South African Medicinal Plants Used in the Treatment of Human Bacterial Infections: An updated Review

Rose Awah Bih, Maropeng Charles Monyama and Sogolo Lucky Lebelo*

Department of Life and Consumer Sciences, School of Agriculture and Life Sciences, University of South Africa, Private Bag X06, Florida, South Africa.
*Corresponding Author e-mail: lebelol@unisa.ac.za

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Traditional medicine based on the use of medicinal plants plays an important role in the preservation of health and well-being of many people globally. Today herbal medicine application is progressively finding more significance especially with the acknowledgement of the challenges of antibiotic resistance. The aim of this review was to collect literature based on the traditional application of South African medicinal plant species used in South Africa to prevent and treat various pathogenic bacterial infections. The search was carried out using key electronic scientific databases including PubMed, Google Scholar, SpringerLink, ProQuest, Science Direct, Elsevier, BioMed Central. Other sources of literature included scientific articles, book chapters, dissertations, theses and websites. It was found that Bacillus spp., Escherichia coli, Staphylococcus aureus and Pseudomonas aeruginosa were the most frequently investigated bacterial pathogens which have developed resistance to most of the available standard antibiotics. Organic and aqueous extracts of many South African plants including Acacia karroo, Psidium guajava, Punica granatum, Eucomis autumnalis, Vernonia amygdalina and Cyathula uncinulata have demonstrated potent antibacterial efficacy against the aforementioned pathogens. This review exemplifies that South African medicinal plants have the potential to be considered as new leads for the development of antibacterial agents against resistant pathogens.

Keywords: Antibiotic resistance, Antimicrobials; Human bacterial infections; Medicinal plants; South Africa.

Medicinal plants play an important role in the preservation of health and well-being of many people and animals across the globe 1-2. In the past, many people have relied on indigenous herbs with remedial actions for the prevention and treatment of infectious diseases 3. There is a growing amount of literature on the use of medicinal plants and their benefits, across the world including South Africa 4-5.

According to ethnobotanical survey, South Africa has a strong history of traditional healing and anchors a rich biodiversity of more than 30 000 plant species 6-8. However, over 4000 species are recognised to have ethnobotanical importance, with more than 3000 plants used for medicinal purposes 9-10. Notably, more than 10% of the world’s higher plant species of medicinal value grow in South Africa 7-8. Furthermore, most
of these plant species are native species while a few are exotic species which were accidentally or deliberately introduced to South Africa over the years.

The use of medicinal plants to treat vast diseases by inhabitants of Sub-Saharan Africa is enormous so that the traditional medicine has been understood as part of African culture. According to researchers, medicinal plants have a myriad of diverse bioactive compounds with complex chemical profiles that contribute to their massive usage in the treatment and prevention of many diseases. These diseases include, but not limited to, asthma, diabetes, cancer, food borne diseases, nosocomial infections, mental and gynaecological problems, hypertension as well as tuberculosis.

However, the majority of the diseases are caused by organisms of bacterial origin including but not limited to *Staphylococcus aureus*, *Escherichia coli*, *Mycobacterium tuberculosis*, *bacillus* spp., *Klebsiella* spp., *Streptococcus* spp. and *Pseudomonas aeruginosa*. Many scientific investigators have reported these bacterial pathogens of being resistant to a majority of the mainstream antibiotics designed to kill them including those of last resort such as carbapenems, colistin, and tigecycline. Due to this phenomenon, the frail are left with no other choice but to explore medicinal herbs as an alternative means to regain health. The aim of the study was to report on South African medicinal plants used in the treatment of human bacterial infections.

**MATERIALS AND METHODS**

The search was carried out using key electronic scientific databases including PubMed, Google Scholar, SpringerLink, ProQuest, Science Direct, Elsevier, BioMed Central. Other sources of literature included scientific articles, book chapters, dissertations, theses and websites. The key words such as “medicinal plants”, “antioxidants”, “bacterial infections”, “traditional medicines”, “bioactive compounds”, and “South Africa”, were used to get the trimmed searches.

**Parts of medicinal plants frequently used**

It has been reported that the herbal preparations used during various treatments come either from whole plant or from parts including the leaves, flowers, tubers, stems, roots, fruits and barks. However, the parts of plants reported as frequently used in traditional medicine practices in South Africa includes but not limited to the ones listed below:

**Bark**

Tree barks are made of a hard outer layer of actively dividing living cells which function as a physical barrier and protects the plant. Some researchers have reported that the barks of most medicinal plants contain substantial amounts of bioactive substances necessary to prevent and cure a variety of infections. According to more than 30% of the woody plant bark used in the Limpopo province in South Africa have been reported to have high medicinal values. In South Africa, more than one third of the plant materials used in traditional medicine comes from the bark of plants.

**Leaf**

The leaf of a plant is an important structure as it manufactures food that the plant needs for its growth and survival through the process of photosynthesis. The leaf is also fused with green substances known as chlorophyll which absorbs sunlight that aids in the conversion of carbon dioxide and water to glucose needed for plant's growth. However, some of the leaves used during traditional medicine practices are known to contain bioactive substances including the leaves of *Burkea Africana*, *Lippia javanica* and *Leucaena leucocephala*. 
Root

Plants' roots help to anchor the plant to a surface by creating resistance and help to transport substances necessary for its growth from the soil to the rest of the plant. In traditional medicine, the application of plant roots either independently or in combination with other plant parts is common as reported by 40-41. Research has demonstrated that most roots of plants used in traditional medicine contain important phytochemicals. Some of the plants that have their roots used as medicine include but not limited to devil's claw root, stinging nettle root and ginseng. According to 41, most traditional healers are convinced that the roots and bulbs of plants or any part hidden beneath the earth contain higher healing powers than any other plant part. In line with this, a research by 46 found out that the roots and other underground parts of plants hold elevated concentrations of plant natural substances. According to an ethnobotanical survey conducted by 27-28, the roots and barks are the most used and preferred over other parts by the indigenous people. Furthermore, was in agreement with this and reported on similar findings that the bark and roots are the most favored parts of plants used by the Tsonga people of Mpumalanga province in South Africa, as illustrated in Figure 1.

