BP105T · B.PHARM THEORY

INTRODUCTION TO PHARMACOGNOSY

Unit II — Cultivation, Collection, Processing and Storage of Drugs of Natural Origin

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From-zero teaching standard: every technical term is defined before use.

Syllabus coverage: Unit II (8 hours).

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UNIT II — CULTIVATION, COLLECTION, PROCESSING & STORAGE

CHAPTER 6: METHODS OF PLANT CULTIVATION AND GOOD AGRICULTURAL & COLLECTION PRACTICES

6.1 Learning Objectives

After studying this chapter, the student will be able to:

1. Explain why medicinal plants are cultivated rather than only collected from the wild.
2. Describe the main methods of plant cultivation: seeds, vegetative propagation, and tissue culture.
3. State the objectives and key steps of WHO Good Agricultural and Collection Practices (GACP).
4. List the requirements for personnel, equipment, and documentation under GACP.
5. Explain the pharmacist's role in ensuring raw material quality at the cultivation stage.

6.2 Introduction — Why Cultivate?

In Unit I we learned that most drugs of natural origin come from plants. A manufacturer of a medicine needs a **large, reliable, uniform supply** of the plant material — every batch of tablets should contain the same amount of active constituent. If material is collected only from wild plants:

- the supply is **irregular** (depends on season, weather, and who goes to the forest);
- the quality is **variable** (plants of different ages, soils, and locations contain different amounts of active constituents);
- the species may be **over-exploited** and driven toward extinction (as happened with kutki and chirata).

Cultivation (deliberately growing medicinal plants like a crop) solves these problems: controlled conditions give a uniform product, year-round availability, and protection of wild populations. This chapter covers how medicinal plants are cultivated and the WHO guidelines that keep this process safe and scientific.

6.3 Definitions

- **Cultivation:** The deliberate growing of plants on a managed scale (farm, plantation, or greenhouse) for a defined purpose — here, for drug production.
- **Collection:** Gathering plant material from **wild-growing (natural) populations**, as opposed to cultivated ones.
- **GACP (Good Agricultural and Collection Practices):** WHO guidelines (2003) that lay down quality standards for the **growing, harvesting, and primary processing** of medicinal plants — whether cultivated or wild-collected.
- **GAP (Good Agricultural Practices):** The cultivation half of GACP — correct site selection, soil management, irrigation, pest control, and harvesting.
- **GCP (Good Collection Practices):** The wild-collection half of GACP — sustainable, legal, clean collection from natural habitats.

Terminology alert. In this subject, GCP means **Good Collection Practices** (of medicinal plants), *not* Good Clinical Practices (the drug-trial GCP). Examiners love this confusion trap — always expand the abbreviation in your answer.

6.4 Methods of Plant Cultivation

Three routes are used, chosen according to the plant's biology and the economics of the crop.

6.4.1 Seed propagation (sexual propagation)

Growing plants from **seeds**. Seeds are sown in nurseries or directly in the field, seedlings are raised, and then transplanted.

Advantages: cheap, easy to transport and store, produces genetically varied plants. **Limitations:** some medicinal plants have seeds with **poor or delayed germination**; the offspring are not identical to the parent, so the active-constituent content can vary; plants raised from seed often take **longer to mature**. **Examples:** *Senna* (*Cassia angustifolia*), *Isabgol* (*Plantago ovata*), *Ashwagandha* (*Withania somnifera*) are commonly raised from seed.

6.4.2 Vegetative propagation (asexual propagation)

Growing new plants from **parts of the parent plant** — stem cuttings, root cuttings, runners, suckers, layering, or grafting — instead of seeds.

Advantages: the new plants are **genetically identical** to the selected parent (uniform active-constituent content); faster than seed raising; the only option for plants that are **seedless or have sterile seeds**. **Limitations:** more labour-intensive; diseases of the parent can be carried to the offspring. **Examples:** *Mint* (*Mentha* species) is propagated by runners/suckers; many medicinal shrubs by stem cuttings.

6.4.3 Plant tissue culture (micropropagation)

Growing whole plants from **tiny pieces of plant tissue (explants) or single cells** on a sterile nutrient medium in glass vessels — the same "plant tissue culture" mentioned in Unit I as a source of drugs.

Advantages: thousands of **disease-free, genetically uniform plants** from a small starting piece in a short time; independent of season; ideal for **rare or endangered species** that cannot be propagated otherwise. **Limitations:** needs a laboratory, trained staff, and sterile conditions — expensive; plants must be **hardened** (gradually accustomed to outdoor conditions) before field transfer. **Pharmacy angle:** tissue culture is also used to produce secondary metabolites directly in bioreactors, and to conserve endangered species like *kutki*.

> **Analogy.** Seed propagation is like raising children — each one is a little different. Vegetative propagation is like photocopying — every copy is identical to the original. Tissue culture is like photocopying *in a clean room, thousands at a time*.

6.5 WHO GACP — Good Agricultural and Collection Practices

6.5.1 Why GACP was needed

Before these guidelines, medicinal plants were often grown or collected without standards: contaminated soil, wrong harvesting time, drying on dirty floors, mixing with other species, no records. The result was **contaminated, misidentified, or weak material** entering medicines. WHO published the *Guidelines on Good Agricultural and Collection Practices (GACP) for Medicinal Plants* in **2003** to fix this.

Objectives of GACP:

1. Ensure the **safety and quality** of medicinal plant materials.
2. Protect **consumers** from contamination (microbes, heavy metals, pesticides).
3. Promote **sustainable** use — protect wild populations and the environment.
4. Encourage **national standards** for cultivation and collection.

6.5.2 GACP requirements — cultivation (GAP)

Step	GACP requirement (what the syllabus expects)
Site selection	Land must be free from contamination (no industrial waste, heavy metals, or sewage irrigation); soil quality and previous land use checked
Seeds / planting material	Botanically identified, of known origin, free from pests and diseases
Cultivation	Correct sowing time, spacing, irrigation with clean water, balanced manuring
Plant protection	Integrated pest management; if pesticides are used, only approved ones, at correct dose and with proper waiting period before harvest
Harvest	At the correct **growth stage and time of day** when active constituents are maximum; no wet/diseased material; clean tools and containers
Primary processing	Prompt drying under hygienic conditions; protection from rain, dust, and animals during drying
Personnel	Trained workers; basic hygiene; protective equipment where needed
Documentation	Records of seed source, cultivation steps, pesticide use, harvest date and quantity, and storage — batch traceability

6.5.3 GACP requirements — collection (GCP)

For material collected from the **wild**:

1. Collection only with **legal permission** (respecting national laws and protected areas).
2. Collectors must be able to **identify the correct species** (avoid confusion with similar-looking plants).
3. Collection must be **sustainable** — leave enough plants for regeneration; do not collect endangered species destructively.
4. Material collected at the **right season and growth stage**; clean containers; no mixing of species.
5. **Documentation** of collection site, date, quantity, and collector.

