant part used, and intended medicinal purpose. The quality peak may vary with the season, developmental stage, and even the time of day. Therefore, harvesting should be based on the concentration of active constituents rather than the total vegetative yield.

For example, the alkaloid content in the leaves of *Hyoscyamus niger* and *Atropa belladonna* is highest at the beginning of flowering, whereas in *Datura stramonium* the maximum alkaloid content is observed during full bloom. Similarly, leaves of *Datura stramonium* collected in the morning contain a higher concentration of alkaloids than those harvested in the evening.

During collection, medicinal plant materials should be handled carefully to prevent contamination and deterioration. The collected material should not come into direct contact with soil, and any adhering soil on underground parts such as roots, rhizomes, and tubers should be removed immediately after collection. Plant materials should be gathered in clean baskets, mesh bags, or other well-aerated containers free from contaminants and residues from previous collections. Different plant species and plant parts should be collected and transported separately to avoid cross-contamination.

Following collection, preliminary processing may be carried out, including cleaning, washing, sorting, removal of foreign matter, and cutting of plant materials. The collected material should be protected from insects, rodents, birds, livestock, and domestic animals. If transportation to processing facilities is delayed, the plant material may be air-dried or sun-dried before transport to prevent spoilage.

WHO Guidelines for Harvesting Medicinal Plants

According to WHO guidelines, medicinal plants should be harvested under conditions that ensure maximum quality and safety. Harvesting should preferably be carried out during dry weather, avoiding rain, dew, wet soil, or excessive humidity. Damaged, diseased, or deteriorated plant parts should be excluded. Care should be taken to prevent contamination with weeds, toxic plants, soil particles, or other foreign matter.

All containers used during harvesting must be clean and stored in dry, pest-free conditions when not in use. Mechanical damage caused by overfilling or excessive stacking of harvested materials should be avoided, as it may reduce product quality. Freshly harvested materials should be transported to processing facilities as quickly as possible to prevent thermal degradation and microbial growth. Any pest control measures applied during harvesting or storage should be properly documented.

Methods of Harvesting Medicinal Plants

Harvesting may be carried out manually or mechanically depending on the type of plant material and economic considerations.

- **Manual Harvesting:** Skilled workers collect plant materials by hand, allowing accurate selection and rejection of adulterants or unwanted materials. This method is essential for drugs such as **Digitalis, Tea, Vinca, and Senna leaves**.
- **Mechanical Harvesting of Underground Parts:** Roots, rhizomes, tubers, and bulbs are harvested using mechanical diggers or lifters. After harvesting, they are thoroughly washed to remove adhering soil.
- **Harvesting of Aerial Parts:** Whole aerial parts of plants are often harvested using binders

for economical large-scale collection.

- **Seed Strippers:** Flowers, seeds, and small fruits are harvested using specialized seed-stripping devices.
- **Beating Method:** In crops such as **clove**, branches are gently beaten with bamboo sticks to collect the mature flower buds.
- **Brushing Method: Cochineal insects** are collected from cactus branches by brushing.
- **Harvesting of Marine Drugs:** Seaweeds used for agar production are collected using long-handled forks.
- **Mowers and Reaping Machines: Peppermint** and **spearmint** are harvested using mowers, whereas **fennel, coriander, and caraway** plants are uprooted and dried. The dried plants are then threshed or beaten, and the fruits are separated by winnowing. Reaping machines may also be used for large-scale harvesting.

Proper collection and harvesting practices ensure the production of high-quality medicinal plant materials and contribute significantly to the standardization, safety, and therapeutic effectiveness of herbal drugs.

Table 1: Collection of various crude drugs

PRIMARY PROCESSING:

- Harvested or collected raw medicinal plant materials should be promptly unloaded and unpacked upon arrival at the processing facility. Prior to processing, the medicinal plant materials should be protected from rain, moisture and any other conditions that might cause deterioration. Medicinal plant materials should be exposed to direct sunlight only where

S. No.	Plant Parts	Time of Collection
1	Bulbs	Late autumn, long after the plant has flowered and fruited is usually best.
2	Barks	Autumn (after leaf fall) or spring (before development of leaves) is generally selected.
3	Roots and Rhizomes	From annuals: shortly before flowering. From biennials: during autumn or winter following the first year growth. From perennials: during autumn or winter following the second or third year’s growth.
4	Leaves	Collection should be done in dry weather while the plant is flowering. It is preferable to collect stems bearing leaves and separate them later. Morning collection is important in some cases, e.g., solanaceous leaves.
5	Flowers	Collection should be done in dry weather and towards the middle of the day after dew has disappeared.
6	Seeds and Fruits	Collection should be done when fully grown and ripe or nearly ripe. In plants showing active seed dispersal, collection is advantageous slightly earlier, e.g., cardamom and strophanthus.

there is a specific need for this mode of drying.

- Medicinal plant materials that are to be used in the fresh state should be harvested/collected and delivered as quickly as possible to the processing facility in order to prevent microbial fermentation and thermal degradation.
- The materials may be stored under refrigeration, in jars, in sandboxes, or using enzymatic and other appropriate conservation measures immediately following harvest/collection and during transit to the end-user. The use of preservatives should be avoided if used, they should conform to national and/or regional regulations for growers/collectors and end-users.
- Medicinal plant materials that are to be employed fresh should be stored under refrigeration, in jars, in sandboxes, or using enzymatic or other appropriate conservation measures, and transported to the end-user in the most expeditious manner possible.
- The use of preservatives should be avoided. If used, this should be documented and they should conform to national and/or regional regulatory requirements in both the source country and the end-user country.
- All medicinal plant materials should be inspected during the primary-processing stages of production, and any substandard products or foreign matter should be eliminated mechanically or by hand.
- For example, dried medicinal plant materials should be inspected, sieved or winnowed to remove discoloured, mouldy or damaged materials, as well as soil, stones and other foreign matter. Mechanical devices such as sieves should be regularly cleaned and maintained.
- All processed medicinal plant materials should be protected from contamination and decomposition as well as from insects, rodents, birds and other pests, and from livestock and domestic animals.

DRYING OF CRUDE DRUGS

Before marketing a crude drug, it is necessary to process it properly, so as to preserve it for a longer time and also to acquire better pharmaceutical elegance. This processing includes several operations or treatments, depending upon the source of the crude drug (animal or plant) and its chemical nature.

Drying is an important post-harvest operation used to remove moisture from crude drugs, thereby preventing microbial growth, enzymatic degradation, and deterioration during storage. It also helps preserve the active constituents and maintain the quality of the drug.

Drying methods are broadly classified into **natural drying** and **artificial drying**.

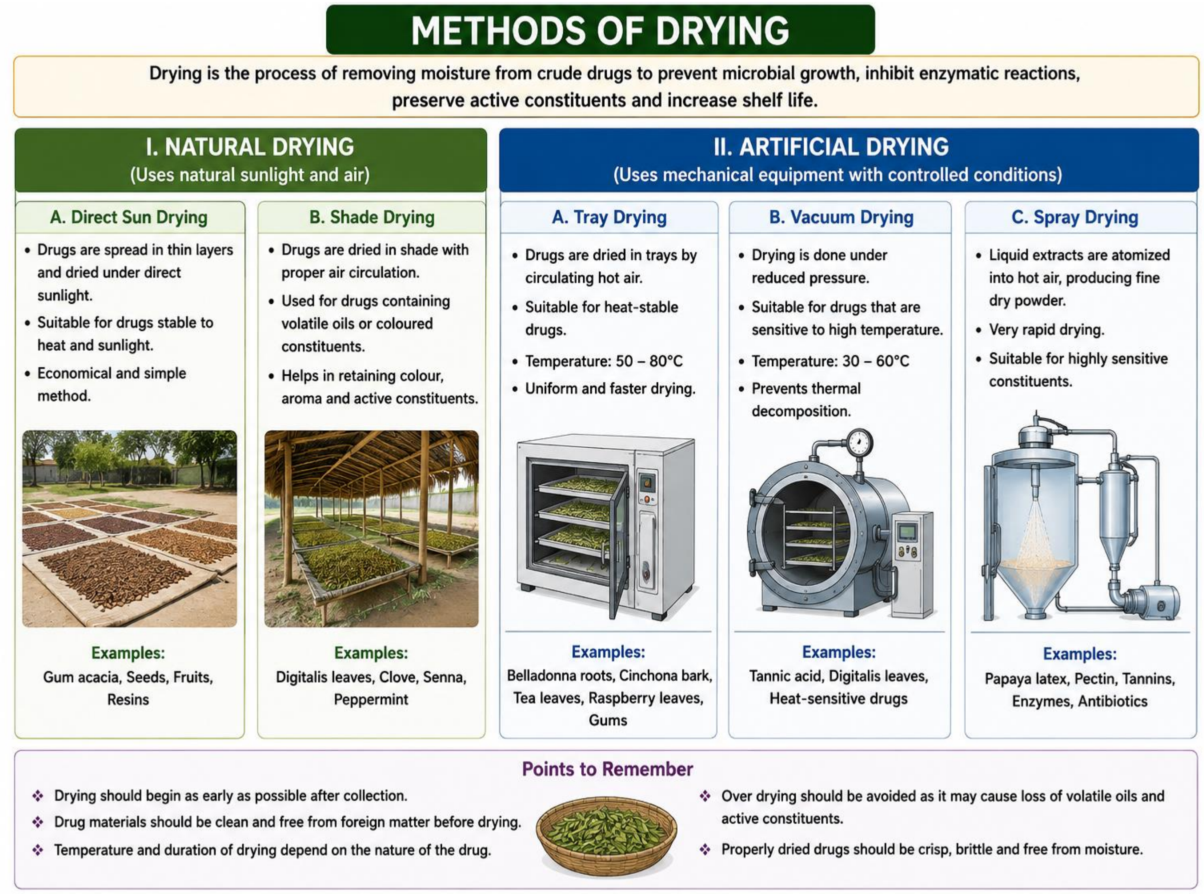


Figure 2: Methods of drying of Natural Drugs

1. Natural Drying

Natural drying utilizes sunlight and natural air circulation and may be carried out either in direct sunlight or in shade.

Sun Drying: Drugs containing heat-stable constituents can be dried directly in sunlight. This method is commonly used for **gum acacia, seeds, and fruits**.

Shade Drying: Drugs containing volatile oils or those whose natural color must be preserved are dried in the shade. Examples include **digitalis leaves, cloves, senna leaves, and peppermint**, where shade drying prevents loss of volatile constituents and discoloration.

2. Artificial Drying

Artificial drying employs controlled conditions of temperature and humidity and is suitable for large-scale commercial processing. Common methods include tray drying, vacuum drying, and spray drying.

a) Tray Dryers

Tray dryers are used for drugs that are stable to heat and do not contain significant amounts of volatile oils. Hot air is circulated through trays containing the drug material, facilitating rapid moisture removal. This method is also useful for deactivating enzymes. Examples include **belladonna roots, cinchona bark, tea leaves, raspberry leaves, and gums**.

b) Vacuum Dryers

Vacuum drying is employed for drugs that are sensitive to high temperatures. Since drying occurs under reduced pressure, moisture is removed at lower temperatures, minimizing degradation of active constituents. Examples include **digitalis leaves** and **tannic acid**.

c) Spray Dryers

Spray drying is used for materials that are highly sensitive to atmospheric conditions and temperature. The liquid or semi-liquid material is converted into a fine mist and rapidly dried by a stream of hot air. This method is generally used for plant extracts and valuable constituents rather than crude drugs. Examples include **papaya latex, pectin, and tannins**.

