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Review Article

DICOMA ANOMALA SOND.: A REVIEW OF ITS BOTANY, ETHNOMEDICINE, PHYTOCHEMISTRY AND PHARMACOLOGY

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ABSTRACT

Dicoma anomala is used as herbal medicine to treat and manage fever, coughs, colds, sore throats, abdominal pain, diarrhea, dysentery, constipation, intestinal worms, and sexually transmitted infections in tropical Africa. The aim of this study was to summarize the research that has been done on the ethnomedicinal uses, phytochemistry, and pharmacological properties of *D. anomala* in tropical Africa. The literature search for information on ethnomedicinal uses and pharmacological activities of *D. anomala* was undertaken using databases such as Web of Science, Scopus, Google Scholar, Science Direct, BioMed Central, PubMed, and Springer link. Other relevant literature sources included books, book chapters, websites, theses, conference papers, and other scientific publications. This study showed that *D. anomala* is used as herbal medicine in 57.1% of the countries in tropical Africa where it is indigenous. The species is used to treat 66 and five human and animal diseases, respectively. Several classes of secondary metabolites including acetylenic compounds, diterpene, flavonoids, phenols, phytosterols, saponins, sesquiterpenes, tannins and triterpenes have been isolated from *D. anomala*. Different aqueous and organic extracts of *D. anomala* exhibited anthelmintic, anticancer, antihyperglycemic, anti-inflammatory, antimicrobial, antioxidant, antiplasmodial, and hepatoprotective activities. The documented information on the botany, ethnomedicinal uses, phytochemistry, and pharmacological properties of *D. anomala* provide baseline data required for further ethnopharmacological studies on the species.

Keywords: *Dicoma anomala*, Ethnopharmacology, Primary health care, Traditional medicine, Tropical Africa.

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INTRODUCTION

Dicoma anomala Sond. is traditionally used as herbal medicine in tropical Africa [1,2]. According to Van Wyk [3], *D. anomala* leaves and roots have commercial potential as remedies for colds, fever, stomach complaints, and as general herbal medicine. Research by Jacot-Guillarmod [4] and Moteetee and Van Wyk [5] showed that *D. anomala* is an important medicinal plant in the *Materia medica* of Lesotho where it is used for most common and everyday ailments, namely, respiratory and digestive problems. In South Africa and Zimbabwe, the species is regarded as a panacea, that is, remedy for all diseases [6,7]. Fresh and dry root or root decoction and tinctures are taken orally to treat fever, coughs, colds, sore throats, abdominal pain, diarrhea, dysentery, constipation, and intestinal worms [6-8]. *D. anomala* is also used to treat gonorrhea and other venereal diseases and as purgative in the treatment of hemorrhoids [7]. Roots of *D. anomala* are sold in informal herbal medicine "*muthi*" markets in Malawi [9,10], Gauteng [11], and the Northern Cape [12] provinces in South Africa. Therefore, *D. anomala* is widely collected from the wild as herbal medicine or the species is collected for sale in herbal "*muthi*" markets. Due to overexploitation as herbal medicine, *D. anomala* is categorized as vulnerable (VU A2d) in Lesotho [13] based on the IUCN Red List Categories and Criteria version 3.1 of threatened species (http://www.iucnredlist.org). Talukdar [13] argued that there has been a decline in the population of *D. anomala* in Lesotho due to habitat loss and excessive harvesting of the species for traditional medicine. The present review is, therefore, aimed at documenting the ethnomedicinal uses, biological activities, and the correlated chemical compounds of *D. anomala* with emphasis on the validation of the ethnomedicinal uses of the species. Results of this review are expected to reveal research challenges and perspectives required to address the knowledge gaps of this important medicinal plant species in tropical Africa.

BOTANICAL DESCRIPTION, OCCURRENCE, AND DISTRIBUTION

The genus *Dicoma* Cass. (Family: Asteraceae) was first described by Cassini in 1817, comprise 50 species and 16 of these occur in southern Africa [14-21]. The genus name *Dicoma* was derived from Greek words "*di*" meaning two and "*kome*" meaning tuft of hair, in reference to the double row of pappus bristles which are characteristic of the species. The species name "*anomala*" is Latin, meaning irregular or deviating from the normal [22]. *D. anomala* is a highly variable species, research by Ortiz and Rodriquez-Oubiña [23] showed that the speciesis a single complex species characterized by three distinct subspecies namely *D. anomala* Sond. subsp. *anomala*, occurring throughout most of the species' range, *D. anomala* Sond. subsp. *attenuata* (S. Moore) Ortiz and Rodriquez-Oubiña, which is restricted to eastern central Angola, the Democratic Republic of Congo and Zambia, and *D. anomala* Sond. subsp. *gerrardii* (Harv. ex F.C. Wilson) Ortiz and Rodriquez-Oubiña. Most published literature, ethnobotany researchers, traditional healers, and local communities do not separate *D. anomala* into specific subspecies, but *D. anomala* sensual to is recognized, and the same approach has been adopted in this study.

