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BP105T

INTRODUCTION TO PHARMACOGNOSY

UNIT II — CULTIVATION, COLLECTION, PROCESSING AND STORAGE OF DRUGS OF NATURAL ORIGIN

Cultivation Methods • WHO GACP / GAP / GCP Guidelines • Factors in Cultivation, Collection & Storage

Plant Hormones • Polyploidy, Mutation & Hybridization for Secondary Metabolites

Ex-situ / In-situ Conservation • Value Addition • Eco-Pharmacognosy (Kutki & Chirata)

B.Pharm — Semester I

PCI Regulations, ER-2020 Syllabus

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1. Methods of Plant Cultivation

Cultivation is the deliberate growing of medicinal plants under controlled or semi-controlled conditions, as opposed to collecting them from the wild. It gives a pharmaceutical manufacturer a more consistent, traceable, and sustainable raw-material supply than wild collection alone.

1.1 Sexual (Seed) Propagation

- Plants raised from **seed** — the most natural method of multiplication.
- Allows **genetic variation and recombination**, which is useful for breeding new varieties but can also mean inconsistent quality between plants.
- Generally **slower** to reach a harvestable/mature stage than vegetative methods.
- Seed quality (viability, purity, freedom from disease) is itself a major quality-control checkpoint — poor seed viability is a recognised problem in several endangered medicinal plants (see Section 7).

1.2 Asexual (Vegetative) Propagation

- Produces **clones** of the parent plant — genetically uniform, and generally **faster** to reach maturity than seed-grown plants.
- Preferred when the desired chemotype (a plant with an unusually high content of a specific constituent) must be preserved unchanged.

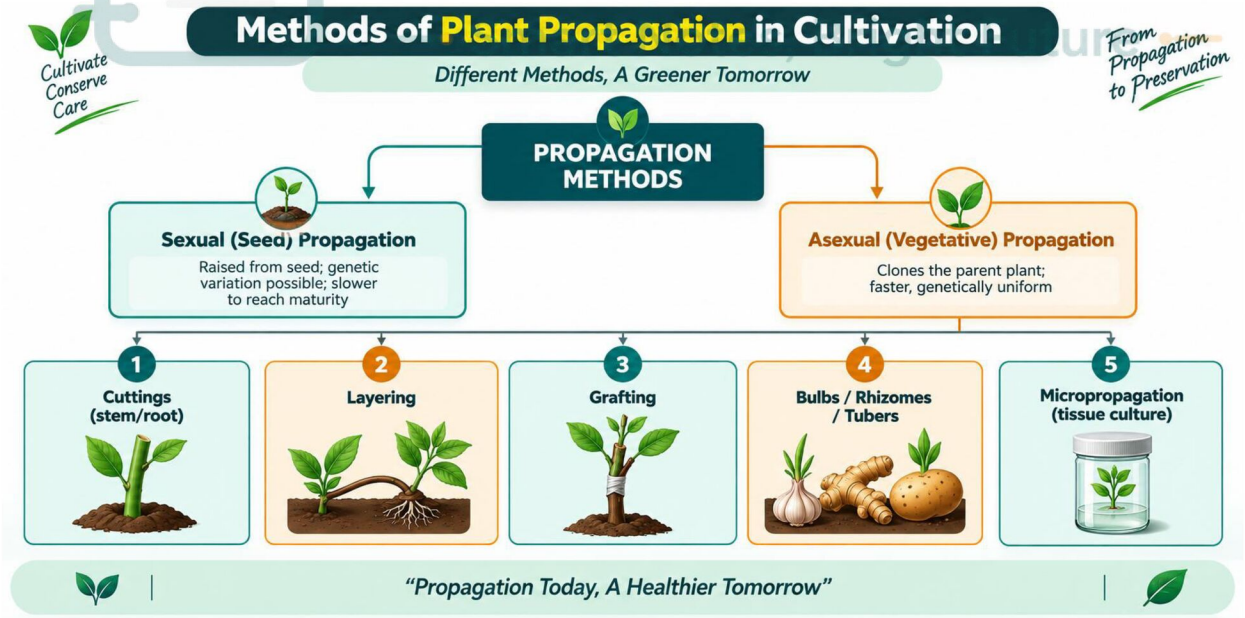

Figure 1.1 — Overview of sexual and asexual (vegetative) propagation methods used in medicinal plant cultivation.

- **Cuttings** (stem or root) — a piece of stem/root planted directly to develop roots and shoots; often treated with auxin rooting hormone (see Section 4).

- **Layering** — a stem is bent and partly buried while still attached to the parent plant; it roots before being cut away as an independent plant.
- **Grafting** — a shoot (scion) from one plant is joined onto the rootstock of another, combining the rootstock's hardiness with the scion's desired growth/chemistry.
- **Bulbs, rhizomes, tubers** — underground storage organs (e.g. ginger, turmeric) that naturally give rise to new shoots when planted.
- **Micropropagation (tissue culture)** — in-vitro multiplication of disease-free, genetically uniform plantlets from a small explant; especially valuable for slow-growing or endangered species (linked to Section 6/7).

1.3 General Cultivation Practice

- **Site and soil selection** — matched to the species' natural growing conditions (altitude, drainage, pH).
- **Seed/planting-material selection** — authenticated, disease-free stock of the correct species and, where relevant, the correct high-yielding chemotype.
- **Agronomic management** — irrigation scheduling, fertiliser application, weed and pest control, and crop rotation where applicable.
- **Harvest planning** — cultivation is planned around the collection stage that gives the highest yield of the desired constituent (see Section 3).
- Cultivation also supports **traceability**: a cultivated crop's growing history, inputs, and location can be documented in a way wild-collected material often cannot.

