INTRODUCTION

Drimia elata Jacq. is an important and well-known medicinal plant in South Africa. Van et al. [1] provide an excellent introduction to the ethnomedicinal properties of D. elata and several other important medicinal plants in South Africa. D. elata is an ingredient of at least two traditional herbal concoctions in South Africa, known as “imbize phuzwato” and “intelezi” that are sold commercially in the country. A herbal tonic, imbize phuzwato is made from a mixture of roots, bulbs, rhizomes, and leaves of Acokanthera oppositifolia (Lam.) Codd, Aster bakanus Burtt Davy ex C.A. Sm., Corchorus asplenifolius Burch., Cyrtanthus obliquus (L.f.) Aiton, Paspalum physodes (Jacq.) Raf. ex Speta, Erica sema cordatum E.Mey., Gnidia kraussiana Meisl. var. kraussiana, Gomphocarpus fruticosus (L.) W.T. Aiton, Gunnera perpensa L., Hypericum aethiopicum Thumb., Ledebouria spp., Lycopodium clavatum L., Monorica balsamina L., Rubia cordifolia L., Scadoxus puniceus (L.) Friis and Nordal, Stephania abyssinica (Quart.-Dill. and A. Rich.) Walk., Tetradenia riparia (Hochst.) Codd, Vitellaria opposis marginata (N.E.Br.) Aubrèè, Watsonia densiflora Bak., and Zanthoxylum capense (Thunb.) Harv. [2,3]. The concoction is used as an energizing and detoxifying tonic used against general body pains, stress, constipation, arthritis, kidney problems, high blood pressure, and to increase sexual prowess [2,3]. D. elata is also an ingredient of “intelezi” whose plant species composition varies from region to region of South Africa. Intelezi is used to protect households from evil spirits and lightning, and also to chase away, ward off or root out evil spirits [4].

D. elata is the third most popular bulbous medicinal plant used in South African traditional therapy [5] and is one of the most wild-harvested species sold in the informal economy trade in the Eastern Cape [6,7], Gauteng [8-10], KwaZulu-Natal [8,11], Limpopo [12], and the Western Cape [13,14] provinces in South Africa. Research by Ndawonde et al. [15] showed that D. elata bulb was sold by >50.0% of the traders in KwaZulu-Natal Province, while Philander et al. [14] revealed that bulbs of the species were sold by 35.0% of the traders in the Western Cape province, with 60.48 kg of the bulb fetching US$26.21. Earlier research by Dold and Cocks [6] revealed that D. elata is among the most frequently traded species in the Eastern Cape Province with 113.9 kg as the mean quantity traded per trader per annum with a kilogram of the bulb fetching US$3.36. Marshall [16] argued that D. elata is scarce and heavily traded in South Africa, characterized by a high monetary value in the country. Due to increasing demand for the species, D. elata is managed in herbal medicine home gardens in the Eastern Cape [17], Limpopo [18-20], and the Western Cape [14] provinces. Research by Wiersum et al. [17] revealed that D. elata is among the ten most frequently cultivated herbal medicines in medicinal home gardens in the Eastern Cape Province. It is, therefore, within this context that the current study was undertaken aimed at summarizing the medicinal uses, phytochemical, and ethnopharmacological properties of D. elata so as to evaluate its therapeutic importance throughout its distributional range.

BOTANICAL PROFILE AND DESCRIPTION OF D. ELATA

The genus Drimia Jacq. is a large group of deciduous geophytes belonging to the family Asparagaceae, previously included in the Hyacinthaceae family. The family of Hyacinthaceae is divided into four monophyletic subfamilies, namely Hyacinthoideae, Ornithogaloideae, Ozingoideae, and Urgineoideae [21]. At present, this family is considered as a subfamily Scilloideae in the expanded Asparagaceae sensu [22,23]. The species in each subfamily synthesize specialized secondary metabolites with Hyacinthoideae synthesizing homoisoflavanes and triterpenoids, Ornithogaloideae (cardenolides and steroidal glycosides), and Urgineoideae synthesizing bufadienolides [23]. The subfamily Urgineoideae has flat or winged seeds characterized by brittle, loosely adhering test a comprising genera Bowiea Harv. ex Hook. f. and Drimia [24]. The genus Drimia is described by Manning et al. [24,25] in an inclusive and broad sense, including genera such as Litanthus Harv., Mucinea M. Pinter et al., Rhadamantus Salisb., Rhodocodon Baker, Sagittanthera Mart-Azorín et al., Thurnanthes C. H. Wright, Tenicra Raf., and Urginea Steinh. The taxonomy of genus Drimia has always...
been difficult with several species treated under genus *Uruginea* until Jessop [26] reduced *Uruginea* to a synonym of *Drinia*. The genus consists of about 100 bulbous species distributed in Southern Africa through tropical Africa to the Mediterranean, Asia, and Madagascar [24]. Synonyms of *D. elata* include *D. alta* R.A. Dyer, *D. citrius* Jacq. ex Willd., *D. purpurascens* J. Jacq., *D. robusta* Baker, *D. villosa* (Lindl.) Kunth, *D. zombensis* Baker, *Idotea elata* Kunth, *I. citrius* (Jacq. ex Willd.) Kunth, *I. purpurascens* (J. Jacq.) Kunth, *I. robusta* (Baker) Kunzle, and *I. villosa* (Lindl.) Kunth [1,27-31].

