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## Antimicrobial activity of crude aqueous extracts of *Moringa oleifera*, *Azadirachta indica*, *Carica papaya*, *Tinospora cordifolia* and *Curcuma longa* against certain bacterial pathogens

**Adil Rasool Paray, M Bhakat, TK Mohanty, P Behare, SA Lone, UR Parry, R Kumar, Ranjana Sinha, HP Yadav, A Rahim, Z Danish and N Shah**

### Abstract

Based on ethno pharmacological and taxonomic information, antimicrobial activities of crude aqueous extracts of five medicinal plants including leaves of *Moringa oleifera*, *Azadirachta indica*, *Carica papaya*, stem and bark of *Tinospora cordifolia*, and rhizomes of *Curcuma longa* were determined *in vitro* by agar well diffusion-method against six pathogenic bacteria. The target bacterial species were *Escherichia coli*, *Proteus* spp., *Enterococcus faecium*, *Enterococcus faecalis*, *Staphylococcus aureus* and *Streptococcus agalactiae*. Leaves of *Moringa oleifera*, *Azadirachta indica* and *Carica papaya*, stem and bark of *Tinospora cordifolia*, and rhizomes of *Curcuma longa* were collected, washed, dried, pulverized and stored at 4°C. Dried powder of selected plant tissues/parts were soaked in distilled water (1:5 ratio) and incubated at 55°C for overnight and filtered to collect the aqueous extract. The filtrate was centrifuged and aqueous extract was obtained. The antibacterial activity measured as a zone of inhibition (in mm) for *Tinospora cordifolia* extract against *E. coli*, *Proteus* spp., *E. faecium*, *E. faecalis*, *S. aureus* and *S. agalactiae* was 5.00±0.70, 11.75±0.62, 7.00±0.40, 7.75±0.25, 4.75±0.85, and 5.00±0.70, respectively. Extract of *Moringa oleifera* exhibited a zone of inhibition (mm) of 7.50±1.04, 12.75±0.85, 10.25±0.62, 10.25±0.85, 8.75±0.47, and 8.50±1.25, respectively against bacterial species mentioned. Similarly, the zone of inhibition measuring (mm), 9.00±0.81, 10.00±1.08, 9.00±0.57, 8.00±0.40, 9.00±0.81, and 4.25±0.62 was found against respective bacterial species for *Azadirachta indica* extract. In the same way, *Carica papaya* was seen to exhibit antimicrobial activity against the bacterial species mentioned to an extent of 7.00±0.40, 11.50±0.86, 8.25±0.47, 7.00±0.91, 6.75±0.85, and 7.75±0.47 mm zone of inhibition, respectively. Similarly, the zone of inhibition (mm) for *Curcuma longa* was measured to be 6.50±0.28, 4.75±0.85, 3.50±0.64, 4.25±0.85, 3.50±0.28, 3.25±0.25, respectively against *E.coli*, *Proteus* spp., *E. faecium*, *E. faecalis*, *S. aureus* and *S. agalactiae*. *M. oleifera* and *A. indica* plant aqueous extracts were seen to possess comparatively higher antibacterial activity. The current investigation supports the belief that these plants are sources of antibacterial agents.

**Keywords:** aqueous, extract, *Moringa oleifera*, *Azadirachta indica*, *Carica papaya*, *Tinospora cordifolia*, *Curcuma longa* and bacteria

### Introduction

Plants tissues and extracts employed in traditional medicine possess a wide range of constituents that can treat infectious diseases. As per World Health Organization (WHO) more than 80% of the world's population relies on traditional medicine for their primary healthcare needs. The medicinal value of plants lies in some phytochemical constituents that produce a definite physiological and pharmacological action in the body. The most important of these bioactive compounds of plants are alkaloids, flavonoids, tannins and phenolic compounds (Edeoga *et al.*, 2005) [15]. Medicinal plants discovered by traditional societies are proving to be an important source of potentially therapeutic drugs and antimicrobial agents. This approach is actually one of several methods that can be applied in selected plants for pharmacological studies (Biswas *et al.*, 2002) [9]. Plants are the richest resource of drugs of traditional systems of medicine, modern medicines, nutraceuticals, food supplements, folk medicines, pharmaceutical intermediates and chemical entities for synthetic drugs (Hammer *et al.*, 1999) [21]. Plants represent the cheapest and safer alternative sources of antimicrobials. Plants like *Tinospora cordifolia* (Giloy), *Azadirachta indica* (Neem), *Carica papaya* (Papita), *Curcuma longa* (Turmeric), and *Moringa oleifera* (Drumstick tree) are known for their antimicrobial and other medicinal properties (Reddy *et al.*, 2015; Rudrappa *et al.*, 2008; Mughal *et al.*, 1999) [41, 43, 29].

*Tinospora cordifolia* (Giloy), one of the noncontroversial and extensively used herbs in Ayurvedic and traditional folklore medicine, is a large deciduous climbing shrub found throughout India. It is known by multiple names like Guduchi, Giloy or Amrita, etc. *T. cordifolia* is a member of Menispermaceae family. It is well known that *Tinospora cordifolia* has antimicrobial property (Reddy *et al.*, 2015) [41]. *Azadirachta indica* (Neem), one of the most useful traditional medicinal plants, is still regarded as "Village dispensary" in India. Most of the parts of the plant such as fruits, seeds, leaves, bark and roots contain compounds with proven antibacterial, antiseptic, antiviral, antipyretic, anti-inflammatory, antiulcer and antifungal properties. *Carica papaya* (Papaya/Papita) belongs to family Caricaceae. Traditionally, its leaves have been used for treatment of a wide range of ailments, including malaria, dengue and jaundice, etc. Various plant tissues of it have antibacterial properties and are effective against various pathogenic organisms. *Curcuma longa* (Turmeric) belongs to Zingiberaceae family. *Curcuma longa* rhizome has been traditionally used as antimicrobial agent (Rudrappa *et al.*, 2008) [43]. Several studies have reported the broad-spectrum antimicrobial activity for curcumin including antibacterial, antiviral, antifungal, and antimalarial activities. *Moringa oleifera* is a medicinally important plant, belonging to family Moringaceae. The plant is native to the Indian subcontinent and is well recognized in India, Pakistan, Bangladesh and Afghanistan as a folkloric medicine (Mughal *et al.*, 1999) [29]. The tree is known by many regional names such as Benzolive, Drumstick tree, Horseradish tree, Kelor, Mlonge, Marango, Mulangay, Sajna and Saijihhan (Fahey, 2005) [16]. *Moringa oleifera* has wide range of antimicrobial properties which have been investigated by a number of studies, using different part and different way of extraction (Adriana *et al.*, 2007) [2]. Therefore, the current study was aimed at investigation of antibacterial activity of these plants using crude aqueous extracts against selected pathogenic bacteria.

