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Antibacterial potential of some plants of traditional use in India against pathogenic strains of *S. aureus*

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Comments

This study exposed a number of useful phytochemicals with appreciable activity against pathogenic strains of *S. aureus*. The findings can usefully be applied by researchers elsewhere for comparison of bioactive constituents and this might be helpful in the rational standardization of herbal remedies obtained from the same plant species elsewhere.

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ABSTRACT

Objective: To evaluate antibacterial sensitivity of 43 ethnomedicinally important plants belonging to 25 different families from Western Uttar Pradesh, a northern province in India, against hospital isolated pathogenic strains of *Staphylococcus aureus* (*S. aureus*).

Methods: Methanol (MeOH) and aqueous extracts of plants were subjected to sensitivity test against *S. aureus* ATCC 25953 and two hospital isolated virulent strains of *S. aureus* SA1 and SA2 following disc diffusion assay to determine sensitivity and agar dilution method to test minimum inhibition concentration using Mueller-Hinton agar.

Results: Potential antibacterial activity was recorded for MeOH extracts against test pathogens, while moderate antibacterial activity was observed in case of aqueous extracts. Out of 43 plant species, 39 species were found sensitive to tested strains. Minimum inhibition concentration values of MeOH extracts were demonstrated at low concentration ranging from 15.5 mg/mL up to 45.5 mg/mL compared to aqueous extracts which were observed ranging from 30.0 mg/mL up to 95.0 mg/mL.

Conclusions: The present findings strongly support traditional uses of these plants in the treatment of infectious maladies and further urge of phytochemical and pharmacological research to develop safer and cheaper drugs for the benefit of ailing humanity.

KEYWORDS

Antibacterial sensitivity, Crude extracts, Ethnobotanical plants, Traditional uses, *S. aureus*, Disc diffusion, MIC

1. Introduction

People have been using plants for the management of different chronic diseases since antiquity[1]. Indigenous systems of medicine particularly Ayurveda, Unani and Chinese practice abundant use of plants or plant parts in preparation of various formulations to cure various ailments[2]. Even today, plant material continues to play a major role in primary health care as therapeutic remedies in developing countries. Besides these recognized systems of medicine, aboriginal people of many countries and various ethnic groups utilize plant-based preparations for the treatment of microorganism caused disorders like scabies, diarrhea, dysentery, typhoid, boils and suppurating wounds, *etc*[3-6]. It clearly indicates that plant-based preparation has at least some degree of antimicrobial activity[7]. The ethnobotanical, medical and phytochemical literature is replete with plant remedies used by various world cultures to ameliorate

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the related pathologies of microorganisms and confirm the presence of antibiotic-like compounds in a large number of plant species[8]. The veracity of such claims can only be established through *in vitro* testing the extracts of these plant species for antimicrobial potential[9]. A large number of plants have been tested for antimicrobial activity but still such data are lacking for a sizeable portion of Indian flora[4]. A variety of compounds, inorganic, organic and natural products have been used to check the growth of bacteria and treat the diseases caused by them. However, after the discovery of antibiotic organic compounds, synthetic or natural are largely used for chemotherapy of infectious diseases[10,11]. Earlier workers reported antibacterial activity on many of the most commonly used plants in traditional medicine[12,13].

