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Review Article

# *ZANTEDESCHIA AETHIOPICA* (L.) SPRENG.: A REVIEW OF ITS MEDICINAL USES, PHYTOCHEMISTRY, AND BIOLOGICAL ACTIVITIES

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**ABSTRACT**

*Zantedeschia aethiopica* is an evergreen monocotyledonous herb widely used as herbal medicine and ornamental plant. The current study is aimed at reviewing the medicinal uses, phytochemistry, and biological activities of *Z. aethiopica*. Information on biological activities, medicinal uses, and phytochemistry of *Z. aethiopica* was gathered from several internet sources which included Scopus, Google Scholar, Elsevier, Science Direct, Web of Science, PubMed, SciFinder, and BMC. Additional information on these aspects was sourced from pre-electronic sources such as journal articles, scientific reports, theses, books, and book chapters obtained from the University Library. The current study revealed that *Z. aethiopica* is mainly used as herbal medicine for boils, burns, gout, inflammation, insect bites, rheumatism, sores, and wounds. Phytochemical and pharmacological studies showed that *Z. aethiopica* extracts and compounds isolated from the species have antibacterial, antifungal, antioxidant, antihistaminic, antialgal, antithrombotic, and anticoagulant activities. This research showed that *Z. aethiopica* is an integral part of the traditional pharmacopeia in several countries where the species is indigenous or naturalized, but there is the lack of alignment between the known medicinal applications, phytochemistry, and biological activities of the species. Therefore, future research should focus on evaluating the chemical and pharmacological properties of *Z. aethiopica* extracts and compounds associated with the species.

**Keywords:** *Araceae*, Ethnopharmacology, Herbal medicine, Southern Africa, *Zantedeschia aethiopica.*

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## INTRODUCTION

*Zantedeschia aethiopica* (L.) Spreng. is an evergreen herb which is a member of a monocotyledonous flowering plants Araceae family also known as arum lily family. *Z. aethiopica* is an important food, medicinal and ornamental plant in Africa, Asia, Australia, Europe, and the United States of America, and recently playing an important role in cleaning up contaminated soils and water [1-6]. Research by Halligan *et al*. [7] and Wei *et al*. [8] showed that *Z. aethiopica* is sold worldwide as an ornamental plant and the species is cultivated commercially as an ornamental flower [9-12] with the foliage and flowers employed principally for coronas and other funeral decorations on altars and shrines and as cut flowers. In South Africa, *Z. aethiopica* is one of the valuable medicinal plant species in the country and the species is included in the book "medicinal plants of South Africa," a photographic guide to the most commonly used herbal medicines in the country, including its botany, major medicinal applications active phytochemical compounds [13]. Similarly, research by Reinsten *et al*. [12] showed that *Z. aethiopica* has commercial potential for the cut flower trade as potted flowers and foliages in South Africa. The tuberous rootstock of *Z. aethiopica* is said to have been a food source in early days in South Africa after extensive boiling to counteract the burning effect of the raphide crystals [14,15]. The leaves and stems of *Z. aethiopica* are cooked as potherbs and leafy vegetables in Lesotho, Zimbabwe, the Eastern Cape, Free State, and KwaZulu-Natal Provinces in South Africa [14-26]. However, the leaves of *Z. aethiopica* are among the top 10 culprits of plant species responsible for about 6.5% of all poisoning cases (about 500 cases and inquiries per year) in the Johannesburg municipal area in South Africa [27]. Although *Z. aethiopica* is not indigenous to New Zealand, the species is the second most common poisonous plant in the country [28]. Research by Botha and Penrith [29], Wink and Van Wyk [30], and Ndhlala *et al*. [31] showed that the cardiac glycosides which have been identified from the species and known to induce paralysis on the central nervous system are probably responsible for the toxic properties of the species. However, Van Wyk *et al*. [27] argued that *Z. aethiopica* is not toxic, but the oxalate crystals associated with the species may cause distress if fresh leaves are eaten. Similarly, Van Wyk *et al*. [13] argued that *Z. aethiopica* should not be eaten fresh as the needle-shaped calcium oxalate crystals cause mechanical irritation of the mucous membranes, causing swelling of the tongue and throat, salivation, nausea, vomiting, and diarrhea. However, *Z. aethiopica* is a valuable medicinal plant, as its rhizomes and roots are sold as herbal medicines in the Limpopo Province in South Africa [32,33] and Brazil [34,35]. It is within this context that the current study was undertaken aimed at providing a comprehensive review of the medicinal value, phytochemistry and biological activities of the compounds isolated from the species, including *Z. aethiopica* crude extracts.