Drying consists of removal of sufficient moisture content of crude drug, so as to improve its quality and make it resistant to the growth of microorganisms. Drying inhibits partially enzymatic reactions.

Drying also facilitates pulverizing or grinding of a crude drug. In certain drugs, some special methods are required to be followed to attain specific standards, e.g. fermentation in case of Cinnamomum zeylanicum bark and gentian roots.

The slicing and cutting into smaller pieces is done to enhance drying, as in case of glycyrrhiza, squill and calumba. The flowers are dried in shade so as to retain their colour and volatile oil content. Depending upon the type of chemical constituents, a method of drying can be used for a crude drug.

Thus, the choice of drying method depends on the nature of the crude drug, the stability of its active constituents, and the desired quality of the final product.

GARBLING (DRESSING)

The next step in preparation of crude drug for market after drying is garbling. This process is desired when sand, dirt and foreign organic parts of the same plant, not constituting drug are required to be removed. This foreign organic matter (extraneous matter) is removed by several ways and means available and practicable at the site of the preparation of the drugs. If the extraneous matter is permitted in crude drugs, the quality of drug surfers and at times, it does not pass pharmacopeial limits. Excessive stems in case of lobelia and stramonium need to be removed, while the stalks, in case of cloves are to be deleted. Drugs constituting rhizomes need to be separated carefully from roots and rootlets and also stem bases. Pieces of iron must be removed with the magnet in case of castor seeds before crushing and by shifting in case of vinca and senna leaves. Pieces of bark should be removed by peeling as in gum acacia.

PACKING OF CRUDE DRUGS

The morphological and chemical nature of drug, its ultimate use and effects of climatic conditions during transportation and storage should be taken into consideration while packing the drugs.

- Aloe is packed in goat skin.
- Colophony and balsam of tolu are packed in kerosene tins, while asafoetida is stored in well closed containers to prevent loss of volatile oil.
- Cod liver oil, being sensitive to sunlight, should be stored in such containers, which will not have effect of sunlight.
- The leaf drugs like senna, vinca and others are pressed and baled. The drugs which are very sensitive to moisture and also costly at the same time need special attention, e.g. digitalis, ergot and squill. Squill becomes flexible; ergot becomes susceptible to the microbial growth, while digitalis looses its potency due to decomposition of glycosides, if brought in contact with excess of moisture during storage. Hence, the chemicals which absorb excessive moisture (desiccating agents) from the drug are incorporated in the containers.
- Colophony needs to be packed in big masses to control autooxidation.
- Cinnamon bark, which is available in the form of quills, is packed one inside the other quill, so as to facilitate transport and to prevent volatilization of oil from the drug.
- The crude drugs like roots, seeds and others do not need special attention and are packed in gunny bags, while in some cases bags are coated with polythene internally. The weight of certain drugs in lots is also kept constant e.g. Indian opium.

STORAGE

Storage facilities for medicinal material should be well aerated, dry and protected from light, and, when necessary, be supplied with air-conditioning and humidity control equipment as well as facilities to protect against rodents, insects and livestock.

- The floor should be tidy, without cracks and easy to clean. Medicinal material should be stored on shelves which keep the material a sufficient distance from the walls; measures should be taken to prevent the occurrence of pest infestation, mould formation, rotting or loss of oil; andinspections should be carried out at regular intervals.
- Continuous in-process quality control measures should be implemented to eliminate

substandard materials, contaminants and foreign matter prior to and during the final stages of packaging. Processed medicinal plant materials should be packaged in clean, dry boxes, sacks, bags or other containers in accordance with standard operating procedures and national and/or regional regulations of the producer and the end-user countries.

- Materials used for packaging should be non-polluting, clean, dry and in undamaged condition and should conform to the quality requirements for the medicinal plant materials concerned. Fragile medicinal plant materials should be packaged in rigid containers.
- Dried medicinal plants/herbal drugs, including essential oils, should be stored in a dry, well- aerated building, in which daily temperature fluctuations are limited and good aeration is ensured
- Fresh medicinal plant materials should be stored at appropriate low temperatures, ideally at 2- 8°C; frozen products should be stored at less than -20°C.
- Small quantity of crude drugs could be readily stored in air tight, moisture proof and light proof container such as tin, cans, covered metal tins or amber glass containers.
- Wooden boxes and paper bags should not be used for storage of crude drugs.
- A number of drugs absorb moisture during their storage and become susceptible to the microbial growth. Some drugs absorb moisture to the extent of 25% of their weight. The moisture, not only increases the bulk of the drug, but also causes impairment in the quality of crude drug. The excessive moisture facilitates enzymatic reactions resulting in decomposition of active constituents e.g. digitalis leaves and wild cherry bark. Gentian and ergot receive mould infestation due to excessive moisture.
- Radiation due to direct sunlight also causes destruction of active chemical constituents, e.g. ergot, cod liver oil and digitalis. Form or shape of the drug also plays very important role in preserving the crude drugs. Colophony in the entire form (big masses) is preserved nicely, but if stored in powdered form, it gets oxidized or looses solubility in petroleum ether.
- Squill, when stored in powdered form becomes hygroscopic and forms rubbery mass on prolonged exposure to air. The fixed oil in the powdered ergot becomes rancid on storage.
- In order to maintain a good quality of ergot, it is required that the drug should be defatted with lipid solvent prior to storage.
- Lard, the purified internal fat of the abdomen of the hog, is to be preserved against rancidity by adding siam benzoin.
- Atmospheric oxygen is also destructive to several drugs and hence, they are filled

completely in well closed containers, or the air in the container is replaced by an inert gas like nitrogen; e.g. shark liver oil, papain, etc.

FACTORS AFFECTING CULTIVATION

Cultivation of medicinal plants offers wide range of advantages over the plants obtained from wild sources. There are few factors to concern which have a real effect on plant growth and development, nature and quantity of secondary metabolites. The factors affecting cultivation are altitude, temperature, rainfall, length of day, day light, soil and soil fertility, fertilizers and pests. The effects of these factors have been studied by growing particular plants in different environmental conditions and observing variations.

Altitude

Altitude is a very important factor in cultivation of medicinal plants. Tea, cinchona and eucalyptus are cultivated favour-ably at an altitude of 1,000–2,000 metres. Cinnamon and cardamom are grown at a height of 500–1000 metres, while senna can be cultivated at sea level. The following are the examples of medicinal and aromatic plants indicating the altitude for their successful cultivation (Table below).

Table 2: The suitable altitudes required for cultivation of Crude Drugs

Plant	**Altitude (Meters)**
Tea	1000-1500
Cinchona	1000-2000
Camphor	1500-2000
Cinnamon	250-1000
Coffee	1000-2000
Clove	Up to 900
Saffron	Up to 1250
Cardamom	600-1600

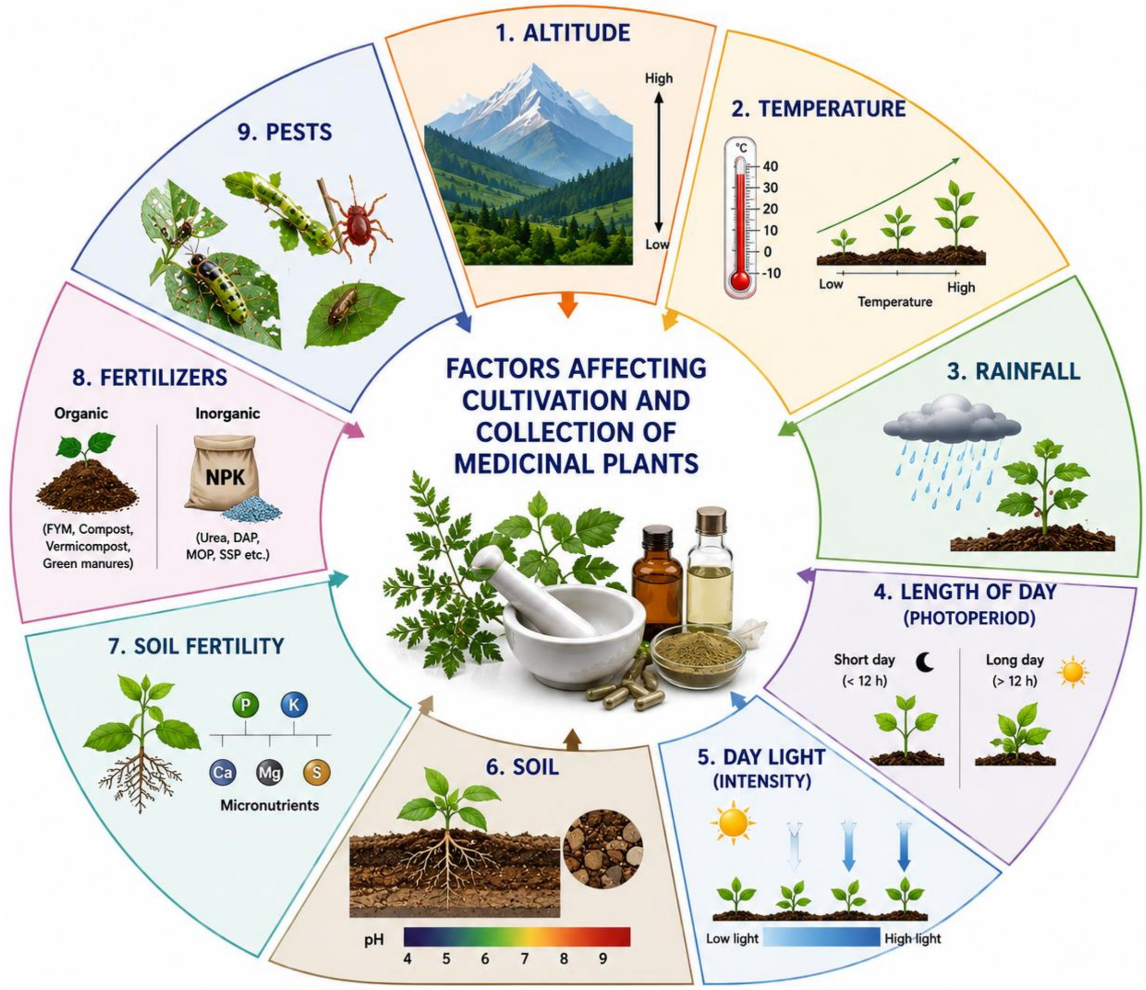


Figure 3: Factor affecting Cultivation and Collection of medicinal plants

Temperature

Temperature is a crucial factor controlling the growth, metabolism and there by the yield of secondary metabolites of plants. Even though each species has become adapted to its own natural environment, they are able to exist in a considerable range of temperature. Many plants will grow better in temperate regions during summer, but they lack in resistance to withstand frost in winter.