*D. elata* is a geophyte with large underground bulb, strap-shaped leaves and long, slender flowering stalk which grows up 1.8 m in height [1,27-29,31]. The flowers are tubular, whitish to purple in color with the tips of the petals characteristically reflexed and the stamens fused into a narrow tube [1]. *D. elata* has been recorded in grassland, often among micks at an altitude ranging from 15 m to 2,500 m a.s.l. [28]. The species has been recorded in Botswana, Angola, Malawi, Kenya, South Africa, Swaziland, Zambia, South Sudan, Tanzania, Sudan, Uganda, Zimbabwe, and Mozambique [1,27-31] (Fig. 1).

**MEDICINAL USES OF D. ELATA**

The medicinal applications recorded from literature were classified into ten medical categories following the Economic Botany Data Collection Standard [32] with some changes proposed by Macía et al. [33] and Grucu et al. [34]. This review showed that *D. elata* is used for treating several medicinal conditions, particularly general ailments, blood and cardiovascular system, reproductive system and sexual health, urinary system, infections and infestations, digestive system, respiratory system, and muscular-skeletal system disorders (Fig. 2). *D. elata* is used as herbal medicine against three out of five diseases categorized by the World Health Organization (WHO) as the top five killer diseases in sub-Saharan Africa in 2012. These diseases include human immunodeficiency virus/acquired immune deficiency syndrome (HIV/AIDS), lower respiratory tract infections, and diarrheal diseases [35]. Most medicinal uses are linked to the bulb and leaf or the entire plant in ritual or magical uses, and the species is also used mixed with other plant species (Table 1). Research by Gurib-Fakim [36] and Maroyi [37,38] revealed that traditional medicines are often prepared by combining several different plant species to effect synergistic properties or to initiate an interaction with a relevant molecular target.

**PHYTOCHEMICAL CONSTITUENTS OF D. ELATA**

*D. elata* is characterized by cardiac glycosides, particularly bufadienolides. All the bufadienolides that have been isolated from *D. elata* are collated in Table 2. Kellerman et al. [59,60] argued that bufadienolide containing plants are toxic to livestock with an estimated 33% of plant-related mortality in cattle in South Africa attributed to this compound. Van et al. [61] argued that there is a danger of accidental poisoning or that people may be harmed if bulbs of *D. elata* are used indiscriminately as rubbing the bulb scales or leaves on bare skin produces a stinging and irritating effect and a skin rash is produced. However, bufadienolides are known to have a wide range of biological activities including anti-tumor, antiproliferative, and cytotoxic activities [62-68].

Koorbanally et al. [69] identified aromatic acids, 4-hydroxy-3-methoxybenzoic acid, 3,4-dihydroxybenzoic acid, and trans-3-(4-hydroxyphenyl)-2-propenoic acid from the ethyl acetate bulb extract of *D. elata*. Matotoka and Masoko [70] identified flavonoids, phlobatannins, saponins, tannins, and terpenoids from the *D. elata* bulb (Table 3). Similarly, Matotoka and Masoko [41] identified alkaloids, flavonoids, saponins, steroids, tannins, and terpenoids from a herbal mixture of *D. elata* bulb mixed with leaves of *Monsonia angustifolia*, *Sarcostemma vinninale* and *Vahlia capensis*, *Kirkia wilmsii* (leaves, roots, and twigs), and *Hypoxis hemerocallidea* (corm).

Okem et al. [71] argued that *D. elata* bulbs obtained from the herbal medicine informal markets in Pietermaritzburg, KwaZulu-Natal Province in South Africa contained high levels of heavy metals, with aluminum, cadmium, manganese, and chromium being above the WHO recommended safety levels (Table 3). Quantities of mineral elements and phytochemical compounds isolated from *D. elata* are listed in Table 3.