2. Good Agricultural and Collection Practices (WHO / GAP / GCP)

- **GACP** (Good Agricultural and Collection Practices) — WHO guidelines, first published in **2003**, giving internationally applicable technical guidance for the cultivation, collection and initial processing of medicinal plant materials.
- **GAP** (Good Agricultural Practices) — the *cultivation* side of GACP.
- **GCP** (Good [Field] Collection Practices) — the *wild-harvest* side of GACP.
- Together, GACP is described as **"the first step in quality assurance"** for herbal medicines — everything downstream (extraction, formulation, finished product testing) depends on the raw material already being of consistent, documented quality.
- **Three main objectives of the WHO GACP guidelines:**
  - Contribute to quality assurance of medicinal plant materials, to improve the quality, safety and efficacy of finished herbal products.
  - Guide the formulation of national/regional GACP guidelines and GACP monographs for individual medicinal plant species.

  - Encourage and support sustainable cultivation and collection in ways that respect and support conservation of medicinal plants and the environment generally.
- A more recent, expanded WHO edition broadens the scope further to explicitly cover **environmental, ethical and legal considerations** — biodiversity conservation, protection of endangered species, intellectual property rights, and benefit-sharing with source communities (linking directly to the biopiracy/TKDL discussion from Unit I).

Term	Covers	Applies to
GACP	Both cultivation and collection, plus initial post-harvest steps	Cultivated AND wild-collected material
GAP	Site, soil, seed, irrigation, fertiliser, pest control	Cultivated material only
GCP	Permission, timing, method, handling of wild harvest	Wild-collected material only

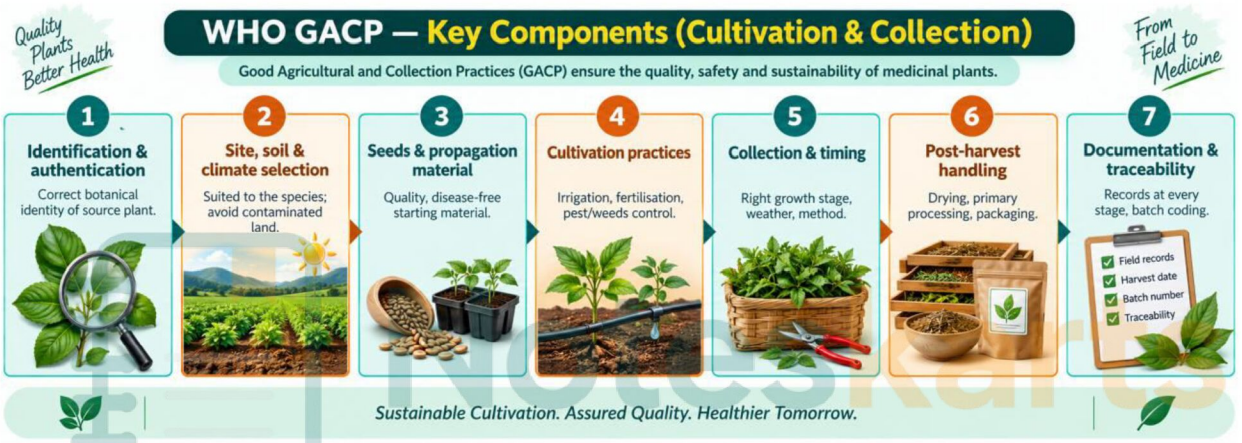

Figure 2.1 — Imp components of the WHO GACP framework, from species identification through to documentation.

2.1 Imp Components of GACP

- **Identification and authentication** — correct botanical identity (species, and where relevant, chemotype/variety) of the source plant, confirmed and documented before cultivation/collection begins.
- **Site, soil and climate** — selected to suit the species' natural requirements; land should be free of contamination from heavy metals, pesticide residues, or prior industrial use.
- **Seeds and propagation material** — quality-checked, disease-free planting material of confirmed identity (Section 1).
- **Cultivation practices** — irrigation, fertilisation, and pest/weed management carried out to minimise chemical residues in the final material.
- **Collection** — correct season, growth stage, time of day, and method (Section 3 covers this in detail).

- **Post-harvest handling** — prompt, controlled drying; sorting to remove foreign matter; primary processing (cutting, comminution) as required.
- **Packaging, storage and transport** — clean, appropriately labelled containers; conditions that protect against moisture, pests, and cross-contamination.
- **Documentation and traceability** — records maintained at every stage (source, batch number, collection date, processing conditions) so any batch can be traced back to its origin.

2.2 Permission, Personnel and Sustainability

- **Permission to collect:** collection permits and landowner consent are required before wild collection; export of material may additionally require phytosanitary certificates and, for CITES-listed species, CITES export/import permits.
- **Technical planning:** the geographical distribution and population density of the target species should be assessed before a collection expedition, so collection does not exceed what the population can sustainably supply.
- **Personnel:** collectors and farm workers should be trained to correctly identify the species (avoiding look-alike plants) and to follow hygiene and safety procedures.
- **Sustainable collection quotas:** wild collection should leave enough mature, reproducing individuals in the population to allow natural regeneration — directly relevant to the endangered-species discussion in Section 7.