Table 3: Optimum Temperature for Drug Cultivation

Plant	**Optimum temperature (◦F)**
Cinchona	60-75
Coffee	55-70
Tea	70-90
Cardamom	50-100

Rainfall

For the proper development of plant, rainfall is required in proper measurements. Xerophytic plants like aloes do not require irrigation or rainfall. The effects of rainfall on plants must be considered in relation to the annual rainfall throughout the year with the water holding properties of the soil. Variable results have been reported for the production of constituents under different conditions of rainfall. Excessive rainfall could cause a reduction in the secondary metabolitesdue to leaching of water soluble substances from the plants.

Day Length and Day Light

It has been proved that even the length of the day has an effect over the metabolites production. The plants that are kept in long day conditions may contain more or less amount of constituents when compared to the plants kept in short day. For example peppermint has produced menthone, menthol and traces of menthofuran in long day conditions and only menthofuran in short day condition.

The developments of plants very much in both the amount and intensity of the light they require. The wild grown plants would meet the required conditions and so they grow but during cultivation we have to fulfill the requirements of plants. The day light was found to increase the amount of alkaloids in belladonna, stramonium, cinchona, etc. Even the type of radiation too has an effect over the development and metabolites of plants.

Soil

Each and every plant species have its own soil and nutritive requirements. The three important basic characteristics of soils are their physical, chemical and microbiological properties. Soil provides mechanical support, water and essential foods for the development of plants. Soil consists of air, water, mineral matters and organic matters. Variations in particle size result in different soils ranging from clay, sand and gravel. Particle size influences the water holding capacity of soil.

The type and amount of minerals plays a vital role in plant cultivation. Calcium favours the growth of certain plants whereas with some plants it does not produce any effects. The plants are able to determine their own soil pH range for their growth; microbes should be taken in to consideration which grows well in certain pH. Nitrogen containing soil has a great momentum in raising the production of alkaloids in some plants. Depending upon the size of the mineral matter, the following names are given to the soil.

Table 4: Type of soil on the basis of particle size.

Particle size (Diameter)	Type of soil
Less than 0.002 mm	Fine Clay
0.002-0.02 mm	Coarse clay or silt
0.02-0.2 mm	Fine sand
0.2- 2.0 mm	Coarse sand

Depending upon the percentage covered by clay, soils are classified as under (Table below.).

Table 5: Type of soil on the basis of percentage covered by clay.

Type of soil	Percentage covered by Clay
Clay	More than 50 % of clay
Loamy	30-50% of clay
Silt loam	20-30% of clay
Sandy loam	10-20% of clay
Sandy soil	More than 70 % sand
Calcarious soil	More than 20 % of lime

Soil Fertility

It is the capacity of soil to provide nutrients in adequate amounts and in balanced proportion to plants. If cropping is done without fortification of soil with plant nutrients, soil fertility gets lost. It is also diminished through leaching and erosion. Soil fertility can be maintained by addition of animal manures, nitrogen-fixing bacteria or by application of chemical fertilizers. The latter is time saving and surest of all above techniques.

Fertilizers and Manures

Plant also needs food for their growth and development. What plants need basically for their growth are the carbon dioxide, sun-rays, water and mineral matter from the soil. Thus, it is seen that with limited number of chemical elements, plants build up fruits, grains, fibres, etc. and synthesize fixed and volatile oils, glycosides, alkaloids, sugar and many more chemicals.

Chemical fertilizers

Animals are in need of vitamins, plants are in need of sixteen nutrient elements for synthesizing various com-pounds. Some of them are known as primary nutrients like nitrogen, phosphorus and potassium. Magnesium, calcium and sulphur are required in small quantities and hence, they are known as secondary nutrients. Trace elements like copper, manganese, iron, boron, molybdenum, zinc are also necessary for plant growths are known as micronutrients. Carbon, hydrogen, oxygen and chlorine are provided from water and air. Every element has to perform some specific function in growth and development of plants. Its deficiency is also characterized by certain symptoms.

Figure 4: Types of Fertilizer, Manures and Biofertilizers

Manures

Farm yard manure (FYM/compost), castor seed cake, poultry manures, neem and karanj seed cakes vermin compost, etc. are manures. Oil-cake and compost normally consists of 3–6% of nitrogen, 2% phosphates and 1–1.5% potash. They are made easily available to plants. Bone meal, fish meal, biogas slurry, blood meal and press mud are the other forms of organic fertilizers.

Biofertilizers

Inadequate supply, high costs and undesirable effects if used successively are the demerits of fertilizers or manures and hence the cultivator has to opt for some other type of fertilizer. Biofertilizers are the most suitable forms that can be tried. These consist of different types of micro organisms or lower organisms which fix the atmospheric nitrogen in soil and plant can use them for their day to day use. Thus they are symbiotic. Rhizobium, Azotobactor, Azosperillium, Bijericcia, Blue-green algae, Azolla, etc. are the examples of biofertilizers.

Pests and Pests Control

Pests are undesired plant or animal species that causes a great damage to the plants. There are different types of pests; they are microbes, insects, non insect pests and weeds.

Microbes

They include fungi, bacteria and viruses. Armillaria Root Rot (Oak Root Fungus) is a disease caused by fungi *Armil-laria mellea* (Marasmiaceae) and in this the infected plant become nonproductive and very frequently dies within two to four years. Plants develop weak, shorter shoots as they are infected by the pathogen. Dark, root-like structures (rhizomorphs), grow into the soil after symptoms develop on plants. The fungus is favoured by soil that is continually damp. Powdery mildew is another disease caused by fungus *Uncinula necato* on leaves, where chlorotic spots appear on the upper surface of leaf. On fruit the pathogen appears as white, powdery masses that may colonize the entire berry surface. Summer Bunch Rot is a disease in which masses of black, brown, or green spores develop on the surface of infected berries caused by a variety microbes like *Aspergillus niger, Alternaria tennis, Botrytis cinerea, Cladosporium herbarum, Rhizopus arrhizus,* Penicillium sp., and others.

Fomitopsis pinicola (Sw.) P. Karst. Belonging to family Fomitopsidaceae causes a diseases known as red-belted fungus. Several other fungi attacks the medicinal plants, like *Pythium pinosurn* causes pythium rhizome rot, *Septoria digitalis* causing leaf spot, little leaf disease by *Phywphthora cinnamomi* Rands (Pythiaceae), etc.

Crown gall disease caused by *Agrobacterium tumefaciens* (Rblzobiaceae). Galls may be produced on canes, trunks, roots, and cordons and may grow to several inches in diameter. Internally galls are soft and have the appearance of disorganized tissue. The pathogen can be transmitted by any agent that contacts the contaminated material. Galls commonly develop where plants have been injured during cultivation or pruning. *Xylella fastidiosa* is a bacterium causes Pierce’s Disease, in this leaves become slightly yellow or red along margins and eventually leaf margins dry or die.

Many viruses are also reported to cause necrosis of leaves, petioles and stems, they are tobacco mosaic virus, mosaic virus, cucumber mosaic virus, tobacco ring spot virus, yellow vein mosaic, etc.

Controlling techniques: Chemical fumigation of the soil, fungicide, bactericide, pruning, proper water and fertilizer management, good sanitation, heat treatment of planting stock, cut and remove the infected parts, geneti-cally manipulating the plants for producing plants to resist fungi and bacteria are practices that are used to prevent or minimize the effects produced by microbes.

Insects

Ants, they are of different varieties, Argentine ant: *Linepi- thema humile,* Gray ants: *Formica aerata* and *Formica perpilosa,* Pavement ant: *Tetramorium caespitum.,* Southern fire ant: *Solenopsis xyloni,* Thief ant: *Solenopsis molesta,* they spoil the soil by making nest and they feed honey dew secreted in plants.

Branch and Twig Borer *(Melalgus confertus)* burrow into the canes through the base of the budor into the crotch formed by the shoot and spur. Feeding is often deep enough to completely conceal the adult in the hole. When shoots reach a length of 10–12 inches, a strong wind can cause the infected parts to twist and break. The click beetle *(Limo-nius canus)* can feed on buds. Cutworms *(Peridroma saucia) (Amathes c-nigrum) (Orthndes rufula)* injures the buds and so the buds may not develop. Leafhoppers *(Erythroneura elegantuhi) (Erythroneum variabilis)* remove the contents of leaf cells, leaving behind empty cells that appear as pale yellow spots. Oak twig pruners *(Anelaphiis* spp. Linsley) are known as shoot, twig and root insects that affects the above men-tioned parts.

Controlling techniques

Tilling the soil will also affects the nesting sites of ants and help to reduce their popula-tions, collection and destruction of eggs, larvae, pupae and adults of insects, trapping the insects, insecticides, creat-ing a situation to compete among males for mating with females, cutworms can be prevented by natural enemies like, predaceous or parasitic insects, mammals, parasitic nematodes, pathogens, birds, and reptiles,

Non insect pests

They are divided in to vertebrates and invertebrates. Ver-tebrates that disrupt the plants are monkeys, rats, birds, squirrels, etc. Non vertebrates are, Webspinning Spider Mites *(Tetranychuspacificus) (Eotetranychus willamettei) (Tetrany-chus urticae)* causes discoloration in leaves and yellow spots. Nematodes *(Meloidogyne incognita) (Xiphinema americanutri) (Criconemella xenoplax)* produces giant cell formation, dis-turbs the uptake of nutrients and water, and interferes with plant growth, crabs, snails are the other few invertebratesthat causes trouble to the plant.

***Controlling techniques**: Construction of concrete ware houses, traps, biological methods, rodenticides, etc.*

Weeds

Weeds reduce growth and yields of plants by competing for water, nutrients, and sunlight.

Weed control enhances the establishment of new plants and improves the growth and yield of established plants. The skilled persons have many weed management tools available to achieve these objectives; however, the methods of using these tools vary from year to year and from place to place.

Few common weeds are, Bermudagrass, It is a vigorous spring- and summer-growing perennial. It grows from seed but its extensive system of rhizomes and stolons can also be spread during cultivation, Dallisgrass, It is a common perennial weed that can be highly competi-tive in newly planted plants; in established plants area it competes for soil moisture and nutrients. Dallisgrass seedlings germinate in spring and summer, and form new plants on short rhizomes that developed from the original root system. The other weeds are pigweeds Amaranthus spp. pineapple-weed *Chamomilla suaveolens,* nightshades Solanum spp., etc.

Apart from these, Parasitic and Epiphytic Plants like dodder (Cuscuta spp. L.), mistletoe (Phoradendron spp. Nutt.), American squawroot (*Conopholis americana*), etc., too affects the growth of plants,

General Methods of Pest Controls

Use of low rates of herbicides: Herbicides are traditionally discussed as two groups: those that are active against germinating weed seeds (preemergent herbicides) and those that are active on growing plants (postemergent herbicides). Some herbicides have both pre-and postemergent activity. Herbicides vary in their ability to control different weed species. Preemergent herbicides are active in the soil against ger-minating weed seedlings. These herbicides are applied to bare soil and are leached into the soil with rain or irrigation where they affect germinating weed seeds. If herbicides remain on the soil surface without incorporation, some will degrade rapidly from sunlight. Weeds that emerge while the herbicide is on the surface, before it is activated by rain or irrigation, will not be controlled. Postemergent herbicides are applied to control weeds already growing in the vineyard. They can be combined with preemergent herbicides or applied as spot treatments during the growing season. In newly planted plants, selective postemergent herbicides are available for the control of most annual and perennial grasses, but not broadleaf weeds.