**Antimicrobial ethno-medicinal plants used in South Africa**

According to World Health Organisation, more than 60% of people depend on traditional medicine for the purpose of preventing and treating diseases. This includes 80% of the populations from underdeveloped and developing countries including South Africa 45, 47. The traditional application of medicinal plants as medicine is one of the key sources of health care in South Africa 10. Additionally, South Africa is reputable for traditional healing using medicinal plants and it is estimated that over 27 million people in both townships and the rural communities prefer and rely on traditional medicine for their primary health care. Of this, reports that 72% of the population are the Black Africans including the Zulus, the Xhosa, the Bapedi, the Venda people, the Northern and the Southern Sotho people make use of traditional herbal medicine the most. A recent survey conducted by, on the use of natural plant products to treat human diseases in the Limpopo province of South Africa had similar findings. However, the remainder of the population including the Whites, mixed race, Indians and Chinese also use traditional medicine but at a lesser extent. Numerous ethnobotanical surveys done in South Africa revealed that a significant amount of plant species are used as medicine especially in regions including KwaZulu-Natal and Limpopo to relieve symptoms of bacterial, fungal and viral infections as shown in Table 2.

Table 1 below shows the various plant species used to treat human ailments, parts, methods of preparation, parts of the plants that are commonly used, traditional therapeutic uses, and the distribution of plant in South Africa.

**Bacterial diseases treated with indigenous medicinal plants in South Africa**

It is not new that people use medicinal herbs to treat common health problems. Previously published ethnobotanical reports elucidates that some of the illnesses and infections commonly prevented or treated with local medicinal plants in South Africa includes, but not limited to, oral infections, heart and lung problems, sexually transmitted infections (STIs), diabetes mellitus, headaches, infertility, erectile disorder, skin problems, gastrointestinal infections including diarrhoea, Human Immunodeficiency Virus / Acquired Immune Deficiency Syndrome (HIV/AIDS) and related infections, wounds, cancer, cardiovascular diseases, respiratory ailments including coughs and tuberculosis (TB), just to name a few.

According to past and resent research, South Africa has an elevated level of infectious diseases burden notably from bacterial origin, even though viral, protozoal and helminthic, as well as yeast infectious agents have also been reported. This is in consistency with the research by.
who reports that a larger proportion of the deaths in South Africa results from infectious diseases including tuberculosis, sexually transmitted infections (STIs) and diarrhea.

**Tuberculosis**

The bacterium, *Mycobacterium tuberculosis* (TB) is the causative pathogen for tuberculosis which is problematic to the medical community and causes more than 1.5 million deaths in a year worldwide. In South Africa it is estimated that 28% of TB infection burden is due to HIV in its population, thus ranking fourth largest globally.

According to a review by, in the year 2013 alone South Africa recorded 860 TB cases per 100 000 people. It is worth noting that tuberculosis has been reported as the leading cause of death in South Africa.

A substantial number of studies have reported TB resistance to many pharmaceutical medications giving rise to multidrug-resistant TB (MDR-TB) and extensively drug-resistant TB (XDR-TB). However, plant natural material has been widely applied to treat TB infections due to the presence of its chemical constituents including alkaloids, glycosides, tannins, phenolics, xanthones, quinones, sterols and triterpenoids.

The Bapedi traditional healers in the Limpopo province use a variety of plants including *Psidia punctulata* (DC.), Vatke and *Xerophyta retinervis* Baker to cure TB and its associated secondary infections. The Jongilanga local community in Mpumalanga also apply medicinal plants to remedy conditions of cancer, TB and acne.

According to a research by, some herbs that are used by the inhabitants of the Free State Province to treat TB are active at very smaller concentrations and these includes *Dicoma anomala* (0.195 – 6.25 mg/ml), *Hermannia depressa* (0.78 – 1.56 mg/ml), *Senecio harveianus* (0.195 – 0.39 mg/ml) and *Lotononis lanceolate* (0.195 - 0.65 mg/ml).

**Sexually transmitted infections (STIs)**

Venereal diseases also called sexually transmitted infections (STIs) are mostly caused by bacterial pathogens including *Treponema pallidum* which causes syphilis, *Neisseria gonorrhoeae* which causes gonorrhoea and *Chlamydia trachomatis* which causes chlamydia infections. However viral and parasitic pathogens have been reported to also cause STIs.

It is estimated that in a year, in South Africa more than 11 million STI infections are recorded in the health registers. The misconceptions and stigma attached to STIs in South Africa cause most of the people to favour traditional homemade remedies using medicinal plants over hospitals and local clinics visits. Apart from that, undesirable effects as well as resistance to most STI orthodox medications have been reported.