## Materials and Methods

### Collection of plant tissues

*Moringa oleifera*, *Azadirachta indica* trees, and *Carica papaya* plants located within institute campus of ABRC, ICAR-NDRI, were identified, and mature fresh leaves were harvested. Similarly, the stem of *Tinospora cordifolia*, and rhizomes of *Curcuma longa* were collected. The collected parts were washed with fresh water followed by distilled water and then air dried for 24 hours at room temperature. The dried plant parts were kept in a hot air oven at 45°C for complete removal of moisture. After drying plant tissues collected were blended, pulverized and stored at 4°C. The whole experiment was conducted using a single source of dried powder of selected plant species.

### Preparation of extracts

Fifty grams of dried powder of selected plant tissues/parts were soaked in 250mL of autoclaved distilled water (1:5 ratio) and incubated at 55°C for overnight in a hot air oven. After incubation filtrate and rest of the residue were separated using cheese cloth. Further, the filtrate was subjected to filtration through filter paper grade-40. Aqueous extract was aliquoted and stored at -20°C till further use. Plate 1 and Plate 1a shows the preparation of plant aqueous extracts.

## Procurement of bacterial cultures

The cultures were procured from National Collection of Dairy Cultures, NCDC, Division of Dairy Microbiology, ICAR-NDRI, Karnal.

## Bacterial susceptibility testing

Assessment of antibacterial activity of these plant aqueous extract against target organisms was done by agar well diffusion assay, according to the method of Wang *et al.* (2012). The sterile plates were previously labelled with description and date. To each petri plate, 15 to 20 mL of liquefied sterilized nutrient agar was transferred and allowed to cool and set. The bacterial cultures were activated prior to the experiment. Soft agar containing target cultures (200 µL) was overlaid. The wells were made with the help of well borer (6 mm). Hot water extracts of plant parts (300 µL) were added into the wells. Finally, petri plates were kept for proper diffusion and overnight incubated at 37°C for 24 hours. At the end of the incubation period, zone formation surrounding the well was measured in mm.

## Statistical analysis

The experiment was done in four replicates, and the data were analyzed using one way ANOVA with post hoc comparison done by Tukey's multiple pairwise comparison test, by use of SPSS software.

## Results

All the five herbal aqueous extracts showed antibacterial activity against all six target bacterial species, although to a varying degree, as shown in Table 1. It was evident from the zone of inhibition around the wells laden with aqueous extracts, seen in petriplates after incubation. Clear variation in the antibacterial activity of the herbal extracts was seen, against all selected organisms. The zone of inhibition also differed for the same extract against different bacterial species (Plate 2).

*Tinospora cordifolia* (Giloy, G) showed the antibacterial activity against all the six target bacterial species. The zone of inhibition measured (in mm) for it against *Escherichia coli*, *Proteus* spp., *Enterococcus faecium*, *Enterococcus faecalis*, *Staphylococcus aureus* and *Streptococcus agalactiae* were 5.00±0.70, 11.75±0.62, 7.00±0.40, 7.75±0.25, 4.75±0.85, and 5.00±0.70, respectively. Extract of *Moringa oleifera*(M) exhibited a zone of inhibition (mm) of 7.50±1.04, 12.75±0.85, 10.25±0.62, 10.25±0.85, 8.75±0.47, and 8.50±1.25, respectively against bacterial species mentioned. Similarly, the zone of inhibition measuring (mm), 9.00±0.81, 10.00±1.08, 9.00±0.57, 8.00±0.40, 9.00±0.81, and 4.25±0.62 was found against respective bacterial species for *Azadirachta indica* (Neem, N) extract. In the same way, *Carica papaya* (Papita, P) was seen to exhibit antibacterial activity against the bacterial species mentioned earlier to an extent of 7.00±0.40, 11.50±0.86, 8.25±0.47, 7.00±0.91, 6.75±0.85, and 7.75±0.47 mm zone of inhibition, respectively. In the same manner, the zone of inhibition (mm) for *Curcuma longa* (Turmeric, T) was measured to be 6.50±0.28, 4.75±0.85, 3.50±0.64, 4.25±0.85, 3.50±0.28, 3.25±0.25, respectively against *E.coli*, *Proteus* spp., *E. faecium*, *E. faecalis*, *S. aureus* and *S. agalactiae*.

*Escherichia coli* was seen to be susceptible to all the five extracts (Fig. 1), with *Azadirachta indica* showing highest activity measured as zone of inhibition in mm (9.00±0.81),

followed by *Moringa oleifera* (7.50±1.04), *Carica papaya* (7.00±0.40), *Curcuma longa* (6.50±0.28) and *Tinospora cordifolia* (5.00±0.70). However, the difference in activity of *Azadirachta indica*, *Moringa oleifera*, *Carica papaya* and *Curcuma longa* was non-significant (P>0.05). The activity of *Tinospora cordifolia* differed significantly (P<0.05) from *Azadirachta indica* only, and not from rest of the extracts.

*Proteus spp.* showed susceptibility to all the extracts, and the highest activity for each of the extracts was seen against it (Fig. 2). *Moringa oleifera* extract was observed to have highest inhibitory activity against it, measured as a zone of inhibition (12.75±0.85 mm). This was followed by *Tinospora cordifolia* (11.75±0.62 mm), *Carica papaya* (11.50±0.86 mm) and *Azadirachta indica* (10.00±1.08 mm). The difference in activity was however statistically non-significant (P>0.05). The lowest extent of activity was observed for an extract of *Curcuma longa* (4.75±0.85), which differed significantly (P<0.05) from the rest four extracts.

