DISCUSSION

5.1. Antimicrobial activities of the test plant species

5.1.1. *Acorus calamus*

In traditional medicine system of India *A. calamus* has been widely used as remedy for a variety of disorders such as emetic, stomachic, dyspepsia, colic, remittent fevers, bronchitis, dysentery of children and snakebite and as nerve tonic and insectifuge (Chopra et al., 1956). Recent scientific studies have further revealed several other biological activities of *A. calamus* extracts or constituents. The plant has been found to show protective effect against nephrotoxicity (Prasad et al., 2006), neuropathy (Muthuram and Singh, 2011) and cardiomyopathy (Singh et al., 2011) in experimental rats and also antifungal (Lee et al., 2004) and antibacterial (Phongpaichit et al., 2005) activities. The important constituents of *A. calamus* rhizome and roots are α- and β-asarone, caryophyllene, isoasarone, methyl isoeugenol and safrol (Namba, 1993; Wang et al., 1998). A new sesquiterpenoid, acorafuran, was also isolated from rhizome of *A. calamus* by Tkachev et al. (2006). According to Asha Devi and Ganjewala (2009) α-and β-asarones are mainly responsible for almost all the biological activities of *A. calamus*. The workers also tested different solvent (petroleum ether, chloroform, hexane and ethyl acetate) extracts of leaf and rhizome of the plant against six Gram negative and two Gram positive bacteria and seven fungal species. They observed that all the bacterial species were resistant to the solvent extracts except *E. coli*. However, the ethyl acetate extract showed marked antifungal activities against the test fungal species. The MIC values of rhizome extract against the susceptible fungal species were between 2mg and 5mg/ml.
In the present study also *A. calamus* extracts showed weak antibacterial activities while the PE and CH extracts showed highly significant antifungal activities. Complete growth inhibition was observed in case of PE extract against *A. alternata*, *A. niger* and *C. lunata* while the CH extract also induced 100% growth inhibition to *A. alternata* and *A. solani*. The MIC values of these extracts against the ten test fungi were between 0.5mg and 2mg/ml. Other researchers (De *et al.*, 1999; Phongpaichit *et al.*, 2005) also demonstrated high antifungal activity of *A. calamus* extracts but their antibacterial property was low. According to MacGaw *et al.* (2002) the antimicrobial activity of *A. calamus* is mainly due the presence of α- and β-asrones. Besides the antimicrobial properties Ghosh *et al.* (2011) demonstrated that the hydroethanolic extract of *A. calamus* rhizome was highly effective against the cattle tick *Rhipicephallus (Boophilus) microplus* giving 100% mortality within 14 DPT. Further, Wiratno *et al.* (2009) reported nematicidal activity of *A. calamus* against root knot nematode *Meloidogyne incognita*. The present finding and previous reports suggest that the rhizome of *A. calamus* can be exploited as an effective antifungal agent.

5.1.2. *Cyaropersmum asperrimum*

*C. asperrimum* syn. *Blepharis asperrima* belongs to the family Acanthaceae which is considered as one of the most advanced and specialized families. Genus *Blepharis* is composed of approximately 100 species distributed in tropical and subtropical regions (Ashour, 2012) including vulnerable plants (Lal *et al.*, 2012) and new species (Vollesen, 2002). *B. edulis* is the only *Blepharis* species reported in Egypt (Ashour, 2012). *Blepharis maderaspatensis* has been reported to be an ethnomedicinal plant of the Kani tribes (Subitha *et al.*, 2011) and Paliyar Tribes of Tamilnadu (Shanmugam *et al.*, 2009). Some work has been done on *Blepharis*. Presence of allantoin, blepharin, catechol, tannin, dihydrofurano-dihydrocoumarin, benzoaxazine
glucoside, banzoxazolone, phenolic compounds and flavone glycosides have been reported from *B. edulis*. Moreover, antibacterial, antifungal, antioxidant, antispasmodic, bronchodilator and antiplatelet aggregation activities of *B. edulis* have also been reported (Saqib et al., 2012). *Cynarospermum asperrimum* is the only member of the genus *Cynarospermum*. Earlier, *C. asperrimum* was put under the genus *Blepharis*. It was only after Vollesen (1999) that it was regarded as a separate genus having only one species. Studies regarding the pharmacological properties of *C. asperrimum* are lacking so far. The present attempt is to find out the antifungal and antibacterial activities of *C. asperrimum*. The result of the investigation showed that only the PE extract of *C. asperrimum* possessed minimal antifungal activity against *A. flavus* and *P. expansum* from among the ten test fungal species. The PE extract shows antibacterial effect against all the four tested bacterial species. Further, the CH extract and the ME extract which were ineffective against the fungal species showed inhibitory effect against three and two bacterial species respectively. This finding is in consistent with the finding of Keymanesh et al., (2009) who reported the antibacterial and antifungal activity from *B. edulis*.