Infectious disease is the number one cause of death worldwide, which accounts for 50% deaths in tropical countries. Bacteria have been associated with some most fatal epidemic diseases like plague, cholera, typhus, diphtheria, tuberculosis, typhoid, pneumonia and dysentery. Particularly in developing countries, in current scenario, *Staphylococcus aureus* (*S. aureus*) has emerged with new forms of virulence and new prototypes of resistance to synthetic and most advanced antimicrobial agents. *S. aureus* is a Gram-positive facultative anaerobic coccal bacterium. Diseases associated are oral and throat infections (stomatitis, tonsillitis and pharyngitis), food poisoning, pneumonia, brain abscess, toxic shock syndrome, skin diseases, folliculitis, infections associated with wounds and burns, postsurgical infections, eye infection, ear infection *etc*. Methicillin-resistant *S. aureus* has emerged to be a great health problem in almost all countries of the world. Methicillin-resistant *S. aureus* infections kill ~19 000 hospitalized American patients annually. Its management is very difficult due to methicillin resistance and controversies in its antibiotic efficacious therapy which becomes even more difficult in case of pediatric patients. Plants have been used to cure different diseases from ancient times[14-16]. In order to overcome the severe problems associated with chronic infections of *S. aureus*, there is an urgent need to identify antimicrobials that are active towards such pathogens. Hence, the present investigation is made to search cheaper and safer phytomedicine (plant-based antibiotics) originated from ethnobotany used by the health practitioners and local folklorist in the region of Western Uttar Pradesh, a northern province in India. In this context, 43 plant species were screened on the basis of their ethnomedicinal uses recorded by the authors in the study area and review of literature against different hospital isolated strains of *S. aureus*[17,18].

2. Materials and methods

2.1. Plant material

Healthy plant species were collected from different localities of rural areas belonging to 5 districts of Western Uttar Pradesh, India (Aligarh, Budaun, Bulandshahr, Farrukhabad and Hathras. The climate is dry in summer with a rise in temperature up to 42 °C and cool in winter up to 6 °C. All plant species were identified by Dr. Athar Ali Khan (Taxonomist), Department of Botany, Aligarh Muslim University Aligarh, Uttar Pradesh, India. Identified plant specimens were kept in the herbarium of the same department and voucher specimen number of each plant was registered separately.

2.2. Preparation of methanol (MeOH) extracts

Plant extracts were prepared using standard techniques[19]. Shade-dried material (leaf, fruit, root and whole plant) of each plant was pulverized in an electric grinder. Powder obtained was stored in a desiccator. About 500 g powder of each plant material was macerated with 95% MeOH in a round bottom flask at room temperature for about 24 h. Mother liquor (crude MeOH extract) was filtered out and residual plant material was again macerated with MeOH for another 24 h. The process was repeated for 4 times to ascertain the maximum yield of MeOH extract of each plant. The MeOH extracts were evaporated to dryness at 35 °C under reduced pressure using rotary evaporator (Buchi, Switzerland) and stored in the deep freezer at -18 °C till further use.

2.3. Preparation of aqueous (AQ) extracts

Shade-dried material (leaf, fruit, root or whole plant) (500 g) of each plant was pulverized and poured with double-distilled water in a closed round bottom flask, and left for 24 h at room temperature. The flask was then refluxed over hot water bath for 1 h and the mother liquor was filtered. The process was repeated for 4 times. The filtrate thus obtained was evaporated to complete dryness under reduced pressure. The residues thus obtained were stored in labeled sterilized screw capped bottles at -18 °C. All extracts were frequently checked for sterility by streaking on nutrient agar plates[20].

2.4. Bacterial susceptibility test

Disc diffusion method was used to determine susceptibility of plant extracts[20]. Standardized inoculums (1-2×10^7 CFU/mL 0.5 McFarland standard) were introduced to the surface of the plates containing Mueller-Hinton agar, which was spread evenly with a glass spreader. A sterile disk (6 mm in diameters) previously soaked in a known concentration of extract (10 mg/mL/disc) was placed at the center of the labeled seeded plate. The plates were incubated aerobically at 37 °C and examined for the zone of inhibition after 24 h.

2.5. Antibiotics

Standard sensitivity discs of chloramphenicol, ciprofloxacin and gentamycin (30 μg/mL/disc each) (Span Diagnostics Limited, Surat, Gujrat, India) were used as positive control to test the sensitivity profile against the reference bacteria.

2.6. Isolation and characterization of pathogenic clinical isolates with individual colony characteristics (S. aureus)

Colonies grown on blood agar medium were large smooth walled

and slightly raised. The colour was creamy yellow frequently surrounded by zones of clear beta-hemolysis. Colonies grown on nutrient agar were similar to blood agar but without haemolytic activity[20].

