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Research Article

The Role of Terpene (Secondary Metabolite)

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ABSTRACT

The terpenoids constitute the largest class of natural products and many interesting products are extensively applied in the industrial sector as flavors, fragrances, spices and are also used in perfumery and cosmetics. By their nature, plants protect themselves by producing some compounds called as secondary metabolites, including terpenes. Significance of constitutive and induced terpenoid defences in conifer resistance is briefly presented. Better knowledge of the mechanism of action of individual terpanes and about the additive and synergistic effects of compounds, will have important implications for forest and agricultural management of pests and pathogens Terpenoids represent the largest and most diverse class of chemicals among the myriad compounds. Plants employ terpenoid metabolites for a variety of basic functions in growth and development but use the majority of terpenoids for more specialized chemical interactions and protection in the abiotic and biotic environment. Moreover, the ecological importance of terpenoids has gained increased attention to develop strategies for sustainable pest control and abiotic stress protection. Terpenoids play several physiological and ecological functions in plant life through direct and indirect plant defenses and also in human society. Plants employ terpenoid metabolites for variety of basic functions in growth and development but use the majority of terpenoids for more specialized chemical interactions and protection in the abiotic and biotic environment. Traditionally, plant-based terpenoids have been used by humans in the food, pharmaceutical, and chemical industries, and more recently have been exploited in the development of biofuel products. Plants are important source for the discovery of new products of medicinal value for drug development and plants secondary metabolites are unique sources for pharmaceuticals food additives, flavors and others industrial values. Importance of these secondary metabolites has resulted in great interest in its production and enhancing its production by means of tissue culture technology in the recent years.

Keywords: Defense mechanism; plant secondary metabolites; terpenes; terpenoids Terpene synthase

INTRODUCTION

These secondary metabolites are major contributors of specific odour, color and taste of plant parts. In the past these organic compounds have thought to be biologically insignificant and therefore plant biologist gave little attention to them(Ahmed et al., 2017). Terpenes are among the most widespread chemically diverse groups of natural products. Terpenes are a unique group of hydrocarbon- based natural products whose structures may be derived from isoprene(Tiwari & Rana, 2015). Terpenoid secondary metabolites occur across a wide range of plant tissue types; those serving as defensive chemicals are often secured in secretory structures(Lerdau, 2003).The importance of terpenes in both nature and human application is difficult to overstate. Basic knowledge of terpene and isoprene biosynthesis and chemistry has accelerated the pace at which scientists have come to understand many plants biochemical and metabolic processes. Secondary metabolites, also known as phytochemicals, natural products or plant constituents are responsible for medicinal properties of plants to which they belong(Zwenger & Basu, 2008).

These products bring diversity and stimulate our senses by having organoleptic properties like color, flavor, and texture and

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contribute to our appetite. FAVs have long been recognized for their nutritive value. They are excellent sources of minerals, essential fatty acids and fibers, but are also unique sources of vitamins (C, E, B, and folic acid). Most of all, they are rich sources of bioactive phytochemicals(Desjardins, 2014).Terpene synthesis is beginning to be understood in respect to the various stages of plant development. Much of this knowledge has been contributed by the plant model, Arabidopsis thaliana. Considering the advances in plant terpene knowledge and potential uses, it is conceivable that they may soon be used in agro biotechnology (Zwenger & Basu, 2014).Plants natural products and essential oil components such as terpenes and phenylpropenes have been shown to have a significant potential for insect control. However, the molecular properties related to their insecticidal activity are not well understood(Dambolena et al., 2016).secondary compounds have signalling functions influence the activities of other cells, control their metabolic activities and co-ordinates the development of the whole plant(Pagare et al., 2016).Terpenoids are the largest family of plant compounds which exhibit enormous structural and functional diversity even if they have a common biosynthetic origin in isopentenyl pyrophospate (IPP). About half of the resin produced by conifer species is composed by monoterpenes, and the other half by diterpenes, while sesquiterpenes occur in small amounts. The majority of terpenoids, such as monoterpenoids, sesquiterpenoids and diterpenoids are classified as "secondary" compounds(Michelozzi, 2013).

Terpenes are an enormous class of natural products spanning well over 30,000 members –they have been used throughout history for a broad variety of purposes including perfume, medicine, and flavoring -Recognized early on as being composed of isoprene fragments(Maimone , 2002). Besides antimicrobial nature, some of which are performed and some of which induced by infection(Article, 2011). As a broad group, terpenes exhibit a range of toxicity from deadly to entirely edible and this is in keeping with their broad range of ecological roles, which include antimicrobial properties and a range of properties that attract symbiotes for the purposes of pollination, seed dispersal, and secondary protective roles and these latter roles include the provision of airborne chemical signals and scents, flavor, and taste(Kennedy & Wightman, 2011). Plants, and the evolutionarily more recent subdivision of flowering plants (angiosperms), have colonized the vast majority of the terrestrial surface, courtesy of rich levels of specialization and intricate relationships with other organisms(Bidigare, 2013). Commercial importance of these secondary metabolites has resulted in a great interest in its production and in exploring possibilities of enhancing its production by means of tissue culture technology in the recent years (Tiwari & Rana, 2015).Terpenes are among the most widespread chemically diverse groups of natural products. Terpenes are a unique group of hydrocarbon- based natural products whose structures may be derived from isoprene. Terpenes are classified by the number of 5-carbon units(Tiwari & Rana, 2015).

The abundance and diversity of terpene compounds in nature can have ecosystem-wide influences. Although terpenes have permeated human civilization since the Egyptians, terpene synthesis pathways are only now being understood in great detail. The use of bioinformatics and molecular databases has largely contributed to analyzing exactly how and when terpenes are synthesized(Zwenger & Basu, 2008).Terpenoids are the most metabolically diverse class of plant bioactive natural products (more than 40,000 known structures)(Furstenberg et al., 2013).