5.1.3. Rotheca serrata

*R. serrata* syn. *Clerodendrum serratum* (Linn.) Moon is a small perennial shrub widely distributed in African and Asian countries though the species is assessed as vulnerable and endangered in northern and central India (Ved et al., 2003). The root of the plant is used for treatment of bronchial asthma and other respiratory diseases, different types of fever and skin infection and also as expectorant and antitussive remedy (Wealth of India, 2001). Gupta et al. (1968) recognized the species as antihistamine and antiallergic agent. The plant is also reported to have wound healing and hepatoprotective properties (Vidyai et al., 2005; Vidya et al., 2007). According to
Narayana et al. (2004) it also forms as an ingredient “Shirutekku” a Shidha drug with high antibacterial properties.

The bark of the plant root is known to contain mainly sapogenins (Rangaswami and Sarangan, 1969) while the leaves contain flavonoids and phenolic acid (Rastogi, 1999). Yang and his associates (2000a,b,c) isolated and identified a number of new compounds like a triterpenoid seponin Se saponin A, a phenylpropanoid glycoside Serratumoside A and two iridoid glucosides Serratoside A and Serratoside B from the aerial parts of the plant.

As far as antimicrobial activity of the species is concerned very few reports are available. Narayana et al. (2004) tested ethanol extracts of C. serratum and Premna herbacea roots against two Gram-positive and six Gram-negative bacterial strains. They observed highly significant antibacterial activity of C. serratum extract against Streptococcus pyogenes-A and Proteus mirabilis. P. herbacea extract was less effective. The present results revealed that all the solvent extracts of leaves of R. serrata could inhibit the four test bacterial strains while A. flavus, A. niger, D. Oryzae and P. expansum showed growth inhibition to different extracts of the plant.

5.1.4. Curcuma leucorrhiza

The genus Curcuma comprises of more than 80 species, many of which have very wide applications in Ayurveda, Sidha, Unani, Homeopathy and Naturopathy as well as in traditional herbal medicine systems China, Japan and Indonesia (Rajamma et al., 2012). Various applications of Curcuma species, cited by the authors and other workers (Chopra et al., 1956; Joy et al., 2001; The Wealth of India, 2001) include treatments for rheumatism, cough, asthma, conjunctivitis, cold, worm infestation, snake bite, scorpion bite, bronchitis, diarrhoea, fever, sprains, contusions and skin
problems like bruises, wounds and skin diseases. The species are also used as tonic, appetiser, carminative, stimulant diuretic, stomachic, astringent, aromatic, antioxidant and blood purifier. *C. longa* is the most widely investigated species of the genus. Besides a number of biological activities including the antimicrobial properties of several *Curcuma* species have been studied. Naz *et al.* (2010) showed antibacterial activity of crude extracts of curcuminooids and essential oil of *C. longa* against four bacterial species. Rajamma *et al.* (2012) examined antibacterial properties of oleoresins extracted from nine species of *Curcuma*. All the oleoresins showed promising inhibitory effect against three bacterial species, while the extract obtained from *C. amada* was most effective.

