REVIEW OF LITERATURE

Introduction and Background

A plant is healthy and disease-free when it carries out physiological functions to the best of its genetic potential. These functions include normal cell division, differentiation and development, absorption of water and minerals and storage of food supplies for reproduction. Whenever plants are disturbed by pathogens or by certain environmental factors, one or more of these functions are interfered with beyond a certain deviation from the normal, they become diseased. Disease is a complex phenomenon that results due to interaction among the host (plant), pathogen and environment.

According to Stakman and Harrar (1957), a plant disease is a physiological or structural abnormality that is deleterious to the plant or to any of its parts or products, or that reduces its economical value. Plant disease may be temporary or permanent, depending on the speed of recovery. A disease may be localised, involving only a limited part of a plant or it may be systemic, when its infection is generalised and spread throughout the plant (Singh, 1992).

Disease of crop plants is one of the most significant constraints in the production of adequate amount of food material for human beings. Although population rise itself is an important factor for the
shortage of food material, but the present average area under cultivation can produce food enough to subsist rather a larger population, because around half of the total expected produce is lost due to various kinds of pests and diseases in the field, during storage or at any time between sowing and consumption of the harvest (Agrios, 2000).

In the history of mankind, plant diseases have been connected with a number of important events. Some such well known events causing loss of human lives are late blight of potato caused by *Phytophthora infestans* de Bary in Ireland in 1945, coffee rust caused by *Hemileia vastatrix* Berk. and Br. in Sri Lanka in 1870, downy mildew of grapes caused by *Plasmopara viticola* (Berk. and Curt.) Berl. and de Toni in France during 1878-1882 and leaf spot of rice caused by *Helminthosporium oryzae* Breda de Haan in Bengal in 1940, etc. The epidemic form of these diseases destroyed crops and led to famine in these countries. This resulted in migration of people from one part of the world to the other. Nevertheless, the importance of plant disease was realised (Agrios, 2000). Nearly 20 percent reduction in yield of major food and cash crops is caused by plant pathogens alone (Oerke *et al.*, 1994), resulting in huge economic losses as well as reduction in food supply.

Among various pathogens, fungi constitute an important group as they inflict damage to crop plants at each stage, i.e. seed germination, seedling growth, plant growth, grain formation and during harvesting and storage. Infection of plants with fungi may also lead to production of toxins, especially in edible parts. Mycotoxicosis is a common group of human and cattle diseases that manifests due
to consumption of toxin-contaminated food material (Jones, 1979; Marasas and Nan Rensburg, 1979).

The pathogenicity of fungi and their potential of causing disease are of economic importance to different agricultural crops. Various disease management methods have been implemented to combat and eradicate pathogenic fungi. These include cultural, regulatory, physical, chemical and biological methods. These methods have yielded limited success. None has been found satisfactory in all respects. *Cultural methods* include avoiding contact with a pathogen, eradicating or reducing the amount of a pathogen inoculum in a plant, field or an area, using healthy planting material followed by flooding of fields and crop rotation, etc. *Regulatory methods* aim at excluding a pathogen from the host or from some geographic area, whereas *physical methods* include protecting the plants from pathogen inoculum that is likely to come, and curing an infection that is already in progress. *Biological methods* also are not applicable everywhere because of non-specificity of the microorganism pests and the bio-agent (Sharma, 1996; Katan, 2000). However, all these methods are effective only when employed well in advance as precautionary measures. Once the disease has appeared, these methods become impractical or ineffective. In that situation, chemical control is the best choice for a grower to control the disease.

**Need for natural products**

At present, the agricultural management depends heavily on external inputs and modern technology. Since World War II, for commercial reasons, traditional agricultural management practices have been replaced with synthetic chemicals for the management of plant pathogens, pests and weeds. Obviously, crop production
increased but it deteriorated the environmental quality and human health (Cutler and Cutler, 1999). Moreover, in addition to environmental deterioration, the increasing incidence of resistance among pathogens towards synthetic chemicals is also a cause of serious concern. Furthermore, apart from the target organism, pesticides also eradicate various other beneficial organisms. Their toxic persistence in soil would contaminate the whole environment (Hayes and Laws, 1991).

These are the problems threatening our environment, and us. Therefore, researchers adapt some alternative methods to reduce the use of synthetic materials. Of these alternatives, natural products can serve the purpose better while having no side effects. They are biodegradable, eco-friendly, relatively broad spectrum, economical (Macias et al., 1997; Cutler, 1999; Patra et al., 2002). Natural products, possess the following advantages:

(i) Huge investment on chemical industry and energy gets reduced,
(ii) The problem of environmental degradation (which is a serious concern as regards synthetic chemicals) is ruled out,
(iii) Biomagnification of nonbiodegradable material in food chain is ruled out,
(iv) Resistance problem in target organism is eliminated,
(v) No possibility of anthropogenic diseases,
(vi) No losses in biodiversity, as natural products are usually specific in their action on target organisms. Further, making structural changes in their chemistry can enhance their bio-efficacy.
Several reasons have accelerated the need for more environmentally and toxicologically safe, selective and efficacious pesticides. Pesticides with commercial success have been discovered through various researches in the laboratory for pesticidal properties. The number of studies conducted to find commercially viable pesticides have increased drastically, therefore, new discovery strategies must be considered. The emphasis on reduced-tillage agriculture will control pathogen/pest but mostly with dependence on chemical control. That is why new pesticides are needed to fully meet this challenge. The increasing incidence of pesticide resistance is also another factor that emphasises on the need for new pesticides. Furthermore, most of the synthetic chemicals that have been commercialised as pesticides carry hydrocarbons with relatively long environmental lives and toxicological properties when compared to most natural compounds. Thus, natural compounds have increasingly become the focus for those interested in discovery of pesticides.

Thousands of secondary products of plants have been identified with estimates of existence of many thousands of these compounds. There are various reports and evidences indicating that most of these compounds help in plant defense mechanism against plant pests and pathogens. In other words, these compounds represent a large reservoir of chemical structures with biological activity. They can be easily used as pesticides. The use of natural plant products against the fungal pathogens, which is a relatively modern approach, is catching up fast. The literature available in this regard has been tabulated below alphabetically:
Table 1: Effect of plant products on fungal pathogens/diseases.