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**Fig. 1.** Percentage of the parts of plants frequently used for preparing traditional medicines in South Africa. Adapted from Lall et al., (2018)
<table>
<thead>
<tr>
<th>Botanical name</th>
<th>Family</th>
<th>Common name</th>
<th>Plant parts used</th>
<th>Method of preparation</th>
<th>Traditional therapeutic uses</th>
<th>Distribution in South Africa (Exotic or Indigenous)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia karroo</td>
<td>Fabaceae (Sub Family Mimosoideae)</td>
<td>Sweet thorn</td>
<td>Leaves Root Gum</td>
<td>Decoction</td>
<td>Oral thrush, mouth ulcers, diarrhoea, stomach ache, dysentery, headache, eye infections, colds, wounds abscesses, STIs</td>
<td>Eastern Cape Mpumalanga (Indigenous)</td>
<td>26, 41, 52-53</td>
</tr>
<tr>
<td><em>Hayne = Vachellia karroo</em> (Hayne) Banfi &amp; Glasso</td>
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<tr>
<td>Acors calamus L.</td>
<td>Acoraceae</td>
<td>Sweet flag</td>
<td>Leaf decoction</td>
<td>Decoction</td>
<td>Diarrhoea, ingestion, dysentery, worms, asthma</td>
<td>KwaZulu-Natal</td>
<td>54-55</td>
</tr>
<tr>
<td>Albizia adianthifolia</td>
<td>Fabaceae</td>
<td>Flat-crown albizia, Rough-bark flat-crown albizia,</td>
<td>Leaf</td>
<td>Decoction</td>
<td>Skin rash (purulent), chicken pox, abscess, eczema, scabies, richy skin complaints, headache, haemorrhoids, bronchitis, cough, sinusitis, respiratory problems, tooth ache, gonorrhoea</td>
<td>Eastern Cape</td>
<td>32, 57-58</td>
</tr>
<tr>
<td>W.Wight</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Allium sativum L.</td>
<td>Aliaceae</td>
<td>Garlic</td>
<td>Leaf Bulb/Rhizome Cloves</td>
<td>Infusion Powder</td>
<td>Throat infection, tuberculosis, asthma, stomach complaints</td>
<td>East Cape (exotic)</td>
<td>59-62</td>
</tr>
<tr>
<td>Aloe arborescens Mill.</td>
<td>Asphodelaceae</td>
<td>krantz aloe</td>
<td>Leaf Root</td>
<td>Infusion Powder</td>
<td>Skin problems, wounds, burns, abrasions, ulcers, inflammation, diarrhoea, constipation, tuberculosis, vomiting, urinary problems</td>
<td>East Cape KwaZulu-Natal</td>
<td>25, 50</td>
</tr>
<tr>
<td>Aloe barbadensis Mill.</td>
<td>Asphodelaceae</td>
<td>Aloe vera</td>
<td>Root Leaf</td>
<td>Infusion Powder</td>
<td>Wounds, burns, oedema, tumour, inflammation, gastric ulcers, HIV/AIDS, stomach complaints, colic</td>
<td>KwaZulu-Natal Mpumalanga North West Western Cape (Indigenous)</td>
<td>19, 63-64</td>
</tr>
<tr>
<td>Artemisia afra Wild.</td>
<td>Asteraceae</td>
<td>Wild wormwood, African wormwood</td>
<td>Leaf Stem</td>
<td>Infusion Inhaled</td>
<td>Cough, colds influenza, fever, and gastrointestinal disorders, earache, intestinal worms, colic, malaria, bladder and kidney problems, gout, mumps, pain</td>
<td>East Cape Free State Gauteng KwaZulu-Natal Limpopo Northern Cape Western Cape</td>
<td>65</td>
</tr>
<tr>
<td>Bidens Pilosa L.</td>
<td>Asteraceae</td>
<td>Black jack</td>
<td>Stem Leaf Root</td>
<td>Infusion</td>
<td>Genital warts, syphilis, abdominal problems, dysentery, diarrhoea, colic, stomach pain, prostate gland tumour, inflammation, wounds or burns</td>
<td>KwaZulu-Natal Limpopo (Exotic)</td>
<td>66-67</td>
</tr>
<tr>
<td>Boophone distrihca (L.F.) Herb.</td>
<td>Amaryllidaceae</td>
<td>Am Century plant</td>
<td>Bulb</td>
<td>Infusion</td>
<td>Inflammation, wounds, skin rashes, burns, boils, cats,</td>
<td>East Cape Free State Gauteng</td>
<td>67-68</td>
</tr>
<tr>
<td>Genus</td>
<td>Family</td>
<td>Part Used</td>
<td>Preparation</td>
<td>Conditions</td>
<td>Locations</td>
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<tr>
<td>Caesalpinia decapetala (Roth)</td>
<td>Fabaceae</td>
<td>Stem, root</td>
<td>Decoction</td>
<td>Gonorrhoea, Dysmenorrhoea</td>
<td>Limpopo (Indigenous-invasive weed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cannabis sativa L. var. sativa</td>
<td>Cannabaceae</td>
<td>Leaf</td>
<td>Maceration</td>
<td>Tuberculosis, headache, pain</td>
<td>Limpopo North-West</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carica papaya L.</td>
<td>Caricaceae</td>
<td>Leaf</td>
<td>Decoction</td>
<td>Gonorrhoea, Stomach problems, venereal infections, STIs</td>
<td>KwaZulu-Natal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassia abbreviata</td>
<td>Fabaceae</td>
<td>Root</td>
<td>Decoction</td>
<td>All STIs, erectile dysfunction, chest pain, asthma, pneumonia, toothache, stomach problems, AIDS (HIV)</td>
<td>Limpopo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Citrus limon (L.) Burm.f.</td>
<td>Rutaceae</td>
<td>Leaf</td>
<td>Decoction</td>
<td>Coughs, colds, unspecified respiratory symptoms, fever, headache, tuberculosis</td>
<td>KwaZulu-Natal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combretum molle R.Bre G. Don</td>
<td>Combretaceae</td>
<td>Leaf</td>
<td>Decoction</td>
<td>Gonorrhoea, sores, syphilis, wounds, asthma, stomach complaints</td>
<td>Free State, Gauteng, KwaZulu-Natal, Limpopo,Mpumalanga, North West (Indigenous)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commelina africana L</td>
<td>Commelinaceae</td>
<td>Root</td>
<td>Decoction</td>
<td>Veneral diseases, menstrual cramps in women, hypertension, infertility, pelvic pains and bladder complaints</td>
<td>Eastern Cape Free State Gauteng, KwaZulu-Natal, LimpopoMpumalanga North West Northern Cape</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curtisia dentata (Burm.f) C.A.Sm.</td>
<td>Cornaceae</td>
<td>Stem bark</td>
<td>Decoction</td>
<td>Stomach complaints, diarrhoea, STIs, pimples</td>
<td>KwaZulu-Natal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diospyros mespiliformis Hochst. Ex A. DC</td>
<td>Ebenaceae</td>
<td>Bark, root (roasted and pulverized)</td>
<td>Infusion, Powdered</td>
<td>Stomach ailments, ulcers diarrhoea, stop vomiting, treat worms, pneumonia, syphilis, cough, tuberculosis, bronchial diseases, leprosy, wounds diarrhoea and abdominal pains</td>
<td>Limpopo (Indigenous)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domheya</td>
<td>Sterculiaceae</td>
<td>Wild pear</td>
<td>Decoction</td>
<td>Tuberculosis, gynaecological problems</td>
<td>KwaZulu-Natal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