D. anomala has been recorded in Angola, Botswana, Burundi, Democratic Republic of Congo, Lesotho, Malawi, Mozambique, Rwanda, South Africa, Tanzania, Uganda, Zambia and Zimbabwe [14-21]. *D. anomala* occurs in stony grasslands, hillsides or flat grassland and in savanna on doleritic or sandy soils at altitudes ranging from 165 to 2075 m [22]. *D. anomala* is an erect, suberect or prostrate, decumbent, and perennial herb-bearing aromatic semi-woody tubers at the base of a woody subterranean stem. It may have few to many hairy, erect stems arising from a woody rootstock. The stems range from 5 to 60 cm long, are branched, yellowish, trail along the ground and over surrounding plants and rocks [16]. The leaves are simple, narrow, positioned alternately on the stem, stalkless, linear or narrowly lanceolate in shape. The upper surface of the leaves is glabrous, olive green, sometimes grey, rough, with a prominent central vein along which the leaf folds inward. The lower surface is white and hairy with a faintly uneven margin. Flower heads are terminal, cup or cone-shaped, cream to pinkish-white in color.

ETHNOMEDICINAL USES OF *D. ANOMALA*

The roots of *D. anomala* are widely used to cure at least 66 and five human and animal diseases and ailments, respectively, in Africa (Table 1). Ethnomedicinal information has been found in Botswana, Lesotho, Malawi, Namibia, South Africa, Swaziland, Tanzania, and Zimbabwe, representing 57.1% of the countries where *D. amomala* is indigenous. The country with the highest number of ethnomedicinal uses is South Africa with 37 records of human ailments treated or managed by concoctions prepared from *D. anomala*, based on 16 literature records (Fig. 1). Lesotho has 32 ethnomedicinal uses with 13 literature records, followed by Zimbabwe with 23 uses and eight literature records, Malawi with 13 uses and three literature records and Namibia with nine uses and single records (Fig. 1). Gastrointestinal disorders such as diarrhea, dysentery and stomach problems, pain, sores and wounds, colds, cough and sore throat, sexually transmitted infections (STIs), blood circulation problems, fever, malaria, and ethnoveterinary medicine (Table 2) are the most commonly treated human and animal ailments and diseases using concoctions prepared from *D. anomala*.

Apart from momotherapeutic preparations, *D. anomala* is also used in combination with other plant species, for example, in Lesotho, the root infusions of *D. anomala* are taken orally mixed with roots of *Berkheya setifera* DC. as remedy for bilious attacks [8]. The root infusion of the species are also taken orally mixed with *Scabiosa columbaria* L. for painful menstruation [4,5,40]. The root infusion of the species is also taken orally mixed with *Helichrysum caespititium* (DC.) Sond. ex Harv., *S. columbaria* and *Zantedeschia albomaculata* (Hook.) Baill. for venereal diseases [8,33]. The root infusion of the species is also given to livestock mixed with *Cymbopogon* spp. as remedy for gall sickness [4,5,40]. In Malawi, root infusion of *D. anomala* is taken orally mixed with roots of *Trichodesma physaloides* (Fenzl) A.DC. as remedy for backache [6]. In Malawi and Zimbabwe, root infusion of *D. anomala* is taken orally mixed with soot and roots of *Aspilia pluriseta* Schweinf. to initiate labour, ensure easy childbirth, and facilitate the expulsion of placenta and clearing of the womb after birth in both women [6].

PHYTOCHEMISTRY

Phytochemical investigations of *D. anomala* have identified several classes of secondary metabolites; including acetylenic compounds, diterpene, flavonoids, phenolic acids, phytosterols, saponins, sesquiterpene lactones, tannins and triterpenes [63-68]. This is typical of Asteraceae taxa which are known to synthesize secondary metabolites such as flavonoids, polyacetylenes, and terpenoids [69]. The aerial parts of *D. anomala* yielded acetylenic compounds, namely, stigmasterol, β-sitosterol, lupeol and some sesquiterpene lactones [63,70]. The sesquiterpene lactones included germacranolides, with a 7,8-lactone function, albicolide and 14-acetoxydicomanolide, with 6,7-lactone closure [63]. Bohlmann *et al*. [64] isolated germacrene D, lupeol, taraxasterol and sesquiterpene lactones from aerial parts of *D. anomala*. The roots of *D. anomala* yielded sitosterols, lupenone, guaianolides and eudesmanolides [64]. Investigation of the aerial parts of *D. anomala* collected in Namibia yielded melampolides, germacranolides and a lactone, in addition to the lupeol and taraxasterol and their acetates, and two flavonoids, cirsimaritin and scutellarein [65]. Van der Merwe [66] isolated (3aS,5aS,9aR,9bS)-5a methyl-3,9-dimethylidene-4,5,9a,9b-tetrahydro-3aHnaphtho[7,8-d] furan-2,8-dione from *D. anomala* roots. Marekerah [26] isolated alkaloids, glycosides, saponins, sterols, and reducing sugars from acetone root extracts of *D. anomala*. Rademeyer *et al*. [67] isolated a dehydrobrachylaenolide, an eudesmane-type sesquiterpene lactone called 3-oxoeudesma-1,4(15),11 (13)-triene-12,6a-olide from *D. anomala* roots. Becker *et al*. [68] isolated a eudesmanolide-type sesquiterpene lactone, 3-oxoeudesma-1,4(15),11(13)-triene-12,6a-lide commonly called dehydrobrachylaenolide from the roots of *D. anomala*. Munodawafa *et al*. [71] isolated saponins and tannins from *D. anomala* roots.