<table>
<thead>
<tr>
<th>Plant species and its parts</th>
<th>Fungal Pathogen/ Disease</th>
<th>Effect (s)</th>
<th>Reference (s)</th>
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</thead>
<tbody>
<tr>
<td>Adenocalyamma alliaceum Miers. Leaves</td>
<td><em>Alternaria solani</em> Sorauer/ early blight of tomato <em>Aspergillus flavus</em> Link. ex. Fries./ yellow rot of groundnut <em>Colletotrichum lindemuthianum</em> Sacc. et. Magn. / anthracnose of pea <em>Drechslera oryzae</em> Van Breda de Haan/ leaf spot of rice <em>Fusarium moniliforme</em> Sheldon/ wilt of sugarcane <em>Rhizoctonia solani</em> Kuhn / sheath blight of rice</td>
<td>Essential oil reduced the radial growth of test pathogens at different concentrations</td>
<td>Chaturvedi et al., 1987</td>
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<td>Adhatoda vasica Nees. Leaves</td>
<td><em>Fusarium oxysporum</em> Schi.ex.Fr./ wilt <em>Pythium debaryanum</em> Hessel./ damping off of pea seedling <em>Rhizoctonia solani</em>/ root rot of eggplant <em>Sclerotium rolfsii</em> Sacc./ foot rot of barley</td>
<td>Leaf juice reduced the radial growth of test pathogens at various concentrations</td>
<td>Kumar and Tripathi, 1991</td>
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<tr>
<td>Aegle marmelos L. Leaves</td>
<td><em>Drechslera oryzae</em>/ leaf spot of rice <em>Pyricularia oryzae</em>/ blast of rice <em>Pythium debaryanum</em>/ damping off of pea seedling <em>Rhizoctonia solani</em>/ root rot of eggplant <em>Sclerotinia sclerotiorum</em> (Lib.) de Bary/ stem rot of chickpea</td>
<td>Leaf juice and benzene extract reduced the radial growth of test pathogens at varying concentrations</td>
<td>Tewari, 1986; Ram, 1989; Singh et al., 1990 Kumar and Tripathi, 1991</td>
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<td>Allium cepa L. Whole bulbs</td>
<td><em>Sclerotium cepivorum</em> Berk./ white rot of onion</td>
<td>Composting onion waste reduced viability of sclerotia</td>
<td>Coventry et al., 2002</td>
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<td>Allium fistulosum L. Seeds</td>
<td><em>Phytophthora capsici</em> (Leonian) A.Alza. and P. H. Taso/ foot rot of black Pepper</td>
<td>Ethanol extract reduced radial growth of pathogen</td>
<td>Sang et al., 2002</td>
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<tr>
<td>Plant Name</td>
<td>Disease Caused by</td>
<td>Effect of Extract</td>
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<td><em>Allium sativum</em> L.</td>
<td><em>Alternaria solani</em> / early blight of tomato</td>
<td>Aqueous extract affected growth in liquid medium and radial expansion</td>
<td>Misra and Dixit, 1976b; Singh et al., 1979</td>
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<td><em>Altrenaria tenuis</em> Nees. / alternaria blight of sunflower</td>
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<td><em>Colletotrichum</em> sp. / anthracnose</td>
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<td><em>Curvularia lunata</em> (Wakker) Boedijn / leaf spot of maize</td>
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<td><em>Fusarium lini</em> Bolley / wilt of linseed</td>
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<td><em>Fusarium nivale</em> (Fr.) Ces. / fusarium patch</td>
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<td><em>Fusarium oxysporum</em> f. sp. ciceri Snyder and Hansen / wilt of chickpea</td>
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<td><em>Fusarium udum</em> Butler / wilt of pigeon pea</td>
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<td><em>Helminthosporium gramineum</em> Rabenth / leaf spot of wheat</td>
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<td><em>Phytophthora drechsleri</em> f. sp. cajani Pal, Grewal and Sarbhoy / stem blight of pigeon pea</td>
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<td><em>Sclerotinia sclerotiorum</em> / stem rot of chickpea</td>
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<td><em>Allium tuberosum</em> Rottl. ex. Spren. Whole plant</td>
<td><em>Aspergillus flavus</em> / yellow rot of groundnut</td>
<td>Ethanol extract reduced radial growth of test pathogens at different concentrations</td>
<td>Mau et al., 2001</td>
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<td><em>Aspergillus niger</em> Van. Tiegh./ collar rot of groundnut</td>
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<td><em>Penicillium italicum</em> Wehmer / blue mould</td>
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<td><em>Amomum subulatum</em> Roxb. Seeds</td>
<td><em>Aspergillus flavus</em> / kernel of corn</td>
<td>Essential oil reduced radial growth of test pathogens at various concentrations</td>
<td>Rahman et al., 1999</td>
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<td></td>
<td><em>Aspergillus niger</em> / collar rot of groundnut</td>
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<td><em>Fusarium oxysporum</em> f. sp. lycopersici (Sacc.) Snyder and Hansen / wilt of tomato</td>
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<td><em>Anagallis arvensis</em> L. Flower</td>
<td><em>Helminthosporium sativum</em> Pammel, King and Bakke / leaf spot of wheat</td>
<td>Aqueous extract reduced radial growth of the pathogens</td>
<td>Qasem and Abu – Blan, 1995,1996</td>
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<td><em>Penicillium digitatum</em> (Sacc. Fries) Sacc. / green mould</td>
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<td><em>Sclerotinia sclerotiorum</em> / cottony stem rot</td>
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<td><em>Verticillium dahliae</em> (Kleb.) Nelson / vascular wilt</td>
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<td><em>Anasterias minuta</em> Hug. Chla. Whole plant</td>
<td><em>Chadosporium cucumerinum</em> Ell. Et Arthur / scab of cucurbit</td>
<td>Methanol extract reduced the radial growth of the pathogen</td>
<td>Chludil et al., 2002</td>
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<td>Species</td>
<td>Pathogen/Infection</td>
<td>Description</td>
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<td><strong>Anethum graveolens</strong></td>
<td><em>Pythium aphanidermatum</em> (Edson) Fitzp.</td>
<td>Damping off of tree seedling</td>
<td>Kishore and Dwivedi, 1991</td>
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<td><strong>Argemone mexicana</strong></td>
<td><em>Aspergillus flavus</em>/kernel of corn</td>
<td>Aqueous extract reduced growth in liquid medium and aflatoxin production</td>
<td>Masood et al., 1991</td>
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<td><strong>Artemisia borealis</strong></td>
<td><em>Cladosporium cucumerinum</em> / scab of cucumber</td>
<td>Dichloromethane extract inhibited radial growth of the pathogen</td>
<td>Wang et al., 1990</td>
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<td><strong>Artemisia dracunculus</strong></td>
<td><em>Colletotrichum acutatum</em> / Simmonds anthracnose of strawberry</td>
<td>Essential oil reduced radial growth of test pathogens at varying concentrations</td>
<td>Meepagala et al., 2002</td>
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<td><strong>Artemisia nilagirica</strong></td>
<td><em>Pythium aphanidermatum</em></td>
<td>Damping off of tree seedling</td>
<td>Kishore and Dwivedi, 1991</td>
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<td><strong>Artemisia princeps</strong></td>
<td><em>Fusarium solani</em> (Mart.) Sacc. / root rot of cucurbits</td>
<td>Essential oil affected radial growth</td>
<td>Yun et al., 1993</td>
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<td><strong>Artemisia vestita</strong></td>
<td><em>Aspergillus niger</em> / fruit rot of tomato</td>
<td>Essential oil reduced radial growth</td>
<td>Kaul et al., 1976</td>
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<td><strong>Atriplex leucoclada</strong></td>
<td><em>Helminthosporium sativum</em> / leaf spot of wheat</td>
<td>Aqueous extract reduced radial growth of the pathogen</td>
<td>Qasem and Abu-Blan, 1996</td>
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<tr>
<td><strong>Azadirachta indica</strong></td>
<td><em>Fusarium oxysporum</em> f. sp. ciceri / wilt of chickpea</td>
<td>Essential oil, ethanol and aqueous extract reduced radial growth and growth in liquid medium at different concentrations. Controlled diseases and increased yield in case of groundnut</td>
<td>Singh et al., 1980; Ghevande, 1989; Singh and Dwivedi, 1990; Amadioha, 2000; Govindachari et al., 2000</td>
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<td><strong>Balloa saxatilis</strong></td>
<td><em>Penicillium digitatum</em> / green mould</td>
<td>Aqueous extract reduced radial growth of test pathogens at varying concentrations</td>
<td>Qasem and Abu-Blan, 1995</td>
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<td><strong>Biscutella didyma L.</strong></td>
<td><em>Penicillium digitatum</em> / green mould</td>
<td>Aqueous extract reduced radial growth of pathogens at different concentrations</td>
<td>Qasem and Abu-Blan, 1995</td>
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<td>Species</td>
<td>Part of Plant</td>
<td>Pathogens</td>
<td>Treatment Method</td>
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<td>Brassica juncea (L.) Czem.</td>
<td>Root, shoot and seeds</td>
<td>Fusarium graminearum Schw.</td>
<td>Aqueous extract reduced radial growth of pathogens at various concentrations</td>
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<td>Fusarium head blight of wheat</td>
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<td>Gaeumannomyces graminis var. triticis Walker/</td>
