Review

Antimicrobial potentials of medicinal plant’s extract and their derived silver nanoparticles: A focus on honey bee pathogen

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Abstract

Infectious (or Communicable) diseases are not only the past but also the present problem in developing as well as developed countries. It is caused by various pathogenic microbes like fungi, bacteria, parasites and virus etc. The medicinal plants and nano-silver have been used against the pathogenic microbes. Herbal medicines are generally used for healthcare because they have low price and wealthy source of antimicrobial properties. Like medicinal plants, silver nanoparticles also have emergent applications in biomedical fields due to their immanent therapeutic performance. Here, we also explore the various plant parts such as bark, stem, leaf, fruit and seed against Gram negative and Gram-positive bacteria, using different solvents for extraction i.e. methanol, ethyl acetate, chloroform, acetone, n. hexane, butanol, petroleum ether and benzene. Since ancient to date most of the countries have been used herbal medicines, but in Asia, some medicinal plants are commonly used in rural and backward areas as a treatment for infectious diseases. In this review, we provide simple information about medicinal plants and Silver nanoparticles with their potentialities such as antiviral, bactericidal and fungicidal. Additionally, the present review to highlights the versatile applications of medicinal plants against honey bee pathogen such as fungi (Ascosphaera apis), mites (Varroa spp. and Tropilaelaps sp.), bacteria (Melissococcus plutonis Paenibacillus larvae), and microsporidia (Nosema apis and Nosema ceranae). In conclusion, promising non-chemical (plant extracts) are innocuous to adult bees. So, we strongly believed that this effort was made to evaluate the status of medicinal plants researches globally.

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1. Introduction

Today infectious (or Communicable) diseases are the most important global problem (Nair et al., 2017), and it has the prime source of the death (Vu et al., 2015), and almost 50,000 people’s deaths per day (Namita and Mukesh, 2012). Infectious diseases due to various pathogenic bacterial strains namely, Staphylococcus aureus (Nathwani et al., 2016), E. coli (Wang et al., 2016) Klebsiella pneumonia (Sidjabat et al., 2011), bloodstream associated Staphylococcus epidermidis (Hijazi et al., 2016) Salmonella spp, Shigella spp.
**Vibrio cholerae** are the most common pathogenic bacteria (Namita and Mukesh, 2012).

According to World health organization (WHO), more than 80% of the humanity inhabitants depend on heritage medicine for their most important health care needs (Nair and Chanda, 2005). The total reported plants species in the world is about 258,650. Among these, more than 10% are used for therapeutic purposes. North-West of Pakistan is granted with a variety of therapeutic plants assets because of diverse geographical and habitat conditions. The medicinal utilization of plants for healing a variety of remedies is a vital part of the region’s cultural heritage (Shinwari, 2010).

The area of Pakistan has 80,943 km$^2$, lies between 60° 55’ to 75° 30’ E longitude and 23° 45’ to 36° 50’ N latitude. Pakistan has a rich flora, about 6000 species of higher plants. It has been reported that 600 to 700 species having good potential for therapeutic uses.

More recently it was reported that plant metabolites are an excellent source to control and reduce microbes (Samoilova et al., 2014; Ribeiro et al., 2018). Medicinal plants have good potential against microorganism, which can be used as an alternate source of antibiotics (Ameya et al., 2017; Girish and Satish, 2008; Shinwari, 2010; Malik et al., 2011; Walter et al., 2011; Rahim et al., 2015).

The medicinal plants are used in India, China and the north east as a source of relief from sickness. The Compound of natural as well as an artificial source has been the base of numerous therapeutic agents (Mahesh and Satish, 2008). India has wealthy tradition background on plant-based drugs both for use in precautionary and medicinal medication. India has rich flora for the improvement of drugs from a medicinal plant. Because of the potential of the Medicinal plants to cure various diseases now the plants are used as novel antimicrobial substances. Considering the vast potentiality of the plant as sources for antimicrobial drugs the present study is based on the review of such plants (Saranraj and Sivasakthi, 2014).

Moreover, the present review to highlights the versatile applications of medicinal plants, as the whole plant, selected parts, or in extract form, such as antiviral, antibacterial, fungicidal, antiparasitic and miticides against bee mites (Varroa destructor). Hence, the advancement of unconventional control approaches is likely and needs to be considered. Besides, that a novel approach to plants extracts application is to mitigate the honey bee pathogen like Bacteria (*Paenibacillus larva*), Mite (*Varroa destructor*), Fungi (*Ascosphaera apis*) had also been reported.

The most important field to generate the nanomaterials for biomedical purposes and other fields (horticulture, electronic, food and power etc) is termed as Nanotechnology (Ahlulwalia et al., 2018; Gurunanathan et al., 2014). Outbreak of the various infectious diseases, the researchers and pharmaceuticals companies are searching for the developed new type of antibiotic against these pathogens. The present period, nanoparticles have emerged due to unique physical and chemical properties, high surface to volume ratio as novel antimicrobial agents (Rai and Ingle, 2012; Duran and Marcato, 2013; Butler et al., 2015). Among the different type of nanoparticles, particularly, the silver nanoparticles has observed for its biomedical applications in the treatment of bacterialid (Tanvir et al. 2017; Manikandan et al., 2015), fungicidal (Sre et al., 2015) antiviral (Villeret et al. 2018; Malachová et al., 2011) and anti-protozoals (Fayaz et al., 2012).

Silver nanoparticles have been renowned practical applications against antibacterial properties. Furthermore, in recent years the Nanosilver potentialities have been evaluated against the different pathogens such as arthropods vectors infections, various types of cancer cells, but still, now there are many questions which are not yet solved, but in future, the scientists have been attention to solve in further research. Importantly, silver nanoparticles being measured for use as an alternative control in bee hives requires significant inhibitory activity against the bee disease without nontoxic effect on adult honeybees.

### 2. Antibacterial potential of medicinal plants

In this portion, we present medicinal plants and their different fractions, different parts (various methods and different microorganisms) (Tables 1 and 2) and both Gram-negative and positive strains of bacteria (Table 1) and their percentage use is shown in (Figs. 1 and 2) respectively. Furthermore, this review demonstrates the silver nanoparticles potentialities against microbes and parasites which are listed in Table 3.

Girish and Satish (2008), studied three plants mainly the leaves portion had been utilized as shown in Table 2. Two Gram-positive (*Bacillus cereus*, *Bacillus subtilis*) and three Gram-negative (*Escherichia coli*, *Pseudomonas aeruginosa* and *Salmonella typhi*) bacteria strains, by using agar well diffusion method. The result indicated that methanol fraction shows a potent result against the entire tested organisms, apart from *Zizyphus sativa* plant inactive against *Salmonella typhi* and *Pseudomonas aeruginosa*. The n-Hexane extracts showed the promising action against both strains, while the *Zizyphus sativa* fraction of n-Hexane also has no performance against *Bacillus cereus* and *Salmonella typhi* (Girish and Satish, 2008).

Nair and his company (2005) evaluated nine plants. Antibacterial activity was tested against 6 bacterial strains, *Pseudomonas testosteroni*, *Staphylococcus epidermidis*, *Klebsiella pneumoniae*, *Bacillus subtilis*, *Proteus morganii* and *Micrococcus flavususing* Agar disk and agar ditch diffusion method. The result showed that *Pseudomonas testosteroni* and *Klebsiella pneumoniae* were the great resistant strains, while the *Sapindus merrutus* has greater bactericidal potential against all the tested strains (Nair et al., 2005).

| Gram positive Bacteria | *Bacillus cereus*, *Bacillus pumilus*, *Bacillus subtilis*, *Staphylococcus*, *Micrococcus*, *Listeria*, *Streptococcus*, *Cocci*, *Lactobacillus* (feci) |
|------------------------|--------------------------------------------------------------------------------------------------|
| Gram negative Bacteria | *Enterobacter*, *Escherichia coli*, Panthoeagglomerans Proteus, *Shigella*, *Pseudomonas aeruginosa*, *Serratia*, *Vibrio*, *Klebsiella*, *Salmonella*, *Yersinia* and *Citrobacter* |
| Fungal species         | *Trichophytonmentagrophytes*, Candidakrussei, Candida albicans, Candida glabrata, Candidakrussei, *Aspergillus*, *A. flavus*, *A. niger*, *Curvularia sp.*, Fusarium sp., *Rhizopus and Candidaparapsilosis* |
| Viruses                | *Monkeypoxvirus*, *respiratorysyncytial virus*, *HIV-1*, *hepatitis B virus*, and *herpes simplex virus type 1*, *Vaccinia virus*, *human parainfluenza virus type 3* (HPIV-3), *Herpes simplex virus type 1 and type 2* (HSV-1 and HSV-2), *tacaribe virus* (TCRV), *hepatitis B virus* (HBV), *Coxsackie virus B3* and *influenza virus* |
| Method Used            | Agar well diffusion, Agar disk diffusion, Agar ditch diffusion, Tube diffusion, Bauer disc diffusion, Broth dilution, Micro dilution, Liquid dilution and Serial dilution |
| Solvent Used           | Methanol, n-Hexane, *Aquosae*, *Chloroform*, *Ethyl Acetate*, *Benzone*, *Petroleum Ether*, *Acetone*, *Ethanol*, *Dichloromethane*, *Dimethyl Sulphoxide* and *Diethyl Ether* |

