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A Review On The Studies On Antimicrobial Activity Of Plant Essential Oils

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Abstract

Rice (Oryza sativa L.) is one of the most important staple food crops of India and is a major source of calories for about 60 per cent of world population and influences the livelihoods and economies of several billion people especially concentrated in Asia. About 53% of the world's rice is grown under irrigated conditions that provide 75% of total global production. The excessive and indiscriminate usage of chemical fungicides and bactericides, to control plant diseases has led to severe environmental problems along with the problem of resistance developed among the pathogens. Presently, under the concept of integrated pest management (IPM), all possible plant pest and disease control methods are integrated to minimize the excessive use of synthetic chemicals and also the incidence of disease. The potential of various essential oils against Gram-positive and Gram-negative bacteria and fungi is being actively investigated in various laboratories across the world. However, studies on antimicrobial activity of essential oils against plant pathogens and their ability to control plant diseases are scanty. The objective of the present study is to check efficacy of new essential oil compounds and inhibitory effect of the growth of bacterial leaf blight pathogen under field condition.

Introduction

Rice is one of the most important crops in India. It suffers from huge yield losses due to blast and blight diseases. Several laboratories are working out strategies to control these diseases. Most of the labs are working on screening for resistance genes against these diseases and are trying to use transgenic approach to contain them. In addition to transgenic approach use of environmentally friendly natural products, which can act as biological control agents, as one of the disease controlling components appears to be a useful disease control strategy.

"Eat leeks in March and wild garlic in May, and all the year after the physicians may play." Traditional Welsh rhyme (230)

"An apple a day keeps the doctor away." Traditional American rhyme

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Finding healing powers in plants is an ancient idea. From prehistoric times, people on all continents have long applied poultices and imbibed infusions of one or several hundreds of indigenous plants. Plants have played a significant role in maintaining human health and improving the quality of human life for thousands of years. Many plants and their products have been attributed to possess antimicrobial, antioxidant, immunostimulant, abortifacient, antihelminthic, astringent, carminative and demulcent properties and have been part of folk medicine since time immemorial. According to the world health organization reports 80% of the earth's inhabitants rely on the traditional medicines for their primary health care needs.

The antiseptic qualities of aromatic and medicinal plants and their extracts have been recognized since antiquity. Attempts to characterize these properties in the laboratory started from the early 1900s (Petrovska BB, 2012). Many drugs that are presently used for their therapeutical properties have originated from plants. For example: artemisinin from *Artemisia annua* is used to treat malaria; reserpine, which is used to control blood pressure is obtained from *Rauwolfia serpentina*; similarly salicylic acid from *Salix albata* is used to relieve pain and fever; digitoxin, digoxin, or some other digilanides which are used in treatment of heart failure diseases are from *Digitalis* (foxglove); taxol, which is used as chemotherapeutic agent for treatment of various cancers is obtained from bark of *Taxus brevifolia*. Despite the establishment of healing properties of numerous plants and plant products, numerous other plants and plant products are yet to be identified and tested for their antibiotic and disease combating properties.

Of the various useful qualities possessed by plants and their products, antimicrobial activity has gained considerable attention due to various reasons. Currently, of the one- quarter to one-half of all pharmaceuticals derived from higher plants, very few find use as antimicrobials since we have relied on bacterial and fungal sources for these activities. Since the advent of antibiotics and synthetic chemicals in the 1950s, little use has been made of plant derivatives as antimicrobials. However, with continued use of antibiotics and other drugs, drug resistance has become widespread. Although strategies have been evolved to combat this menace by using combinations of antibiotics and by the development of second, third and fourth generation antibiotics of different kinds, there has been an increasing awareness that perhaps plant products of therapeutic value are the best bet as safer drugs. Coupled with this trend, a second look at medical folklore and traditional plant based therapies is giving an impetus to plant based antimicrobial preparations. It was reported that in United States of America, in 1996, sales of botanical medicines increased 37% over 1995 (Bent S, 2008). Another very important driving factor for the renewed interest in plant antimicrobials, in the past 20 years, has been the rapid rate of extinction of plant species. There is a feeling among natural product-chemists and microbiologists alike that the multitude of potentially useful phytochemical structures that could be synthesized chemically is at risk of being lost irretrievably. This provided the impetus for the screening of antimicrobial properties of various plant products. Hence, it is worthwhile to identify natural plant products with antimicrobial properties.