*Enterococcus faecium* was also found susceptible to the inhibitory action of plant aqueous extracts mentioned (Fig. 3). *Moringa oleifera* extract exhibited highest inhibitory activity against it, measured as a zone of inhibition of 10.25±0.62 mm. Its activity differed non-significantly (P>0.05) with *Azadirachta indica* and *Carica papaya* measuring zone of inhibition (mm) as 9.00±0.57 and 8.25±0.47, respectively. Zone of inhibition measured for *Tinospora cordifolia* was 7.00±0.40 mm, which was significantly different (P<0.05) from that of *Moringa oleifera*. However, it differed non-significantly (P>0.05) when compared with activities of *Azadirachta indica* and *Carica papaya*. *Curcuma longa* showed the least activity with a zone of inhibition measuring 3.50±0.64 mm. The activity of *Curcuma longa* was significantly lower (P<0.05) when compared to other four extracts.

*Enterococcus faecalis* also showed susceptibility to all aqueous extracts used, although to a varying degree (Fig. 4). The highest activity against it was seen for *Moringa oleifera*

extract (10.25±0.85 mm). This was followed by *Azadirachta indica* (8.00±0.40 mm) and *Tinospora cordifolia* (7.75±0.25 mm). The difference between these three was however statistically non-significant (P>0.05). *Carica papaya* showing 7.00±0.91 mm, the zone of inhibition differed in its activity, significantly (P<0.05) from *Moringa oleifera* and not from any of other extracts. *Curcuma longa* with a zone of inhibition of 4.25±0.85 mm differed significantly (P<0.05) in its activity from all other extracts.

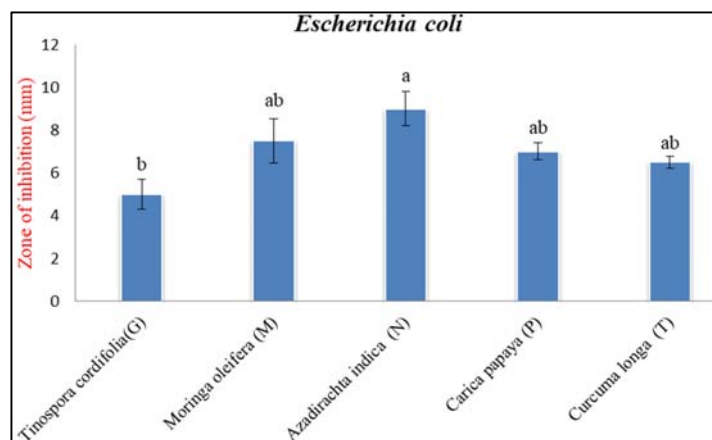
*Staphylococcus aureus* was observed to be susceptible to all the extracts (Fig. 5), with *Azadirachta indica* having highest activity against it, measuring a zone of inhibition of 9.00±0.81 mm. Next to it were *Moringa oleifera* (8.75±0.47 mm) and *Carica papaya* (6.75±0.85 mm). Both of these differed non-significantly (P>0.05) when compared to *Azadirachta indica* and also amongst themselves. These were followed by *Tinospora cordifolia* (4.75±0.85 mm) and *Curcuma longa* (3.50±0.28 mm), in their antibacterial activity against *S. aureus*. *Tinospora cordifolia* showed non-significant (P>0.05) difference when compared to *Carica papaya*. The activity of *Curcuma longa* was significantly lower (P<0.05) than all other extracts.

*Streptococcus agalactiae*, like the other target bacterial species, showed susceptibility to extracts (Fig. 6) although to a varying extent. *Moringa oleifera* extract showed the highest zone of inhibition (8.50±1.25 mm), followed by *Carica papaya* (7.75±0.47 mm). However, the difference in activity between the two was statistically non-significant (P>0.05). After these, the activity was seen in the extracts of *Tinospora cordifolia* (5.00±0.70 mm) and *Azadirachta indica* (4.25±0.62 mm). The difference in activity of these two was non-significant (P>0.05). However, both differed significantly (P<0.05) from rest three extracts. *Curcuma longa* (3.25±0.25 mm) exhibited lowest antibacterial activity against *Streptococcus agalactiae*. Its activity differed significantly (P<0.05) from rest of four extracts.

**Table 1:** Antibacterial activity (zone of inhibition) of plant aqueous extracts against various bacterial species (Mean ± SE; n=4)

Bacterial species	<i>Tinospora cordifolia</i> (G) mm	<i>Moringa oleifera</i> (M) mm	<i>Azadirachta indica</i> (N) mm	<i>Carica papaya</i> (P) mm	<i>Curcuma longa</i> (T) mm
<i>Escherichia coli</i>	5.00 <sup>b</sup> ± 0.70	7.50 <sup>ab</sup> ± 1.04	9.00 <sup>a</sup> ± 0.81	7.00 <sup>ab</sup> ± 0.40	6.50 <sup>ab</sup> ± 0.28
<i>Proteus spp.</i>	11.75 <sup>a</sup> ± 0.62	12.75 <sup>a</sup> ± 0.85	10.00 <sup>a</sup> ± 1.08	11.50 <sup>a</sup> ± 0.86	4.75 <sup>b</sup> ± 0.85
<i>Enterococcus faecium</i>	7.00 <sup>b</sup> ± 0.40	10.25 <sup>a</sup> ± 0.62	9.00 <sup>ab</sup> ± 0.57	8.25 <sup>ab</sup> ± 0.47	3.50 <sup>c</sup> ± 0.64
<i>Enterococcus faecalis</i>	7.75 <sup>ab</sup> ± 0.25	10.25 <sup>a</sup> ± 0.85	8.00 <sup>ab</sup> ± 0.40	7.00 <sup>bc</sup> ± 0.91	4.25 <sup>c</sup> ± 0.85
<i>Staphylococcus aureus</i>	4.75 <sup>bc</sup> ± 0.85	8.75 <sup>a</sup> ± 0.47	9.00 <sup>a</sup> ± 0.81	6.75 <sup>ab</sup> ± 0.85	3.50 <sup>c</sup> ± 0.28
<i>Streptococcus agalactiae</i>	5.00 <sup>bc</sup> ± 0.70	8.50 <sup>a</sup> ± 1.25	4.25 <sup>c</sup> ± 0.62	7.75 <sup>ab</sup> ± 0.47	3.25 <sup>c</sup> ± 0.25