6.6 Pharmacy Relevance

A pharmacist in industry, quality control, or community practice is affected by cultivation quality:

- **QC pharmacist:** checks raw material against pharmacopoeial standards — GACP-compliant material passes more reliably.
- **Manufacturing pharmacist:** uniform raw material → uniform extract → uniform finished product.
- **Community pharmacist:** can counsel that "herbal" does not automatically mean safe — contamination and adulteration begin in the field, which is why GACP exists.

6.7 India Context

India's **National Medicinal Plants Board (NMPB)** promotes cultivation of medicinal plants and supports farmers with subsidies and buy-back arrangements. Institutions like the **Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow**, develop improved varieties and cultivation technology (for example, high-yielding mint varieties). The **Ayurvedic Pharmacopoeia of India** quality standards assume properly cultivated/collected material.

6.8 High-Yield Points

- Cultivation gives **uniform, reliable, sustainable** supply; wild collection is irregular and risks extinction.
- Three cultivation methods: **seeds (cheap, variable) → vegetative (uniform clones) → tissue culture (mass uniform, expensive)**.
- WHO GACP guidelines were published in **2003**; they cover **cultivation + wild collection + primary processing**.
- GCP in pharmacognosy = **Good Collection Practices** (not Clinical).
- GACP pillars: clean site → identified planting material → correct harvest time → hygienic drying → full documentation.

6.9 Common Confusions & Mistakes

- **Confusion:** GAP vs GACP. **Clarification:** GAP (agricultural) + GCP (collection) = GACP (the WHO guideline covering both).
- **Confusion:** GCP meaning. **Clarification:** in pharmacognosy = Good Collection Practices.
- **Mistake:** writing that tissue culture is the cheapest method. It is the most **expensive** but most productive per unit of starting material.
- **Mistake:** saying wild collection is always better ("more natural"). For medicine manufacture, **cultivation is preferred** for uniformity and sustainability.

6.10 Mnemonic

"Sow Clean, Pick Right, Dry Fast, Write All" — the GACP sequence: good **sow**ing material, **clean** site, **pick** at the right time, **dry** quickly and hygienically, **write** (document) everything.

6.11 Chapter Summary

- Medicinal plants are **cultivated** (not only wild-collected) to obtain a uniform, dependable, sustainable supply of raw material.
- Methods: **seed propagation** (cheap, genetically variable), **vegetative propagation** (uniform clones), and **plant tissue culture** (mass, disease-free, uniform plants — expensive).
- WHO **GACP (2003)** sets quality standards for growing, collecting, and primary processing of medicinal plants: clean sites, identified material, correct harvest timing, hygienic drying, trained personnel, and complete documentation.
- Wild collection must be legal, correctly identified, sustainable, and documented.

6.12 One-Minute Revision

- Why cultivate? Uniformity + reliable supply + conservation.
- 3 methods: seeds / vegetative / tissue culture.
- GACP = WHO 2003; GAP = cultivation, GCP = collection.
- Harvest at peak active-constituent stage; dry hygienically; document everything.

6.13 Questions

MCQs

1. WHO GACP guidelines for medicinal plants were published in: (a) 1993 (b) 2003 (c) 2013 (d) 2023
2. In pharmacognosy, GCP stands for: (a) Good Clinical Practices (b) Good Collection Practices (c) Good Cultivation Procedures (d) General Collection Protocol
3. Which propagation method gives genetically identical plants? (a) Seed sowing (b) Vegetative propagation (c) Both equally (d) Neither
4. Under GACP, pesticides on medicinal plants: (a) are banned (b) may be used if approved, at correct dose with waiting period (c) may be used freely (d) are replaced by antibiotics
5. Mint is commercially propagated by: (a) seeds (b) runners/suckers (c) tissue culture only (d) grafting

Viva

1. Why is cultivation preferred over wild collection for drug manufacture?
2. What are the objectives of WHO GACP?
3. Differentiate GAP and GCP.
4. List the advantages of vegetative propagation.
5. Why is documentation a GACP requirement?

Application-based

1. A company wants a uniform belladonna leaf supply for atropine tablets. Which propagation method would you recommend and why?
2. A farmer's senna field is next to a sewage-fed plot. What GACP principle is violated, and what risk does it create?

Answers: 1-(b), 2-(b), 3-(b), 4-(b), 5-(b)

6.14 References

- WHO. *WHO Guidelines on Good Agricultural and Collection Practices (GACP) for Medicinal Plants.* Geneva: World Health Organization; 2003.
- Evans WC. *Trease and Evans Pharmacognosy.* 16th ed. London: Saunders Elsevier; 2009.
- Kokate CK, Purohit AP, Gokhale SB. *Pharmacognosy.* Pune: Nirali Prakashan. (Standard Indian textbook covering cultivation and collection.)

CHAPTER 7: FACTORS INFLUENCING CULTIVATION, COLLECTION AND STORAGE

7.1 Learning Objectives

After studying this chapter, the student will be able to:

1. List the environmental and human factors that influence cultivation of medicinal plants.
2. Explain how each factor affects the **yield of active constituents** (not just plant growth).
3. State the rules for correct collection and storage of crude drugs.
4. Explain why storage conditions can destroy a drug's activity.

7.2 Introduction — Growing the Plant Is Not Enough

A farmer can grow a big, healthy-looking plant that contains **almost none** of the active constituent — or a smaller plant rich in it. This is the central idea of the chapter: for medicinal plants, success is measured not by how the plant *looks* but by how much **active constituent** it contains. Cultivation, collection, and storage must all be managed to **maximize and preserve** these constituents.

7.3 Definitions

- **Active constituent:** the chemical compound (or group) in the crude drug responsible for its therapeutic action (e.g., quinine in cinchona bark).
- **Yield:** here, the amount of active constituent obtained — per plant, per hectare, or per batch — not just the weight of plant material.
- **Post-harvest handling:** everything done after harvesting — drying, packing, storage, transport — that determines whether quality is preserved or lost.

7.4 Factors Influencing Cultivation

7.4.1 Climate (temperature, rainfall, light, humidity)

Each medicinal plant has a preferred climate. Temperature and light directly affect photosynthesis and the formation of secondary metabolites. **Classic example:** *Cinchona* grown at higher altitudes produces more quinine; peppermint oil composition changes with day length and temperature.