3. Factors Influencing Cultivation, Collection and Storage

The concentration of the active constituent in a crude drug is rarely fixed — it shifts with growing conditions, the exact moment of collection, and how the material is stored afterward. This section works through the main variables at each stage.

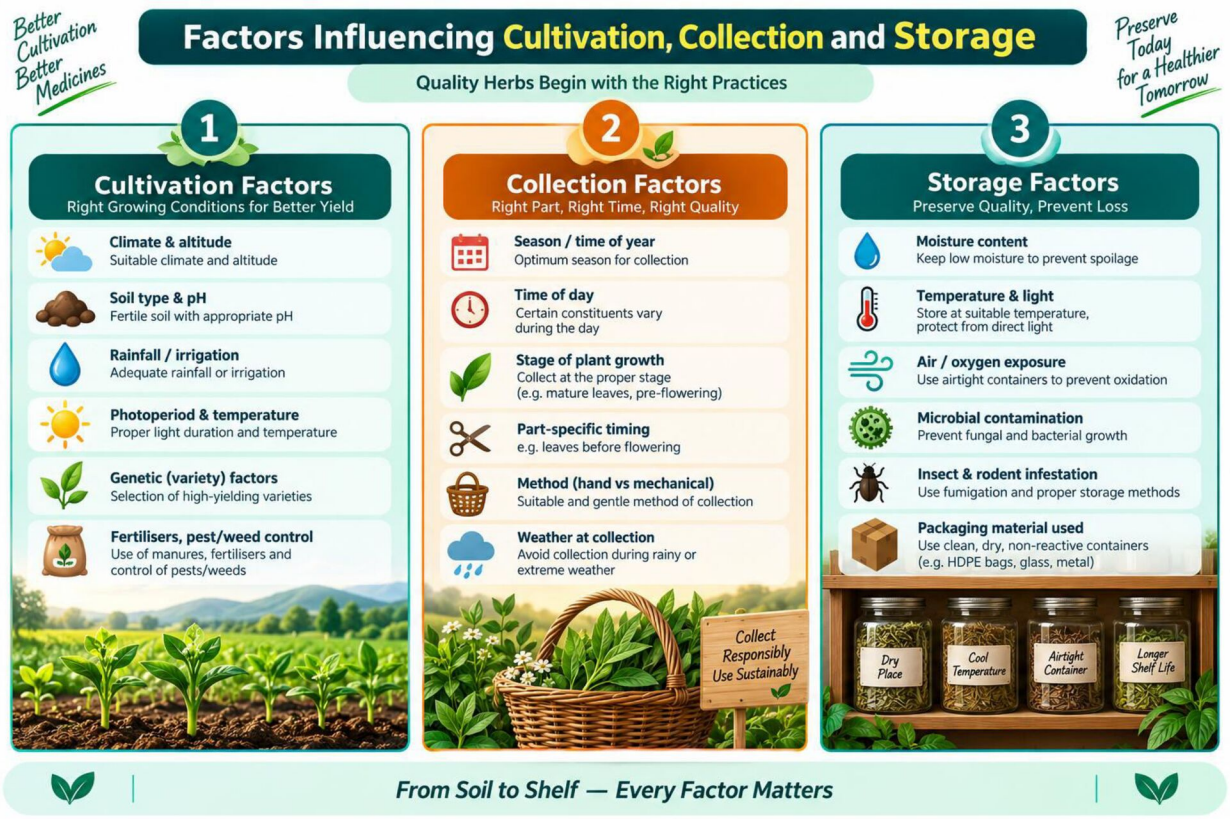

Figure 3.1 — The main factors influencing cultivation, collection and storage of medicinal plants.

3.1 Factors Influencing Cultivation

- **Climate and altitude** — many high-value medicinal plants (e.g. Kutki, Chirata) are adapted to specific Himalayan altitude bands and cannot simply be grown anywhere.
- **Soil type and pH** — affects nutrient availability and root development; some species need well-drained, slightly acidic soil, others require different conditions entirely.
- **Rainfall and irrigation** — both water deficit and waterlogging can reduce growth and alter secondary metabolite accumulation.
- **Photoperiod and temperature** — day length and temperature regulate flowering time and can shift the balance between vegetative growth and metabolite production.
- **Genetic (varietal) factors** — different cultivated varieties (chemotypes) of the same species can differ severalfold in active-constituent content.
- **Agronomic inputs** — fertiliser type/dose, and pest and weed control, all affect both yield and the purity of the final material (excess fertiliser or pesticide residue is itself a quality problem).

3.2 Factors Influencing Collection

- **Season/time of year** — the classic pharmacognosy rule of thumb: alkaloid content is often highest just before flowering; glycoside content is often highest at or after flowering; root/rhizome drugs are usually collected after the aerial parts have died back (dormant season), when reserves have moved underground.

- **Time of day** — some volatile-oil-rich drugs are best collected in the early morning, before heat volatilises the oil.
- **Stage of plant growth/maturity** — collecting too early or too late can both reduce yield of the target constituent.
- **Part-specific timing** — different parts of the same plant are collected at different times (e.g. leaves before flowering, fruits/seeds fully ripe, bark in early spring when it separates easily).
- **Method of collection** — hand collection allows selective, less damaging harvesting; mechanical collection is faster but risks contamination with foreign matter and unwanted plant parts.
- **Weather at collection** — material collected in wet weather is harder to dry promptly, raising the risk of microbial spoilage before processing.