Frequent wetting of the soil promotes more rapid herbicide degradation in the soil. Herbicide degradation is generally faster in moist, warm soils than in dry, cold soils.

Figure 5: Pest Control Methods

Other Factors that Affect the Cultivated Plants

Air Pollution

It has been demonstrated that air pollutants can cause mortality and losses in growth of plants. Nearly all species of deciduous and coniferous trees are sensitive to some pollutants. There are many chemicals released into the atmosphere singly and as compounds. In addition, other compounds are synthesized in the atmosphere.. Generally, pollution injury first appears as leaf injury. Spots between the veins, leaf margin discoloration, and tip burns are common. These symptoms can also be influenced by host sensitivity, which is effected by genetic characteristics and environmental factors.

Herbicide

Herbicides should be handled very carefully; misapplication of herbicides can often damage non- target plants. The total extent of such damage remains unclear, but localized, severe damage occurs. Symptoms of herbicide injury are variable due to chemical mode of action, dosage, duration of expo-sure, plant species, and environmental conditions. Some herbicides cause growth abnormalities such as cupping or twisting of foliage while others cause foliage yellowing or browning, defoliation, or death.

PLANT GROWTH REGULATORS

We all know that plants need light, water, oxygen and nutrition to grow and develop. All these qualify asextrinsic factors. While extrinsic factors are important, did you know that plant growth depends on intrinsic factors too? They can be intracellular genes or intercellular chemicals. These chemicals are called Plant Growth Regulators.

Plant Growth Regulators are defined as small, simple chemicals produced naturally by plants to regulatetheir growth and development.

Plant Growth Regulators can be of a diverse chemical composition such as gases (ethylene), terpenes (gibberellic acid) or carotenoid derivates (abscisic acid). They are also referred to as plant growth substances, phytohormones or plant hormones. Based on their action, they are broadly classified as follows:

Plant Growth Promoters – They promote cell division, cell enlargement, flowering, fruiting andseed formation. Examples are auxins, gibberellins and cytokinins.

Plant Growth Inhibitors – These chemicals inhibit growth and promote dormancy and abscissionin plants. An example is an abscisic acid.

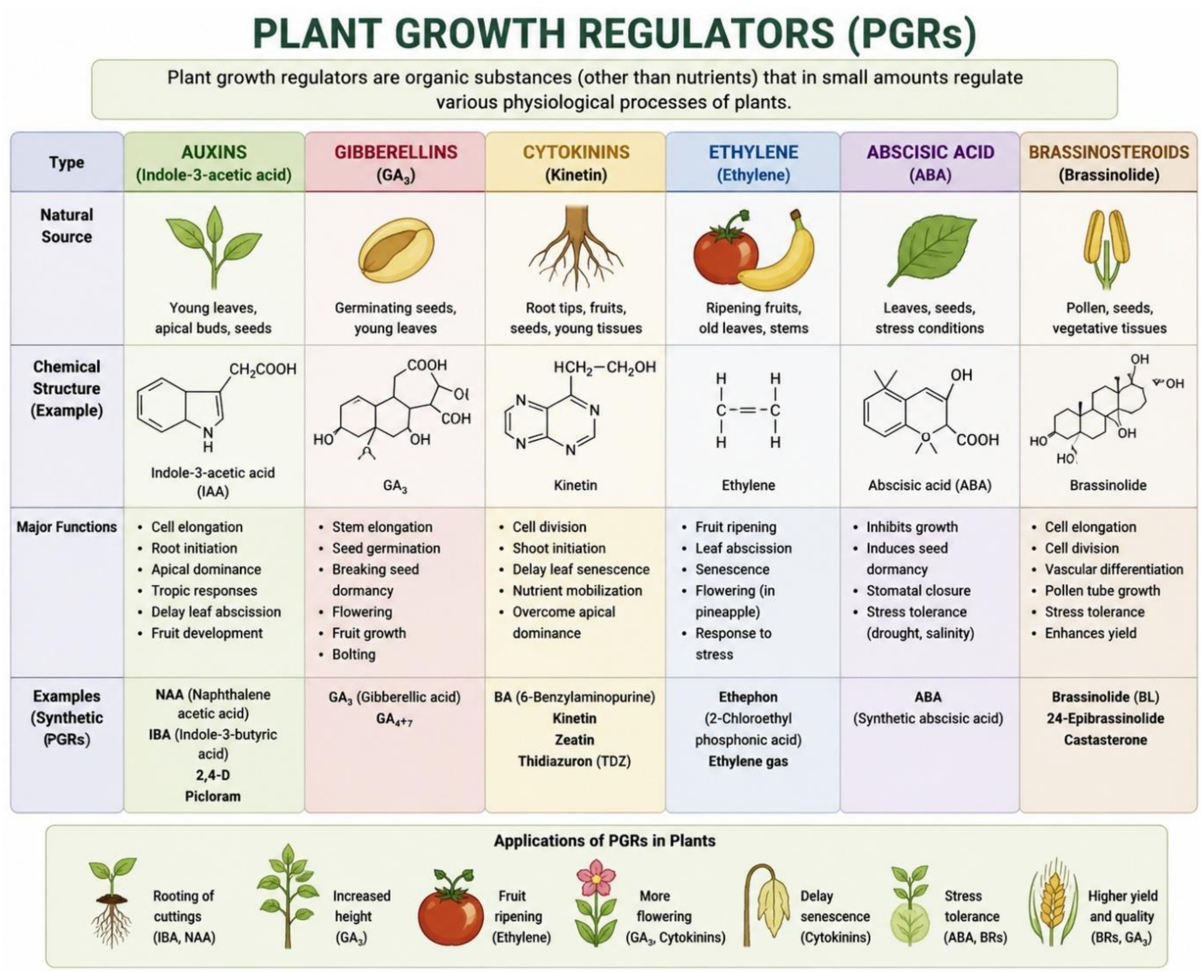
Note: Ethylene can be a promoter or an inhibitor, but is largely a Plant Growth Inhibitor. All plant growth regulators were discovered accidentally.

Auxins

Auxins were the first growth hormone to be discovered. They were discovered due to the observations of Charles Darwin and his son, Francis Darwin. The Darwins observed that the coleoptile (protective sheath) in canary grass grows and bends towards the source of light. This phenomenon is ‘phototropism’. In addition, their experiments showed that the coleoptile tip was the site responsible forthe bending. Finally, this led to the isolation of the first auxin by F. W. Went from the coleoptile tip of oat seedlings.

Types

First isolated from human urine, auxin is a term applied to natural and synthetic compounds that have growth regulating properties. Plants produce natural auxins such as Indole-3-acetic acid (IAA) and Indolebutyric acid (IBA). Natural auxins are found in growing stems and roots from where they migrate to their site of action. Naphthalene acetic acid (NAA) and 2, 4-dichlorophenoxyacetic (2, 4-D) are examples of synthetic auxins.



PLANT GROWTH REGULATORS (PGRs)

Plant growth regulators are organic substances (other than nutrients) that in small amounts regulate various physiological processes of plants.

Type	AUXINS (Indole-3-acetic acid)	GIBBERELLINS (GA_3)	CYTOKININS (Kinetin)	ETHYLENE (Ethylene)	ABSCISIC ACID (ABA)	BRASSINOSTEROIDS (Brassinolide)
Natural Source	Young leaves, apical buds, seeds	Germinating seeds, young leaves	Root tips, fruits, seeds, young tissues	Ripening fruits, old leaves, stems	Leaves, seeds, stress conditions	Pollen, seeds, vegetative tissues
Chemical Structure (Example)	Indole-3-acetic acid (IAA)	GA_3	Kinetin	Ethylene	Abscisic acid (ABA)	Brassinolide
Major Functions	• Cell elongation • Root initiation • Apical dominance • Tropic responses • Delay leaf abscission • Fruit development	• Stem elongation • Seed germination • Breaking seed dormancy • Flowering • Fruit growth • Bolting	• Cell division • Shoot initiation • Delay leaf senescence • Nutrient mobilization • Overcome apical dominance	• Fruit ripening • Leaf abscission • Senescence • Flowering (in pineapple) • Response to stress	• Inhibits growth • Induces seed dormancy • Stomatal closure • Stress tolerance (drought, salinity)	• Cell elongation • Cell division • Vascular differentiation • Pollen tube growth • Stress tolerance • Enhances yield
Examples (Synthetic PGRs)	NAA (Naphthalene acetic acid) IBA (Indole-3-butyric acid) 2,4-D Picloram	GA_3 (Gibberellic acid) GA_{4+7}	BA (6-Benzylaminopurine) Kinetin Zeatin Thidiazuron (TDZ)	Ethephon (2-Chloroethyl phosphonic acid) Ethylene gas	ABA (Synthetic abscisic acid)	Brassinolide (BL) 24-Epibrassinolide Castasterone

Applications of PGRs in Plants

Rooting of cuttings (IBA, NAA) · Increased height (GA_3) · Fruit ripening (Ethylene) · More flowering (GA_3, Cytokinins) · Delay senescence (Cytokinins) · Stress tolerance (ABA, BRs) · Higher yield and quality (BRs, GA_3)

Figure 6: Plant Growth regulators

Effects

- Promote flowering in plants like pineapple.
- Help to initiate rooting in stem cuttings.
- Prevent dropping of fruits and leaves too early.
- Promote natural detachment (abscission) of older leaves and fruits.
- Control xylem differentiation and help in cell division.

Applications

- Used for plant propagation.
- To induce parthenocarpy i.e. the production of fruit without prior fertilization.
- 2, 4-D is widely used as a herbicide to kill dicotyledonous weeds.
- Used by gardeners to keep lawns weed-free.

Gibberellins

It is the component responsible for the ‘bakane’ disease of rice seedlings. The disease is caused by the fungal pathogen *Gibberella fujikuroi*. E. Kurosawa treated uninfected rice seedlings with sterile filtrates of the fungus and reported the appearance of disease symptoms. Finally, the active substance causing the disease was identified as gibberellic acid.

Types

There exist more than 100 gibberellins obtained from a variety of organisms from fungi to higher plants. They are all acidic and are denoted as follows – GA1, GA2, GA3 etc. GA3 (Gibberellic acid) is the most noteworthy since it was the first to be discovered and is the most studied.

Effects

- Increase the axis length in plants such as grape stalks.
- Delay senescence (i.e. ageing) in fruits. As a result, their market period is extended.
- Help fruits like apples to elongate and improve their shape.

Applications

- The brewing industry uses GA3 to speed the malting process.
- Spraying gibberellins increase sugarcane yield by lengthening the stem.
- Used to hasten the maturity period in young conifers and promote early seed production.
- Help to promote bolting (i.e. sudden growth of a plant just before flowering) in cabbages and beet.

Cytokinins

F. Skoog and his co-workers observed a mass of cells called 'callus' in tobacco plants. These cells proliferated only when the nutrient medium contained auxins along with yeast extract or extracts of vascular tissue. Skoog and Miller later identified the active substance responsible for proliferation andcalled it kinetin.