Wilson *et al.* (2005) studied antimicrobial activities of different solvent (petroleum ether, hexane, chloroform, acetone and ethanol) extracts of *C. zedoaria* and *C. malabarica* against six bacterial and two fungal strains. *C. malabarica* has similar use as *C. leucorrhiza* as a source of starch. As a similar observation with the present study, the workers also found that *S. aureus* was susceptible to all the solvent extracts, while none of the extracts showed inhibitory effect against *E. coli*. All the extracts also inhibited the growth of *Candida albicans*. The MIC values of the extracts against the organisms ranged from 0.01 to 0.94 mg/ml. The present results also revealed that the three solvent extracts of *C. leucorrhiza* have effective antifungal activity the PE extract being most effective. On the other hand *S. aureus* was the only bacterial species inhibited by the extracts.

5.1.5. *Equisetum hyemale*

*Equisetum* is the only surviving genus of Sphenopsida (Gierlinger *et al.*, 2008). The genus has a history stretching back to the Crustaceous and possibly as far back as
the Triassic and perhaps be the oldest living genus of vascular plants (Hauke, 1978). The genus consists of species which are often used in traditional medicine systems. *E. arvense* is reported to possess antinociceptive, anti-inflammatory, antidiabetic, antioxidant or free radical scavenging, antimicrobial, anti-haemorrhagic, astringent, anticonvulsive, cytotoxic, diuretic, hepato-protective, vasorelaxant, wound healing and platelet anti-aggregant properties. The stems of *E. hyemale* have been used as diuretic, diaphoretic, astringent homeostasis and for treatment of eye-diseases (Park and Tomohiko, 2011). Phytochemistry of the plant also shows the presence of minerals like silicic acid and silicates, potassium, calcium, aluminium, sulphur, magnesium and manganese, phenolic acids, phenolic pterosins, phenolic glycosides, triterpenoids, alkaloids, saponins, phytosterols, branched and long chain dicarboxylic acids and other constituents like true proteins and enzymes (mainly thiaminase) (Sandhu *et al*., 2010). Phytochemical study using high resolution Raman imaging reveals the presence of silica, pectin, hemicelluloses (glucomannan) and cellulose from the shoots of *E. hyemale* (Gierlinger *et al*., 2008). Six compounds from the stem of *E. hyemale* were also isolated and based on the spectral evidence, their structures were elucidated as trans-feruloyl-4-β-glucoside, cis-feruloyl-4-β-glucoside, transcaffeoyl-3-β-glucoside, kaempferol-3-sophoroside, kaempferol-3-sophoroside-7-β-glucoside, and herbacetin-3-sophoroside-8-β-glucoside (Park and Tomohiko, 2011). Presence of such secondary metabolites is a clear indication of the *E. hyemale* to possess antimicrobial property. But studies regarding antimicrobial activities of *E. hyemale* is lacking so far. Only recently, Ferrazzano *et al*. (2013) showed strong antibacterial activity of *E. hyemale*.

In the present investigation it was found that all the three extracts were either ineffective or showed negligible antifungal activity against the test fungal strains. But the three extracts were inhibitory to all the four bacterial species. Uzun *et al*. (2004)
examined petroleum ether and ethanol extracts of *E. telmateia* against different microorganisms by disc-diffusion method and reported that petroleum ether extracts showed certain activity on *S. aureus*, *S. epidermidis* and *Candida albicans*. Milovanović and coworkers (2007) also tested hydro-alcoholic extract of *E. telmateia* against certain fungi and bacteria and reported that the extracts showed good antimicrobial activity against Gram-negative bacteria. Further, they reported that the extracts had little influence on fungi. Our present finding suggests the extracts of *E. hyemale* to be effective against both Gram-positive and Gram-negative bacteria with highest inhibition against *E. faecalis*. Radulović et al. (2006) reported that 1:10 dilution of the essential oil of *E. arvense* possess a broad spectrum antimicrobial activity against all tested bacterial (*S. aureus, E. coli, Klebsiella pneumoniae, P. aeruginosa* and *Salmonella enteritidis*). In another finding, Radojevic et al. (2012) showed that the extracts of *E. telmateia* possess significant antibacterial activity against Gram-positive bacteria and weak to moderate activity against 7 fungal species.