PHARMACOLOGICAL ACTIVITIES

The following activities have been reported from *D. anomala* including anthelmintic [58,72], anticancer [66,70], antihyperglycemic [73,74], anti-inflammatory[47],antimicrobial[26,28,71,75-77],antioxidant[26,71,74,78,79], antiplasmodial [66,80], hepatoprotective [56,79], toxicity, and cytotoxicity [68,71,74,80,81].

ANTHELMINTIC

Ndamba *et al*. [58] evaluated *in vivo* antischistosomal activities of *D. anomala* root extracts by administering the extracts orally to hamsters infected with *Schistosoma haematobium* cercariae. The results obtained showed moderate activity with worm load of 201 and 1874 egg count in comparison with a single worm load and 137 egg count exhibited by the control, praziquantel [58]. Similarly, Mølgaard *et al*. [72] evaluated the anthelmintic effects of *D. anomala* root extracts against cysticercoids of the cestode *Hymenolepis diminuta*. The extracts killed the newly excysted cysticercoids within an hour, when incubated in a culture medium. The lethal concentrations of *D. anomala* extracts were 31.0 mg/ml after an hour and 1.0 mg/ml after 24 h [72]. These pharmacological evaluations are of importance in the traditional use of *D. anomala* against intestinal worms in Lesotho [8], Namibia [35], South Africa [8,34], and Tanzania [8], as herbal medicine against bilharzia in Zimbabwe [58] and future research focussing on control and management of schistosomiasis in tropical Africa.

ANTICANCER

Van der Merwe [66] evaluated *in vitro* anticancer activities of (3aS,5aS,9aR,9bS)-5amethyl-3,9-dimethylidene-4,5,9a,9b-tetrahydro-

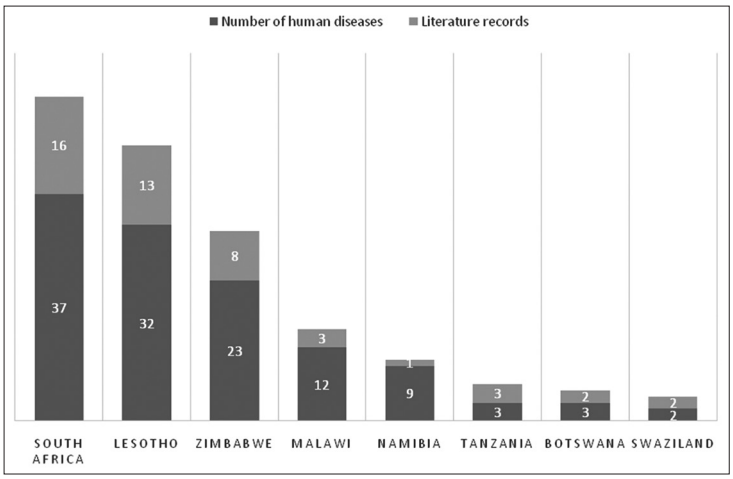

Fig. 1: Major diseases and ailments treated by *Dicoma anomala* in tropical Africa