Means bearing different superscripts in a row differ significantly (P<0.05)



**Fig 1:** Antibacterial activity of plant extracts (300 µL) against *E.coli* Values bearing different superscripts differ significantly (P<0.05)

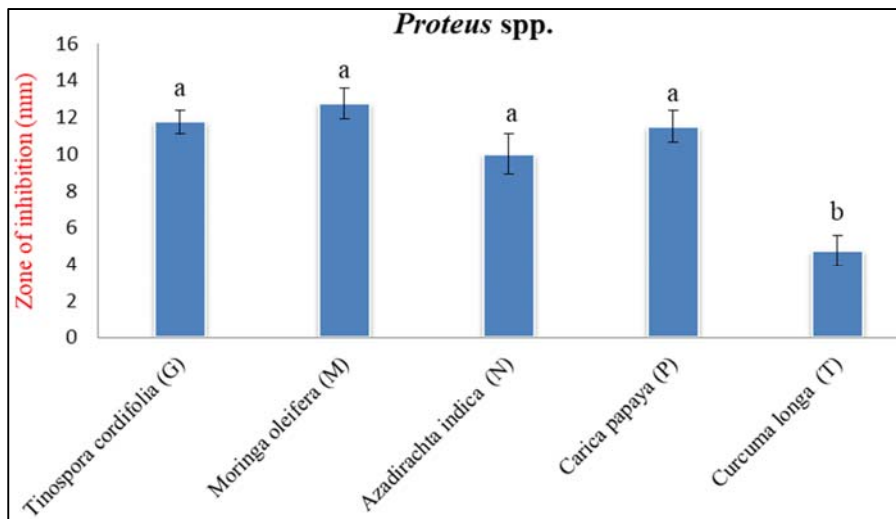


Fig 2: Antibacterial activity of plant extracts (300 µL) against *Proteus* spp. Values bearing different superscripts differ significantly (P<0.05)

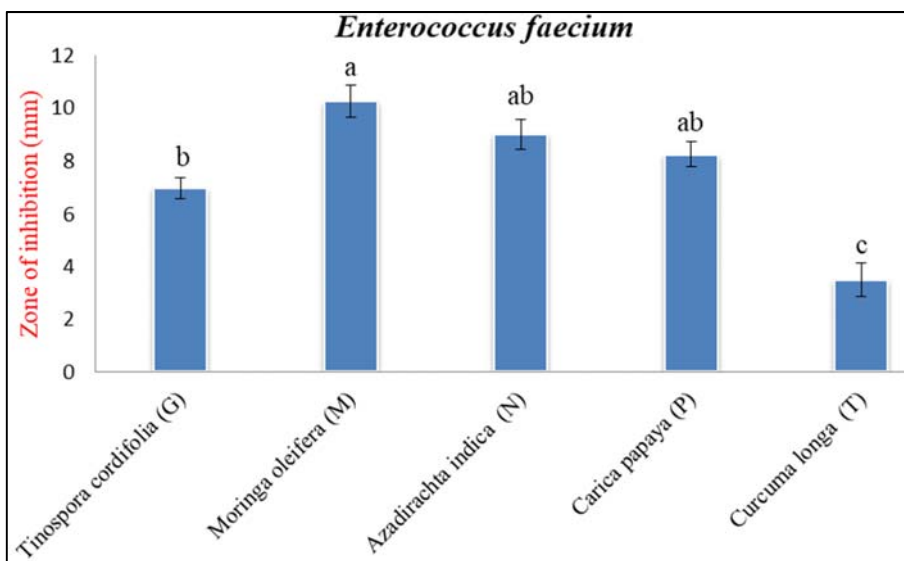


Fig 3: Antibacterial activity of plant extracts (300 µL) against *E. faecium* Values bearing different superscripts differ significantly (P<0.05)

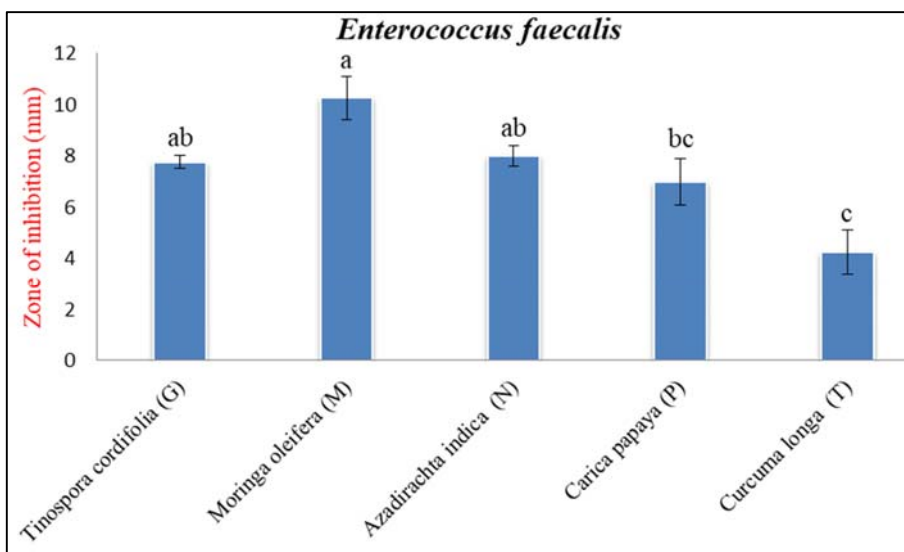


Fig 4: Antibacterial activity of plant extracts (300 µL) against *E. faecalis* Values bearing different superscripts differ significantly (P<0.05)