Recent estimates suggest that over 30'000 different terpenes have been characterized from natural sources(Zwenger & Basu, 2014) .They have been used throughout history for a broad variety of purposes including perfume, medicine, and flavoring recognized early on as being composed of isoprene fragments(Maimone, 2002).Terpenes are the most numerous and structurally diverse plant natural products for this reason, a system of nomenclature has been established(Zwenger & Basu, 2008). Major constituents of such induced volatile blends include terpenoids, aromatic compounds, and degradation and transformation products derived from fatty acids(Boland, 2018).Terpenes are polymers of isoprenoid units. These isoprenoid units are five carbon compounds and are favorite nature's building blocks. In terpenes these isoprenoids are arranged in regular head to tail fashion. The side chains of Vitamin A, E, K, squalene hydrocarbon found in shark, humans) are all constituents of terpenes(Kandi et al .,2015).

Chemotaxonomy consists of the investigation of the distribution of chemical compounds. Since ancient times, the essential oil and terpenoids of many aromatic plants have been used as bioactive ingredients in drug, food, perfumery and cosmetic formulations all over the world and so it is worthwhile to study their role in chemotaxonomy.They are distributed in families like Myrtaceae, Lauraceae, Rutaceae, Lamiaceae, Asteraceae, Umbelliferae, Verbenaceae and Piperaceae. To detect even traces of chemical compounds during chemical analysis sophisticated techniques have also been introduced in chemotaxonomy of medicinal plants (Approach, 2013).They are the major components of resin, and of turpentine produced from resin. The name "terpene" is derived from the word "turpentine". Terpenes are major biosynthetic building blocks within nearly every living creature. Steroids, for example, are derivatives of the triterpenes squalene. When terpenes are modified, such as by oxidation or rearrangement of the carbon skeleton, the resulting compounds are generally referred to as terpenoids. Some authors will use the term terpene to include all terpenoids. Terpenoids are also known Isoprenoid(Zwenger & Basu, 2014). The functional diversity of chemicals within plants is best demonstrated by terpenoids(Theis & Lerdau, 2003). The term terpenes originate from turpentine (lat. balsamum terebinthinae). Turpentine, the so-called "resin of pine trees", is the viscous pleasantly smelling balsam which flows upon cutting or carving the bark and the new wood of several pine tree species (Pinaceae). Turpentine(S. Kandi et al., 2015).The term terpene usually refers to a hydrocarbon molecule while terpenoids refers to a terpene that has been modified, such as by the addition of oxygen. Isoprenoids are, therefore, the building blocks of other metabolites such as plant hormones, sterols, carotenoids, rubber, the phytol tail of chlorophyll, and turpentine(Zwenger & Basu, 2008). An enormous range of plant substances are covered by the word 'terpenoid', a term which is used to indicate that all such substances have a common origin(Approach, 2013).

Terpenes and terpenoids are the primary constituents of the essential oils of many types of plants and flowers. Essential oils are used widely as natural flavor additives for food, as fragrances in perfumery, and in traditional and alternative medicines such as aromatherapy. Synthetic variations and derivatives of natural terpenes and terpenoids also greatly expand the variety of aromas used in perfumery and flavors used in food additives. Terpenes are a large and varied class of natural products, produced primarily by a wide variety of plants, insects, microoroganisms and animals(Zwenger & Basu, 2014). Terpenes that consist of multiple isoprene units are the largest class of organic compounds produced by various plants, and one of the major components of forest aerosols (Cho et al., 2017) .

The distribution of terpenes in nature has been studied extensively. Indeed, the distribution of terpenes within species has received attention(Zwenger & Basu, 2008). Plants wield and arsenal of structurally diverse chemical compounds called secondary metabolites, which equip them strategies to deter enemies, fend off pathogens, supersede competitors and surpass environmental constraints(Kennedy & Wightman, 2011). It has long been known that the basic unit of most secondary plant metabolites, including terpenes, consists of isoprene, a simple hydrocarbon molecule. Many terpenes remain to be discovered so they will undoubtedly intrigue scientists for years, as their applications are only beginning to be fully realized. The importance of terpenes in both nature and human application is difficult to overstate(Zwenger & Basu, 2008).We use one class of secondary metabolites, the terpenes, as a case study for exploring the factors regulating the evolution of metabolite function(Theis & Lerdau, 2003).Terpenes are a diverse group of more than 30,000 lipid-soluble compounds(Kennedy & Wightman, 2011). Terpenes comprise the biggest group of secondary metabolites and are free by their common biosynthetic origin from acetyl-coA or glycolytic intermediates(Pagare et al., 2016). In addition, understanding of the relationship between the diverse chemical structures of terpenes and the in vivo physiological roles of these compounds may provide critical insights for the future development of therapeutics with enhanced selectivity and specificity. So far, many studies have extensively reported the pharmaceutical activities of monoterpenes among the terpenes(Cho et al., 2017). Secondary metabolites or secondary compounds are compounds that are not required for normal growth and development, and are not made through metabolic pathways common to all plants. In plant kingdom they are limited to occurrence and may be restricted to a particular taxonomic group genus, species or family(Kumar et al., 2015).

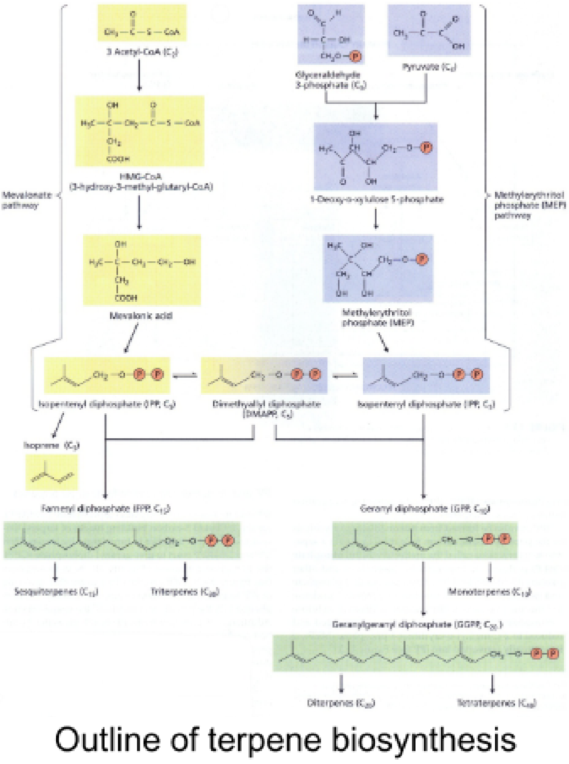
The term terpene usually refers to a hydrocarbon molecule while terpenoids refers to a terpene that has been modified, such as by the addition of oxygen. Isoprenoids are, therefore, the building blocks of other metabolites such as plant hormones, sterols, carotenoids, rubber, the phytol tail of chlorophyll, and turpentine(Zwenger & Basu, 2008).Some of these compounds have also been elucidated to have role against herbivores and to attract pollinators, allelopathic agents, and protection against toxicity, UV-light sheilding and signal transduction(Kennedy & Wightman, 2011).Terpenoids are the largest and most diverse family of natural products, ranging in structure from linear to polycyclic molecules and in size from the five-carbon hemiterpenes to natural rubber, comprising thousands of isoprene units(Kumar et al., 2015).