2.7. Determination of minimum inhibition concentration (MIC)

MIC was measured by agar dilution method by diluting the plant extracts in 10% dimethyl sulphoxide using various concentrations ranging from 10.0 mg/mL up to 100.0 mg/mL. Equal volume of each extract and nutrient broth were mixed in a test tube. Specifically, 0.1 mL of standard inoculums (1-2×10^7 CFU/mL) was added to each tube. Tubes were incubated aerobically at 37 °C for 18-24 h and two control tubes were maintained for each test batch. Those contained antibiotic control (tube containing plant extract and growth medium) and organism control (tube containing growth medium, physiological saline and inoculums). The lowest concentration of extract that produced no visible growth (no turbidity) when compared with the control tube was regarded as MIC[21,22].

2.8. Test of microorganisms

In the present study, following bacterial strains were used: standard strains: *S. aureus* ATCC 25953 (directly purchased from the American Type Culture Collection, USA); Hospital isolates: *S. aureus* SA1 and SA2 (procured from the Department of Microbiology, Jawaharlal Nehru Medical College, Aligarh Muslim University, Aligarh, Uttar Pradesh, India). The strains were maintained on nutrient agar slope at 4 °C and sub cultured before use.

2.9. Statistical analysis

The variation between experiments was estimated by standard deviations and statistical significance of changes was estimated by student's *t*-test method.

3. Results

International standards of sensitivity to evaluate antimicrobial potential were adopted to test MeOH and AQ extracts of 43 plant species of ethnomedicinal background belonging to 25 plant families. Plants were screened for possible antibacterial activity against one standard strain of *S. aureus* ATCC 25953 and two clinical isolates of *S. aureus* SA1 and SA2.

Table 1 demonstrates 43 plant species, solvents (MeOH & AQ) used along with their yield. Table 2 demonstrates antibacterial activity of plants screened using disc diffusion method. Table 3 demonstrates MIC values using agar dilution method. MIC values of MeOH extracts were observed at low concentrations ranging from 15.5 mg/mL up to 45.5 mg/mL, however, for AQ extracts, it were observed between 30.0 mg/mL up to 95.0 mg/mL.

Table 1
Description of plant parts used and solvent used with their yield.

