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Phytochemical Profile And Antimicrobial (Antibacterial And Antifungal) Activities Of Cassia Tora And Crateva Adansonii

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Abstract
Medicinal plants are known to be good sources of bioactive compounds that have therapeutic effects against infectious and oxidative stress related diseases. The current research determined the phytochemical content, antimicrobial, and antioxidant properties of Cassia tora L. (Fabaceae) and Crateva adansonii DC. Two Indian species that are ethnomedicinally significant are (Capparaceae). Soxhlet and water-bath extracts (aqueous and solvent extracts, methanol and n-hexane) were used to extract various parts of the plant. Screening of qualitative phytochemicals showed that both species had phenols, flavonoids, saponins, tannins, terpenoids, and alkaloids, which validated the chemical diversity of the two species. The agar-well diffusion method of antimicrobial activity revealed that the methanolic extract of C. tora seeds and C. adansonii stems had maximum antimicrobial activity against Staphylococcus aureus (20 mm) and Pseudomonas aeruginosa (18 mm), and antifungal activity was also notable against Aspergillus niger (17-19 mm). Methanolic extracts were more effective than aqueous and n-hexane fractions, which implies that active constituents were extracted differently by solvents. The presence of potent hydrogen-donating phenolics and flavonoids was confirmed by the concentration-dependent antioxidant potential, which was similar to the standard ascorbic acid using the DPPH radical-scavenging assay. The paper supports the historical application of these plants and outlines their possible use as natural sources of antioxidants and antimicrobials. The findings form a scientific foundation of the creation of phytopharmaceutical preparations and promote additional separation and characterization of particular bioactive compounds to be used in treatment.
Keywords: *Cassia tora L., Crateva adansonii DC., phytochemicals, antioxidant, antibacterial, antifungal*

1. INTRODUCTION

Medicinal plants have been a part of the traditional healthcare systems since centuries and still remain a major part in the modern pharmacological studies. In the world, almost 80 percent of the population uses herbal medicine as the main health care requirement, which shows the significance of plant-based medicines [1]. The various secondary metabolites in these plants such as alkaloids, flavonoids, phenolic compounds, saponins, and terpenoids, which have antioxidant, antimicrobial, anti-inflammatory, and anticancer properties, are credited with their therapeutic efficacy [2]. Such bioactive compounds have become the subjects of growing interest as natural substitutes of synthetic drugs, especially in the background of the growing antimicrobial resistance and the disorders associated with oxidative stress.

Cassia tora L. (syn. Senna tora, family Fabaceae) and Cratevadasonii DC. (family Capparaceae) are some of the medicinally important species that have been of scientific and ethnobotanical interest because of their extensive pharmacological repertoire and traditional medicinal use in Indian and Southeast Asian medicine. Cassia tora is an annual herb that is widely distributed in tropical and subtropical areas and is used extensively in Ayurveda and folk medicine in the treatment of skin conditions, liver diseases, constipation and microbial infections [3]. Its seeds and leaves are also used in the traditional preparation as laxatives, antifungal and antioxidants [4]. Phytochemical researches also show that C. tora contains vast quantities of various compounds, including but not limited to anthraquinones, naphthopyrones, glycosides, flavonoids, and phenolic acids, and as such, animal studies have a broadly diverse pharmacological profile [5].

The study entailed ethnopharmacology of a locally known medicinal tree Crateva adansonii, commonly referred to as Varuna in the treatment of urinary tract infection, inflammation and digestive disorders. It has alkaloids, saponins and tannins in the bark, leaves and roots which have antimicrobial and antioxidant properties. The plant has also been used centuries ago as Ayurvedic medicine because of its hepatoprotective and anti-inflammatory effects [6]. C. tora and C. adansonii have potential in therapeutic applications because of their phytochemical richness and traditional application as well as are prospective subjects of natural drug discovery and formulation.

An important process that entails phytochemical analysis is a scientific validation of medicinal plants. The types of compounds that lead to biological activities are determined by qualitative and quantitative tests. Harborne [7]

stressed the significance of conventional phytochemical screening techniques to guarantee the reproducibility and scientific reliability. These tests are usually directed to major groups of phytoconstituents like phenolics, flavonoids, tannins and alkaloids, which are pharmacologically potent. Specifically, the phenolic and flavonoid compounds are good free radical scavengers, which play a role in the antioxidant defence system of plants [8]. The antioxidant activity mechanism is based on the neutralization of reactive oxygen species (ROS) and inhibition of lipid peroxidation, which are the main causes of oxidative stress-associated pathologies.

It is therefore clear that despite the increasing scientific focus on underutilized and wild plant species, the latter can serve as a new source of phytochemicals and bioactive compounds. The economic and ecological importance of such less known species in India was emphasized by Karuppusamy [9], which are still very unexplored despite their potential pharmacological potential. Some of these useful resources include Cassia tora and Crateva adansonii, which provide viable alternatives to the development of phytotherapeutic agents. This point of view is supported by recent research: phenolic compounds of Senna tora sprouts were mentioned to have neuroprotective properties against glutamate-induced oxidative stress, and they showed a high antioxidant and cytoprotective potential [10]. The comparative phytochemical studies indicated that the phytochemical composition of S. tora differs geographically, which affects its antioxidant activity. These results emphasize the relevance of the environment and extraction parameters to the bioactivity of plant-derived compounds.