**Table 1**

Microorganism, methods and solvents described in the text.
| Sr. no. | Plant Name | Part Used | Essential oil | Whole plant | Stem | Root/ Rhizome | Seed | Flower | Fruit | Bark | References |
|---------|------------|-----------|---------------|-------------|------|---------------|------|--------|-------|------|------------|
| 1       | Ajugabracteosa | Leaves | – | – | – | – | – | – | – | – | Girish and Satish (2008) |
| 2       | Calotropis procera | Leaves | – | – | – | – | – | – | – | – | Girish and Satish (2008) |
| 3       | Zizyphus sativa | Leaves | – | – | – | – | – | – | – | – | Girish and Satish (2008) |
| 4       | Sopinduse marginatus | Leaves | – | – | – | – | – | – | – | – | Nair et al. (2005) |
| 5       | Hibiscus rosasinensis | Leaves | – | – | – | – | – | – | – | – | Nair et al. (2005) |
| 6       | Mirabilis jalapa | – | – | – | – | – | – | – | – | – | Nair et al. (2005) |
| 7       | Rhoeo discolor | Leaves | – | – | – | – | – | – | – | – | Nair et al. (2005) |
| 8       | Nycanthus arbor-tristis | Leaves | – | – | – | – | – | – | – | – | Nair et al. (2005) |
| 9       | Colocasia esculenta | – | – | – | – | – | – | – | – | – | Nair et al. (2005) |
| 10      | Gracilariacorticata | Leaves | – | – | – | – | – | – | – | – | Nair et al. (2005) |
| 11      | Dictyota sp | Leaves | – | – | – | – | – | – | – | – | Nair et al. (2005) |
| 12      | Pulicariawightiana | Leaves | – | – | – | – | – | – | – | – | Nair et al. (2005) |
| 13      | Anisomeles indica | Leaves | – | – | – | – | – | – | – | – | Ramasamy and Manoharan (2004) |
| 14      | Blumealacera | Leaves | – | – | – | – | – | – | – | – | Ramasamy and Manoharan (2004) |
| 15      | Melia azedarach | Leaves | – | – | – | – | – | – | – | – | Ramasamy and Manoharan (2004) |
| 16      | Phyllanthususambar | Leaves | – | – | Root | – | – | – | – | – | Aliero and Afolayan (2006) |
| 17      | Gallnsogacilata | Leaves | – | – | – | – | – | – | – | – | Poonkothai et al. (2005) |
| 18      | Hippophaerhamnoides | – | – | – | – | Seeds | – | – | – | – | Kumar et al. (2007) |
| 19      | Parkiyanica | – | Essential oil | – | – | – | – | – | – | – | Saha et al. (2007) |
| 20      | Hemidesmusindicus (L.) | – | Essential oil | – | – | – | – | – | – | – | Kumar et al. (2007) |
| 21      | Eclipta alba | – | – | – | – | – | – | – | – | – | Kumar et al. (2007) |
| 22      | Coscinium fenestratum | – | Essential oil | – | – | – | – | – | – | – | Kumar et al. (2007) |
| 23      | Tephrosiapurpurea | – | Essential oil | – | – | – | – | – | – | – | Kumar et al. (2007) |
| 24      | Menthae nepeta | Leaves | – | – | – | – | – | – | – | – | Kumar et al. (2007) |
| 25      | Pongamia pinnata | – | – | – | – | – | – | – | – | – | Kumar et al. (2007) |
| 26      | Puerarin | – | – | – | – | – | Seeds | – | – | – | Kumar et al. (2007) |
| 27      | Symlocosracemosa | – | – | – | – | – | – | Seeds | – | – | Kumar et al. (2007) |
| 28      | Euphorbiabirta | – | – | – | – | – | – | – | – | – | Kumar et al. (2007) |
| 29      | Tinospora cordifolia | – | Essential oil | – | – | – | – | – | – | – | Kumar et al. (2007) |
| 30      | Thespesia populnea | – | Essential oil | – | – | – | – | – | – | – | Kumar et al. (2007) |
| 31      | Jasminum officinale | – | Essential oil | – | – | – | – | – | – | – | Kumar et al. (2007) |
| 32      | Marrubium vulgare | Leaves | – | Essential oil | – | – | – | – | – | – | Warda et al. (2009) |
| 33      | Thymus pallidus | – | – | – | – | – | – | – | – | – | Warda et al. (2009) |
| 34      | Eryngium ilicifolium | – | – | Whole plant | – | – | – | – | – | – | Warda et al. (2009) |
| 35      | Lavandula officinalis | – | Essential oil | – | – | – | – | – | – | – | Warda et al. (2009) |
| 36      | Mimosa pudica | Leaves | – | – | – | – | – | – | – | – | Balakrishnan et al. (2006) |
| 37      | Angelonervigera | – | – | – | – | – | – | – | – | Balakrishnan et al. (2006) |
| 38      | Sida cordifolia | Leaves | – | – | – | – | – | – | – | Balakrishnan et al. (2006) |
| 39      | Acalypha indica | – | – | – | – | – | – | – | – | Ushimaru et al. (2007) |
| 40      | Mollugo haloides | – | – | Whole plant | – | – | – | – | – | Ushimaru et al. (2007) |
| 41      | Nelumbo nucifera | Leaves | – | – | – | – | – | – | – | Ushimaru et al. (2007) |
| 42      | Garcinia mangostana | Leaves | – | – | – | – | – | – | – | Ushimaru et al. (2007) |
| 43      | Punicagranatum | Leaves | – | – | – | – | – | – | – | Ushimaru et al. (2007) |
| 44      | Quercus infectoria | – | – | Whole plant | – | – | – | – | – | Ushimaru et al. (2007) |
| 45      | Daturaramel | Leaves | – | Essential oil | – | – | – | – | – | – | Saranraj (2011) |
| 46      | Phylla nodiflora | – | Essential oil | – | – | – | – | – | – | – | Saranraj (2011) |
| 47      | Zingiber officinalis | – | Essential oil | – | – | – | – | – | – | – | Norajit et al. (2007) |
| 48      | Alpinia galanga | – | Essential oil | – | – | – | – | – | – | – | Norajit et al. (2007) |
| 49      | Curcuma longa | – | Essential oil | – | – | – | – | – | – | – | Norajit et al. (2007) |
| 50      | Boesenbergia purpurea | – | Essential oil | – | – | – | – | – | – | – | Norajit et al. (2007) |
| 51      | Anomum xanthophyllum | – | Essential oil | – | – | – | – | – | – | – | Norajit et al. (2007) |
| 52      | Pterocarpus santolensis | – | Essential oil | – | – | – | – | – | – | – | Norajit et al. (2007) |
| 53      | Lippia alba | – | Essential oil | – | – | – | – | – | – | – | Norajit et al. (2007) |
| 54      | Zingiber officinalis | – | Essential oil | – | – | – | – | – | – | – | Norajit et al. (2007) |
| 55      | Curcuma longa | – | Essential oil | – | – | – | – | – | – | – | Norajit et al. (2007) |
| 56      | Commiphora mukul | – | Essential oil | – | – | – | – | – | – | – | Norajit et al. (2007) |