Types

Cytokinins were discovered as kinetin. Kinetin does not occur naturally but scientists later discovered several natural (example – zeatin) and synthetic cytokinins. Natural cytokinins exist in root apices anddeveloping shoot buds – areas where rapid cell division takes place.

Effects

- Help in the formation of new leaves and chloroplast.
- Promote lateral shoot growth and adventitious shoot formation.
- Help overcome apical dominance.
- Promote nutrient mobilisation which in turn helps delay leaf senescence.

Abscisic Acid

Three independent researchers reported the purification and characterization of three different inhibitors – Inhibitor B, Abscission II and Dormin. Later, it was found that all three inhibitors were chemically identical and were, therefore, together were given the name abscisic acid. Abscisic acidmostly acts as an antagonist to Gibberellic acid.

Effects

- Regulate abscission and dormancy.
- Inhibit plant growth, metabolism and seed germination.
- Stimulates closure of stomata in the epidermis.
- It increases the tolerance of plants to different kinds of stress and is, therefore, called 'stresshormone'.
- Important for seed development and maturation.
- It induces dormancy in seeds and helps them withstand desiccation and other unfavourable growth factors.

Ethylene

A group of cousins showed that a gaseous substance released from ripe oranges hastens the ripening of unripe oranges. Consequently, they found that the substance was ethylene – a simple gaseous Plant Growth Regulator. Ripening fruits and tissues undergoing senescence produce ethylene inlarge amounts.

Effects

- Affects horizontal growth of seedlings and swelling of the axis in dicot seedlings.
- Promotes abscission and senescence, especially of leaves and flowers.
- Enhances respiration rate during ripening of fruits. This phenomenon is 'respiratory climactic'.
- Increases root growth and root hair formation, therefore helping plants to increase their absorption surface area.

Application

Ethylene regulates many physiological processes and is, therefore, widely used in agriculture. The most commonly used source of ethylene is Ethephon. Plants can easily absorb and transport an aqueous solution of ethephon and release ethylene slowly.

- Used to break seed and bud dormancy and initiate germination in peanut seeds.
- To promote sprouting of potato tubers.
- Used to boost rapid petiole elongation in deep water rice plants.

- To initiate flowering and synchronising fruit-set in pineapples.
- To induce flowering in mango.
- Ethephon hastens (quickly/ fast) fruit ripening in apples and tomatoes and increases yield by promoting female flowering in cucumbers. It also accelerates abscission in cherry, walnut and cotton.

In summary, one or the other plant growth regulator influences every phase of growth or development in plants. These roles could be individualistic or synergistic; promoting or inhibiting. Additionally, more than one regulator can act on any given life event in a plant. Along with genes and extrinsic factors, plant growth regulators play critical roles in plant growth and development. Factors like temperature and light affect plant growth events (vernalisation) via plant growth regulators.

POLYPLOIDY, MUTATION AND HYBRIDIZATION IN CULTIVATION OF MEDICINAL PLANTS

Mutation- Change in gene

Polyploidy- Multiplicity of gene

Hybridization- Formation of hybrid species

Types of genetic material variations- two type

- Phenotypic variation- These are the changes due to environment and these are not permanent and hereditary.
- Genetic variations- Changes in genetic material those are permanent and hereditary.

Mutation

When a change occurs in genome of an individual which is not caused by environment and it may make permanent evolutionary change, it is termed as Mutation. It is represented as a sudden change in genotype causing qualitative and quantitative adulteration of genetic material.

Advantages- Mutation can cause morphological, anatomical and chemical changes which can increaseyield.

Disadvantages- The plant may become susceptible (sensitive) to climatic conditions and disease whichcan cause slow growth.

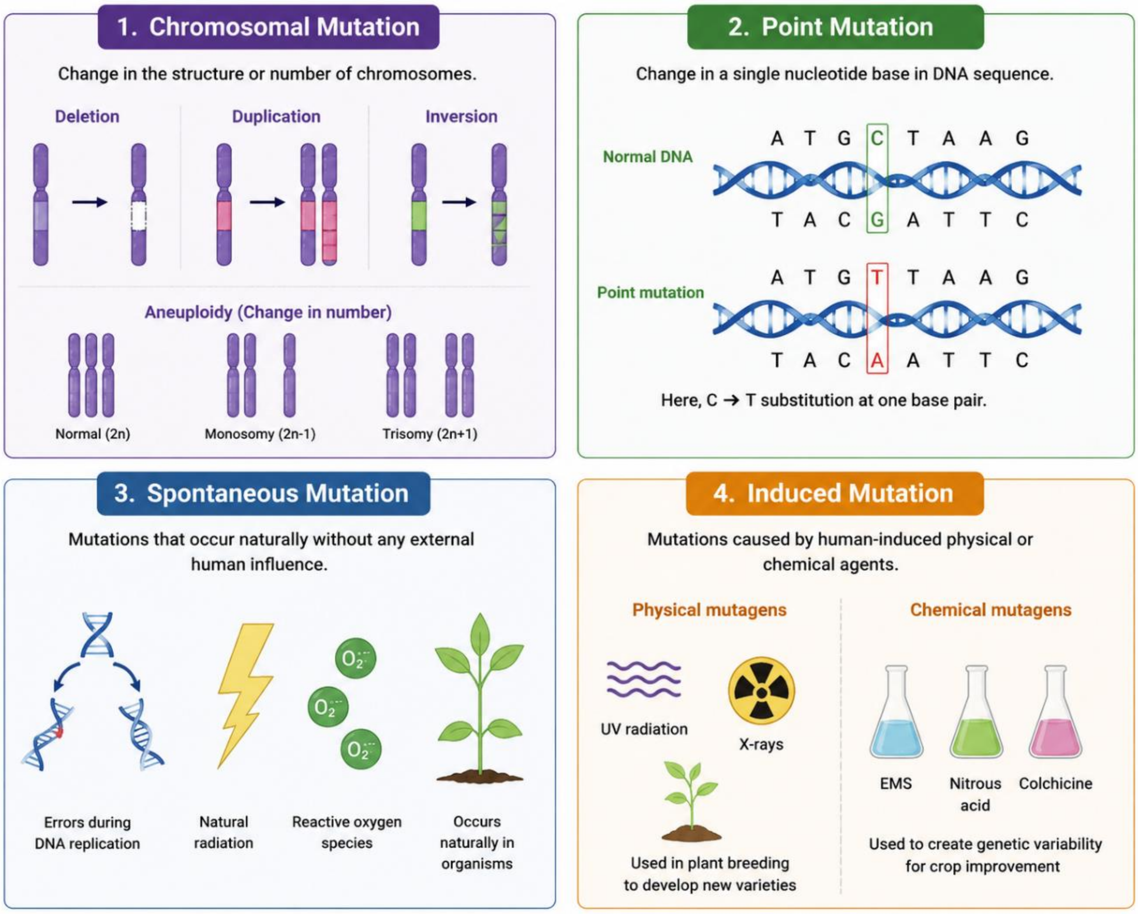


Figure 7: Various Types of Mutation

Types of mutation-

1. Chromosomal mutation- Change in amount or position of genetic material.
2. Point mutation- When change is on small point of DNA (gene).
3. Spontaneous mutation- Sudden change due to some unknown reasons.
4. Induced mutation- When any chemical or substance or radiation is used to induce the mutation is called Induced mutation and the substances which are using to induce are called Mutagens.

Mutations can be artificially produced by certain agents called mutagens or mutagenic agent. They are two types:

a. Physical mutagens:

i. **Ionizing radiations:** X-rays, gamma radiation and cosmic rays.

ii. Non-ionizing radiation: U.V. radiation,

b. Chemical mutagens:

i. **Alkylating and hydroxylating agents:** Nitrogen and sulpher mustard; methyl and ethylsulphonate, ethylethane sulphonates, Nitrous acid.

ii. **Acridines:** Acridines and proflavins.

Example of Mutation-

- Irradiation of Poppy seeds with cobalt-60 gives a mutant with increase morphine content from 0.32% to 0.52%.
- Selection of sweet Lupins by X-rays radiation as mutagen.
- An experiment performed in USA, *Mentha piperita* plant which was irradiated to produce adominant mutant for Verticillium resistance.
- In India mutant species of Capsicum annum with increase yield 20% to 60% of Capsaicin was isolated by treating with Sodium azide and Ethylmethyl sulphonate.

Ionizing radiation cause breaks in the chromosome. These cells then show abnormal cell divisions. If these include gametes, they may be abnormal and even die prematurely. Non-ionizing radiation like Ultra Violet rays are easily absorbed by purine and pyrimidines. The changed bases are known as photoproducts. U.V. rays cause two changes in pyrimidine to produce pyrimidine hydrate and pyrimidine dimmers. Thymine dimer is a major mutagenic effect of U.V. rays that disturbs DNA double helix and thus DNA replication.

Polyploidy

Plants whose cells contain two sets of chromosomes, derived at fertilization from the union of one set from the pollen and one set from the egg cells, are described as diploids and denoted by “2X”. The term polyploidy is applied to plants with more than two sets of chromosomes in the cells; when four sets are present the plants are described as tetraploids and denoted by “4X”.

Types of Polyploidy-

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; 3X), for example sterile saffron crocus, or seedless watermelons, also common in the phylum Tardigrada
- **Tetraploid** (four sets; 4X), for example Salmonidae fish, the cotton *Gossypium hirsutum*
- **Pentaploid** (five sets; 5X), for example Kenai Birch (*Betula papyrifera* var. *kenaica*)
- **Hexaploid** (six sets; 6X), for example wheat, kiwifruit
- Heptaploid or septaploid (seven sets; 7X)
- **Octaploid** or **octoploid**, (eight sets; 8X), for example *Acipenser* (genus of sturgeon fish), dahlias
- **Decaploid** (ten sets; 10X), for example certain strawberries

  - **Dodecaploid** (twelve sets; 12X), for example the plants *Celosia argentea* and *Spartina anglica* or the amphibian Xenopus ruwenzoriensis.
- **Extra-chromosomal-** In this plants occur with one or more chromosome which are extra to its somatic number. Example- *Datura stramonium* having 25 chromosomes (2n+1) shows 136% increase in alkaloidcontent.
- **Chemodemes or** Chemical **races-** these are chemically separate group within species. These are group ofplants of species which have similar morphological character but different chemical constituents