Reactive oxygen species are the byproducts of normal cell metabolism that when produced excessively may lead to oxidative stress and cell damage. Antioxidants counter this by scavenging the free radicals and restoring the redox balance [8]. Antioxidants of plant origin are especially useful since they have a variety of pharmacological effects that minimize oxidative stress and antimicrobial, anti-inflammatory, and hepatoprotective effects. Plant metabolites such as flavonoids, phenolics and tannins have dual antioxidant and antimicrobial properties, which contribute to their therapeutic activity. Ali [2] showed that Senna tora extracts have good antioxidant and antimicrobial effects, and thus they can be used as functional foods and herbal medicines.

The antimicrobial properties of plant-derived compounds have been known long enough. Cowan [1] described that phenolic compounds interfere with the cell membrane of microbes, denature proteins and prevent the production of nucleic acids, thus, hindering bacterial growth. The growing prevalence of antibiotic-resistant pathogens across the world has brought back the need to find plant-based antimicrobial agents that could be used as safer alternatives. Research has revealed that solvent extracts especially methanol and ethanol are more likely to have greater antimicrobial activity since they dissolve a wider range of bioactive compounds than aqueous extracts. This method has been effectively used to test Cassia tora and Crateva adansonii which exhibit anti-browning properties against Gram-positive and Gram-negative bacteria and fungal species.

The 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay is a widely used procedure to evaluate the antioxidant activity of plant extracts that has been first introduced by Brand-Williams et al. [11]. The assay principle is a reduction in the purple colored DPPH radical to the yellow colored diphenylpicrylhydrazine which indicates the hydrogen giving ability of the test sample. The level of decolorization is proportional to the antioxidant properties of the extract. The DPPH assay remains one of the used analysis tools due to its simplicity, time, and reproducibility. It is also applicable in estimating the radical scavenging capacity of the phenolic rich extracts of such plants as Cassia tora and Crateva adansonii.

The contemporary health problems necessitate the utilization of medicinal plants that are acquired by the application of biodiversity and sustainable consumption of the plants. The underutilized wild edible and medicinal species most have unique phytochemical profiles and can be used to design novel application in therapy [9]. The structural stability of the seed and morphological properties of the seed especially of Cassia tora have been described and has been utilized in pharmaceutical preparations [12]. Due to their availability, versatility and stability and potential to be utilized on large scale cultivation and industrialized, these species are also applicable in phytopharmaceuticals and nutraceuticals.

Cassia tora and Crateva adansonii have undergone extensive traditional use, no systematic scientific evaluation of the plant has been conducted to back the combination of phytochemical, antioxidant and antimicrobial action of both the plants. The current research was thus meant to fill this gap by conducting a comprehensive phytochemical profiling, antibacterial and antifungal assay, and antioxidant assay using aqueous and solvent extracts.

This research aims at comparing and contrasting the phytochemical compounds, antibacterial, antifungal and antioxidant activities of Cassia tora and Crateva adansonii through standard extraction and analytical procedures. The study will justify the traditional applications of the plants by laying the phytochemical foundation of their biological properties and emphasize their potential in the future as natural sources of developing plant-based antimicrobial and antioxidant preparations.

2. MATERIALS AND METHODS

2.1 Plant Material and Identification

Fresh plant materials of Cassia tora L. (Fabaceae) and Crateva adansonii DC. (Capparaceae) were collected in January from Anand, Gujarat, India. Cassia tora seeds, stems, and leaves were obtained from roadside areas, whereas Crateva adansonii stems and leaves were collected from a private farm. Botanical identification and authentication were carried out by a qualified taxonomist at Sardar Patel University, and voucher specimens were deposited in the departmental herbarium.

2.2 Chemicals and Reagents

All the solvents and reagents were of analytical grade. Methanol, n-hexane, ferric chloride, sodium hydroxide, copper sulfate, hydrochloric acid, sulfuric acid, and Folin-Ciocalteu reagent were bought at Merck (India). Agar-agar, Nutrient Agar (NA) and Potato Dextrose Agar (PDA) were purchased at HiMedia Laboratories (India). Analytical standards were DPPH and ascorbic acid.

2.3 Preparation of Plant Extracts

2.3.1 Aqueous Extraction

Twenty grams of powdered plant material were mixed with 150 mL distilled water. For **hot-water extraction**, the mixture was heated in a water bath at 80 °C for 2–3 hours with intermittent stirring. For **cold-water extraction**, the mixture was kept on an orbital shaker at 140 rpm for 16 hours. Filtrates were concentrated using a rotary vacuum evaporator and stored at 4 °C in airtight containers.

2.3.2 Solvent Extraction (Soxhlet Method)

For solvent extraction, 20 g of plant powder were extracted successively with n-hexane (non-polar) and methanol (polar) using a Soxhlet apparatus for 3 hours at 64–69 °C. The extracts were concentrated under reduced pressure using a rotary evaporator and stored at 4 °C until further use.