## BOTANICAL DESCRIPTION OF *Z. AETHIOPICA*

*Z. aethiopica* is a perennial, robust, evergreen or deciduous, erect and clump-forming herbaceous plant with a thick rhizome and white fleshy roots. *Z. aethiopica* grows up to 150 cm in height with large, fleshy leaves developing from the tuberous rhizome [36-39]. The leaves are dark glossy green in color, lack a persistent basal meristem, are large, leathery and hairless, ovate in shape with parallel-pinnate veins, characterized by a thick and spongy leaf stalk. The minute yellow or cream-colored flowers are borne in a dense group on a finger-like column (so-called spadix), surrounded by a large, white, leaf-like structure (the spathe) [13]. A dense mass of small, fleshy, soft, berry-like yellow fruits develops at the base of the spadix. *Z. aethiopica* is native to Lesotho, South Africa, and Swaziland [14,17,36,37,40-42]. In Southern Africa, *Z. aethiopica* has been recorded in sandy or rocky places, along the coast, mountain grasslands, usually seasonally damp depressions and permanent springs at an altitude ranging from 20 m to 2250 m above sea level [38,39,41]. *Z. aethiopica* is also naturalized in Australia, Brazil, Hawaii, India, Italy, Kenya, Malawi, New Zealand, Philippines, Portugal, Réunion, South America, Spain, Tanzania, Tunisia, the United Kingdom, and Zambia [42-50].

The genus *Zantedeschia* Spreng. consists of seven species, namely, *Z. aethiopica* (L.) Spreng., *Zantedeschia albomaculata* (Hook.) Baill.,

*Zantedeschia rehmannii* Engl., *Zantedeschia pentlandii* (Watson) Wittm., *Zantedeschia elliottiana* (Watson) Engl., *Zantedeschia jucunda* Letty, and *Zantedeschia odorata* P.L.Perry. [37]. *Z. aethiopica* is named after Prof Giovanni Zantedeschi (1773–1846), an Italian botanist and physician [14,51,52]. The species name "aethiopica" is indirectly related to Ethiopia as in classical times, the name was used in reference to "south of the known world," that is, South of Libya and Egypt, now known as Southern Africa [14,52]. *Z. aethiopica* is commonly referred to as "arum lily," "calla lily," "cape white alum lily," "Egyptian lily," "florist's calla," and "garden calla" in English [13,14,23]. The synonyms associated with *Z. aethiopica* include *Calla aethiopica* L., *Richardia aethiopica* (L.) Spreng., *Richardia Africana* Kunth, and *Z. aethiopica* (L.) Spreng. var. minor Engl. [37,40-42,48].

## MEDICINAL USES OF *Z. AETHIOPICA*

The leaves, rhizomes, roots, stems, and the whole plant parts of *Z. aethiopica* are used as herbal medicines against 33 human diseases in tropical Africa, Asia, and North America (Table 1). *Z. aethiopica* is mainly used as herbal medicine for boils, burns, gout, inflammation, insect bites, rheumatism, sores, and wounds (Fig. 1). Other medicinal applications recorded in at least two literature sources include asthma, colds, flu, headache, heartburn, infections, infertility, respiratory problems, sore throat, and as a protective charm (Table 1). Such wide usage of *Z. aethiopica* as herbal medicine implies that the species is a valuable source of therapeutic agents required for plant-derived natural products or their derivatives.