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<td>take-all of wheat</td>
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<td>Rhizoctonia solani/</td>
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<td>root rot of barley</td>
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<td>Pythium irregulare Buissman./</td>
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<td>pythium brown rot of wheat</td>
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<td>Brassica juncea (L.) Czem.</td>
<td>Leaves and stem</td>
<td>Fusarium sambucinum Fckl.</td>
<td>Aqueous extract reduced radial growth of test pathogens at different concentrations</td>
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<td>B. niger (L.) Koch.</td>
<td></td>
<td>fusarium dry rot of potato</td>
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<td>Helminthosporium solani Dur. and Mont./</td>
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<td>silver scurf on potato tuber</td>
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<td>Verticillium dahliae/</td>
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<td>vascular rot of potato</td>
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<td>Brassica napus L. var. glauca (Roxb.) Schulz.</td>
<td>Root</td>
<td>Aphanomyces spp.</td>
<td>Methanol extract reduced radial growth of test pathogens at varying concentrations</td>
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<td>root rot of pea</td>
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<td>Gaeumannomyces spp.</td>
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<td>Pythium spp.</td>
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<td>Rhizoctonia spp.</td>
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<td>Brassica oleracea L. var. capitata L.</td>
<td>Whole plant</td>
<td>Fusarium oxysporum f. sp. conglutinans/ (Wr.) Snyder and Hansen</td>
<td>Amended soil reduced propagule number of test pathogens in soil</td>
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<td>wilt of cabbage</td>
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<td>Pythium ultimum Trow./</td>
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<td>soft rot of tulip bulb</td>
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<td>Sclerotium rolfsii/</td>
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<td>collar rot of chickpea</td>
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<td>Boswellia thurifera Colebr.</td>
<td>Leaves</td>
<td>Aspergillus niger/ sooty rot</td>
<td>Essential oil affected radial growth of the pathogen</td>
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<td>Caesulia axillaries Roxb.</td>
<td>Whole plant</td>
<td>Pythium aphanidermatum/</td>
<td>Essential oil reduced radial growth of the pathogen</td>
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<td>Calligonum comosum L.</td>
<td>Branches</td>
<td>Aspergillus flavus/</td>
<td>Methanol extract reduced radial growth</td>
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<td>fruit rot</td>
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<td>Callistemon lanceolatus Stapf.</td>
<td>Whole plant</td>
<td>Pythium aphanidermatum/</td>
<td>Essential oil reduced radial growth of the pathogen</td>
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<td>Calotropis procera (Aiton) Aiton.</td>
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<td>Aspergillus flavus/</td>
<td>Ethanol extract reduced radial growth of test pathogens at different concentrations</td>
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<td>yellow rot of groundnut</td>
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<td>Curvularia lunata/</td>
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<td>leaf spot of maize</td>
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<td>Drechslera tetramera (Mc Kinney) Subram. and Jain./</td>
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<td>leaf spot of pearl millet</td>
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<td>Fusarium moniliforme</td>
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<td>wilt of sugarcane</td>
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</table>
| **Cananga odorata**  
(Lam.) Hook. F. and Thoms. | **Aspergillus niger**/sooty rot | Essential oil reduced radial growth of the pathogen | Baratta *et al.*, 1998 |
|-----------------------------|---------------------------------|---------------------------------------------------|---------------------|
| **Capsicum annuum**  
L. var. *acuminatum*  
Finger. Fruit | **Penicillium expansum** Link. ex. S.F.Gray./blue green mould of carrot **Rhizopus oryzae** Went and Prin./seedling damping off of rice | Methanol extract inhibited radial growth of test pathogens at various concentrations | Iorizzi *et al.*, 2002 |
| **Carthamus nitidus**  
Boiss. Aerial part | **Penicillium digitatum**/green mould **Sclerotinia sclerotiorum**/cottony stem rot **Verticillium dahliae**/vascular wilt | Aqueous extract reduced radial growth of test pathogens at different concentrations | Qasem and Abu-Blan, 1995 |
| **Cassia tora** L.  
Root, seeds and bark | **Sclerotinia sclerotiorum**/stem rot of chickpea | Amendment soil reduced percentage of post-emergence infection | Ram, 1989 |
| **Cedrus deodara** (D. Don) G. Donf. Wood chips | **Aspergillus niger**/sooty rot **Curvularia ovoidae** Hiroe. and Wata) Muntan./leaf spot of black gram | Essential oil inhibited mycelial growth | Singh and Tripathi, 1999 |
| **Centaurea iberica**  
Spren. Flower | **Penicillium digitatum**/green mould **Sclerotinia sclerotiorum**/cottony stem rot **Verticillium dahliae**/vascular wilt | Aqueous extract reduced radial growth of test pathogens at different concentrations | Qasem and Abu-Blan, 1995 |
| **Chelidonium majus**  
L. Root | **Cladosporium herbarum** (Pers.) Link. ex S. F. Gary./black mould of wheat | Methanol extract affected radial growth | Mau *et al.*, 2001 |
| **Chenopodium murale** L.  
Flower | **Alternaria solani**/early blight of potato **Penicillium digitatum**/green mould **Sclerotinia sclerotiorum**/cottony stem rot **Verticillium dahliae**/vascular wilt | Aqueous extract reduced radial growth of test pathogens at various concentrations | Qasem and Abu-Blan, 1995, 1996 |
| **Chromolaena odorata** (L.) R. M. King.  
Leaves | **Curvularia lunata**/leaf spot of maize **Rhizopus sp.**/rot of amaranth **Ustilaginoidea virens** (Cooke) Takahashi/  
false smut of rice **Ustilago maydis** (de Candolle) Corda./smut of corn | Hot water extract reduced radial growth of test pathogens at different concentrations | Awuah, 1989 |
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<tr>
<td><em>Cinnamomum cassia</em> Nees. Whole plants</td>
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<td><em>Lawsonia inermis</em> L. Leaves</td>
<td><em>Phaeoisariopsis personata</em> (Berk. and M.A. Curtis) Arx. / late leaf spot of groundnut <em>Puccinia arachidis</em> / rust of groundnut</td>
<td>Aqueous leaf extract controlled both disease and increased the yield</td>
<td>Ghewande, 1989</td>
</tr>
<tr>
<td>Species</td>
<td>Pathogen Description</td>
<td>Treatment Method</td>
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<td>Lonchocarpus castilloi</td>
<td>Pythium aphanidermatum! dampening off of tree seedling</td>
<td>Petrol extract reduced radial growth</td>
<td>Gomez-Garibay et al., 1990</td>
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<tr>
<td>Lycopersicon esculentum (L.) Mill.</td>
<td>Botrytis cinerea/gray mould of chickpea</td>
<td>Volatile from crushed leaves reduced radial growth of the pathogen</td>
<td>Hamilton-Kemp et al., 1992</td>
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<td>Lysichitum americanum Hult. and St. John.</td>
<td>Fusarium oxysporum/wilt Cladosporium herbarum/black mould of wheat</td>
<td>Cupric chloride extract inhibited radial growth at different concentrations</td>
<td>Hanawa et al., 2000</td>
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<td>Majorana hortensis Moench, Meth.</td>
<td>Aspergillus niger/sooty rot</td>
<td>Essential oil reduced radial growth of the pathogen</td>
<td>Baratta et al., 1998</td>
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<td>Medicago sativa L. whole plants</td>
<td>Verticillium dahiae/vascular wilt of potato</td>
<td>Aqueous extract eliminated the pathogen from soil</td>
<td>Gilbert and Griebel, 1969</td>
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<tr>
<td>Melaleuca alternifolia Cheel. Leaves</td>
<td>Botrytis cinerea/gray mould</td>
<td>Essential oil reduced radial growth of pathogen</td>
<td>Jobling, 2000</td>
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<td>Mentha piperita L. Leaves</td>
<td>Aspergillus flavus/kernel of corn</td>
<td>Essential oil affected radial growth and spore germination</td>
<td>Montes-Belmont and Carvajal, 1998</td>
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<tr>
<td>Miscanthus sinensis Ander. (E. As.) Aerial part</td>
<td>Pycnoria oryzae/blast of rice</td>
<td>Methanol extract inhibited spore germination</td>
<td>Mori et al., 1987</td>
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<td>Mollugo pentaphylla L. (As.)- Medi. Whole plant</td>
<td>Cladosporium cucumerinum/scab of cucumber</td>
<td>Methanol extract reduced radial growth of the pathogen</td>
<td>Hamburger et al., 1989</td>
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<td>Murraya koenigii (L.) Spr. Leaves</td>
<td>Pythium debaryanum/damping off of pea seedling</td>
<td>Aqueous extract reduced radial growth of pathogen</td>