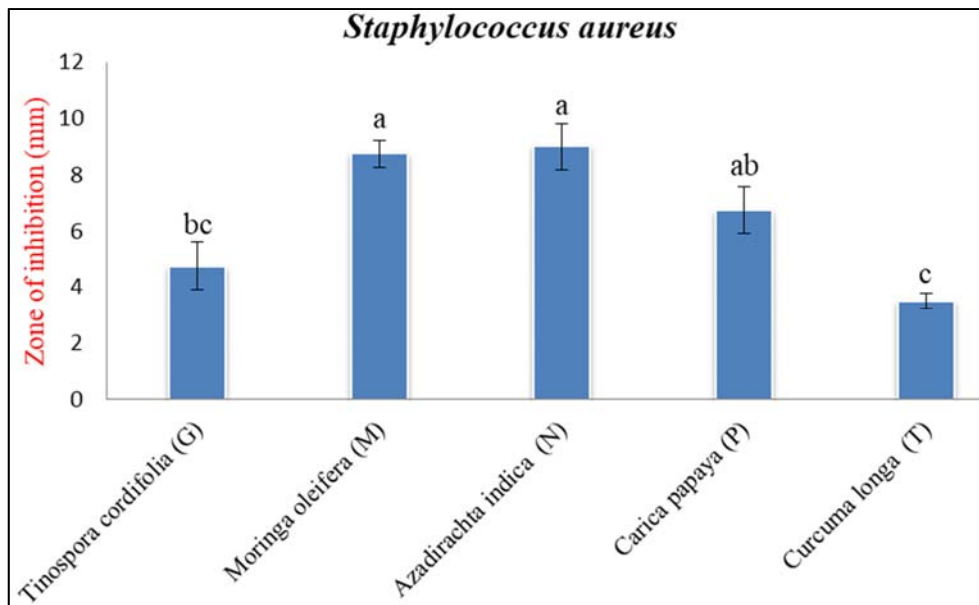


Fig 5: Antibacterial activity of plant extracts (300 µL) against *S. aureus* Values bearing different superscripts differ significantly (P<0.05)

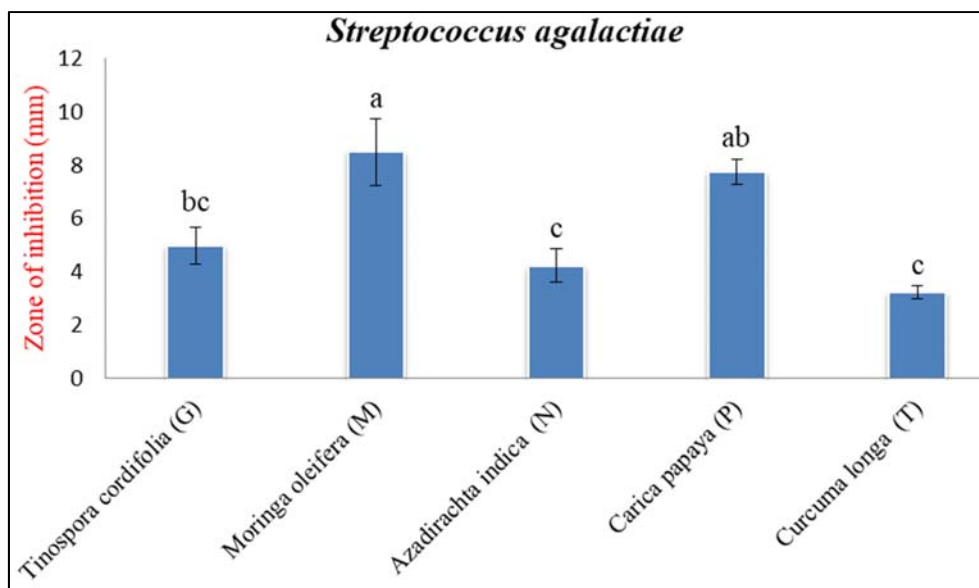


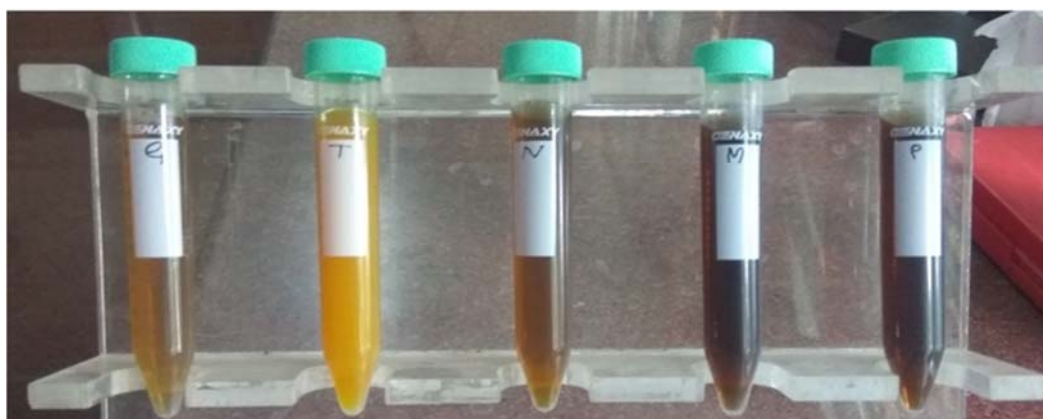
Fig 6: Antibacterial activity of plant extracts (300 µL) against *S. agalactiae* Values bearing different superscripts differ significantly (P<0.05)



