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# Plant secondary metabolites and their role- a review

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**ABSTRACT**

*Plants are the largest biochemical and pharmaceutical stores ever known on our planet. The medicinal value of plants emanate from bio- active substances known as secondary metabolites. These are derived by unique biosynthetic pathways from primary metabolites. Secondary metabolites have a wide range of chemical structures and biological activities. These can be specifically found in certain taxa of plants and vary in presence among different parts of plant organs. Although secondary metabolites don't perform direct metabolic functions but fulfills specific functions like, in protecting plants from herbivores and microbial infection, as attractants for pollinators and seed-dispersing animals, as allelopathic agents, UV protectants etc. These compounds can also be used as dyes, fibres, glues, oils, waxes, flavoring agents, drugs and perfumes. This review is an attempt to understand the secondary metabolites, their role and pharmacological properties.*

***Keywords: Medicinal plants, pharmacological activities, secondary metabolites,***

## I INTRODUCTION

The world is blessed with natural and unique medicinal plants. Medicinal plants have been used since ages as remedies against human diseases [1]. Medicinal plant is defined as any plant which in one or more of its organs, contains substances that can be used for therapeutic purposes or which are precursors for the synthesis of useful drugs [2]. According to World Health Organization (WHO) (2002) medicinal plants are the best source to obtain variety of drugs. As such these plants should be properly investigated in order to gain better understanding about their properties, safety and efficacy [3].

Natural products are a source of synthetic and traditional herbal medicine and are still the primary health care systems [4]. Traditional knowledge of human health and herbal medicine has recently become a major global concern [5]. In the past two decades, nearly two thirds of approved new drugs were obtained from natural plant products [6] and this plant based therapeutics is gaining popularity both in developing and developed countries as these are natural in origin, have no adverse side effects and are easily available at affordable prices [7].

Plants owe their medicinal properties to their specialized biochemical potentialities which include the synthesis and accumulation of enormous display of secondary chemicals. In recent years, secondary metabolites became a subject of dramatically increasing interest relevant to their significant practical implication for medicinal, nutritive and cosmetic purposes, as well as to their indisputable importance in plant stress physiology [8]. These possess important biological and pharmacological activities, such as anti-cancer, anti-oxidative, anti-allergic, antibiotic, hypoglycemic and anti-inflammatory [9].

## II. PLANT SECONDARY METABOLITES:

Plants produce an amazing diversity of phytochemicals and these phytochemicals not only play a vital role for growth and development but are also important in the interaction between the plant and its environment [10]. Plants are able to exhibit various molecular mechanisms as a defense system and these responses could be generally divided into three main groups. Firstly, signalling of stress-activated molecules leading to changes of osmotic and ionic homeostasis as well as detoxification mechanism. Secondly, up-regulation of different gene expression leading to synthesis of specific proteins (e.g. heat-shock proteins and LEA proteins) and some protective molecules (e.g. sugars, polyalcohols and amino acids). Thirdly, generation of reactive oxygen species (ROS) and activation of antioxidant systems by synthesizing secondary metabolites such as flavonoids and phenolic compounds [11].

### 2.1. Types and Role of plant secondary metabolites:

#### 2.1.1.Terpenes

Terpenes constitute the largest and most diverse group of natural products. Of the tens of thousands of natural products identified to date, 25-50% of these are estimated to be terpenes [12]. These are biosynthesized through mevalonic acid pathway and methylerythritol phosphate (MEP) pathway [13]. The basic structural element of terpenes are five carbon isoprene units and on the basis of C5 units terpenes can be classified as hemiterpenes (single C5 unit), monoterpenes (two), sesquiterpenes (three), diterpenes (four), sesterpenes (five), triterpenes (six), tetraterpenes (eight) and polyterpenes (many) [14] . The name terpene actually originated from the word turpentine resin of pine trees [15]. They occur in both angiosperms as well as gymnosperms but are generally more prevalent in the latter, especially conifers [16]. These occur widely in the leaves and fruits of higher plants, conifers, citrus and eucalyptus [13].

Terpenes can negatively impact herbivores through toxic and deterrent effects [17]. Toxicity may result from several mechanisms, including inhibition of ATP formation, interference with hormone production, and binding proteins or sterols in the gut [17].