5.1.6. *Euphorbia hirta*

*E. hirta* L. also known as asthma weed is a common medicinal plant which exhibits a broad range of biological activities, such as antimalarial, anti-inflammatory, galactogenic, antiasthmatic, antidiarrhoeal, antioxidant, antifertility, antiamoebic, anti-allergic, antitetanic, diuretic, antioxidant, anti-tumor, anti-diabetic, anxiolytic and sedative, antihypertensive, anthelmintic, larvicidal, immunomodulatory, cytotoxic, aflatoxin inhibition, cardiovascular and vasodepressor activities (Mamun-Or-Rashid et al., 2013). Phytochemistry of the whole plant reveals the presence of afzelin, quercitrin, myricitrin, rutin, quercitin, euphorbin-A, euphorbin-B, euphorbin-C, euphorbin-D, kaempferol, gallic acid, protocatechuic acid, β-amyrin, 24-methylenecycloartenol, β-sitosterol, heptacosane, nonacosane, shikmic acid,
tinyatoxin, choline, camphol, rhamnose and chtolphenolic acid. Flavonoids, polyphenols, tannins, sterols, alkaloids, glycosides and triterpenoides are also present in the leaves of the plant (Mamun-Or-Rashid et al., 2013).

The methanol extract of *E. hirta* was shown to possessed antibacterial effects against species of *Shigella* (Ananthanand Nalini, 1995). Mohamed et al. (1996) also tested the ethanolic extract of *E. hirta* using the paper disc diffusion technique and found to display antifungal activity against the plant pathogens *Colletotrichum capsici*, *Fusarium pallidoroseum*, *Botryodiplodia theobromae*, *Alternaria alternata*, *Penicillium citrinum*, *Phomopsis caricae-papayae* and *Aspergillus niger*.

The present study found that ME extract possessed significant antifungal activity against *A. flavus*, *A. niger*, *C. lunata* and *T. viride*. The PE and the CH extracts showed moderate antifungal activity against three and two fungal species respectively. Regarding the antibacterial activity, the PE and the CH extract showed inhibition to all the four bacterial species tested, exerting greater effect against the Gram-positive bacteria. This finding is in agreement to the reports of Parekh et al. (2005) that extracts of *E. hirta* were more active against Gram-positive bacteria than Gram-negative bacteria.

Besides the antimicrobial activity, the ethanolic extract of *E. hirta* showed moderate nematicidal activity against *Meloidogyne incognita* Taba et al. (2008). Antitrypanosomal activity of the plant was also observed by Abiodun et al. (2012).

5.1.7. *Hyptis suaveolens*

The reported medicinal uses of *H. suaveolens* are stimulant, carminative, galactogogue and sudorific in catarrhal conditions and applied to parasitical cutaneous
diseases (Wealth of India, 2001). The plant is also reported as an invading weed species which encroaches the native species in Vindhyan plateau especially in the rocky areas with sandy substrate and high soil pH (Sharma et al., 2009). The plant has been widely investigated as antimicrobial and insecticidal agent especially among the African countries. In 2007 Mandal and co-workers studied the antimicrobial properties of the plant against five bacteria and three fungi. The steam distillation and PE extracts displayed antifungal activity and wide spectrum antibacterial property except against *S. aureus*. The methanol extract was less effective against the test organisms. In the present work also the PE extract showed inhibitory effect against all the test fungi except *D. oryzae* while the CH and ME extracts were effective against only five and two fungal species. In a similar finding Bobbarala et al. (2009) and Mbatchou et al. (2010) also reported that the methanolic extract of *H. suaveolens* showed no antifungal activity against *A. niger*. The later researchers further observed that PE and CH extracts showed higher antifungal activity against *A. niger* and *Fusarium* species. Krishnamurthy and Shashikala (2006) found 87.43% reduction in aflatoxin B<sub>1</sub> production by *A. flavus* isolated from soybean seeds when the seeds were treated with leaf powder of *H. suaveolens*. When the essential oil of the plant was tested against *F. oxysporum* f. sp. *gladioli*, Tripathi et al. (2009) observed complete inhibition of mycelial growth at 0.998 and 0.748 mg/ml concentrations of the oil in poisoned food technique and volatile activity assay method, respectively.