(continued on next page)
| Sr. no. | Plant Name          | Part Used | Essential oil | Whole plant | Stem | Root/ Rhizome | Seed | Flower | Fruit | Bark | References                  |
|--------|---------------------|-----------|---------------|-------------|------|---------------|------|--------|-------|------|-----------------------------|
| 57     | Pimpinella anisum   | – –       | plants        | Whole plants| – – | – – – – – – | – – | – – | – – | Al-Daihan et al. (2013)    |
| 58     | Elaeagnus angustifolia | Leaves   | – –           | Stem | Root | – – – – | – | – | – |  – Khan et al. (2013)     |
| 59     | Elaeagnus angustifolia | Leaves   | – –           | – | – | – – | – | – | – | Farzaei et al. (2015)     |
| 60     | Stephanotisflabellata | – –       | – – | – | – | – | – | – | – |  – Sennal et al. (2009)   |
| 61     | Woodfordia fruticosa | – –       | – | – | – | – | Flowers | – | – | – | Chougale et al. (2009)  |
| 62     | Beta vulgaris        | – –       | Whole plant   | – | – | – | – | – | Bark | Kumaraswamy et al. (2008) |
| 63     | Bidens pilosa        | – –       | Whole plant   | – | – | – | – | – | – | Patel et al. (2007)  |
| 64     | Buxus sempervirens   | – –       | Whole plant   | – | – | – | – | – | – | Patel et al. (2007)  |
| 65     | Cinnamomum cassia     | – –       | Whole plant   | – | – | – | – | – | – | Patel et al. (2007)  |
| 66     | Cinchona officinalis  | – –       | Whole plant   | – | – | – | – | – | – | Patel et al. (2007)  |
| 67     | Gliricidia sepium     | – –       | Whole plant   | – | – | – | – | – | – | Patel et al. (2007)  |
| 68     | Justicia secunda     | – –       | Whole plant   | – | – | – | – | – | – | Patel et al. (2007)  |
| 69     | P. paniculata        | – –       | Whole plant   | – | – | – | – | – | – | Patel et al. (2007)  |
| 70     | Piper nigrum         | – –       | Whole plant   | – | – | – | – | – | – | Patel et al. (2007)  |
| 71     | Bixa orellana        | – –       | Whole plant   | – | – | – | – | – | – | Patel et al. (2007)  |
| 72     | Jr. senegalensis      | – –       | Whole plant   | – | – | – | – | – | – | Patel et al. (2007)  |
| 73     | Spilanthes acmella   | – –       | Whole plant   | – | – | – | – | – | – | Patel et al. (2007)  |
| 74     | Azadirachta indica   | – –       | – | – | – | – | Seeds | – | – | – | El-Mahmood et al. (2010) |
| 75     | Albizia lebbeck (L.) | Leaves | – | – | – | – | – | – | – | Patel et al. (2007)  |
| 76     | Christia ovata (Roxb.) | Leaves | – | – | – | – | – | – | – | Patel et al. (2007)  |
| 77     | Emblica officinalis   | – –       | – | – | – | – | – | – | – | Patel et al. (2007)  |
| 78     | Emblica officinalis   | – –       | – | – | – | – | – | – | – | Patel et al. (2007)  |
| 79     | Eucalyptus deglupta  | Leaves | – | – | – | – | – | – | – | Patel et al. (2007)  |
| 80     | Eucalyptus tereticornis | Leaves     | – | – | – | – | – | – | – | Patel et al. (2007)  |
| 81     | Eupatorium odoratum   | Leaves | – | – | – | – | – | – | – | Patel et al. (2007)  |
| 82     | Ocimum basilicum     | Leaves | – | – | – | – | – | – | – | Patel et al. (2007)  |
| 83     | Hevea brasiliensis   | Leaves | – | – | – | – | – | – | – | Patel et al. (2007)  |
| 84     | Lantana camara       | Leaves | – | – | – | – | – | – | – | Patel et al. (2007)  |
| 85     | Acaia nitida         | Leaves | – | – | – | – | Root | – | – | – | Mahesh and Satish (2008) |
| 86     | P. betle             | Leaves | – | – | – | – | Root | – | – | – | Mahesh and Satish (2008) |
| 87     | P. paniculata        | – –       | Whole plant   | – | – | – | – | – | – | Patel et al. (2007)  |
| 88     | Withania somnifera   | Leaves | – | – | – | – | – | – | – | Patel et al. (2007)  |
| 89     | Ziziphus mauritiana  | Leaves | – | – | – | – | Root | – | – | – | Patel et al. (2007)  |
| 90     | Lantana indica       | Leaves | – | – | – | – | – | – | – | Patel et al. (2010)  |
| 91     | Ardisia crenata      | Leaves | – | – | – | – | – | – | – | Patel et al. (2010)  |
| 92     | Acerola              | Leaves | – | – | – | – | – | – | – | Patel et al. (2010)  |
| 93     | Boerhavia diffusa    | Leaves | – | – | – | – | – | – | – | Patel et al. (2010)  |
| 94     | Solanum melongena    | Leaves | – | – | – | – | – | – | – | Patel et al. (2010)  |
| 95     | Vitex negundo       | Leaves | – | – | – | – | – | – | – | Patel et al. (2010)  |
| 96     | Butea monosperma     | Leaves | – | – | – | – | – | – | – | Patel et al. (2010)  |
| 97     | P. betle             | Leaves | – | – | – | – | – | – | – | Patel et al. (2010)  |
| 98     | Andrographis paniculata | Leaves | – | – | – | – | – | – | – | Patel et al. (2010)  |
| 99     | Syzygium aromaticum   | – | – | – | Stem, | – | – | – | – | Phattayakorn and Wanchitaanawong (2009) |
| 100    | Piper nigrum         | Leaves | – | – | – | – | – | – | – | Phattayakorn and Wanchitaanawong (2009) |
| 101    | Curcuma longa Linn.  | Leaves | – | – | – | Rhizome | – | – | – | Phattayakorn and Wanchitaanawong (2009) |
| 102    | Panicum miliaceum Linn.  | Leaves | – | – | – | – | – | – | – | Phattayakorn and Wanchitaanawong (2009) |
| 103    | Garcinia cambogia Linn.  | Leaves | – | – | – | – | – | – | – | Phattayakorn and Wanchitaanawong (2009) |
| 104    | Andrographis paniculata | Leaves | – | – | – | Stem | – | – | – | Phattayakorn and Wanchitaanawong (2009) |
| 105    | Senna alata (Linn.)  | Leaves | – | – | – | – | Seed | – | – | – | Phattayakorn and Wanchitaanawong (2009) |
| 106    | Boesenbergia pandurata | Leaves | – | – | – | – | Rhizome | – | – | – | Phattayakorn and Wanchitaanawong (2009) |
| 107    | Cassia angustifolia  | Leaves | – | – | – | – | – | – | – | Phattayakorn and Wanchitaanawong (2009) |
| Sr. no. | Plant Name | Part Used | Essential oil | Whole plant | Stem | Root/ Rhizome | Seed | Flower | Fruit | Bark | References |
|--------|------------|-----------|---------------|-------------|------|--------------|------|--------|-------|------|------------|
| 108    | Cinnamomum zeylanicum | Leaves | – | – | – | – | – | – | – | Bark | Phattayakorn and Wanchaitanawong (2009) |
| 109    | Caesalpinia sappan Linn. | – | – | – | – | – | – | – | – | Bark | Phattayakorn and Wanchaitanawong (2009) |
| 110    | Curcuma xanthorrhiza | – | – | – | – | – | – | – | – | Rhizome | Phattayakorn and Wanchaitanawong (2009) |
| 111    | Syzygium aromaticum Linn. | – | – | – | – | – | – | – | – | Stem | Phattayakorn and Wanchaitanawong (2009) |
| 112    | Piper betle Linn. | Leaves | – | – | – | – | – | – | – | – | Phattayakorn and Wanchaitanawong (2009) |
| 113    | Curcuma longa Linn. | – | – | – | – | – | – | – | – | Rhizome | Phattayakorn and Wanchaitanawong (2009) |
| 114    | Punicagranatum Linn. | – | – | – | – | – | – | – | – | Fruit | Phattayakorn and Wanchaitanawong (2009) |
| 115    | Garciniamangostana Linn. | – | – | – | – | – | – | – | – | Fruit | Phattayakorn and Wanchaitanawong (2009) |
| 116    | Andrographispaniculata | Leaves | – | – | Stem | – | – | Flower | – | – | Phattayakorn and Wanchaitanawong (2009) |
| 117    | Sennaalata (Linn.) | – | – | – | – | – | Seed | – | – | – | Phattayakorn and Wanchaitanawong (2009) |
| 118    | Boesenbergiapandurata | – | – | – | – | – | – | Rhizome | – | – | Phattayakorn and Wanchaitanawong (2009) |
| 119    | Cassia angustifolia | Leaves | – | – | – | – | – | – | – | – | Phattayakorn and Wanchaitanawong (2009) |
| 120    | Cinnamomumzeylanicum | – | – | – | – | – | – | – | – | Bark | Phattayakorn and Wanchaitanawong (2009) |
| 121    | Caesalpiniasappan Linn. | – | – | – | – | – | – | – | – | Bark | Phattayakorn and Wanchaitanawong (2009) |
| 122    | Curcuma xanthorrhiza | – | – | – | – | – | – | – | – | Rhizome | Phattayakorn and Wanchaitanawong (2009) |
| 123    | Carthamustinctorius Linn. | – | – | – | – | – | – | – | – | Flower | Phattayakorn and Wanchaitanawong (2009) |
| 124    | Derris scandens | – | – | – | – | – | – | – | – | Fruit | Phattayakorn and Wanchaitanawong (2009) |
| 125    | Cyperusrotundus Linn. | – | – | – | – | – | – | – | – | Rhizome | Phattayakorn and Wanchaitanawong (2009) |
| 126    | Acanthus ebracteatus | Leaves | – | – | Stem | – | – | – | – | – | Phattayakorn and Wanchaitanawong (2009) |
| 127    | Tinosporacistroph(L.) | – | – | – | – | – | Stem | – | – | – | Phattayakorn and Wanchaitanawong (2009) |
| 128    | Eclipta prostate | Leaves | – | – | Stem | – | – | Flower | – | – | Phattayakorn and Wanchaitanawong (2009) |
| 129    | Phyllanthusemblica Linn. | – | – | – | – | – | – | – | – | Fruit | Phattayakorn and Wanchaitanawong (2009) |
| 130    | AzadirachtaindicaA. | Leaves | – | – | – | – | – | – | – | Fruit | Phattayakorn and Wanchaitanawong (2009) |
| 131    | Morindacrispa, | – | – | – | – | – | – | – | – | – | Phattayakorn and Wanchaitanawong (2009) |
| 132    | Sennasiamea | – | – | – | – | – | – | – | – | – | Phattayakorn and Wanchaitanawong (2009) |
| 133    | Morus alba Linn. | Leaves | – | – | – | – | – | – | – | – | Phattayakorn and Wanchaitanawong (2009) |
| 134    | Citrus aurantium | – | – | – | – | – | – | – | – | Fruit | Phattayakorn and Wanchaitanawong (2009) |
| 135    | Calotropis procera | – | – | – | – | – | – | – | – | Flower | Phattayakorn and Wanchaitanawong (2009) |
| 136    | Aloe Vera | – | – | – | Stem | – | – | – | – | – | Phattayakorn and Wanchaitanawong (2009) |
| 137    | Azadirachta indica | Leaves | – | – | – | – | – | – | – | – | Yasmeen et al. (2012) |
| 138    | Allium sativum | – | – | – | – | – | – | – | – | – | Yasmeen et al. (2012) |
| 139    | Calotropis procera | Leaves | – | – | – | – | – | – | – | Rhizome | Yasmeen et al. (2012) |
| 140    | Cannabis sativa | Leaves | – | – | – | – | – | – | – | – | Yasmeen et al. (2012) |
| 141    | Carum carvi | – | – | – | – | – | – | – | – | – | Yasmeen et al. (2012) |
| 142    | Eucalyptus camaldulensi | Leaves | – | – | – | – | – | – | – | – | Yasmeen et al. (2012) |
| 143    | Lantana camara, | – | – | – | – | – | – | – | – | Flower | Yasmeen et al. (2012) |
| 144    | Mangifera indica, | Leaves | – | – | – | – | – | – | – | – | Yasmeen et al. (2012) |
| 145    | Mentha piperita, | Leaves | – | – | – | – | – | – | – | – | Yasmeen et al. (2012) |
| 146    | Nigella sativa, | – | – | – | – | – | – | – | – | Seed | Yasmeen et al. (2012) |
| 147    | Opuntia | – | – | Whole plant | – | – | – | – | – | Flower | Yasmeen et al. (2012) |
| 148    | Ficusindica, | – | – | Whole plant | – | – | – | – | – | – | Yasmeen et al. (2012) |
| 149    | Piper nigrum | Leaves | – | – | – | – | – | – | – | Fruit | Yasmeen et al. (2012) |
| 150    | Zingiberofficinalis | – | – | – | – | Rhizome | – | – | – | – | Yasmeen et al. (2012) |
| Sr. no. | Plant Name | Part Used | Essential Oil | Whole plant | Stem | Root/ Rhizome | Seed | Flower | Fruit | Bark | References |
|--------|------------|-----------|---------------|-------------|------|---------------|------|--------|-------|------|------------|
| 151    | Achyranthes bidentata | Leaves | – | – | – | – | – | – | – | – | – | Janovska et al. (2003) |
| 152    | Belamcanda chinensis | Leaves | – | – | – | – | – | – | – | – | – | Janovska et al. (2003) |
| 153    | Chelidonium majus | Leaves | – | – | – | – | – | – | – | – | – | Janovska et al. (2003) |
| 154    | Houttuynia cordata | Leaves | – | – | – | – | – | – | – | – | – | Janovska et al. (2003) |
| 155    | Platycodon grandiflorum | Leaves | – | – | – | – | – | – | – | – | – | Janovska et al. (2003) |
| 156    | Rehmannia glutinosa | – | – | – | – | – | – | – | – | – | – | Janovska et al. (2003) |
| 157    | Sanguschisandra officinalis | Leaves | – | – | – | – | – | – | – | – | – | Janovska et al. (2003) |
| 158    | Schizandra chinensis | – | – | – | – | – | – | – | – | – | – | Janovska et al. (2003) |
| 159    | Tribulus terrestris | Leaves | – | – | – | – | – | – | – | – | – | Janovska et al. (2003) |
| 160    | Tussilago farfara | – | – | – | – | Whole plant | – | – | – | – | – | Janovska et al. (2003) |
| 161    | Achillea millefolium | Leaves | – | – | – | – | – | – | – | – | – | Nascimento et al. (2000) |
| 162    | Caryophyllum aromaticum | Leaves | – | – | – | – | – | – | – | – | – | Nascimento et al. (2000) |
| 163    | Melissa officinalis | Leaves | – | – | – | – | – | – | – | – | – | Nascimento et al. (2000) |
| 164    | Ocimum basilicum | Leaves | – | – | – | – | – | – | – | – | – | Nascimento et al. (2000) |
| 165    | Psidium guajava | Leaves | – | – | – | – | – | – | – | – | – | Nascimento et al. (2000) |
| 166    | Punicum granatum | Leaves | – | – | – | – | – | – | – | – | – | Nascimento et al. (2000) |
| 167    | Rosmarinus officinalis | Leaves | – | – | – | – | – | – | – | – | – | Nascimento et al. (2000) |
| 168    | Salvia officinalis | Leaves | – | – | – | – | – | – | – | – | – | Nascimento et al. (2000) |
| 169    | Syzygium jambos | Leaves | – | – | – | – | – | – | – | – | – | Nascimento et al. (2000) |
| 170    | Thymus vulgaris | Leaves | – | – | – | – | – | – | – | – | – | Nascimento et al. (2000) |
| 171    | Albizia lebeck | Leaves | – | – | – | – | – | – | – | – | – | Acharya et al. (2009) |
| 172    | Terminalia chebula | Leaves | – | – | – | – | – | – | – | – | – | Acharya et al. (2009) |
| 173    | Syzygium cumini | – | – | – | – | – | – | – | – | – | – | Acharya et al. (2009) |
| 174    | Solanum nigrum | Leaves | – | – | – | – | – | – | – | – | – | Acharya et al. (2009) |
| 175    | Picrorhiza kurrooa | – | – | Whole plant | – | – | – | – | – | – | – | Acharya et al. (2009) |
| 176    | Butea monosperma | Leaves | – | – | – | – | – | – | – | – | – | Acharya et al. (2009) |
| 177    | Saraca indica | Leaves | – | – | – | – | – | – | – | – | – | Acharya et al. (2009) |
| 178    | Aegle marmelos | Leaves | – | – | – | – | – | – | – | – | – | Acharya et al. (2009) |
| 179    | Withania somnifera | Leaves | – | – | – | – | – | – | – | – | – | Acharya et al. (2009) |
| 180    | Tamarix Gallica | – | – | Whole plant | – | – | – | – | – | – | – | Zaouia et al. (2010) |
| 181    | Muscari Comosum | – | – | Whole plant | – | – | – | – | – | – | – | Zaouia et al. (2010) |
| 182    | Rheinolepis | – | – | Whole plant | – | – | – | – | – | – | – | Zaouia et al. (2010) |
| 183    | Taraxacum officinale | – | – | Whole plant | – | – | – | – | – | – | – | Zaouia et al. (2010) |
| 184    | Zygophyllum album | – | – | Whole plant | – | – | – | – | – | – | – | Zaouia et al. (2010) |
| 185    | Urtica dioica | – | – | Whole plant | – | – | – | – | – | – | – | Zaouia et al. (2010) |
| 186    | Silybum marianum | – | – | Whole plant | – | – | – | – | – | – | – | Zaouia et al. (2010) |
| 187    | Tragacanthum | – | – | Whole plant | – | – | – | – | – | – | – | Zaouia et al. (2010) |
| 188    | Bhamnussp | – | – | Whole plant | – | – | – | – | – | – | – | Zaouia et al. (2010) |
| 189    | Sedum kamtschaticum | Leaves | – | – | – | Root | – | – | – | – | – | Kang et al. (2011) |
| 190    | Geum japonicum | Leaves | – | – | – | Root | – | – | – | – | – | Kang et al. (2011) |
| 191    | Geranium sibiricum | Leaves | – | – | – | Root | – | – | – | – | – | Kang et al. (2011) |
| 192    | Saururus chinensis | Leaves | – | – | – | Root | – | – | – | – | – | Kang et al. (2011) |
| 193    | Agrimonia pilosa | Leaves | – | – | – | – | – | – | – | – | – | Kang et al. (2011) |
| 194    | Houttuynia cordata | Leaves | – | – | – | – | – | – | – | – | – | Kang et al. (2011) |
| 195    | Perilopatus scens | – | – | – | – | Root | – | – | – | – | – | Kang et al. (2011) |
| 196    | Agastacherus | Leaves | – | – | – | Root | – | – | – | – | – | Kang et al. (2011) |
| 197    | Persicaria | Leaves | – | – | – | – | – | – | – | – | – | Philip et al. (2009) |
| 198    | Persicaria grandiflora | Leaves | – | – | – | – | – | – | – | – | – | Philip et al. (2009) |
| 200    | Curcuma zedoaria | – | – | – | – | Rhizome | – | – | – | – | – | Philip et al. (2009) |
| 201    | Curcuma mangga | – | – | – | – | Rhizome | – | – | – | – | – | Philip et al. (2009) |
| 202    | Curcuma inodora | – | – | – | – | Rhizome | – | – | – | – | – | Philip et al. (2009) |
| 203    | Zingiber officinale var. officinale | – | – | – | – | Rhizome | – | – | – | – | – | Philip et al. (2009) |
| 204    | Zingiber officinale var. rubrum | – | – | – | – | Rhizome | – | – | – | – | – | Philip et al. (2009) |
| 205    | Curcuma aeruginosa | – | – | – | – | Rhizome | – | – | – | – | – | Philip et al. (2009) |
| 206    | Hypericum scabrum | – | – | – | – | Rhizome | – | – | – | – | – | Philip et al. (2009) |
| 207    | Myrtus communis | – | – | Whole plant | – | – | – | – | – | – | – | Ghasemi et al. (2010) |
| 208    | Pistacia atlantica | – | – | Whole plant | – | – | – | – | – | – | – | Ghasemi et al. (2010) |
In another study, three plants were used. The result indicated that acetone and methanol fractions of all the tested plants display stout antibacterial effect, while the petroleum ether and aqueous did not show any result. *Pseudomonas aeruginosa* and *Serratia marcescens* were comparatively more sensitive (Ramasamy and Pseudomonas aeruginosa did not show any result. stout antibacterial effect, while the petroleum ether and aqueous that acetone and methanol fractions of all the tested plants display supreme antibacterial effect. The same MIC values i.e. (0.049 mg/L, 20 mg/mL and 80 mg/mL) (Aliero and Afolayan, 2006).