3.3 Factors Influencing Storage

- **Moisture content** — the single most important storage variable; inadequately dried material is prone to mould growth, enzymatic degradation, and loss of potency.
- **Temperature and light** — heat and light can degrade sensitive constituents (e.g. volatile oils, some glycosides) over time; cool, dark storage is generally preferred.
- **Air/oxygen exposure** — oxidation can degrade certain constituents; airtight or vacuum packaging reduces this risk for sensitive materials.
- **Microbial contamination** — inadequate drying or humid storage conditions allow fungal growth, which can also introduce **mycotoxins**, a serious safety concern.
- **Insect and rodent infestation** — physically destroys stored material and introduces contamination; requires proper warehouse hygiene and, where permitted, fumigation.
- **Packaging material** — must protect against moisture, light, and pests without introducing its own contamination (e.g. inappropriate plastics reacting with volatile constituents).
- **Duration of storage** — most crude drugs have a practical shelf life; potency should be re-verified for material stored beyond the recommended period.

3.4 Processing of Crude Drugs (Post-Harvest)

Processing bridges collection and storage: freshly collected plant material is highly perishable, and correct primary processing is what turns it into a stable crude drug fit for storage, transport, and later extraction.

- **Cleaning/garbling** — removal of foreign matter (soil, stones, other plant parts, damaged material) immediately after collection, before drying begins.

- **Drying** — the most critical processing step; removes moisture to a safe level (typically below ~10–14% depending on the drug) to halt enzymatic degradation and prevent mould growth.
  - **Sun-drying** — cheapest method; risks photodegradation of light-sensitive constituents and contamination from dust/insects.
  - **Shade-drying** — preferred for drugs containing volatile oils, chlorophyll, or light-sensitive constituents that sun-drying would degrade.
  - **Oven/artificial (hot-air) drying** — faster, temperature-controlled, and more hygienic; temperature must still be kept low enough not to destroy heat-labile constituents.
  - **Freeze-drying (lyophilisation)** — used for particularly delicate material; preserves constituents very well but is costly, so reserved for high-value drugs.

Drying method	Best suited for	Main drawback
Sun-drying	Robust, low-value bulk material	Photodegradation; dust/insect contamination
Shade-drying	Volatile oils, coloured/light-sensitive drugs	Slower; needs more space and time
Oven / hot-air drying	Most commercial-scale processing	Heat can degrade sensitive constituents if not controlled
Freeze-drying	High-value, heat-labile material	Expensive; not practical for bulk drugs

- **Comminution (size reduction)** — cutting, chopping, or powdering dried material to the particle size needed for the next step (extraction, packaging, or direct use); also increases surface area for more efficient extraction.
- **Sorting and grading** — separating material by size, colour, or quality grade, which is often tied directly to its market value.
- **Sterilisation/decontamination** (where required) — steam or other approved treatment to reduce microbial load without unacceptably degrading the active constituents.
- **Packing** — into clean, labelled, appropriately moisture-proof containers immediately after processing, minimising the time the dried material is exposed to ambient humidity before storage begins (Section 3.3).

4. Plant Hormones and Their Applications in Cultivation

Plant hormones (phytohormones) are naturally occurring signalling molecules that regulate growth and development. Synthetic analogues of several of them are used deliberately in medicinal plant cultivation and micropropagation to improve rooting, germination, and yield.