India, with a variety of climatic and physiographical conditions has been bestowed with floral diversity. Rich traditional medicine knowledge in the form of ayurvedic literature is available. About 45,000

different plant species are found, of which 2000 are frequently used to cure various ailments. These plants and their products, which are known to possess various biological properties, need to be tested at laboratory levels before using them as therapeutic agents (Cowan MM, 1999).

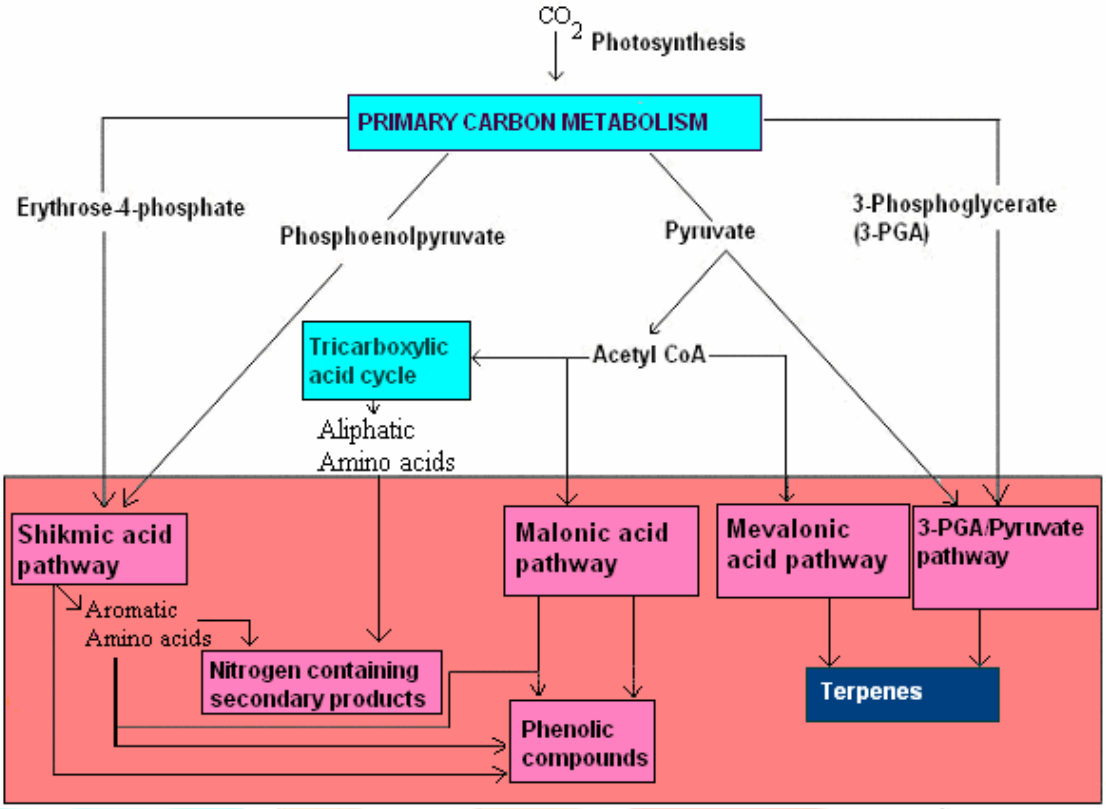
Phytochemicals

The biological properties of various plants and their products are imparted by various secondary metabolites (phytochemicals) produced by them. Plants produce a large and diverse array of organic compounds that, generally speaking, appear to have no direct function in growth and development, and these are named as secondary metabolites. They also differ from primary metabolites of plants such as chlorophyll, amino acids, nucleotides, simple carbohydrates etc. in having a restricted distribution in the plant kingdom. Plant secondary metabolites can be divided mainly into three chemically distinct groups:

1. Terpenes: These are the largest class of secondary products synthesized from acetyl CoA or from basic intermediates of glycolysis.
2. Phenolic compounds: Aromatic substances formed via the shikimic acid pathway or the malonic acid pathway.
3. Nitrogen-containing secondary products, such as alkaloids, which are primarily biosynthesized from amino acids.