2.4 Phytochemical Screening

Qualitative phytochemical analysis was carried out on aqueous, methanolic, and n-hexane extracts using standard protocols to detect the presence of phenols, flavonoids, carbohydrates, proteins, alkaloids, saponins, tannins, terpenoids, and steroids.

The color development was noted to ensure the positive reactions (e.g. blue-green color of phenols using ferric chloride test, yellow color of flavonoids using NaOH test and white precipitate of alkaloids using Mayer reagent).

2.5 Microorganisms and Culture Conditions

Staphylococcus aureus (Gram-positive), Pseudomonas aeruginosa (Gram-negative) and Aspergillus niger (fungal strain) were the test organisms. The microbial cultures were all obtained Shri A.N. Patel P.G. Institute of Science and Research, Anand, India. Bacteria and fungi were grown in Nutrient Agar and Potato Dextrose Agar respectively, 24 hours and 4872 hours, at 37 o C and 28 o C respectively. The positive controls used to test bacteria and fungi were ampicillin (10 mg/mL) and Fluconazole (10 mg/mL), respectively.

2.6 Antimicrobial Assay

The agar well diffusion method was used to determine the antibacterial as well as antifungal activities of the extracts. Microbial suspensions of standardized concentrations (0.5 McFarland, which is about 1 x 10 8 CFU/mL) were inoculated to agar plates. Extract (200mg/mL) was placed in wells (6 mm) containing 100 uL extract. Solvents with no reaction acted as negative control. Bacteria and fungi were incubated in plates where inhibition zones were taken after 24-72 hours at 37 °C and 28 o C respectively. All experiments were carried out in triplicates and results were presented in the form of mean and standard deviation (SD).

2.7 Antioxidant Activity

The DPPH radical scavenging assay was done to assess antioxidant potential. Plant extracts were added to a 0.1 mM DPPH solution in methanol and prepared in different concentrations (200-1000 0.g/mL). The absorbance was then determined at 517nm with a UV-VIS spectrophotometer after incubation of the sample at room temperature and in the dark over a period of 30 minutes. Ascorbic acid was employed as a conventional antioxidant. DPPH radical percentage inhibition was determined as:

$$\%\text{Inhibition} = \frac{\mathrm{A_{control}} - \mathrm{A_{sample}}}{\mathrm{A_{control}}} \times 100$$

IC_{50} values were determined from concentration-response curves using regression analysis.

2.8 Statistical Analysis

All experimental data were expressed as mean ± SD for three replicates (n = 3). Statistical significance between groups was analyzed by one-way analysis of variance (ANOVA), followed by Tukey's post-hoc test using SPSS v.26.0. Values of $p < 0.05$ were considered statistically significant.

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3. RESULTS

3.1 Phytochemical Screening

The qualitative phytochemical study of the extracts of Cassia tora and Crateva adansonii showed that they contained a number of bioactive compounds such as phenols, flavonoids, carbohydrates, proteins, saponins, terpenoids, and steroids. Most of the methanol and aqueous extracts contained alkaloids.

Hot and cold aqueous extracts of Cassia tora were found to react strongly with phenols, flavonoids and saponins whereas Crateva adansonii extracts reacted moderately with flavonoids and terpenoids. Table 1 presents these results and Figure 1 (Cassia tora) and Figure 2 (Crateva adansonii) illustrate the results.

The existence of phenolic and flavonoid compounds in the two species implies that they may be antioxidant and antimicrobial agents. Methanol is a polar solvent that extracted a greater number of phytoconstituents compared to nonpolar n-hexane.

Table 1. Phytochemical analysis of aqueous extracts of medicinal plants

No.	Plant Name	Extraction method	phenol	Flavanoids	Carbohydrates	Protein	Alkaloids	Saponines	Tannins	Terpenoids	Steroids
1	Cassia Tora										
	Seed	Hot	+	+	+	+	_	+	_	+	+
		Cold	+	+	+	+	_	+	_	+	+
	Stem	Hot	+	_	+	_	_	+	_	+	+
		Cold	+	_	+	_	_	+	_	+	+
	Leaf	Hot	+	+	+	+	_	+	+	+	+
		Cold	+	+	+	+	_	+	+	+	_
2	Crateva Adansonii										
	Stem	Hot	_	+	_	+	_	+	_	+	_
		Cold	_	+	_	_	_	+	_	+	_
	Leaf	Hot	+	_	+	+	_	+	+	_	_
		Cold	+	+	_	_	_	+	+	+	_