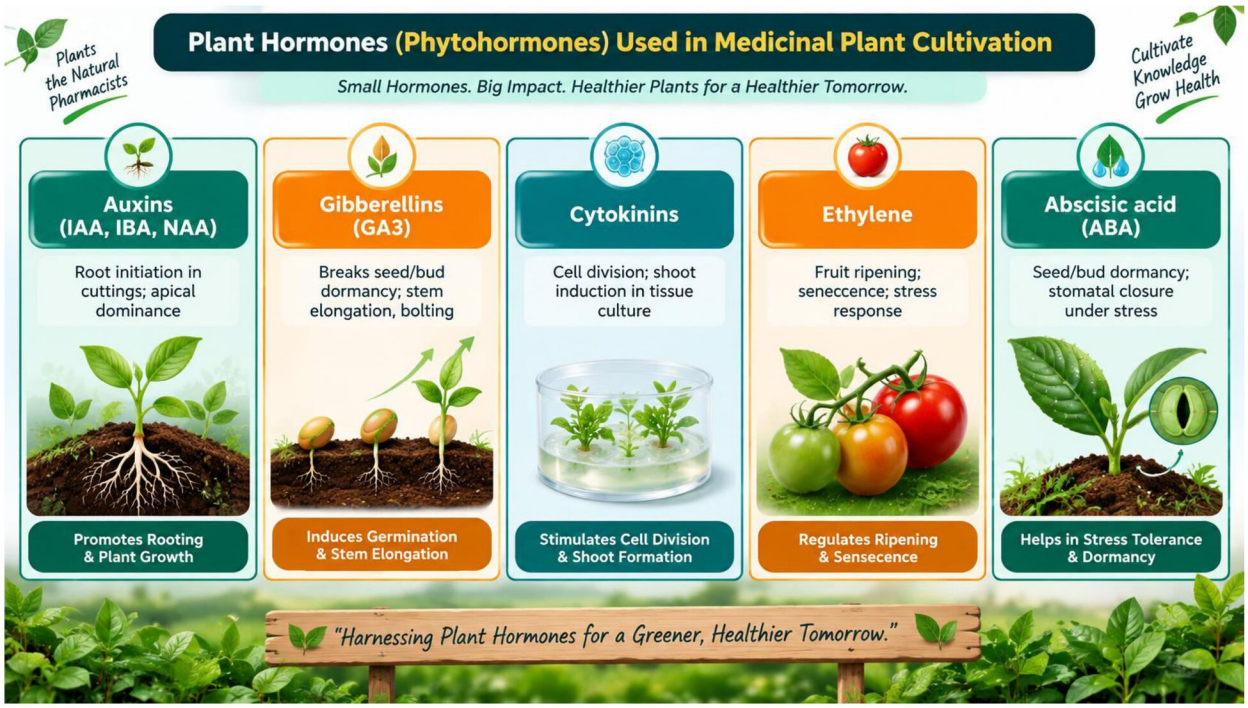

Figure 4.1 — The five major classes of plant hormones and their main applications in cultivation.

- **Auxins** (IAA, IBA, NAA) — promote **root initiation in cuttings** (the single most common horticultural use in medicinal plant propagation) and control apical dominance. Cuttings are often dipped in an auxin (e.g. IBA) rooting powder/solution before planting.
- **Gibberellins** (GA3) — **break seed and bud dormancy**, promote stem elongation and bolting, and can be used to improve germination rates of otherwise slow- or poor-germinating medicinal-plant seeds (a recognised problem in species such as Chirata).
- **Cytokinins** — promote **cell division**; in tissue culture, the ratio of cytokinin to auxin in the medium determines whether an explant develops shoots (high cytokinin:auxin) or roots (high auxin:cytokinin) — a Imp practical control point in micropropagation.
- **Ethylene** — regulates **fruit ripening and senescence** and is produced as part of the plant's stress response; relevant to post-harvest handling of fruit/seed drugs.
- **Abscisic acid (ABA)** — maintains **seed and bud dormancy** and triggers stomatal closure under water stress; relevant to seed storage behaviour and drought-stress management in cultivation.

4.1 Practical Applications in Medicinal Plant Cultivation

- **Improving vegetative propagation success** — auxin treatment of cuttings increases rooting percentage and speed, especially useful for species that are difficult to root from cuttings alone.
- **Breaking dormancy for uniform germination** — gibberellin treatment of seed lots helps synchronise germination, useful when uniform crop stands are needed for mechanised cultivation.

- **Micropropagation** — precise combinations of auxins and cytokinins in tissue-culture media allow mass clonal multiplication of elite, high-yielding, or endangered genotypes (linking to Sections 1 and 6).
- **Yield and quality management** — hormone treatments can be used to influence flowering time, fruit set, or senescence timing, helping align the harvest window with the plant's peak constituent content (Section 3).

5. Polyploidy, Mutation and Hybridization for Secondary Metabolites

Beyond agronomic management, the genetic makeup of the plant itself can be deliberately altered to improve the yield or profile of the secondary metabolites it produces. Three classical approaches are used: inducing polyploidy, inducing mutations, and hybridization.

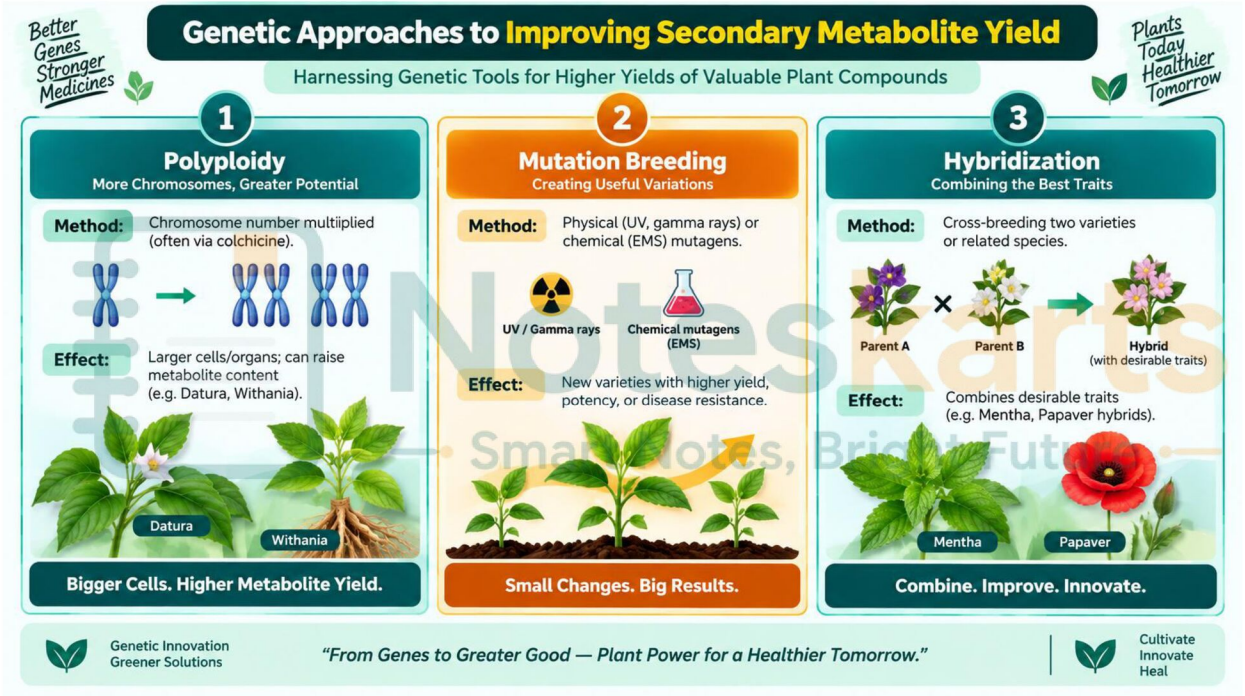

Figure 5.1 — Three genetic approaches used to improve secondary metabolite yield in medicinal plants.

