Review of Literature

Green plants because of their vast diversity contained a wide spectrum of plant defense chemicals most of which make a vital contribution to the list of medicines for human health even today. These plant defense chemicals present in different complex forms which cause behavioral and physiological effects on pest have already been identified (Srivastava et al., 2000; Lopez et al., 2001). When these chemicals come in human and animal body through food chain, they would not show side effects because most of these chemicals are present in our food system and body of consumers is already resistant against these chemicals.

A perusal of literature shows the several plants have been found to possess pronounced fungitoxic, insect repellent and insecticidal activity against different storage pests. Aqueous or organic extracts of the plants have been reported time to time to demonstrate pronounce as pesticidal activity. However, only in some cases the In Vivo efficacy of such products has been reported. The present review has been presented under the following heads:

- Investigations on fungitoxicity of angiospermic plant extracts against storage fungi.
- Insecticidal and insect repellent activity of higher plant extracts against storage insects.
- Investigations on fungitoxicity of essential oils of angiospermic plant against storage fungi and insects.

Investigations on Fungitoxicity of Angiospermic Plant Extracts against Storage Fungi

A perusal of literature shows that several angiospermic plants have been found to possess pronounced fungitoxic activity against mycelial growth or spore germination of different storage fungi. Mostly extracts of fresh plant parts prepared in water or in some organic
solvents have been assayed by different techniques for antifungal screening, however, stored plant samples have been used only by a few investigators.

The plants have been selected randomly or pertaining to certain families. Most of the workers made preliminary fungitoxic screening of plants and only a few paid attention to investigate detailed fungitoxic properties of the active plants. Chief findings on antifungal activity of angiospermic plants are presented in chronological order in Table-A where the parts of plants used for screening are given in parenthesis.