Poonkothai and his colleagues demonstrated leaves of a single plant against both strains of bacteria using Agar well diffusion method. The results showed instead of *Escherichia coli* and Pseudomonas aeruginosa, all the fractions i.e. acetone, petroleum ether and benzyl ethyl acetate of the leaves of *Galinisoga ciliate* have strong property against *Bacillus subtilis* (Poonkothai et al., 2005). The bactericidal potential of *Parrotia persican* leaves was tested against *Yersinia enterocolitica* and *Yersinia enterocolitica*, the MIC values were found to be 750 ppm and 1000 ppm respectively (Mohammad et al., 2007). Furthermore, the author and his friends tested the *parikajavanica* medicinal plant bark against three different bacterial strains. The result demonstrated that excluding *Escherichia coli* all the tested bacteria showed the strong result (Saha et al., 2007).

Recently, Kumar et al. examined 12 medicinal plants. The disc diffusion method result showed that among the 12 plants the 07 medicinal plants could forbid the growth of *Propioni bacterium acnes*. Amid that *Hemidesmus indicus, Coscinium fenestratum, Tephrosia purpurea, Euphorbia hirta, Symplocos racemosa, Curcubita pepo and Eclipta alba* had strong inhibitory effects. Based on a broth dilution method, the *Coscinium fenestratum* extract had the supreme antibacterial effect. The same MIC values i.e. (0.049 mg/mL) for both bacterial species and the MBC values were 0.049 and 0.165 mg/mL against *Propioni bacterium acnes* and *Staphylococcus epidermidis* (Kumar et al., 2007).

### Table 2 (continued)

| Sr. no. | Plant Name | Part Used | Essential oil | Whole plant | Stem | Root/ Rhizome | Seed | Flower | Fruit | Bark | References |
|---------|------------|-----------|---------------|-------------|------|---------------|------|--------|-------|------|------------|
| 209     | Arnebiaeuchroma, | – | – | Whole plant | – | – | – | – | – | – | – | – |
| 210     | Salvia hydranga, | – | – | Whole plant | – | – | Roots | – | – | – | – | – |
| 211     | Satureja buckthriarica, | – | – | – | – | – | – | – | – | – | – |
| 212     | Thymus daenensis | – | – | Essential oils | – | – | – | – | – | – | – |
| 213     | Kelisia dorsotissima | – | – | Essential oils | – | – | – | – | – | – | – |

### References

- Saha et al. (2007)
- Aliero and Afolayan (2006)
- Poonkothai et al. (2005)
- Mohammad et al. (2007)
- Hassan et al. (2009)
- Prabhath and Navneet (2010)
- Prabhath and Navneet (2010)
In recent study four (04) medicinal plants were used, the result was to be found that, the methanol extract of Marrubium vulgare, Thymus pallidus and Lavandula stoechas shows significant result against bacterial strains (Warda et al., 2009). Sidaco xidifolia Minos apudica and Aegle marmelos medicinal plants were used against bacterial strains. The result indicated that highest zone of inhibition Sida coxidifolia against Bacillus subtilis (35 mm) and Salmonella typhi (26 mm), while the rest plants also show activity against tested organisms (Balakrishnan et al., 2006).

Ushimaru and his company (2009) tested three (03) plants against bacterial strains. The results demonstrated that the aqueous fraction of Mollugo latoides and Acal ypha indica were displayed potent activity against Escherichia coli at various concentrations, Nelumbo nucifera alcoholic extract was to be found 0.390 mg/mL against Klebsiella pneumonia (Ushimaru et al., 2007).

Moreover, three plants and their various parts were used; all the plants displayed the great potential against the tested bacteria. The MICs and MBCs were to be observed for Staphylococcus aureus of 0.1, 0.2 and 0.1 mg/mL, 0.4–1.6 mg/mL and 0.4, 3.2 and 1.6 mg/mL, respectively (Saranraj, 2011). The author examined the phytochemicals and bacterial activity of Datura metel leaf, using Ager well diffusion method. The author reported that ethanol fraction of the plant had the highest zone of inhibition (26 mm) against Bacillus subtilis and Escherichia coli, while the Staphylococcus aureus has the lowest zone of inhibition (8 mm). The ethyl acetate fraction display strong zone of inhibition against E. coli, but no effect against Pseudomonas aeruginosa (Saranraj, 2011).

The author and his co-authors used phyla nodiflora plant against bacteria. The author and his coworker concluded that n-hexane and n-butanol fractions were observed to be positive against E. coli and P. aeruginosa, while the chloroform, n-butanol, ethyl acetate and n-hexane fractions show potential action against Salmonella and MRSA except for the crude fraction (Ullah et al., 2013).

Norajit and his coworkers screened the essential oil of five plants used by disc diffusion method. The outcomes of the essential oils obtained from Boesenbergia pandurata and Amomum xanthioides stop the growth of all tested bacteria, while the essential oil of Zingiber officinale had the highest potential against three positive strains of bacteria (S. aureus, B. cereus and L. monocyotogenes). It was to be found that the minimum concentration of inhibition to be 6.25 mg/mL against B. cereus and L. monocyotogenes (Norajit et al., 2007).

In another study, two plants were used. The results indicated that the acetone extract had displayed significant property against all strains, 0.0156 mg/mL against Staphylococcus aureus, while 2 mg/mL against Enterobacter cloacae. The essential oil obtained from Lippia javanica was also found to be reasonable result against Entamoeba histolytica. The inhibitory concentrations (IC50) of 25 and 100 mg/mL, respectively (Samie et al., 2009).

Al-Daihan et al. phytochemically screened four different medicinal plants used against different bacterial strains. The result shows that methanol extract of C. molmol and C. longa against S. pyogenes and S. aureus displayed maximum activity (19 mm), while the minimum activity of aqueous fraction against P. anisum against E. coli and P. aeruginosa (7 mm) (Al-Daihan et al., 2013). Khan and his company examined Elaeagnus angustifolia plant against different bacteria. The various parts of the plant were used i.e. leaves, branches, stem bark, root and root bark. The author reported that methanolic crude extract, n-hexane, and ethyl acetate showed bactericidal activity against Er scherichia coli, Staphylococcus aureus, while n-hexane and ethyl acetate also showed an antibacterial effect against Pseudomonas aeruginosa (Khan et al., 2013).

The Elaeagnus angustifolia leaves were also used for bactericidal and antioxidant potential. The result was to be found that, methanolic fraction inhibit the growth of Yersinia enterocolitica, while the MIC range against clinical strain coagulate negative Staphylococci to be 3250–6500 μg/mL (Okmen and Turkcan, 2013a; Okmen and Turkcan, 2013b). Furthermore, the soft extract of the Elaeagnus angustifolia was used. The author summarized that all samples showed the potent activity against the bacteria (Farzaei et al., 2015). Samwal and his coworkers (2009) demonstrated the rhizome of the plant species against antimicrobial property. Three extracts were used, the result summarized that among this only ethanolic fraction had strong activity against the tested microorganisms. Using novobiocin (15 μg/mL) as standard to check the zone of inhibition, the minimum inhibition concentration was to
be found 50 µg/mL against *S. mutants* and *S. epidermidis* (Semwal et al., 2009).

*Woodfordia fruticosekurz* medicinal plant was used to check the antibacterial potential. The results summarized that the various amount of acetone (80 µg and 120 µg) were shows promising activity against all the tested bacteria. It was further tested against standard antibiotic erythromycin) (Chougale et al., 2009). In another study, *Betulautilis* was used for antibacterial and phytochemical analysis using Agar well diffusion method. And they used 15 microorganisms namely, *Escherichia coli*, *Klebsiella pneumonia*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Salmonella paratyphi*, *Salmonella typhi*, *Salmonella typhimurium*, *Shigella flexneri*, *Shigella sonnei*, *Staphylococcus aureus*, *Streptococcus faecalis*, *Shigella boydii*, *Citrobacter spp.*, *Salmonella paratyphi* B and *Shigella boydii*. The result indicated that methanol, ethanol and aqueous extracts were to be found significant activity against all the tested bacteria, while petroleum and chloroform extract inactive (Kumaraswamy et al., 2008).