KwaZulu-Natal, Limpopo, Mpumalanga, Western Cape, Gauteng.
rotundifolia
(Hochst.) Planch.
var. rotundifolia

Euclea divinorum
Hieron.

Euclea natalensis
A.DC

Euclea castanoides
(Mill.) Chitt

Faurea saligna
Harv.

Ficus carica
Linn.

Galeonia africana L.

Garcinia gerrardi
Harv. ex Sim

Helichrysum caespititium (DC.) Harv.
<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Family</th>
<th>Part Used</th>
<th>Preparation</th>
<th>Uses</th>
<th>Province</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Helichrysum glomeratum</em> Klatt</td>
<td>Asteraceae</td>
<td>Everlastings</td>
<td>Whole plant</td>
<td>decoction</td>
<td>North West (Indigenous)</td>
<td></td>
</tr>
<tr>
<td><em>Moringa okeifera</em> Lam.</td>
<td>Moringaceae</td>
<td>Horse-radish tree, Drumstick tree</td>
<td>Gum Pod Leaf Root</td>
<td>Decoction Juice</td>
<td>Free State KwaZulu-Natal Limpopo</td>
<td>(indigenous-endemic) 86-87</td>
</tr>
<tr>
<td><em>Olea europaea subsp. Africana</em></td>
<td></td>
<td>Wild Olive Fruit Leaf</td>
<td>Infusion</td>
<td>Bloody stool, immature fruits are consumed as astringents against diarrhoea, urinary and bladder infections</td>
<td>KwaZulu-Natal</td>
<td>(Indigenous) 25</td>
</tr>
<tr>
<td><em>Opuntia ficus-indica</em> Mill.</td>
<td>Cactaceae</td>
<td>Indian fig Sweet prickly pear</td>
<td>Root Leaf (cladodes)</td>
<td>Decoction Topical application</td>
<td>Limpopo (Exotic)</td>
<td>27, 71, 75</td>
</tr>
<tr>
<td><em>Parinari curatellifolia</em> Planch. ex Bernh.</td>
<td>Chrysobalanaceae</td>
<td>Mobola-plum</td>
<td>Leaf Bark</td>
<td>Decoction</td>
<td>Limpopo Mpumalanga (Indigenous) 80, 88</td>
<td></td>
</tr>
<tr>
<td><em>Pelargonium sidoides</em> DC.</td>
<td>Geraniaceae</td>
<td>Rose-scented Pelargonium, Cape Pelargonium</td>
<td>Root Leaf</td>
<td>Decoction Powdered</td>
<td>Eastern Cape Free state KwaZulu-Natal</td>
<td>(indigenous) 7, 13, 25, 59</td>
</tr>
<tr>
<td><em>Penthorus longifolia</em> (Bernh.) Engl</td>
<td>Amaranthaceae</td>
<td>Red Cape Beech Purple currant</td>
<td>Bark</td>
<td>Infusion</td>
<td>Eastern Cape KwaZulu-Natal Limpopo Mpumalanga (Exotic) 89</td>
<td></td>
</tr>
<tr>
<td><em>Prunus africana</em> (Hook.f.) kalkman</td>
<td>Rosaceae</td>
<td>African cherry</td>
<td>Bark Root</td>
<td>Infusion</td>
<td>Eastern Cape (indigenous) 25</td>
<td></td>
</tr>
<tr>
<td><em>Psidiya punctulata</em> (DC.) Vahl</td>
<td>Asteraceae</td>
<td>Sticky</td>
<td>Root</td>
<td>Pounded</td>
<td>Limpopo (Indigenous) 5</td>
<td></td>
</tr>
<tr>
<td><em>Psidium guajava</em> L.</td>
<td>Myrtaceae</td>
<td>Fruit</td>
<td>Leaf Bark Root</td>
<td>Decoction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant Name</td>
<td>Family</td>
<td>Parts Used</td>
<td>Uses</td>
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</tr>
<tr>
<td><em>Punica granatum</em> Linn.</td>
<td>Punicaceae</td>
<td>Root, Peel, Fruit</td>
<td>Diarrhoea, diabetes mellitus, asthma, stomach problems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Salvia aurea</em> L. (= <em>Salvia africana-lutea</em> L.)</td>
<td>Lamiaceae</td>
<td>Whole plant, Aerial parts</td>
<td>Bronchitis, cough, colds and flu, female problems, diarrhoea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Salvia disermas</em> L.</td>
<td>Lamiaceae</td>
<td>Whole plant</td>
<td>Tuberculosis, cough, influenza, bacterial infections, cold</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Salvia repens</em> L.</td>
<td>Lamiaceae</td>
<td>Root, Leave</td>
<td>Stomach problems, diarrhoea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sansevieria hyacinthoides</em> (L.) Druce</td>
<td>Dracaenaceae</td>
<td>Whole plant</td>
<td>Ear infection, earache, tooth ache, diarrhoea, intestinal worms, stomach complaints, ulcers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Scadoxus puniceus</em> (L.) Friis &amp; Nordal</td>
<td>Amaryllidaceae</td>
<td>Leaf, Bulb</td>
<td>Abdominal pains, stomach complaints, diarrhoea, nausea, kidney and urinary infections, tonsillitis, pneumonia, tuberculosis, Stomach problems, oedema, wound infections, prostate inflammation, digestive disorders, yeast infections, kidney and renal problems, diabetes, hypertension, gonorrhoea, intestinal gas, blood purifier, heart-water, dysmenorrhoea, eye infections, diarrhoea, pneumonia</td>
<td></td>
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</tr>
<tr>
<td><em>Scrophularia pinnata</em> (Lam) Kuntze ex Thell</td>
<td>Asteraceae</td>
<td>Whole plant, Root, Aerial parts</td>
<td>Pulmonary sicknesses, tuberculosis, cough, chest colds, expectorant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sclerocarya birrea</em> (A. Rich.) Hochst.</td>
<td>Anacardiaceae</td>
<td>Bark</td>
<td>Eczema, acne, boils, enema for stomach ache, oils, dysentery, diarrhoea, Kidney pain, toothache, fever, UTIs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Searsia burchellii</em> (Sond. Ex Engl.) Moffett</td>
<td>Anacardiaceae</td>
<td>Leaf</td>
<td>Pulmonary sicknesses, tuberculosis, cough, chest colds, expectorant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Solanum lycopersicum</em> L.</td>
<td>Solanaceae</td>
<td>Fruit</td>
<td>Diarrhoea, asthma, cancer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant Name</td>
<td>Family</td>
<td>Common Name</td>
<td>Part Used</td>
<td>Preparation</td>