**Table - A: Investigations on angiospermic plant extracts for their antifungal activity against storage fungi**

<table>
<thead>
<tr>
<th>Investigator(s)</th>
<th>Plants investigated</th>
<th>Chief findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anand &amp; Johar (1957)</td>
<td>Several plants species</td>
<td>Three plants were most effective against <em>Aspergillus niger</em></td>
</tr>
<tr>
<td>Abdullaeva (1962)</td>
<td><em>Allium sativum</em> and <em>A. cepa</em> (seed)</td>
<td>Exhibited volatile toxicity against <em>Fusarium oxysporum, Rhizoctonia solani.</em></td>
</tr>
<tr>
<td>Bhargava et al. (1981)</td>
<td>Leaf extract of some plant species</td>
<td><em>Ocimum canum</em> was found most effective against <em>A. flavus</em> and <em>A. versicolor.</em></td>
</tr>
<tr>
<td>Dubey et al. (1982a)</td>
<td>Extracts of 40 higher plants</td>
<td>Leaf extract of <em>Citrus medica</em> and <em>Erigeron bonariensis</em> showed absolute toxicity against <em>A. flavus</em> and <em>A. versicolor.</em></td>
</tr>
<tr>
<td>Varadpande and Sangai (1983)</td>
<td><em>Glossocardia bosvallea</em></td>
<td>Seed and entire plant extracts were inhibitory to the growth of <em>Aspergillus niger.</em></td>
</tr>
<tr>
<td>Privindrachary et al. (1984)</td>
<td>50 plant species (different parts)</td>
<td><em>Artobotrys odoratissimus</em> (leaves and flower) <em>Delonix regia</em> (flower, leaves and bark) <em>Euphorbia microphylla</em> (leaves), <em>Oxalis conrialata</em> (petiole and bulb),</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Plant Material</td>
<td>Activity</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Shrivastava <em>et al.</em> (1984)</td>
<td><em>Parthenium hysterophorus</em> (inflorescence, leaves, stem and roots)</td>
<td>MIC of extract of inflorescence, stem and leaves was 100 ppm but of roots was 1000 ppm against three species of Aspergillus (<em>A. niger, A. sulphureus &amp; A. fumigatus</em>)</td>
</tr>
<tr>
<td>Saxena and Tripathi (1985)</td>
<td>Leaves of 15 aromatic plants</td>
<td>Most effective leaves of <em>Cuminum cyminum, Ocimum sanctum, Angelica sp. and Lantana camara</em> inhibited the spore germination of <em>Aspergillus niger, Mucor mucedo</em> and <em>Alternaria alternata</em>.</td>
</tr>
<tr>
<td>Upadhyay <em>et al.</em> (1985)</td>
<td>Leaves of 30 plant species</td>
<td>Only <em>Anisomeles ovata</em> showed activity against <em>Aspergillus flavus</em>.</td>
</tr>
<tr>
<td>Chary and Reddy (1986)</td>
<td>11 plant spp. (latex)</td>
<td>Latex of <em>Ficus benghalensis, Tabernaemontana divaricata</em> and <em>Vallaris solanica</em> were found effective against <em>Penicillium citrinum</em> which produces citrinin.</td>
</tr>
<tr>
<td>Davidyuk <em>et al.</em> (1987)</td>
<td>Leaves of 38 spp. of Clematis</td>
<td>Exhibited strong activity against species of <em>Aspergillus</em>.</td>
</tr>
<tr>
<td>Tiwari <em>et al.</em> (1987)</td>
<td>Leaves of <em>Aegle marmelos</em> and <em>Eupatorium capillifolium</em></td>
<td>Inhibited mycelial growth of <em>Aspergillus flavus</em> and <em>Penicillium oxalicum</em>.</td>
</tr>
<tr>
<td>Kalaichelvan and Mahadevan (1988)</td>
<td>Groundnut (Shell Extracts)</td>
<td>Spore germination of <em>Alternaria alternata</em> and <em>Curvularia spicata</em>.</td>
</tr>
<tr>
<td>Mishra <em>et al.</em> (1988)</td>
<td>Leaf extract of</td>
<td>Inhibited mycelial growth of</td>
</tr>
<tr>
<td>Authors</td>
<td>Plant(s) and Extracts</td>
<td>Activity against Fungi</td>
</tr>
<tr>
<td>-----------------------</td>
<td>---------------------------------------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Mishra et al. (1988)</td>
<td>Leaf extract of <em>Ageratum conyzoides</em>, <em>Chrysanthemum sp.</em></td>
<td>Exhibited strong activity against <em>Aspergillus sydowi</em>.</td>
</tr>
<tr>
<td>Naidu (1988)</td>
<td><em>Codiaeum variegatum</em> (leaf extract)</td>
<td>Showed antifungal activity against <em>Alternaria alternata</em> and <em>Fusarium oxysporum</em>.</td>
</tr>
<tr>
<td>Rusia and Shrivastava (1988)</td>
<td>Ethanol extracts of <em>Aegle marmelos</em>, <em>Sapium eugeniaefolium</em>, <em>Morinda citrofolia</em>, <em>Vitex negundo</em></td>
<td><em>Aegle marmelos</em> effective against <em>Curvularia lunata</em>, <em>Aspergillus niger</em> and <em>Rhizopus nodulens</em>. <em>Sapium eugeniaefolium</em> was toxic against <em>Alternaria alternata</em>, <em>Aspergillus niger</em> and <em>Curvularia lunata</em>, <em>Morinda citrofolia</em> effective against <em>A. niger</em>, <em>Vitex negundo</em> was toxic against <em>C. lunata</em> and <em>R. nodulens</em>.</td>