Table 1: Ethnomedicinal uses of *D. anomala* in tropical Africa

Use	Plant parts used	Country practiced	References
Abdominal pains	Root infusion taken orally	Zimbabwe	[6,24-26]
Abortifacient	Root infusion taken orally	Malawi	[27]
Acne	Tuber used in combination with *E. elephantina* (Burch.) Skeels	South Africa	[28-30]
Antidote for any poison	Root decoction taken orally	South Africa, Zimbabwe	[6,26,31]
Anti-emetic	Root infusion taken orally	Malawi	[6]
Aphrodisiac	Root infusion taken orally	Malawi	[27]
Asthma	Tuber decoction taken orally	South Africa	[32]
Backache	Root infusion taken orally	Lesotho	[5]
Backache	Root infusion taken orally mixed with roots of *T. physaloides* (Fenzl) A.DC.	Malawi	[6]
Bilious attacks	Root infusions taken orally mixed with roots of *B. setifera* DC.	Lesotho	[32]
Bladder problems	Root decoction taken orally	South Africa	[12]
Bladder problems in women	Root infusion taken orally and root burnt and smoke directed toward pudendum	Zimbabwe	[6]
Blood circulation diseases	Root decoction taken orally	Namibia, South Africa	[8,34-36]
BC	Leaf and root infusion taken orally	Lesotho	[37,38]
Cardiovascular disorders	Root infusion taken orally	Namibia, South Africa	[34,35]
Cataracts	Root infusion taken orally	Zimbabwe	[6]
Chest pains	Root decoctions taken orally	Swaziland	[39]
Colds	Root decoction taken orally	Lesotho, Namibia, South Africa, Zimbabwe	[4,8,12,24,34,35,40,41]
Constipation and flatulency	Root infusions taken orally	Lesotho	[5,40]
Cough	Bark, root decoction taken orally	Botswana, Malawi, Namibia, South Africa	[6,27,32-35,42,43]
Dermatitis	Not stated	South Africa	[44]
Diabetes	Leaf and root infusion taken orally	Lesotho, South Africa	[5,37,45]
Diarrhea	Root decoction taken orally	Botswana, Lesotho, Namibia, South Africa, Zimbabwe	[4,5,8,26,40,41,46-49]
Dizziness	Root infusion taken orally	Zimbabwe	[6]
Dysentery	Root decoction taken orally	Lesotho, Namibia, South Africa, Tanzania, Zimbabwe	[8,26,34,35,42,50]
Enema	Root decoction taken orally	South Africa	[12]
Enemas	Root decoction taken orally	South Africa	[8]
Fever	Root decoction taken orally	Lesotho, South Africa, Zimbabwe	[6,34,41]
Genital problems	Root decoction taken orally	South Africa	[12]
Gonorrhea	Root infusion taken orally	Zimbabwe	[6,26]
Hemorrhoids	Root infusion taken orally	Namibia	[35]
Headache	Root infusion taken orally	Malawi	[27]
Heartburn	Root infusions taken orally	Lesotho	[5]
HIV related infections	Leaf and root infusion taken orally	Lesotho	[37]
Indigestion during pregnancy	Root infusion taken orally	South Africa	[31,51]
Induce labor	Leaf, root infusion taken orally	Lesotho, Zimbabwe	[38,52]
Induce labor	Root infusion taken orally mixed with soot and roots of *A. pluriseta* Schweinf.	Malawi, Zimbabwe	[6]
Infertility	Leaf, root decoction taken orally	Lesotho, South Africa	[8,38,52,53]
Intestinal parasites	Not stated	South Africa	[44]
Intestinal worms	Root decoction taken orally	Lesotho, Namibia, South Africa, Tanzania	[8,34,35]
Kidney problems	Root decoction taken orally	South Africa, Swaziland	[12,54]
Luck charm, protective charm	Tuber used as talisman and body washed with infusion or a piece kept under tongue	Malawi, Zimbabwe	[6,9,27,46,55]
Madness	Body washed with root infusion	Zimbabwe	[6]
Malaria	Root infusion taken orally	Zimbabwe	[26]
Measles	Root decoction taken orally	South Africa	[36]
Nasal congestion	Root powder used as snuff	Lesotho	[5]
Pain	Root decoction taken orally	Lesotho, Zimbabwe	[6,41]
Painful menstruation	Leaf, root infusion taken orally	Lesotho	[38]
Painful menstruation	Root infusion taken orally mixed with *S. columbaria* L.	Lesotho	[4,5,40]
Painful uterus	Root powder inserted into vagina	Zimbabwe	[6]

(Contd...)

Table 1: *(Continued)*

Use	Plant parts used	Country practiced	References
Pneumonia	Root infusion taken orally	South Africa, Zimbabwe	[6,7]
Prostrate problems	Root decoction taken orally	South Africa	[12]
Purgatives	Root decoction taken orally	Lesotho, South Africa	[8,34]
Respiratory complaints	Root decoction taken orally	South Africa	[42]
Rheumatism	Root decoction taken orally	Lesotho, Malawi	[27,41]
Ringworm	Root powder used as ointment	Lesotho, South Africa	[30,34,56,57]
Schistosomiasis	Root decoction taken orally	Zimbabwe	[58]
Skin lesions	Root powder mixed with fat used as ointment	Lesotho, South Africa	[32,47,57]
Skin sores	Root ointment applied on skin	Lesotho, Zimbabwe	[26,57]
Sore throat	Root infusion taken orally	Malawi, Zimbabwe	[6,27]
STIs	Root decoction taken orally	South Africa	[36]
Stomach problems	Leaf and root decoction taken orally	Botswana, Lesotho, Malawi, South Africa, Tanzania, Zimbabwe	[4,26,27,34,37,43,47,48,59,60]
Swollen legs	Root decoction taken orally	South Africa	[36]
Syphilis	Roots	Zimbabwe	[26]
Tonic	Roots taken orally	South Africa	[61,62]
Toothache	Root decoction taken orally	Lesotho	[4,8,40]
TB	Leaf and root infusion taken orally	Lesotho	[37]
TB	Tuber infusion taken orally mixed with *O. sphaerocarpa* R. Fern and A. Fern. bark	South Africa	[32]
Ulcer	Not stated	South Africa	[44]
Uterine disorder	Leaf, root infusion taken orally	Lesotho	[38]
Venereal diseases	Root infusion taken orally mixed with *H. caespititium* (DC.) Sond. ex Harv., *S. columbaria* and *Z. albomaculata* (Hook.) Baill.	Lesotho	[5,32]
Venereal diseases	Root infusion taken orally	South Africa	[34]
Vermifuge	Root infusion taken orally	Lesotho	[5]
Uterine disorder	Leaf and root infusion taken orally	Lesotho	[37]
Wasting in infants	Root decoction taken orally	Zimbabwe	[26]
Whooping cough	Tuber infusion taken orally mixed with *O. sphaerocarpa* R. Fern and A. Fern. bark	South Africa	[32]
Womb problems	Root decoction taken orally	South Africa	[12]
Wounds and sores	Flower, root powder mixed with fat used as ointment	Lesotho, Malawi, South Africa	[4,5,8,27,30,34,40,47,56,57]
Ethnoveterinary medicine			
Intestinal worm infestations	Root decoction	South Africa	[8]
Gall sickness	Root infusion taken mixed with *Cymbopogon* spp.	Lesotho	[4,5,40]
Gall sickness	Leaf and root infusion taken orally	Lesotho, South Africa	[8,37]
Wounds and sores	Root decoction	Lesotho	[8]
Sterility in animals	Root decoction	Lesotho, South Africa	[8]