**PHARMACOLOGICAL PROPERTIES OF D. ELATA**

Pharmacological studies on *D. elata* bulb and leaf extracts exhibited potent in vitro pharmacological activities including acetylcholinesterase enzyme inhibitory [2], antibacterial [2,43,50,70-80], antifungal [2,76], antimycobacterial [50], anticancer [81], anti-inflammatory [2,72,82,83], antioxidant [43,70], hemagglutinating [84], and cytotoxicity [43] activities.

Acetylcholinesterase enzyme inhibitory activities

Ndhlala et al. [2] investigated the acetylcholinesterase enzyme inhibitory activities of aqueous bulb extracts of *D. elata* using the enzyme isolated from electric eels with galanthamine as the positive control. The extract showed moderate AChE inhibitory activity of 50.0% with half maximal inhibitory concentration (IC50) value of 487.4±8.0 µg/mL [2]. The ability of *D. elata* bulb extracts to inhibit acetylcholinesterase shows potential therapeutic potential of the species in the management of memory loss and neurodegenerative disorders.

**Antibacterial activities**

Luyt et al. [72] evaluated antibacterial activities of aqueous, ethyl acetate, and ethanol bulb and leaf extracts of *D. elata* against Bacillus.
| Medicinal use                          | Parts of the plant used                                                                 | References                      |
|---------------------------------------|----------------------------------------------------------------------------------------|---------------------------------|
| Blood and cardiovascular system       | Bulbs or imbiza phuzwata concoction                                                    | [2,3,39-42]                    |
| Blood purification                    | Bulbs mixed with leaves, roots, and twigs of Kirkia wilmsii Eng., Hypoxis herero callidea Fisch., C. A. Mey. and Avé-Lall. (corms), Monsonia angustifolia E. Mey. ex A. Rich. (leaves), and leaves of Sarcostemma movinale (L.) Br. and Vahlia capensis (L. f.) Thunb. | [43]                            |
| Hypertension                          | Bulbs hold                                                                                | [2,3,19,44]                    |
| Digestive system                      | Bulbs mixed with leaves, roots, and twigs of Kirkia wilmsii, Hypoxis eroca lidea (corms), Monsonia angustifolia (leaves), and leaves of Sarcostemma movina, and Vahlia capensis | [43]                            |
| Constipation                          | Imbiza phuzwata concoction                                                               | [2,3]                           |
| Emetic                                | Bulbs                                                                                   | [37,45-47]                     |
| General ailments                      | Bulbs                                                                                   | [48]                            |
| Angina pain                           | Bulbs                                                                                   | [48]                            |
| Body pains                            | Imbiza phuzwata concoction                                                               | [2,3]                           |
| Energizing tonic                      | Imbiza phuzwata concoction                                                               | [2,3]                           |
| Fever                                 | Bulbs and leaves or bulbs mixed with roots of Artemisia afrjaca ex Wild., Siphonochilus aethiopicus (Schweinf.) B. L. Burtt and Erythrina caffra Thunb. | [45,49,50]                     |
| Headache                              | Bulbs                                                                                   | [1]                             |
| Heart tonic                           | Bulbs                                                                                   | [47]                            |
| Internal sores                        | Bulbs                                                                                   | [41]                            |
| Sores                                 | Bulbs and leaves                                                                        | [51]                            |
| Stress                                | Imbiza phuzwata concoctions                                                             | [2,3]                           |
| Infections and infestations           | Bulbs mixed with twigs of Sarcostemm avinale (L.) R. Br. and roots of Elaeodendron transvaalense (Burtt Davy), R. H. Archer, Elephant rhizo elephantina (Burch.) Skeels and Zanthoxyllum capense (Thunb). Harv. and bark of Sclerocarya birrea (A. Rich.) Hochst. | [19,52,53]                     |
| STIs                                  | Bulbs mixed with roots of Elaeodendron transvaalense, Elephant rhizo elephantina (roots), Sarcostemm avinale (twigs), Sclerocarya birrea (bark), and Zanthoxyllum capense (root) | [55]                            |
| Tuberculosis                          | Bulbs or bulbs mixed with roots of Callilepis isalauerea DC, Croton menyharthii Pax, Senna Italica Mill. and bulb of Siphonochilus aethiopius (Schweinf.) B. L. Burtt or bulbs mixed with the bark of Warburgia asalutaris (G. Bertol.) Chiov. or bulbs mixed with leaves of Ricinus communis L. or bulbs mixed with roots of Dioica anomala Sond. and bulb of Eucomis autumnalis (Mill.) Chitt. | [48,50]                         |
| Muscular-skeletal system              | Bulbs and imbiza phuzwata concoction                                                    | [2,3,39]                       |
| Arthritis                             | Bulbs                                                                                   | [41]                            |
| Back pain                             | Bulbs                                                                                   | [41]                            |
| Edema                                 | Bulbs                                                                                   | [1]                             |
| Inflammation                          | Bulbs and leaves                                                                        | [51]                            |
| Muscle pain                           | Bulbs                                                                                   | [41]                            |
| Swelling                              | Bulbs                                                                                   | [39]                            |
| Pain                                  | Bulbs and leaves or bulb mixed with leaves, roots, and twigs of Kirkia wilmsii, Hypoxis herero callidea (corm), Monsonia angustifolia (leaves), and leaves of Sarcostemma vimaline and Vahlia capensis | [43,46,51]                     |
| Reproductive system and sexual health | Imbiza phuzwata concoction or bulbs mixed with leaves, roots, and twigs of Kirkia wilmsii, Hypoxis herero callidea (corm), Monsonia angustifolia (leaves), and leaves of Sarcostemma vimaline and Vahlia capensis | [2,4,3]                         |
| Aphrodisiac                           | Imbiza phuzwata concoction or bulbs mixed with leaves, roots, and twigs of Kirkia wilmsii, Hypoxis herero callidea (corm), Monsonia angustifolia (leaves), and leaves of Sarcostemma vimaline and Vahlia capensis | [2,4,3]                         |
| Erectile dysfunction                  | Bulbs                                                                                   | [56]                            |
| Impotence                             | Bulbs                                                                                   | [19,57]                         |
| Infertility                           | Bulbs                                                                                   | [1,18,19,57]                    |