Patel and his company screened (2007) medicinal plants against antimicrobial potential. The result demonstrated that aqueous fractions of *Bidenspilosa*, *Jacaranda mimosifolia*, and *Piper pulchrum* shows significant action against *Bacillus cereus* and *Escherichia coli* than antibiotic gentamycin sulfate. While the ethanol fraction of all samples was active against *Staphylococcus aureus* except for *Justicia secunda*. Furthermore, *Bixa orellana*, *Justicia secunda* and *Piper pulchrum* showed minimum MICs against *Escherichia coli* (0.8, 0.6 and 0.6 µg/mL, respectively) compared to gentamycin sulfate (0.98 g/mL). *Bixa orellana* was found to be strong MIC against *Bacillus cereus* (0.2 µg/mL) than gentamycin sulfate (0.5 µg/mL) (Patel et al., 2007).

Seeds of the *Azadarichat indica* were used against pathogenic bacteria. The results showed that both strains growth were inhib-

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**Fig. 2.** (a) Number of various plant parts used in the review, showing antibacterial potential. (b) Percentage use of Gram-positive Bacteria. (c) Percentage use of Gram-negative Bacteria. (d) The Gram positive VS Gram negative% use in the text.
Main Gram - ve Bacteria used in the review and there percentage use

- Escherichia coli
- Pseudomonas aeruginosa
- Klebsiella
- Proteus
- Serratia
- Salmonella
- Shigella
- Vibrio
- Yersinia
- Enterobacter
- Pantoea agglomerans
- Citrobacter
- Xanthomonas axonopodis

Fig. 2 (continued)

(c)

(d)

Gram-ve VS Gram+ve bacteria percentage use

- Gram-ve: 59%
- Gram+ve: 41%

Fig. 2 (continued)

It is also found that gram positive are more susceptible as compared to gram negative bacteria. The control laboratory strains were reported as more sensitive to the toxic effects of the crude extracts than the corresponding test bacteria. Hexane extracts were reported as more effective, producing larger zones of growth inhibition sizes and smaller MIC and MBC values, than the aqueous
extracts. The MIC values ranged from 1.59 to 25 mg/mL while the MBC values ranged from 3.17 to 50 mg/mL (El-Mahmood et al., 2010).

Recently, Maity et al. (2010) evaluated the antimicrobial activity of the leaves of eight plants species. The various fractions of Albizia lebbeck, Cleistanthus collinus, Emblica officinalis, Eucaulypus deglupta, Eupatorium odoratum, Ocimum sanctum and Hevea brasiliensis were showed the healthier zone of inhibition (>11 mm) against Escherichia coli, Klebsiella pneumoniae, Staphylococcus aureus, Bacillus cereus, Vibrio cholerae and Candida albicans. The zone of inhibition of 11–13 mm was reported by Lantana camara against Klebsiella pneumoniae, Staphylococcus aureus, Bacillus cereus, Vibrio cholerae and Candida albicans. The extract of Butea frondosa, Melastoma malabathricum, Terminalia Arjuna, and Lycopodium japonicum were showed to be significant activity (8–11 mm) against all the tested bacteria. The plants like Adina cordifolia, Asparagus racemosus, Aegle marmelos, Cassia tora, Dillenia pentagona, Valeriana wallichii were found to be a poor activity (5–8 mm) against all the tested bacteria. Ocimum basilicum were found to be reasonable activity (05–08 mm). The MIC values of plant extracts were found to exhibit significant at 0.35–0.80 mg/mL. Among the tested plants, Albizia lebbeck, Cleistanthus collinus, Emblica officinalis, Eucaulypus deglupta, Eupatorium odoratum, Ocimum sanctum and Hevea brasiliensis were reported to show the minimum MIC values of 0.17–0.25 mm. Among the tested plants, Albizia lebbeck, Cleistanthus collinus, Emblica officinalis, Eucaulypus deglupta, Eupatorium odoratum, Ocimum sanctum and Hevea brasiliensis were reported to show the minimum MIC values of 0.17–0.25 mm. The ethanol extracts of the three herbs (Malacca tree, cassod tree, and pomegranate) were the most efficient antimicrobial. The results were to be found that, the bactericidal potential of the crude extracts of selected plants i.e. B. persicum, A. concinna, A. lebbeck, A. nobilis, C. indica, S. albicaule, V. nigundu, and B. diffusa, and was shown significant performance against all tested bacteria (Menghani et al., 2011).

Phattayakorn and friend (2009) screened antimicrobial potential of various medicinal plants. The results were exposed that; Piper betle could inhibit all strains of bacteria. Furthermore, Phylanthus emblica (Malacca tree), Senna siamea (cassod tree) and Punica granatum (pomegranate) show greater significant (P < 0.05) antimicrobial activity when compared with other herb extracts, with the zone of inhibition ranging from 12.330.58 to 25.017.3 mm. The ethanol extracts of the three herbs (Malacca tree, cassod tree, and pomegranate) were the most efficient antimicrobial compounds. The values of minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC) of the herb extracts were 0.3–2.4, >3 and 1.2–2.4 (w/v), respectively (Phattayakorn and Wanchaitanawong, 2009).

Yasmeen et al. (2012) evaluated fourteen plants species. Serial dilution method for antibacterial activity, while Nessler reagents and colorimetric method were used for estimation of Ammonia and urease activity. The results indicated that, the Allium sativum alcoholic and aqueous fractions had shown (pH: 8.5560, 8.8480, Ammonia: 4.42, 3.52 µg/mL, Urease: 0.009, 0.007 IU/mL respectively) as compared to control positive (pH: 9.03, Ammonia: 6.7 µg/mL, Urease: 0.013 IU/mL). However, alcoholic extracts of Mangifera indica (8.8820, 5.42 µg/mL, 0.010 IU/mL), Mentha piperita (8.8880, 4 µg/mL, 0.008 IU/mL) and aqueous extract of Opuntia ficus-indica (8.8100, 5.22 µg/mL, 0.010 IU/mL) to be found moderate activity against P. mirabilis. Furthermore, alcoholic and aqueous fractions of Eucalyptus camaldulensis (pH: 8.91, 8.96, Ammonia: 5.16, 5.06 µg/mL, Urease: 0.01, 0.01 IU/mL) had poor inhibitory effect. They also reported that all the commercial products were to be found the excellent antibacterial property (pH: 4.8–6.8, Ammonia: 0 µg/mL, Urease: 0 IU/mL). The rest of the herbal extracts were not significantly different (p < 0.05) from positive control. It was concluded that all products had strong antibacterial activity against P. mirabilis (Yasmeen et al., 2012).