Plant species used	Plant part used	Solvent used	Yield/500 g (g)
Achyranthes aspera (*A. aspera*)	Leaf	MeOH, AQ	55, 40
Acalypha indica (*A. indica*)	Leaf	MeOH, AQ	55, 41
Aegle marmelos (*A. marmelos*)	Fruit	MeOH, AQ	70, 58
Ageratum conyzoides (*A. conyzoides*)	Whole plant	MeOH, AQ	55, 42
Aloe vera (*A. vera*)	Leaf	MeOH, AQ	68, 55
Amaranthus spinosus (*A. spinosus*)	Whole plant	MeOH, AQ	55, 40
Argemone maxicana (*A. maxicana*)	Leaf	MeOH, AQ	55, 42
Bacopa monnieri (*B. monnieri*)	Whole plant	MeOH, AQ	55, 45
Boerhavia diffusa (*B. diffusa*)	Whole plant	MeOH, AQ	55, 45
Butea moonosperma (*B. moonosperma*)	Leaf	MeOH, AQ	55, 45
Calotropis procera (*C. procera*)	Leaf	MeOH, AQ	55, 42
Cassia tora (*C. tora*)	Leaf	MeOH, AQ	55, 44
Chenopodium album (*C. album*)	Leaf	MeOH, AQ	55, 45
Citrullus colocynthis (*C. colocynthis*)	Fruit	MeOH, AQ	55, 42
Clerodendrum inerme (*C. inerme*)	Leaf	MeOH, AQ	48, 36
Croton bonplandianum (*C. bonplandianum*)	Leaf	MeOH, AQ	60, 45
Cuscuta refexa (*C. refexa*)	Whole plant	MeOH, AQ	40, 55
Cycas rumphii (*C. rumphii*)	Leaf	MeOH, AQ	45, 50
Cynodon dactylon (*C. dactylon*)	Whole plant	MeOH, AQ	40, 55
Dactyloctenium aegyptium (*D. aegyptium*)	Leaf	MeOH, AQ	55, 45
Datura inoxia (*D. inoxia*)	Whole plant	MeOH, AQ	42, 55
Eclipta prostrata (*E. prostrata*)	Fruit	MeOH, AQ	68, 60
Emblica officinalis (*E. officinalis*)	Whole plant	MeOH, AQ	55 , 42
Euphorbia thymifolia (*E. thymifolia*)	Whole plant	MeOH, AQ	56, 35
Euporbia hirta (*E. hirta*)	Leaf	MeOH, AQ	56, 40
Hibiscus rosa-sinensis (*H. rosa-sinensis*)	Leaf	MeOH, AQ	40, 55
Ipomea cairica (*I. cairica*)	Leaf	MeOH, AQ	45, 50
Lantana camara (*L. camara*)	Fruit	MeOH, AQ	50, 40
Leucas cephalotes (*L. cephalotes*)	Leaf	MeOH, AQ	57, 42
Melia azedarach (*M. azedarach*)	Leaf	MeOH, AQ	55, 40
Murraya koenigii (*M. koenigii*)	Leaf	MeOH, AQ	55, 44
Nerium indicum (*N. indicum*)	Whole plant	MeOH, AQ	58, 45
Oxystelma esculentum (*O. esculentum*)	Leaf	MeOH, AQ	55, 42
Phyllanthus fraternus (*P. fraternus*)	Leaf	MeOH, AQ	56, 42
Ricinus communis (*R. communis*)	Leaf	MeOH, AQ	56, 44
Solanum nigrum (*S. nigrum*)	Leaf	MeOH, AQ	56, 38
Sida cordata (*S. cordata*)	Leaf	MeOH, AQ	56, 43
Sphaeranthus indicus (*S. indicus*)	Fruit	MeOH, AQ	56, 44
Tagetes patula (*T. patula*)	Whole plant	MeOH, AQ	56, 44
Trapa bispinosa (*T. bispinosa*)	Fruit peel	MeOH, AQ	56, 40
Tridex procumbens (*T. procumbens*)	Root	MeOH, AQ	55, 42
Trifolium alexandrinum (*T. alexandrinum*)	Leaf	MeOH, AQ	50, 40
Withania somnifera (*W. somnifera*)	Root	MeOH, AQ	56, 43

All seven Euphorbiaceous plant species, *A. indica*, *C. bonplandianum*, *E. thymifolia, E. hirta, E. officinale, P. fraternus and R. Communis* were found sensitive to test pathogens except two plants *C. bonplandianum* and *E. thymifolia* which were resistant to hospital isolated strain SA2. Out of two members of Amaranthaceae, *A. aspera* was sensitive to all strains but *A. spinosus* was found to be resistant. Of two members of Rutaceae, MeOH extracts were sensitive and AQ extract of *A. marmelos* was found to be insensitive. However, both extracts of *M. koenigii* were found to be sensitive. Out of five members of Asteraceae, *A. conyzoides, E. alba, S. indicum, T. patula and T. procumbens*, all were found to be sensitive to test pathogens except two plants *A. conyzoides* and *E. alba* were found to be resistant to SA2 strain. Liliaceae member (*A. vera*), Fabaceae members (*B. monosperma* and *T. alexandrinum*), Asclepiadaceae members (*C. procera* and *O. esculentum*), Caesalpinaceae member (*C. tora*), Meliaceae member (*M. azedarach*) and Papaveraceae member (*A. mexicana*) exhibited sensitivity to all test strains. Scrophulariaceae member

Table 2

The zone of inhibition of plants against *S. aureus* strains by disc diffusion method (mm).