5.1 Polyploidy

- **Polyploidy** = a cell or organism carries more than the normal two complete sets of chromosomes (e.g. triploid, tetraploid).
- Most commonly **induced artificially using colchicine**, an alkaloid from Colchicum autumnale (autumn crocus) that disrupts spindle-fibre formation during cell division, so chromosomes fail to separate and the resulting cell ends up with a doubled chromosome number.
- **Effects:** polyploid plants often show larger cells, larger organs (leaves, flowers, fruit), and — relevant here — can show **altered, sometimes higher, secondary**

metabolite content, since gene dosage for biosynthetic pathways increases along with chromosome number.

- **Examples cited in pharmacognosy:** induced polyploidy has been studied in *Datura* species (tropane alkaloid content) and in *Withania somnifera* (ashwagandha; withanolide content), among others.
- **Limitation:** the effect on metabolite content is not guaranteed or uniform across species — it must be verified experimentally for each case, and polyploid plants can also show reduced fertility.

5.2 Mutation Breeding

- Uses **mutagens** to induce random, heritable changes in a plant's DNA, then screens the resulting population for individuals with improved traits.
- **Physical mutagens:** UV light, gamma rays, X-rays.
- **Chemical mutagens:** ethyl methanesulfonate (EMS) and related alkylating agents.
- **Goals:** higher yield of the target constituent, improved disease resistance, better agronomic characteristics (e.g. shorter stature, synchronised flowering), or an altered ratio of constituents.
- Once a useful mutant is identified, it is typically propagated **vegetatively** (Section 1) to preserve the new trait unchanged, since sexual reproduction could reintroduce variation.

5.3 Hybridization

- **Cross-breeding** two different varieties, cultivars, or closely related species to combine desirable traits from each parent in the offspring.
- **Classic pharmacognosy examples:** *Mentha* (mint) hybrids combining menthol content with better agronomic performance; *Papaver* (opium poppy) breeding programmes aimed at particular alkaloid ratios (e.g. higher thebaine, lower morphine, for specific pharmaceutical feedstock needs).
- Hybrid vigour (heterosis) can also improve overall growth and yield, indirectly increasing total metabolite output per hectare even without changing the metabolite concentration itself.

Exam framing: all three techniques share the same underlying goal — improving the **genetic potential** of the crop for secondary metabolite production — but they work by different mechanisms: polyploidy changes chromosome number, mutation breeding changes DNA sequence, and hybridization recombines existing genetic variation from two parents.

Technique	What changes	Typical agent/method	Propagated onward by
Polyploidy	Chromosome number	Colchicine treatment	Vegetative (to fix the trait)

Technique	What changes	Typical agent/method	Propagated onward by
Mutation breeding	DNA sequence	UV/gamma rays, EMS	Vegetative (to fix the trait)
Hybridization	Combination of two parents' genes	Controlled cross-pollination	Seed (F1) or vegetative (to fix a stable line)

6. Ex-Situ and In-Situ Conservation; Value Addition

Overharvesting, habitat loss, and slow natural regeneration have pushed a growing number of medicinal plants toward scarcity.

Conservation strategies are generally grouped into two broad categories, depending on whether the plant is protected within or outside its natural habitat.