Venkataswamy et al. (2010) screened the leaves of the single plant. The results were found that the aqueous and methanol fraction of the leaf shows maximum inhibition against E. coli, Proteus vulgaris, Staphylococcus aureus, Streptococcus pyogenes, Klebsiella pneumonia, while moderate inhibitory action against Pseudomonas aeruginosa and Salmonella typhi (Venkataswamy et al., 2010). Recently, eight Indian medicinal plants were screened for antimicrobial potential. The results were to be found that, the bactericidal potential of the crude extracts of selected plants i.e. B. persicum, A. concinna, A. lebbeck A. nobilis, C. indica, S. albicaule, V. nigundu, and B. diffusa, and was shown significant performance against all tested bacteria (Menghani et al., 2011).
| S. no | Plant name | Common name | Bacteria | Fungus | Part used | References |
|-------|------------|-------------|----------|--------|-----------|------------|
| 1.    | Trachyspermum ammi | Ajwain | P. larvae | Whole plant | Ansari et al. (2016) |
| 2.    | Punugundullosa | Almond | P. larvae | Whole plant | Ansari et al. (2016) |
| 3.    | Ocimum tenuiflorum | Tulsi | P. larvae | Whole plant | Ansari et al. (2016) |
| 4.    | Citrus bergamia | Bergamot | P. larvae | Whole plant | Ansari et al. (2016) |
| 5.    | Juniperus virginiana | Cedar wood | P. larvae | Whole plant | Ansari et al. (2016) |
| 6.    | Azadirachta indica | Neem | P. larvae | Whole plant | Ansari et al. (2016) |
| 7.    | Elettaria cardamomum | Cardamom | P. larvae | Whole plant | Ansari et al. (2016) |
| 8.    | Murraya koenigii | Curry | P. larvae | Whole plant | Ansari et al. (2016) |
| 9.    | Zingiber officinale | Ginger | P. larvae | Whole plant | Ansari et al. (2016) |
| 10.   | Vetiveria zizanoides | Khas | P. larvae | Whole plant | Ansari et al. (2016) |
| 11.   | Daucus carota | Carrot | P. larvae | Whole plant | Ansari et al. (2016) |
| 12.   | Laurus nobilis | Bay | P. larvae | Whole plant | Ansari et al. (2016) |
| 13.   | Citrus bergamia | Bergamot | P. larvae | Whole plant | Ansari et al. (2016) |
| 14.   | Melaleuca alternifolia | Cajeput | P. larvae | Whole plant | Ansari et al. (2016) |
| 15.   | Ocimum sanctum | Tulsi | P. larvae | Whole plant | Ansari et al. (2016) |
| 16.   | Pimenta dioica | Jamaica pepper | P. larvae | Whole plant | Ansari et al. (2016) |
| 17.   | Lotus corniculatus | Mountain pepper | P. larvae | Whole plant | Ansari et al. (2016) |
| 18.   | Myristica fragrans | Nutmeg | P. larvae | Whole plant | Ansari et al. (2016) |
| 19.   | Aniba rosea | Rosewood | P. larvae | Whole plant | Ansari et al. (2016) |
| 20.   | Mentha piperita | Peppermint | P. larvae | Whole plant | Ansari et al. (2016) |
| 21.   | Illicium verum | Star anise | P. larvae | Whole plant | Ansari et al. (2016) |
| 22.   | Limonum crassifolium | Lime | P. larvae | Whole plant | Ansari et al. (2016) |
| 23.   | Matricaria chamomilla | Chamomile | P. larvae | Whole plant | Ansari et al. (2016) |
| 24.   | Mentha arvensis | Corn mint | P. larvae | Whole plant | Ansari et al. (2016) |
| 25.   | Anethum graveolens | Dill | P. larvae | Whole plant | Ansari et al. (2016) |
| 26.   | Pelargonium graveolens | Geranium | P. larvae | Whole plant | Ansari et al. (2016) |
| 27.   | Simmondsia chinensis | Jojoba | P. larvae | Whole plant | Ansari et al. (2016) |
| 28.   | Sesamum indicum | Sesame | P. larvae | Whole plant | Ansari et al. (2016) |
| 29.   | Triticum vulgare | Wheat germ | P. larvae | Whole plant | Ansari et al. (2016) |
| 30.   | Baccharis halimifolia | Groundsel bush | V. destructor | Whole plant | Damiani et al. (2011) |
| 31.   | M. thunbergii var. verticillata | Pepper | V. destructor | Whole plant | Damiani et al. (2011) |
| 32.   | Lavandula x intermedia | Lavandin | Acshaoferaapis | Whole plant | Larraw et al. (2001) |
| 33.   | Coriandrum sativum | Coriander | A. shiokeraapis | Whole plant | Larraw et al. (2001) |
| 34.   | Lavandula officinalis | Lavanda | A. shiokeraapis | Whole plant | Larraw et al. (2001) |
| 35.   | Lavandula angustifolia | False camphor | A. shiokeraapis | Whole plant | Larraw et al. (2001) |
| 36.   | Ocimum basilicum | Basil | A. shiokeraapis | Whole plant | Larraw et al. (2001) |
| 37.   | Tagetes minuta | Tagetes | A. shiokeraapis | Whole plant | Larraw et al. (2001) |
| 38.   | Rosmarinus officinalis | Rosemary | A. shiokeraapis | Whole plant | Larraw et al. (2001) |
| 39.   | Eucalyptus globulus | Eucalyptus | A. shiokeraapis | Whole plant | Larraw et al. (2001) |
| 40.   | Polygonum bistorta | Bistort | Paenibacillus larvae | Leaves, stem | Cecotti et al. (2012) |
| 41.   | Polygonum bistorta | Bistort | Melissococcus platani | Leaves, stem | Cecotti et al. (2012) |
| 42.   | Tamarindus indica | Mountain pepper | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 43.   | Syzygium aromaticum | Clove | A. shiokeraapis | Bud | Ansari et al. (2017) |
| 44.   | Piper betle | Betel | A. shiokeraapis | Leaves | Ansari et al. (2017) |
| 45.   | Anisomelis indica | Kala Bhangra | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 46.   | Mentha spicata | Spearmint | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 47.   | Matricaria chamomilla | Chamomile | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 48.   | Daucus carota | Carrot | A. shiokeraapis | Seed | Ansari et al. (2017) |
| 49.   | Cuminum cyminum | Cumin | A. shiokeraapis | Seed | Ansari et al. (2017) |
| 50.   | Ocimum gratissimum | Clove basil | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 51.   | Allium sativum | Garlic | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 52.   | Aegle marmelos | Stone apple | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 53.   | Pelargonium graveolens | Geranium rose | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 54.   | Callistemon citrinus | Bottle brush | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 55.   | Myristica fragrans | Nutmeg | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 56.   | Cymbopogon martini | Palmrosa oil | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 57.   | Elettaria cardamomum | Cardamom | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 58.   | Foeniculum vulgare | Fennel seed oil | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 59.   | Trachyspermum ammi | Ajwain oil | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 60.   | Anethum graveolens | Dill oil | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 61.   | Cannabis sativa | Hempseed oil | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| 62.   | Gilepticocoronaria | Garland Daisy oil | A. shiokeraapis | Whole plant | Ansari et al. (2017) |
| S. no | Plant | Common name | Mites | Bacteria | Fungus | Part used | References |
|-------|-------|-------------|-------|----------|--------|-----------|------------|
| 63.   | Azadirachta indica | Neem | Varroia jacobseni | Ascospaera apis | Whole plant | Melathopoulos et al. (2000) |
| 64.   | Brassica napus | Canola oil | Varroia jacobseni | Ascospaera apis | Whole plant | Melathopoulos et al. (2000) |
| 65.   | Azadirachta indica | Neem | Acrapiswoodi | Ascospaera apis | Whole plant | Melathopoulos et al. (2000) |
| 66.   | Brassica napus | Canola oil | Acrapiswoodi | Ascospaera apis | Whole plant | Melathopoulos et al. (2000) |
| 67.   | Lavandula angustifolia | English lavender | Ascospaera apis | Whole plant | Boudegga et al. (2010) |
| 68.   | Rosmarinus officinalis | Rosemary | Ascospaera apis | Whole plant | Boudegga et al. (2010) |
| 69.   | Salvia officinalis | Sage | Ascospaera apis | Whole plant | Boudegga et al. (2010) |
| 70.   | Thymus vulgaris | Thyme | Ascospaera apis | Whole plant | Boudegga et al. (2010) |
| 71.   | Mentha piperita | Peppermint | Ascospaera apis | Whole plant | Boudegga et al. (2010) |
| 72.   | Pelargonium graveolens | Rose geranium | Ascospaera apis | Whole plant | Boudegga et al. (2010) |
| 73.   | Prunus dulcis | Almond | Ascospaera apis | Whole plant | Boudegga et al. (2010) |
| 74.   | Citrus aurantium | Key lime | Ascospaera apis | Whole plant | Boudegga et al. (2010) |
| 75.   | Olea europaea | Olive | Ascospaera apis | Whole plant | Boudegga et al. (2010) |
| 76.   | Laurensobolis | Bay laurel | Nosema ceranae | Whole plant | Porrini et al. (2011) |
| 77.   | Rosmarinus officinalis | Rosemary | V. destructor | P. larvae | Whole plant | Maggi et al. (2011) |
| 78.   | Azadirachta indica | Neem | V. destructor | P. larvae | Whole plant | Anjum et al. (2015) |
| 79.   | Vitex trifolia | Barbata | V. destructor | P. larvae | Whole plant | Anjum et al. (2015) |
| 80.   | Azadirachta indica | Neem | Bacillus subtilis | Whole plant | Anjum et al. (2015) |
| 81.   | Azadirachta indica | Neem | Staphylococcus hominis | Whole plant | Anjum et al. (2015) |
| 82.   | Vitex trifolia | Barbata | Bacillus subtilis | Whole plant | Anjum et al. (2015) |
| 83.   | Vitex trifolia | Barbata | Staphylococcus hominis | Whole plant | Anjum et al. (2015) |
| 84.   | Carapoaianensis | Andiroba oil | V. destructor | P. larvae | Whole plant | Santos et al. (2012) |
| 85.   | Copaifera langsdorffii | Copaiba oil | V. destructor | P. larvae | Whole plant | Santos et al. (2012) |
| 86.   | Lepidium latifolium | Pepperwort | V. destructor | Whole plant | Razavi et al. (2015) |
| 87.   | Zataria multiflora | Satar | V. destructor | Whole plant | Razavi et al. (2015) |
| 88.   | Populus fremontii | Fremonts | V. destructor | P. larvae | Whole plant | Wilson et al. (2017) |
| 89.   | Olea europaea | Olive | P. larvae | Whole plant | ARENAS (2015) |
| 90.   | Olea europaea | Olive | Nosema species | Leaves | ARENAS (2015) |
| 91.   | Olea europaea | Olive | Melissosoccus plutomius | Leaves | ARENAS (2015) |
| 92.   | Thymus satureoides | Thyme | V. destructor | Whole plant | Ramzi et al. (2017) |
| 93.   | Origanum elongatum | Majorana | V. destructor | Whole plant | Ramzi et al. (2017) |
| 94.   | Lippia berlandieri | Oregano | Beauveria bassiana | Whole plant | Ramzi et al. (2017) |
| 95.   | Lippia berlandieri | Oregano | Metarhizium anisopliae | Whole plant | Ramzi et al. (2017) |
| 96.   | Thymus kotschyanus | Thymol | V. destructor | Whole plant | Ghasemi et al. (2011) |
| 97.   | Ferula assa-foetida | Devils dung | V. destructor | Whole plant | Ghasemi et al. (2011) |
| 98.   | Eucalyptus camaldulensis | River red gum | V. destructor | Whole plant | Ghasemi et al. (2011) |
| 99.   | Ocimum basilicum | Basil | P. larvae | Whole plant | Mährig et al. (2011) |
| 100.  | Thymus vulgaris | Thyme | P. larvae | Whole plant | Mährig et al. (2011) |
| 101.  | Urtica dioica | Nettle | P. larvae | Whole plant | Mährig et al. (2011) |
| 102.  | Humulus lupulus | Common hop | P. larvae | Whole plant | Flesar et al. (2010) |
| 103.  | Myrtus communis | Myrtle | P. larvae | Whole plant | Flesar et al. (2010) |
| 104.  | Achyranthes bidentata | Macela | P. larvae | Whole plant | Gonzalez and Marioli (2010) |
| 105.  | Chenopodium ambrosioides | Wormseed | P. larvae | Whole plant | Gonzalez and Marioli (2010) |
| 106.  | Eucalyptus cinerea | Argyle apple | P. larvae | Whole plant | Gonzalez and Marioli (2010) |
| 107.  | Gnaphalium australis | P. larvae | Whole plant | Gonzalez and Marioli (2010) |
| 108.  | Lippia tubinata | P. larvae | Whole plant | Gonzalez and Marioli (2010) |
| 109.  | Marrubium vulgare | Common horehound | P. larvae | Whole plant | Gonzalez and Marioli (2010) |
| S. no | Plant Common name | Common name | Mites | Bacteria | Fungus | Part used | References |
|-------|------------------|-------------|-------|----------|--------|-----------|------------|
| 110.  | Minthostachys verticillata | Peperina | P. larvae | Whole plant | Gonzalez and Marioli (2010) |
| 111.  | Origanum vulgare | Common originum | P. larvae | Whole plant | Gonzalez and Marioli (2010) |
| 112.  | Tagetes minuta | Black mint | P. larvae | Whole plant | Gonzalez and Marioli (2010) |
| 113.  | Thymus vulgaris | Thyme | P. larvae | Whole plant | Gonzalez and Marioli (2010) |
| 114.  | Laurus nobilis | Bay laurel | P. larvae | Whole plant | Damiani et al. (2014) |
| 115.  | Piper betle | Betel | A. apis | Whole plant | Chantawannakul et al. (2005) |
| 116.  | Cinnamomum cassia | Cassia | A. apis | Whole plant | Chantawannakul et al. (2005) |
| 117.  | Lavandula angustifolia | Lavenda | V. destructor | Whole plant | Damiani et al. (2009) |
| 118.  | Laurus nobilis | Laurel | V. destructor | Whole plant | Damiani et al. (2009) |
| 119.  | Thymus vulgaris | Thyme | V. destructor | Whole plant | Beligon et al. (2013) |
| 120.  | Scutia umbrosa | Coronilha | Paenibacillus species | Whole plant | Fuselli et al. (2007) |
| 121.  | Acantholippia serapioides | Andean thyme | P. larvae | Whole plant | Fuselli et al. (2008) |
| 122.  | Citrus paradise | Grapefruit | P. larvae | Whole plant | Fuselli et al. (2008) |
| 123.  | Citrus sinensis | Sweet orange | P. larvae | Whole plant | Fuselli et al. (2008) |
| 124.  | Citrus limon | Lemon | P. larvae | Whole plant | Fuselli et al. (2008) |
| 125.  | Citrus nobilis | Mandarin | P. larvae | Whole plant | Fuselli et al. (2008) |
| 126.  | Artemisia absinthium | Wormwood | P. larvae | Whole plant | Fuselli et al. (2008) |
| 127.  | Artemisia annua | Sweet wormwood | P. larvae | Whole plant | Fuselli et al. (2008) |
| 128.  | Lepechinia floribunda | Pitcher sage | P. larvae | Whole plant | Damiani et al. (2009) |
| 129.  | Tagetes minuta | Black mint | V. destructor | Whole plant | Damiani et al. (2009) |
| 130.  | Tessaria absinthium | Black mint | V. destructor | Whole plant | Fuselli et al. (2008) |
| 131.  | Aloysia gratissima | Whitebrush | A. apis | Whole plant | Dellacasa et al. (2003) |
| 132.  | Heterotheca latifolia | Camphorweed | A. apis | Whole plant | Dellacasa et al. (2003) |
| 133.  | Lippia integrifolia | A.apis | Whole plant | Dellacasa et al. (2003) |
| 134.  | Lippia turbinata | A. apis | Whole plant | Dellacasa et al. (2003) |
| 135.  | Achyrocline vueeoides | Macela | Varroa mites | P. larvae | Whole plant | Sabaté et al. (2012) |
| 136.  | Achyrocline vueeoides | Thyme | Varroa mites | P. larvae | Whole plant | Ariana et al. (2002) |
| 137.  | Achyrocline vueeoides | Savory | Varroa mites | P. larvae | Whole plant | Ariana et al. (2002) |
| 138.  | Mentha spicata | Spearmint | Varroa mites | P. larvae | Whole plant | Reyes et al. (2012) |
| 139.  | Mentha spicata | Thyme | Varroa mites | P. larvae | Whole plant | Reyes et al. (2012) |
| 140.  | Flourensia sp | Palmarosa | P. larvae | Whole plant | Hernández-López et al. (2014) |
| 141.  | Flourensia sp | Citronella grass | P. larvae | Whole plant | Gende et al. (2009) |
| 142.  | Flourensia sp | Black mint | P. larvae | Whole plant | Gende et al. (2009) |
| 143.  | Flourensia sp | Green anise | P. larvae | Whole plant | Fuselli et al. (2010) |
| 144.  | Pimpinella anisum | Fennel | P. larvae | Whole plant | Fuselli et al. (2010) |
| 145.  | Melaleuca alata | Tea tree | P. larvae | Whole plant | Fuselli et al. (2010) |
| 146.  | Melaleuca alternifolia | Citronella | P. larvae | Whole plant | Fuselli et al. (2010) |
| 147.  | Melaleuca alternifolia | Tea tree | P. larvae | Whole plant | Fuselli et al. (2010) |
| 148.  | Cymbopogon winterianus | Palmarosa | P. larvae | Whole plant | Fuselli et al. (2010) |
| 149.  | Cymbopogon martini | Cinnamon | Bacillus larva | A. apis | Whole plant | Fuselli et al. (2010) |
| 150.  | Cinnamomum verum | Palmarosa | Bacillus larva | A. apis | Whole plant | Fuselli et al. (2010) |
| 151.  | Laurus nobilis | Bay leaf | Bacillus larva | A. apis | Whole plant | Calderone et al. (1994) |
| 152.  | Cinnamomum camphora | Camphor | Bacillus larva | A. apis | Whole plant | Calderone et al. (1994) |
| 153.  | Syzygium aromaticum | Clove | Bacillus larva | A. apis | Whole plant | Calderone et al. (1994) |
| 154.  | Cymbopogon winterianus | Citronella | Bacillus larva | A. apis | Whole plant | Calderone et al. (1994) |
| 155.  | Origanum vulgare | Origanum | Bacillus larva | A. apis | Whole plant | Calderone et al. (1994) |
| 156.  | Thymus vulgaris | Thyme | Bacillus larva | A. apis | Whole plant | Calderone et al. (1994) |
Pseudomonas aeruginosa, Escherichia coli, Bacillus cereus and Staphylococcus aureus. Out of ten medicinal plants, five plants showed antimicrobial potentials, while the Tussilago farfara, Chelidonium majus and Sanguisorba officinalis were most active medicinal plant against antimicrobes (Janovska et al., 2003).