1



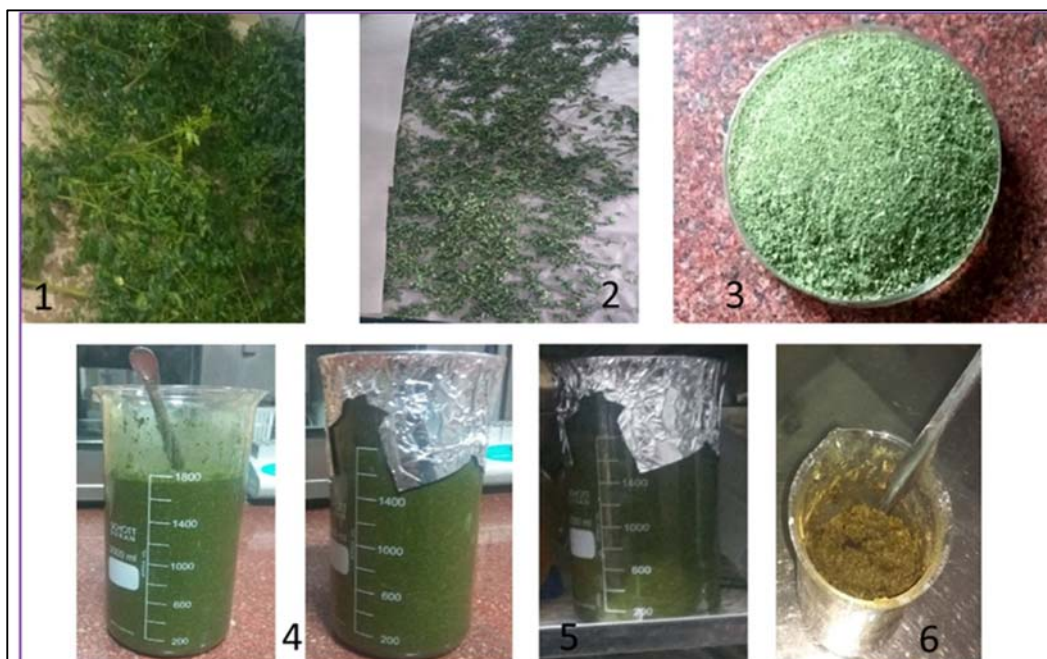
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**Plate 1:** Preparation of plant aqueous extracts:

1. Dried powder of stem and bark of *Tinospora cordifolia*, Giloy (G); rhizomes of *Curcuma longa*, Turmeric (T); leaves of *Azadirachta indica*, Neem(N), *Moringa oleifera* (M) and *Carica papaya*, Papita (P).
2. Powders mixed with distilled water (1:5), then incubated overnight at 55°C.
3. Collected aqueous extracts



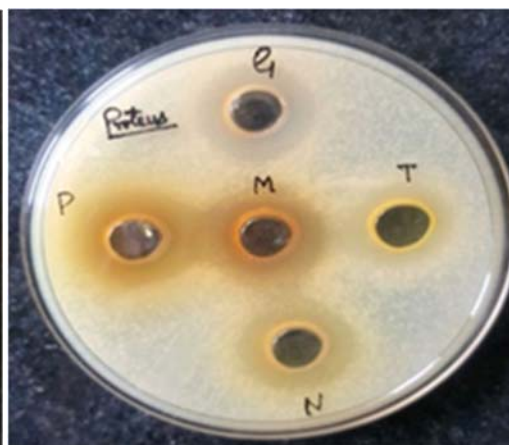


**Plate 1a:** Preparation of *Moringa oleifera* leaf extract

1. Fresh *Moringa oleifera* leaves (washed after collection).
2. Drying of *Moringa oleifera* leaves under shade at room temperature.
3. *Moringa oleifera* dried leaf powder.
4. *Moringa oleifera* leaf powder mixed with distilled water (1:5).
5. Incubation at 55°C overnight.
6. *Moringa oleifera* leaf powder (mixed with distilled water) after incubation.
7. Collection of *Moringa oleifera* leaf extract after filtration.
8. Residue left.



1



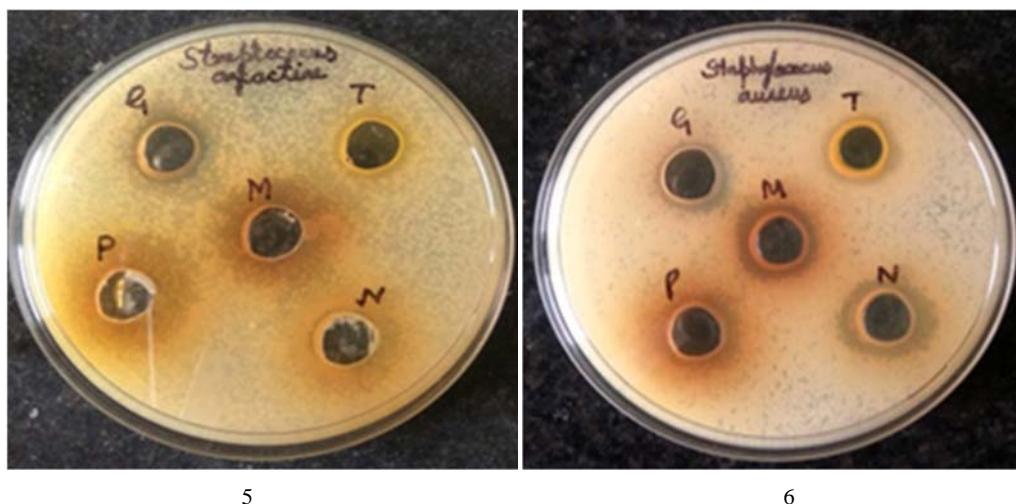
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**Plate 2:** Antibacterial activity of plant aqueous extracts against various bacterial species.

1: *E. coli* 2: *Proteus* spp. 3: *E. faecium* 4: *E. faecalis* 5: *S. aureus* 6: *S. agalactiae*

*Tinospora cordifolia*, Giloy (G); *Carica papaya*, Papita (P); *Moringa oleifera* (M); *Azadirachta indica*, Neem (N); *Curcuma longa*, Turmeric (T)

## Discussion

The results revealed the broad spectrum activity of plant aqueous extracts. The results were in accordance with various earlier reports advocating antibacterial activity of herbal extracts under present study. However, the variations in the zone of inhibition observed may be attributed to geographical reasons leading to slight changes in phytochemical constituents.