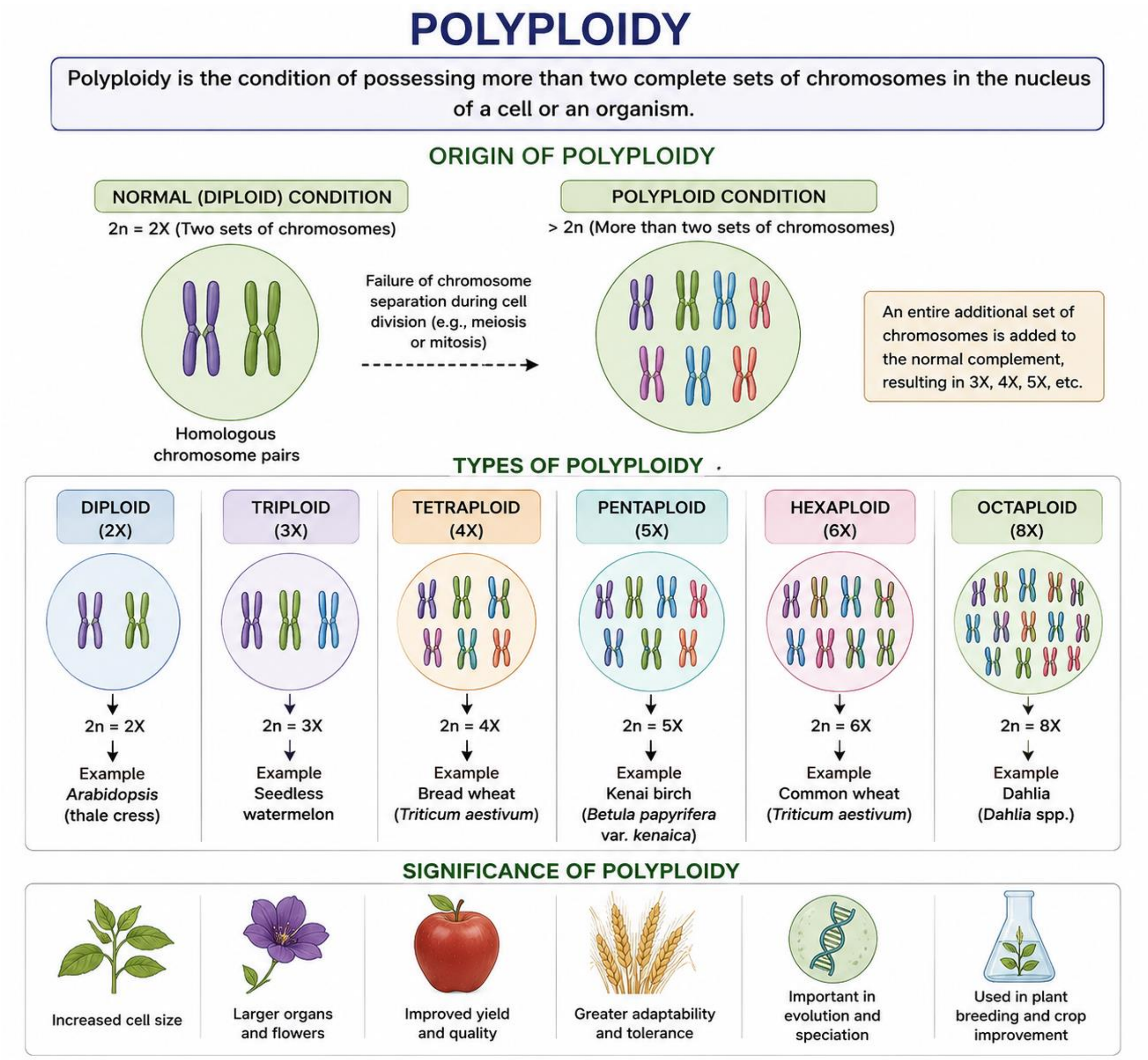


Figure 8: Types of Polyploidy in Plants

Causes of Polyploidy

- Cell generation- During cell division cells not divide properly and daughter cell containstetraploidy conditions.

- Physical agents- Like temperature shock, centrifugation and X-rays.
- Chemical agents- Like Colchicine, Sulphanilamide, Mercurus chloride, Hexachlorocyclo hexane.

Advantages of polyploidy-

- Formation of new species.
- Adaptability to various habitats.
- Biobhemical variation in plant that may increase amount of phytoconstituents.

Colchicine

It is the main cause of polyploidy. It is an alkaloid obtained from Corm of *Colchicum luteum* and *Colchicum autumnale*, family- Liliaceae. It mainly acts at Anaphase stage of cell division and prevent sister chromatids from separating in two daughter nuclei. These chromatids remain attach and this type of cell on further cell division causes polyploidy.

Mechanism of action for Colchicine-

It causes interaction with di-sulphide bond of spindle protein into fibrous protein which is necessary for separation of sister chromatids during cell division.

Examples-

- *Datura stramonium*- 4n strain shows 60-150% increase in Tropane alkaloids content.
- *Atropa belladonna*- 4n strain shows 68% increase in tropane alkaloid content.
- *Hyoscyamus niger*- 4n strain shows 22.5% increase in tropane alkaloid.
- *Carum carvi*- 4n strain shows 6-10% increase in volatile oil content.

.Hybridisation

It is mating or crossing of two genetically dissimilar plants having desired genes or genotypes and bringing them together into one individual called hybrid. The process through which hybrids are produced is called hybridization.

Hybridization particularly between homozygous strains, which have been inbred for a number of generations, introduces a degree of heterozygosis with resultant hybrid vigour often manifest in the dimensions and other characteristic of the plants. A hybrid is an organism which results from crossing of two species or varieties differing at least in one set of characters.

Types-

Monohybrid- The hybrid is differ in one pair of character. Dihybrid- Differ in two pair of characters similarly Trihybrid, Tetrahybrid, Pentahybrid, Polyhybrid.

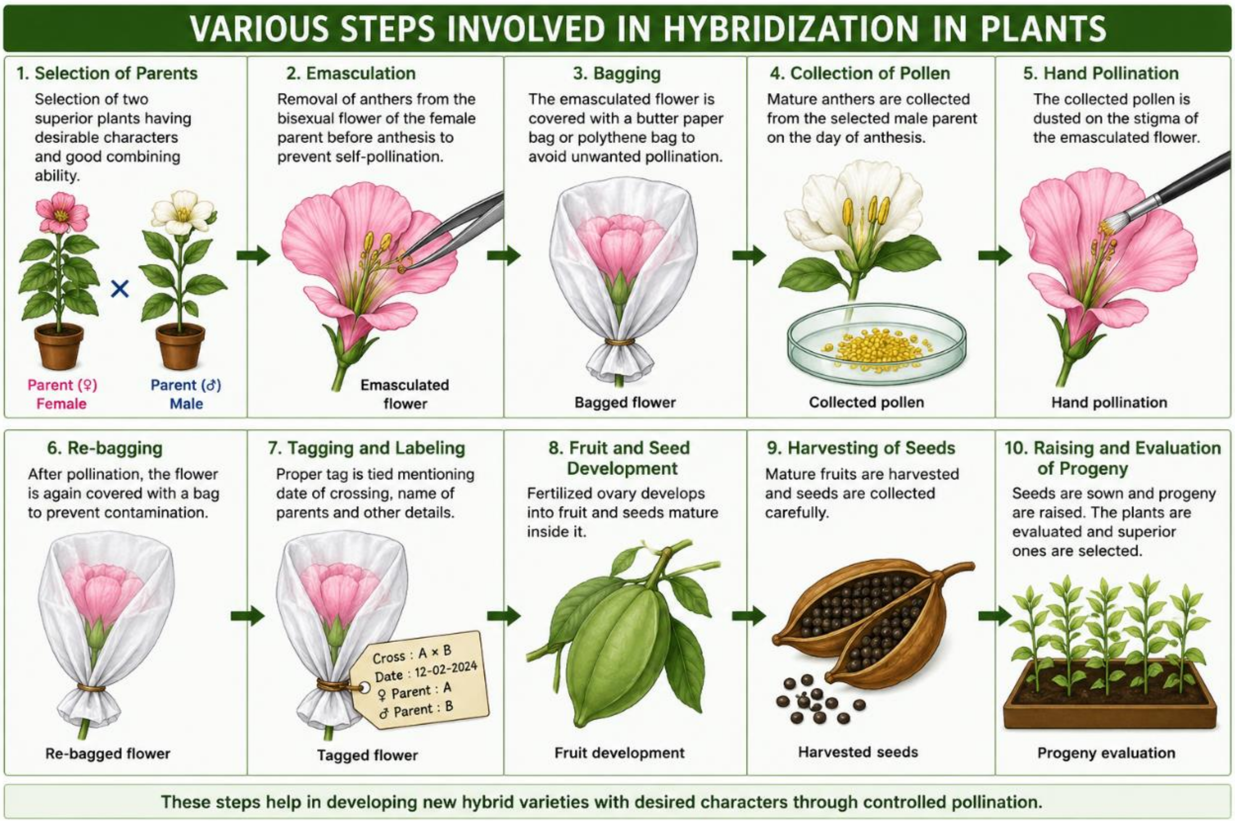


Figure 9: Steps involved in Hybridization

The following steps are involved in hybridization of plant:

1. **Selection of Parents:**

   Healthy parent plants possessing desirable characters such as high yield, disease resistance, improved quality, or enhanced secondary metabolite production are selected.

2. **Preparation of Female Parent:**

   The flower selected as the female parent is identified before anthesis and prepared for controlled pollination.

3. **Emasculation:**

   Anthers are carefully removed from the bisexual flower of the female parent before dehiscence to prevent self-pollination.

4. **Bagging:**

   The emasculated flower is immediately covered with a butter paper or polythene bag to prevent contamination by unwanted pollen grains.

5. **Collection of Pollen:**

   Mature anthers are collected from the selected male parent plant and pollen grains are separated carefully.

6. **Pollination:**

   The collected viable pollen grains are transferred onto the stigma of the emasculated flower using a brush, needle, or forceps.

7. **Re-bagging:**

   After pollination, the flower is again covered with a bag to avoid foreign pollen contamination.

8. **Tagging and Labelling:**

   A tag is attached mentioning details such as parent names, date of crossing, and cross number for proper identification.

9. **Seed Development and Harvesting:**

   After successful fertilization, fruits and seeds develop. Mature seeds are collected, dried, and stored properly.

10. **Raising and Evaluation of Progeny:**

    The hybrid seeds are sown and the resulting plants are evaluated for desirable characters. Superior hybrids are selected for further breeding or cultivation.

Advantages-

- It gives a single variety with favorable characters.
- It can develop some new characters which were not present in their parents.
- The technique is used in plant tissue culture and it gives more secondary metabolites production as well as disease resistant species. The new technique of hybridization is Protoplast culture.

Examples-

- *Mentha piperita* is a hybrid of *Mentha aquatica* and *Mentha spicata*. It gives more volatile oil production.
- Hybrid of *Withania somnifera* Israeli and South African variety gives 3 new Withanolides.
- Hybrid of *Digitalis purpurea* and *Digitalis lanata* gives new Lanatosides production.
- Hybrid of *Solanum incanum* and *Solanum malongena* gives high Solasodine content.

CONSERVATION OF MEDICINAL PLANTS

The medicinal plants are globally valuable sources of herbal product and they are disappearing at a high speed due to increasing demand. So, it is very necessary to conserve the plant species which are medicinally important and near to be extinct.

Conservation is about preservation of plants for future, preventing damage and loss to our cultural heritage.

Various threats to medicinal plants-

- Over exploitation
- Excessive use for daily basis
- Danger from pest and disease
- Deforestation

Methods for conservation-

- In-situ conservation
- Ex-situ conservation

In-situ conservation-

It is the conservation and maintenance of medicinal plants species in its natural habitat or environment by biosphere reserves (protect their environment and make it suitable for growth). It is conservation within the ecosystem to which the plant is adapted, whether as wild or crop cultivar in farmer's field as components of the traditional agricultural systems.