</tr>
<tr>
<td>Adebajo et al. (1989)</td>
<td>Ethylacetate and methanol extracts of <em>Eugenia uniflora</em>.</td>
<td>Low-grade activity against <em>Aspergillus flavus</em>.</td>
</tr>
<tr>
<td>Awuah (1989)</td>
<td>5 West African plants</td>
<td>Extracts were evaluated <em>in vitro</em> for fungitoxicity against <em>Curvularia lunata</em> and <em>Rhizopus sp.</em>. Steam distillate from leaves of <em>Cymbopogon citrates</em> inhibited 4 fungi. Hot water extracts from fresh leaves of <em>Ocimum gratissimum</em> and <em>Chromoleana odorata</em> and dry fruits of <em>Xylopia</em></td>
</tr>
<tr>
<td>Reference</td>
<td>Extract Details</td>
<td>Results</td>
</tr>
<tr>
<td>----------------------------</td>
<td>-------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Rizki et al. (1989)</td>
<td>Extracts of different parts of 32 plants</td>
<td>Eleven of the plant extracts inhibited <em>Aspergillus niger</em>, <em>A. flavus</em> and <em>Penicillium citrinum</em> and some plant extracts showed strong stimulatory effect against test organisms.</td>
</tr>
<tr>
<td>Tiwari et al. (1990)</td>
<td>Leaf extracts of <em>Citrus medica</em> and <em>Cleome viscosa.</em></td>
<td>Showed absolute toxicity against <em>Aspergillus flavus</em> and <em>Penicillium oxalicum.</em></td>
</tr>
<tr>
<td>Mishra &amp; Dubey (1990a)</td>
<td>Aqueous extracts of leaves of 15 higher plants</td>
<td><em>Prunus persica</em> exhibited strong activity against <em>A. flavus.</em></td>
</tr>
<tr>
<td>Ginesta-Peris et al. (1994)</td>
<td>Extracts of <em>Xanthium spinosum</em></td>
<td>Effective against <em>Penicillium italicum</em> and <em>Aspergillus flavus.</em></td>
</tr>
<tr>
<td>Mohamed et al. (1996)</td>
<td>Ethanolic extracts of 58 plants</td>
<td><em>Piper betle</em> was highly effective against <em>Aspergillus niger.</em></td>
</tr>
<tr>
<td>Kowalczyk &amp; Krzyzanowska (1999)</td>
<td>5 species of family Dipsaceace</td>
<td>Showed strong toxicity against <em>Aspergillus fumigatus</em></td>
</tr>
<tr>
<td>Zrobi &amp; Aldedaya (1999)</td>
<td>Extracts of some fruits</td>
<td>Showed activity against <em>A. niger</em></td>
</tr>
<tr>
<td>Singh &amp; Singh (2000)</td>
<td>Aqueous &amp; organic solution extracts of 50 plants.</td>
<td>Extracts of <em>Trachyspermum ammi</em>, <em>Allium sativum</em>, <em>Syzygium aromaticum</em> and <em>Plectranthus rugosus</em> were most effective against <em>A. flavus</em> and <em>A. niger.</em></td>
</tr>
<tr>
<td>Study</td>
<td>Extract / Extractant</td>
<td>Effectiveness</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Radha et al. (2000)</td>
<td>Crude leaf extract of <em>Syzygium travancoricum</em></td>
<td>Effective against <em>Aspergillus terreus</em>.</td>
</tr>
<tr>
<td>Uiral et al. (2001)</td>
<td>Garlic juice</td>
<td>Against storage fungi.</td>
</tr>
<tr>
<td>Khan et al. (2001)</td>
<td>Extracts from leaves, stem and root barks of <em>Omalanthus herrosus</em>.</td>
<td>Effective against <em>Aspergillus niger</em></td>
</tr>
<tr>
<td>Bahra &amp; Purohit (2002)</td>
<td>Extracts of <em>Argemone maxicana</em> and <em>Azadirachta indica</em></td>
<td><em>Azadirachta indica</em> effective against <em>Aspergillus flavus</em></td>
</tr>
<tr>
<td>Boer et al. (2005)</td>
<td>Aqueous, Methonal and Ethanal extracts of <em>Coccinia adoensis</em></td>
<td>Extracts were effective against <em>Aspergillus fumigatus</em> &amp; <em>Fusarium sp.</em></td>
</tr>
<tr>
<td>Magro et al. (2006)</td>
<td>Aqueous extracts of Chamomile, Cinnamon, French lavender, <em>Garlic Malva</em>, Peppermint</td>
<td>Chamomile and Malva were most effective against <em>Aspergillus niger</em> &amp; <em>Penicillium sp.</em></td>
</tr>
<tr>
<td>Guleria &amp; Kumar 2006</td>
<td>Extracts of <em>Vitex negundo</em>, <em>Zontoxyllum alatum</em>, <em>Ipomea carnea</em>, <em>Cinnamomum camphora</em></td>
<td>Leaf extracts were against <em>Alternaria alternata</em> &amp; <em>Curvularia lunata</em>.</td>
</tr>
<tr>
<td>Kumar et al., (2006)</td>
<td>61 Indian medicinal plants from 33 families</td>
<td>Twenty-eight plant extracts showed activity against <em>Candida albicans</em> and <em>Aspergillus niger</em></td>
</tr>
</tbody>
</table>
Alanis-Garza *et al.*, (2007)  
Leaf extract of *Artemia salina*  
Effective against *Candida albicans* and *Aspergillus fumigants*