(Contd...)
Table 1: (Continued)

| Medicinal use          | Parts of the plant used                                              | References       |
|------------------------|-----------------------------------------------------------------------|------------------|
| Blocked nose           | Bulbs or bulbs mixed with roots of *Artemisia afra,* *Siphonochilus aethiopicus,* and *Erythrina caffra* | [50]             |
| Chest pains            | Bulbs and leaves or bulbs mixed with leaves of *Lippia javanica* (Burm. f.) Spreng.* | [48-50]          |
| Colds                  | *transvaalense* (Burtt Davy) R. H. Archer Bulbs and leaves              | [45,46,49]       |
| Cough                  | Bulbs mixed with leaves of *Lippia javanica*                           | [50]             |
| Expectorant            | Bulbs                                                                  | [45,47]          |
| Runny nose             | Bulbs mixed with leaves of *Lippia javanica*                           | [50]             |
| Ritual or magical uses | *Intelezi* herbal concoction                                          | [4,45]           |
| Protect households from evil spirits and lightning, and also to chase away, ward off or root out evil spirits |                                                               |
| Urinary system         | Leaves                                                                 | [1,15,58]        |
| Bladder complaints     | Leaves                                                                 | [1,15,58]        |
| Kidney problems        | *Impiza phuzwata* concoction                                          | [2,3]            |
| Uterus problems        | Bulbs and leaves                                                        | [1,15,58]        |

HIV: Human immunodeficiency virus, AIDS: Acquired immune deficiency syndrome, STIs: Sexually transmitted infections

Table 2: Bufadienolides isolated from *D. elata* bulb using NMR spectroscopy

| Bufadienolides               | Extract                  | References       |
|------------------------------|--------------------------|------------------|
| Proscillaridin A             | Chloroform: isopropanol  | [72,73]          |
| Scilliroside                 | Chloroform or chloroform-n-butanol | [74]                   |
| 12β-hydroxyacetylscilliroside| Chloroform or chloroform-n-butanol | [74]                   |
| 12β-hydroxyacetylscilliroside| Chloroform or chloroform-n-butanol | [74]                   |
| Hellebrigenin-3-0-β-glucoside| Chloroform or chloroform-n-butanol | [74]                   |
| 16β-hydroxyhellebrigenin      | Chloroform or chloroform-n-butanol | [74]                   |
| 16β-hydroxyhellebrigenin-3-O-β-glucoside| Chloroform or chloroform-n-butanol | [74]                   |
| 5β,16β-dihydroxybufalin-3-O-β-glucoside| Chloroform or chloroform-n-butanol | [74]                   |
| 6β-acetoxy-3β,12β,14β-tetrahydroxybufalin-4,20,22-trienolide (12β-hydroxyscilliroside)| Dichloromethane | [75]                   |
| 14β-hydroxybufalin-4,20,22-trienolide 3β-0-(α-L-rhamnopyranosyl)[(1→4)]-β-glucopyranosyl [1→3]-α-L-rhamnopyranoside [1→6] (bufalin)| Dichloromethane | [75]                   |
| 6β-acetoxy-3β,12β,14β-trihydroxy-12-oxobufalin-4,20,22-trienolide | Dichloromethane | [69]                   |
| 6β-acetoxy-3β,12β,14β-tetrahydroxybufalin-4,20,22-trienolide (12β-hydroxyscilliroside) | Dichloromethane | [69]                   |