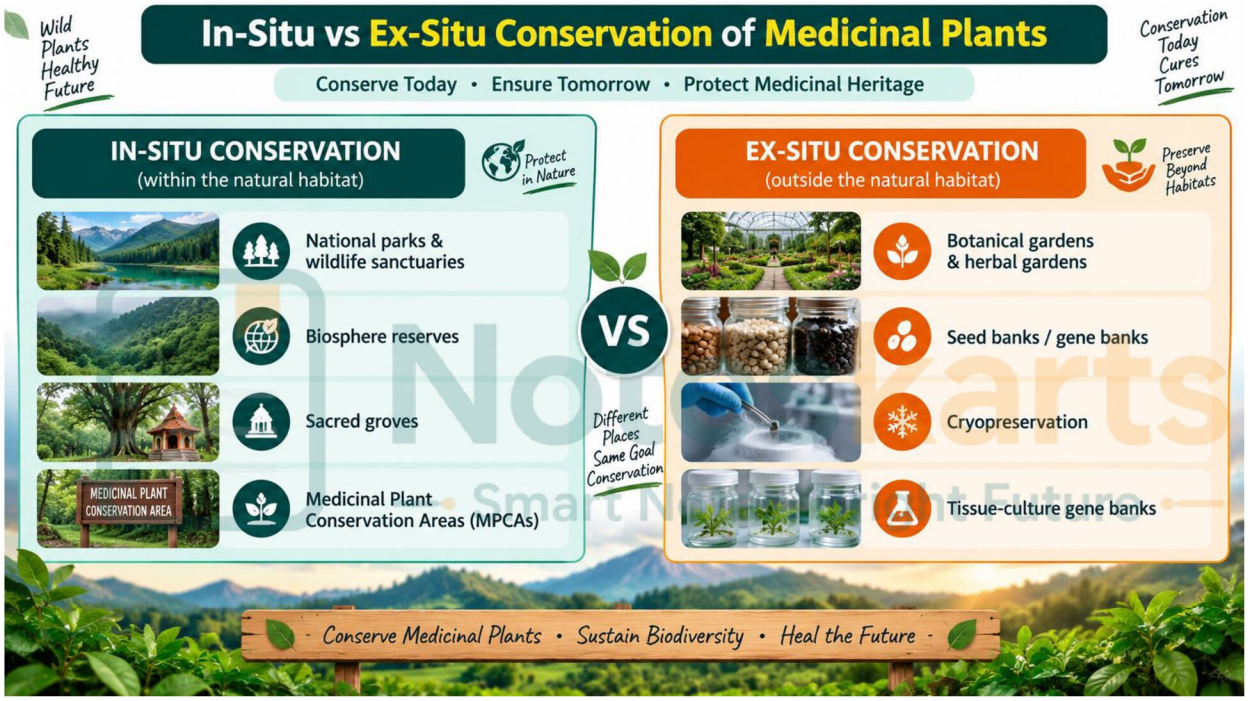

Figure 6.1 — In-situ and ex-situ conservation strategies for medicinal plants.

6.1 In-Situ Conservation

In-situ conservation means protecting a species within its natural habitat.

- The plant is conserved along with:
- **National parks and wildlife sanctuaries** — legally protected areas where habitat and species are conserved together.
- **Biosphere reserves** — larger protected zones that combine conservation with sustainable use by local communities.
- **Sacred groves** — patches of forest traditionally protected by local communities for religious/cultural reasons, which often incidentally conserve rare medicinal plants.

- **Medicinal Plant Conservation Areas (MPCAs)** — areas specifically designated to protect wild populations of medicinal plant species.
- **Advantage:** preserves the plant's natural genetic diversity and its co-evolved ecological relationships (pollinators, soil microbes) that ex-situ methods cannot fully replicate.

6.2 Ex-Situ Conservation

- Ex-situ conservation means protecting a species outside its natural habitat.
- The plant is maintained under human-managed conditions..
- **Botanical gardens and herbal gardens** — living collections maintained for conservation, education, and research.
- **Seed banks / gene banks** — store seed under controlled low-temperature, low-humidity conditions for long-term preservation.
- **Cryopreservation** — storage of seeds, pollen, or tissue at ultra-low temperatures (usually in liquid nitrogen), halting metabolic activity almost completely for very long-term storage.
- **Tissue-culture gene banks** — in-vitro plantlets or callus cultures maintained under slow-growth conditions; particularly useful for species with recalcitrant seed (seed that cannot survive drying/freezing) or very slow natural propagation.
- **Advantage:** protects the species from an acute threat to its wild habitat, and provides a controlled source of planting material for reintroduction or cultivation.

6.3 Strategies for Value Addition of Medicinal Plants

- **Value addition** means processing a raw medicinal plant into a form that commands a higher market price than the unprocessed crude drug — spreading economic benefit further and reducing pressure to over-harvest for marginal returns.
- **Standardisation** — producing a quality-assured, marker-compound-standardised extract rather than selling raw, variable material.
- **Product diversification** — converting raw material into extracts, essential oils, tinctures, or finished formulations rather than exporting only unprocessed drug.
- **Geographical Indication (GI) tagging** — certifying a medicinal plant product's authentic regional origin (as has been done for several Indian medicinal and aromatic plants), commanding a premium and protecting against misrepresentation.
- **Quality certification** — organic certification, GACP/GMP compliance certificates, and pharmacopoeial-standard compliance all add buyer confidence and price.
- **Community-based enterprises** — involving local collectors in primary processing (rather than selling only raw material) captures more value locally and creates an economic incentive for sustainable, rather than exhaustive, harvesting.

Worked example: raw, unprocessed Chirata sold as whole dried plant material fetches a comparatively low price; the same material processed into a standardised, marker-compound-quantified extract for a pharmaceutical or nutraceutical buyer commands a substantially higher price per kilogram — illustrating why value addition, not just increased harvest volume, is now emphasised as the more sustainable route to raising farmer/collector income.

7. Eco-Pharmacognosy and Conservation of Endangered Medicinal Plants

- **Eco-pharmacognosy** is an approach that integrates ecological principles with pharmacognosy, aiming to ensure that medicinal plants are identified, harvested, and used in ways that are ecologically sustainable, not just pharmacologically effective.
- It treats a medicinal plant population in the wild as a **renewable resource that can be exhausted** if harvesting outpaces natural regeneration — and looks for harvesting protocols, cultivation alternatives, or synthetic/biotechnological substitutes that relieve pressure on wild populations.
- **Relevant tools:** CITES trade restrictions, IUCN Red List assessment, sustainable-harvest quotas, promotion of cultivation over wild collection, and biotechnological production (plant tissue culture, as covered in Unit I) as an alternative source.