<td>Uses</td>
<td>Provenance</td>
</tr>
<tr>
<td>-------------------------------</td>
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<td>---------------------------------------------------------------------------</td>
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<td>-----------------------------</td>
</tr>
<tr>
<td>Syzygium cordatum</td>
<td>Myrtaceae</td>
<td>Water berry</td>
<td>Bark</td>
<td>Decoction</td>
<td>Stomach complaints, diarrhoea, STIs, respiratory complaints, burns, tuberculosis</td>
<td>KwaZulu-Natal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Leaf</td>
<td>Infusion</td>
<td></td>
<td>Mpumalanga</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fruit</td>
<td></td>
<td></td>
<td>Western Cape (Exotic)</td>
</tr>
<tr>
<td>Sutherlandia frutescens (L.)</td>
<td>Fabaceae</td>
<td>Cancer bush</td>
<td>Aerial parts (leaves, stem, flowers, and pods)</td>
<td>Infusion</td>
<td>Stomach, kidney and liver problems, cancers, diabetes, flu, rheumatism, fever, wounds and</td>
<td>Eastern Cape Free</td>
</tr>
<tr>
<td>Hochst. ex C. Krauss subsp.</td>
<td></td>
<td></td>
<td>Roots</td>
<td>Decoction</td>
<td>eyes infections, inflammation, HIV/AIDS, improves cachexia (muscle-wasting), gonorrhoea, STIs</td>
<td>State KwaZulu-Natal</td>
</tr>
<tr>
<td>cordatum</td>
<td></td>
<td></td>
<td>Leaves</td>
<td></td>
<td></td>
<td>Mpumalanga</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Root</td>
<td></td>
<td></td>
<td>Northern Cape</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Leaf</td>
<td></td>
<td></td>
<td>Western Cape (Indigenous)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fruit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tulbaghia violacea</td>
<td>Alliaceae</td>
<td>Wild garlic</td>
<td>Leaf</td>
<td>Decoction - steam</td>
<td>Coughs, asthma, colds, fever, sinus headaches, cancer of the oesophagus, tuberculosis,</td>
<td>Eastern Cape</td>
</tr>
<tr>
<td>Harv.</td>
<td></td>
<td></td>
<td>Bulb</td>
<td>Inhaled under blanket</td>
<td>intestinal worms</td>
<td>17, 49, 61</td>
</tr>
<tr>
<td>Vernonia amygdalina Del.</td>
<td>Asteraceae</td>
<td>Bitter leaf</td>
<td>Leaf</td>
<td>Decoction</td>
<td>Gastrointestinal problems, diarrhoea, schistosomiasis, amoebic dysentery, diarrrhoea, measles,</td>
<td>Eastern Cape</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Root</td>
<td>Crushed</td>
<td>fevers, malaria, cough, hepatitis, venereal diseases</td>
<td>KwaZulu-Natal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Squeezed</td>
<td></td>
<td>Limpopo (Indigenous)</td>
</tr>
<tr>
<td>Warburgia salutaris (G.</td>
<td>Cancellaceae</td>
<td>Pepper-bark tree</td>
<td>Bark</td>
<td>Decoction</td>
<td>Coughs, chest problems, colds, influenza, diarrhoea, toothache, headache, skin problems,</td>
<td>Gauteng KwaZulu-Natal</td>
</tr>
<tr>
<td>Bertol.) Chiov. (Endangered</td>
<td></td>
<td></td>
<td>Leaf</td>
<td>Infusion</td>
<td>gastric ulcers, venereal diseases</td>
<td>Limpopo</td>
</tr>
<tr>
<td>species)</td>
<td></td>
<td></td>
<td></td>
<td>Powdered</td>
<td></td>
<td>Mpumalanga (Exotic)</td>
</tr>
<tr>
<td>Vernonia americana</td>
<td>Olacaceae</td>
<td>Blue Sour-plum</td>
<td>Bark</td>
<td>Decoction</td>
<td>STIs (clean blood), painful menstruation, venereal diseases, headache due to indigestion,</td>
<td>Limpopo</td>
</tr>
<tr>
<td>L. var. americana</td>
<td></td>
<td></td>
<td>Root</td>
<td>Powdered</td>
<td>bloody stools, diarrhoea, dysentery in children, coughs, asthma, eye infections</td>
<td>(Exotic)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Venereal diseases, STIs, syphilis, bilharzia, worms, skin and wound infections, eye problems,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>painful tonsils, diarrhoea, dysentery, severe stomach pains, colic, cough, chest-pains,</td>
<td>KwaZulu-Natal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Limpopo-northern and central parts (Indigenous)</td>
</tr>
<tr>
<td>Vernonia coffia Sond. var.</td>
<td>Olacaceae</td>
<td>Large Sour-plum</td>
<td>Leaf</td>
<td>Decoction</td>
<td>Venerable Diseases, STIs, syphilis, bilharzia, worms, skin and wound infections, eye problems,</td>
<td></td>
</tr>
<tr>
<td>coffea</td>
<td></td>
<td></td>
<td>Root</td>
<td>Powdered</td>
<td>painful tonsils, diarrhoea, dysentery, severe stomach pains, colic, cough, chest-pains,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Seed</td>
<td>Roasted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific name of Plant</td>
<td>Common name of plant</td>
<td>Type of extract</td>
<td>Sensitive pathogen</td>
<td>Reported biological ingredients</td>
<td>References</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
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<td>-----------------------------------------------------------------------------------</td>
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<td></td>
</tr>
<tr>
<td><em>Allium sativum</em></td>
<td>Garlic</td>
<td>Aqueous, ethanol and chloroform extracts</td>
<td>MDR-TB and XDR-TB, <em>Escherichia coli</em>, <em>Salmonella typhi</em>, <em>Staphylococcus aureus</em>, <em>Streptococcus agalactiae</em>, <em>Klebsiella pneumoniae</em>, <em>Proteus mirabilis</em>, <em>Bacillus subtilis</em>, <em>Helicobacter pylori</em></td>
<td>Allcin which is an alkaloid</td>
<td>133-134</td>