7.4.2 Soil (type, pH, nutrients, drainage)

Soil provides water and minerals. pH and nutrient balance affect both growth and constituent formation — for instance, **alkaloid content** in several plants responds to nitrogen availability. Waterlogged or contaminated soils harm the crop and can introduce heavy metals into the drug.

7.4.3 Altitude

Altitude combines temperature, light intensity, and UV exposure. Many Himalayan medicinal plants (kutki, chirata) produce their characteristic constituents only at **high altitude**; the same species grown in the plains may be chemically poor.

7.4.4 Water / irrigation

Too little water stunts growth; too much causes root diseases and dilutes constituents. Clean irrigation water is a GACP requirement — sewage water introduces pathogens and heavy metals.

7.4.5 Manures and fertilizers

Balanced nutrition supports healthy growth, but **excessive nitrogen** can push a plant to make leaves instead of secondary metabolites, lowering drug quality. Organic manures are generally preferred for medicinal crops.

7.4.6 Plant age and growth stage

Active constituents are usually maximum at a **particular stage** — e.g., senna leaves are collected at a defined maturity; belladonna leaves at flowering. Harvesting too early or too late gives weak material.

7.4.7 Time of collection (season, time of day)

Constituent levels fluctuate daily and seasonally. **Examples:** volatile-oil plants are often collected in the **morning** before the sun evaporates the oil; rhubarb collected in summer differs from winter collections.

7.4.8 Pests, diseases, and weeds

Pests damage the crop and the wounds invite microbes. Weeds compete for water and nutrients — and a **weed harvested by mistake is an adulterant** (links to Unit III).

7.4.9 Genetic / varietal factor

Within one species, different **varieties or chemotypes** contain different amounts of active constituent. Selecting and propagating a high-yielding variety is the first step of quality — this connects directly to Chapter 9 (hybridization, polyploidy).

> **Memory hook.** The nine factors spell **C-S-A-W-M-A-T-P-G** — "Climate, Soil, Altitude, Water, Manures, Age, Time, Pests, Genetics."

7.5 Rules for Collection

1. Collect at the **correct growth stage, season, and time of day** for maximum active constituents.
2. Collect only the **correct plant part** (leaf, bark, root…) and the **correct species** — correct botanical identification is essential.
3. Do not collect **diseased, insect-damaged, or decayed** material.
4. Use **clean tools and containers**; do not mix different species or plant parts.
5. For wild collection: follow GCP — legal permission, sustainable quantities, documentation.

7.6 Processing and Storage

7.6.1 Why processing matters

Fresh plant material contains water and active enzymes. If it is piled up wet, **fermentation and mould growth** begin within hours, destroying constituents and producing toxins. Prompt **drying** stops enzyme action and microbial growth.

7.6.2 Storage enemies and rules

Enemy	Damage caused	Storage rule
Moisture	mould growth, fermentation, hydrolysis of glycosides	dry to safe moisture; airtight/moisture-proof packing
Heat	evaporation of volatile oils; degradation of constituents	cool storage, away from sun
Light	bleaches colour; degrades light-sensitive constituents	opaque containers / dark rooms
Air (oxygen)	oxidation of oils and resins (rancidity)	well-closed containers
Insects and rodents	eat the drug; droppings contaminate it	clean godowns, fumigation where permitted, inspection
Mixing	one drug contaminating another	separate, labelled containers

General storage rules: store in **clean, dry, well-ventilated** godowns; keep containers **off the floor** (on pallets); **label** every container with drug name, batch, and date; follow **first-in-first-out** so old stock is used first; inspect periodically.

7.7 Pharmacy Relevance

- A QC pharmacist **rejects** consignments that arrive mouldy, insect-infested, or mixed — most such defects trace back to bad drying or storage.
- Storage rules for crude drugs are the **same principles** behind "store in a cool, dry place" on medicine labels.
- Understanding these factors helps a pharmacist advise manufacturers and farmers — an emerging professional role in India's herbal industry.

7.8 High-Yield Points

- Quality = **active-constituent content**, not plant size.
- Nine cultivation factors: **Climate, Soil, Altitude, Water, Manures, Age/stage, Time of collection, Pests, Genetics**.
- Harvest at the stage/season/time when constituents peak; volatile-oil drugs often collected in the **morning**.
- Storage enemies: **moisture, heat, light, air, insects** — store cool, dry, dark, airtight, labelled.

7.9 Common Confusions & Mistakes

- **Confusion:** "bigger plant = better drug." **Clarification:** a large plant can be chemically poor; judge by **constituent content**.
- **Mistake:** writing that fertilizers always improve quality. Excess nitrogen can **reduce** secondary metabolite formation.
- **Mistake:** omitting **time of day** in collection answers — it is a distinct syllabus factor with the volatile-oil example.

7.10 Mnemonic

"Cool, Dry, Dark, Tight, Labelled Right" — the five storage rules every crude-drug godown follows.

7.11 Chapter Summary

- Medicinal-plant quality is judged by **active-constituent yield**, influenced by climate, soil, altitude, water, manures, plant age, collection time, pests, and genetics.
- Collection must target the **right species, part, stage, season, and time of day**, with clean tools and no mixing.
- Prompt drying prevents fermentation and mould; storage must defeat **moisture, heat, light, air, and insects** through cool, dry, dark, airtight, labelled storage with stock rotation.

7.12 One-Minute Revision

- 9 factors: C-S-A-W-M-A-T-P-G.
- Collect right species/part/stage/season/time; morning for volatile oils.
- Dry promptly; store cool-dry-dark-airtight-labelled; FIFO.

7.13 Questions

MCQs

1. Volatile-oil-bearing plants are best collected: (a) at noon (b) in the morning (c) at midnight (d) during rain
2. Which storage enemy causes hydrolysis of glycosides? (a) Light (b) Moisture (c) Cold (d) Labelling
3. Excess nitrogen fertilizer may: (a) always increase alkaloids (b) reduce secondary metabolite formation (c) kill all pests (d) improve drying
4. High-altitude Himalayan plants grown in plains often show: (a) higher constituent content (b) lower constituent content (c) no change (d) faster flowering only
5. FIFO in crude-drug storage means: (a) fastest drying method (b) first-in-first-out stock use (c) fumigation protocol (d) foreign matter limit

Viva

1. Why is active-constituent content a better quality measure than plant weight?
2. Name the factors influencing cultivation of medicinal plants.
3. Why are volatile-oil drugs collected in the morning?
4. List the enemies of stored crude drugs and one control measure for each.
5. Why must containers be labelled and stored off the floor?