Ghorbanina *et al.*, (2008)  
Leaf extract of *Azadirachta indica*  
Shows inhibition of *Aspergillus parasiticus*.

Masoko *et al.*, (2008)  
Leaf extract of *Combretum nelsonii*  
Shows strong antifungal activity against *Aspergillus fumigantus*

Thus it is evident from the above table that although several plant species have been tested for their antifungal activity during *in vitro* condition, only a few of them have been tried for their efficacy in control of storage infestations of food commodities during *In Vivo* conditions. Further, the fungitoxicity of the plants may vary in their different parts as well as against different test fungi. Besides, effect of storage period, the solvents used for extracts and the age of the plants may also influence the fungitoxicity.

**Insecticidal and insect repellent activity of higher Angiospermic plant extracts against storage insects.**

Some higher plant extracts have been tested for their efficacy against storage insect pests. Paul *et al.* (1965) reported solvent extract of rhizomes of *Acorus colamus* to be insecticidal against *Sitophilus oryzae, Latheticus oryzae, Tribolium castaneum* and *Heterotermes indicala*. Jaipal *et al.* (1984) found neem leaf extracts to be toxic against *Rhizopertha dominica*. Extracts and oil of Cedar wood (*Cedrus deodara*) were toxic against *Callosobruchus chinensis* (Singh and Rao, 1985). Jha *et al.* (1987) reported extracts of *Adhatoda vasic* to exhibit strong antifeedant activity against *Sitophilus oryzae*. Mohanty *et al.*, (1988) found extracts of *Clerodendron viscosum* and *Blumea eriantha* to be insecticidal against stored grain pests viz. *Callosobruchus chinensis* and *Sitophilus oryzae*. Qureshi *et al.* (1988) reported insecticidal and insect repellent activity of acetone extracts of *Ageratum* sps., *Valeriana wallichii, Euphorbia pulcherima* and *Psoralea corilifolia* against red flour beetle *Tribolium castaneum*. Su and Horvat (1988) reported acetone extracts of seeds of *Anethum graveolens* and its component viz. d-carvone and dillapiol, to possess insecticidal against flour beetle and rice weevils. Dixit and Savai (1989) reported insect repellent activity of extract of *Tridex procumbens* against *Calandra granaria* and *Tribolium confusum*.
Oji (1991) recommended Piper guineese dust and ethanolic extracts in the protection of stored *Zea mays* against maize weevil. Crude ethanolic extract of aerial part of flower of *Veratrum album* exhibited insecticidal activity against *Tribolium* sps. (Sener et al., 1991). Tiwari and Saxena (1993) reported and feeding deterrent activity of methanolic extract of *Spearanthus indicus* against *Tribolium castaneum* Herbst. Bhattacharya et al. (1993) reported ether extract of *Ranunculus sceleratus* cause high mortality in red flour beetle. No insect could survive at 1 and 5 percent concentration of the extract beyond 15 and 10 days respectively. Ho et al. (1994) found the grain protectant activity of methanolic or hexane extracts of flower buds of cloves against *Tribolium castaneum* and *Sitophilus zeamais*. Husain (1995) found both the adults and 6th instar larvae of *Tribolium castaneum* repelled from the food medium treated with *Solanum xanthocarpum* leaf dust conditioned with 100 percent, 70 percent, 50 percent, 30 percent and 20 percent flour. Singh and Pandey (1996) founds seeds of chick pea could be effectively protected from the pulse beetle, *Callosbruchus chinensis* by administering dried neem leaf powder at rate of 100-400 mg/50 gm seed in storage. Neem leaf powder could significantly reduce the beetle population at 0.2, 0.4, 0.6 and 0.8 percent doses (w/w) as compared to control. Pati et al. (1996) evaluated some plant extracts as repellents against the pulse beetle and found aqueous extracts of *Azadirachta indica*, *Acorus calamus*, *Curcuma longa* and *Annona squamosa* to be highly effective. Patro & Pati (1997) screened aqueous extracts of some plants against pulse beetle. *Callosbruchus chinensis* Linn and found the extract of *Acorus calamus* more toxic than *Azadirachta indica*. Weaver et al. (1997) found floral extract of *Mexican marigold. Tagets minuta* was toxic to adult male and female maize weevils. *Sitophilus zeamais*, the LD$_{50}$ values ranged from 35 to 47 mg per weevil across sex and photoperiod. Whereas LD$_{90}$ values ranged from 319 to 816 µg. per weevil. Lale & Abdulrahman (1999) found the neem powder was highly effective against *Callosobruchus maculatus* in stored cowpea.
Investigations on Fungitoxicity of Essential Oils of Angiospermic Plant against Storage Fungi and Insects.

A number of essential oils have been tested for their toxicity against various storage fungi. The findings of various workers on effective oils tested against different fungi have been tabulated so as to have comparative idea (Table-B).