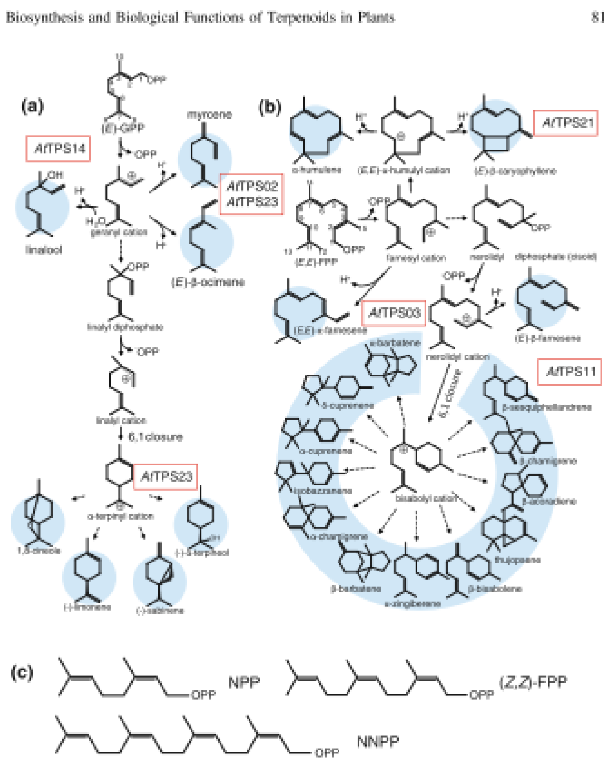
The size of Terpenes ranges from five carbon hemiterpenes to large size complexes including rubber containing thousands of isoprene units. All terpenes are classified according to five-carbon isopentane units of the core structure(Kennedy & Wightman, 2011).Introductory chapters on terpenoid biosynthesis usually highlight the large number of terpenoid compounds found in nature according.The prenyl diphosphate intermediates built by condensation of these five-carbon units are used as precursors for the biosynthesis of terpenoids with fundamental functions in growth and development and for the formation of a large number of terpenoids compounds with more specialized roles in the interaction of plants with their environment. It is the latter group of terpenoids that is characterized by its tremendous structural diversity as a consequence of divergent biosynthetic gene evolution Specialized(Tholl, 2016).

TERPENOIDS BIOSYNTHETIC PATHWAYS

Terpenoid biosynthesis usually highlights the large number of terpenoid compounds found in nature. Indeed, the structural diversity associated with at least 40,000 compounds makes the class of terpenoids one of the most impressive examples in the divergent evolution of plant chemicals. The evolutionary success of this compound class is in part based on simplicity of constructing different size molecules. Advanced functional genomics approaches provide unlimited access to the biosynthetic genes and molecular regulators of terpenoid-producing plants, and, at the same time, allow deeper insight to the complexity of plant terpenoid metabolism and regulation terpenoid metabolic pathways and give updates on the regulation and functional diversification of their genes and enzymes(Tholl, 2016).

Biosynthetic reactions are energy consuming, fuelled by the energy released by glycolysis of carbohydrates and through the citric acid cycle(Kabera, 2018). Mass Spectrometry (GC-MS), and calculated their concentrations and emission rates of terpenes. Besides GC-MS, we also used techniques of molecular biology (real-time polymerase chain reaction, PCR) to quantify the gene expression of terpene synthases(Castells, 2015).Here it is reported that the different groups of terpenoid volatiles also exhibit significant differences in their 12 C/13 C ratio, which depend upon whether the universal building block IDP is produced predominantly from the MVA or MEP pathway(Boland, 2018). Some antimicrobial compounds are synthesized before pathogen attack. Infection induces additional antipathogen defenses (Agr, 2009).Terpenoids are classified according to the number of isoprene units they synthesis and contain; isoprene, which itself is synthesized and released by plants, comprises 1 unit and is classified as a hemiterpene; monoterpenes incorporate 2 isoprene units, sesquiterpenes incorporate 3 units, diterpenes comprise 4 units, sesterpenes include 5 units, triterpenes incorporate 6 units, and tetraterpenes 8 units(Kennedy & Wightman, 2011). Both primary and secondary metabolites are found among the terpenoids and the same compound may have both primary and secondary roles. Secondary metabolites may often be created by modified synthetic pathways from primary metabolite, or share substrates of primary metabolite origin(Kabera, 2018).



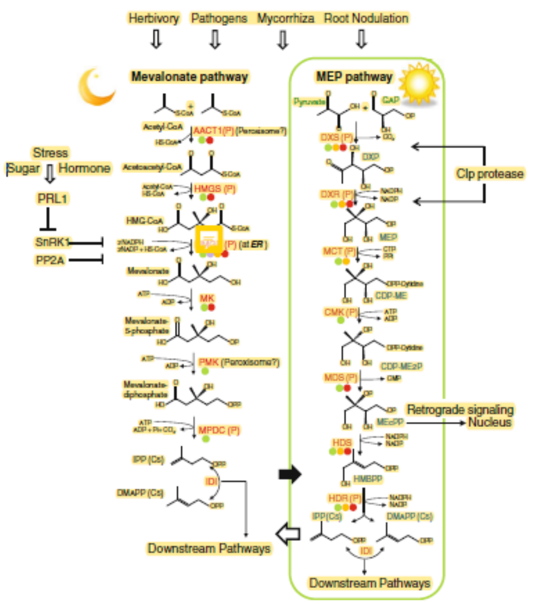


The cytosolic pathway is mevalonic acid pathway (MVA) which works within most eukaryotes and synthesizes sesquiterpenes(Ahmed et al., 2017). Terpenoids constitute a large family of phytoconstituents of little functional and structural common ground. Steroids, carotenoids, and gibberelic acid are just some of its members. They are composed by the most important group of active compounds in plants with over than 23,000 known structures. They are polymeric isoprene derivatives and synthesized from acetate via the mevalonic acid pathway. During their formation, the isoprene units are linked in head and tail(Kabera, 2018).