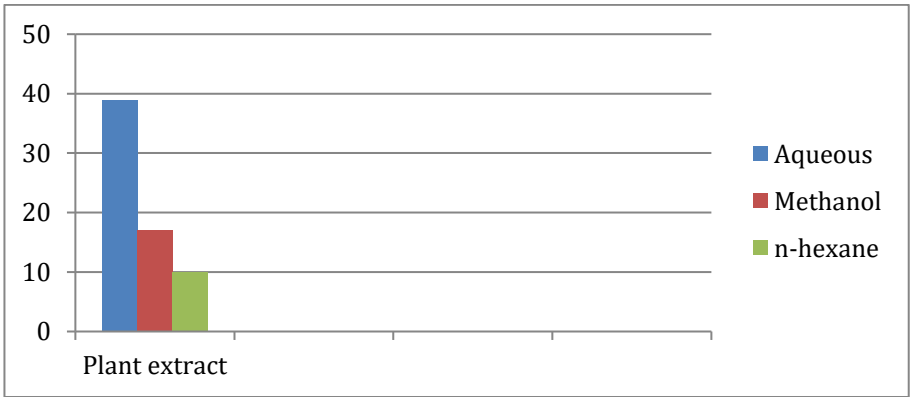

Figure 1. Phytochemical analysis of Cassia tora

Figure 2. Phytochemical analysis of Crateva adansonii

3.2 Antibacterial Activity

The antibacterial activity of aqueous and solvent extracts of Cassia tora and Crateva adansonii was assessed against Staphylococcus aureus and Pseudomonas aeruginosa using the agar well diffusion method.

In Cassia tora, the methanolic seed extract showed the highest inhibitory zone (20 mm) against S. aureus, followed by cold-water extracts (19 mm). P. aeruginosa was moderately inhibited by methanol stem extract (17 mm). The results are summarized in Table 2.

Similarly, for Crateva adansonii, methanolic stem extract exhibited maximum inhibition (18 mm) against S. aureus, while n-hexane leaf extract showed moderate inhibition (14 mm) (Table 4.3). Figure 3, Figure 4, Figure 5 and Figure 6 represent the corresponding inhibition zones.

The extracts produced by using methanol showed better antibacterial potential of both plants because bioactive compounds are more likely to be dissolved in polar solvents. S. aureus (Gram-positive) was more sensitive than P. aeruginosa as Gram-negative one, which is consistent with the difference in cell wall permeability.

Table 2. Antibacterial activity of Cassia tora

No.	Plant name	Part name	Extraction method	Zone of inhibition of Staphylococcus aureus	Zone of inhibition of Pseudomonas aeruginosa
1	Cassia tora	Seed	Cold	19mm	Negative
			Hot	20mm	17mm
			Methanol	Negative	17mm
			η-hexane	19mm	18mm
		Stem	Cold	Negative	Negative
			Hot	Negative	Negative
			Methanol	12mm	17mm
			η-hexane	19mm	16mm
		Leaf	Cold	Negative	Negative
			Hot	Negative	10mm
			Methanol	13mm	13mm
			η-hexane	Negative	Negative

Table 3. Antibacterial activity of Crateva adansonii

No.	Plant name	Part Name	Extraction method	Zone of inhibition of Staphylococcus aureus	Zone of inhibition of Pseudomonas aeruginosa
1.	Crateva adansonii	Stem	Cold	20mm	18mm
			Hot	18mm	19mm
			Methanol	19mm	17mm
			η-hexane	Negative	Negative
		Leaf	Cold	18mm	17mm
			Hot	12mm	Negative
			Methanol	Negative	15mm
			η-hexane	Negative	Negative

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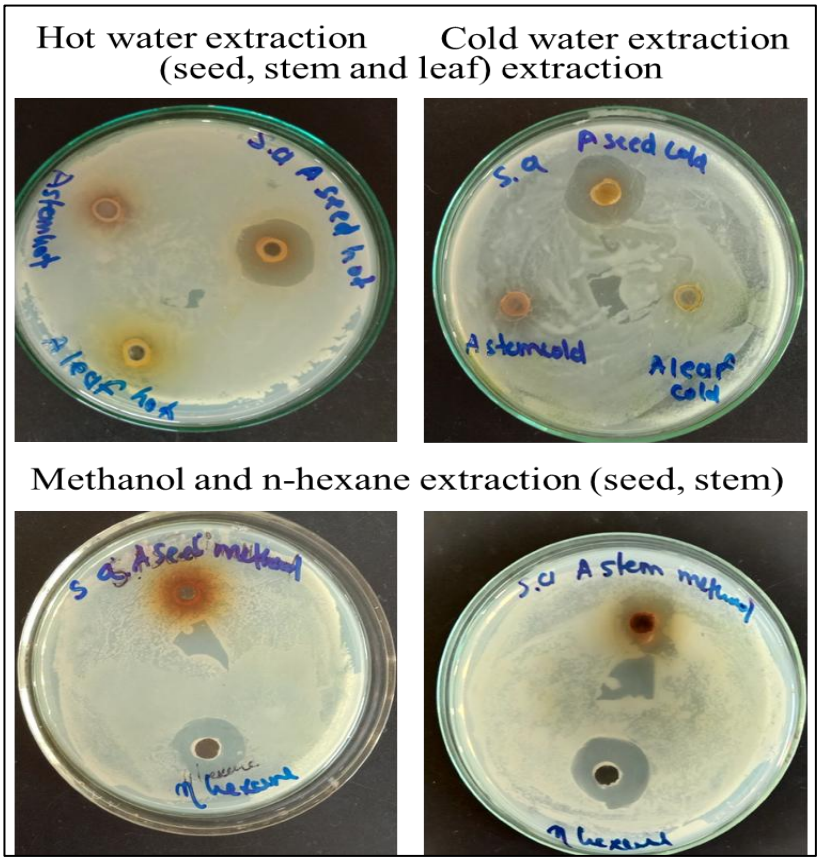