7.1 Case Study — Kutki (Picrorhiza kurroa)

- **Family:** Plantaginaceae (older texts: Scrophulariaceae).
- **Habitat:** alpine western Himalayas (Kashmir to Sikkim), at altitudes of roughly **2,700–4,500 m**.
- **Part used:** dried rhizome and root.
- **Imp constituents:** iridoid glycosides — **picroside I and picroside II** (together with kutkoside, the mixture is called “kutkin”/“picroliv” in formulated products).
- **Pharmacological use:** hepatoprotective (its best-documented action), also antioxidant, anti-inflammatory, and immunomodulatory.
- **Threat status:** classified as **endangered**, and listed under **CITES Appendix II**, meaning international trade requires a permit certifying the material's source.
- **Why it became endangered:** slow natural growth rate, destructive harvesting (the whole rhizome/root is uprooted, killing the plant), habitat degradation, and rising commercial demand for herbal liver formulations.

7.2 Case Study — Chirata (Swertia chirayita)

- **Family:** Gentianaceae.

- **Habitat:** temperate Himalayas (from Kashmir through Nepal and Bhutan), at altitudes roughly **1,200–3,300 m**.
- **Part used:** whole plant (collected at the flowering/fruiting stage).
- **Imp constituents:** bitter compounds — **amarogentin** and **swertiamarin** (secoiridoid glycosides), plus xanthones such as mangiferin.
- **Pharmacological use:** traditionally antipyretic (fever) and a bitter digestive tonic; also studied for hepatoprotective and antidiabetic activity.
- **Threat status:** classified as **critically endangered** by the IUCN — a more severe category than Kutki's.
- **Why it became critically endangered:** unregulated over-exploitation of wild stock (it is one of the most heavily traded Himalayan medicinal herbs), combined with **poor natural seed viability and germination**, which slows natural population recovery even where habitat is intact.

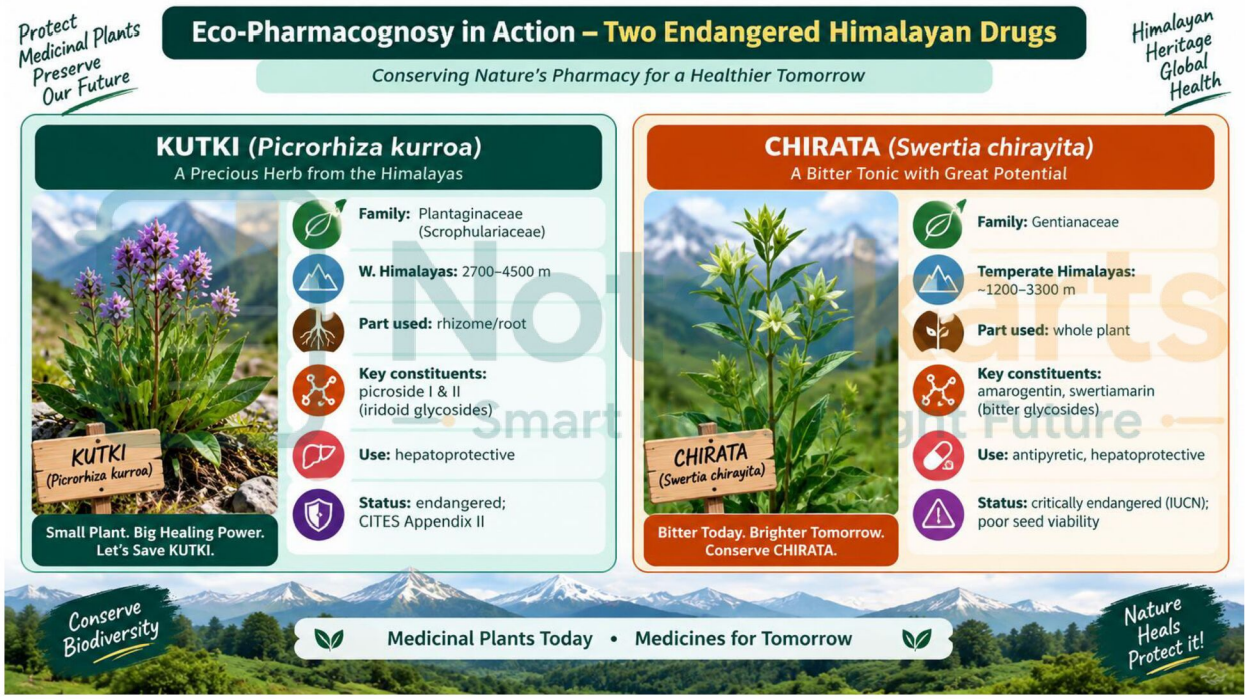

Figure 7.1 — Kutki and Chirata compared: family, habitat, active constituents, use, and conservation status.

7.3 Conservation Strategies Applied to Kutki and Chirata

- **Promoting cultivation** as an alternative to wild collection, including distributing quality planting material to farmers in suitable Himalayan agro-climatic zones.
- **In-vitro propagation/micropropagation** to multiply planting stock rapidly without depleting wild populations (directly applying the tissue-culture principles from Unit I and Section 1 of this unit).
- **Community-based sustainable harvest protocols** — rotational harvesting, minimum size/age limits before a plant may be collected, and leaving a proportion of the population to regenerate.

- **Regulatory protection** — CITES listing (Kutki) and IUCN Red List recognition (Chirata) increase international scrutiny of trade and support conservation funding and policy attention.
- **Research into seed biology** (particularly for Chirata) to overcome poor germination and support both wild-population recovery and cultivation.

Exam framing: Kutki and Chirata are useful paired examples because they show two different endangerment routes to the same broad problem — Kutki mainly from destructive harvesting of a slow-growing rhizome, and Chirata from a combination of heavy trade demand and an intrinsic biological bottleneck (poor seed viability) that limits how fast the population can recover even when protected.