Application-based

1. Two belladonna leaf consignments arrive — one mouldy, one clean. Trace the likely field/storage failures behind the mouldy lot.
2. A farmer asks whether doubling urea will double his ashwagandha's withanolide content. What do you advise?

Answers: 1-(b), 2-(b), 3-(b), 4-(b), 5-(b)

7.14 References

- Evans WC. *Trease and Evans Pharmacognosy.* 16th ed. London: Saunders Elsevier; 2009.
- WHO. *WHO Guidelines on Good Agricultural and Collection Practices (GACP) for Medicinal Plants.* Geneva: WHO; 2003.

CHAPTER 8: PLANT HORMONES AND THEIR APPLICATIONS IN CULTIVATION

8.1 Learning Objectives

After studying this chapter, the student will be able to:

1. Define plant hormones (phytohormones).
2. Name the five classical plant hormones and one key function of each.
3. Explain at least one practical application of each hormone in medicinal-plant cultivation.
4. Relate hormone applications to better yield of crude drugs.

8.2 Introduction — Chemical Messengers of Plants

Animals have hormones (like insulin) that carry messages through the body. **Plants have hormones too** — chemicals made in tiny amounts in one part of the plant that control growth in another part. A farmer who understands these messengers can **command** plants: "grow roots here," "ripen now," "stay fresh longer." This chapter introduces the five classical plant hormones and how each is put to work in medicinal-plant cultivation.

8.3 Definition

- **Plant hormone (phytohormone):** an organic chemical produced naturally in the plant in very small quantities that regulates growth, development, and responses to the environment.
- Key idea: **tiny amount, large effect** — the same principle as human hormones.

8.4 The Five Classical Plant Hormones

8.4.1 Auxins — the root makers

- **Main natural auxin:** indole-3-acetic acid (IAA).
- **Functions:** stimulate **root formation** on cuttings; control bending toward light; maintain apical dominance (main shoot suppressing side branches).
- **Cultivation application:** stem cuttings of medicinal plants are dipped in auxin powder/solution (e.g., IBA — indole-3-butyric acid) to **speed and uniform rooting** — essential for vegetative propagation (Chapter 6).

8.4.2 Gibberellins — the shoot stretchers

- **Main example:** gibberellic acid (GA3).
- **Functions:** stem elongation; **breaking seed dormancy**; promoting germination and flowering in some species.
- **Cultivation application:** treating seeds with gibberellic acid **breaks dormancy and improves germination** of medicinal plants whose seeds otherwise sleep for months; used to increase cane/sugar yield in sugarcane (a classic textbook example of hormone application in crop improvement).

8.4.3 Cytokinins — the cell dividers

- **Main examples:** zeatin (natural), kinetin and benzyladenine (synthetic).
- **Functions:** promote **cell division** and shoot formation; **delay ageing (senescence)** of leaves.
- **Cultivation application:** the standard hormone for **shoot multiplication in plant tissue culture** — combined with auxins, cytokinins regenerate whole plants from tiny explants; also used to keep harvested leafy material fresh longer.

8.4.4 Abscisic acid (ABA) — the stress manager

- **Functions:** induces **dormancy** in seeds and buds; closes leaf pores (stomata) during water shortage — the plant's "drought alarm."
- **Cultivation application:** understanding ABA helps manage **water stress and dormancy**; ABA-related treatments improve survival of tissue-culture plantlets during hardening and transplanting.

8.4.5 Ethylene — the ripener

- **Functions:** a **gaseous** hormone; promotes **fruit ripening**, flower fading, and leaf fall.
- **Cultivation application: ethephon** (a compound that releases ethylene) is used to **uniformly ripen fruits** and to regulate flowering/fruiting in plantation crops.

8.5 Summary Table — Hormones at a Glance (exam favourite)

Hormone	Key natural example	Main function	Cultivation application
Auxins	IAA	root initiation, apical dominance	rooting of stem cuttings (IBA powder)
Gibberellins	GA3	stem elongation, break dormancy	improve seed germination; break dormancy
Cytokinins	Zeatin	cell division, delay senescence	shoot multiplication in tissue culture
Abscisic acid	ABA	dormancy, drought response	stress/dormancy management; transplant survival
Ethylene	Ethylene (gas)	fruit ripening	uniform ripening (ethephon)

8.6 How Hormones Connect to Drug Yield

Hormones do not directly "make" the active constituent, but by controlling **rooting, germination, shoot multiplication, and stress survival**, they decide how many healthy plants reach harvest — and healthy, correctly developed plants give the best constituent yield. In tissue culture (Chapter 6), the **auxin–cytokinin balance** is the actual dial that technicians turn: more cytokinin → shoots; more auxin → roots.

> **Analogy.** If the plant is a factory, hormones are the **supervisors' whistle signals** — one whistle starts the root shift, another starts the shoot shift, another calls a rest (dormancy). The farmer blows the right whistle at the right time.

8.7 Pharmacy Relevance

- Pharmacists working in herbal raw-material production use hormone treatments to **multiply elite, high-constituent varieties** quickly (links Chapters 8 → 9).
- Tissue-culture laboratories supplying planting material to farmers run on auxin/cytokinin protocols — a career avenue for pharmacognosy graduates.
- Understanding dormancy and germination helps in **seed testing and certification** of planting material.

8.8 High-Yield Points

- Five classical hormones: **Auxins, Gibberellins, Cytokinins, Abscisic acid, Ethylene**.
- Auxins → **rooting of cuttings**; Gibberellins → **break seed dormancy**; Cytokinins → **shoot multiplication in tissue culture**; ABA → **dormancy/stress**; Ethylene → **ripening (gas)**.
- **Auxin–cytokinin ratio** controls shoot vs root formation in tissue culture.

8.9 Common Confusions & Mistakes

- **Confusion:** ABA vs gibberellins. **Clarification:** they are **opponents** — gibberellins break dormancy and promote germination; ABA imposes dormancy.
- **Mistake:** calling ethylene a liquid spray. It is a **gas**; ethephon is the liquid that releases it.
- **Mistake:** saying cytokinins make roots. **Auxins** make roots; cytokinins make **shoots**.

8.10 Mnemonic

"A Gardener Can Always Excel" — **A**uxins (roots), **G**ibberellins (germination), **C**ytokinins (cell division/shoots), **A**BA (alarm/dormancy), **E**thylene (ripening).