Besides the antimicrobial activity recent studies have revealed that *H. suaveolens* extracts especially the essential oil have highly effective insecticidal and insect repellent properties against a number of insect pest and insect vectors. Keita et al. (2006) showed high toxicity of PE extract of seeds of the plant against the diamond black moth (*Plutella xylostella*). Tripathi and Upadhyay (2009) and Conti
et al. (2011) reported insecticidal and repellent properties of the essential oil against several coleopteran storage pest species, *Sitophilus granaries*, *Callosobruchus maculans*, *Rhyzopertha dominica* and *Tribolium castaneum*. Adda et al. (2011) could compare the efficacy of aqueous extract of *H. suaveolens* with insecticide Furadan in controlling pink stalk borer, *Sesamia calamitis* on maize. Solvent extracts of the plant showed effective larvicidal action against *Culex quinquefasciatus* (Kovendan et al., 2012), while the essential oil was larvicidal as well as repellent against *Aedes albopictus* Conti et al. (2012). Abagli and Alavo (2011) also reported that the essential oil was as effective as N, N-dimethyl-3-methylbenzamide for personal protection against mosquito bite.

The chemical composition of different extracts and essential oil of *H. suaveolens* have been widely investigated. The presence of alkaloids, flavonoids, flavons, terpenoids, tannins, phenols, aldehydes and ketones have been detected in the plant extracts (Edeoga et al., 2006; Mbatchou, 2010). Tripathi et al. (2009) identified 24 compounds in the essential oil while Conti et al. (2011) reported as many as fifty six compounds, the major compounds being monoterpenes hydrocarbons, sesquiterpene hydrocarbons, oxygenated monoterpenes and oxygenated sesquiterpenes.

5.1.8. *Melastoma malabathricum*

Different plant parts of *M. malabathricum* have been known to have wide range of medicinal values including antipyretic, anti inflammatory, antinociceptive, antidiarrhoeal, antivenom, wound healing, anti ulcer, anti coagulant, platelet activating factor inhibitor, cytotoxic, antioxidant, antiviral and antiparasitic effects (Joffry et al., 2012). Presence of flavonoids, triterpenes, tannins, phenolics, anthocyanins, saponins,
glycosides, steroids, amides have also been reported from different parts of the plant. (Joffry et al., 2012; Sirat et al., 2010).

The present investigation revealed that the extracts of *M. malabathricum* were ineffective against the ten test fungal species. Insignificant inhibitory effect was observed against *C. lunata* and *F. oxysporum* by PE extract *F. oxysporum* by ME extract. However, Johny et al. (2011) showed antifungal activity of leaf extract of the plant against *Colletotrichum capsici*. Though the extracts of *M. malabathricum* possessed mild antifungal property, the PE extract was effective against all the four tested bacterial species with the maximum inhibition found in *P. aeruginosa* followed by *S. aureus*. The CH extract was effective against *S. aureus* only while the ME extract was effective against three bacterial species (*E. faecalis, P. aeruginosa* and *S. aureus*). These findings conform with the findings of Choudhury et al. (2011) where the methanol and acetone extracts of *M. malabathricum* showed significant antibacterial activity against *S. aureus, Streptococcus* sp. and *E. coli*. Sunilson et al. (2008) also tested the antibacterial effects of the methanol extract of *M. malabathricum* and reported to be effective against different clinical wound isolates of *S. aureus* and *P. aeruginosa*. However, our findings disagree with findings of Zahra et al. (2012) who evidenced that ethanol and aqueous extracts of the plant displayed antibacterial activity against Gram-positive bacteria only (*S. aureus* and *Streptococcus agalactiae*) while there were no activities against the Gram-negative bacteria *E. coli* and *Klebsilla pneumonia*. The presence of these secondary metabolites may be responsible for the antimicrobial activity of the extracts.