Secondary metabolites are broad range of compounds from different metabolite families that can be highly inducible in stress conditions(Pagare et al., 2016). Successful engineering of terpenoids products in plants critically depends on the flux of precursors delivered by the core isoprenoid biosynthetic pathways and, consequently, on the dynamic regulation of these biosynthetic routes.(Tholl, 2016).They suggest that terpene synthase genes may impact phylogenetic organization of some plants. For example, some terpene genes are more closely related in certain plant species, in which the species themselves were previously thought to be distantly related(Zwenger & Basu, 2008).Plants use two independent pathways to produce IPP and DMAPP: the primarily cytosolic mevalonic acid (MVA) pathway and the plastidial methylerythritol phosphate (MEP) pathway, MVA pathway predominantly provides the precursors for the cytosolic biosynthesis of sesquiterpenoids, polyprenols, phytosterols, brassinosteroids, and triterpenoids, and for terpenoid biosynthesis in mitochondria. In addition to the transcriptional regulation of MVA and MEP pathway genes and their different paralogues, isoprenoid-pathway fluxes are controlled at posttranscriptional/-translational levels and by feedback regulation. Therefore, this chapter primarily gives an overview of both pathways with some emphasis on those in Arabidopsis and provides updates on the different modes of regulation(Tholl, 2016).

MVA and MEP Pathways—A brief summary of their biosynthetic Steps. The MVA pathway in plants consists of six steps and starts with the Claisen-type condensation of two molecules acetyl-CoA to acetoacetyl-CoA (AcAc-CoA) catalyzed by acetoacetyl-CoA thiolase (AACT). In a subsequent aldol condensation reaction catalyzed by HMG-CoA synthase (HMGS), AcAc-CoA is combined with a third molecule of acetyl-CoA to form the C6-compound S-3-hydroxy-3-methylglutaryl-CoA (HMG-CoA).Response to different stresses, feedback regulation, and the role of HMGS in sterol metabolism .In the following rate-limiting step, HMG-CoA reductase (HMGR) catalyzes the conversion of S-HMG-CoA to Rmevalonate in two NADPH-dependent reduction steps(Tholl, 2016).

Multiple biotic and abiotic factors, which may or may not induce expression, were also considered in respect to terpene synthase gene expression. Possibly even more important is the fact that expression of terpene synthases were examined across the life cycle of Arabidopsis, which countered some wet lab experimental data previously published. Terpenoid biosynthetic pathways and their subcellular organization. Enzymes are marked in red; specialized terpenoids are marked in blue; all other intermediates and terpenoid end products are in black. Solid and dashed arrows indicate single and multiple enzymatic steps, respectively. The single isoprene unit, therefore, represents the most basic class of terpenes, the hemiterpenes(Zwenger & Basu, 2008). Abbreviations not mentioned in the text: IPS isoprene synthase; GRR geranylgeranyl reductase; OPS oligoprenyl diphosphate (OPP) synthase; SPS solanesyl diphosphate (SPS) synthase; SQS squalene synthase HMGR proteins are membrane-bound with two membrane-spanning sequences and a highly conserved catalytic C-terminal domain. VA produced by HMGR is finally converted into IPP via three enzymatic steps: two ATP-dependent phosphorylation steps, catalyzed by mevalonate kinase (MK) and phosphomeval- onate kinase (PMK), and an ATP-driven decarboxylative elimination catalyzed by mevalonate diphosphate decarboxylase (MVD or MPDC)(Tholl, 2016). Terpenes are the most numerous and structurally diverse plant natural products (Zwenger & Basu, 2008). Plant DXS enzymes carry a highly conserved thiamine phosphate binding domain and are divided in the class-I type enzymes with primary expression in photosynthetic and floral tissues and the class-II type enzymes with more distinct roles in specialized metabolism(Tholl, 2016). The nomenclature of terpene compounds is ostensibly complex, yet can be quickly elucidated upon closer examination. The isoprene unit, which can build upon itself in various ways, is a five-carbon molecule, isoprene unit bonded with a second isoprene is the defining characteristic of terpene, which is also a monoterpene (C10) (Zwenger & Basu, 2008). While sesquiterpenes contain three isoprene units (C15), diterpenes (C20) and triterpenes (C30) contain two and three terpene units, respectively. Tetraterpenes consist of four terpene units and polyterpenes are those terpenes containing more than four terpene units (i.e., more than eight isoprene units)(Zwenger & Basu, 2008).



Arrows indicate preferred trafficking of isoprenoid precursors between the cytosol and plastids in light (white) and dark (black) exposed tissues. Abbreviations for enzymes (red) and metabolites (black—MVA pathway; blue—MEP pathway) are as described in the text support a key function of HMGS in the MVA pathway. In the following rate-limiting step, HMG-CoA reductase (HMGR) catalyzes the conversion of S-HMG-CoA to R-mevalonate in two NADPH-dependent reduction steps(Tholl, 2016). Enzymes are marked in red; specialized terpenoids are marked in blue; all other intermediates and terpenoid end products are in black. Short-chain cis prenyltranferases are marked in green.Abbreviations not mentioned in the text: IPS isoprene synthase; GRR geranylgeranyl reductase; OPS oligoprenyl diphosphate (OPP) synthase; SPS solanesyl diphosphate (SPS) synthase; SQS squalene synthase HMGR proteins are membrane-bound with two membrane-spanning sequences and a highly conserved catalytic C-terminal domain(Tholl, 2016). Plant volatiles are typically lipophilic liquids with high vapor pressures. Non-conjugated plant volatiles can cross membranes freely and evaporate into the atmosphere when there are no barriers to diffusion (Kumar et al., 2015).Plant DXS enzymes carry a highly conserved thiamine phosphate binding domain and are divided in the class-I type enzymes with primary expression in photosynthetic and floral tissues and the class-II type enzymes with more distinct roles in specialized metabolism. There is clear evidence for the role of pathway intermediates and downstream metabolites in the regulation of the core terpenoid biosynthetic steps at transcriptional and posttranslational level. However, plastidial IPP isomerase activity might be necessary to produce an optimal ratio of IPP and DMAPP for the downstream condensation reactions and to provide precursors for a possible transport to the cytosol(Tholl, 2016).