This conservation cannot succeed without the complete cooperation and involvement of local people.

Ex-situ conservation-

It involves conservation of biodiversity outside the native or natural habitat where the genetic variation is maintained away from its original location. It fulfills the requirement of present or future economic, social and environmental needs. It also includes propagation and assessment of molecular diversity. The various ex-situ methods are-

a) **In-vitro regeneration-** It include plant/explants growth, maintenance under disease free condition retention of regenerative potential, genetic stability and ensuring that there is no change to the live material. It is also useful for fast propagation of a number of red listed medicinal and aromatic plants that are difficult to propagate through conventional means.

b) **Cryobanks for conservation-** Cryopreservation of plant cells and meristems is an important tool for long term storage of germplasm or experimental material without genetic alteration using a minimum space and maintenance. It is basically meant for storage of germplasm. It involves the use of liquid nitrogen having -196^{o}C temperature at which zero metabolism or non-dividing state occurs in plant cells and tissues.

c) **Low temperature germplasm storage-** Preservation of plant tissues at low temperatures (-10 to - 20^{o}C) and for relatively short storage periods but in the absence of ice crystallization.

d) **Seed storage modules-** Seeds are best suited for storage. Seeds can be maintained for relatively long periods at low temperatures (-18ºC or lower) after altering their moisture content (5-8%).

e) **Low pressure storage-** In this surrounding atmospheric pressure is lowered and suitable for storage of plant material for short and long term.

f) **Low oxygen storage-** In this, the oxygen level is reduced and the atmospheric pressure is maintained at 260mmHg by adding inert gas like nitrogen.

Table 6: Difference between In-situ and Ex-situ Conservation

Feature	In-situ Conservation	Ex-situ Conservation
Definition	Conservation of plants in their natural habitat	Conservation of plants outside their natural habitat
Aim	Protect plants along with ecosystem and biodiversity	Protect endangered species under controlled conditions
Method	National parks, biosphere reserves, forest conservation	Botanical gardens, seed banks, tissue culture, nurseries
Advantage	Maintains natural evolution and ecological interactions	Enables mass propagation and easier monitoring
Limitation	Affected by natural disasters and habitat destruction	Expensive and may reduce natural adaptability
Examples	Conservation of Kutki in Himalayan regions	Tissue culture and seed bank conservation of Chirata

ECO-PHARMACOGNOSY

Eco-pharmacognosy is a branch of pharmacognosy that deals with the sustainable use, conservation, cultivation, and ethical harvesting of medicinal plants while protecting biodiversity and ecosystems. It combines principles of ecology, environmental science, pharmacognosy, conservation biology, and sustainable agriculture to ensure long-term availability of medicinal resources without damaging nature.

The concept became important because excessive exploitation of medicinal plants from forests caused depletion of many valuable species. Eco-pharmacognosy therefore promotes:

- Sustainable harvesting
- Biodiversity conservation
- Environment-friendly cultivation
- Protection of endangered medicinal plants
- Conservation of traditional knowledge
- Reduction of pressure on wild plant populations

Role of Eco-Pharmacognosy in Conservation of Kutki

Biological Source

Kutki consists of the dried rhizomes and roots of *Picrorhiza kutki* belonging to the family Scrophulariaceae (sometimes placed under Plantaginaceae).

Geographical Source

It is mainly found in the alpine Himalayan regions of India, Nepal, and Tibet at high altitudes.

Chemical Constituents

Picrorhiza kutki

- Iridoid glycosides: Picroside I, Picroside II, Kutkoside
- Apocynin
- Cucurbitacins

Uses

- Hepatoprotective
- Bitter tonic
- Antipyretic
- Used in liver disorders, jaundice, and digestive problems

Endangered Status

Kutki is endangered because of excessive collection from wild habitats and slow natural regeneration.

Role of Eco-Pharmacognosy in Conservation of Kutki with Years and Events

Kutki is an endangered Himalayan medicinal plant mainly used for hepatoprotective and anti-inflammatory purposes. Excessive collection of rhizomes, habitat destruction, and slow natural propagation led to rapid depletion of wild populations. Eco-pharmacognosy helps in its conservation through sustainable utilization and biodiversity protection.

Timeline of Eco-Pharmacognosy and Conservation Efforts for *Picrorhiza kurroa* (Kutki)

Year/Period	Initiative/Event	Contribution to Eco-pharmacognosy and Kutki Conservation
1992	Convention on Biological Diversity (CBD)	Emphasized conservation and sustainable utilization of medicinal plant biodiversity. Promoted conservation of Himalayan medicinal plants, sustainable use of *Kutki*, and protection of traditional medicinal knowledge.
1997	Inclusion of Kutki in CITES Appendix II	Due to overexploitation and growing international demand, *Kutki* was included in CITES Appendix II. This regulated international trade, reduced illegal export, and encouraged cultivation as an alternative to wild collection.
2000	Establishment	NMPB initiated programs for conservation and

	of National Medicinal Plants Board (NMPB)	development of medicinal plants. It promoted sustainable cultivation, in-situ and ex-situ conservation, nursery development, and farmer training for *Kutki*.
2002	Biological Diversity Act	The Act strengthened protection of medicinal plant biodiversity, regulated commercial exploitation of *Kutki*, and promoted equitable and sustainable utilization of biological resources.
2005 onwards	Sustainable Harvesting Awareness Programs	Awareness campaigns in Himalayan regions educated collectors to harvest only mature rhizomes, avoid uprooting entire plants, and adopt rotational harvesting practices to support natural regeneration.
2006	Restriction on Wild Collection in Uttarakhand	Restrictions on the collection of endangered medicinal plants helped reduce overexploitation, encouraged cultivation and herbal farming, and supported recovery of natural *Kutki* populations.
2010 onwards	Promotion of Commercial Cultivation	Government agencies and herbal industries promoted large-scale cultivation of *Kutki*, reducing pressure on wild populations, encouraging sustainable farming practices, and improving farmers' livelihoods.
2020–2025	NMPB Conservation and GACP Programs	Strengthened implementation of Good Agricultural and Collection Practices (GACP), supported conservation nurseries and seed banks, and promoted scientific cultivation and sustainable harvesting methods.
2022	Sami-Sabinsa Conservation Initiative	Conservation programs focused on ethical sourcing, biodiversity conservation, and sustainable commercial cultivation, thereby reducing dependence on forest-derived *Kutki*.

Role of Eco-Pharmacognosy in Conservation of Chirata

Biological Source

Chirata consists of the dried whole plant of *Swertia chirata* belonging to the family Gentianaceae.

Geographical Source

It is commonly found in temperate Himalayan regions of India, Nepal, and Bhutan.Chemical Constituents

- Amarogentin
- Swertiamarin
- Chiratin
- Xanthones

Swertia chirrata

Uses

- Bitter tonic
- Antimalarial
- Antipyretic

- Used in fever, skin diseases, and digestive disorders

Endangered Status

Chirata has become endangered due to overexploitation, habitat destruction, and indiscriminate collection.

Role of Eco-Pharmacognosy in Conservation of Chirata with Years and Events

Chirata is an endangered medicinal herb widely used as a bitter tonic and antipyretic agent. Excessive harvesting before seed maturation and habitat destruction caused serious decline in its natural population. Eco-pharmacognosy supports its conservation through ecological and sustainable approaches.

Year/Period	**Initiative/Event**	**Contribution to Eco-pharmacognosy and Chirata Conservation**
1992	Convention on Biological Diversity (CBD)	Emphasized conservation and sustainable use of medicinal plant biodiversity. Encouraged protection of *Chirata* habitats, sustainable utilization practices, and conservation of traditional medicinal resources.
2000	Establishment of National Medicinal Plants Board (NMPB)	NMPB was established to promote conservation, cultivation, and sustainable utilization of medicinal plants. It supported cultivation programs, farmer participation, and awareness regarding *Chirata* conservation.
2001–2003	Chirata Conservation Programs in Sikkim	Community-based conservation initiatives were introduced in the Sikkim Himalayas. These programs encouraged harvesting only after seed formation, habitat restoration, and cultivation of *Chirata*.
2002	Biological Diversity Act, India	Provided legal protection to medicinal plant biodiversity, regulated commercial exploitation, and promoted sustainable conservation and utilization of medicinal resources.
2005 onwards	Sustainable Collection Awareness Programs	Training programs for collectors promoted seasonal and sustainable harvesting practices, prevented premature uprooting of plants, and increased awareness of biodiversity conservation.
2010 onwards	Promotion of Commercial Cultivation	Government-supported cultivation programs encouraged ex-situ cultivation in farms and herbal gardens, reducing pressure on wild populations and improving the availability of *Chirata*.
2017	Ex-situ Cultivation Research in Sikkim	Studies demonstrated successful cultivation of *Chirata* at lower altitudes, supporting scientific conservation outside its natural habitat and reducing dependence on wild collection.
2020–2025	NMPB Conservation and GACP Programs	Promotion of Good Agricultural and Collection Practices (GACP), sustainable cultivation and harvesting, seed bank establishment, nursery development, and long-term conservation strategies.

Recent Years	Tissue Culture and Micropropagation Research	Biotechnological approaches enabled rapid multiplication of disease-free plants, restoration of endangered populations, and reduction of harvesting pressure on natural habitats.

MCQs on Cultivation, Collection, Processing and Storage of Drugs of Natural Origin

1.

Which organization published GACP guidelines for medicinal plants in 2003?

A. WHO

B. ICMR

C. FAO

D. UNESCO

Answer: A

2.

GACP stands for:

A. Good Agricultural and Chemical Practices

B. Good Agricultural and Collection Practices

C. General Agricultural Conservation Practices

D. Good Analytical Cultivation Practices

Answer: B

3.

Which factor mainly affects the secondary metabolite content of medicinal plants?

A. Colour of flowers

B. Environmental conditions

C. Shape of leaves

D. Size of seeds

Answer: B

4.

Which soil type is considered ideal for most medicinal plants?

A. Sandy soil

B. Loamy soil

C. Clay soil

D. Saline soil

Answer: B

5.

Which cultivation method involves growing plants from seeds?

A. Asexual propagation

B. Vegetative propagation

C. Sexual propagation

D. Tissue culture

Answer: C

6.

Which method of sowing distributes seeds uniformly over soil?

A. Dibbling

B. Layering

C. Broadcasting

D. Grafting

Answer: C

7.

Plant tissue culture is an example of:

A. Sexual propagation

B. Aseptic propagation

C. Natural propagation

D. Pollination

Answer: B

8.

Which irrigation method supplies water drop by drop directly to roots?

A. Flood irrigation

B. Boom irrigation

C. Drip irrigation

D. Hand watering

Answer: C

9.

Which hormone mainly promotes cell elongation?

A. Cytokinin

B. Auxin

C. Ethylene

D. ABA

Answer: B

10.

Which plant hormone promotes fruit ripening?

A. Gibberellin

B. Cytokinin

C. Ethylene

D. Auxin

Answer: C

11.

Which hormone delays senescence in plants?

A. Cytokinin

B. ABA

C. Ethylene

D. Auxin

Answer: A

12.

Polyploidy refers to:

A. Change in leaf shape

B. Presence of multiple chromosome sets

C. Seed dormancy

D. Mutation in roots

Answer: B

13.