**Table-B : Fungitoxicity of essential oils against storage fungi**

<table>
<thead>
<tr>
<th>Investigator(s)</th>
<th>Essential oils</th>
<th>Test Fungi</th>
<th>Chief findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haerdtl (1962)</td>
<td><em>Eucalyptus sp.</em></td>
<td><em>Aspergillus niger</em></td>
<td>-</td>
</tr>
<tr>
<td>Dovgich (1971)</td>
<td>Basil, Coriander and Fennel</td>
<td><em>Aspergillus oryzae</em></td>
<td>-</td>
</tr>
<tr>
<td>Arora and Pandey(1977)</td>
<td><em>Cymbopogon citratus, Mentha arvensis</em>, Sweet basil</td>
<td></td>
<td>Mentha oil was most active both, in <em>In Vivo</em> and <em>in vitro</em> conditions</td>
</tr>
<tr>
<td>Kher and Chaurasia(1977)</td>
<td><em>Pongamia pinnata, Apium graveolens</em></td>
<td>15 storage fungi</td>
<td>Pure oils were most active.</td>
</tr>
<tr>
<td></td>
<td>(leaves), <em>Azadirachta indica</em> (seeds)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sharma and Gautam(1977)</td>
<td><em>Nepeta hindostana</em></td>
<td>10 storage fungi</td>
<td>Pure oil exhibited good antifungal activity.</td>
</tr>
<tr>
<td>Mathela and Sinha (1978)</td>
<td><em>Aster thomsoni, A. penduncularis, Seliunum tenuifolium, Cymbopogon jwarancusa</em></td>
<td><em>Aspergillus sp.</em></td>
<td>Oil of <em>C. jwarancusa</em> exhibited best response.</td>
</tr>
<tr>
<td>Grover and Rao</td>
<td><em>Psoralea corylifolia</em></td>
<td><em>Aspergillus</em></td>
<td>The oil was</td>
</tr>
<tr>
<td>Authors</td>
<td>Species</td>
<td>Fungi</td>
<td>Activity</td>
</tr>
<tr>
<td>-------------------------</td>
<td>--------------------------------------------------------------</td>
<td>----------------------------------------</td>
<td>------------------------------------</td>
</tr>
<tr>
<td>Lahariya and Rao (1979)</td>
<td><em>Cyperus scariosus</em>, <em>Ocimum basilicum</em></td>
<td><em>Aspergillus fumigatus</em>, <em>A. niger</em></td>
<td>The oil of <em>C. scariosus</em> was found most active.</td>
</tr>
<tr>
<td>Mishra <em>et al.</em> (1979)</td>
<td><em>Randia dumentorium</em></td>
<td><em>Fusarium moniliforme</em>, <em>F. solani</em></td>
<td>Pure oil was moderately effective</td>
</tr>
<tr>
<td>Sharma and Singh (1979a)</td>
<td><em>Oenanthe javanica</em></td>
<td>9 storage fungi</td>
<td>Pure oil was most active.</td>
</tr>
<tr>
<td>Sharma and Singh (1979b)</td>
<td>15 oils</td>
<td>11 storage fungi</td>
<td>Pure oils of <em>Trachyspermum ammi</em> was most active.</td>
</tr>
<tr>
<td>Suri and Thind (1979)</td>
<td><em>Cinnamomum camphora</em>, <em>Eucalyptus camaldulensis</em>, <em>Ocimum killimandscharicum</em>, <em>Valeriana wallichii</em></td>
<td><em>Aspergillus fumigatus.</em></td>
<td>Most of the oils were found active.</td>
</tr>
<tr>
<td>Suri <em>et al.</em> (1979)</td>
<td><em>Eucalyptus citriodora</em></td>
<td><em>Aspergillus niger</em></td>
<td>Pure oil exhibited strongest activity.</td>
</tr>
<tr>
<td>Dikshit (1980)</td>
<td><em>Cedrus deodara</em></td>
<td>15 storage fungi</td>
<td>The oil showed strongest toxicity at 5000 ppm.</td>
</tr>
<tr>
<td>Narayan <em>et al.</em> (1980a)</td>
<td><em>Carum carvi</em>, <em>Foeniculum vulgare</em>, <em>Trachyspermum ammi</em></td>
<td><em>Aspergillus fumigatus</em>, <em>A. niger</em></td>
<td>Pure oil of <em>T. ammi</em> was most active.</td>
</tr>
<tr>
<td>Narayan <em>et al.</em> (1980b)</td>
<td><em>Cinnamomum zeylanicu</em></td>
<td><em>Aspergillus fumigatus</em>, <em>A. niger</em>, <em>Rhizopus</em></td>
<td>Pure oil was tested at 1:64 dilution <em>A. niger</em></td>
</tr>
<tr>
<td>Study</td>
<td>Species/Strains</td>
<td>Fungi/Conditions</td>
<td>Observations</td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------------------------------------</td>
<td>---------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Bhargava et al.</td>
<td>Ocimum canum</td>
<td>13 storage fungi</td>
<td>The oil exhibited strong toxicity at 3000 and 5000 ppm.</td>
</tr>
<tr>
<td>(1981)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dikshit et al.</td>
<td>Cedrus deodara</td>
<td>Some storage fungi</td>
<td>Protected spices from fungal deterioration up to 12 months.</td>
</tr>
<tr>
<td>(1982)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dubey et al.</td>
<td>Ocimum canum and Citrus medica</td>
<td>Storage fungi</td>
<td>Protected fungal deterioration of some spices and were found superior to synthetic chemicals.</td>
</tr>
<tr>
<td>(1983a)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kala et al.</td>
<td>Zingiber sp., Lemon grass, Palma rosa and Mentha sp.</td>
<td>Aspergillus parasiticus</td>
<td>The Mentha oil was most potent.</td>
</tr>
<tr>
<td>(1984)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dikshit et al.</td>
<td>Schinus molle</td>
<td>Alternaria alternata, Aspergillus flavus</td>
<td>Effective concentration of the oil varied from 200-900 ppm and exhibited narrow range of activity.</td>
</tr>
<tr>
<td>(1986)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dixit (1986)</td>
<td>Several plants</td>
<td>Aspergillus flavus, A. niger</td>
<td>Ocimum gratissimum was found most effective.</td>
</tr>
<tr>
<td>Tripathi et al.</td>
<td>Trachyspermum</td>
<td>Aspergillus</td>
<td>MIC of the oil was</td>
</tr>
</tbody>
</table>