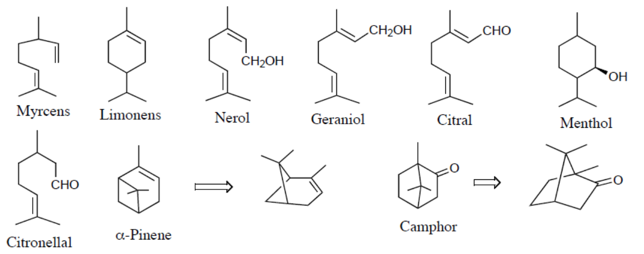
Most of the commonly occurring terpenoids can be found existing in a remarkable variety of diverse plants. As an example, ß-Caryophyllene can be found in plants as varied as black pepper, cloves, some cannabis sativa strains, rosemary, and hops(Theis & Lerdau, 2003) .They are also used in commercial insecticides for being having low toxicity for mammals(Ahmed et al., 2017). . Despite the advances in analytical methods to evaluate the composition of essential oil, CC remains a powerful technology for separation and characterization of specific compounds of interest (Kumar et al., 2015).

MAJOR TYPES OF TERPENE

Terpenoids are classified according to the number of isoprene units they contain; isoprene, which itself is synthesized and released by plants, comprises 1 unit and is classified as a hemiterpene; monoterpenes incorporate 2 isoprene units, sesquiterpenes incorporate 3 units, diterpenes comprise 4 units, sesterpenes include 5 units, triterpenes incorporate 6 units, and tetraterpenes 8 units. As a broad group, terpenes exhibit a range of toxicity from deadly to entirely edible and this is in keeping with their broad range of ecological roles, (Kennedy & Wightman, 2011). Terpenes are classified by the number of 5-carbon units.

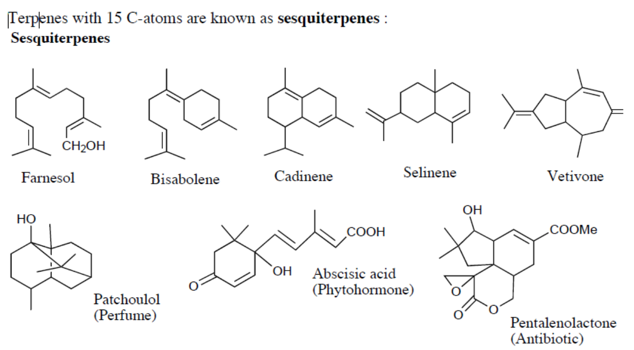
Monoterpenes (C10)

Terpenes comprsing 10-C are Monoterpenes. Early on it was recognized that the majority of terpenoid natural products contain a multiple of 5 C atoms. Hemiterpenes consist of a single isoprene unit(Zwenger & Basu, 2014). Many derivatives of monoterpenes are important tools in plant defense against pathogens e.g. pyrethroids are monoterpenes estors which occur in leaves of Chrysanthemum species and pose neurotoxic insecticidal activities for many insects like bees, wasps, beetles and moths (Ahmed et al., 2017) .Other monoterpenes such as α-pinene and 1, 8-cineole also exert neuroprotective effects by regulating gene expression(Cho et al., 2017).



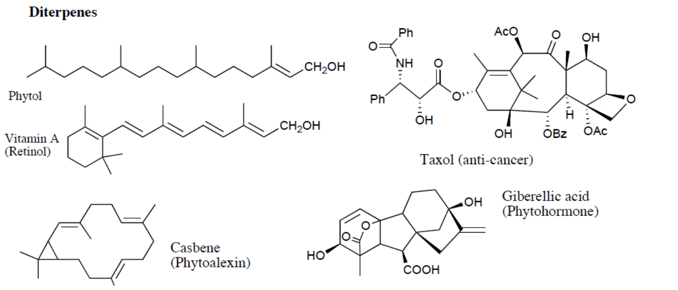
Sesquiterpenes (C15)

Terpenes comprising 15-C are sesquiterpene (one and half terpenes). Despite their presence in essential oils, numerous sesquiterpenes act as phytoalexins, antibiotic compounds produced during microbial attacks, and as antifeedants that deter herbivory(Ahmed ,et al., 2017). Abscisic acid the plant hormone is a 15-C sesquiterpene; it is produced from Xanthoxin (15-C precursor) which is formed by asymmetric cleavage of a carotenoid (C-40) (Ahmed et al., 2017). Farnesyl diphosphate (FPP), the product of FPP synthase, is the precursor to a wide variety of sesquiterpenoids. Under certain circumstances, farnesol is also capable of initiating, via phosphorylation to



Diterpenes (C20)

Terpenes comprising20-C are diterpenes. Diterpenes compounds arise from geranyl diphosphate, and present 20 carbon units in their basic skeletal type(Ahmed et al., 2017). One of the simplest and most important of the diterpenes is phytol, a reduced form of geranylgeraniol, which forms the lipophilic side-chain of the chlorophylls (Kumar et al., 2015). Abietic acid is a diterpene found in pines and leguminous trees. It is present in or along with resins in resin canals of the tree trunk(Mazid, Khan, & Mohammad, 2011). cDNAs encoding GGPP synthase have been isolated from two diterpene producing plants, Scoparia dulcis and Croton sublyratus.125 Both cloned genes showed high amino acid sequence homology (60–70%) to other plant enzymes and contained highly conserved aspartate-rich motifs, and were expressed in E. coli to yield active enzymes(Dewick, 2002).