The biological properties displayed by plants have been attributed to their ability to synthesize such compounds. The ability of these compounds to form complexes with certain enzymes or directly inhibit enzymes, toxic effects on membrane structure and integrity, quenching of free radicals, stimulation of natural killer cells in the humans, modulation of steroid concentrations etc. could be among important mechanisms underlying their biological activity. However, quite often, exact mechanisms in particular cases remain to be clarified.

Fig Diagrammatic representation showing synthesis of Terpenes in plants



Plant Essential Oils

Of the many plant products, a wide variety of plant essential oils are known to possess a variety of biological properties (Sharifi-Rad J *et al*., 2017). Essential oils occur in plants and in general give the plants their characteristic odours, flavors, or other such properties. The essential oils seem to be the by-products of plant metabolism and their function is not clearly understood. But some of them are known as attractants of pollinating agents like insects, and others as defense providing agents against parasites, hostile insects, browsing animals etc. In addition their role is also seen as allelopathic chemicals. They are frequently found in glandular hairs that project outward from the epidermis of the plant serving to 'advertise' the toxicity of the plant, thus repelling potential herbivores even before they take a trial bite (Glas JJ, 2012). Most of the known essential oils belong to 87 angiospermic families; notably among them are Asteraceae, Geraniaceae, Poaceae, Myrtaceae, Lamiaceae, Rutaceae, and Apiaceae. The essential oils are distilled from plant parts and represent very complex mixtures of organic compounds. They are found to contain a variety of compounds, with monoterpenes (C_{10}) and sesquiterpenes (C_{15}) being the most abundant. Other compounds like diterpenes (C_{20}), a variety of low molecular weight aliphatic hydrocarbons (linear, ramified, saturated and unsaturated), acids, alcohols, acyclic esters or lactones, and exceptionally nitrogen and sulphur containing compounds may also be present in these oils (Seema A. Kulkarni, 2021). Although in some plant species one main constituent of the oil may predominate, but in many spp. no single compound predominates and instead, there is a balance of various components (Sharifi-Rad M *et al*., 2017).

Essentials oils have many uses in day-to-day life and in industry. They are widely used as flavoring agents in foods and confectionaries, and as spices. They are also used in the perfume and cosmetic industry for

fragrance. They are also used in some of the modern skin care products because of the complexity of their active compounds, strong fragrant properties and better marketing value. They are also proposed as natural conservation agents for cosmetic preparations because of their antimicrobial activities (Sharmeen JB, 2021).

Antimicrobial Properties Of Plant Essential Oils

One of the important biological properties of these essential oils is their antimicrobial nature, and in many cases this activity was found to be due to the presence of active monoterpene constituents (Chouhan S *et al*., 2017). This antimicrobial activity of plant essential oils and extracts has formed the basis of many applications, including raw and processed food preservation, pharmaceuticals, alternative medicine and natural therapies (K. A. Hammer, 1996).

In fact the antimicrobial properties of essential oils derived from plants have been empirically recognized for centuries, but scientifically being confirmed only from recently (Mallappa Kumara Swamy., 2016). Another property of the plant products that is generating considerable interest is their ability to control plant diseases. Till now chemical control remains the main measure to reduce the incidence of plant diseases. Two serious problems hamper against the effective use of the chemical fungicides and bactericides in controlling plant pathogenic microbes. One, as already discussed, is the development of resistance by plant pathogenic fungi and bacteria, and the other problem is the presence of high level toxic residues in agricultural products due to the application of higher concentrations of chemicals in an attempt to overcome the problem of resistant plant pathogenic microbes. Hence the exploitation of natural substances such as essential oils, safer to consumers and the environment, for the control of plant diseases is presently looked upon. Letessier *et al*., in 2001 showed that the application of 0.05% hyssops oil can reduce the rust infection of broad bean caused by *Uromyces viciae-fabae*, while application of 0.05% hyssops oil, post inoculation, reduced the infection of powdery mildew of barley seedlings caused by *Blumeria graminis* f. sp. *Hordei*.