Review of Literature
<p>| (1986) | <em>ammi</em> (L.) (oil from fruits) | <em>flavus, A. niger</em> | found to be 800 ppm and showed broad range of toxicity. Moreover, the oil protected groundnut seeds at 5000 ppm for one year. |
| Upadhyay <em>et al.</em> (1986) | <em>Citrus aurantifolia</em> | <em>Aspergillus flavus</em> | Fungitoxic at 2000 ppm but at 3000 ppm showed fungicidal nature. |
| Dubey and Tripathi (1987) | <em>Piper betle</em> (oils from leaves) | <em>Aspergillus flavus</em> and 13 other test fungi | The oil was fungistatic at 500 μl/litre. |
| Shukla and Tripathi (1987b) | <em>Pimpinella anisum</em> | <em>Aspergillus flavus</em> | Exhibited strong fungitoxicity at 1000 ppm. |
| Mishra <em>et al.</em> (1988b) | <em>Cymbopogon martinii</em> | <em>Aspergillus flavus, A. fumigatus, A. parasiticus</em> | Exhibited fungitoxicity at 3000, 2000 and 900 ppm respectively. |
| Akgul (1989) | <em>Nigella sativa</em> (seed essential oil) | 10 moulds | The essential oil strongly showed fungitoxicity against storage fungi. |</p>
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Species/Plant Name</th>
<th>Fungus/Species</th>
<th>MIC of the Oil/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dube et al.</td>
<td><em>Ocimum basilicum</em></td>
<td><em>Aspergillus flavus</em></td>
<td>1.5 ml/litre.</td>
</tr>
<tr>
<td>Farag et al.</td>
<td>Essential oils of some spices (Thyme, Cumin, Clove, Caraway, Rosemary, Sage)</td>
<td><em>Aspergillus parasiticus</em></td>
<td>Showed complete inhibition of the fungus and aflatoxin production.</td>
</tr>
<tr>
<td>Mishra et al.</td>
<td><em>Callistemon lanceolatus</em>, <em>Caesalia axillaris</em>, <em>Chenopodium ambrosioides</em>, <em>Cinnamomum zeylanicum</em>, <em>Citrus medica</em>, <em>Eucalyptus citriodora</em>, <em>Lantana indica</em>, <em>Melaleuca leucadendron</em>, <em>Ocimum canum</em>, <em>O. gratissimum</em>, <em>Rosa chinensis</em></td>
<td><em>Aspergillus flavus</em></td>
<td>The essential oils showed strong fungitoxicity between 2000-5000 ppm.</td>
</tr>
<tr>
<td>Onawunmi</td>
<td>Lemon grass oil</td>
<td><em>Aspergillus fumigatus</em></td>
<td>The essential oil showed strong fungitoxicity.</td>
</tr>
<tr>
<td>Mishra and Dubey</td>
<td><em>Aegle marmelos</em>, <em>Amomum subulatum</em>, <em>Ageratum houstonianum</em>, <em>Alpinia galanga</em>, <em>Artmisia vulgaris</em>, <em>Curcuma longa</em>, <em>Curcuma longa</em></td>
<td><em>Aspergillus flavus</em></td>
<td>Amomum oil was most effective. MIC 3000 ppm and showed broad range of toxicity.</td>
</tr>
<tr>
<td>Study</td>
<td>Plant Species</td>
<td>Fungi</td>
<td>Activity</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>--------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Mishra et al. (1991)</td>
<td><em>Cymbopogon martinii var motia</em> (foliage), <em>Pimpinella anisum</em> (aniseed), <em>Vetiveria zizanioides</em> (vertiver)</td>
<td><em>Aspergillus flavus</em></td>
<td><em>Cinnamomum camphora</em> oil was most effective. MIC 4000 ppm and showed fungistatic nature and broad range.</td>
</tr>
<tr>
<td>Kishore et al. (1993)</td>
<td>Essential oils of <em>Anthum graveolens, Chenopodium ambrosioides, Citrus medica and Lippia alba</em></td>
<td>Against 5 storage fungi</td>
<td>Chenopodium oil was found to provide complete protection to fumigated wheat samples at 1000 ppm without phytotoxic effects.</td>
</tr>
<tr>
<td>Authors</td>
<td>Plant Species</td>
<td>Pesticide Target</td>
<td>Toxicity/Activity</td>
</tr>
<tr>
<td>--------------------</td>
<td>--------------------------------</td>
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</tr>
<tr>
<td>Mishra &amp; Dubey</td>
<td>Essential oils of 14 plants</td>
<td><em>A. flavus</em></td>
<td>Toxicity at 1000 ppm with long shelf life, broad range of toxicity and non-phytotoxic in nature.</td>
</tr>
<tr>
<td>Trillini et al.</td>
<td>Essential oils of <em>Piper angustifolium</em></td>
<td><em>A. flavus, A. fumigatus</em></td>
<td>Showed strong activity.</td>
</tr>
<tr>
<td>Bishop &amp; Thornton</td>
<td>Essential oil of <em>Monarda citriodora</em> and <em>Melaleuca alternifolia</em></td>
<td>15 post-harvest fungus</td>
<td>Exhibited strong activity <em>in vitro</em> conditions.</td>
</tr>
<tr>
<td>Irasema et al.</td>
<td>Orange essential oil</td>
<td><em>Aspergillus parasiticus</em></td>
<td>Exhibited activity.</td>
</tr>
<tr>
<td>Dubey et al.</td>
<td>Essential oils of <em>Ocimum gratissimum</em>, <em>Zinziber consumunar</em>, <em>Cymbopogon citratus</em>, <em>Caesulia axillaris.</em></td>
<td><em>A. flavus</em></td>
<td>MIC varied between 500-1300 ppm without animal toxicity, oils showed activity to control biodeterioration of food commodities.</td>
</tr>
<tr>
<td>Shukla et al.</td>
<td>Essential oil of <em>Citrus</em></td>
<td><em>A. flavus</em> &amp;</td>
<td>Fungicidal activity</td>
</tr>
<tr>
<td>Year</td>
<td>Subject</td>
<td>Species</td>
<td>Concentration</td>
</tr>
<tr>
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<td>----------------------------------------------</td>
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</tr>
<tr>
<td>(2000)</td>
<td>sinensis</td>
<td>Alternaria alternata</td>
<td>at 0.5% concentration.</td>
</tr>
<tr>
<td>Castellanous et al. (2001)</td>
<td>Essential oil of Chrysanthemum coronanum</td>
<td>A. flavus &amp; P. digitatum</td>
<td>Showed strong activity</td>
</tr>
<tr>
<td>Chebli et al. (2003)</td>
<td>Cymbopogon citratus, Citrus citratus, C. reticulata, C. aurantifolia</td>
<td>A. flavus</td>
<td>Cymbopogon citratus was more effective.</td>
</tr>
<tr>
<td>Fraternale et al. (2003)</td>
<td>Thymus mastichina</td>
<td>Storage fungi</td>
<td>-</td>
</tr>
<tr>
<td>Nguefack et al. (2004)</td>
<td>Five essential oils</td>
<td>Fusarium moniliformae, A. flavus and A. fumigatus</td>
<td>O. gratissimum oil is most effective upto 800 ppm.</td>
</tr>
<tr>
<td>Guynat et al. (2005)</td>
<td>20 essential oils</td>
<td>Aspergillus spp., Penicillium spp.</td>
<td>Cinnamo rosemary oils are more effective</td>
</tr>
<tr>
<td>Matan et al. (2006)</td>
<td>Mixture of Cinnamon &amp; Clove oils</td>
<td>A. flavus, P. roqueforti, Mucor plumbeus,</td>
<td>Volatile activity of oils are highly effective.</td>
</tr>
<tr>
<td>Researchers</td>
<td>Essential Oil Source &amp; Species</td>
<td>Pathogen/Species</td>
<td>MIC/Antifungal Activity</td>
</tr>
<tr>
<td>----------------------</td>
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</tr>
<tr>
<td>Ramezani (2006)</td>
<td>Essential oil of <em>Eucalyptus citriodora</em></td>
<td><em>Alternaria triticina</em></td>
<td>MIC 1500 ppm</td>
</tr>
<tr>
<td>Pawar &amp; Thaker (2006)</td>
<td>75 different essential oils</td>
<td><em>A. niger</em></td>
<td>Includes <em>Cinnamomum zeylanicum</em> (bark), <em>C. zeylanicum</em> (leaf), <em>C. cassia</em>, <em>Syzygium aromaticum</em>, and <em>Cymbopogon citratus</em> which showed inhibitory effect against <em>A. flavus</em>.</td>
</tr>
<tr>
<td>Pinto et al., 2006</td>
<td>Essential oil of <em>Thymus pulegioides</em></td>
<td><em>Candida and Aspergillus species</em></td>
<td>Shows strong antifungal activity.</td>
</tr>
<tr>
<td>Kumar et al., 2007</td>
<td>Essential oil of <em>Chenopodium ambrosioides</em></td>
<td><em>A. flavus</em></td>
<td>The oil completely inhibited the mycelial growth at 100µg/ml.</td>
</tr>
<tr>
<td>Helal et al., 2007</td>
<td>Essential oil of <em>Cymbopogon citratus</em> L.</td>
<td><em>A. flavus</em></td>
<td>The oil completely inhibited the mycelial growth</td>
</tr>
<tr>
<td>Barra et al., 2007</td>
<td>Essential oil of <em>Pistacia lentiscus</em></td>
<td><em>Aspergillus flavus Fusarium oxysporum</em></td>
<td>Showed strong activity</td>
</tr>
<tr>
<td>Rasooli et al., 2008</td>
<td>Essential oil of <em>Rosmarinus</em></td>
<td><em>Aspergillus parasiticus</em></td>
<td><em>T. capticum</em> oil showed a stronger</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Essential Oil Source</td>
<td>Pathogen(s)</td>
<td>Result</td>
</tr>
<tr>
<td>----------------------</td>
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<td>--------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Bouaziz. et al., 2009</td>
<td><em>Salvia officinalis</em></td>
<td>Storage fungi</td>
<td>The oil was effective</td>
</tr>
</tbody>
</table>
Thus, it is evident from above Table that most of the oils were effective against test fungi at extremely lower concentrations and exhibited broad range of activity. However, detailed In Vivo efficacy for control of fungal infestation of stored food commodities has been done with only a few essential oils.