8.11 Chapter Summary

- Plant hormones are **tiny-amount chemical messengers** regulating plant growth.
- The five classical hormones are **auxins, gibberellins, cytokinins, abscisic acid, and ethylene**, each with distinct functions.
- In medicinal-plant cultivation they are applied for **rooting cuttings (auxins), breaking seed dormancy (gibberellins), shoot multiplication in tissue culture (cytokinins), stress/dormancy management (ABA), and uniform ripening (ethylene)**.
- The **auxin–cytokinin balance** is the control dial of micropropagation.

8.12 One-Minute Revision

- 5 hormones: Auxins–Gibberellins–Cytokinins–ABA–Ethylene.
- Roots = auxin; dormancy broken = gibberellin; shoots in culture = cytokinin; dormancy imposed = ABA; ripening gas = ethylene.
- GA vs ABA are functional opponents.

8.13 Questions

> **MCQs**

1. The hormone used for rooting stem cuttings is: (a) cytokinin (b) auxin (c) ethylene (d) ABA
2. Seed dormancy is broken by: (a) ABA (b) gibberellins (c) ethylene (d) cytokinins
3. In tissue culture, shoot multiplication is promoted by: (a) auxins (b) cytokinins (c) ethylene (d) ABA
4. Which plant hormone is a gas? (a) Auxin (b) Gibberellin (c) Ethylene (d) Cytokinin
5. ABA and gibberellins are: (a) synergistic in dormancy (b) functional opponents (c) both gases (d) both root promoters

Viva

1. Define phytohormone.
2. Name the five classical plant hormones.
3. How are auxins used in vegetative propagation?
4. What is the role of the auxin–cytokinin ratio in tissue culture?
5. Give one cultivation application of ethylene.

Application-based

1. A nursery fails to root ashwagandha stem cuttings. Which hormone treatment would you suggest, and how is it applied?
2. A seed lot of a medicinal plant shows 20% germination due to dormancy. Which hormone could improve this, and what is the physiological logic?

Answers: 1-(b), 2-(b), 3-(b), 4-(c), 5-(b)

8.14 References

- Evans WC. *Trease and Evans Pharmacognosy.* 16th ed. London: Saunders Elsevier; 2009.
- Taiz L, Zeiger E. *Plant Physiology.* (Standard reference for phytohormone functions.)

CHAPTER 9: POLYPLOIDY, MUTATION AND HYBRIDIZATION — BREEDING BETTER MEDICINAL PLANTS

9.1 Learning Objectives

After studying this chapter, the student will be able to:

1. Define polyploidy, mutation, and hybridization in simple terms.
2. Explain how each technique can **increase the yield of secondary metabolites**.
3. Give one classic medicinal-plant example for each technique.
4. Explain why breeders target secondary metabolites rather than just plant size.

9.2 Introduction — From Ordinary Plants to Super Plants

In Chapter 7 we learned that the **genetic variety** of a plant decides how much active constituent it can make. This chapter asks: can we *improve* the genetics deliberately? Plant breeders have three classical tools — **polyploidy** (doubling chromosome sets), **mutation** (creating new variations), and **hybridization** (crossing two parents) — to create varieties that are richer in the drug's active constituents. These are the same principles behind high-yielding food crops, applied here to medicine.

9.3 Definitions

- **Gene:** a unit of heredity — a piece of DNA carrying instructions for one trait.
- **Chromosome:** the packaged structure carrying many genes; normal body cells are **diploid (2n)** — two sets of chromosomes, one from each parent.
- **Polyploidy:** a condition in which cells contain **more than two complete sets of chromosomes** — e.g., triploid (3n), tetraploid (4n).
- **Mutation:** a sudden, heritable **change in the DNA sequence** — creating a new trait that did not exist in the parent.
- **Hybridization: crossing two genetically different parent plants** so the offspring (hybrid) combines traits of both.
- **Secondary metabolites:** the plant chemicals that are not needed for basic growth but often act as drugs — alkaloids, glycosides, volatile oils (detailed in Unit IV). Breeders try to raise *their* yield.

9.4 Polyploidy — Doubling the Instruction Sets

9.4.1 What it is

If a normal plant is diploid (2n), a **tetraploid** (4n) carries four chromosome sets — literally double the genetic instructions. Polyploids often have **larger cells, larger organs** (bigger leaves, flowers, seeds), and — crucially for pharmacognosy — frequently produce **higher amounts of secondary metabolites**.

9.4.2 How it is induced

The classic inducing agent is **colchicine**, an alkaloid from *Colchicum autumnale* (autumn crocus). Colchicine blocks the spindle fibres during cell division, so chromosomes duplicate but the cell does not divide — doubling the chromosome number in one step. A lovely irony the syllabus intends you to notice: a **plant drug (colchicine) is the tool used to improve other plant drugs**.

9.4.3 Classic example — *Atropa belladonna*

Tetraploid belladonna plants produce significantly **more tropane alkaloids** (atropine/hyoscyamine) than diploid ones, along with larger leaves. This is the textbook example examiners expect.

9.4.4 Advantages and limitations

Advantages: often higher secondary-metabolite content; larger plant organs; achievable in one generation.
Limitations: not every species responds well; polyploids may be **sterile** or grow slowly; the effect must be verified — doubling chromosomes does not *guarantee* richer chemistry.

9.5 Mutation — Creating New Variations

9.5.1 What it is

A **mutation** is a sudden heritable change in DNA. Most mutations are useless or harmful, but very rarely one creates a plant with a **desirable new trait** — more oil, more alkaloid, disease resistance. Breeders **induce** mutations with radiation (X-rays, gamma rays) or chemicals, grow thousands of plants, and select the rare winners. This is called **mutation breeding**.

9.5.2 Examples with reference to secondary metabolites

- **Mint (*Mentha*) varieties:** mutation breeding has produced strains with **higher volatile-oil content** and better oil quality.
- **The penicillin story (microbial parallel):** the mould *Penicillium chrysogenum* was exposed to X-rays and UV light to create mutant strains producing **far more penicillin** than the original — the same mutation-breeding logic, applied to a microbe (links to Unit I's penicillin milestone).
- **Opium poppy and other alkaloid crops** have been improved by selecting favourable mutants.

9.5.3 Advantages and limitations

Advantages: can create traits that did not exist in the parent; works where hybridization is difficult.
Limitations: random — thousands of plants must be screened to find one useful mutant; most mutations are harmful.

9.6 Hybridization — Combining the Best of Two Parents

9.6.1 What it is

Hybridization = crossing parent A (high yield) × parent B (disease resistant) → offspring combining both traits. If the hybrid outperforms both parents, that bonus is called **hybrid vigour (heterosis)**.