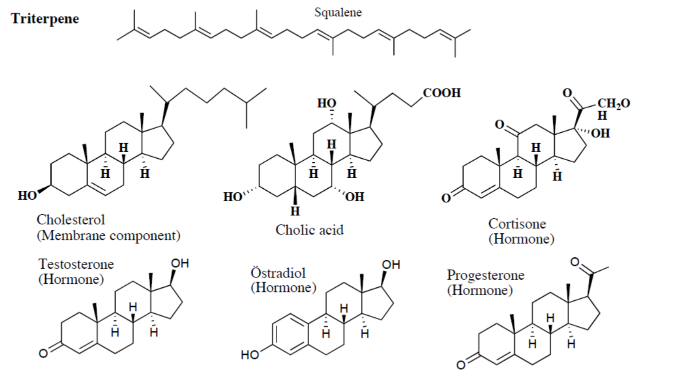


Sesterterpenes (C25)

May be the least common group of terpenoids. This class of compounds arises from geranylfarnesyl diphosphate, which by cyclization can give rise to various skeletal types, presenting different oxidation levels and several biological activities. Although many examples of these natural terpenoids are known, they are primarily isolated from fungi and marine organisms. Considering the large range of polarity nature presented by both diterpene and sesterterpene, the isolation and purification techniques vary and can be classic TLC, preparative thin-layer chromatography (PTLC), CC, flash chromatography (FC), or modern high performance liquid chromatography (HPLC), multiflash chromatography, vacuum liquid chromatography (VLC), solid-phase extraction and others(Kumar et al., 2015).

Triterpenes (C30)

Terpenes comprising 30-C are triterpenes, which are a large class arised from squalene, formed by coupling of two farnesyl diphosphate units.A number of biologically active important products like steroidal saponins, sterols, bile acids, mammalian sex hormones, cardioactive glycosides and corticosteroids result from skeletal modifications of side chains (Ahmed, et al., 2017).

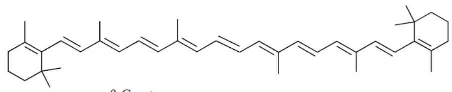


Tetraterpenes (C40)

Terpenes comprising 40-C are tetraterpenes. Despite plants these are also formed by bacteria, algae and fungi. Terpenes comprising 40-C are tetraterpenes, which constitute a large group of natural dyes and possess a variety of functions (Ahmed et al., 2017).More than 650 carotenoids (C40) are found in nature, constituting the largest group of natural dyes. The carotenoids are substances with very special properties possessed by no other group of substances; these form the basis of their many varied functions and actions in all kinds of living organisms(Kumar et al.,2015).The carotenoids are isoprenoid compounds, biosynthesized by tail-to-tail linkage of two geranyl diphosphate molecules. This produces the parent C40 carbon skeleton from which all the individual variations are derived(Kumar et al., 2015). This skeleton can be modified: A. by cyclization at one end or both ends of the molecule to give the seven different end groups B. by changes in hydrogenation level, and C by addition of oxygen-containing functional groups(Kumar et al., 2015).Various adsorbents have been applied in carotenoid analysis, including Al2O3, silica, magnesium oxide (MgO), calcium hydroxide [Ca (OH)2], calcium carbonate [CaCO3], siliceous earth as hyflosupercell and others(Kumar et al.,2015). determinations, standard purifications, biological evaluations of carotenoids and the purification of synthesized carotenoids, especially by flash chromatography(Kumar et al., 2015).

In contrast to other classes of terpenes that vary greatly in structure and molecular size, the steroids constitute a family of terpenes with a common structural feature, namely, the steroid ring system:

Tetraterpene



ß-Carotene
(Pigment, Provitamin A)

Polyterpenes (C5)n

Terpenes comprising more than forty carbons are polyterpenes. Rubber is a polyterpenes which contains 1500-15000 isopentane units, and all of the C-C double bonds have cis-configuration whereas in gutta rubber all the double bonds are in trans-configuration(Ahmed et al., 2017).

THE ROLE OF TERPENE IN PLANTS

Terpenoids play several physiological and ecological functions in plant life through direct and indirect plant defenses and also in human society because of their enormous applications in the pharmaceutical, food and cosmetics industries(Abbas et al., 2017). The function of terpenes in plants is generally considered to be both ecological and physiological: Allelophathy, Insecticidal, Insect pollinators, Plant hormone (Abscisic acid, gibberlellin)(Tiwari & Rana, 2015).The role they play in the plant is not, to date, well known or understood, but it may be beyond the protection. Their classification is based on chemical structure, composition, their solubility in various solvents, or the pathway by which they are synthesized (Kabera, 2018). Plants are organisms under constant biotic stress. Due to their sessile condition, they have developed a plethora of physical and chemical defences to make front to herbivores and pathogens. Chemical defences are very versatile: many plants have permanent reserves of chemical compounds (known as constitutive defences) to face aggressions immediately, but these defences can also increase, change and de novo compounds can be produced when biotic aggressions are detected(induced defences)(Castells, 2015).

Terpenes composed of 5-C isopentanoid units, are toxins and feeding deterrents to many herbivores. Phenolics synthesized primarily from products of the shikimic acid pathway, have several important defensive role in the plants .All ecosystems contain a wide variety of bacteria, viruses, fungi, nematodes, mites, insects, mammals and other herbivorous animals, greatly responsible for heavy reduction in crop productivity. By their nature, plants protect themselves by producing some compounds called as secondary metabolites(Mazid et al., 2011).Chemical defences are very versatile: many plants have permanent reserves of chemical compounds to face aggressions immediately, but these defences can also increase, change and de novo compounds can be produced when biotic aggressions are detected (induced defences) (Castells, 2015).

Plants protect themselves by producing secondary metabolites like terpenes, against a variety of herbivores and pathogenic microorganisms as well as various kinds of abiotic stresses(Article, 2011).As a broad group, terpenes exhibit a range of toxicity from deadly to entirely edible and this is in keeping with their broad range of ecological roles, which include antimicrobial properties and a range of properties that attract symbiotes for the purposes of pollination, seed dispersal, and secondary protective roles. These latter roles include the provision of airborne chemical signals and scents, flavor, and taste(Kennedy & Wightman, 2011). More than 100,000 chemical compounds are considered to play defensive roles in plants. About 20-30,000 of these compounds are terpenes, a type of hydrocarbons that has a very wide range of structures and functions. Terpenes are known to be very important defences in conifers, a small yet very important division of plants spread throughout the world(Castells, 2015). Secondary metabolites (SM) are compounds that are not necessary for a cell (organism) to live, but play a role in the interaction of the cell (organism) with its environment. These compounds are often involved in plants protection against biotic or abiotic stresses (Pagare et al., 2016). The role of terpenes in interactions between Scots pine and the PPM had been studied before, but nothing was known about the responses of pines regarding terpene emission rates, systemic reactions or terpene biosynthesis(Castells, 2015).