## CHEMICAL AND PHYTOCHEMISTRY OF *Z. AETHIOPICA*

Carneiro *et al*. [89] and Pelo [90] quantified mineral elements in flower stalks, leaves, rhizomes, and roots of *Z. aethiopica* including heavy metals such as cadmium, copper, chromium, iron, lead, manganese, and mercury (Table 2). The concentrations of the heavy metals in *Z. aethiopica* are below the permissible FAO or the WHO limits set by Codex Alimentarius Commission [91], and therefore, the use of the species as food or its extracts as herbal medicines may not result in heavy metal toxicity. Medicinal plants growing in different geographical areas usually accumulate different levels of heavy metals [92,93]. Phytochemical compounds that have been identified from flowers, fruits, leaves, and regreened sphates, and stems of *Z. aethiopica* include alkaloids, anthraquinones, cardiac glycosides, flavonoids, glucose, saponins, soluble starch, steroids, sucrose, tannins, and terpenoids [90,94-96]. Other phytochemical compounds that have been

**Table 1: Medicinal applications of *Zantedeschia aethiopica***

| Medicinal use | Parts of the plant used | Country | References |
|---|---|---|---|
| Arthritis | Roots | South Africa | [53] |
| Asthma | Roots and rhizome mixed with honey | South Africa | [13,54-56] |
| Augment labor | Whole plant | South Africa | [30] |
| Backache | Leaves | South Africa | [57] |
| Boils | Leaves | India, Lesotho, Malawi, South Africa, and Swaziland | [13-17,20,23,48,53,55,58-68] |
| Bronchitis | Leaves | South Africa | [13] |
| Burns | Leaves and rhizomes | India, Mexico, and South Africa | [10,48,55,67,69-71] |
| Chlamydia | Roots | South Africa | [33] |
| Colds | Roots | South Africa | [32,72] |
| Cough | Whole plant | South Africa | [31] |
| Fever | Whole plant | Tanzania | [73] |
| Flu | Roots | South Africa | [32,72] |
| Gastrointestinal problems | Whole plant | South Africa | [31] |
| Gout | Leaves, roots, and stems | India, Lesotho, Malawi, and South Africa | [13-17,20,23,48,53,55,58-60,62,63,66-68] |
| Headache | Leaves and rhizomes | South Africa | [57,74] |
| Heartburn | Rhizome mixed with honey | South Africa | [13,54] |
| Infections | Leaves and roots | South Africa | [57,75] |
| Infertility | Roots | South Africa | [76-78] |
| Inflammation | Leaves | India and South Africa | [57,79] |
| Injuries | Leaves | India | [80] |
| Insect bites | Leaves and stems | India, Malawi, and South Africa | [14,48,55,58-60,63,67] |
| Lung ailments | Roots | South Africa | [53] |
| Measles | Roots | South Africa | [33] |
| Pain | Leaves | South Africa | [57] |
| Protective charm | Leaves | Lesotho | [16,17,20,23,62,66,68] |
| Respiratory problems | Leaves | Lesotho | [16,17,20,62,66,68] |
| Rheumatism | Leaves, stems, and rhizome mixed with honey | India, Lesotho, Malawi, and South Africa | [13-17,20,23,48,54,55,57-60,62,63,66-68] |
| Snakebite | Roots mixed with petroleum jelly | South Africa | [76] |
| Sores | Leaves and roots | India, Lesotho, Malawi, South Africa, and Swaziland | [13-17,20,23,48,53,55,58-68,70,81-83] |
| Sore throat | Leaves, rhizomes, and rhizome mixed with honey | South Africa | [13,54,55,71,84,85] |
| Venereal diseases | Roots | South Africa | [75] |
| Vomiting | Roots | South Africa | [53] |
| Wounds | Leaves, rhizomes, and roots | India, Lesotho, South Africa, and Swaziland | [13,15-17,20,23,48,55,57,58,61-68,70,81-83,85-87] |
| Ethnoveterinary medicine | | | |
| Redwater | Rhizome | South Africa | [88] |

identified from fruits, leaves, and regreened sphates of *Z. aethiopica* include cytokinin, cycloartane triterpenes, fatty acids, galactolipids, galactosyldiacylglycerols, phytosterols, and steroids [90,95,97-101] (Table 3).