<td></td>
</tr>
<tr>
<td><em>Combretum imberbe</em></td>
<td>Leadwood</td>
<td>Acetone extract, Crude and organic extracts</td>
<td><em>Candida albicans</em>, <em>Cryptococcus neoformans</em>, <em>Schistosoma haematobium</em>, <em>Staphylococcus aureus</em>, <em>Streptococcus sanguinis</em>, <em>Lactobacillus acidophilus</em>, <em>Helicobacter pylori</em></td>
<td>Triterpenoids including glycosidic derivatives of hydroxy-imberbic acid, imberbic acid, glycosides based on imberbic acid</td>
<td>135-137</td>
<td></td>
</tr>
<tr>
<td><em>Combretum molle</em></td>
<td>Velvet willows</td>
<td>Crude and organic extracts</td>
<td><em>Bacillus cereus</em>, <em>Staphylococcus aureus</em>, <em>Escherichia coli</em>, <em>Pseudomonas aeruginosa</em></td>
<td>Flavonoids, Steroids, Tannins, Triterpenoids</td>
<td>135, 138-139</td>
<td></td>
</tr>
<tr>
<td><em>Euclea divinorum</em></td>
<td>Magic quarry</td>
<td>Root-bark organic and aqueous extract</td>
<td><em>Bacillus subtilis</em>, <em>Escherichia coli</em>, <em>Staphylococcus aureus</em>, <em>Streptococcus sanguinis</em>, <em>Lactobacillus acidophilus</em></td>
<td>Alkaloids, Saponins, Tannins, Amino acids, Flavonoids, Phenols, Triterpenoids, Hyperforin</td>
<td>139-140</td>
<td></td>
</tr>
<tr>
<td><em>Hypericum perforatum</em> L.</td>
<td>St. John’s Wort</td>
<td>Organic extract</td>
<td><em>Staphylococcus aureus</em>, Methicillin-resistant <em>Staphylococcus aureus</em>, <em>Helicobacter pylori</em></td>
<td>Polyphenols including ellagic</td>
<td>141</td>
<td></td>
</tr>
<tr>
<td><em>Punica granatum</em></td>
<td>Pomegranate</td>
<td>Peel, fruit skin and whole</td>
<td><em>Staphylococcus aureus</em>, <em>Escherichia coli</em></td>
<td></td>
<td>142-144</td>
<td></td>
</tr>
<tr>
<td>Plant</td>
<td>Fruit/Root</td>
<td>Extract Type</td>
<td>Bacteria/Other Organisms</td>
<td>Additional Information</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
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<td>----------------------------------------------------------------</td>
<td>---------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelargonium sidoides DC</td>
<td>Rose-scented Pelargonium ORCape Pelargonium</td>
<td>Fruit-hot water and organic extract</td>
<td><em>Pseudomonas aeruginosa</em>, <em>Klebsiella pneumoniae</em>, <em>Saccharomyces cerevisiae</em>, <em>Salmonella typhimurium</em>, <em>Bacillus Subtilis</em>, <em>Yersinia enterocolitica</em>.</td>
<td>Tannins, ellagic acid, and gallic acid. Alkaloid, Flavonoid, Glycoside, Phenol, Condensed and hydrolysable tannins, Coumarins, Flavonoids, Gallic acid, Hydroxycinnamic acid, Proanthocyanins, Phenolic acids including gallic acid.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schrebera alata</td>
<td>Wild Jasmine</td>
<td>Organic extract</td>
<td><em>MRSA</em>, <em>Candida albicans</em>, <em>Multidrug-resistant</em>, <em>Pseudomonas aeruginosa</em>, <em>Bacillus cereus</em>, <em>Escherichia coli</em></td>
<td>Flavonoids, Sterols, Alkaloids, Tannins, Quinones, Terpenoids, Saponins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terminalia sericea</td>
<td>Silver clutter-leaf, Silver terminalia</td>
<td>Organic root and leaf extracts</td>
<td><em>Helicobacter pylori</em>, <em>Human immunodeficiency virus</em>, <em>Mycobacterium tuberculosis</em>, <em>Mycobacterium smegmatis</em>, <em>Pseudomonas aeruginosa</em>, <em>Staphylococcus aureus</em></td>
<td>Alkaloids, Flavonoids, Tannins, Saponins, Phenolic acids, Lignans, Steroids, Glycosides</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vernonia amygdalina</td>
<td>Bitter leaf</td>
<td>Organic and aqueous extracts</td>
<td><em>Escherichia coli</em>, <em>Pseudomonas aeruginosa</em>, <em>Staphylococcus aureus</em></td>
<td>Vernolide, Vernodalol, Vernodalin, Vernodalinoil, Vernomy gdin, hydroxvemolide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ximenia caffra</td>
<td>Sour-plum</td>
<td>Leaf, root-organic and aqueous extract</td>
<td><em>Neisseria gonorrhoeae</em>, <em>Escherichia coli</em>, <em>Bacillus subtilis</em>, <em>Staphylococcus aureus</em>, <em>Acinetobacter baumannii</em>, <em>Bacillus subtilis</em>, <em>Bacillus cereus</em>, <em>Escherichia coli</em>, <em>Methicillin-resistant</em> <em>Staphylococcus aureus</em>,</td>
<td>Flavonoids Tannins Polyphenols including gallic acid, catechin, quercetin and kaempferol Terpene including zingiberene, Phenols including gingerol, paradols, and shogaol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zingiber officinale Roscoe</td>
<td>Ginger</td>
<td>Organic and aqueous extracts</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Many ethnobotanical surveys in South Africa have reported that most indigents apply a vast number of medicinal plants for the treatment of STIs including but not limited to Acacia karroo, Bidens pilosa, Carica papaya, Diospyros mespiliformis, Ficus abutilifolia, Rheicissus tridentata subsp. cuneifolia, Ximenia caffra, Vachellia karroo, Trichilia dregeana, Terminalia sericea Cambess, Typha capensis Rohrb and Ziziphus mucronata Wild. subsp. mucronata. According to a research conducted by 104, the root extracts of Acacia karroo and Rheicissus tridentata subsp. cuneifolia plants were active against Neisseria gonorrhoeae with MIC value of 0.8 mg/ml and 0.4 mg/ml respectively.