Many derivatives are important agents of insect toxicity(Mazid et al., 2011). Plants have been interacting with insects for several hundred million years, leading to complex defense approaches against various insect feeding strategies. Insect herbivory induce several internal signals from the wounded tissues, including calcium ion fluxes, phosphorylation cascades and systemic- and jasmonate signaling(Furstenberg et al., 2013). As some terpenes are produced by the plants for defense, the presence of these compounds will be affected by pest pressure or drought, depending on the terpene. In cases of defensive terpenes, environmental factors such as pest pressure or drought may increase terpene production, as part of the plant's built-in survival tactic. Biotic and abiotic conditions affect terpene production. Mechanisms by which light, tem- perature, or physical damage modify terpene concentrations have been well-studied. Light(Theis & Lerdau, 2003). Some of these compounds have also been elucidated to have role against herbivores and to attract pollinators, allelopathic agents, and protection against toxicity, UV-light sheilding and signal transduction. Plants wield and arsenal of structurally diverse chemical compounds called secondary metabolites, which equip them strategies to deter enemies, fend off pathogens, supersede competitors and surpass environmental constraints. These chemicals are produced under specific abiotic stresses and pathogenic attacks, therefore impart survival tactics to plants (Ahmed, et al., 2017).

Secondary metabolites are from different metabolites families that can be highly inducible in response to stresses. Primary metabolites perform essential metabolic roles by participating in nutrition and reproduction(Pagare et al.,2016).Terpene conundrums are that some phytochemicals can act as both deterrent and attractant. As an example, 1,8-cineole, a monoterpene found in psychoactive sage and lemon balm extracts, acts as a toxin to coleoptera and some species of flies but not as a consequence of its cholinesterase inhibitory properties. It is also harmless to some other taxa, for instance honeybees, and acts as a fragrant attractant for insect pollination (Kennedy & Wightman,2011). These compounds often differ between individuals from the same population of plants in respect of their amount and types. SMs are used as especially chemical such as drugs, flavours, fragrances, insecticides, and dyes by human because of a great economic value. IN fact, the specific constituents in a certain species have been used to help with systematic determination, groups of secondary metabolites being used as markers for botanical classification (chemotaxonomy)they are like terpenes(Pagare et al., 2016).

It may also contribute to the indirect defense mechanism of attracting the natural insect predators of attacking herbivores by the emission of an induced cocktail of chemicals(Kennedy & Wightman, 2011). The different roles of many of the MVA and MEP pathway isozymes depend on their expression in specific cellular tissues and are often divided into essential functions to provide terpenoid precursors in primary metabolism, growth, and development, and more specific functions in stress response and specialized metabolism. For example, in Brassica juncea, HMGS is represented by a four-member gene family. The construction of terpenoids with more than five carbons requires a sufficient supply of IPP and its more reactive, electrophilic isomer DMAPP(Tholl, 2016). key property of terpenoids is that they are generally present in complex mixtures that play multiple, differing, or additive ecological roles for the plants (Kennedy & Wightman, 2011).

The complexity of the regulatory network also becomes apparent when metabolic disturbances and changes in metabolic flux generated by over expression or reduced expression of genes of the core isoprenoid pathways promote pathway feedback or feed forward signals that modify the expression of up- or downstream genes. Although terpenoids serve important primary functions as photosynthetic pigments (carotenoids), electron carriers (side-chains of ubiquinone and plastoquinone), regulators of growth and development (gibberellins, abscisic acid, strigolactones, brassinosteroids, cytokinins),in protein glycosylation (dolichols),or as elements of membrane structure and function (phytosterols), specialized terpenoid metabolites (covered here), in particular, have been recognized for an array of biological roles.Volatile or semivolatile, low-molecular–weight terpenoids, which include isoprene, monoterpenoids, sesquiterpenoids, and diterpenoids, are implicated in the protection of plants against abiotic stress and in various biotic interactions(Tholl, 2016).

THE ROLE OF TERPENE FOR HUMAN

Secondary metabolites, also known as phytochemicals, natural products or plant constituents are responsible for medicinal properties of plants to which they belong (Kabera, 2018). Terpenoids are important for plant survival and also possess biological and pharmacological properties that are beneficial to humans(Singh & Sharma, 2015). As soon as an insect herbivore starts to feed on a plant, several defense signals are induced, leading to diffident that the forest atmosphere is beneficial to human health and that terpenes are the main components of forest aerosols, we reviewed the effects of various terpenes from Korean forests on human health, especially on immunity, cancer, and neuronal health(Cho et al., 2017). Terpenes are an enormous class of natural products spanning well over 30,000 members -They have been used throughout history for a broad variety of purposes including perfume, medicine, and flavoring - Recognized early on as being composed of isoprene fragments(Dewick, 2002).

Traditionally, terpene-containing plant oil has been used to treat various diseases without knowing the exact functions or the mechanisms of action of the individual bioactive compounds(Cho et al., 2017). They are polymeric isoprene derivatives and synthesized from acetate via the mevalonic acid pathway. During their formation, the isoprene units are linked in head and tail fashion. The number of units incorporated into a particular terpene serves as a basis for their classification and use. Many of them have pharmacological activity and are used for diseases treatment both in humans and animals(Kabera, 2018).

Terpenes with more complex structures than monoterpenes, including sesquiterpenoids derived from sesquiterpenes by biochemical modifications, have demonstrated anticancer ability as well(Cho et al., 2017). In many cases, the effects of these phytochemicals on the human CNS might be linked either to their ecological roles in the life of the plant or to molecular and biochemical similarities in the biology of plants and higher animals. This review assesses the current evidence for the efficacy of a range of readily available plant-based extracts and chemicals that may improve brain function and which have attracted sufficient research in this regard to reach a conclusion as to their potential effectiveness as nootropics(Kennedy & Wightman, 2011). However, only few studies have focused on the beneficial effects of terpene components of plant essential oils on neuronal health. So far, several terpenes, produced by a variety of plants, have been associated with neuronal health. (Cho et al., 2017).Therefore, as a main component of plant essential oils, terpenes may be beneficial to human neuronal health(Cho et al., 2017).