5.1.9. *Melolitus indicus*

Besides a number of medicinal properties *M. indicus* has been reported as one of the obnoxious weeds which is not significantly affected by soil solarization (El-
keblawy and Al-hamadi, 2009; Arora and Yaduraju, 1998), the plant also can tolerate herbicides like imazethapyr, terbutryn, and prometryn reducing the yield of field crops. Hand-weeding gave excellent control of the weed and increased yield (Mohamed \textit{et al.}, 1997). At the same time Zahran (1998) reported that \textit{M. indicus} forms effective nitrogen fixing nodules. The plant has been mentioned by different authors as having wide medicinal values, the seeds being used as anthelmintic, antipyretic, for curing heart diseases, bronchitis, leprosy, bowel complaints and infantile diarrhoea. The plant is used as a discutient, emollient, and as fomentation. It is also useful as a plaster for swelling. It is also considered as astringent and narcotic (Chopra \textit{et al.}, 1956; Kirtikar and Basu, 1935; Anon., 1962). A pharmacognostic study the plant showed the presence of tannins, xanthoprotein, starch, cystine, sterols, triterpenoids, reducing sugars, saponins and alkaloids (Kshetrapal \textit{et al.}, 1985). The presence of C-glycosides, methylene-dioxypterocarpan, pterocarpane and prenylated pterocarpan which had been reported by several workers was cited by Yadava and Jain (2005). The authors also isolated a new flavone glycoside 5,7,4′-trihydroxy-6,3′-dimethoxyflavone-7-O-\(\alpha\)-L-arabinopyranosyl(1→6)-O-\(\beta\)-D-galactopyranoside from the seeds of this plant.

The present finding showed that different solvent extracts of the plant could not inhibit the growth of the test fungal species except \textit{C. lunata} which was inhibited by the PE and CH extracts. The ME extract was ineffective against all the tested fungi. On the other hand all the extracts showed antibacterial activity against all the four bacterial species except CH and ME extracts against \textit{E. coli}. The MIC and MBC values against these bacteria ranged from 0.78 to 6.25mg/ml. The presence of secondary metabolites like tannins, sterols, triterpenoids, saponins and alkaloids may be responsible for the biological activity.
5.1.10. *Tithonia diversifolia*

*T. diversifolia* commonly known as Mexican sunflower or Mexican arnica is an annual weed growing aggressively in abandoned lands, road-sides, river banks and cultivated farmlands. The plant is adaptable to most soils (Olabode *et al*., 2007). Though a native of Central America, it has become naturalized in many tropical countries including the North-East regions of India. The folk medicine of Mexico used the species for treatment of gastric ulcer while other medicinal uses include treatment of hepatitis, diabetes, malaria and pain (Sanchez-Mendoza *et al*., 2011). The workers also isolated and identified a gastroprotective agent tagitinin C from the plant. The local healers used the flower heads for treatment of wounds and bruises (Sinha, 1996). The plant is also used in phytoremediation of heavy metal polluted soils (Adesodun *et al*., 2010; Adejumo *et al*., 2011).

The phytochemical studies of *T. diversifolia* have shown the presence of sesquiterpenes and flavonoids (Zhao *et al*., 2012). The authors also isolated two new compounds along with 14 known compound from the species. The main components of essential oil of the leaves are α-pinene, β-caryophyllene, germacrene D, β-pinene and 1,8-cineole, while the flower essential oil mainly comprises germacrene D, β-caryophyllene and bicyclogermacrene (Moronkola *et al*., 2007).

Several reports on antimicrobial and pesticidal activities of *T. diversifolia* are available. Its insecticidal activity against cowpea storage bruchid (*Callobrochus maculates*) was reported by Adedire and Akinneye (2003). The leaves had been used for management of storage pests in Uganda (Mugisha-Kamatenesi *et al*., 2008). Osipitan and Oseyemi (2012) observed antitermite activity of aqueous extract of the plant. The aqueous extract of the leaves was found to give similar control index with
standard drug Ivermectin against scabies of rabbits caused by the mite *Sarcoptes scabiei* (Hang et al., 2012).