Some plant families are notable also for their ability to synthesize and secrete antimicrobial terpenes as a defense compound against fungal and bacterial challenges [18] . Still other plants that occupy resource-limited habitats such as deserts are known to constitutively secrete terpenes into their rhizosphere as a means of inhibiting the growth of competitor plant species [19]. In addition to this plants can produce volatile terpenes in order to attract specific insects for pollination [16]. Terpenes also have an important role to play as signal compounds or chemical messengers and growth regulators (phytohormones) of plants [20].

There have been many applications of terpenes in human societies. Pharmaceutical and food industries have exploited them for their potentials and effectiveness as medicines and flavor enhancers. Perhaps the most widely known terpene is rubber, which has been used extensively by humans [21].

Other important terpenes include camphor, menthol, pyrethrins (insecticides), rosin (a diterpene), limonene, carvone, hecogenin (a detergent) and digitoxigen [22]. Terpenes have also been used in bioremediation. Suttinun *et al*. [23] revealed that bacteria used in bioremediation of trichloroethylene (TCE) showed an increased capability to uptake TCE in the presence of cumene. Additional terpenes included in the study were limonene, carvone and pinene. However, cumene showed the most beneficial effects. Matura *et al*. [24] investigated that some terpenes act as causative agents of contact dermatitis and fragrance allergies.

Certain terpenes have a well-characterized function in plant growth or development like gibberellins (diterpene), sterols (triterpene), carotenoids (tetraterpenes), abscisic acid (sesquiterpene) and dolichols (polyterpene) [13]. The monoterpene esters called pyrethroids that occur in the leaves and flowers of *Chrysanthemum* sp. show very striking insecticidal activity. Among the nonvolatile terpene antiherbivore compounds are the limonoids, a group of triterpenes (C30) well known as bitter substances in citrus fruit activity [13].

**2.1.2. Alkaloids**

The term alkaloid, coined by German pharmacist Carl Meissner in 1819, has its origin in the Arabic name *al-qali*, the plant from which soda was first isolated [22]. The alkaloids are a large family of more than 15,000 nitrogen-containing secondary metabolites found in approximately 20% of the vascular plant species. The nitrogen atom in these substances is usually part of a heterocyclic ring, a ring that contains both nitrogen and carbon atoms [13].

Archeological evidence has demonstrated the use of alkaloids (plant parts or extracts) since 4000 B.C., and they continue to be very important today [25]. Alkaloids are usually synthesized from one of a few common amino acids in particular, lysine, tyrosine, and tryptophan. However, there can be other precursors like terpenes, purines, acetate derived polyketides. On the basis of ring structure alkaloids can be subdivided into pyrrolidine, piperidine, pyrrolidizine, quinolizidine, isoquinoline, protoberberine, aporphine, morphanine, quinoline, acridone, indole, monoterpene indole, diterpene or steroid alkaloids [26]. Some of the physiologically active alkaloids used in modern medicine include ajmaline, atropine, morphine caffeine, cocaine, coniine, scopolamine, vinblastine etc. [23].

The alkaloids often have physiological effects on the central nervous system with examples of anxiolytic [27] , analgesic and hallucinogenic effects [28]. In plants the alkaloids are often used as protection against animals, as many of them are toxic by affecting neurotransmission [29]. On cellular level, the mode of action of alkaloids in animals is quite variable. Some interfere with components of the nervous system, especially the chemical transmitters, other affect membrane transport, protein synthesis and miscellaneous enzyme activities [30].

**2.1.3.Saponins**

Saponins are high-molecular-weight secondary metabolites consisting of triterpenoidal or steroidal aglycone, designated genin or sapogenin, covalently linked to one or more sugar moieties [31], having a wide distribution in the plant kingdom [32]. They are active constituents of more than 100 families including endophytic fungi of terrestrial and marine origin [33]. The presence of both lipid-soluble (the steroid or triterpene) and water soluble (the sugar) elements in one molecule gives saponins detergent properties, and they form a soapy lather when shaken with water [34]. Their soap-like nature makes them useable as surfactants and adjuvants for vaccines to enhance macromolecule penetration [34].