9.6.2 Classic medicinal-plant examples

- ***Cinchona* hybrids:** crossing *Cinchona ledgeriana* (high quinine) with *C. succirubra* (hardy, vigorous) produced hybrids combining **high quinine content with robust growth** — historically important for the antimalarial bark supply.
- ***Mentha* hybrids:** peppermint (*Mentha* × *piperita*) itself is a natural hybrid (*M. aquatica* × *M. spicata*); deliberate mint crosses are bred for **higher menthol content** in the volatile oil.
- ***Artemisia annua* hybrids:** crosses between high-artemisinin lines raise the **artemisinin yield** of the crop — directly relevant to antimalarial drug supply (links to Unit I's artemisinin milestone).
- ***Digitalis* crosses** have been explored for improved cardiac glycoside content.

9.6.3 Advantages and limitations

Advantages: combines known good traits predictably; hybrid vigour can raise both biomass and constituent yield. **Limitations:** takes several generations of selection; hybrids may not breed true (seed from a hybrid can segregate) — so elite hybrids are often maintained by **vegetative propagation** (Chapter 6 ties in).

9.7 Comparison Table (exam favourite)

Feature	Polyploidy	Mutation	Hybridization
What changes	chromosome number (2n → 4n)	DNA sequence (random)	gene combination (two parents)
Inducing agent	colchicine	X-rays, gamma rays, chemicals	controlled pollination
Speed	one generation	many plants screened	several generations
Classic example	tetraploid *Atropa belladonna* (more alkaloids)	high-oil mint mutants; penicillin mould mutants	*Cinchona* hybrids (quinine + vigour)
Key risk	sterility, slow growth	mostly harmful mutants	hybrid may not breed true

9.8 Why Target Secondary Metabolites?

A food-crop breeder wants **more grain**. A medicinal-plant breeder wants **more medicine per plant** — i.e., a higher percentage of alkaloid, glycoside, or volatile oil. A variety with slightly smaller leaves but **double the alkaloid content** is the winner, because the factory extracts the chemical, not the leaf. This is why the syllabus says "with reference to secondary metabolites."

> **Analogy.** Polyploidy is giving the factory **double the machinery**; mutation is **randomly rewiring** machines hoping one runs faster; hybridization is **merging two good factories** into one.

9.9 Pharmacy Relevance

- Every "high-yielding variety" of senna, ashwagandha, or mint released by CIMAP is the product of these breeding tools — pharmacists in industry depend on them for **economical raw material**.
- Understanding breeding helps QC pharmacists interpret **batch-to-batch variation** and set realistic specifications.
- These concepts underpin modern **biotechnology** approaches (Unit IV/V context) — classical breeding is their foundation.

9.10 India Context

CIMAP (Central Institute of Medicinal and Aromatic Plants), Lucknow, has released improved varieties of mint, ashwagandha, senna, and other crops using selection, hybridization, and mutation breeding — a major reason India leads in mint-oil production. The **National Medicinal Plants Board** promotes cultivation of such improved varieties among farmers.

9.11 High-Yield Points

- Three breeding tools: **polyploidy (chromosome doubling), mutation (DNA change), hybridization (crossing parents)**.
- **Colchicine** induces polyploidy; it is itself a plant alkaloid.
- Tetraploid **belladonna** → more tropane alkaloids (classic example).
- **Cinchona hybrids** → high quinine + vigour; **mint/Artemisia crosses** → more oil/artemisinin.
- Breeders target **secondary-metabolite yield**, not just plant size.

9.12 Common Confusions & Mistakes

- **Confusion:** polyploidy vs hybridization. **Clarification:** polyploidy changes chromosome *number* within one lineage; hybridization *combines genes* from two parents.
- **Mistake:** writing that mutation breeding is precise. It is **random** — selection among thousands of plants does the work.
- **Mistake:** claiming colchicine is synthetic. It is a **natural alkaloid** from *Colchicum autumnale*.

9.13 Mnemonic

"PMH — Plants Made Healthier": **P**olyploidy (double chromosomes), **M**utation (new traits), **H**ybridization (best of both parents).

9.14 Chapter Summary

- **Polyploidy** (e.g., colchicine-induced tetraploid *Atropa belladonna*) raises chromosome sets and often **secondary-metabolite content**.
- **Mutation breeding** (radiation/chemicals) creates new variants; rare winners give **higher oil/alkaloid** strains (mint; penicillin mould).
- **Hybridization** combines parental strengths — *Cinchona*, mint, and *Artemisia* hybrids with **higher quinine, menthol, and artemisinin**.
- All three are judged by **secondary-metabolite yield**, the true currency of medicinal crops.

9.15 One-Minute Revision

- PMH: Polyploidy–Mutation–Hybridization.
- Colchicine → tetraploid belladonna → more alkaloids.
- Cinchona hybrid = quinine + vigour.
- Target = secondary metabolites, not biomass.

9.16 Questions

> **MCQs**

1. Colchicine induces: (a) mutation (b) polyploidy (c) hybridization (d) dormancy
2. Tetraploid *Atropa belladonna* is famous for: (a) smaller leaves (b) higher tropane alkaloid content (c) seedlessness (d) faster flowering
3. Mutation breeding is: (a) precise gene editing (b) random, followed by selection (c) crossing two species (d) doubling chromosomes
4. A *Cinchona ledgeriana* × *C. succirubra* cross aimed to combine: (a) colour and taste (b) high quinine and vigour (c) oil and resin (d) height and thorns
5. Medicinal-plant breeders primarily target: (a) plant height (b) secondary-metabolite yield (c) flower colour (d) root length

Viva

1. Define polyploidy, mutation, and hybridization.
2. How does colchicine induce polyploidy?
3. Why is tetraploid belladonna pharmaceutically important?
4. What is hybrid vigour?
5. Why do breeders target secondary metabolites?

Application-based

1. A company needs double the quinine from the same plantation area. Which breeding approach would you suggest, and what is the historical precedent?
2. A breeder's colchicine-treated plants are sterile. Is the experiment a failure? Discuss.

Answers: 1-(b), 2-(b), 3-(b), 4-(b), 5-(b)

9.17 References

- Evans WC. *Trease and Evans Pharmacognosy.* 16th ed. London: Saunders Elsevier; 2009.
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CHAPTER 10: CONSERVATION, VALUE ADDITION AND ECO-PHARMACOGNOSY

10.1 Learning Objectives

After studying this chapter, the student will be able to:

1. Differentiate **in-situ** and **ex-situ** conservation with examples.
2. Explain strategies for **value addition** of medicinal plants.
3. Define **eco-pharmacognosy** and explain its role in sustainable conservation.
4. Discuss why **kutki** and **chirata** are cited as endangered medicinal plants needing conservation.