D. anomala: Dicoma anomala, O. sphaerocarpa: Ozoroa sphaerocarpa, H. caespititium: Helichrysum caespititium, S. columbaria: Scabiosa columbaria, Z. albomaculata: Zantedeschia albomaculata, A. pluriseta: Aspilia pluriseta, B. setifera: Berkheya setifera, T. physaloides, Trichodesma physaloides, E. elephantina, Elephantorrhiza elephantina, BC: Breast cancer, TB: Tuberculosis

Table 2: Major disease or ailment categories reported

Disease or ailment category	Number of literature reports
Gastrointestinal disorders	24
Pain, sores and wounds	19
Colds, cough and sore throat	15
STIs	7
Blood circulation problems	5
Fever and malaria	5
Ethnoveterinary medicine	5

STIs: Sexually transmitted infections

3aHnaphtho[7,8-d]furan-2,8-dione isolated from *D. anomala* and root extract against the panels of human cancer cell lines such as leukaemia (L) lines, non-small cell lung cancer lines, colon cancer lines, central nervous system cancer lines, melanoma (M) lines, ovarian cancer lines, renal cancer lines, prostate cancer lines, and breast cancer (BC) lines. The compound showed GI_{50} value of 0.67 µg/ml [66]. Similarly, Mukanganyama *et al*. [70] evaluated the inhibition of human recombinant GSTP1-1 by sesquiterpene lactone isolated from *D. anomala*. The compound was found to be a potent GST P1-1 inhibitor showing 75% and 84% inhibition at 33 µM and 100 µM, respectively. These findings serve as a scientific validation for the use of *D. anomala* against BC in Lesotho [37,38].

ANTIHYPERGLYCAEMIC

Balogun and Ashafa [73] evaluated the antidiabetic activities of water, ethanol, hydroethanol, and methanol root extracts of *D. anomala* using the *in vitro* inhibition of α-amylase and α-glucosidase as well as against streptozotocin (STZ)-induced diabetic Wistar rats. The effect of administration of extract at 125, 250, and 500 mg/kg bodyweight on water consumption, feed intake, body-weight, blood

glucose, carbohydrate-metabolizing enzymes, antioxidant enzymes, glycosylated hemoglobin, and lipid profiles was determined in STZ (60 mg/kg body weight)-induced diabetic rats with comparison to glibenclamide, 5 mg/kg body weight. All extracts showed activity against α-amylase and α-glucosidase, but water extract revealed the most effective inhibition with an IC_{50} value of 51.90 and 27.41 μg/ml, respectively. The extract reversed toward normal control the elevated food or water intake, blood glucose levels, lipid peroxidation, lipid profiles, glycosylated hemoglobin and activities of gluconeogenesis enzymes with a concomitant decrease in body-weight, activities of enzymatic antioxidants, glycolytic enzymes as well as the high density lipoprotein-cholesterol level brought-about by STZ administration. Balogun and Ashafa [74] evaluated the antidiabetic activities of flavonoids isolated from the root extract of *D. anomala* using the inhibition of α-AML and α-GCD sucrase and maltase activities. Balogun and Ashafa [74] also evaluated the kinetic activities of flavonoids isolated from the root extract of *D. anomala* using the carbohydrate digestive enzymes including, alpha-glucosidase, sucrose, and maltase. The kinetics of mode of inhibition of alpha-amylase, alpha-glucosidase, sucrase, and maltase by flavonoids extract of *D. anomala* revealed an uncompetitive, non-competitive, competitive and non-competitive inhibition, respectively. These findings corroborate the traditional usage of the species as herbal medicine for diabetes in Lesotho and South Africa [5,37,45].

