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Biotechnological approaches to enhance Plant Secondary Metabolites

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Abstract

Medicinal and aromatic plants are known to produce secondary metabolites that find use as flavoring agents, fragrances, insecticides, dyes, and drugs. Biotechnology offers several choices through which secondary metabolism in medicinal plants can be altered in innovative ways, to overproduce phytochemicals of interest, to reduce the content of toxic compounds, or even to produce novel chemicals. Detailed investigation of chromatin organization and microRNAs affecting biosynthesis of secondary metabolites as well as exploring cryptic biosynthetic clusters and synthetic biology options, may provide additional ways to harness this resource.

Many plants yield phytochemicals known as secondary metabolites, which are pharmaceutically important and are extracted directly from the plants collected from natural habitats. Regardless of conventional methods, biotechnological approaches especially plant tissue culture techniques play a unique role in producing and extracting secondary metabolites at the industrial level. This book chapter discusses the various strategies adopted for secondary metabolite production in plants[10].

Plant cell and tissue cultures hold great promise for the controlled production of a myriad of useful secondary metabolites on demand. Discoveries of cell cultures capable of producing specific medicinal compounds at a rate similar or superior to that of intact plants have accelerated in the last few years.[12] To obtain high yields suitable for commercial exploitation, efforts have been focused on isolating the biosynthetic activities of cultured cells, achieved by optimizing the cultural conditions, selecting high-producing strains, and employing precursor feeding, transformation methods, and immobilization techniques[3]. Transgenic hairy root cultures have revolutionized the role of plant tissue culture in secondary metabolite production. They are unique in their genetic and biosynthetic stability, faster in growth, and more easily maintained. Using this methodology, a wide range of chemical compounds has been synthesized[4]. Advances in tissue culture, combined with

improvement in genetic engineering of pharmaceuticals, nutraceuticals, and other beneficial substances[6]. Recent advances in the molecular biology, enzymology, and fermentation technology of plant cell cultures suggest that these systems will become a viable source of important secondary metabolites[1]. Genome manipulation is resulting in relatively large amounts of desired compounds produced by plants infected with an engineered virus, whereas transgenic plants can maintain constant levels of production of proteins without additional intervention[1]. Large-scale plant tissue culture is found to be an attractive alternative approach to traditional methods of the plantation as it offers a controlled supply of biochemicals independent of plant availability[9].

Many higher plants are major sources of natural products which are used as pharmaceuticals, flavor and fragrances, dye and pigments, pesticides, and food additives. The search for new plant-derived chemicals has become a priority in current and future efforts toward sustainable conservation and rational utilization of biodiversity. In recent years, the evolving commercial importance of secondary metabolites has led to a great interest in the production and enhancement of bioactive plant metabolites using tissue culture technologies. Plant cell culture systems represent a potential renewable source of valuable medicinal compounds which are not limited by the low yields associated with natural harvest or the high cost associated with complex chemical synthesis as well as provide more resistance to pathogens and adverse environmental and climatic conditions. Different strategies, using *in vitro* systems such as undifferentiated cell cultures and hairy root culture, have been extensively studied to improve the production of plant chemicals as they are more genetically stable[8].

Secondary metabolites in medicinal plants:

Medicinal plants, the oldest source of pharmacologically active compounds continue to cater to the therapeutic need of the majority of the population in the developing world. They remained to be the only source of useful medicinal compounds for centuries and constitute the principle basis of traditional medicine systems of the world's oldest civilizations. It is estimated that even today two-thirds of the world population relies on plant-derived drugs. According to an estimate of the World Health Organization (WHO), 80% of the population of developing countries relies on plant-derived medicines for their primary health care requirements. Medicinal plants have played a dominant role in the introduction of new therapeutic agents. Based on the knowledge of plants gathered from various ancient medical writings, folklore, cultures, and civilizations, field observation, and consultation with folk medicine men, research on medicinal plants has been undertaken all over the world for the development of new herbal drugs. Modern pharmacopoeia contains at least 25% of drugs derived from plants and many others are synthetic analogs built on prototype compounds isolated from plants. Plant-based drugs are included in the pharmacopoeia of Russia, Japan, Germany, and other developed and developing countries[5]. Presently plant-derived secondary metabolites (active constituents) are in use and the medicines made from them represent a significant part of the total therapeutic agents.

Additionally, a lot of important steroid compounds and hormones are derived semi synthetically from plant precursors. However, crude drugs still hold considerable importance for medical treatment. Recently, there is a tendency towards a more natural way of living in the entire world resulting in a growing focus on the importance of medicinal plants and the traditional health care system. Because of this awareness, the international trade in plants of medicinal importance is growing phenomenally, often detrimental to their natural habitats. Indiscriminate harvesting leads to the extinction of natural populations which are still the[7]. The only source of raw material. Many of the medicinal plants are under severe threat, which can be gauged from the fact that an increasing number of species are being substituted in herbal preparations[11]. There is, therefore, a need to strike a balance between conservation and use. It is imperative viable strategies to conserve the surviving populations and their genetic resource of at least critically important species are formulated to avoid further loss.

Future perspectives :

Traditionally, secondary metabolites in plants have been investigated by phytochemists. Originally classified as waste products, these compounds more recently have been investigated extensively by ecologists and pharmacologists, and many complex biological functions have been discovered. Secondary metabolites occur nearly in all living organisms, within bacteria as well as in mammals, and are especially prominent in those organisms lacking an immune system. Functions of plant secondary metabolites comprise attractants, such as color pigments and scents, repellents such as antifeedants against insects and mammals, or toxins that affect the growth and development of animal and microbial predators. Conversely, insects can employ plant-synthesized compounds to their advantages, such as signals for feeding and oviposition and location of prey. Microbes also use secondary metabolites as carbon sources, and bacteria utilize them for quorum-sensing, an aspect recently discovered. Despite the diversity of recognized functions, the biochemical processes underlying these interactions are few. Primarily, they relate to the ability of these small molecules to bind to receptor regions of various proteins such as keys into locks. This review attempts a summary of current knowledge of secondary plant metabolism with a focus on the history of discovery, development of analytical techniques, theories of origin and function, signal pathways, biosynthesis, and assessment of biological activities. Outlined is current utilization by, and future perspectives in different disciplines, such as chemosystematics, chemical ecology, and agricultural biotechnology. Examples illustrate the strong potential of research in secondary metabolism, particularly in comparison to more established disciplines such as developmental biology and physiology.

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