Figure 3. Antibacterial activity of Cassia tora aqueous and solvent extracts against Staphylococcus aureus

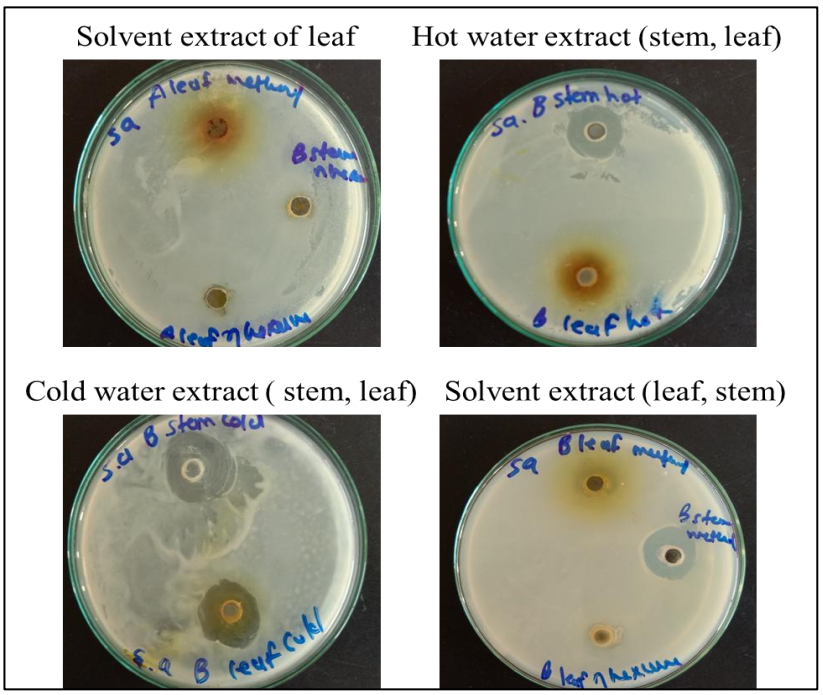

Figure 4. Antibacterial activity of Crateva adansonii aqueous extract and solvent extract against Staphylococcus aureus

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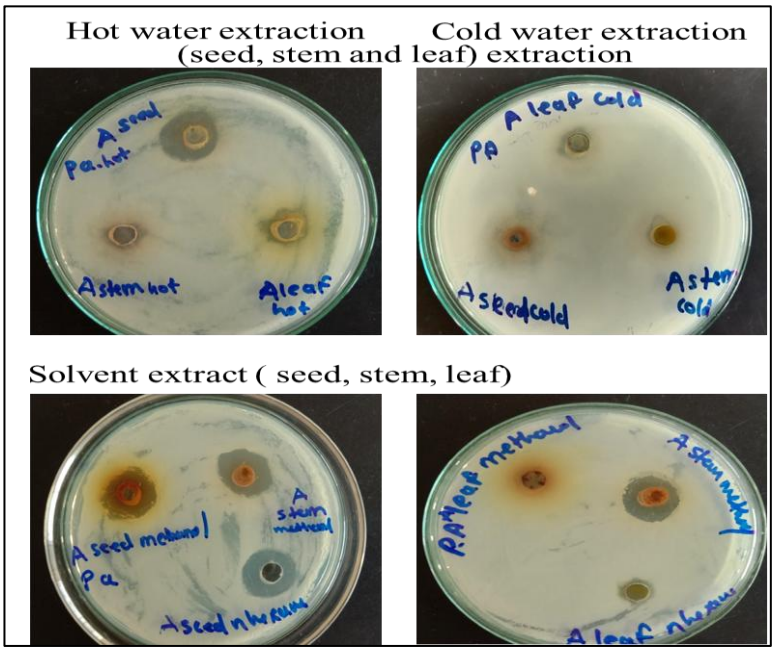

Figure 5. Antibacterial activity of Cassia tora aqueous and solvent extract against Pseudomonas aeruginosa

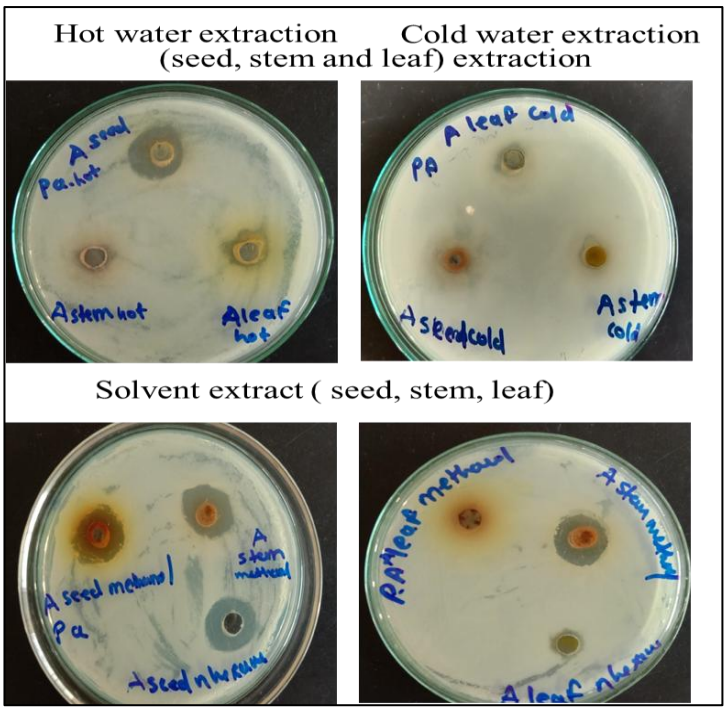

Figure 6. Antibacterial activity of Crateva adansonii aqueous and solvent extracts against Pseudomonas aeruginosa