In another study, different plants species were screened for phytochemicals and biological activities. The result exposed that, great potential against antimicrobes were found for the extracts of Syzygium jambos and Caryophyllus aromaticus, which inhibited 57.1% 64.2 and 64.2% of the tested bacterial strains, respectively, while strong activity against antibiotic-resistant bacteria (83.3%). Some plant extracts were inactive, while in case of association of plant extracts and antibiotic to be found active against antibiotic resistant bacteria. The extracts clove, jambolan, pomegranate and thyme inhibited the growth of Pseudomonas aeruginosa (Nascimento et al., 2000).

Acharya et al. (2009) evaluated the antimicrobial activity total nine plants. All of these plants had a bacterial effect. Further, Syzygium cuminii, Skeels (Myrtaceae) and Terminalia chebula Retz (Combretaceae) was observed the most promising bactericidal action, inhibiting the growth of all tested organism, especially Bacillus subtilis, Aeromonas hydrophila and Vibrio cholera. The MBC was found to be in the range of 0.25–4 mg/ml (Acharya et al., 2009).

Recently, the antimicrobial activities of total nine plants were evaluated. The author reported that among nine plants the most active plants were Muscari Comosanum, Rhihetoilei ssp and Tamarix gallica. Among the all tested extracts, the methanolic fraction of Rhihetoilei ssp and aqueous extract of Tamarix gallica were to be found most active, and their diameter was in the range of 15 mm, 22 mm and 10 mm, 17 mm respectively (Zaouia et al., 2010).

In another study, eight plants were reported against Gram-negative and Gram-positive bacteria strains. The microorganisms were obtained from American Type Culture Collection (ATCC) and Proteus mirabilis (CDC S 17), Proteus vulgaris (CDC 527C), and Listeria monocytogenes. Namely, Staphylococcus aureus (ATCC 29213), Staphylococcus epidermidis (ATCC 1228), Bacillus subtilis (ATCC 31091), Bacillus cereus (ATCC 11778), Salmonella typhimurium (ATCC14028), Pseudomonas aeruginosa (ATCC 9027), E. coli (ATCC 31165), Salmonell enteritidis (ATCC 4931), Klebsiella pneumoniae (ATCC 13883), E. coli O157:H7 (ATCC 43894), Enterobact aerogenes (ATCC 29010), Shigella dysenteriae (ATCC 29026). The result showed that all plants extracts were active against both tested strains. Furthermore, Gram-negative was found strong potential than Gram positive bacteria (Kang et al., 2011).

Philip et al. (2009) were studied eight plants. The aqueous fraction had no inhibition, while all the tested plants were to be found inactive in Escherichia coli. However, Curcuma mango displayed action against the tested bacterial strain (Philip et al., 2009). In another study the author reported 8 medicinal plants and their various parts; the results showed that the essential oils of T. daenensis and M. communis were most active against antimicrobes. The MIC values were to be found for essential oils and active extract 0.039 and 10 mg/ml. Furthermore, some plants extracts and their oils also used as food preservation (Ghasemi et al., 2010).

Recently, seven medicinal plants were examined for antibacterial potential, the result indicated that the methanolic extract of Phyllanthus niruri (stone breaker) was to be found strong action against Staphylococcus sp, while the aqueous and methanolic fraction had minimum activity as compared to methanolic (Selvamohan et al., 2012). The author used total six plants, against dental pathogens. All the plants were active against all the tested pathogens. The methanolic extract of T. chebula was to be observed highest zone of inhibition against S. aureus 27 mm, while the lowest value for petroleum ether extract of A. aspera and M. elengi against S. aureusand S. mutans (9 mm). It was concluded that high contents of phytochemicals in these plants might have exerted synergistic antimicrobial effect (Prabhat and Navneet, 2010).

Hassan and his company screened various medicinal plants. The result indicated that Escherichia coli, Salmonella typshi, Pseudomonas aeruginosa were the most inhibited microorganisms. The extract of Sphar eranthu hirtus was the most active against multi-drug resistant Pseudomonas aeruginosa and enterohemorrhagic E. coli. The ethanolic extract of S. hirtus exhibited a higher effect than the hot water extract (Hassan et al., 2009). The author investigated six plants leaves against Klebsiella, Pseudomonas and E. coli. The result was to be found that, the aqueous lemon leaf fraction against E. coli, while Eucalyptus leaf ethanol extract against Klebsiella shows potent activity. Furthermore, except Tulsi plant, Pseudomonas showed resistant to all tested fractions (Zwetlana et al., 2014).

Johnson and his colleagues (2011) screened five important medicinal plants, and the results observed that the maximum of Aloe vera plant was to be exposed against S. aureusand E. coli, while Lanatracamara inactive against bacterial strains. However, the aqueous fraction of the Pongamia pinnata had more active as compared to alcoholic extract against E. coli. Calotrops procera medicinal plant showed antibacterial potential against E. coli and Staphylococcus aureus, while Datura stramonium only active against Staphylococcus aureus (Johnson et al., 2011).

3. A novel application of plant extracts against honey bee pathogens

Honeybees would seem particularly vulnerable to pests and pathogens as each colony is a dense group of individuals. Although honeybees possess many types of defenses against diseases, such as hygienic behavior or the production of anti-microbial substances, colonies still suffer from a number of diseases and pests (Martin, 2001; Simone-Finstrom et al., 2017). But they are threatened by various pathogens like Gut microflora and parasitic mites globally and this may lead to serious consequences (Ansari et al., 2017). Some of the important pathogens of Honey bees are Paenibacillus larva (Bacteria), Varroa destructor (mite) and Ascosphaera apis (Fungi).

Recently, it was demonstrated that, in Europe and the US, prominent losses of honeybee colonies are associated with the mite Varroa destructor (Ryabov et al., 2017; Oddie et al. 2017). The spore-forming bacterium Paenibacillus larva (Genersch, 2010) are the agent causing American foulbrood (AFB) (Alvarado et al., 2017). It is a widespread larval pathogen of the honey bee, infecting young larvae through ingestion of contaminated food. The bacterial spores germinate and proliferate in the midgut lumen after which they start to breach the epithelium and invade the haemocoeal. Young larvae (from the first and second instars) are highly susceptible to this disease and can become infected by as few as 10 spores. However, the dosage-mortality relationship is greatly affected by larval age, genetic makeup and bacterial strain. This disease can be mitigated both through hygienic behavior by adult workers and through larval resistance traits (Qin et al., 2006).

Besides that, essential oils are being used to control these microbial strains. Such strategy allows an alternative way for the control of this serious disease affecting honey and its by-products (wax, pollen and propolis). Also, it can meet consumer demand for a diminution or absence of other antimicrobial chemical substances, which can be substituted by the addition of natural substances.

More, recently in vitro studies have revealed that propolis, and specific compounds within propolis, prevent the development of two infectious pathogens of honey bees, Paenibacillus larva and Ascosphaera apis (Wilson et al., 2017; Borba and Spivak, 2017).
The essential oils proved to be highly effective against *Paenbacillus larvae* are Jamaica pepper oil (*Pimenta dioica*), mountain pepper oil (*Litsea cubeba*), ajwain oil (*Trachyspermum ammi*), corn mint oil, spearmint oil (*Mentha spicata*), star anise oil (*Illicium verum*), nutmeg oil (*Myristica fragrans*), camphor oil (*Cinnamomum camphora*) (Ansari et al., 2016), Barbaka (*Vitex trifolia*) and neem extracts (*Azadirachta indica*) (Anjum et al., 2015), nettle (*Urtica dioica*), basil (*Ocimum basilicum*) (Mârghitaș et al., 2011), Argyle apple (*Eucalyptus cinerea*), Peperina (*Minthostachys verticillata*) (Gonzalez and Marioli, 2010), Nepeta clarkei water extracts against honey bee pathogen *Paenbacillus larvae* (Anjum et al., 2017) laurel (*Laurus nobilis*) (Damiani et al., 2014), Corinhiha (*Scutia buxifolia*) (Boligon et al., 2013), grapefruit (*Citrus paradisi*) (Fuselli et al., 2008), wormwood (*Artemisia absinthium*), sweet wormwood (*Artemisia annua*), Lepechinia floribunda (*sartchesigans*) (Fuselli et al., 2008), Achyrocline satureoides (*Macela*) (Sabaté et al., 2012), *Flourensia riparia*, *Flourensia fiebrigii* (Reyes et al., 2013), Hypericum perforatum (Hernández-López et al., 2014) (as mentioned in Table 4).

