CHAPTER 12

SECONDARY METABOLITES

Introduction

Plants produce a variety of compounds that can be divided into primary metabolites and secondary metabolites. Primary metabolites are essential for the survival of the plant and include sugars, proteins and amino acids. Secondary metabolites were once believed to be waste products. They are not essential to the plant's survival, but the plant does suffer without them. Secondary metabolites also have many uses. Some are beneficial, and others can be toxic. Secondary metabolites protect plants against being eaten by herbivores and against being infected by microbial pathogens. They serve as attractants (odour, colour, taste) for pollinators and seed-dispersing animals. They function as agents of plant-plant competition and plant-microbe symbiosis. The ability of plants to compete and survive is therefore profoundly affected by the ecological functions of their secondary metabolites. Plant secondary metabolites can be divided into three chemically distinct groups: **terpenes, phenolics and nitrogen-containing compounds**.

Terpenes

The terpenes or terpenoids are the largest class of secondary metabolites. Most of the diverse substances of this class are insoluble in water. Certain terpenes have well-characterized functions in plant growth or development. The gibberellins, an important group of plant hormones, are diterpenes. Brassinosteroids, another class of plant hormones with growth-regulating functions, originate from triterpenes. The vast majority of terpenes involved in *plant defenses*.

Terpenes are toxins and feeding deterrents to many herbivorous insects and mammals; thus they appear to play important defensive roles in the plant kingdom. For example, monoterpene esters called *pyrethroids*, found in the leaves and flowers of *Chrysanthemum* species, show striking insecticidal activity.

In conifers such as piner, monoterpenes accumulate in resin ducts found in the needles, twigs, and trunk. These compounds are toxic to numerous insects, including bark beetles, which are serious pests of conifer species throughout the world. Many plants contain mixtures of volatile monoterpenes and sesquiterpenes, called essential oils, that lend a characteristic odour to their foliage. Peppermint, lemon, basil, and sage are examples of plants that contain essential oils. The chief monoterpene constituent of lemon oil is limonene; that of peppermint oil is menthol. Essential oils have well-known insect repellent properties.

Phenolic compounds

Plants produce a large variety of secondary compounds that contain a phenol group: a hydroxyl functional group on an aromatic ring. These substances are classified as *phenolic compounds, or phenolics*. Plant phenolics are

a chemically heterogeneous group. Some are soluble only in organic solvents, some are water-soluble carboxylic acids and glycosides, and others are insoluble polymers. Many serve as defenses against herbivores and pathogens. Others function of phenolic compounds are in mechanical support, in attracting pollinators and fruit dispersers, in absorbing harmful ultraviolet radiation, or in reducing the growth of nearby competing plants.

The coloured pigments of plants provide visual cues that help to attract pollinators and seed dispersers. These pigments are of two principal types. They are *carotenoids and flavonoids*. Carotenoids are yellow, orange and red terpenoid compounds that also serve as accessory pigments in photosynthesis. The flavonoids also include a wide range of coloured substances. The most widespread group of pigmented flavonoids is the *anthocyanins*, which are responsible for most of the red, pink, purple, and blue colours observed in flowers and fruits. Two other groups of flavonoids found in flowers are *flavones and flavonols*. These flavonoids generally absorb light at shorter wavelengths than do anthocyanins, so they are not visible to the human eye*Isoflavonoids*, which are found mostly in legumes, have several different biological activities.

A second category of plant phenolic polymers with defensive properties is the *tannins*. They are general toxins that can reduce the growth and survival of many herbivores when added to their diets. In addition, tannins act as feeding repellents to a great variety of animals. Mammals such as cattle, deer, and apes characteristically avoid plants or parts of plants with high tannin contents. Plant tannins also serve as defenses against microorganisms.

Nitrogen-containing compounds

A large variety of plant secondary metabolites have nitrogen as part of their structure. *Alkaloids* and *cyanogenic glycosides* are nitrogen containing compounds. Most nitrogenous secondary metabolites are synthesized from common amino acids. The *alkaloids* are a large family of more than 15,000 nitrogen-containing secondary metabolites. They are found in approximately 20% of vascular plant species. As a group, alkaloids are best known for their striking pharmacological effects on vertebrate animals. Alkaloids are usually synthesized from one of a few common amino acids – in particular, lysine, tyrosine, or tryptophan. However, the carbon skeleton of some alkaloids contains a component derived from the terpene pathway. Several different types, including nicotine and its relatives are derived from ornithine, an intermediate in arginine biosynthesis. The B vitamin nicotinic acid (niacin) is a precursor of the pyridine (six-membered) ring of this alkaloid.

Morphine is the first alkaloid isolated from the plant *Papaver sonniferum*, or the opium poppy. It is used as a pain reliever in patients with severe pain levels and cough suppressant. Another example of an alkaloid is **cocaine**. It can be highly dangerous and addictive. However, it has also been used as an anesthetic. Cocaine has long been used by the people of South America to alleviate hunger. Perhaps the most loved and known alkaloid is **caffeine**. It has protective properties for the plants. It is isolated from cocoa, coffee and

tea. *Cyanogenic glycosides* release the well-known poisonous gas hydrogen cyanide (HCN). The presence of cyanogenic glycosides deters feeding by insects and other herbivores such as snails and slugs. As with other classes of secondary metabolites, however, some herbivores have adapted to feed on cyanogenic plants and can tolerate large doses of HCN.

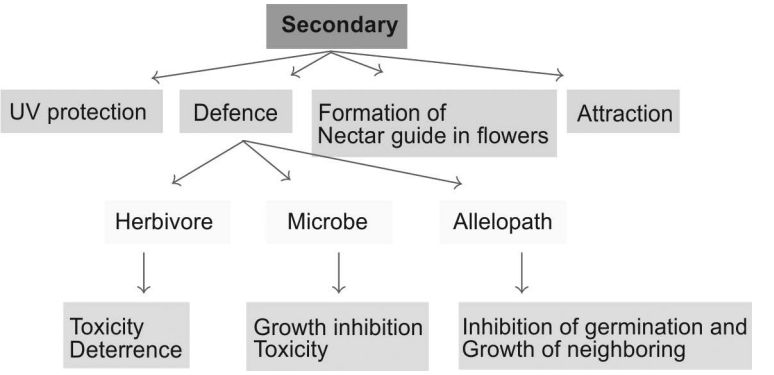

Fig. 87 : ***Uses of secondary metabolites.***

Uses of secondary metabolites

- Induced plant defenses against insect herbivores.
- Jasmonic acid activates many defensive responses.
- Some plant proteins inhibit herbivore digestion.
- Herbivore-induced volatiles have complex ecological functions.
- Plant defenses against pathogens.
- Some antimicrobial compounds are synthesized before pathogen attack.
- Infection induces additional antipathogen defenses.
- Phytoalexins often increase after pathogen attack.
- Some plants recognize specific pathogen-derived substances.
- A single encounter with a pathogen may increase resistance to future attacks.
- Interactions of plants with non-pathogenic bacteria can trigger induced systemic resistance.