Triterpenoid saponins are found principally in dicotyledons while steroidal saponins occur in monocots [35]. The nature and the functional groups on the aglycone backbone as well as the nature and number of sugars vary greatly resulting in diverse group of saponins [36]. Their physicochemical and biological properties feature structural diversity, which led to a number of traditional and industrial applications [37].

Just like other secondary metabolites the main function of saponins is to provide protection to the plants against many pathogens and herbivores. At the molecular level saponins cause membrane perturbation by the formation of pores on the membrane [38].

Saponins exhibit different biological and pharmacological actions such as immunomodulatory, anti-tumor, anti-inflammatory, molluscicidal, anti-viral, anti-fungal, hypoglycemic, hypocholesterolemic [39]. Saponins have a diverse range of properties, which include sweetness, bitterness [40], foaming, emulsifying [36] and haemolytic properties [41]. Saponins have wide applications in beverages and confectionery, as well as in cosmetics [42] and pharmaceutical products [41]. They are believed to form the main constituents of many plant drugs and folk medicines, and are considered responsible for numerous pharmacological properties [43].

**2.1.4.Phenolics**

Phenolics are one of the most ubiquitous groups of secondary metabolites found throughout the plant kingdom [44]. They encompass a very large and diverse group of aromatic compounds characterized by a benzene ring (C6) and one or more hydroxyl groups [45]. Phenolics are often produced and accumulated in the sub-epidermal layers of plant tissues exposed to stress and pathogen attack [46]. The concentration of a particular phenolic compound within a plant tissue is dependent on season and may also vary at different stages of growth and development [47].

Most plant phenolics are derived from the phenylpropanoid and phenylpropanoid acetate pathways and fulfill a very broad range of physiological roles in plants [22]. Plant phenolics may be divided in two classes: (i) preformed phenolics that are synthesized during the normal development of plant tissues and (ii) induced phenolics that are synthesized by plants in response to physical injury, infection or when stressed by suitable elicitors such as heavy metal-salts, UV-irradiation, temperature, etc. (phytoalexins). Induced phenolics may also be constitutively synthesized but, additionally, their synthesis is often enhanced under biotic or abiotic stress [48]. All phenolic compounds exhibit intense absorption in the UV region of the spectrum and those that are coloured absorb strongly in the visible region as well [49].

Plants originated in an aquatic environment but their successful evolutionary adaptation to land was achieved largely by massive formation of "plant phenolic" compounds [22] . These exhibit several health beneficial activities such as anti-oxidant, anti-inflammatory, anti-hepatotoxic, anti-tumoral and anti-microbial [50]. They are used as the starting ingredients in the industrial production of drugs, herbicides, synthetic resins and additives to inhibit microbial growth in various ranges of pesticides [51].

A number of simple and complex phenolics act as phytoalexins, phytoanticipins and nematicides against soil-borne pathogens and phytophagous insects [49]. These also provide structural integrity and scaffolding support to plants. Plants need phenolic compounds for pigmentation, growth, reproduction, resistance to pathogens and for many other functions. Besides their involvement in plant-animal and/or plant-microorganism relationships, plant phenolics have also key roles as the major red, blue and purple pigments, as antioxidants and metal chelators, as signalling agents both above and below ground between plant and other organisms, and as UV light screens [49].

**2.1.5.Tannins**

Tannin was originally coined by Seguin to describe the substances present in vegetable extracts, which are responsible for converting animal skin into leather [52]. These comprised of a large assemblage of natural products which have unpleasant taste and are employed in tanning leather [53]. However, the term is widely applied to any large polyphenolic compound containing sufficient hydroxyls and other suitable groups (such as carboxyls) to form strong complexes with proteins and other macromolecules [54].

Tannins are distributed all over the plant kingdom, having high molecular weight of 500 to more than 3000, found mostly in leaves, bark and wood of plants [55]. It is the astringency of tannins that causes the dryness and puckery sensation in the mouth following the consumption of red wine, strong tea, or an unripened fruit [56]. Based on their chemical structure and properties, tannins can be divided into two main groups: hydrolysable and condensed tannins [57].