Similarly, the aqueous extracts of Bidens Pilosa leaf (mean MIC 83.2 mg/ml) and Ximenia caffra root (mean MIC 62.1 mg/ml) showed inhibitory activity against Neisseria gonorrhoeae pathogen. Also, Trichilia dregeana produces a mean MIC of 2.0 mg/ml against Treponema pallidum. A review by 57, 105, agrees with this and reports on similar findings on the use of medicinal plants to treat STIs in South Africa.

**Diarrhoea**

According to 106, diarrhoea is a common symptom that is usually related with the disorders of the gastrointestinal tract and is typically characterised by increased in the regularity of bowel movement associated with watery stools. Infectious diarrhoea other gastrointestinal illnesses are frequently triggered by resistant strains of medically important bacteria including B. cereus, E. coli, S. aureus, Salmonella typhimurium (S. typhimurium), Proteus vulgaris (P. vulgaris), and Shigella spp. Similarly, viral as well as parasitic diarrhoea has been reported. diarrhoea has been reported as the major cause of death in low and middle income countries with over 6.9% death rate reported 108-109. In South Africa, the indigents usually apply various medicinal plants to remedy gastrointestinal diseases and conditions associated with diarrhoea 12, 108. The pomegranate plant (Punica granatum), has been widely used to alleviate many health conditions including diarrhoea due to its rich phytochemical constituents such as flavonoids, alkaloids, saponins, tannins, phenols and anthocyanins. According to 132, the fruit peel extract of Punica granatum inhibits the growth of MRSA with zones of inhibition ranging from 22.0 mm to 11.3 mm. Similar research by 112 agrees with this and adds that the juice of pomegranate fruit shows inhibitory properties against B. cereus, E. coli, and S. aureus and produces 26.0 mm, 20.0 mm and 26.0 mm as diameter of inhibition respectively. Notwithstanding, the bark extract of Sclerocarya birrea shows activity against diarrhoeal pathogens with low MIC values including S. typhimurium (0.20 mg/ml), B. cereus (0.29 mg/ml), S. aureus (0.35 mg/ml), P. vulgaris (0.75 mg/ml) and E. coli (0.95 mg/ml). On the other hand, the extract from the leaf of Psidium guajava (P. guajava) shows killing properties against B. cereus, S. typhimurium and S. aureus with MIC values of 0.34, 0.65 and 0.93 mg/ml respectively. Additionally, 25 had similar findings and reports on the MIC values of various medicinal plants in South Africa against diarrhoeal entero-pathogens including Aloe arborescense against S. aureus (0.018 mg/ml), Eucomis comosa against Enterococcus faecalis (0.078 mg/ml) and Acacia mearnsii against S. typhimurium (0.039 mg/ml). This is consistent with the research conducted by 113 on the use of indigenous herbal plants in South Africa to treat diarrhoea caused by enteropathogenic bacterial organisms.

In a majority of instances, reports showed that one plant can be useful in curing multiple conditions and/or diseases (mono-therapy), for example garlic scientifically known as Allium sativum, is used to treat throat infections, TB, asthma, stomach diseases. Similarly, the cape aloe (Aloe ferox) is used in KwaZulu-Natal to remedy burns, sunburn, acne, insect bites, skin irritation, toothaches, stomach problems, sinusitis.