Many plant essential oils were tested for their antimicrobial activities. Origanum essential oil, which is used as a food flavoring, has been shown to possess a broad spectrum of antimicrobial activity due to high content of phenolic derivatives such as carvacrol and thymol present in it. It was found to inhibit various food spoiling organisms, which include the species of *Aspergillus*, *Hansenula*, and human pathogenic fungi such as *Trichophyton rubrum*, *Candida albicans* (Goyal S *et al*., 2018). The essential oils of *Artemisia afra*, *Pteronia incana* and *Rosmarinus officinalis* were found to display antimicrobial activity against 41 microbial strains, which includes food spoilage and common human/plant pathogenic bacterial and yeast strains. Among these three essential oils, the essential oils of *A. afra* and *R. officinalis* were found to show higher antimicrobial activity than *P. incana* (Mangalagiri N, 2021). The essential oil of hyssop was found to inhibit plant pathogenic fungi like *Pyrenophora avenae* and *Pyricularia oryzae*, in *in vitro* conditions. Further it was found to inhibit the germination of conidia and uredospores of *Botrytis fabae* and *Uromyces viciae-fabae* respectively (Letessier *et al*., 2001). The essential oil of *Melaleuca alternifolia* (Tea tree oil), which is well characterized and found to contain approximately a hundred terpenes and their related

alcohols was found to possess antibacterial, antifungal, antiviral and anti-inflammatory properties *in vitro* (Carson *et al*., 2002). The essential oils of thyme, dictamnus, rosemary, sage, marjoram, and pennyroyal were found to inhibit plant pathogenic fungi such as *Botrytis cinerea*, *Fusarium sp*., and a bacterium *Clavibacter michiganensis*. Thyme, dictamnus and marjoram oils were found to be rich in carvacrol, while rosemary and sage oils were rich in eucalyptol (Anastasiou, T. I. *et al*., 2019). The essential oils of black pepper, geranium, clove and nutmeg were found to exhibit considerable inhibitory effects against twenty five bacteria, of which nine are Gram-positive and sixteen are Gram-negative (Huan Yuchen *et al*., 2020). In a comparative study of some essential oils against various microorganisms by Man, Adrian *et al*., (2019), the essential oils of lemon grass, oregano and bay were found to inhibit *Acinetobacter baumanii*, *Aeromonas veronii*, *Candida albicans*, *Enterococcus faecalis*, *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Salmonella enterica*, *Serratia marcescens* and *Staphylococcus aureus*. In the same study the essential oils of rosewood, coriander, palm rosa, tea tree, niaouli, peppermint, spearmint, sage and marjoram were found to inhibit all the above mentioned microorganisms except *P. aeruginosa*. Further in this study it was found that essential oils of pumpkin, macadamia, evening primrose, apricot kernel, sweet almond and clary sage failed to inhibit any of the above mentioned microorganisms. The essential oil of *Backhousia citriodora*, which contain a very high percentage of citral, was found to inhibit various bacteria and fungi (Piotr Szweda & Barbara Kot, 2018). Basil essential oils, including basil sweet linalool and basil methyl chavicol were found to show antimicrobial activity against various Gram-positive and Gram-negative bacteria, yeasts and moulds. Basil methyl chavicol at 1% (v/v) when used as washing material for fresh lettuce (which is an important step in production of MPF salads) reduced viable count of microbial flora on fresh lettuce comparable to that of using 125 ppm chlorine. Chlorine washing systems which are employed might produce harmful by products such as chloramines and trihalomethanes. Because of this, now there is a great interest in using basil or other plant essential oils as natural alternatives for the washing of selected fresh salad to replace or reduce the concentration of chlorine (Xylia P *et al*., 2021).

However, to the best of our knowledge no comprehensive studies of these essential oils on various drug resistant bacteria, their ability to cure plasmids carrying drug resistant genes, the possible mode of action of these essential oils, and the ability of these essential oils to protect plants against plant pathogenic bacteria and fungi were done.

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