The result of the present investigation regarding the antimicrobial activity of *Tinospora cordifolia* is supported by various earlier studies. Reddy *et al.* (2015) [41] reported that *Tinospora cordifolia* is known to have antibacterial property. Narayanan *et al.* (2011) [32] reported activity of its extract against *E. coli*, *S. aureus*, and various other Gram-positive bacteria. Shanthi and Nelson (2013) [48] also observed the antimicrobial activity of its aqueous extracts. Francesca *et al.* (2014) [17] indicated its activity against methicillin-resistant *Staphylococcus aureus* (MRSA). Nagaprashanthi *et al.* (2012) [31] also demonstrated antibacterial activity of hydro alcoholic stem extract of *Tinospora cordifolia* against bacterial species including *Staphylococcus aureus*, *Escherichia coli*, etc. as well as its antifungal activity. Mishra *et al.* (2014) [28] have also reported antibacterial activity of *T. Cordifolia* against *E. coli*, *S. aureus*, *P. vulgaris*, etc. Sharma and Prajapati (2016) [49] have observed the antibacterial activity of *Tinospora cordifolia* against *E. coli*, *S. aureus* with a different zone of inhibitions at different concentrations. *Tinospora cordifolia* has been subjected to chemical investigations extensively and a number of chemical constituents belonging to different groups such as alkaloids, terpenoids, lignans and flavonoids, tannins, cardiac glycosides, phenolics, aliphatic compounds and steroids have been reported (Bansal *et al.*, 2012) [7], which may account for the antibacterial property of its extracts. It has been reported that many of these phytochemicals present in stem extracts of this plant have antibacterial activity, like Berberine (Cernakova *et al.*, 2002) [13], Palmitine (Yuan *et al.*, 2010) [58], Isocolumbin, Jatrorrhizin (Yuan *et al.*, 2010) [58], Palmitine and Barberine (Vollekova *et al.*, 2003) [56] have been reported to have an antifungal activity too.

Similarly, results of antibacterial activity of *Azadirachta indica* (Neem) can be well said to be in accordance with several earlier studies. Bohora *et al.* (2010) [10] have observed the significant antibacterial activity of Neem leaf extract against *E. faecalis* and mixed bacterial cultures. Singh and

Sastri (1981) [52] observed its antibacterial activity. Bezalwar *et al.* (2014) [8] reported its anti-*Staphylococcal* activity. Both Neem and Turmeric extracts possess antibacterial activity against different organisms including *S. aureus*, *E. coli*, etc. (Panday *et al.*, 2014) [39]. Alzoreky and Nakahara (2003) [3] have also reported its antibacterial activity. Sinaga *et al.* (2016) [50] reported that Gram-positive bacterial strains were more sensitive than the Gram-negative ones. Maragathavalli *et al.* (2012) [27] also found the antimicrobial activity of Neem leaf extracts. Owolabi *et al.* (2017) [38] reported antibacterial activity of Neemleaf water extract against *Escherichia coli*, and *Staphylococcus aureus*, showing a clear zone of inhibition ranging from  $10 \pm 0$  mm to  $15.5 \pm 0.71$  mm. Constituents of alkaloids, terpenoids, tannins and flavonoids of *A. Indica* (Makkar *et al.*, 2007) [25] are responsible to overcome microbial infection especially having antioxidant and antibacterial biological activities (Scalbert and Williamson, 2000) [47]. These chemicals might show the antibacterial activity by their ability to make a complex with the bacterial cell walls. Inhibitory activity towards DNA topoisomerase II enzyme by azadiractin, a bioactive metabolite of Neem (Scalbert, 1991) [46] might also involve in the antibacterial potential. *Azadirachta indica* leaves possessed good antibacterial activity (Saradha and Subbarao, 2011) [45]. Some bioactive compounds from Neem leaf extract include nimbidin, mahmoodin having antibacterial activity; and cyclic trisulphide and cyclic tetrasulphide, having antifungal activity (Biswas *et al.*, 2002) [9].

In the same way as above, results of antibacterial activity of *C. papaya* were supported by earlier findings of various researchers. Singh *et al.* (2016) [51], reported activity of *C. papaya* and Neem water extract against gram-positive *S. aureus*. Antibacterial activity of aqueous extract of *Carica papaya* leaves was also reported by Chandra *et al.* (2011) [14] against *S. aureus* and *E. coli*. Mangalanayaki and Nirosha (2013) [26] demonstrated antibacterial activity of the leaves of the *Carica papaya* against *S. aureus* and *E. coli*, etc. by well diffusion method. Ogunjobi and Ogunjobi (2011) [37] reported activity against eight different bacterial strains, including *Staphylococcus aureus* and *Proteus vulgaris* also. Among the Gram-positive and Gram-negative bacteria tested against the leaf extract of *C. papaya*, the Gram-negative bacteria were more susceptible, especially *Proteus vulgaris* to the extracts. The fact that the extracts were active against both Gram



negative and Gram-positive bacteria, may indicate a broad spectrum of activity. The results cited here were in support of the results found in the present investigation. Preliminary phytochemical analyses have revealed the presence of alkaloids, tannins, saponins and phenols (Nirosha and Mangalanayaki, 2013) [26] in its extracts. Papaya leaf extracts have phenolic compounds, such as protocatechuic acid, p-coumaric acid, 5, 7- dimethoxycoumarin, caffeic acid, kaempferol, quercetin and chlorogenic acid (Romasi *et al.*, 2011) [42]. Young leaves are rich in flavonoids (kaempferol and myricetin), alkaloids (carpaine, pseudocarpaine, dehydrocarpaine I and II), phenolic compounds (ferulic acid, caffeic acid, chlorogenic acid), the cynogenetic compounds (benzylglucosinolate) found in leaves. It is by dint of phytochemicals in the extracts, that they show an antibacterial property.