Even though indigenous plants have proven very useful to mankind, however over-exploitation of these plants threatened some species to disappear or near disappear on earth. Due to this, the government of South Africa has introduced regulations and thus label some plants as endangered, and/or protected species including Curtisia dentata commonly called “assegai” in Afrikaans, Warburgia salutaris known as peppercorn tree, and Zanthoxylum capense – a protected tree. It is interesting to note that, while some of the plants used as medicine are largely distributed in the wild or grown in gardens at home, a majority...
are indigenous \(^7\). Of this, a smaller proportion are exotic and/or endemic in some parts in South Africa including Limpopo, Mpumalanga and KwaZulu Natal provinces \(^1\).

**Pathogenic bacterial infections**

Infectious diseases are major cause of mortality and disability, and remain the second leading cause of death across the globe \(^3, 5, 114-115\). This phenomenon is further exacerbated by the emergence of both old familiar and new unrecognised infectious disease pandemics \(^116-118\). Microbial infectious diseases cause more than 50% of all the deaths that occur in the underdeveloped nations particularly African countries \(^3, 21, 100\).

There is a rising amount of information to indicate that most of the diseases which are problematic to human health are said to be infectious and are mostly caused by pathogenic microorganisms including bacteria, viruses, parasites and fungi \(^95, 115, 118-120\). It is of importance to note that infectious diseases occurring as a result of bacterial infections are reported to be the number one killer disease than any other category of disease globally \(^95, 114\). These bacterial infections accounts for 43% mortality rate recorded in the underdeveloped countries whilst only 1% of the mortality rate is recorded in the developed countries \(^121\).

The high level of infectious disease burden in a population with minimal health resources, comes with the associated ramifications including death. According to Stats \(^95\), recorded deaths in South Africa for the period between 2014-2017 caused by infectious and parasitic diseases was 78,562 amounting to 17.2% demises. A substantial amount of health-care costs in South Africa has also been incurred as a result of infectious diseases \(^35\).

**Plants as alternative source of antimicrobials**

Plants are generally known to be the biggest stores of naturally occurring biochemical compounds and are capable of manufacturing diverse natural chemical constituents including toxins and/ or pheromones as a form of defence mechanism against other organisms or for pollination respectively \(^3, 122-123\). These chemical substances are of course not placebo but are fused with low molecular weight potent bioactive constituents also known as secondary metabolites \(^124-125\).

As early as the 1850s, plants’ secondary metabolites have received intense investigation \(^125-126\). Currently, more than 12,000 bioactive compounds from plants have been isolated and are further classified based either on their chemical composition and structure, their biosynthetic origin or their solubility \(^124, 127\). Due to this, the compounds were further segregated as alkaloids, terpenoids, phenolics, saponins, lipids and carbohydrates \(^128-129\). These chemicals have promising therapeutic effects on which human beings rely on \(^34\). The presence of these phytochemical constituents in plants perhaps explains their countless applications in traditional medicine \(^129-130\).

**The inhibitory properties of South African medicinal plants against bacterial pathogens**

After unsuccessful attempts to eliminate pathogens with conventional medicines due to drug resistance, some plant secondary metabolites were considered. Numerous scientific studies have revealed significant antibacterial activities of some plants against multidrug-resistant pathogens of bacterial origin \(^128, 130-131\) (Table 2).

According to \(^132\); organic and aqueous extracts of *Vernonia amygdalina* shows antibacterial effect against *Pseudomonas aeruginosa*, *Klebsiella* spp., *Streptococcus* spp., *Bacillus cereus*, *Bacillus pumilus*, *Bacillus subtilis*, *Enterobacter cloacaem*, *E. coli* and *Staphylococcus aureus*. In a research conducted by \(^25\), plant extracts from *Psidium guajava*, *Eucomis autumnalis* and *Cyathula uncinulata* showed promising antibacterial effect against *S. aureus* with minimum inhibitory concentration (MIC) values ranging from 0.018 mg/ml to 2.5 mg/ml. Correspondingly, \(^101\) reported that the extracts from the leaves of *Eucomis autumnalis* was active against *Bacillus pumilus*, *Escherichia coli* and *Staphylococcus aureus* at a minimum inhibitory concentration (MIC) of 0.098 mg/ml, 0.130 mg/ml and 0.098 mg/ml respectively. This is in consistence with the research conducted by \(^105\) in which the *Bolusanthus speciosus* bark used by the Veda indigents to treat venereal diseases showed good inhibitory activity against *E. coli* and *S. aureus* with ranges of MIC values between 0.012 mg/ml and 0.098 mg/ml. This validates the idea that plants could be used as alternative source of antibiotics.
CONCLUSION

The reviewed publications are focussed on biological activities, antioxidant and antimicrobial activities of South African plants used to treat human bacterial infections. Yet additional data and published clinical trials are still needed to confirm therapeutic properties of the researched medicinal plants. The practice of traditional medicine through the application of plant natural product still plays a vital role in fulfilling the rudimentary health care needs of the people of South Africa. Acacia karroo, Bidens pilosa, Diospyros mespiliformis and Ximenia caffra were the commonly applied herbs for the treatment of venereal diseases. On the other hand, diarrhoea and other stomach related ailments caused by pathogenic bacteria were remedied with Allium sativum, Eucomis comosa, Psidium guajava, Punica granatum and Aloe spp. Moreover, Aloe barbadensis, Cassia abbreviata, Helichrysum caespititium, Hypoxis colchicifolia and Sutherlandia frutescens were mostly used by HIV positive patients to alleviate opportunistic infections including TB, diarrhoea and skin infections. The leaves, bark and root were frequently used plant parts while the preferred methods of preparation were decoction and infusion. This study demonstrates the usefulness of plant natural product as medicine to prevent and treat human pathogenic infections caused by resistant bacteria in South Africa.

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Conflict of interest

The authors declare no conflict of interest.

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