Plant species	Local name	Standard strain (*S. aureus* ATCC 25953)		Hospital isolated strain (*S. aureus* SA1)		Hospital isolated strain (*S. aureus* SA2)	
		MeOH	AQ	MeOH	AQ	MeOH	AQ
A. aspera	Chirchita, apamarg, onga	10.0	7.0	10.0	7.0	10.0	7.0
A. indica	Aristamanjari, khokali	11.0	8.2	10.8	7.8	10.8	7.8
A. marmelos	Bael	8.2	N	7.8	N	7.8	N
A. conyzoides	Janglipudina	8.2	N	7.8	N	N	N
A. vera	Alua, gheegwar	10.2	7.0	10.2	7.0	10.2	7.0
A. spinosus	Katelichaulai	N	N	N	N	N	N
A. maxicana	Pilikateri	9.8	7.2	9.2	6.8	9.2	6.8
B. monnieri	Brahmi	8.8	7.0	8.0	7.0	N	N
B. diffusa	Punarnava	9.4	7.2	9.0	6.8	N	N
B. moonosperma	Dhak	11.2	9.8	10.6	9.2	10.2	8.4
C. procera	Madar, aak	11.6	8.8	10.8	8.1	10.6	7.8
C. tora	Sickle pod, sickle senna	10.2	7.0	10.0	7.0	10.0	7.0
C. album	Chaulayee	N	N	N	N	N	N
C. colocynthis	Indrayan	7.4	N	7.0	N	N	N
C. inerme	Lanjai	11.2	9.4	10.2	8.4	10.2	8.4
C. bonplandianum	Three-leaved caper, bantulsi	8.8	N	7.5	6.2	N	N
C. refexa	Aakashbel	11.2	7.4	11.2	7.4	N	N
C. rumphii	Queen sago	9.8	N	9.2	N	N	N
C. dactylon	Doob	10.8	8.4	10.2	7.4	N	N
D. aegyptium (L.)Wild.		7.7	N	7.6	N	N	N
D. inoxia	Dhatura	8.8	N	9.2	6.5	N	N
E. prostrata	Bhangra	9.7	6.2	9.7	6.2	N	N
E. officinalis	Amla	11.2	9.4	10.2	8.4	10.2	7.4
E. thymifolia	Nayoti	9.7	6.2	9.7	6.2	N	N
E. hirta	Doodhi	8.2	6.5	8.0	6.2	8.0	6.2
H. rosa-sinensis	Gudhal	11.2	N	10.8	N	10.8	N
I. cairica	Railway creeper	8.2	N	8.0	N	N	N
L. camara	Gajukampa, galpushpi	9.4	N	9.4	N	N	N
L. cephalotes	Guma	9.4	7.2	9.0	6.8	N	N
M. azedarach	Bakayan	11.2	9.4	10.2	8.4	10.2	7.4
M. koenigii	Kadipatta	10.8	8.4	10.2	8.0	10.8	7.8
N. indicum	Kaner	9.7	6.2	9.7	6.2	N	N
O. esculentum	Dudiyalata	11.8	9.2	9.8	8.4	9.4	8.2
P. fraternus	Bhuiamla	10.2	8.4	9.2	8.0	9.2	8.0
R. communis	Arand, andi	11.2	8.8	11.0	8.2	10.00	8.2
S. nigrum	Makoi	8.8	6.8	7.7	6.4	7.8	6.4
S. cordata	Bhuinli, bala	N	N	N	N	N	N
S. indicus	Mundi	11.2	9.0	11.0	8.2	10.00	8.0
T. *patula*	Genda	10.2	8.4	9.2	8	9.2	8.0
T. bispinosa	Water chestnut, singhada	12.0	8.0	N	N	N	N
T. procumbens	Khal-muriya, tal-muriya	12.2	9.4	11.2	7.0	10.9	7.0
T. alexandrinum	Barsim	8.4	6.8	8.2	6.2	8.0	6.2
W. somnifera	Ashwagandha	9.4	7.8	9.4	7.8	N	N
Chloramphenicol		14.0	-	11.0	-	10.0	-
Ciprofloxacin		20.0	-	18.0	-	18.0	-
Gentamycin		21.0	-	20.0	-	20.0	-

MeOH and AQ concentration: 10 mg/mL/disk; Values are the mean of replication of three; N: No antibacterial activity; Standard strains: chloramphenicol: 30 μg/mL/disc; ciprofloxacin: 30 μg/mL/disc; gentamycin: 30 μg/mL/disc; Incubation temperature: 37 ˚C; Incubation time: 24 h.