Tannins are medicinally important because of their astringent properties. They promote rapid healing and the formation of new tissues on wounds and inflamed mucosa. Tannins are used in the treatment of varicose ulcers, hemorrhoids, minor burns, frostbite as well as inflammation of gums. Internally tannins are administered in cases of diarrhea, intestinal catarrh and in cases of heavy metal poisoning as an antidote [58]. It is assumed that the biological role of many types of tannins in the plant is related to protection against infection, insects, or animal herbivory [59].

Tannins can cause regression of tumors that are already present in tissue, but if used excessively over time, they can cause tumors in healthy tissue [54]. They also possess various useful activities i.e., anti-viral [60], anti-bacterial [61] and anti-parasitic [62]. Tannins also have a protective role against oxidative stress and degenerative diseases. These are also known as proanthocyanadinis possessing significant properties like antioxidant, anti-apoptosis, anti-aging, anti-carcinogenic, anti-inflammatory and anti-artherosclerosis [63].

The anti-carcinogenic and anti-mutagenic potentials of tannins may be related to their anti-oxidative property, which is important in protecting cellular oxidative damage, including lipid peroxidaton [64]. Tannins are used as mordant in dyeing, manufacture of ink, sizing paper and silk, and for printing fabrics. Tannins are also used for clarifying beer or wine, in photography or as a coagulant in rubber manufacture [65].

This class of phytochemicals has uniquely high affinity for precipitating proteins and complexing with all kinds of biomolecules [66]. Although moderate amounts of specific polyphenolics may have health benefits for humans, the defensive properties of most tannins are due to their toxicity, which is generally attributed to their ability to bind proteins nonspecifically [13].

It has long been thought that plant tannins complex proteins in the guts of herbivores by forming hydrogen bonds between their hydroxyl groups and electronegative sites on the protein. More recent evidence indicates that tannins and other phenolics can also bind to dietary protein in a covalent fashion. The foliage of many plants contains enzymes that oxidize phenolics to their corresponding quinone forms in the guts of herbivores [67]. Protein–tannin binding process has a negative impact on herbivore nutrition. Tannins can inactivate herbivore digestive enzymes and create complex aggregates of tannins and plant proteins that are difficult to digest. Herbivores that habitually feed on tannin-rich plant material appear to possess some interesting adaptations to remove tannins from their digestive systems [13].

**2.1.6.Flavonoids**

Flavonoids are low molecular weight secondary metabolites ubiquitously present in plants, encompassing more than 10,000 structures [68]. They represent the most common and widely distributed class of plant phenolics. These possess 15 carbons arranged in two aromatic rings connected by a three-carbon bridge. This structure of flavonoids result from two separate biosynthetic pathways: the shikimic acid pathway and the malonic acid pathway. Flavonoids are classified into different groups, primarily on the basis of the degree of oxidation of the three-carbon bridge [13]. The major subgroups include chalcones, flavones, flavonols, flavandiols, anthocyanins, and proanthocyanidins or condensed tannins [69].

Flavonoids have attracted considerable interest because of their potentially beneficial effects in humans; they have been reported to have anti-viral, anti-allergic, anti-platelet, anti-inflammatory, anti-tumor, and anti-oxidant activities [70]. Recently, phenolics and flavonoids have been considered as great antioxidants and proved to be more effective than Vitamin C, E and carotenoids [71]. These are involved in a wide range of physiological processes, such as pigmentation for fruits and flowers [72], attracting pollinators and seed dispersal [73], interactions of plant with microbes and animals [74], auxin transportation [75] , and protecting the plant from UV-B damage [76]. In addition, they are required for signaling symbiotic bacteria in the legume rhizobium symbiosis [77]and are important in root and shoot development [78].

### III CONCLUSION

The secondary metabolites represent a chemical interface between plants and the environment and hence their synthesis is significantly altered by environmental factors like season, altitude, radiation, soil nutrition etc. In recent times the interest in plants rich in bioactive components has tremendously intensified due to their beneficial effects on human health. So, keeping in mind the important potentialities of plant secondary metabolites, there is more and more need to characterize a huge number of plants for their secondary metabolite profiling.

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