ANTI-INFLAMMATORY

Shale *et al*. [47] evaluated anti-inflammatory activities of hexane, methanol and water leaf and root extracts of *D. anomala* using the cyclo-oxygenase bioassay. Hexane leaf extracts showed anti-inflammatory activity above 85% while hexane root extract showed activity of 79% which was not significantly different ($p<0.05$) from activity of 87% displayed by the control, indomethacin [47]. These results support the traditional use of *D. anomala* in various inflammatory ailments and diseases such as sores, wounds, microbial infections, and injuries that result in cell damage and death.

ANTIMICROBIAL

Vlietinck *et al*. [75] evaluated antimicrobial activities of root extracts of *D. anomala* against *Candida albicans*, *Escherichia coli*, *Microsporum canis*, *Pseudomonas aeruginosa, Staphylococcus aureus,* and *Trichophyton mentagrophytes* using agar diffusion and agar dilution methods with neomycin and nystatin as controls. The extract showed activities against *M. canis, S. aureus,* and *T. mentagrophytes*. Vlietinck *et al*. [75] also evaluated antiviral activities of root extracts of *D. anomala* against poliomyelitis, coxsackie, semliki forest, herpes simplex and measles using the 50% endpoint titration technique. The root extract also showed antiviral properties, that is a reduction factor of the viral titer of 10 against poliomyelitis and weak activity against coxsackie, semliki forest, herpes simplex, and measles viruses.

Steenkamp *et al*. [76] evaluated antibacterial activities of *D. anomala* root aqueous and methanol extracts against *E. coli, P. aeruginosa, S. aureus,* and *Streptococcus pyogenes* using the micro-well dilution method with phenol as positive control. All *D. anomala* extracts showed the minimum inhibition concentration (MIC) values >4 mg/ml against all the selected bacteria [76]. Munodawafa *et al*. [71] evaluated the antimicrobial activities of *D. anomala* methanol root extracts against *Aspergillus niger*, *C. albicans, E. coli, P. aeruginosa, S. aureus,* and *Staphylococcus* Group A using the agar well-diffusion method. The extracts showed activity against *S. aureus* and *Staphylococcus* Group A with 3.25±0.5 mm and 4.25±0.5 mm zones of imbibition, respectively. The MIC values for *S. aureus* and *Staphylococcus* Group A were >10.0 mg/ml and 2.5 mg/ml, respectively [71]. The extract also showed some activity against *C. albicans* with 5.5±0.58 mm zone of imbibition and the MIC value of 1.25 mg/ml [71].

Mabona *et al*. [28] and Mabona [77] evaluated the antimicrobial activities of aqueous and dichlomethane/methanol (1:1) tuber extracts of *D. anomala* using the micro-titer plate dilution technique against dermatologically relevant pathogens such as *Brevibacillus agri*, *C. albicans, M. canis, Propionibacterium acnes, P. aeruginosa, S. aureus, Staphylococcus epidermidis,* and *T. mentagrophytes* with ciprofloxacin and Amphotericin B as positive controls and acetone and dimethyl sulfoxide as negative controls. Mabona *et al*. [28] and Mabona [77] found varied antimicrobial activities of the aqueous and dichlomethane/methanol (1:1) tuber extracts with MIC values ranging from 0.03 mg/ml to 16.00 mg/ml.

Marekerah [26] evaluated the antimicrobial activities of *D. anomala* acetone, chloroform, and petroleum ether root extracts against high vaginal swab, that is, a combination of different bacteria and fungi such as *E. coli, Klebsiella* spp., *Proteus* spp., and *S. aureus* [26] with ciprofloxacin as control. Antimicrobial activities of *D. anomala* extracts of 5 mg/ml represented by zones of imbibition ranged between 8.67 and 12.67 mm and for the 1 mg/ml extract, the range was 6.67–8.67 mm. Acetone and chloroform extracts showed MIC values of 0.8 mg/ml while MIC value of petroleum ether extract was 0.9 mg/ml against the MIC value of 0.125 displayed by the control, ciprofloxacin [26]. These findings give some validation for the traditional use of *D. anomala* for treating acne vulgaris, skin infections, STIs, gastrointestinal disorders, sores, wounds, and other microbial infections.