Many terpenoid-containing herbal extracts have therefore resisted the identification of a single active component, while adequate standardization of herbal extracts has also proved elusive(Kennedy & Wightman, 2011). Tumorigenesis is a multifaceted process, the progression of which is associated with several hallmarks, including uncontrolled cell growth, dysregulation of apoptosis, activation of invasion, induction of angiogenesis, and metastasis.Given that terpenes are major components of essential oils of various medicinal plants with neuroprotective functions, studies to find the beneficial roles of terpenes in neurodegenerative diseases will provide promising way to develop therapeutics(Cho et al., 2017).

Humans consume a wide range of foods, drugs, and dietary supplements that are derived from plants and which modify the functioning of the central nervous system (CNS). The psychoactive properties of these substances are attributable to the presence of plant secondary metabolites, chemicals that are not required for the immediate survival of the plant but which are synthesized to i Ginkgo biloba leaf extracts (GB) have been used medicinally for several millennia and are of some the most commonly taken herbal products globally(Kennedy & Wightman, 2011). In addition to the use of terpenes in the perfume and food industries, there is a wide array of medicinal properties to terpenes. The fact that each terpene has many different medical benefits gives rise to the overlapping synergies between them; this is something every ethnobotanist knows. The strategy of deliberately overlapping terpene benefits greatly increases the chances of effective results in treatment(Theis & Lerdau, 2003). Terpenes have been shown to exert anti-tumorigenic effects against such processes in a number of in vivo and in vitro systems, thus suggesting their potential uses as chemotherapeutic agents for treating tumors(Cho et al., 2017). Medical application proposed by those who sell medicinal oil range from skin treatment to remedies for cancer and are often based on historical use of these oils for this purpose. Interest in essential oils has revived in recent decades with the popularity of aromatherapy, a branch of alternative medicine which claims that the specific aromas carried by essential oils have curative effects(Approach, 2013). ß-Myrcene is the most commonly found terpene in cannabis, often in high concentrations. Its medicinal properties are well-known, most significantly for use in treating pain and inflammation. Because of its calming effect both mentally and physically, Myrcene is also used to treat psychosis and muscle spasms. Its properties are also used synergistically with other terpenes and cannabinoids(Theis & Lerdau, 2003).

In many cases, the effects of these phytochemicals on the human CNS might be linked either to their ecological roles in the life of the plant or to molecular and biochemical similarities in the biology of plants and higher animals(Kennedy & Wightman, 2011). Approximately one-half of all licensed drugs that were registered worldwide in the 25 y period prior to 2007 are natural products or their synthetic derivatives(Kennedy & Wightman, 2011). They are also useful for treating stress linked problems, digestive problems, tension, headache, allergy, insomnia and eruptions. It also affects the body's hormone producing glands(Approach, 2013). A huge scientific literature focusing on psychoactive herbal extracts and their phytochemicals, encompassing hundreds of thou- sands of scientific papers, has emerged over recent decades. The vast majority of these papers describe in vitro investigations of the potential mechanisms of action of putatively psychoactive phytochemicals, whereas a much smaller proportion explores their effects in vivo in animals and only a tiny minority investigate their efficacy in humans(Kennedy & Wightman, 2011).

The following comprises a review concentrating on those few nonprescription plant extracts and phytochemicals that have garnered enough evidence in human trials to arrive at some sort of in- dication. Antibacterial, antifungal properties of essential oils play important roles in their topical applications on cuts, burns and wounds. For example, eucalyptus oil has antibacterial effect on pathogenic bacteria in the respiratory tract(Approach, 2013). Interest in essential oils has revived in recent decades with the popularity of aromatherapy, a branch of alternative medicine which claims that the specific aromas carried by essential oils have curative effect sight help move this field of research forward. These similarities suggest 2 broad, alternate, but complementary hypotheses as to the factors underpinning the effects of secondary metabolites on human brain function. The second is that the effects are predicated on the similarities between the nervous systems of humans and those of the most prevalent, natural herbivores of plants, in particular, insects. In this case, phytochemicals whose synthesis has been retained by a process of natural selection on the basis of their ability to interact with the CNS of herbivorous or symbiotic insects will also interact with the human CNS system via the same mechanisms, with either similar, or in some cases dissimilar, behavioral effects(Kennedy & Wightman, 2011)

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CONCLUSION

Plants as sessile organisms face many stress situations and their growth and productivity are adversely affected in the form of various abiotic and biotic stress factors as well as against diverse microbial pathogens, herbivores and competitors. As a result of this, plants have evolved a number of inducible and/or performed mechanisms in defense against nature's wrath. Secondary metabolites have been effective in reducing the likelihood of herbivory, pathogen attack, overcoming stress constraints, adapting to changing environment, controlling competitors and limiting the cost as well as maintain benefits of mutualism. Secondary metabolites are the useful natural products that are synthesized through secondary metabolism in the plants. The production of some secondary metabolites is linked to the induction of morphological differentiation and it appears that as the cells undergo morphological differentiation and maturation during plant growth. It is observed that in-Vitro production of secondary metabolites is much higher from differented tissues when compared to non-differentiated or less –differentiated tissues. There are lots of advantages of these metabolites like there is recovery of the products will be easy and plant cultures are particularly useful in case of plants which are difficult or expensive and selection of cell lines for high yield of secondary metabolites will be easy. Many other examples could be presented with plant metabolic engineering as this research area is developing actively. Metabolic engineering is probably a large step forward but playing on the genes will not solve all the problems that have prevented the development of commercial success in the field of plant secondary metabolites. And Advances in plant cell cultures could provide new means for the cost-effective, commercial production of even rare or exotic plants, their cells, and the chemicals that they will produce. Knowledge of the biosynthetic pathways of desired compounds in plants as well as of cultures is often still rudimentary, and strategies are consequently needed to develop information based on a cellular and molecular level. Because of the complex and incompletely understood nature of plant cells in-Vitro cultures, case-by-case studies have been used to explain the problems occurring in the production of secondary metabolites from cultured plant cells. Advance research has succeeded in producing a wide range of valuable secondary phytochemical in unorganized callus or suspension cultures till to date; in other cases production requires more differentiated micro plant or organ cultures. The cells of any plants, tropical or alpine, could easily be multiplied to yield their specific metabolites.

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