<td>Kumar and Tripathi, 1991</td>
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<td>Musa paradisiaca L. Root</td>
<td>Aspergillus flavus/kernel of corn Fusarium sp.</td>
<td>Benzene extract reduced radial growth of test pathogens at different concentrations</td>
<td>Sharma et al., 1989</td>
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<td>Myristica fragrans Houtt. (Mace.) M. fragrans Houtt (Nutmeg.) Seeds</td>
<td>Aspergillus flavus/kernel of corn Aspergillus niger/collar rot of groundnut Fusarium oxysporum f. sp. lycopersici/wilt of tomato</td>
<td>Essential oil reduced radial growth of test pathogens at various concentrations</td>
<td>Rahman et al., 1999</td>
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<td>Nyctanthes arbor-tristis L. Leaves</td>
<td>Pycnoria oryzae/blast of rice Rhizoctonia solani/sheath blight of rice</td>
<td>Ethanol extract reduced radial growth of test pathogens at varying concentrations</td>
<td>Tewari and Nayak, 1991</td>
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<tr>
<td>Ocimum basilicum L. Leaves and</td>
<td>Alternaria sp./alternaria blight</td>
<td>Essential oil reduced radial growth and spore</td>
<td>Prasad et al., 1986; Montes-Belmont</td>
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<td>Plant Species</td>
<td>Species Part</td>
<td>Pathogens</td>
<td>Effect of Essential Oil</td>
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<td>Ocimum kilimandscharicum Guerk.</td>
<td>Whole plant</td>
<td><em>Alternaria</em> sp. / alternaria blight, <em>Aspergillus niger</em> / collar rot of corn, <em>Helminthosporium oryzae</em> / leaf spot of rice</td>
<td>Essential oil reduced radial growth of test pathogens at different concentration</td>
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<tr>
<td>Olea europaea L. (Olive.)</td>
<td>Fruit and leaves</td>
<td><em>Aspergillus niger</em> / sooty rot</td>
<td>Hexane extract reduced radial growth of the pathogen</td>
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<td>Ononis antiquorum L.</td>
<td>Aerial part</td>
<td><em>Penicillium digitatum</em> / green mould, <em>Sclerotinia sclerotiorum</em> / cottony stem rot, <em>Verticillium dahliae</em> / vascular wilt</td>
<td>Aqueous extract reduced radial growth of test pathogens at various concentrations</td>
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<td>Origanum vulgare L.</td>
<td>Whole plant</td>
<td><em>Aspergillus flavus</em> / yellow rot of groundnut, <em>Aspergillus niger</em> / fruit rot</td>
<td>Essential oil reduced radial growth and spore germination of test pathogens at different concentrations</td>
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<tr>
<td>Plant Name</td>
<td>Pathogen Description</td>
<td>Extract/Extracts Used</td>
<td>Results</td>
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<td>Pachira aquatica Abul.</td>
<td>Underground and leaves Pythium ultimum/ soft rot of tulip bulb</td>
<td>Ethyl acetate extract reduced radial growth of the pathogen</td>
<td>Shibatani et al., 1999</td>
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<td>Papaver orientale L.</td>
<td>Root Cladosporium herbarum/ black mould of wheat</td>
<td>Methanol extract affected radial growth</td>
<td>Ma et al., 2000</td>
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<td>Parietaria diffusa (L.) Koch. Early Flowering</td>
<td>Penicillium digitatum/ green mould Sclerotinia sclerotiorum/ cottony stem rot Verticillium dahliae/ vascular wilt</td>
<td>Aqueous extract reduced radial growth of test pathogens at different concentrations</td>
<td>Qasem and Abu-Blan, 1995</td>
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<td>Pelargonium sp. Whole plant</td>
<td>Aspergillus niger/ vegetable rot</td>
<td>Methanol extract reduced radial growth of the pathogen</td>
<td>Lis-Balchin and Deans, 1996</td>
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<td>Pimpinella anisum L. Fruit</td>
<td>Alternaria alternata/ alternaria blight of potato Alternaria solani/ early blight of potato Aspergillus niger / collar rot Colletotrichum capsici/ die-back of horse gram Fusarium udum/ wilt of pigeon pea</td>
<td>Essential oil reduced radial growth of test pathogens at different concentrations</td>
<td>Shukla and Tripathi, 1987</td>
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<td>Pinus spp. Whole plant</td>
<td>Pythium debaryanum/ damping off of pea seedling</td>
<td>Essential oil reduced radial growth of the pathogen</td>
<td>Kishore and Dwivedi, 1991</td>
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<tr>
<td>Piper arboreum H. B. K. F. tuberculatum Jacq. Leaves and seeds</td>
<td>Cladosporium herbarum/ black mould of wheat Cercospora sorghi (Ell. and Ev.)/ leaf spot of maize</td>
<td>Methanol and ethanol extracts inhibited radial growth of test pathogens at different concentrations</td>
<td>Silva et al., 2002</td>
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<td>Piper betel L. Leaves</td>
<td>Pyricularia oryzae/ blast of rice Rhizoctonia solani/ Sheath blight of rice</td>
<td>Ethanol and aqueous extract reduced radial growth of test pathogens and controlled disease</td>
<td>Tewari and Nayak, 1991</td>
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<td>Piper longum L. Whole plant</td>
<td>Botrytis cinerea/ cucumber gray mold Phytophthora infestans de Bary/ late blight of potato Puccinia recondita Dietl and Holw./ leaf rust of wheat Pyricularia oryzae/ blast of rice</td>
<td>Hexane extract reduced disease infection in vivo</td>
<td>Lee et al., 2001</td>
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<td>Plantago lanceolata L. Flower</td>
<td>Penicillium digitatum/ green mould Sclerotinia sclerotiorum/ cottony stem rot Verticillium dahliae/</td>
<td>Aqueous extract reduced radial growth of test pathogens at different concentrations</td>
<td>Qasem and Abu-Blan, 1995</td>
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<td>Plant Name</td>
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<td>Pathogens</td>
<td>Extract Effect</td>
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<td>Pongamia pendula R. Grah.</td>
<td>Leaves</td>
<td>Phaeoisariopsis personata/ late leaf spot of groundnut Puccinia arachidis/ rust of groundnut</td>
<td>Aqueous leaf extract controlled disease and increased the yield</td>
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<td>Prosopis juliflora (Sw.) DC.</td>
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<td>Aspergillus flavus/ yellow rot of groundnut Aspergillus niger/ sooty rot</td>
<td>Ethanol extract inhibited radial growth of test pathogens at various concentrations</td>
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<td>Ranunculus asiaticus L. Flower</td>
<td>Flower</td>
<td>Alternaria solani/ early blight of potato Penicillium digitatum/ green mould Sclerotinia sclerotiorum/ cotty stem rot Verticillium dahliae/ vascular wilt</td>
<td>Aqueous extract reduced radial growth of test pathogens at different concentrations</td>
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<td>Reynoutria sachalinensis (F. Schmidt.) Leaves</td>
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<td>Botrytis cinerea/ gray mould of grapes Sphaerotheca fuliginea (Schl. ex Fr.) Pollacci. / powdery mildew of cucumber</td>
<td>Leaf extract increased fruit per plant</td>
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<tr>
<td>Rhazya stricta Decne. Leaves</td>
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<td>Aspergillus flavus/ fruit rot Aspergillus niger/ sooty rot</td>
<td>Methanol extract inhibited radial growth of pathogens at varying concentrations</td>
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<td>Rosmarinus officinalis L. Leaves</td>
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<td>Aspergillus flavus/ kernel of corn Aspergillus niger/ sooty rot</td>
<td>Aqueous extracts and essential oil reduced radial growth, spore germination of pathogens and stimulated soil respiration by increasing bacterial population</td>
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<td>Rumex crispus L. Aerial part</td>
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<td>Helminthosporium sativum/ leaf spot of wheat</td>
<td>Aqueous extract reduced radial growth of the pathogen</td>
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<td>Ruta graveolens L. Leaves</td>
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<td>Fusarium solani/ root rot of cucurbits Penicillium spp./ green mould Pyrenochaeta lycopersici Schneider and Gerlach/ corky root rot of tomato Verticillium dahliae/ vascular wilt of potato</td>
<td>Aqueous extract reduced radial growth of test pathogens at different concentrations</td>
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<td>Saraca indica L. Leaves</td>
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<td>Fusarium oxysporum/ wilt Pythium debaryanum damping off of pea seedling</td>
<td>Aqueous extract reduced radial growth of pathogens at different concentrations</td>
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<td>Satureja thymbra L. Leaves</td>
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<td>Penicillium citrinum Thom./ green mould</td>
<td>Essential oil affected spore germination and growth in liquid medium</td>
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<td>Saussurea lappa (Dene.) C.B. Claruc. Root, seeds and bark</td>
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<td>Sclerotinia sclerotiorum/ stem rot of chickpea</td>
<td>Soil amendment reduced percentage of post-emergence infection</td>