Some essential oils have been tested for their insecticidal and insect repellent activity against insect pests. Su et al. (1972a) reported protectent activity of eight Citrus oil against cowpea weevils (*Callosobruchus maculatus*). Su et al. (1972b) screened oils of peels of eight fruits and found lemon, grape, fruits, lime, kumquat and tangerine to be highly toxic against cowpea weevil (*Callosobruchus maculatus*) but were found to be moderately toxic against rice weevil (*Sitophilus oryzae*). Essential oil of *Vetiveria zinzanioides* showed insect repellent activity (Meniwald, 1982). Su. et al. (1982) reported insect repellent activity of oil of *Curcuma longa* against *Tribolium castaneum*. Krishnarajan et al. (1985) reported that the volatile oils of *Cymbopogon citratus*, *C. hardus*, *Citrus aurantifolia* and *Vitex negundo* controlled infestation of *Sitotroga cerealella* in stored Paddy. They also found terpenes of these oils to check *Sitotroga cerealella* in stored Paddy. The oil of Cedar wood (*Cedrus deodara*) exhibited toxicity against *Callosobruchus chinensis* (Singh and Rao, 1985). Mohiuddin et al. (1987) observed repellent activity of seventeen plant oil against red flour beetle (*Tribolium castaneum*). Saraswathi & Purushotham (1987) observed significant insect repellent activity of Citronella oil (*Cymbopogon varidus*) against storage grain pests viz., *Tribolium castaneum* and *Bruchus chinensis*. Dubey et al. (1989) reported insect repellent activity of *Ocimum basilicum* against *Allocophora faveicollis*. Essential oil of *Foeniculum vulgare*, *Pimpinella anisum* and anethole are insect repellent against *Tribolium castaneum* (Shukla et al., 1989). Srivastava et al. (1989) reported Japanese mint oil to be effective against insect infestation of pigeon pea and did not exhibit any adverse effect on nutritive value.