10.2 Introduction — Saving the Medicine Chest

Unit I taught that nature is our oldest pharmacy. But pharmacies can run out of stock: when a wild medicinal plant is collected faster than it regrows, it slides toward **extinction** — and a drug source is lost forever. India has lived this problem with Himalayan plants like **kutki** (*Picrorhiza kurroa*) and **chirata** (*Swertia chirayita*), both heavily collected from the wild for their bitters and liver-protective uses. This chapter covers how we **conserve** medicinal plants, how we add **value** to them, and the philosophy of **eco-pharmacognosy** that ties it together.

10.3 Definitions

- **Conservation:** protecting natural resources so they remain available for the future — using without using up.
- **In-situ conservation:** protecting a species **in its natural habitat** — "in place."
- **Ex-situ conservation:** protecting a species **outside its natural habitat** — "out of place" — in gardens, banks, or laboratories.
- **Value addition:** processing or improving raw material so it earns a **higher price** and serves users better (drying, grading, extracting, formulating, certifying).
- **Eco-pharmacognosy:** applying **ecological principles to pharmacognosy** — studying and using medicinal plants in ways that keep ecosystems alive and productive.
- **Endangered species:** a species at serious risk of extinction in the wild.

> **Terminology alert.** *In-situ* = "in its original situation" (the forest). *Ex-situ* = "out of its situation" (the seed bank). The Latin does the remembering for you.

10.4 In-situ Conservation — Protection at Home

What it is: the species stays where it evolved — in forests, meadows, and mountains — and the **habitat** is protected.

Methods:

1. **National parks and wildlife sanctuaries** — legal protection of entire habitats.
2. **Biosphere reserves** — large protected landscapes with buffer zones where limited sustainable use is allowed.
3. **Sacred groves** — forest patches traditionally protected by local communities for religious reasons; India has thousands, and they shelter many medicinal plants.
4. **Regulated harvesting rules** — permits, quotas, and closed seasons so wild collection stays within what the population can replace.

Advantages: the species keeps **evolving** with its environment; whole ecosystems (pollinators, soil microbes) are preserved; cheapest per species at scale. **Limitations:** cannot protect against climate change or habitat destruction outside the reserve; a single disaster can wipe out a small population.

10.5 Ex-situ Conservation — Protection Away From Home

What it is: the species (or its seeds, tissues, or DNA) is maintained **outside** its habitat.

Methods:

1. **Botanical gardens and arboreta** — living collections; also educate the public.
2. **Seed banks (gene banks)** — seeds dried and stored at low temperature for decades; the world's backup hard drive for plants.
3. **Field gene banks** — living plantations of important varieties maintained as clone collections.
4. **Cryopreservation** — storing seeds, tissues, or embryos in **liquid nitrogen (−196 °C)**, suspending life almost indefinitely.
5. **Tissue culture repositories** — endangered species maintained as sterile cultures (Chapter 6's technique becomes a conservation tool).

Advantages: protects against extinction even if the wild habitat is destroyed; material readily available for research and reintroduction. **Limitations:** expensive; the species **stops evolving** with its environment; limited genetic diversity if few samples are stored.

In-situ vs Ex-situ — comparison table (exam favourite)

Feature	In-situ	Ex-situ
Where	natural habitat	gardens, banks, labs
Examples	national parks, sacred groves	seed banks, cryopreservation
Evolution	continues	paused
Cost	lower per species	higher (infrastructure)
Best for	whole ecosystems	backup against extinction

> **Exam line:** the two methods are **complementary, not competing** — in-situ keeps evolution running; ex-situ keeps a backup. Always write this sentence.

10.6 Strategies for Value Addition

A farmer selling raw dried roots earns little; the same roots, **graded, powdered, extracted, or formulated**, earn far more — and the buyer gets a better product. Value addition also *reduces pressure on wild stocks*, because cultivated, processed material replaces wild collection.

Strategies:

1. **Scientific post-harvest processing** — correct drying, cleaning, and grading (Chapter 7 in action); graded material fetches premium prices.
2. **Primary processing into extracts and powders** — standardized extracts, essential-oil distillation (mint oil, eucalyptus oil).
3. **Quality certification** — organic certification, GACP compliance, and pharmacopoeial testing raise market value and export potential.
4. **Formulation into finished products** — tablets, capsules, syrups, and AYUSH formulations instead of raw herb export.
5. **Branding and traceability** — documented source-to-shelf chains (GACP documentation, Chapter 6) that buyers trust.
6. **Cultivation of improved varieties** — high-yielding, high-constituent varieties (Chapters 8–9) raise income per hectare.

> **One-line logic for exams:** value addition = **more income per kg + better quality + less wild-collection pressure**.

10.7 Eco-Pharmacognosy — The Philosophy

Definition: eco-pharmacognosy applies **ecology to pharmacognosy** — it studies medicinal plants as members of living ecosystems and insists that drug discovery and production must **sustain** those ecosystems.

Its role in sustainable conservation:

1. **Prefer cultivation over wild collection** for commercial demand (Chapters 6–9 supply the how).
2. **Harvest sustainably** where wild collection continues — right season, right plant part (leaves rather than whole-plant uprooting where possible), quotas.
3. **Find substitutes and alternatives** — a related, abundant species or a cultivated source can replace a threatened one.
4. **Link livelihoods to conservation** — when local communities earn more from *cultivating* a plant than from stripping the wild, they become its protectors (this is where value addition, §10.6, joins conservation).
5. **Monitor and document** — population studies tell us which species are declining before it is too late.

10.8 Case Studies — Kutki and Chirata

The syllabus names these two deliberately — they are the **warning stories** of Indian pharmacognosy.

- **Kutki (*Picrorhiza kurroa*)** — a small Himalayan herb whose **rhizomes** are a famous bitter tonic and hepatoprotective drug (it reappears in Unit V under hepatoprotectives). Because the **underground part** is harvested, collection kills the plant. Years of wild harvesting for the AYUSH and herbal industries pushed wild populations into decline; it is treated as a **threatened/endangered species in its natural habitat**.
- **Chirata (*Swertia chirayita*)** — a Himalayan herb whose **whole plant** is used as a bitter tonic and febrifuge. Whole-plant harvesting plus habitat pressure made it **vulnerable in the wild**.