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<td>Schrebera alata</td>
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<td>Botrytis cinerea/</td>
<td>Methanol extract reduced</td>
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<td>Effect on radial growth</td>
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<td><em>Hochst.</em> Welw.</td>
<td>gray mould</td>
<td>the radial growth of test pathogens at different concentrations</td>
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<td>Whole plant</td>
<td><em>Fusarium oxysporum</em> / wilt</td>
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<td><em>Pythium ultimum</em> / soft rot of tulip bulb</td>
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<td><em>Rhizoctonia solani</em> / root rot</td>
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<td><em>Sclerotium rolfsii</em> / foot rot of barley</td>
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<td><em>Verticillium dahliae</em> / vascular wilt</td>
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<td><em>Seseli indicum</em> Wight.</td>
<td><em>Pythium debaryanum</em> / damping off of pea seedling</td>
<td>Essential oil reduced radial growth of the pathogen</td>
<td>Kishore and Dwivedi, 1991</td>
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<td>and Arn. Whole plant</td>
<td><em>Aphanomyces euteiches</em> Drechsler / root rot of pea</td>
<td>Soil amendments reduced root rot severity and the number of infective propagules of test pathogen</td>
<td>Muchlchen et al., 1990</td>
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<td><em>Sinapis alba</em> L.</td>
<td><em>Alternaria solani</em> / early blight of potato</td>
<td>Aqueous extract reduced radial growth of test pathogens at various concentrations</td>
<td>Qasem and Abu - Blan, 1995, 1996</td>
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<td><em>Helminthosporium sativum</em> / leaf spot of wheat</td>
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<td><em>Penicillium digitatum</em> / green mould</td>
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<td><em>Rhizoctonia solani</em> / root rot</td>
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<td><em>Sclerotinia sclerotiorum</em> / cottony stem rot</td>
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<td><em>Verticillium dahliae</em> / vascular wilt</td>
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<td><em>Sisymbrium irio</em> L.</td>
<td><em>Aspergillus flavus</em> / kernel of corn</td>
<td>Aqueous extract reduced radial growth of aflatoxin production</td>
<td>Massod et al., 1991</td>
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<td>Flower</td>
<td><em>Penicillium digitatum</em> / green mould</td>
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<td><em>Sclerotinia sclerotiorum</em> / cottony stem rot</td>
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<td><em>Verticillium dahliae</em> / vascular wilt</td>
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<td><em>Solanum nigrum</em> L.</td>
<td><em>Aspergillus niger</em> / vegetable rot</td>
<td>Methanol extract reduced radial growth of the pathogen</td>
<td>Chah et al., 2000</td>
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<td>Fruit and leaves</td>
<td><em>Pythium debaryanum</em> / damping off of pea seedling</td>
<td>Aqueous extract reduced radial growth</td>
<td>Kumar and Tripathi, 1991</td>
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<td><em>Sclerotium rolfsii</em> / collar rot of chic ea</td>
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<td><em>Solanum torvum</em> Sw.</td>
<td><em>Aspergillus niger</em> / sooty rot</td>
<td>Ethanol extract reduced radial growth of the pathogen</td>
<td>Shah et al., 1986</td>
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<td>Ripe fruit</td>
<td><em>Pythium debaryanum</em> / damping off of pea seedling</td>
<td>Aqueous extract reduced radial growth</td>
<td>Govindachari et al., 1999</td>
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<td><em>Solidago Canadensis</em> L.</td>
<td><em>Aspergillus niger</em> / sooty rot</td>
<td>Methanol extract reduced the number of rust pustules</td>
<td>Ramassagh et al., 2002</td>
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<td>Leaves</td>
<td><em>Stachys camptoneura</em> Gilg. ex. Busse.</td>
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<td><em>Puccinia arachidis</em> / rust of groundnut</td>
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<td><em>Swietenia mahogani</em> (L.) Jacq. Seeds</td>
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<td>Plant Name (Scientific Name)</td>
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<td>Antimicrobial Activity/Effect</td>
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<td>Anthracnose of banana</td>
<td>Fusarium proliferatum/crown rot</td>
<td>Essential oil reduced radial growth of the pathogen</td>
<td>Kishore and Dwivedi, 1991</td>
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<td>Crown rot</td>
<td>Lasiodiplodia theobromae/stem rot of papaya</td>
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<td>Aspergillus flavus/kernel of corn</td>
<td>Essential oil inhibited radial growth and spore germination</td>
<td>Srivastava et al., 2001</td>
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<td>Tithonia ambrosioides</td>
<td>Aspergillus niger/yellow rot of groundnut</td>
<td>Methanol extract reduced radial growth of the pathogen</td>
<td>Ohiri and Uzodinma, 2000</td>
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<td>Dietr. Root</td>
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<td>Terminalia alata D.</td>
<td>Aspergillus niger/sooty rot</td>
<td>Aqueous extract reduced radial growth of pathogen</td>
<td>Montes-Belmont and Carvajal, 1998</td>
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<td>Terminalia ciliata M. Roem.</td>
<td>Puccinia arachidis/rust of groundnut</td>
<td>Essential oil reduced rust pustule emergence</td>
<td>Singh and Tripathi, 1999; Dwivedi and Singh, 1999</td>
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<td>Root</td>
<td>Aspergillus niger/sooty rot</td>
<td>Chloroform extract reduced radial growth of test pathogens at various concentrations</td>
<td>Nawaz et al., 2001</td>
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<td>Terminalia oliveri</td>
<td>Carvularia ovoidae/leaf spot of black gram</td>
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<td>P. ex. Olive. Leaves</td>
<td>Helminthosporium oryzae/leaf spot of rice</td>
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<td>Trachyspermum ammi L.</td>
<td>Macrophoma phaseolina/(Tassi.) Geid./root rot of eggplant</td>
<td>Essential oil reduced radial growth of test pathogens at various concentrations</td>
<td>Singh et al., 1980; Singh and Tripathi, 1999; Dwivedi and Singh, 1999</td>
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<td>Whole plant and seeds</td>
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<td>Trichilia heudelotti P.</td>
<td>Aspergillus niger/fruit rot</td>
<td>Methanol extract reduced radial growth of the pathogen</td>
<td>Aladesanmi and Odediran, 2000</td>
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<td>ex. Olive. Leaves</td>
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<td>Tridax procumbens L.</td>
<td>Phyaeomariopsis personata/late leaf spot of groundnut</td>
<td>Aqueous leaf extract controlled both diseases and increased the yield</td>
<td>Ghewande, 1989</td>
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<td>Leaves</td>
<td>Puccinia arachidis/rust of groundnut</td>
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<td>Uvaria narum Wall. Leaves</td>
<td>Phytophthora capsici/root rot of black Pepper</td>
<td>Aqueous extract inhibited radial growth of the pathogen</td>
<td>Bindu et al., 1998</td>
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<td>Species</td>
<td>Pathogens</td>
<td>Treatment</td>
<td>Reference</td>
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| *Viscum cruciatum* Siebe. ex. Boiss. Pre-flowering | *Penicillium digitatum* green mould  
*Sclerotinia sclerotiorum* cottony stem rot  
*Verticillium dahliae* vascular wilt | Aqueous extract reduced radial growth of test pathogens at various concentrations             | Qasem and Abu – Blan, 1995   |
| *Vitis negundo* L. Root, seeds and bark | *Sclerotinia sclerotiorum* stem rot of chickpea | Soil amendment reduced percentage of post - emergence infection                            | Ram, 1989                     |
| *Vitis vinifera* L. Fruit | *Botrytis cinerea* bunch rot of grapes | Aqueous, ethanol and diethyl ether extracts reduced radial growth of the pathogen           | Padgett and Morrison, 1990   |
| *Xylopia aethiopica* (Dun.) A. Rich. Dry fruit | *Curvularia lunata* leaf spot of maize  
*Rhizopus sp.* rot of amaranth  
*Ustilaginaeoides virens* false smut of rice  
*Ustilago maydis* / smut of corn | Aqueous extract reduced radial growth of test pathogens at different concentrations       | Awuah, 1989                   |
| *Zingiber officinale* Rose.  
*Z. chrysanthum* Rose. Rhizome and leaves | *Alternaria* sp. / alternaria blight  
*Fusarium* sp. / wilt  
*Pyricularia oryzae* / blast of rice  
*Sclerotium rolfsii* / foot rot of chickpea | Ethanol extract and essential oil reduced radial growth of pathogens at various concentrations | Endo et al., 1990; Singh et al., 1992 |
| *Zygophyllum hamianes* Schwein.  
*Z. gatarense* Hadid. Leaves | *Aspergillus niger* fruit rot | Methanol extract reduced radial growth of the pathogen | Basher et al., 1992 |
Role of essential oils