3.3 Antifungal Activity

Antifungal was assayed on Aspergillus niger. In both plants, high levels of inhibition were evident especially with the methanolic and n-hexane extracts. The cassia tora methanolic leaf extract had the highest inhibition zone (18 mm) when compared with aqueous extract (10 mm). In the case of Crateva adansonii, the zone of the methanolic stem extract was 19 mm and n-hexane extract showed an intermediate inhibition (12 mm). Table 4 and Table 5 give these results, which are also graphically represented in Figure 7, Figure 8 and Figure 9. The observed antifungal activity is indicative of antifungal secondary metabolites, which could be phenolic or flavonoid compounds, and break fungal membrane integrity.

Table 4. Antifungal activity of Cassia tora

No.	Plant name	Part name	Extraction Method	Zone of inhibition of Aspergillus niger
1	Cassia tora	Seed	Cold	14mm
			Hot	9mm

			Methanol	17mm
			η-hexane	Negative
		Stem	Cold	Negative
			Hot	Negative
			Methanol	9mm
			η-hexane	Negative
		Leaf	Cold	Negative
			Hot	Negative
			Methanol	Negative
			η-hexane	Negative

Table 5. Antifungal activity of Crateva adansonii

No.	Plant name	Part name	Extraction Method	Zone of inhibition of Aspergillus niger
1.	Crateva adansonii	Stem	Cold	Negative
			Hot	Negative
			Methanol	19mm
			η-hexane	12mm
		Leaf	Cold	Negative
			Hot	Negative
			Methanol	Negative
			η-hexane	12mm

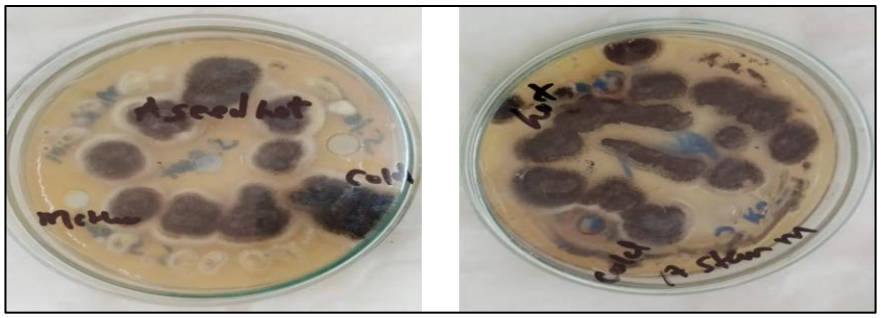

Figure 7. Antifungal activity of Cassia tora (seed, stem)