## BIOLOGICAL ACTIVITIES OF *Z. AETHIOPICA*

The following biological activities have been reported from the leaf and root extracts and compounds isolated from *Z. aethiopica*: Antibacterial [54,63-65,90,96], antifungal [54,63-65,102,103], antithrombotic and anticoagulant [104], antioxidant [105], antihistaminic [54], and antialgal [95] activities.

### Antibacterial activities

Nielsen *et al*. [63] evaluated antibacterial activities of methanol leaf and stem extracts of *Z. aethiopica* against *Citrobacter*, *Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa,* and *Mycobacteria smegmatis* using the microbroth dilution method with gentamicin and ciprofloxacin as positive controls. The extracts exhibited weak activities with minimum inhibitory concentration (MIC) values ranging from 625 µg/ml to >2500 µg/ml which were much higher than MIC values of 0.3 µg/ml to 19.5 µg/ml exhibited by the controls [63]. Pratush *et al*. [96] evaluated antibacterial activities of ethanolic and aqueous extracts of the rhizomes of *Z. aethiopica* against *S. aureus*, *P. aeruginosa, E. coli, Bacillus subtilis*, *K. pneumonia, Serratia marcescens, Shigella* spp., and *Salmonella* typhi using disk diffusion method. The extracts exhibited activities against all the tested pathogens with the exception of *S. marcescens* and *Shigella* spp. with zone of inhibition ranging from 2.3 mm to 4.1 mm [96]. De Almeida *et al*. [106] evaluated antibacterial activities of floral protein extracts of *Z. aethiopica* against *E. coli*, *K. pneumoniae, Proteus mirabilis*, *Salmonella typhimurium, Shigella flexneri, Streptococcus pyogenes,* and *S. aureus* using microdilution method. *E. coli* was the only pathogen that inhibited the extract by 96.3% [106]. Mabona [64] and Mabona *et al*. [65] evaluated the antibacterial activities of aqueous and dichloromethane:methanol (1:1) leaf extracts of *Z. aethiopica* using the microtiter plate assay against dermatologically relevant pathogens such as *Brevibacillus* agri, *Propionibacterium acnes, P. aeruginosa, S. aureus,* and *Staphylococcus epidermidis* with ciprofloxacin as a positive control. The extracts exhibited activities with MIC values ranging from 0.5 mg/ml to >16.00 mg/ml [64,65]. Motlhatlego [54] evaluated the antibacterial activities of aqueous, dichloromethane, 80% ethanol and petroleum ether leaf, rhizome, root, and stem extracts of *Z. aethiopica* against *S. pyogenes, K. pneumoniae,* and *S. aureus* using microdilution technique with neomycin as a positive control and *Haemophilus parainfluenzae* using disk diffusion method with ampicillin and penicillin as positive controls. The extracts exhibited activities with MIC values ranging from 0.8 mg/ml to >12.5 mg/ml and zone of inhibition of 21.1 mm which was comparable to 18.9 mm to 21.6 mm exhibited by ampicillin and penicillin [54]. Pelo [90] evaluated antibacterial activities of chloroform: methanol, ethyl acetate, hexane, and waterleaf extracts of *Z. aethiopica* against *Bacillus cereus, B. subtilis, Enterobacter cloacae, Enterobacter aerogenes, Enterococcus faecalis, K. pneumoniae, M. smegmatis, P. mirabilis, Proteus vulgaris, P. aeruginosa,* and *S. aureus* using disk diffusion method and microdilution method. Only chloroform:methanol extract exhibited activities against *M. smegmatis* with zone of inhibition ranging from 7 mm to 11 mm. The MIC susceptible assay revealed that organic extracts were active against the tested pathogens with MIC values ranging from 0.3 mg/mL to 8.0 mg/mL [90].