Essential oils are the subtle, aromatic and volatile liquids extracted from the flowers, seeds, leaves, stems, bark and roots of herbs, bushes, shrubs and trees, through distillation. According to ancient Egyptian hieroglyphics and Chinese manuscripts, essential oils were used to heal the sick. They are supposed to be the oldest form of medicine known to man and considered to be more valuable than gold. Scientists are now investigating the incredible healing substances found in essential oils.

The essential oils can easily penetrate the cell showing their ability to be effective in destroying pathogens. These are aromatic; therefore, many of the benefits can be obtained by simply inhaling them. Besides, these can also be the best air filtration system when diffused and remove metallic particles from the air and increase atmospheric oxygen.

Essential oils have often been defined as the *life-blood* of the plant. They are a system of medicine that is in harmony with our environment and us. Unlike synthetic chemicals, essential oils do not remain in the soil and leave no toxicity behind. Scientific researches effectively displayed the potent medicinal properties of these oils. Though they are found abundantly in the plant, yet their availability depends on the time of the day when the plant is cut, the type of soil, climates even altitude and the distillation process. Once produced, essential oils can easily evaporate. They also need to be kept from extremes of temperature. Therefore, essential oils are, as said, highly effective to manage diseases and also useful for environment but one should know how to produce, protect and practice them. Scientifically speaking, essential oils are very complex mixtures of different
compounds. Their constituents are mainly monoterpenes and sesquiterpenes, which are hydrocarbons with the general formula \((\text{C}_5\text{H}_8)_n\). There are various reports available on the effect of these oils on different plant pathogens. As far as these studies are concerned, this unique formula shows no side effects as synthetic chemical materials have on the human health and environment. Their potential in crop protectivity also is another positive point for use of these natural oils. These documented reports led the agricultural researcher to do more study to use essential oils commercially. The following properties are catching the attention of the scientists worldwide:

(i) Exhibit wide array of biological activity,
(ii) Toxic at very low concentrations,
(iii) Novel modes of action,
(iv) No mammalian toxicity,
(v) Provide prototypes for the synthesis of new pesticides
(vi) Considerable potential of crop protectivity against disease and pest management in other situations,
(vii) Safe to the user and the environment.

Because of these reasons, essential oils and their components are widely used for disease and pest management purpose. The available literature on such studies is listed below:
<table>
<thead>
<tr>
<th>Plant species and its parts</th>
<th>Fungal Pathogen/ Disease</th>
<th>Reference(s)</th>
</tr>
</thead>
</table>
| *Adenocalymma alliaceum* Miers. Leaves | *Alternaria solani* / early blight of tomato  
*Aspergillus flavus* / yellow rot of groundnut  
*Colletotrichum lindemuthianum* / anthracnose of pea  
*Drechslera oryzae* / leaf spot of rice  
*Fusarium moniliforme* / wilt of sugarcane  
*Rhizoctonia solani* / sheath blight of rice | Chaturvedi *et al.*, 1987 |
| *Amomum subulatum* Roxb. Seeds | *Aspergillus flavus* / kernel of corn  
*Aspergillus niger* / collar rot of groundnut  
*Fusarium oxysporum* f. sp. *lycopersici* / wilt of tomato | Rahman *et al.*, 1999 |
| *Anethum graveolens* L. Whole plant | *Pythium aphanidermatum* / damping off of tree seedling | Kishore and Dwivedi, 1991 |
| *Artemisia dracunculus* L. var. *dracunculus* Pursh, Fl. Aerial parts | *Colletotrichum acutatum* / anthracnose of strawberry  
*Colletotrichum fragariae* / anthracnose of strawberry  
*Colletotrichum gloeosporioides* / anthracnose of strawberry | Meepagala *et al.*, 2002 |
| *Artemisia nilagirica* (Clarke) Pamp. Leaves | *Pythium aphanidermatum* / damping off of tree seedling | Kishore and Dwivedi, 1991 |
| *Artemisia princeps* var. *orientalis* Willd. Leaves | *Fusarium solani* / root rot of cucurbits | Yun *et al.*, 1993 |
| *Artemisia vestita* Wall. A. *vulgaris* L. Leaves | *Aspergillus niger* / fruit rot of tomato | Kaul *et al.*, 1976 |
| *Azadirachta indica* A. Juss. Leaves, trunk, bark and seeds | *Fusarium oxysporum* f. sp. *ciceri* / wilt of chickpea  
*Phaeoisariopsis personata* / late leaf spot of groundnut  
*Puccinia arachidis* / rust of groundnut  
*Pyricularia oryzae* / blast of rice  
*Rhizoctonia solani* / root rot  
*Sclerotinia rolfsii* / foot rot of barley  
*Sclerotinia sclerotiorum* / cottony stem rot | Singh *et al.*, 1980; Ghanwade, 1989; Singh and Dwivedi, 1990; Amadioha, 2000; Govindachari *et al.*, 2000 |
<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Pathogen/Insect</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boswellia thurifera Colebr. Leaves</td>
<td>Aspergillus niger/sooty rot</td>
<td>Baratta et al., 1998</td>
</tr>
<tr>
<td>Caesulia axillaries Roxb. Whole plant</td>
<td>Pythium aphanidermatum/ damping off of tree seedling</td>
<td>Kishore and Dwivedi, 1991</td>
</tr>
<tr>
<td>Callistemon lanceolatus Stapf. Whole plant</td>
<td>Pythium aphanidermatum/ damping off of tree seedling</td>
<td>Kishore and Dwivedi, 1991</td>
</tr>
<tr>
<td>Cananga odorata (Lam.) Hook. F. and Thomson Leaves</td>
<td>Aspergillus niger/sooty rot</td>
<td>Baratta et al., 1998</td>
</tr>
<tr>
<td>Cedrus deodara (D. Don.) G. Don. Wood chips</td>
<td>Aspergillus niger/sooty rot Curvularia avoidae/ leaf spot of black gram</td>
<td>Singh and Tripathi, 1999</td>
</tr>
<tr>
<td>Chrysanthemum indicum L. Leaves</td>
<td>Pythium aphanidermatum/ damping off of tree seedling</td>
<td>Kishore and Dwivedi, 1991</td>
</tr>
<tr>
<td>Cinnamomum verum J. Presl. Bark</td>
<td>Aspergillus flavus/ kernel of corn Aspergillus niger/ collar rot of groundnut Fusarium oxysporum f. sp. lycopersici/ wilt of tomato</td>
<td>Bullerman, 1974; Rahman et al., 1999</td>
</tr>
<tr>
<td>Cinnamomum zeylanicum Blume. Leaves and bark</td>
<td>Aspergillus niger/sooty rot Aspergillus flavus/ kernel of corn Colletotrichum musae / anthracnose of banana Fusarium proliferatum / crown rot Lasiodiplodia theobromae / crown rot</td>
<td>Baratta et al., 1998; Montes-Belmont and Carvajal, 1998; Ranasinghe et al., 2002</td>
</tr>
<tr>
<td>Citrus medica L. Seeds</td>
<td>Puccinia arachidis/ rust of ground nut</td>
<td>Govindachari et al., 2000</td>
</tr>
<tr>
<td>Clematis gouriana Roxb ex DC Leaves</td>
<td>Alternaria tenuis/ alternaria blight of sunflower Curvularia lunata/ leaf spot of maize Helminthosporium gramineum/ leaf spot of wheat</td>
<td>Misra and Dixit, 1976a</td>
</tr>
<tr>
<td>Coriandrum sativum L. Fruit</td>
<td>Aspergillus flavus/ kernel of corn Aspergillus niger/ fruit rot Fusarium oxysporum f. sp. lycopersici/ wilt of tomato</td>
<td>Rahman et al., 1999</td>
</tr>
<tr>
<td>Coridothymus capitatus (L.) Reichb. Thyme. Whole plant</td>
<td>Aspergillus flavus/ yellow rot of groundnut Aspergillus niger/ collar rot of groundnut</td>
<td>Paster et al., 1990</td>
</tr>
<tr>
<td>Cuminum cyminum L. Whole plant</td>
<td>Aspergillus flavus/ kernel of corn Aspergillus niger/</td>
<td>Singh and Upadhyay, 1991; Rahman et al., 1999</td>
</tr>
<tr>
<td>Plant Species</td>
<td>Disease/Pathogen</td>
<td>Author(s) and Year</td>
</tr>
<tr>
<td>---------------</td>
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</tr>
<tr>
<td>Curcuma angustifolia</td>
<td>Fusarium oxysporum f. sp. lycopersici, Helminthosporium oryzae</td>
<td>Banerjee and Nigam, 1977</td>
</tr>
<tr>
<td></td>
<td>Yellow rot, fruit rot</td>
<td></td>
</tr>
<tr>
<td>Cymbopogan martini (Roxb.) C. oliveri J. Watso.</td>
<td>Aspergillus flavus, Aspergillus niger</td>
<td>Singh et al., 1980</td>
</tr>
<tr>
<td></td>
<td>Helminthosporium oryzae</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leaf spot of rice</td>
<td></td>
</tr>
<tr>
<td>Dalbergia paniculata Roxb.</td>
<td>Helminthosporium oryzae, Fusarium solani</td>
<td>Ramachandraiah, 1991</td>
</tr>
<tr>
<td></td>
<td>Leaf spot of rice, root rot of cucurbits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kernel of corn</td>
<td></td>
</tr>
<tr>
<td>Elelaria cardamomum L.</td>
<td>Aspergillus flavus, Aspergillus niger</td>
<td>Rahman et al., 1999</td>
</tr>
<tr>
<td></td>
<td>Kernel of corn, collar rot of groundnut</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fusarium oxysporum f. sp. lycopersici, wilt of tomato</td>
<td></td>
</tr>
<tr>
<td>Eucalyptus citriodora Hook.</td>
<td>Alternaria triticina, Alternaria solani, Helminthosporium oryzae, Rhizoctonia solani</td>
<td>Ramezani et al., 2002</td>
</tr>
<tr>
<td></td>
<td>Leaf blight of wheat, early blight of tomato, leaf spot of rice, sheath blight of rice, root rot of eggplant</td>
<td></td>
</tr>
<tr>
<td>Foeniculum vulgare Miller</td>
<td>Aspergillus flavus, Aspergillus niger, Pythium aphanidermatum</td>
<td>Kishore and Dwivedi, 1991; Patra, 2002</td>
</tr>
<tr>
<td></td>
<td>Yellow rot, vegetable rot, damping off of tree seedling</td>
<td></td>
</tr>
<tr>
<td>Hibiscus cannabinus L.</td>
<td>Colletotrichum acutatum, Colletotrichum fragariae, Colletotrichum gloeosporioides</td>
<td>Kobaisy et al., 2001</td>
</tr>
<tr>
<td></td>
<td>Anthracnose of straw berry, anthracnose of strawberry</td>
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<tr>
<td>Homalomena aromatica Schott.</td>
<td>Aspergillus niger, Fusarium graminearum</td>
<td>Singh et al., 2000</td>
</tr>
<tr>
<td></td>
<td>Sooty rot, fusarium head blight of cereals</td>
<td></td>
</tr>
<tr>
<td>Hypericum maculatum Crantz.</td>
<td>Aspergillus niger</td>
<td>Gudzic et al., 2002</td>
</tr>
<tr>
<td></td>
<td>Fruit rot</td>
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<tr>
<td>Plant Name</td>
<td>Plant Part</td>
<td>Fungi/Phytopathogen</td>
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<tr>
<td><em>Hyptis suaveolens</em></td>
<td>Leaves</td>
<td><em>Aspergillus niger</em>/sooty rot</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Colletotrichum falcatum</em>/anthracnose of sugarcane</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Fusarium udum</em>/wilt of pigeon pea</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Rhizoctonia solani</em>/root rot</td>
</tr>
<tr>
<td><em>Juniperus communis</em></td>
<td>Whole plant</td>
<td><em>Pythium aphanidermatum</em>/damping off of tree seedling</td>
</tr>
<tr>
<td><em>Majorana hortensis</em></td>
<td>Leaves</td>
<td><em>Aspergillus niger</em>/sooty rot</td>
</tr>
<tr>
<td><em>Melaleuca alternifolia</em></td>
<td>Leaves</td>
<td><em>Botrytis cinerea</em>/gray mould</td>
</tr>
<tr>
<td><em>Mentha piperita</em></td>
<td>Leaves</td>
<td><em>Aspergillus flavus</em>/kernel of corn</td>
</tr>
<tr>
<td><em>Myristica fragrans</em></td>
<td>Seeds</td>
<td><em>Aspergillus flavus</em>/kernel of corn</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Aspergillus niger</em>/collar rot of groundnut</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Fusarium oxysporum f. sp. lycopersici</em>/wilt of tomato</td>
</tr>
<tr>
<td><em>Ocimum basilicum</em></td>
<td>Leaves and</td>
<td><em>Alternaria sp</em>/alternaria blight</td>
</tr>
<tr>
<td></td>
<td>inflorescence</td>
<td><em>Aspergillus flavus</em>/kernel of corn</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Aspergillus niger</em>/collar rot of groundnut</td>
</tr>
<tr>
<td><em>Ocimum basilicum</em></td>
<td>Whole plant</td>
<td><em>Alternaria sp</em>/alternaria blight</td>
</tr>
<tr>
<td></td>
<td>Benth.,</td>
<td><em>Aspergillus niger</em>/collar rot of groundnut</td>
</tr>
<tr>
<td></td>
<td><em>pilosum</em> Benth.,</td>
<td><em>Alternaria sp</em>/alternaria blight</td>
</tr>
<tr>
<td></td>
<td><em>thyrsiflorum</em> Benth.,</td>
<td><em>Aspergillus niger</em>/collar rot of groundnut</td>
</tr>
<tr>
<td></td>
<td><em>purpurascens</em> Benth.</td>
<td><em>Helminthosporium oryzae</em>/leaf spot of rice</td>
</tr>
<tr>
<td><em>Ocimum sanctum</em></td>
<td>Leaves and</td>
<td><em>Alternaria sp</em>/alternaria blight</td>
</tr>
<tr>
<td></td>
<td>inflorescence</td>
<td><em>Aspergillus flavus</em>/yellow rot of groundnut</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Aspergillus niger</em>/collar rot of groundnut</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Alternaria sp</em>/alternaria blight</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Pyricularia oryzae</em>/blast of rice</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Rhizoctonia solani</em>/sheath blight of rice</td>
</tr>
<tr>
<td><em>Origanum vulgare</em></td>
<td>Whole plant</td>
<td><em>Aspergillus flavus</em>/yellow rot of groundnut</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Aspergillus niger</em>/fruit rot</td>
</tr>
<tr>
<td>Plant</td>
<td>Condition</td>
<td>Disease/Infection</td>
</tr>
<tr>
<td>-------------------------------</td>
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<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>Pimpinella anisum L.</td>
<td>Fruit</td>
<td>Alternaria alternata/alternaria blight of potato</td>
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<tr>
<td></td>
<td></td>
<td>Alternaria solani/early blight of potato</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aspergillus niger/collet rot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Colletotrichum capsici/die-back of horse gram</td>
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<td></td>
<td></td>
<td>Fusarium udum/wilt of pigeon pea</td>
</tr>
<tr>
<td>Pinus spp.</td>
<td>Whole plant</td>
<td>Pythium debaryanum/damping off of pea seedling</td>
</tr>
<tr>
<td>Satureja thymbra</td>
<td>Leaves</td>
<td>Penicillium citrinum/green mould</td>
</tr>
<tr>
<td>Seseli indicum</td>
<td>Wight and Arn.Wholes plant</td>
<td>Pythium debaryanum/damping off of pea seedling</td>
</tr>
<tr>
<td>Syzygium aromaticum (L.)</td>
<td>Leaves and bark</td>
<td>Aspergillus niger/sooty rot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Colletotrichum musae/anthracnose of banana</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fusarium proliferatum/crown rot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lasiodiplodia theobromae/crown rot</td>
</tr>
<tr>
<td>Tagetes erecta L.</td>
<td>Whole plant</td>
<td>Pythium debaryanum/damping off of pea seedling</td>
</tr>
<tr>
<td>Teloxys ambrosioides (L.)</td>
<td>Whole plant</td>
<td>Aspergillus flavus/kernel of corn</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thymus vulgaris L.</td>
<td>Leaves</td>
<td>Aspergillus flavus/kernel of corn</td>
</tr>
<tr>
<td>Toona ciliata M. Teomer</td>
<td>Wood</td>
<td>Puccinia arachidis/rust of groundnut</td>
</tr>
<tr>
<td>Trachyspermum ammi L.</td>
<td>Whole plant and seeds</td>
<td>Aspergillus niger/sooty rot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carvularia ovoidea/leaf spot of black gram</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Helminthosporium oryzae/leaf spot of rice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Macrophomina phaseolina/root rot of eggplant</td>
</tr>
</tbody>
</table>
General effect of some pure compounds for the management of diseases