*Curcuma longa* rhizome has been traditionally used as an antimicrobial agent (Rudrappa *et al.*, 2008) [43]. Curcumin or diferuloylmethane with a chemical formula of (1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-dione) and other curcuminoids constitute the main phytochemicals of *Curcuma longa* rhizome (Ammon *et al.*, 1991) [4]. The antibacterial study on aqueous extract of *C. longa* rhizome demonstrated the inhibitory activity against *Staphylococcus aureus*, and *E. coli* amongst various other organisms (Niamsa *et al.*, 2009) [34]. The extract of turmeric showed activity against *S. aureus*, as studied by Ungphaiboon *et al.* (2005) [54]. The extracts of *C. longa* demonstrated antibacterial effect against *Streptococcus*, *Staphylococcus* and many otherspecies. Indeed, it was shown that the addition of 0.3% (w/v) of aqueous curcumin extract to the cheese caused the reduction in bacterial counts of various organisms including *E. coli*. Moreover, it has decreased the *S. aureus* contamination after 14 days of cold storage (Hosny *et al.*, 2011) [22]. Curcumin also exhibited inhibitory activity on methicillin-resistant *S. aureus* strains (MRSA) (Mun *et al.*, 2013) [30]. Kumar *et al.* (2016) [24], demonstrated activity of extracts of Neem and Turmeric and found 11±1 mm zone of inhibition against *E.coli* for extracts of both, using leaves of Neem and rhizome of Turmeric for extract preparation. These studies mentioned are in accordance with our findings. Reduction in proteinase secretion and alteration of membrane-associated properties of ATPase activity are some possible critical factors for antibacterial activity of curcumin, present in the extract of *Curcuma longa* rhizome (Neelofar *et al.*, 2011) [33].

Similar results as that of the present study have been reported by some earlier researchers, although to a varying degree of activity, in case of *Moringa oleifera*. *Moringa oleifera* has a wide range of antibacterial properties which have been investigated by a number of studies, using different parts and different ways of extraction (Adriana *et al.*, 2007) [2]. Extracts of various *Moringa* tissues have been used as antibacterial agents (Caceres *et al.*, 1991) [12]. *Moringa* leaf, in the opinion of Thilza *et al.* (2010) [53], is having a natural antibacterial property. Bukar *et al.* (2010) [11] reported antibacterial activity of *Moringa oleifera* extracts against *Escherichia coli*, *Staphylococcus aureus* and many other bacterial species. Gomashe *et al.* (2014) [20] revealed that aqueous extract of *Moringa oleifera* was inhibitory to *Escherichia coli* (12 mm inhibition zone). Nikkon *et al.* (2003) [35] reported *in-vitro* antibacterial activity of the compound isolated from *Moringa oleifera* against *Staphylococcus aureus*. Abalaka *et al.* (2012) [1] reported aqueous crude extracts of the leaf of *M. oleifera* were active against *E. coli* and other few bacteria. *Escherichia*

*coli* showed a zone of inhibition higher than *Staphylococcus aureus*. The variations in activity may be due to a variety of bacterial gene that leads bacteria to be resistant to antibacterial agents. Priya *et al.* (2011) [40] evaluated the antibacterial activity in the aqueous leaf extracts of *Moringa* against pathogenic bacteria like *Escherichia coli* and *Staphylococcus aureus*. Thilza *et al.* (2010) [53] and Anthonia (2011) [5] reported a sensitivity of *E. coli* to extract of *Moringa oleifera*. Vinoth *et al.* (2012) [55] screened *Moringa oleifera* leaf water extract for antibacterial activity and found *Staphylococcus aureus* sensitive to it. Saadabi *et al.* (2011) [44] reported leaf extracts had activity against *Enterococcus faecalis*, and *Escherichia coli*. Priya *et al.* (2011) [40] also reported that leaf extracts showed moderate inhibition against *Escherichia coli*, and *Staphylococcus aureus*. Ashok *et al.* (2003) [6] reported antibacterial activity of the aqueous extracts of *Moringa oleifera* as inhibitory against *S. aureus* (10 mm), *E. coli* (12 mm) and *P. vulgaris* (10 mm).

All the above-cited research findings are in support of antibacterial potential of *Moringa oleifera* leaf extract. *Moringa* contains a range of fairly unique phytochemicals possessing antibacterial activity. Khosla (2017) [23], reported the presence of phytochemicals having antibacterial activity in *Moringa oleifera* aqueous leaf extract, including, 2-Formyl-1-indanone, 4-phenyl-1,2,3-thiadiazole, methyl cinnamate, 2-naphthol, glyphosate, evoxine, pseudopelletierine, 2-methylimidazole, 5-phenyl-1,3-pentadiyne, droserone, danielone, quinic acid, s-propyl 1-propanesulfinothioate, etc. *Moringa oleifera* also has been reported to contain benzyl isothiocyanate, niazimicin, pterygospermin, and 4-{ $\alpha$ -L-rhamnopyranosyloxy} benzyl glucosinolate, some of which have antibacterial activity (Fuglie, 2000; Fuglie *et al.*, 2001) [18, 19].

Further, the anti-microbial activities of these plant extracts could be enhanced if active components are purified and adequate dosage determined for proper administration. This will go a long way in proper usage of these herbal constituents in treating various ailments, and also in curbing administration of inappropriate concentration, a common practice among many traditional medicines practitioners. But *in vivo* studies on these medicinal plants are necessary and should aim at determining toxicity of active constituents, their negative effects, serum- attainable levels, pharmacokinetic properties and diffusion in different body tissues. Based on this, further chemical and pharmacological investigations to isolate and identify active chemical constituents in extracts of plants and to screen other potential bioactivities may be recommended. Individual plants may vary in chemical make-up because of genetic and environmental factors, and hence resulting in varying activities. The studies carried out by different scientists during different times have proved the natural variability in percentage content of the phytochemicals and hence the antibacterial activity.

## Conclusion

The crude aqueous extracts of leaves of *Moringa oleifera*, *Azadirachta indica*, *Carica papaya*, stem and bark of *Tinospora cordifolia*, and rhizomes of *Curcuma longa* possess antibacterial activity, and could be a possible source to obtain new and effective antibacterial agents of plant origin that can be employed to treat infections caused by multi-drug resistant strains of pathogens. However, it is necessary to further investigate the active bio components, their toxicity, side effects and pharmaco-kinetic properties. Further, individual plants vary in their phytochemical make-up, owing to

geographical, soil and environmental reasons, and accordingly the biological activity of extracts may differ. The obtained results provide support to traditional use of these plant extracts in treating infectious diseases.

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#### Conflict of Interest

Authors do not have any conflict of interest.

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