The efficacy of some essential oils has been evaluated in the management of biodeterioration of some commodities caused by fungi and insects. The essential oil of *Pogostemon heyneanus*, *Ocimum basilicum* and *Eucalyptus sp.* has shown insecticidal activity against *Sitophilus oryzae*, *Stegobium paniceum*, *Tribolium castaneum* and
Callosobruchus chinensis (Deshphande et al. 1974; Deshpande and Tipnis, 1977). Fumigant activity and reproductive inhibition induced by a number of essential oils and their monoterpenoids has also been evaluated against the bean weevil Acanthoscelides obtectus and the moth Sitotroga cerealella (Klingauf et al. 1983; Regnault-Roger and Hamraoui, 1995). Garg and Jain (1991) found the oil of Zingiber officinale repellent against the agricultural pest Bruchus pisorum during the in vitral trail Chandar et al. (1993) reported the turmeric and mustard oil as protectant against infestation of red flour beetle, Tribolium castaneum. Mohiuddin et al. (1993) tested twelve vegetable oils for their repellent activity against red flour beetle, Tribolium castaneum and their toxic effect against lesser grain borer, Rhyzopertha dominica for a period of eight weeks. The best repellent activity was found in the oil of neem. Lakhanpal et al. (1995) screened nine edible oils against pulse beetle in black gram seeds cotton seed oils proved to be the best among them. Don-Pedro (1996) evaluated fumigant toxicity of Citrus peel oil against Callosobruchus maculatus and Sitophilus zeamais. The 24 h LC50 value of lime peel oil (typical Citrus oil) vapour against C. maculatus was 7.99 µg litre⁻¹ which made it 1.5 and 1.6 times less toxic against the smaller S. zeamais and the longer D. maculatus adult insects. Bioactivity of eugenal, a major component of essential oil of Ocimum suave (wild.) against four species of stored-product caleoptera has been evaluated by Obeng-ofori and Reichumuth (1997). Toxicity and protectent potential of camphor, a major component of essential oil of Ocimum kilimandscharicum against stored product beetles has been tested by Obengofori et al. (1988) and found that camphor exhibited strong insecticidal and repellent activity. Verma et al. (2000) found Lippia alba oil to be highly toxic against Callosobruchus maculatus and Tribolium castaneum by contact toxicity method, however, oil could not show activity by fumigant method. Kimami & Sum (2001) evaluated insecticidal and repellent activity of Chrysanthemum cineraiaefolium against Sitophilus oryzae and Tribolium castaneum and found that S. oryzae was susceptible insect. Bekele and Hassanali (2001) have evaluated insecticidal activity of Ocimum kilimand-scharicum and O. kenyense Oils and their components against Rhizopertha dominica & Sitophilus zeamais.

The essential oil of Cyambopogon citratus has shown its In Vivo fumigant activity in the management of storage fungi and insects of some cereals without exhibiting mammalian toxicity on albino rats (Mishra et al. 1992). Kishor et al. (1993) tested the

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essential oils of *Anethum graveolens*, *Chenopodium ambrosioides* & *Lippia alba* for their potentiality to control fungal deterioration of wheat during storage. The Chenopodium oil was found to provide complete protection of fumigated wheat samples at 1000 µl/ml without phytotoxic effects. The essential oil of *Ocimum gratissimum*, *Zingiber cassumunar*, *Cymbopogon citratus* and *Caesulia axillaris* have been screened for their fumigant activity against fungal deterioration of wheat and it has been found that Caesulia and Cyambopogon oil have ability to control fungal deterioration of wheat during storage without animal toxicity (Dubey *et al.*, 2000).