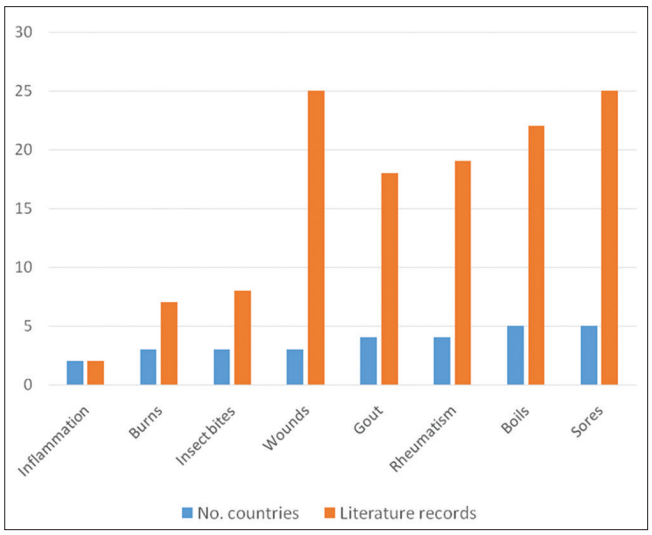


**Fig. 1: Medicinal applications of *Zantedeschia aethiopica***

### Antifungal activities

Motsei [102] and Motsei *et al*. [103] evaluated antifungal activities of aqueous, ethanol, ethyl acetate, and hexane leaf extracts of *Z. aethiopica* against *Candida albicans* standard strain ATCC 10231 and two clinical isolates from a 5-month-old baby and an adult using the broth microdilution method with amphotericin B as a positive control. The extracts exhibited weak activities with MIC values ranging from >8.4 mg/ml to >25.0 mg/ml [102,103]. Nielsen *et al*. [63] evaluated antifungal activities of methanol leaf and stem extracts of *Z. aethiopica* against *C. albicans* and *Microsporum audouinii* using the microbroth dilution method with nystatin as a positive control. The extracts exhibited moderate activities with MIC value of 312.5 µg/ml against both fungi in comparison to MIC value of 19.5 µg/ml exhibited by the control [63]. Mabona [64] and Mabona and Van Vuuren [65] evaluated the antifungal activities of aqueous and dichloromethane:methanol

**Table 2: Mineral element composition of *Zantedeschia aethiopica***

| Element | Value | FAO/WHO permissible limit | Plant part | References |
|---|---|---|---|---|
| Cadmium (mg/kg) | 0.002 | 0.02 | Leaves | [90] |
| Calcium (mg/kg) | 1.2–7.7 | - | Flower stalks, leaves, rhizomes, and roots | [89,90] |
| Chromium (mg/kg) | 0.003 | 1.3 | Leaves | [90] |
| Copper (mg/kg) | <0.001 | 10.0 | Leaves | [90] |
| Iron (mg/kg) | 0.04 | 20.0 | Leaves | [90] |
| Lead (mg/kg) | 0.03 | 2.0 | Leaves | [90] |
| Magnesium (mg/kg) | 2.8 | - | Flower stalks, leaves, rhizomes, and roots | [89] |
| Manganese (mg/kg) | 0.003 | 5.5 | Leaves | [90] |
| Mercury (mg/kg) | 0.006 | 0.6 | Leaves | [90] |
| Nitrogen (mg/kg) | 25.9 | - | Flower stalks, leaves, rhizomes, and roots | [89] |
| Phosphorus (mg/kg) | 6.2 | - | Flower stalks, leaves, rhizomes, and roots | [89] |
| Potassium (mg/kg) | 0.09–0.37 | - | Flower stalks, leaves, rhizomes, and roots | [89,90] |
| Sodium (mg/kg) | 0.005 | - | Leaves | [90] |
| Strontium (mg/kg) | 0.003 | - | Leaves | [90] |
| Sulfur (mg/kg) | 0.07 | - | Flower stalks, leaves, rhizomes, and roots | [89] |
| Zinc (mg/kg) | <0.001 | 50.0 | Leaves | [90] |