It is an ecto-parasitic mesostigmata mite. *Varroa* causes many physical and physiological detrimental effects at the individual bee and colony levels. Repeated *Varroa* feeding on adult bee and brood hemolymph injures the bees physically, leads to a reduction in their protein content and wet and dry body weights, and interferes with organ development. In addition, the parasitic mite and the viruses they vector contribute to morphological deformities like small body size, shortened abdomen, deformed wings. These morphological deformities reduce vigor and longevity. They also affect flight duration and the homing ability of foragers (Conte et al., 2010).

The *Varroa* mite is responsible for the horizontal and vertical transmission of many viruses like DWV, SBV, APV, IAPV and KBV. The horizontal transmission of viruses from nurse bees to larvae occurs through larval food and via brood to adults (Conte et al., 2010). Usually, untreated *Varroa*-infested colonies usually die within six months to two years of mite infestation at the colony level (Conte et al., 2010). V. destructor is supposed to be a very serious threat to the honey bees. *Varroa* parasitism plays in the recent honey bee losses worldwide (Conte et al., 2010). To lower the hazardous effects caused by V. destructor, several plant extracts have been found to be extremely effective. These are Groundsel bush (*Baccharis flabellate*), Peperina (*Minthostachys verticillata*) (Damiani et al., 2011), Pepperwort (*Lepidium latifolium*) (Razavy et al., 2011), Thymol (*Thymus kotschyanus*) (Ghasemi et al., 2017), Argyle apple (*Eucalyptus cinerea*), *Baccharis flabellate* (Damiani et al., 2014), Coronilha (*Coronilha*), laurel (*Laurus nobilis*), ajwain oil (*Pimpinella anisum*), clove bud oil (*Cinnamomum zeylanicum*), cumin seed oil and clove bud oil (Ansari et al., 2017), Pelargonium oil (*Pelargonium graveolens*), Thyme oil (*Thymus vulgaris*) (Boudegga et al., 2010), *Cinnamomum cassia* and Piper betel (Chantawannakul et al., 2005), *Tessaria absinthioides*, *Alyssia gratissima*, *Heterotheca latifolia*, *Lippia juneliana*, *L. integrifolia* and *L. turbinata* (Dellacasa et al., 2003).

Two microsporidia species have been shown to infect *Apis melifera*, *Nosema apis* and *Nosema ceranae*. The honey bee immune response is significantly suppressed by *N. ceranae* infection, although this effect was not observed following infection with *N. apis*. Immune suppression would also increase susceptibility to other bee pathogens and senescence.

Despite the importance of both *Nosema* species in honey bee health, there is no information about their effect on the bees’ immune system (Antúnez et al., 2009). One plant extract was found to be highly effective against this pathogen i-e *Laurus nobilis* (Porrini et al., 2011).

### 4. Emerging and remarkable applications of silver nanoparticles exploiting as anti-agent

Silver is one of the most important metals which are used in various fields, in magnetic, optics, electronics (Emam and Ahmed, 2016), besides these it has also used as anticancer, bactericidal, fungicidal, antiviral and anti-protozoal agent (Lansdown, 2006). As antimicrobes potentials, silver is one of the most important metals and generally examined against with antimicrobial properties (Lansdown, 2006). It has been reported that, at low amount silver has great potential against microorganisms, while the silver nanoparticles at high concentration (>10 μM), toxic against mammals as well as host organisms (Conrad et al., 1999). In one other report, Lansdown demonstrated that nanosilver is pharmaceutical recommended as well as nontoxic to human beings (Lansdown, 2006).

#### 4.1. Bactericidal potential of silver nanoparticles

Nano-Silver has great potential against both strains i.e. Gram-positive and Gram-negative bacteria and also against the antibiotic resistant bacteria (Kim et al., 2007). The bactericidal action of NSPs depends on concentration and size of NSPs. Generally, small particles sizes at low concentration can kill bacteria while high concentration has also effective against ant microbes. The shape of NSPs has also a great influence on antimicrobial function. Sadeghi and his coworkers examined three different shapes of nanosilver namely silver nanoparticles, silver nanorods and silver nanoparticles against *Staphylococcus aureus* and *E. coli*. Among these, the nanoparticles had the excellent antimicrobial activity (Sadeghi et al., 2012).

From the research survey, it has been also proved that combined form of different antibiotic and nanosilver have a potent role as compared to their alone usage. In a recent study, it is reported that the combining effect of amoxicillin and naosilver against *E. coli* found greater than they have used alone (Li et al., 2005). NSPs are important to test against antimicrobes. Some studies have been reported against this type of pathogen by Kumar et al. (2014) and Velmurugan et al. (2013). The exact mechanism of Ag nanoparticles is not completely clear. It is reported that DNA damage, cell membrane damage, mitochondrial damage and oxidative stress are involved (Velmurugan et al., 2013). Silver nanoparticles when to react with a thiol group, the resultant product reactive oxygen
species (ROS) are formed. As a result, it inhibits the respiratory enzyme and thus leads to cell death (Krishnaraj et al., 2010).

Recent literature showed that the biocidal effect of maltose reduced silver nanoparticles (AgNPs) is effective against honey bee bacterial diseases (American foulbrood and European foulbrood pathogens) (Culha et al., 2017). Similarly, tea tree oil (TTO) nanoparticles were found efficacious against P. larvae and Melissococcus plutonius (Christ Vianna Santos et al., 2014) These bacterial bee pathogens have been gaining a reputation as there are few satisfying control options beyond citing the problem of resistance to medicine/antibiotics using conventionally. Additionally, Glycerol Nano capsules were able to destroy spores of Paenibacillus larvae without causing harm to bees (Lopes et al., 2016). Therefore, researches with nanotechnology characterize, possibly, a viable control option for infectious diseases in honey bees.

4.2. Fungicidal potential of nano silver

One of the other important infectious diseases which cause a significant burden on healthcare is fungus (Brown et al., 2012a, b). To control this infection in human beings, researchers’ required a new type of antifungal agents (Brown et al., 2012a; Zuo et al., 2016). Like bacteria, NSPs has also fungicidal action against broad spectrum fungi. In one study Kim and his company reported antifungal performance of 44 strains of six fungal species. Among these Trichophyton mentagrophytes, Candida krusei, Candida albicans, Candida glabrata, Candida krusei and Candida parapsilosis growth stop applying NSPs (Kim et al., 2008). The silver and chitosan nanoparticles were tested against Rhizoctonia solani, Alternaria alternata and A. flavus from chickpea seeds and they showed potent fungicidal properties (Kaur et al., 2012).

Savithramma and his colleagues demonstrated antifungal activity against A. flavus, A. niger, Curvularia spp., Fusarium spp. and Rhizopus spp, using silver nanoparticles synthesized from medicinal plants namely, Svensonia hyderobadensis, Boswellia ovalifoliolata and Shorea tumbuguga. All the tested NSPs showed significant properties against the entire tested microorganism, while among these, nanosilver obtained from Svensonia hyderobadensis had excellent activity as compared to other plants (Savithramma et al., 2011).

In a recent study, silver nanoparticles and natamycin were tested against 216 strains of fungi from patients suffering from severe keratitis. Among these, 112 isolates of Fusarium, 82 isolates of Aspergillus and 10 Alternaria isolates. The result showed that silver nanoparticles had great potential than natamycin (Xu et al., 2013). The exact mechanism of NSPs against fungi is not yet clear, but it was observed that nanosilver can damage the cellular membrane and inhibit the normal budding process (Kim et al., 2009; Nasrollahi et al., 2011).

In addition, new natural biocides like biopolymer chitosan and three monoterpenes i.e. camphor, menthol and thymol were found useful against Honey bee pathogenic fungi and bacteria (Rabea and Badawy, 2014). Similarly, a compound juglone (walnut green husk extracts) also showed antifungal against different pathogenic fungi including A. Apis (Wianowska et al., 2016).

4.3. Virucidal potential of nano silver

It was also reported that small size SNPs like 25 cm or less nanosilver are more effective against viral infection (Speshock et al., 2010). Lara and his colleagues reported that nanosilver inhibits the initial stages of HIV-1 cycle. The mechanism of binding of NSPs attachment with glycoprotein 120, also inhibits cluster of differentiation 4-dependent binding, fusion and infectivity. Thus they perform an antiviral action to block HIV-1 cell free and cell associated infection (Lara et al., 2010). Different studies have proven the behavior of SNPs without a capping agent means naked nanosilver antiviral properties of various viruses, namely Vaccinia virus (Trefry and Woolsey, 2013), human parainfluenza virus type 3, Herpes simplex virus type 1 and type 2 (Gaikwad et al., 2013), tacaribe virus (Speshock et al., 2010), hepatitis B virus (Lu et al., 2008), Coxsackie virus B3 (Ben Salem et al., 2012), influenza virus (Xiang et al., 2011) and monkey pox virus (Rogers et al., 2008).

Several studies also explain the behavior of coated SNPs as an antiviral agent namely, respiratory syncytial virus (Sun et al., 2008), human immunodeficiency virus type-1 (Lara et al., 2011) and HSV (Baram-Pinto et al., 2009). It was observed that nano silver coated with poly (N-vinyl-2-pyrrolidone) having size about 1–10 nm were most effective to inhibit replication of HIV (Elechiguerra et al., 2005).

Although, very little information regarding the silver nanoparticles against honey bee viruses has been yet investigated. Sacbrood virus (SBV) a single-stranded RNA virus severely infectious in honey bee colonies all over Asia. Hence, silver ions were found effective against natural KSBV (Korean sac brood virus) infection in A. cerana. colonies. In this research, bioaccumulation in bees and recommended concentrations of silver residue in honey or other hive products were not considered (Ahn et al., 2015).

5. Conclusion

The antibacterial activities of medicinal plants are mostly carried out in Pakistan and India for ethno-pharmacological information, while critically to evaluate the relationship between the antimicrobial potential, phyto-chemical isolation and traditional medicine uses. Medicinal plants and Silver Nanoparticles studies are very important for various types of biological activities and there different therapeutic applications. Plant based silver nanoparticles have open applications in various fields such as optical, electronic and various biological properties. Due to these emergent potentials of Silver Nanoparticles, it is also used as therapeutic platforms in biomedical agriculture/apiculture. Furthermore, before their wide use in medical fields and apiculture, it is very important to know their impact on human health adult bees and hive products as well. This review indicates general information about the different medicinal plants having bactericidal, miticidal, virucidal etc potentials which have been used globally. We expect that this review will be helpful for future studies because these medicinal plants have various important phytochemicals which are an easy tool for scientific studies to choose the valuable plants and their potential for bactericidal activities.

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