(*B. monnieri*), Cuscutaceae member (*C. reflexa*) and Nyctaginaceae member (*B. diffusa*) exhibited sensitivity against one test strain *i.e.*, SA1. MeOH extract of Cucurbitaceae member (*C. colocynthis*) was found to be sensitive to only one strain *i.e.* SA1. Verbenaceae member (*C. inerme*) was found to be sensitive to all strains; while MeOH extract of *L. camara* was found to be resistant. Cycadaceae member (*C. rumphii*) exhibited sensitivity against one test strain *i.e.*, SA1. Poaceae member of *C. dactylon* was found to be sensitive to SA1. MeOH extract of *D. aegyptium* could only exhibit activity against SA1 strain. Extracts of Solanaceae members *D. innoxia* and *W. somnifera* were sensitive to SA1; while *S. nigrum* extracts inhibited growth of all the test pathogens. MeOH extract of Malvaceae member *H. rosasinensis* was sensitive to both strains. *S. cordata* extracts remained resistant to all of them. MeOH extract of Convolvulaceae (*I. cairica*) could only exhibit activity against SA1 strain. Both extracts of Lamiaceae member (*L. cephalotes*) and Apocynaceae member (*N. indicum*) were found to be sensitive to SA1 strain.

Table 3
The MIC of plants against *S. aureus* strains (mg/mL).