(1:1) leaf extracts of *Z. aethiopica* using the microtiter assay against dermatologically relevant pathogens such as *C. albicans, Microsporum canis,* and *Trichophyton mentagrophytes* with amphotericin B as a positive control. The extracts exhibited activities with MIC values ranging from 1.0 mg/ml to 4.0 mg/ml [64,65]. Motlhatlego [54] evaluated the antifungal activities of aqueous, dichloromethane, 80% ethanol and petroleum ether leaf, rhizome, root, and stem extracts of *Z. aethiopica* against *C. albicans* using microdilution technique with

**Table 3: Phytochemical composition of *Zantedeschia aethiopica***

| Phytochemical | Value | Plant parts | References |
|---|---|---|---|
| Galactolipids | - | Leaves and regreened sphates | [99] |
| Galactosyldiacylglycerols | - | Leaves and regreened sphates | [99] |
| α-linolenic acid | - | Leaves and regreened sphates | [95,99] |
| 13-hydroxy-α-linolenic acid | - | Leaves | [95] |
| Linoleic acid | - | Leaves and regreened sphates | [95,99] |
| 9-hydroxy-linoleic acid | - | Leaves | [95] |
| 12-hydroxy-linoleic acid | - | Leaves | [95] |
| Myristic acid | - | Leaves and regreened sphates | [99] |
| Oleic acid (%) | 14.1 | Leaves and regreened sphates | [90,99] |
| Palmitic acid | - | Leaves and regreened sphates | [99] |
| Palmitoleic acid | - | Leaves and regreened sphates | [99] |
| Stearic acid | - | Leaves and regreened sphates | [99] |
| $\Delta^3$-trans-hexadecenoic acid | - | Leaves and regreened sphates | [99,100] |
| Cycloartenol | - | Leaves | [95] |
| 24-methylene-cycloartanol | - | Leaves | [95] |
| (24R)-24-Ethyl-cholest-5-en-3β-ol (%) | 93.1 | Leaves | [95] |
| (24R)-24-Methyl-cholest-5-en-3β-ol (%) | 0.7 | Leaves | [95] |
| (24S)-24-Ethyl-cholest-5,22-dien-3β-ol (%) | 1.1 | Leaves | [95] |
| 24-Methylene-cholest-7-en-3β-ol (%) | 0.2 | Leaves | [95] |
| 4α-Methyl-24-methylene-cholest-7-en-3β-ol (%) | 0.3 | Leaves | [95] |
| (24R)-24-Ethyl-cholest-4-en-6β-ol-3-one (%) | 0.7 | Leaves | [95] |
| (24R)-24-Methyl-5α,8-epidioxy-cholest-6,22-dien-3β-ol (%) | 1.4 | Leaves | [95] |
| (24R)-24-Ethyl-cholest-5-en-3β,7β-diol (%) | 0.7 | Leaves | [95] |
| (24R)-24-Ethyl-cholest-5-en-3β,7α-diol (%) | 0.2 | Leaves | [95] |
| (24R)-24-Ethyl-cholest-5-en-3β-ol-7-one (%) | 1.6 | Leaves | [95] |
| Pinoresinol | - | Leaves | [95] |
| 3-(4-hydroxy-3-methoxy)-phenyl-1,2-propandiol | - | Leaves | [95] |
| 3-(4-hydroxy-3-methoxy-phenyl)-1,2,3-propantriol | - | Leaves | [95] |
| 2-(3,4-dihydroxy)-phenyl-ethyl-β-D-glucopyranoside | - | Leaves | [95] |
| Isoswertiajaponin | - | Leaves | [95] |
| Isoswertisin | - | Leaves | [95] |
| 3-(4β-D-glucopyranosyloxy-3-methoxy)-phenyl-2E-propenol | - | Leaves | [95] |
| 3-(4-hydroxy-3-methoxy)-phenyl-2E-propenyl-1β-D-glucopyranoside | - | Leaves | [95] |
| 3-(4β-D-glucopyranosyloxy-3,5-dimethoxy)-phenyl-2E-propenol | - | Leaves | [95] |
| 3-(4-hydroxy-3,5-dimethoxy)-phenyl-2E-propenyl-1β-D-glucopyranoside | - | Leaves | [95] |
| 1-(4-hydroxy-3-methoxy)-phenyl-2-[4-(1,2,3-tri-hydroxypropyl)-2-methoxy] -phenoxy-1,3-propandiol | - | Leaves | [95] |
| 1-(4-hydroxy-3-methoxy)-phenyl-2-[4-(2,3-dihydroxypropyl)-2-methoxy] -phenoxy-1,3-propandiol | - | Leaves | [95] |
| 6-(o-hydrobenzylamino)-9-β-D-ribofuranosylpurine | - | Fruits | [98] |
| 6-(o-hydrobenzylamino)-2-methylthio-9-β-D-glucofuranosylpurine | - | Fruits | [97] |
| Allyl decanoate (%) | 0.02 | Leaves | [90] |
| 2-Azido-2-methylpentane (%) | 0.01 | Leaves | [90] |
| Aziridine, 2,2-dimethyl (%) | 0.2 | Leaves | [90] |
| Benzene, 1,2,3-trimethyl (%) | 0.003 | Leaves | [90] |
| Docosanoic acid, methyl ester (%) | 0.01 | Leaves | [90] |
| E-1,8-decadiene (%) | 0.1 | Leaves | [90] |
| 11-Dodecen-1-al (%) | 0.02 | Leaves | [90] |
| 1-Dodecyne (%) | 0.1 | Leaves | [90] |
| Undecane (%) | 0.006 | Leaves | [90] |
| 2 (3H)-Furanone, dihydro-4-methyl (%) | 0.1 | Leaves | [90] |
| 9-Octadecenoic acid (Z) (%) | 0.1 | Leaves | [90] |
| 17-Octadecynoic acid (%) | 0.3 | Leaves | [90] |
| 9,12-Octadecadienal (%) | 0.3 | Leaves | [90] |
| 9,12-Octadecadienoyl chloride, (Z, Z) | 0.2 | Leaves | [90] |
| 2-Oxetanone, 3,3-dimethyl (%) | 0.3 | Leaves | [90] |
| Phenol, 2-methyl-5-(1-methylethyl) (%) | 0.004 | Leaves | [90] |
| Phenol, 4,4'-(1-methylethylidene) bis (%) | 0.003 | Leaves | [90] |
| Phenol, 5-methyl-2-(1-methylethyl) (%) | 0.008 | Leaves | [90] |
| Stigmastan-3,5-diene (%) | 0.1 | Leaves | [90] |
| Stigmastan-6,22-dien, 3,5-dedihydro (%) | 0.06 | Leaves | [90] |
| d1-α-Tocopherol (%) | 0.004 | Leaves | [90] |
| Campesterol | - | Leaves | [101] |
| β-Sitosterol | - | Leaves | [101] |
| Stigmasterol | - | Leaves | [101] |