Among four plant species tested against *C. lunata*, causal organism of maize leaf spot, aqueous extracts of *Phyllanthus amarus* and *T. diversifolia* were found to be most effective (Akinbode, 2010). Kareru et al. (2010) examined the efficacy of herbal soaps prepared with *T. diversifolia*, *Aloe secundiflora* and *Azadirachta indica* and found that the soap with *T. diversifolia* extract was most effective against *E. coli* but not effective against *Candida albicans*. The present study showed that all the ten fungal species were inhibited by PE extract of *T. diversifolia* except *A. alternata*. The CH and ME extracts were effective against four and five fungal species, respectively. All the four bacterial species were also susceptible to all the three extracts. *S. aureus* showed wider zone of growth inhibition than the other species when tested against PE and CH extracts. Ogundare (2007) also reported that CH and ME extract of the plant inhibited *S. aureus* and *Salmonella typhi*.

A large number of references on antimicrobial activities of several plant species are available. Most of the workers have reported narrow- or broad-spectrum and less or more effective antimicrobial activities of plants especially those species which have medicinal values. The plants are rich sources of antimicrobial compounds. It is estimated that the total number of plant chemicals may exceed 4,00,000 of which 10,000 plant chemicals have defensive functions (Swain, 1977). Many previous studies (Parekh and Chanda, 2008; Pundir and Jain, 2010; Mahalingam et al., 2011; Yousuf et al., 2012; Sathya et al., 2012; Salihu and Ado, 2013; Raji and Raveendran, 2013) have shown that a plant species may not be equally effective against all the test fungal or bacterial species. The basic principle of target specificity of a metabolite or the susceptibility of a microbial species or its related group to a specific compound is
of practical importance in designing an antibiotic or a pesticide for control of specific pathogens or groups of pathogens. Extract-organism specific antimicrobial activities of different solvent extracts of leaf, bark and branch wood extracts and latex of *Himatanthus articulates* had been observed (Sequeira *et al.*, 2009). Some of the extracts were very effective against some organisms while others were totally inactive. The methanolic and ethanolic extracts of *Sesame radiatum* showed broad spectrum antibacterial activity while the aqueous extract was ineffective (Shittu *et al.*, 2007). It was also found that methanolic extract of *Abrus pulchellus* was more active against Gram-positive bacteria as compared to Gram-negative bacteria. There was further observation that among different solvent extracts of *Solanum seaforthianum* stem, the methanolic extract exhibited high degree of antibacterial activity (Xavier *et al.*, 2013).

These observations in corroboration with the present findings show that different solvent extracts of a plant species may have different spectra of antimicrobial activity that can be explained by the solubility or insolubility of the active compound(s) in the solvent used for extraction.

Among the plant species tested higher and broad spectrum antifungal activities were observed in *A. camus, C. leucorrhiza, H. suaveolens* and *T. diversifolia* while the other species, *C. asperrimum, R. serrata, E. hyemale, E. hirta, M. malabathricum* and *M. indicus* showed low or narrow spectrum antifungal activities. As far as antibacterial properties are concerned the three solvent extracts of *C. asperrimum, R. serrata, E. hyemale, E. hirta, M. indicus* and *T. diversifolia* were effective against the tested bacterial strains, while *A. calamus, C. leucorrhiza, H. suaveolens* and *M. Malabathricum* extracts showed less effective antibacterial activities.
5.2. Management of blue mould of apple with plant extracts

Blue mould of apple or fruit rot of apple is a widespread post harvest disease causing heavy economic loss. The pathogen *Penicillium expansum* can infect the fruit even below 0°C (Singh and Sumbali, 2007). It also produces the mycotoxin patulin (Ikeura *et al.*, 2011) and toxic secondary metabolites which are known to be mutagenic, neurotoxic, nephrotoxic and immunosuppressive (Machinsky and Midio, 1995). Although the chemical fungicides are effective for prevention of fungal post harvest diseases of fruits the consumers are more concerned with the potential health hazards associated with these fungicides. Thus alternative methods for management of these diseases, especially for those commodities which are consumed in raw forms, are of great importance. Aqil *et al.* (2010) expressed that use of botanicals is one of the available alternatives with least health hazards.