Triploid plants generally show:

A. High fertility

B. Sterility

C. No flowering

D. No roots

Answer: B

14.

Seedless watermelon is an example of:

A. Diploid

B. Triploid

C. Tetraploid

D. Pentaploid

Answer: B

15.

Bread wheat is:

A. Tetraploid

B. Pentaploid

C. Hexaploid

D. Octaploid

Answer: C

16.

Which chemical is commonly used to induce polyploidy?

A. Ethanol

B. Acetone

C. Colchicine

D. Ether

Answer: C

17.

Mutation caused naturally without external agents is:

A. Artificial mutation

B. Spontaneous mutation

C. Induced mutation

D. Hybrid mutation

Answer: B

18.

Mutation induced by radiation or chemicals is:

A. Point mutation

B. Spontaneous mutation

C. Induced mutation

D. Chromosomal mutation

Answer: C

19.

Hybridization is mainly used for:

A. Weed control

B. Development of improved varieties

C. Drying drugs

D. Storage of crude drugs

Answer: B

20.

In-situ conservation means:

A. Conservation outside natural habitat

B. Conservation in seed banks

C. Conservation in natural habitat

D. Conservation in laboratories

Answer: C

21.

Botanical gardens are examples of:

A. In-situ conservation

B. Ex-situ conservation

C. Wild conservation

D. Natural conservation

Answer: B

22.

Seed banks are mainly used for:

A. Irrigation

B. Storage of genetic material

C. Drying plants

D. Fertilizer preparation

Answer: B

23.

Eco-pharmacognosy mainly deals with:

A. Chemical synthesis of drugs

B. Sustainable use of medicinal plants

C. Plant anatomy

D. Extraction techniques only

Answer: B

24.

Kutki belongs to the genus:

A. Swertia

B. Picrorhiza

C. Rauwolfia

D. Digitalis

Answer: B

25.

Chirata belongs to the genus:

A. Picrorhiza

B. Swertia

C. Mentha

D. Solanum

Answer: B

26.

Kutki is mainly used as:

A. Antidiabetic

B. Hepatoprotective

C. Anticancer

D. Antifungal

Answer: B

27.

Which medicinal plant is known as a bitter tonic?

A. Aloe

B. Senna

C. Chirata

D. Clove

Answer: C

28.

Which practice is recommended under eco-pharmacognosy?

A. Overharvesting

B. Sustainable harvesting

C. Deforestation

D. Excess pesticide use

Answer: B

29.

The best season for bark collection is generally:

A. Summer

B. Rainy season

C. Autumn or spring

D. Winter only

Answer: C

30.

Leaves are generally collected:

A. During rainy weather

B. During flowering stage

C. Before seed germination

D. At midnight

Answer: B

31.

Flowers are preferably collected:

A. Early morning with dew

B. During rainfall

C. Midday after dew disappears

D. At night

Answer: C

32.

Drying helps to:

A. Increase moisture

B. Prevent microbial growth

C. Increase fermentation

D. Destroy active constituents

Answer: B

33.

Shade drying is preferred for:

A. Volatile oil-containing drugs

B. Minerals

C. Heavy metals

D. Resins only

Answer: A

34.

Tray dryers are used in:

A. Artificial drying

B. Natural drying

C. Freeze storage

D. Fermentation

Answer: A

35.

Garbling means:

A. Drying of crude drugs

B. Grinding of crude drugs

C. Removal of foreign matter

D. Extraction of oils

Answer: C

36.

Which of the following is removed during garbling?

A. Active constituents

B. Foreign organic matter

C. Alkaloids

D. Glycosides

Answer: B

37.

Airtight containers are mainly used for:

A. Volatile oil-containing drugs

B. Metals

C. Fresh fruits

D. Sand

Answer: A

38.

Which condition is ideal for crude drug storage?

A. Moist and hot

B. Dry and cool

C. Wet and warm

D. Humid and bright

Answer: B

39.

Which factor promotes microbial growth during storage?

A. Low moisture

B. High moisture

C. Low temperature

D. Darkness

Answer: B

40.

Direct sunlight may cause:

A. Increase in active constituents

B. Oxidation of constituents

C. Water absorption

D. Root formation

Answer: B

41.

Fumigation is mainly used for:

A. Irrigation

B. Pest control in storage

C. Pollination

D. Hybridization

Answer: B

42.

Which fertilizer is a biofertilizer?

A. Urea

B. Rhizobium

C. Superphosphate

D. Potash

Answer: B

43.

Azotobacter mainly helps in:

A. Potassium fixation

B. Nitrogen fixation

C. Phosphate precipitation

D. Weed control

Answer: B

44.

Which factor affects flowering due to day length?

A. Altitude

B. Rainfall

C. Photoperiod

D. Soil pH

Answer: C

45.

Soil pH mainly affects:

A. Colour of flowers

B. Nutrient availability

C. Seed size

D. Fruit shape

Answer: B

46.

Excess rainfall may cause:

A. Increased alkaloids always

B. Waterlogging

C. Better drying

D. Seed dormancy only

Answer: B

47.

Which practice helps conserve endangered medicinal plants?

A. Excess harvesting

B. Habitat destruction

C. Controlled cultivation

D. Burning forests

Answer: C

48.

The use of biotechnology for rapid multiplication of plants is:

A. Fermentation

B. Micropropagation

C. Winnowing

D. Garbling

Answer: B

49.

Which conservation method preserves plants in gene banks?

A. In-situ conservation

B. Ex-situ conservation

C. Wild harvesting

D. Crop rotation

Answer: B

50.

The major objective of eco-pharmacognosy is:

A. Increasing forest destruction

B. Sustainable utilization of medicinal plants

C. Excess drug extraction

D. Artificial pollination only

Answer: B

2 Marks Questions

Q. No.	**Question**	**Bloom's Taxonomy**
1	Define Good Agricultural and Collection Practices (GACP).	Remembering
2	What is polyploidy?	Remembering
3	Define *in-situ* conservation.	Remembering
4	What is eco-pharmacognosy?	Remembering
5	Name any two plant growth regulators used in medicinal plant cultivation.	Remembering
6	Differentiate between *in-situ* and *ex-situ* conservation.	Analyzing
7	Analyze why shade drying is preferred for volatile oil-containing drugs.	Analyzing
8	Apply the concept of photoperiod to explain its influence on the cultivation of medicinal plants.	Applying
9	Evaluate the importance of sustainable harvesting in medicinal	Evaluating

	plant conservation.	
10	Suggest a suitable conservation method for an endangered medicinal plant with justification.	Creating

Distribution: L1 = 5, L2 = 3, L3 = 2

5 Marks Questions

Q. No.	**Question**	**Bloom's Taxonomy**
1	Explain WHO guidelines for Good Agricultural and Collection Practices (GACP).	Remember
2	Describe different methods of drying crude drugs.	Remember
3	Explain different methods of pest control in medicinal plant cultivation.	Remember
4	Write a note on plant hormones used in medicinal plant cultivation.	Remember
5	Explain factors affecting cultivation and collection of medicinal plants.	Remember
6	Compare sexual and asexual propagation methods with suitable examples.	Analyze
7	Analyze how processing and storage affect the quality of crude drugs.	Analyze
8	Explain the role of mutation and polyploidy in medicinal plant improvement.	Applying
9	Assess the significance of eco-pharmacognosy in sustainable utilization of medicinal plants.	Evaluate
10	Recommend suitable cultivation and conservation measures for maintaining medicinal plant biodiversity.	Create

Distribution: L1 = 5, L2 = 3, L3 = 2

10 Marks Questions

Q. No.	**Question**	**Bloom's Taxonomy**
1	Describe various methods of cultivation of medicinal plants in	Understanding

	detail.	
2	Explain collection, processing, garbling, packing, and storage of crude drugs.	Understanding
3	Discuss plant growth regulators and their role in medicinal plant cultivation.	Understanding
4	Explain different types of polyploidy with suitable examples.	Understanding
5	Describe WHO-GACP guidelines for medicinal plants with suitable examples.	Understanding
6	Compare in-situ and ex-situ conservation methods with their merits and demerits.	Analyzing
7	Analyze factors affecting cultivation, collection, and storage of medicinal plants.	Analyzing
8	Apply the principles of mutation, hybridization, and polyploidy to improve secondary metabolite production in medicinal plants.	Applying
9	Evaluate the role of eco-pharmacognosy in the conservation of endangered medicinal plants such as Kutki and Chirata.	Evaluating
10	Develop a sustainable cultivation and conservation strategy for medicinal plants to ensure long-term availability and biodiversity conservation.	Creating

Distribution: L1 = 5 (50%), L2 = 3 (30%), L3 = 2 (20%)

Difficulty-Level Mapping

Level	**Bloom's Taxonomy**
Level 1	Remembering, Understanding
Level 2	Applying, Analyzing
Level 3	Evaluating, Creating

Competency-Based Learning (CBL)

Fill in the Blanks

1. WHO guidelines for medicinal plants are called ___________.
2. Conservation of plants in natural habitat is called ___________ conservation.
3. ___________ hormone promotes fruit ripening.

4. Removal of foreign matter from crude drugs is known as ___________.
5. Seedless watermelon is an example of ___________ plant.

Match the Column

Column A	Column B
1. Auxin	a. Fruit ripening
2. Ethylene	b. Cell elongation
3. Botanical garden	c. Artificial drying
4. Tray dryer	d. Ex-situ conservation
5. Drip irrigation	e. Water-saving method

True / False

1. Shade drying is suitable for volatile oil-containing drugs.
2. Polyploidy means reduction in chromosome number.
3. GACP guidelines were published by WHO.
4. Biofertilizers improve soil fertility.
5. Ex-situ conservation occurs in natural habitat.

Problem-Based Learning (PBL)

Fill in the Blanks

1. A crude drug became mouldy due to high ___________ content during storage.
2. A farmer used tissue culture for rapid multiplication, which is an example of ___________ propagation.
3. Excess rainfall in medicinal plant fields may cause ___________.
4. Kutki conservation programs promote ___________ cultivation to reduce wild harvesting.
5. Plants developed using colchicine are called ___________ plants.

Match the Column

Column A	Column B
1. Excess rainfall	a. Loss of volatile oils
2. Shade drying	b. Waterlogging

Column A	Column B
3. National parks	c. Multiple chromosome sets
4. Polyploidy	d. In-situ conservation
5. Improper storage	e. Microbial growth

True / False

1. Sustainable harvesting helps conserve medicinal plants.
2. Drip irrigation reduces water wastage.
3. Eco-pharmacognosy promotes overexploitation of medicinal plants.
4. Improper drying may lead to microbial spoilage.
5. Day length affects flowering in medicinal plants.

Table 1: CBL Answers

Fill in the Blanks	1. GACP	2. In-situ	3. Ethylene	4. Garbling	5. Triploid
Match the Column	1–b	2–a	3–d	4–c	5–e
True / False	True	False	True	True	False

Table 2: PBL Answers

Fill in the Blanks	1. Moisture	2. Aseptic	3. Waterlogging	4. Commercial	5. Polyploid
Match the Column	1–b	2–a	3–d	4–c	5–e
True / False	True	True	False	True	True