amphotericin B as a positive control. The extracts exhibited activities with MIC and minimum fungicidal concentration (MFC) values ranging from 1.6 mg/ml to >12.5 mg/ml which was comparable to MIC and MFC values of 0.008 mg/ml and 0.01 mg/ml, respectively, which were exhibited by the controls [54].

**Antithrombotic and anticoagulant activities**

Kee *et al*. [104] evaluated antithrombotic and/or anticoagulant activities of methanol and aqueous leaf extracts of *Z. aethiopica* using the thrombin and clotting time (thrombin induced and $CaCl_2$ induced) assays. The extract displayed anticoagulant activities with half maximal inhibitory concentration ($IC_{50}$) value of 3.1 mg/ml [104].

**Antioxidant activities**

Li *et al*. [105] evaluated the antioxidant activities of the flower extracts of *Z. aethiopica* using the ferric-reducing antioxidant power (FRAP) and Trolox equivalent antioxidant capacity (TEAC) assays. The extracts exhibited FRAP value of 22.1 ± 0.6 µmol Fe(II)/g wet weight while the TEAC value was 9.2±0.4 µmol Trolox/g wet weight and the total phenolic content was 3.1±0.01 mg GAE/g wet weight. The main phenolic compounds were epicatechin (37.9 mg/100 g), gallic acid (30.8 mg/100 g), and protocatechuic acid (42.6 mg/100 g). Li *et al*. [105] also evaluated the insoluble-bound components of the residue using the NaOH hydrolysis and FRAP value was 0.7±0.08 µmol Fe(II)/g wet weight, TEAC (0.3±0.04 µmol Trolox/g wet weight), and the total phenolic content was 0.3±0.01 mg GAE/g wet weight.