The present study showed that treatment of apple fruits with aqueous extracts of *A. calamus* and *C. leucorrhiza* could give 44.59% and 67.18% reduction in fruit rot of apple. In a previous study Singh and Sumbali (2007) also reported that aqueous extracts of *Mentha piperita*, *Eucalyptus globosus*, *Adhatoda vasica*, *Aegle marmelos*, *Xanthoxylum armatum*, *Ricinus communis*, *Adiantum capillus veneris* and *Thuja occidentalis* induced more than 90% control of *P. expansum* rot of apple in pre-infection treatment while *Azadirachta indica*, *Mentha spicata* and *Vitex negundo* extracts gave more than 90% rot control in post-infection treatment. Among 16 plant species Ikeura *et al.* (2011) found that volatile extracts of *Allium sativum* was most effective in growth inhibition of *P. expansum*. When tested for the efficacy of preventing apple rot they further found that direct solution contact and vapour contact (exposure) treatments of apple fruits with garlic extract significantly reduced the diameters of lesion caused by *P. expansum* infection. They recommended longer
period of fumigation with low concentration of garlic extract against *P. expansum* for long term storage of apple fruits. These findings as well as the result of the present investigation clearly show that plant extracts can be effectively used for management of blue mould of apple.

5.3. Seed treatment of rice with plant extracts

Treatment of rice seeds with 11 plant extracts showed reduction in per cent occurrence of associated seed mycoflora. Among the plant extracts the most effective extracts were PE and CH extracts of *A. calamus* and PE extract of *C. leucorrhiza* as these extracts showed complete control of seed mycoflora. Other extracts which were also effective in reducing fungal infestation of rice seeds were ME extracts of *C. leucorrhiza*, *T. diversifolia*, *E. hirta* and *R. serrata* and CH extract of *R. serrata*. Several reports of effective control of rice seed mycoflora with plant extract treatment are available. Aqueous extract of leaves of *Cycas revoluta* (Kumar, 1990) and rhizome powder of *A. calamus* (Rao and Ratna Sudhakar, 1992) could successfully control seed mycoflora of rice. Mishra and Tewari (1992) reported that ethanol extract of *Polyalthia longifolia* leaves showed fungicidal effect on seed borne fungal pathogens of rice. Satish *et al.* (2007) showed that out of 52 plants, 12 plant extracts showed high antifungal activity against eight seed borne *Aspergillus* species. In general ME extracts were more effective but in *Polyalthia longifolia* the PE extract was more effective. Riazuddin *et al.* (2009) observed that garlic extract was highly effective in controlling seed borne fungal pathogens of rice followed by leaf extract of *Azadirachta indica*. Seed treatment of rice with aqueous extract of *Plumeria acutifolia* could reduce the disease index of *Rhizoctonia solani* infection of rice to 18% as compared to 77.5% of control set (Sengupta *et al.*, 2008). Yeasmin *et al.* (2012) tested extracts of clove of *Allium sativum* and leaf of *Allamanda cathartica* for their effect on prevalence of seed
borne pathogens on rice seeds. They found that all the treatments significantly reduced seed fungi. Seed treatment with garlic extract at 1:0 and 1:1 dilution with water could completely control seed fungi which was comparable to treatment with standard seed fungicide Provax-200.

The present investigation also showed that among different plant extracts, the rhizome extracts of *A. calamus* and *C. leucorrhiza* could completely control seed mycoflora of rice during the 90 days storage period. These findings as well as the reports of previous workers undoubtedly prove that the effective plant species can be utilized as ecofriendly antifungal seed treatment agents for the management of seed mycoflora and seed borne pathogens.