Monoterpenes are supposed to be the simplest representatives of the terpenes. They are the largest group of secondary metabolites (Elakovich, 1988; Abrahim et al., 2000). They are constituents of a number of aromatic plants such as Artemisia spp. (Ahmad and Misra, 1994), Curila spicata Benth. (Manns, 1995), Cymbopogon citratus (Nees.) Stapf., Micromeria sp. (Dudai et al., 1999), Eucalyptus sp. (Kohli, 1990; Orihara and Furuya, 1994), Lavandula angustifolia Mill. Gard., Rosmarinus officinalis L., Salvia fruticosa Mill. Gard. and Origanum vulgare L. (Karamanoli et al., 2000). They play an important role as plant protectants and pollinator attractants (Swain, 1977; Fischer et al., 1991; Paiva, 2000). Lately, their toxicity towards fungi is being explored so as to use them for disease management purposes (Mahmoud, 1994; Saikia et al., 2001). They are desirably short-lived in soil because of high vapour pressure, no leaching to ground water and low mammalian toxicity (Isman, 2000). Their modes of action are reported to be different from synthetic chemicals, so they may serve as prototypes in relation to synthesis of lead molecules for future pesticides (Dayan et al., 1999).

Yoshida et al. (1987) reported that among fractions derived from garlic, ajoene showed the strongest activity against Aspergillus niger and Candida albicans. In another study, Singh et al. (1990) showed the same compound inhibited the spore germination of some plant pathogenic fungi.

Two flavonoids from root of Clerodendron infortunatum L. namely carbriuvin and quercetin showed antifungal activity against spore germination of Alternaria carthami and Helminthosporium oryzae (Roy et al., 1996). Gopalakrishnan et al. (1997) isolated xanthones from the
fruit hulls of *Garcinia mangostana* L. and reported the antifungal activity against *Fusarium oxysporum*, *Alternaria tenuis* and *Drechslera oryzae*. Recently, Govindachari *et al.* (2000) examined cedrelone from *Toona ciliata* M. Roem.; azadiradione from *Azadirachta indica* A. Juss.; limonin, limonol and nomilinic acid from *Citrus medica* L. and found that all compounds showed antifungal activity against *Puccinia arachidis* to reduce rust pustula emergence with different effects.

Some of the active components which are very useful against pathogens and the type of effects they cause are tabulated here:

**Table 3: Effects of pure compounds extracted from plants source on the fungal pathogens/diseases.**

<table>
<thead>
<tr>
<th>Pure compound</th>
<th>Fungal Pathogen/Disease</th>
<th>Effect (s)</th>
<th>Reference (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ajoene</td>
<td><em>Altemaria solani</em></td>
<td>early blight of potato</td>
<td>Baldwin et al., 1962</td>
</tr>
<tr>
<td></td>
<td><em>Altemaria triticina</em></td>
<td>blight of wheat</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Aspergillus niger</em></td>
<td>sooty rot</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Curvularia sp.</em></td>
<td>leaf spot</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Fusarium lini</em></td>
<td>wilt of linseed</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Fusarium udum</em></td>
<td>wilt of pigeon pea</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Phytophthora drechsleri</em> f. sp. cajani</td>
<td>stem blight of pigeon pea</td>
<td>Yoshida et al., 1987</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Growth in liquid medium was affected at different concentrations and some morphological changes was observed</td>
<td>Singh <em>et al.</em>, 1990; Singh <em>et al.</em>, 1992</td>
</tr>
<tr>
<td>Allicin</td>
<td><em>Aspergillus niger</em></td>
<td>sooty rot</td>
<td>Yoshida <em>et al.</em>, 1987</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Growth in liquid medium was affected at different concentrations</td>
<td></td>
</tr>
<tr>
<td>Asafoetida</td>
<td><em>Ascochyta rabiei</em> (Pass.)</td>
<td>blight of chickpea</td>
<td>Churasia and Ram, 1990</td>
</tr>
<tr>
<td></td>
<td><em>Rhizoctonia solani</em></td>
<td>root rot</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Sclerotinia sclerotiorum</em></td>
<td>cottony stem rot</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Radical growth and sclerotia formation were affected</td>
<td></td>
</tr>
<tr>
<td>Cinnamic aldehyde</td>
<td><em>Aspergillus flavus</em></td>
<td>kernel of corn</td>
<td>Bullerman <em>et al.</em>, 1977; Vaughn and Spencer, 1994</td>
</tr>
<tr>
<td></td>
<td><em>Fusarium sambucinum</em></td>
<td>fusarium dry rot of potato</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Radial growth and aflatoxin production of test pathogens were inhibited</td>
<td></td>
</tr>
<tr>
<td>Citral</td>
<td><em>Aspergillus niger</em></td>
<td>collar rot of groundnut</td>
<td>Batt <em>et al.</em>, 1983</td>
</tr>
<tr>
<td></td>
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<td>Reduced radial growth and aflatoxin production</td>
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<td>Compound</td>
<td>Pathogens</td>
<td>Effect on Pathogens</td>
<td>References</td>
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<td>Citronellal</td>
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<td>Kurita et al., 1981 Mahmoud, 1994</td>
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<td>Citronellol</td>
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<td>Clerodin</td>
<td><em>Fusarium oxysporum</em> f. sp. <em>lycopersici</em> wilt of tomato</td>
<td>Radial growth was inhibited</td>
<td>Cole et al., 1991</td>
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<td>Clerodin</td>
<td><em>Verticillium tricorpus</em> Isaac./vascular wilt of almond</td>
<td>Radial growth and spore germination were affected</td>
<td>Cole et al., 1991</td>
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<td>Eugenol</td>
<td><em>Aspergillus flavus</em> kernel of corn <em>Aspergillus niger</em> fruit rot</td>
<td>Radial growth and aflatoxin production of test pathogens were inhibited</td>
<td>Bullerman et al., 1977</td>
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<td>Geraniol</td>
<td><em>Aspergillus niger</em> collar rot of groundnut</td>
<td>Inhibited radial growth and aflatoxin production</td>
<td>Batt et al., 1983</td>
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<td>Jodrellin B</td>
<td><em>Verticillium tricorpus</em> vascular wilt of potato</td>
<td>Spore germination was affected</td>
<td>Cole et al., 1991</td>
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<td>Linalool</td>
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<td>Isothiocyanates</td>
<td><em>Fusarium graminearum</em> fusarium head blight of wheat <em>Gaeumannomyces graminis var. tritici</em> take- all of wheat <em>Pythium irregularare</em> phytophthora brown rot of wheat <em>Rhizoctonia solani</em> root rot of barley</td>
<td>Radial growth of pathogens were affected</td>
<td>Sarwar et al., 1998</td>
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<td>Salicylaldehyde</td>
<td><em>Fusarium sambucinum</em> fusarium dry rot of potato</td>
<td>Reduced radial growth of pathogen</td>
<td>Vaughn and Spencer, 1994</td>
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<td>Terpinene</td>
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<td>Xanthones</td>
<td><em>Fusarium oxysporum</em> wilt</td>
<td>Inhibited radial growth of test pathogens</td>
<td>Gopalakrishnan et al., 1997</td>
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<td><em>Drechlera oryzae</em> leaf spot of rice</td>
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<td><em>Alternaria tenuis</em> alternaria blight of sunflower</td>
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