**Antihistaminic activities**

Motlhatlego [54] evaluated the antihistaminic activities of the ethanolic leaf, rhizome, root, and stem extracts of *Z. aethiopica* using antihistamine assay. The leaf extracts exhibited histamine receptor binding of 88% at both concentrations of 400 µg/ml and 800 µg/ml [54].

**Antialgal activities**

Greca *et al*. [95] evaluated antialgal activities of ethyl acetate and methanol leaf extracts of *Z. aethiopica* against *Selenastrum capricornutum* using a paper disk assay. The extracts showed inhibitory effects. Greca *et al*. [95] assayed compounds pinoresinol, 3-(4-hydroxy-3-methoxy)-phenyl-1,2-propandiol, 3-(4-hydroxy-3-methoxy-phenyl)-1,2,3-propantriol, 2-(3,4-dihydroxy)-phenyl-ethyl-β-D-glucopyranoside, isoswertiajaponin, isoswertisin, 3-(4β-D-glucopyranosyloxy-3-methoxy)-phenyl-2E-propenol, 3-(4-hydroxy-3-methoxy)-phenyl-2E-propenyl-1β-D-glucopyranoside, 3-(4β-D-glucopyranosyloxy-3,5-dimethoxy)-phenyl-2E-propenol, and 3-(4-hydroxy-3,5-dimethoxy)-phenyl-2E-propenyl-1β-D-glucopyranoside at concentrations from $10^{-3}$M to $10^{-5}$M in broth, while compounds 1-(4-hydroxy-3-methoxy)-phenyl-2-[4-(1,2,3-tri-hydroxypropyl)-2-methoxy]-phenoxy-1,3-propandiol and 1-(4-hydroxy-3-methoxy)-phenyl-2-[4-(2,3-dihydroxypropyl)-2-methoxy]-phenoxy-1,3-propandiol tested by paper disk assays. Only compounds 1-(4-hydroxy-3-methoxy)-phenyl-2-[4-(1,2,3-tri-hydroxypropyl)-2-methoxy]-phenoxy-1,3-propandiol and 1-(4-hydroxy-3-methoxy)-phenyl-2-[4-(2,3-dihydroxypropyl)-2-methoxy]-phenoxy-1,3-propandiol (0.1 µmol) gave 15 mm–23 mm diameters of inhibition which was similar to activities exhibited by the control algicide $CuSO_4$. The compounds pinoresinol, 3-(4-hydroxy-3-methoxy)-phenyl-1,2-propandiol, and 3-(4-hydroxy-3-methoxy-phenyl)-1,2,3-propantriol showed weak activities causing 40% inhibition at $10^{-4}$ M [95].

## CONCLUSION

*Z. aethiopica* is a well-known medicinal plant species in Southern Africa where the species is indigenous. The species has been introduced in several countries and is now regarded an important component of indigenous pharmacopoeia in Brazil, India, Malawi, Mexico, and Tanzania where the species is naturalized. The historical traditional usage of *Z. aethiopica* as herbal medicine in Southern Africa and other regions where the species is naturalized calls for detailed phytochemical and pharmacological studies aimed at correlating its documented ethnomedicinal uses with the phytochemical and pharmacological properties of the species. There is a need for clinical and toxicological evaluations since *Z. aethiopica* contains potentially toxic compounds. Therefore, future research should focus on identification of toxic compounds, the possible side effects caused by taking *Z. aethiopica* as herbal medicine, and mechanisms of how potential toxic components of the species can be managed when the species is used as herbal medicine.

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## AUTHORS' CONTRIBUTIONS

The author declares that this work was done by the author named in this article.

## CONFLICTS OF INTEREST

The author declares that he has no conflicts of interest.

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