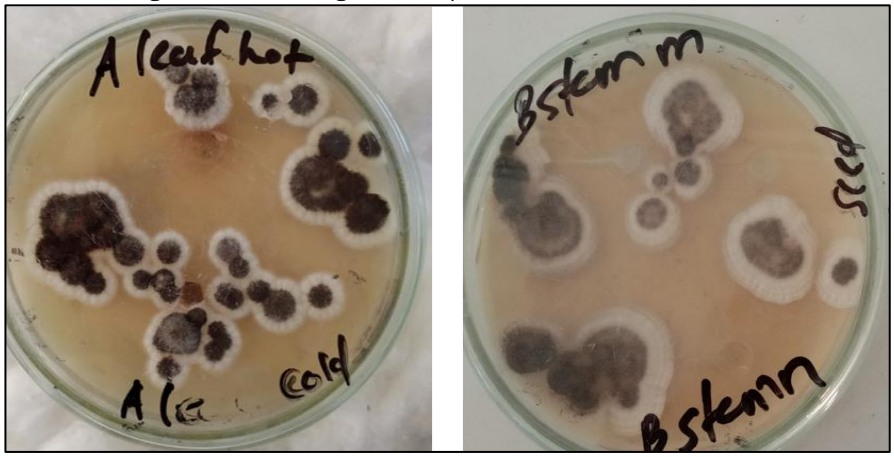

Figure 8. Antifungal activity of Cassia tora leaf and Crateva adansonii stem

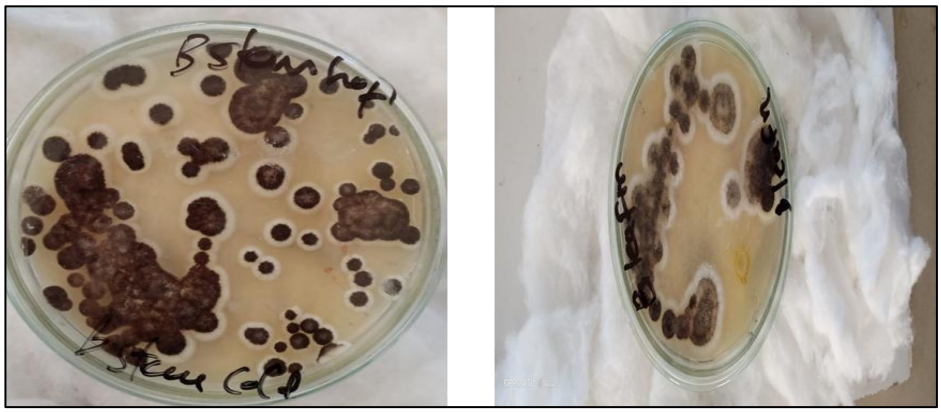

Figure 9. Antifungal activity of Crateva adansonii leaf and stem

3.4 Antioxidant (DPPH) Activity

The DPPH radical scavenging assay was used to find the antioxidant activity of the extracts. The extent of decolorization was used to identify the radical scavenging capacity of the extracts. Cassia tora and Crateva adansonii exhibited great scavenging capacity of DPPH in their methanolic extracts at different concentrations (200-800 ug/mL). The ascorbic acid standard demonstrated the strongest activity, followed by methanol extracts, while n-hexane extracts showed moderate results. The DPPH assay confirmed the antioxidant potential of both plants, directly correlating with their phenolic and flavonoid content identified earlier.

3.5 Summary of Findings

- Both Cassia tora and Crateva adansonii exhibited rich phytochemical profiles.
- Methanolic extracts demonstrated the highest antimicrobial and antioxidant activities.
- S. aureus was more susceptible than P. aeruginosa, while A. niger was moderately inhibited.
- The strong DPPH scavenging capacity supports the presence of antioxidant phytochemicals.

4. DISCUSSION

This research study has shown that Cassia tora and Crateva adansonii have high phytochemical, antimicrobial and antioxidant potentials, thus confirming their ethnopharmacological value. The two plants had a variety of secondary metabolites including phenols, flavonoids, saponins, and terpenoids, which were in line with previous phytochemical studies [13]. These bioactive compounds are rich and give the biochemical basis of the good antimicrobial and antioxidant activities of the methanolic and aqueous extracts. The quality of the obtained results that were obtained with the assistance of the use of the methanol extraction proves the polarity advantage of the solvent used in extracting phenolic and flavonoid constituents that play the role of being the cause of the significant biological effects [14].

Phytochemical screening showed that both C. tora and C. adansonii possess a diverse range of secondary metabolites, which is in line with the findings of other studies that have identified these compounds as the cause of antimicrobial and antioxidant activity [13, 15]. The reactions of methanolic extracts were stronger in phenolics and flavonoids, which proves that polar solvents dissolve larger amounts of active constituents than non-polar solvents do. Devhare and Gokhale [13] also found that the methanolic extracts of C. tora had greater antioxidant and antiulcer activity than aqueous extracts or hexane extracts. This change in solvents can be explained by the fact that methanol can easily penetrate plant tissues and dissolve phenolic compounds. Saponins and tannins are also important as they are known to cause disruption of the membrane and inhibition of the microbes, which is also confirmed in the present study.

The antibacterial activity showed that the C. tora and C. adansonii extracts exhibited better antibacterial activity against Staphylococcus aureus (Gram-positive) than against Pseudomonas aeruginosa (Gram-negative). This finding is in line with the overall knowledge that Gram-negative bacteria have an outer lipopolysaccharide layer, which limits the penetration of polar compounds, hence they are comparatively more resistant [16]. The inhibition zones of methanolic and aqueous extracts of C. tora seeds and C. adansonii stems were between 1820 mm, which confirmed their high antibacterial activity. These are consistent with the results of Arulpandi and Kanimozhi [13], who established that the methanolic leaf extracts of C. tora had a high inhibitory effect against S. aureus and Escherichia coli. The mechanism of action here can be described as inhibitory effects of phenolic and flavonoid compounds which have the ability to either denature bacterial proteins, change cell membrane permeability, or prevent the production of nucleic acids.

These findings confirm the antimicrobial activity of C. adansonii, which is in line with the findings of Wagay et al. [15], who found significant antibacterial activity of Crateva religiosa bark extracts against Gram-positive

pathogens. The resemblant genus-level antimicrobial reaction favors the chemotaxonomic association amid the Crateva species. These observations support the fact that the active metabolites in the methanolic extracts can interfere with the growth of microbes by both modulating oxidative stress and by direct interference with membranes.

The antifungal tests against Aspergillus niger showed that the methanolic extracts of C. tora (1718 mm) and C. adansonii (19 mm) had a significant zone of inhibition. These are in line with the results of Dubey and Sett [17] who had reported antifungal activity of C. tora seeds against common pathogenic fungi. The antifungal effect could be explained by flavonoids and phenolic acids which can form complexes with extracellular proteins and cell wall polysaccharides and interfere with the integrity of fungal cells. The fact that C. adansonii can suppress the growth of A. niger also confirms its potential as a source of natural antifungal compounds, which is also in line with the antimicrobial profiling results reported by Wagay et al. [15].