Plant species and specimen number	Plant family	Hospital isolated strain (*S. aureus*) SA1		Hospital isolated strain (*S. aureus*) SA2	
		MeOH	AQ	MeOH	AQ
A. aspera (AV012)	Amaranthaceae	⩾25.5	⩾60.0	⩾30.5	⩾65.0
A. indica (AV0102)	Euphorbiaceae	⩾20.0	⩾60.0	⩾25.5	⩾65.0
A. marmelos (AV0112)	Rutaceae	⩾40.5	N	⩾45.5	N
A. conyzoides (AV0121)	Asteraceae	⩾55.5	N	N	N
A. vera (AV0122)	Liliaceae	⩾20.0	⩾70.0	⩾20.05	⩾70.0
A. spinosus (AV042)	Amaranthaceae	N	N	N	N
A. maxicana (AV433)	Papaveraceae	⩾25.5	⩾80.5	⩾25.5	⩾80.5
B. monnieri (AV0411)	Scrophulariaceae	⩾35.0	⩾45.0	N	N
B. diffusa (AV01612)	Nyctaginaceae	⩾25.5	⩾75.0	N	N
B. moonosperma (AV8012)	Fabaceae	⩾20.5	⩾30.0	⩾20.5	⩾40.0
C. procera (AV8092)	Asclepiadaceae	⩾25.5	⩾40.0	⩾30.5	⩾40.0
C. tora (AVS124)	Caesalpinaceae	⩾20.5	⩾60.0	⩾30.5	⩾65.0
C. album (AV0125)	Chenopodiaceae	N	N	N	N
C. colocynthis (AV512)	Cucurbitaceae	⩾45.0	N	N	N
C. inerme (AV572)	Verbenaceae	⩾20.5	⩾40.0	⩾20.5	⩾45.0
C. bonplandianum (AV612)	Euphorbiaceae	⩾40.5	⩾85.0	N	N
C. refexa (AV812)	Cuscutaceae	⩾15.5	⩾55.0	N	N
C. rumphii (AV662)	Cycadaceae	⩾25.5	N	N	N
C. dactylon (AV992)	Poaceae	⩾20.5	⩾55.0	N	N
D. aegyptium (AV998)	Poaceae	⩾55.5	N	N	N
D. inoxia (AV922)	Solanaceae	⩾25.5	⩾85.0	N	N
E. prostrata (AVX012)	Asteraceae	⩾20.5	⩾75.0	N	N
E. officinalis (AVX016)	Euphorbiaceae	⩾20.5	⩾35.0	⩾20.5	⩾50.0
E. thymifolia (AVK012)	Euphorbiaceae	⩾30.5	⩾95.5	N	N
E. hirta (AVK0102)	Euphorbiaceae	⩾35.5	⩾80.5	⩾35.5	⩾95.5
H. rosa-sinensis (AV7012)	Malvaceae	⩾20.5	N	⩾20.5	N
I. cairica (AVB012)	Convolvulaceae	⩾35.5	N	N	N
L. camara (AVXB81)	Verbenaceae	⩾25.5	N	N	N
L. cephalotes (AV222)	Lamiaceae	⩾20.5	⩾70.5	N	N
M. azedarach (AV332)	Meliaceae	⩾20.5	⩾35.0	⩾20.5	⩾35.0
M. koenigii (AV512)	Rutaceae	⩾20.5	⩾45.5	⩾20.5	⩾45.5
N. indicum (AV712)	Apocynaceae	⩾25.5	⩾95.5	N	N
O. esculentum (AV912)	Asclepiadaceae	⩾20.5	⩾35.0	⩾20.5	⩾35.0
P. fraternus (AV702)	Euphorbiaceae	⩾25.5	⩾45.5	⩾25.5	⩾45.5
R. communis (AV0Y21)	Euphorbiaceae	⩾20.5	⩾35.0	⩾25.5	⩾35.0
S. nigrum (AV0BB1)	Solanaceae	⩾40.5	⩾85.0	⩾40.5	⩾85.0
S. cordata (AV01F1)	Malvaceae	N	N	N	N
S. indicus (AVG12)	Asteraceae	⩾15.5	⩾35.5	⩾20.0	⩾35.5
T. patula (AVG14)	Asteraceae	⩾35.5	⩾45.5	⩾35.5	⩾45.5
T. bispinosa (AVX42)	Trapaceae	N	N	N	N
T. procumbens (AVBOT12)	Asteraceae	⩾20.5	⩾75.5	⩾25.5	⩾85.5
T. alexandrinum (BOT15)	Fabaceae	⩾40.5	⩾60.0	⩾40.5	⩾60.0
W. somnifera (BOT560)	Solanaceae	⩾35.5	⩾35.5	N	N

Values are the mean of replication of three; N: No antibacterial activity; Incubation temperature: 37 °C; Incubation time: 24 h.

4. Discussion

Screening of the ethnobotanical plants is a pre-requisite to evaluate their therapeutic potential and it can lead to the isolation of new bioactive compounds[23,24]. Plants are rich source of antibacterial agents, which could be effectively used in human disease management. Plants have served humans as a source of food, shelter and clothing since time immemorial[25]. Before invention of antibiotic in 19th century, man completely relied on plant sources to treat all diseases and disorders[26]. Traditional medicines or folk medicines are an important source of potentially useful new compounds for the development of chemotherapeutic agents[12]. The essential values and uses of some plants have been worked out and published, but many of them remain unexplored to date. Therefore, there is a necessity to explore their uses and conduct broad-spectrum and extensive studies to discover their medicinal properties. A special feature of angiosperm plants is their capacity to produce a large number of organic chemicals of high structural diversity. Hence, 43 plant species of the local flora have been screened for their antibacterial potential for the first time and among these, 39 plant species have been identified to possess antibacterial activity against human pathogenic bacteria *S. aureus*. Chenopodiaceae member (*C. album*), Malvaceae member (*S. cordata*) and Amaranthaceae member (*A. spinosus*) were found to be resistant to all test strains. It was brought to knowledge that all Euphorbiaceous and Asteraceae plant species and both plant extracts (MeOH and AQ) of *A. aspera, M. koenigii, A. vera, B. monosperma, T. alexandrinum, C. procera, O. esculentum, C. tora, M. azedarach, A. mexicana* and