ANTIOXIDANT

D. anomala showed antioxidant activities of 50% with LC_{50} value of 3000 μg/ml demonstrating high safety margins [71]. Balogun and Ashafa [78] evaluated the *in vitro* antioxidant activities of *D. anomala* ethanol and methanol root extracts using the 1,1-diphenyl-2-picrylhydrazyl (DPPH), 2,2-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid (ABTS), hydroxyl and superoxide anion scavenging abilities as well as metal chelating and reducing power of the extracts. *D. anomala* ethanol extract exhibited some activity with IC_{50} value of 0.77 μg/ml for the nitric oxide scavenging and methanol extract with IC_{50} value of 3.50 μg/ml for metal chelating. Marekerah [26] evaluated the antioxidant activities of *D. anomala* acetone, chloroform, and petroleum ether root extracts using the phosphomolybdate assay. The acetone crude extract of *D. anomala* gave 3.49 μg ascorbic acid equivalence (AAE)/10 μg, chloroform displayed 2.89 μg AAE/10 μg, while petroleum ether had least antioxidant activity with 0.95 μg AAE/10 μg [26]. Balogun and Ashafa [79] evaluated the antioxidant activities of *D. anomala* aqueous, ethanol, hydroethanol and methanol root extracts using DPPH, nitric oxide, metal, chelating, ABTS, superoxide anion, and hydroxyl radicals assays. The aqueous extract exhibited the best activities with IC_{50} value of 15.20±0.03 μg/ml, 11.70±0.10 μg/ml, and 0.84±0.05 μg/ml *in vitro* in DPPH, hydroxyl, and superoxide anion radicals, respectively, when compared with the standard. For the nitric oxide and ABTS inhibitions, best effects were exhibited by ethanolic and hydroethanolic extracts with IC_{50} value of 0.77±0.07 μg/ml and 0.60±0.02 μg/ml, respectively [79]. The hydroethanolic extract had the highest amount of total antioxidant of 213.40±0.99 mg gallic acid equivalents (GAE)/100 g and total phenolic contents of 426.80±0.73 mg GAE/100 g, while the highest amount of flavonoids was found in the ethanolic extract amounting to 61.24±0.23 mg QUE/100 g [79]. Balogun and Ashafa [74] evaluated the free radical scavenging activities of flavonoids isolated from the root extract of *D. anomala* using DPPH, ABTS, hydroxyl radical, nitric oxide scavenging, metal chelating, and reducing power activities. The best antioxidant activity was demonstrated in ABTS and nitric oxide having IC_{50} values ranging from 386.90±4.91 μg/ml to 736.00±38.12 μg/m, which was comparable to the IC_{50} values of 522.20±12.38 μg/ml to 1075.00±29.35 μg/ml demonstrated by the standard, quercetin. Therefore, the antioxidant activities demonstrated by the root extracts are probably due to the presence of flavonoids.

ANTIPLASMODIAL

Tselanyane [80] evaluated antiplasmodial activities of aqueous, chloroform, hexane, ethyl acetate, petroleum ether and methanol leaf,

root and twig extracts of *D. anomala* against *Plasmodium falciparum*, a chloroquine-sensitive strain (D10) and chloroquine-resistant strains (RSA11, K1, and FAC8) using the parasite lactate dehydrogenase (pLDH) assay. The extracts showed activity ranging from IC_{50} values of 0.42±0.04 µg/ml to >100 µg/ml [80]. Van der Merwe [66] evaluated the antiplasmodial activities of ethanol root extract of *D. anomala* against chloroquine-sensitive D10 and choroquine-resistant strain K1 *P. falciparum* using the pLDH assay. The ethanol extract exhibited an IC_{50} of 1.4 µg/ml [66]. Becker *et al*. [68] evaluated *in vitro* antiplasmodial activities of 3-oxoeudesma-1,4(15),11(13)-triene-12,6a-lide isolated from *D. anomala* against chloroquine-sensitive D10 strain and chloroquine-resistant K1 strain *P. falciparum* using the pLDH assay. The compound showed an IC_{50} of 0.455 µg/ml against the chloroquine-sensitive D10 strain and 1.0 µg/ml against the chloroquine-resistant K1 strain when tested *in vitro* [68]. Van der Merwe [66] evaluated *in vitro* antiplasmodial activities of the compound (3aS,5aS,9aR,9bS)-5amethyl-3,9-dimethylidene-4,5,9a,9b-tetrahydro-3aHnaphtho[7,8-d] furan-2,8-dione isolated from *D. anomala* against chloroquine-sensitive D10 strain and chloroquine-resistant K1 strain *P. falciparum* using the pLDH assay. The compound showed an IC_{50} of 0.38 µg/ml against the chloroquine-sensitive D10 strain and 0.06 µg/ml against the chloroquine-resistant K1 strain when tested *in vitro* [66]. These results corroborate the traditional uses of *D. anomala* as remedy for fever and Malaria in Lesotho [41], South Africa [34], and Zimbabwe [6,26].

HEPATOPROTECTIVE

Balogun and Ashafa [56] evaluated the protective potentials of the aqueous root extract of *D. anomala* against isoproterenol-induced myocardial damage in Wistar rats. Various concentrations of 125, 250, and 500 mg/kg body weight of the extract and their effects on the rats' feed and water intake, body weight changes, serum enzymes, aspartate transaminase, alanine transaminase, creatinine phosphokinase, tissue antioxidant enzymes, including catalase, glutathione peroxidase, and lipid peroxidation were determined during a 30-day experimental period. Histopathological examination of isoproterenol-induced myocardial rats treated with the extract revealed evidence of oedema and myocardial necrosis at 125 and 250 mg/kg body weight doses; however, these alterations were ameliorated or cleared at 500 mg/kg dose, suggesting attainment of maximum efficacy. Similarly, Balogun and Ashafa [79] evaluated the hepatoprotective activities of *D. anomala* aqueous, ethanol, hydroethanol and methanol root extracts on body weight, feed and water intake, biochemical parameters and organ histology of Wistar rats during the 15 days study. Pre-treatment and treatment with different concentrations of *D. anomala* extracts significantly attenuated the elevated serum activities of aspartate, transaminase, alanine transaminase levels while increasing the activities of superoxide dismutase, catalase, and glutathione peroxidase. The histopathological evaluations revealed extensive liver damage characterized by severe vacuolar and cytoplasmic degeneration, hepatic necrosis, and cellular infiltration in pre-treated groups while in the treated groups; such liver damages were not observed most especially at 500 mg/kg dose [79]. These results showed the hepatoprotective potential of *D. anomala* aqueous root extracts against CCl_4-induced oxidative stress and therefore, D. anomala extracts could play an important role in the management or treatment of cardiac-related diseases.