The importance of such results is that A. niger is considered to be resistant to standard antifungal agents and the identification of natural inhibitors facilitates the production of safe plant-based antifungal preparation. The existence of the alkaloids and terpenoids in the extracts also justifies the presence of antifungal activity because the compounds have been reported to disrupt fungal enzymatic systems and membrane permeability.

The antioxidant assay of C. tora and C. adansonii indicated high radical scavenging activity in the methanolic extracts whose inhibition value rose with the increase in concentration. The DPPH scavenging activity observed is in line with the earlier studies of the antioxidant activity of phenolic-rich plant extracts [11, 18]. The hydrogen-donating property of the phenolic and flavonoid compounds in the extracts is directly proportional to the reduction of DPPH radicals. The findings of this research support the fact that antioxidant property of the two plant species is dose-dependent and this implies that the two plant species can be used as natural antioxidants in pharmaceutical and food industries.

The results obtained in this paper are comparable to El Babili et al. [19] who verified the validity and consistency of DPPH method in establishing the antioxidant potential of medicinal plant extracts. Babili et al. [18] reported the precision of colorimetric DPPH assays as compared to spectrophotometric methods of estimating the antioxidant potential of Moroccan medicinal plants. The fact that these studies are similar to the present results could be interpreted as the methodological validity of DPPH radical assays to screen antioxidant activity. The scavenging ability of this high value is comparable to ascorbic acid which confirms the high electron donating ability of active phytochemicals.

At the molecular level, the antioxidant activity is largely controlled by the ability of bioactive compounds in counteracting the reactive oxygen species and stabilizing the free radicals [20]. The antioxidant effect of the identified phenolic and flavonoid compounds of C. tora and C. adansonii is likely to be by hydrogen atom transfer (HAT) and single-electron transfer (SET). This dual action allows them to be effective scavenging agents of the free radicals, in addition to being able to terminate oxidative chain reactions. These compounds have a few hydroxyl functions and this raises the ability of these compounds to stabilize the radical. The results also confirm the hypothesis that methanol extracts are rich in phenolics and constitute an important part of the free radical scavenging and oxidative stress reduction, which is why they can be used in the traditional use as the restorative and detoxifying agents.

Comparative analysis of C. tora and C. adansonii reveals a similarity between both species regarding bioactive profile, whereas the dissimilarity is in the activity pattern which is solvent-dependent. Methanol extracts of C. tora were somewhat more effective as antibacterial agents, though. adansonii extracts were more effective as antifungal agents. These complementary effects indicate that they can be synergistically used in herbal preparations against mixed infections. The general findings verify that these plants may be used as sources of multifunctional phytochemicals with therapeutic effects.

The antimicrobial results obtained in the laboratory are consistent with the existing Clinical and Laboratory Standards Institute (CLSI) guidelines, which makes the results reliable in the interpretation of the inhibition zone diameters [16]. The results support the idea that both species may be regarded as promising sources of bioactive extracts that can be used in accordance with the contemporary pharmacological requirements. The results also provide the future research opportunities on the synthesis of nanoparticles by using plant extracts. Jayabalan [21] proved that C. tora was capable of reducing and stabilizing silver nanoparticles in the biosynthesis process and this increased antimicrobial activity implying that the present findings can be applied in nanophytomedicine.

The findings affirm that Cassia tora and Crateva adansonii have potent antimicrobial and antioxidant properties, which are directly proportional to the phytochemical composition. Methanolic extracts were more effective because they had increased solubility of polar bioactive compounds. Their antioxidant potential was confirmed by the DPPH assay, and it was in line with the globally accepted methodologies. The findings support the conventional application of the two plants in the treatment of infections and oxidative stress-related conditions.

To improve the therapeutic efficacy and clinical applicability, future research should aim at isolating and characterizing particular active compounds and investigate synergistic formulations, which may include green nanotechnology.

5. CONCLUSION

The current study scientifically confirms the conventional therapeutic significance of Cassia tora and Crateva adansonii by establishing their high phytochemical content and high biological actions. The secondary metabolites of the two species were diverse with phenols, flavonoids, saponins, tannins, and terpenoids that together lead to the high antimicrobial and antioxidant properties. Of the solvents that were tested, methanol was the best extractant, with higher concentrations of polar bioactive compounds, which increased antibacterial and antifungal activity. The C. tora and C. adansonii methanolic extracts exhibited significant antimicrobial effects on Staphylococcus aureus, Pseudomonas aeruginosa, and Aspergillus niger and thus justify their use as natural antimicrobial agents. The DPPH radical-scavenging activity demonstrated a high antioxidant activity similar to the standard ascorbic acid, highlighting their capability to counteract the free radicals and reduce oxidative stress. The results confirm that these plants are a good source of natural antioxidants and antimicrobials that can be used in the development of pharmaceuticals and nutraceuticals. Further research ought to be directed at the isolation, characterization and mechanistic explanation of individual phytochemicals, and development of synergistic blends to achieve greater therapeutic effectiveness. The overall assessment herein therefore connects the ethnobotanical information with the scientific validation that will lead to a sustainable use of these medicinal species in the current herbal drug studies.

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