S. nigrum were found to be sensitive to the test pathogens, as they are traditionally employed for some of the diseases associated with *S. aureus*. Hence, these plants are important candidate for further investigations on isolation and characterization of the bioactive principles responsible for antibacterial activity. The incidences of fatal bacterial infection are dramatically increasing in spite of remarkable advances in antibiotic chemotherapy and development of new synthetic moieties[27]. Of great concern is the increasing incidence of infections caused by pathogenic strains of *S. aureus* with acquired multidrug resistance[28]. New and safe antibacterial agents with significant inhibitory activity against multidrug-resistant pathogenic strains of *S. aureus* are urgently needed for the treatment of severe multi-resistant hospital and community acquired infections[29-32]. The present findings strongly support traditional uses of aforementioned plants species. Results firmly indicate the potential of these plants for further work on isolation and characterization of the active principles responsible for antibacterial activity and their exploitation as therapeutic agents. Furthermore, the development of natural antimicrobials will undoubtedly help to decrease the negative effects of synthetic antibiotics in the treatment of diseases associated with pathogenic strains of *S. aureus*.

Present scientific investigation envisaged the possible antibacterial potential of some of the most commonly used plants in traditional use from rural areas of five districts of Western Uttar Pradesh, a northern province of India. A total of 43 plants species of ethnobotanical importance were selected and screened for their antibacterial potential against pathogenic bacterial strains of *S. aureus*, one of the most commonly found bacteria associated with many diseases which acquires resistant to most of the common widely used antibiotics. Our findings showed that a total of 39 plant species were sensitive to these test pathogens. We concluded from our investigation that traditional plants can serve as one of the best source of antibiotics which are cheaper, safer and easily available remedies for rural populace. Concisely, further phytochemical and pharmacological investigations will help to develop broad-spectrum antibiotics.

Conflict of interest statement

We declare that we have no conflict of interest.

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Comments

Background

The potential for microbial resistance to existing therapeutic agents continues to be a major concern and an impetus for continuous search for more efficacious agents. This is more pertinent to the more virulent pathogenic microbial species like *S. aureus*. The authors of this research have clearly demonstrated this point as being the impetus for undertaking this research.

Research frontiers

Medicinal plants with potentially useful antimicrobial activities often go unnoticed and undocumented due to the paucity of research in this area. A mass antibacterial screening of ethnomedicinally important plants from different families against hospital isolated pathogenic strains of *S. aureus* is innovative and should be encouraged.

Related reports

The Kirby-Bauer disk diffusion susceptibility test and agar dilution method are standard tests employed for evaluating *in vitro*, the efficacy and potency of antimicrobial agents. Plant extraction with at least two different solvents is highly recommended, making it possible to elucidate individual constituents whose contributions to the overall antimicrobial activity may otherwise go undetected with one-solvent extraction.

Innovations and breakthroughs

Mass evaluations of traditional remedies for antimicrobial actions against clinical isolates are innovative. Further, the research, coming from Indian subcontinent, might usefully expose variations in biodiversity of potentially active plant constituents arising from regional, environmental and species differences among others when compared with same species elsewhere.

Applications

Plant-derived medicines have contributed immensely to medicine as shown in this article. Phytochemicals are invaluable source of lead compounds in high throughput screening technologies for drug inventions. Millions of compounds have to be screened to obtain only a few hits. Therefore, the more active constituents discovered for chemical libraries, the better.

Peer review

Research involving screening of plant chemicals for bioactivity should be encouraged. Active phytochemicals are valuable sources of lead compounds in modern screening technologies. This study exposed a number of useful phytochemicals with appreciable activity against pathogenic strains of *S. aureus*. It is interesting that these findings which come from herbal remedies were employed by herbal medicine practitioners in India. The findings can usefully be applied by researchers elsewhere for comparison of bioactive constituents and this might be helpful in the rational standardization of herbal remedies obtained from the same plant species elsewhere.

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