TOXICITY AND CYTOTOXICITY

Tselanyane [80] evaluated *in vitro* cytotoxicity of aqueous, chloroform, hexane, ethyl acetate, petroleum ether and methanol leaf, root and twig extracts of *D. anomala* against a Chinese hamster ovary (CHO) cell line using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay. The extracts showed some activity with IC_{50} values ranging from 0.44 µg/ml to 31.33 µg/ml [80]. Van der Merwe [66] evaluated *in vitro* cytotoxicity of the compound (3aS,5aS,9aR,9bS)-5amethyl-3,9-dimethylidene-4,5,9a,9b-tetrahydro-3aHnaphtho[7,8-d]furan-2,8-dione isolated from *D. anomala* against CHO cell line using the MTT assay. The compound showed IC_{50} value of 4.2 µg/ml [66]. Becker *et al*. [68] evaluated *in vitro* cytotoxicity of *D. anomala* against CHO cell line using the MTT assay. Becker *et al*. [68] evaluated *in vitro* cytotoxicity of the compound 3-oxoeudesma-1,4(15),11(13)-triene-12,6a-lide isolated from *D. anomala* against (CHO cell line using the MTT assay. The compound showed IC_{50} value of 17.2 µM against 35.8 µM displayed by chloroquine [68]. Asita *et al*. [81] evaluated the cytotoxicity, genotoxicity, and modulation of cyclophosphamide and ethyl methanesulfonate-induced genotoxicity of methanolic root extracts of *D. anomala* using the *Allium cepa* assay. The three concentrations (0.0625 mg/ml, 0.125 mg/ml, 0.25 mg/ml) of *D. anomala* tested were cytotoxic and genotoxic to the *A. cepa* root meristem cells. The mixture of cyclophosphamide at 1.25 mg/ml with each concentration of extract of *D. anomala* separately was cytotoxic and genotoxic to the root tip meristem cells of *A. cepa*. The mixture of ethyl methane sulfonate at 0.25 mg/ml with each concentration of extract of *D. anomala* separately was genotoxic to the root tip meristem cells of *A. cepa*. These results suggest that the tested concentrations of root extracts of *D. anomala* exerted mitodepressive or cytotoxic effects on cell division of *A. cepa* root meristem cells [81]. Munodawafa *et al*. [82] evaluated toxicity of *D. anomala* tuber using the brine shrimp (*Artemia salina*) toxicity bioassay test with *Nerium oleander* as positive control. *D. anomala* extract showed LC_{50} value of 3 040±1060 µg/ml which was considered to be relatively safe to use and much higher than the LC_{50} value of 142±68.2 µg/ml exhibited by the positive control [82]. Balogun and Ashafa [74] evaluated the cytotoxic activities of flavonoids isolated from the root extract of *D. anomala* using the brine shrimp lethality assay. The result of the lethality assay showed a potent cytotoxic effect of the flavonoids with LC_{50} value 0.510 mg/ml. It is clear that detailed toxicity and cytotoxicity studies for such a widely used medicinal plant in tropical Africa are required.

CONCLUSION

Based on its wide use as herbal medicine in tropical Africa, *D. anomala* should be subjected to detailed ethnopharmacological evaluation aimed at elucidating its chemical, pharmacological, and toxicological properties. Such detailed ethnopharmacological research is required to substantiate medicinal claims associated with the species. For example, assessment of the antimycobacterial activities of the extracts of *D. anomala* are required as the species is widely used as herbal medicine against tuberculosis (TB) and other respiratory infections in Lesotho and South Africa [32,37,42]. Pulmonary TB is a highly communicable disease and represents a serious public health problem in the tropical and subtropical countries [83,84]. In the development of health care, herbal and pharmaceutical products, evaluation of the correlation between ethnomedicinal uses and phytochemistry and pharmacological properties is important. Based on current research results, it is difficult to correlate the ethnomedicinal uses of the species with the few phytochemical profiling and pharmacological evaluations that have been done so far. At the present moment, there is not yet enough systematic data regarding phytochemistry, pharmacological properties, and clinical research on *D. anomala* extracts and compounds. Detailed pharmacological studies should be carried out to provide some insight into the therapeutic potential of the species.

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AUTHOR' CONTRIBUTIONS

I declare that this work was done by the author named in this article.

CONFLICT OF INTEREST

No conflict of interest is associated with this work.

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