Conservation response (the eco-pharmacognosy playbook in action):

1. **Cultivation protocols** developed so farmers grow them instead of collectors stripping the mountains (in-situ pressure relieved by ex-situ-style cultivation).
2. **Agro-techniques and improved planting material** distributed through institutions and the National Medicinal Plants Board.
3. **Regulation of wild collection** and promotion of **substitutes** where acceptable.
4. **Tissue culture** for mass multiplication of planting material.

> **Exam-ready sentence:** "Kutki and chirata illustrate why eco-pharmacognosy matters: wild over-harvesting of roots/whole plants endangers the species, and the remedy is cultivation, regulated collection, and value addition — conservation through sustainable use."

10.9 Pharmacy Relevance

- Pharmacists in the herbal industry must ensure raw materials come from **legal, sustainable sources** — buying endangered wild-collected material is both unethical and a regulatory risk.
- Knowledge of conservation status helps in **substitution decisions** and in counselling about "rare herb" marketing claims.
- This chapter connects pharmacognosy to **environmental pharmacy** — a growing field.

10.10 India Context

India's **National Medicinal Plants Board (NMPB)** funds cultivation and conservation projects; **CIMAP Lucknow** and state agricultural universities develop agro-techniques for threatened species; **botanical gardens** (e.g., the network coordinated through national institutions) maintain living collections; **sacred groves** of the Western Ghats and Northeast remain community-led in-situ reserves.

10.11 High-Yield Points

- **In-situ** = in natural habitat (parks, sanctuaries, sacred groves); **ex-situ** = outside habitat (seed banks, botanical gardens, cryopreservation at −196 °C).
- The two are **complementary** — always state this.
- **Value addition** = processing/certification/formulation that raises price, quality, and reduces wild-collection pressure.
- **Eco-pharmacognosy** = ecology applied to pharmacognosy; conservation through sustainable use.
- **Kutki** (*Picrorhiza kurroa*, rhizome drug) and **chirata** (*Swertia chirayita*, whole-plant drug) — Himalayan species threatened by wild over-harvesting; conserved via cultivation, regulation, and tissue culture.

10.12 Common Confusions & Mistakes

- **Confusion:** in-situ vs ex-situ examples. **Clarification:** national park = in-situ; seed bank = ex-situ. If the plant is where nature put it, it's in-situ.
- **Mistake:** writing that ex-situ alone is enough. Examiners expect "**complementary**" — ex-situ is a backup, not a replacement.
- **Mistake:** describing kutki/chirata only as "liver drugs" without the conservation angle the syllabus wants — the Unit II point is their **endangered status and conservation**.

10.13 Mnemonic

"Innie stays IN, Exie EXits" — in-situ: the plant stays **in** its home; ex-situ: the plant **exits** to a bank or garden.

10.14 Chapter Summary

- **In-situ conservation** (parks, sanctuaries, sacred groves, regulated harvest) protects species in their habitat and lets evolution continue.
- **Ex-situ conservation** (botanical gardens, seed banks, field gene banks, cryopreservation, tissue culture) provides backup outside the habitat.
- The two approaches are **complementary**.
- **Value addition** (processing, extracts, certification, formulation, branding) raises income and quality while reducing wild-collection pressure.
- **Eco-pharmacognosy** applies ecological thinking to drug plants: cultivate rather than strip, harvest sustainably, substitute wisely, and link livelihoods to conservation.
- **Kutki and chirata** are Himalayan drugs endangered by wild over-harvesting; their rescue playbook is cultivation + regulation + tissue culture.

10.15 One-Minute Revision

- In-situ (home) vs ex-situ (away) — complementary.
- Seed bank, −196 °C cryopreservation, tissue culture = ex-situ.
- Value addition: process → certify → formulate → brand.
- Eco-pharmacognosy: conservation through sustainable use.
- Kutki (rhizome) + chirata (whole plant): wild-harvested toward endangerment; saved by cultivation.

10.16 Questions

> **MCQs**

1. Cryopreservation stores plant material in liquid nitrogen at: (a) −20 °C (b) −80 °C (c) −196 °C (d) 0 °C
2. Sacred groves are an example of: (a) ex-situ conservation (b) in-situ conservation (c) value addition (d) mutation breeding
3. Kutki is endangered mainly because: (a) its flowers are picked (b) its rhizomes are harvested, killing the plant (c) it needs no water (d) it is a new species
4. In-situ and ex-situ conservation are: (a) competing methods (b) complementary methods (c) identical methods (d) obsolete methods
5. Which is NOT a value-addition strategy? (a) Grading and certification (b) Essential-oil distillation (c) Uprooting wild plants faster (d) Formulation into tablets

Viva

1. Differentiate in-situ and ex-situ conservation with two examples each.
2. What is eco-pharmacognosy?
3. Why are kutki and chirata cited as conservation concerns?
4. List four value-addition strategies for medicinal plants.
5. At what temperature is cryopreservation done, and why so cold?

Application-based

1. A company wants chirata raw material without harming wild populations. Design a three-point sourcing plan using this chapter's concepts.
2. A farmer earns little from raw kutki rhizomes. Suggest a value-addition pathway from harvest to market.

Answers: 1-(c), 2-(b), 3-(b), 4-(b), 5-(c)

10.17 References

- WHO. *WHO Guidelines on Good Agricultural and Collection Practices (GACP) for Medicinal Plants.* Geneva: WHO; 2003.
- Evans WC. *Trease and Evans Pharmacognosy.* 16th ed. London: Saunders Elsevier; 2009.
- National Medicinal Plants Board (NMPB), Government of India — programmes for cultivation and conservation of medicinal plants.

UNIT II INFOGRAPHIC CONCEPT — "FROM SEED TO SHELF, SUSTAINABLY"

Layout: a horizontal five-stage pipeline, left to right, each stage a rounded card with an icon:

1 · CULTIVATE	2 · NURTURE	3 · BOOST	4 · CONSERVE	5 · ADD VALUE
seeds / cuttings / tissue culture (Ch 6)	9 factors: climate, soil, altitude, water... (Ch 7)	hormones (auxin–cytokinin) + breeding (PMH) (Ch 8–9)	in-situ + ex-situ; save kutki & chirata (Ch 10)	grade → extract → certify → formulate (Ch 10)

GACP (WHO 2003): clean site · right harvest time · hygienic drying · document everything.

Eco-pharmacognosy: use without using up.

UNIT II REFERENCES (COMBINED)

- WHO. *WHO Guidelines on Good Agricultural and Collection Practices (GACP) for Medicinal Plants.* Geneva: World Health Organization; 2003.
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