NMR: Nuclear magnetic resonance

subtilis, *Escherichia coli*, *Klebsiella pneumoniae*, *Micrococcus luteus*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Staphylococcus epidermidis* using disk-diffusion assay with neomycin (2 μg/ml) as the positive control. Only ethyl acetate bulb extract was active against *B. subtilis*, *K. pneumoniae*, *M. luteus*, *P. aeruginosa*, and *S. aureus* with inhibition ratios ranging from 0.1 to 0.63 [72]. Ncube et al. [76] evaluated antibacterial activities of aqueous, dichloromethane, ethanolic, and petroleum ether extracts of bulb and leaves of *D. elata* between spring, summer, autumn, and winter seasons against *Bacillus subtilis*, *S. aureus*, *E. coli*, and *K. pneumoniae* using the microdilution bioassay with neomycin (μg/ml) as the positive control. The extracts were active in all seasons except for winter when the leaves are not available showing minimum inhibitory concentration (MIC) values ranging from 0.8 mg/ml to 12.25 mg/ml [76]. Ndhlala et al. [2] evaluated the antibacterial activities of aqueous, petroleum ether, dichloromethane, and ethanol bulb extracts of *D. elata* against *Bacillus subtilis*, *E. coli*, *K. pneumoniae*, and *S. aureus* using the microdilution bioassay with neomycin as the positive control. The extracts showed activities with MIC values ranging from 0.8 to 4.0 mg/ml [2]. Baskann et al. [77] evaluated the antibacterial activities of ethanol bulb, leaf, shoot, and stemlet extracts of *in vitro* and *ex vitro* regenerated *D. elata* in comparison to naturally-grown plants against *S. aureus*, *Enterococcus faecalis*, *E. coli*, and *P. aeruginosa* using the microdilution method with neomycin (100 μl) as the positive control. All extracts exhibited activities with MIC values ranging from 0.2 mg/ml to 12.5 mg/ml [77]. Okem et al. [71] evaluated antibacterial activities of ethanol stem bulb extracts of *D. elata* against *E. coli* and *S. aureus* using microdilution assay with neomycin (2 μg/ml) as the positive control. The extracts exhibited activities with MIC values ranging from 0.63 mg/ml to 12.5 mg/ml [71]. Okem et al. [78] evaluated the effects of cadmium and aluminum accumulation on antibacterial activities of ethanol stem bulb extracts of *D. elata* against *E. coli* and *S. aureus* using microdilution assay with neomycin (2 μg/ml) as the positive control. The control extracts exhibited MIC values of 0.8 mg/ml and 0.8 mg/ml against *S. aureus* and *E. coli*, respectively, while antibacterial activities decreased in extracts exposed to increasing heavy metal stress with MIC values ranging from 0.8 mg/ml to 12.5 mg/ml [78]. Madisha [50] evaluated the antibacterial activities of ethanol, methanol, hydroethanol, and dichloromethane bulb extracts of *D. elata* against *Bacillus cereus*, *E. faecalis*, *E. coli*, *Neisseria gonorrhoeae*, *Proteus vulgaris*, *P. aeruginosa*, *Shigella flexneri*, *S. aureus*, *Staphylococcus epidermidis*, and *Vibrio parahaemolyticus* using agar well dilution method and streak plate disc diffusion assays. The extracts revealed varying degrees of activities with the zone of inhibition values ranging from 0.0 mm to 19.0 mm and MIC values ranging from 0.1 mg/ml to 12.5 mg/ml. Madisha [50] also evaluated the antibacterial activities of ethanol and hydroethanol bulb extracts of *D. elata* mixed with roots of *Elephantorrhiza elephantina* and leaves of *Aloe marlothii* and *Maurea angolensis* against *B. cereus*, *E. faecalis*, *E. coli*, *N. gonorrhoeae*, *P. vulgaris*, *P. aeruginosa*, *S. flexneri*, *S. aureus*, *S. epidermidis*, and *V. parahaemolyticus* using agar well dilution method and streak plate disk diffusion assays. The extracts exhibited activities against tested pathogens with MIC values ranging from 0.4 mg/ml to 16.5 mg/ml [50]. Matotoka and Masoko [70] evaluated antibacterial activities of acetone and hexane extracts of *D. elata* bulb against *S. aureus*, *E. faecalis*, *E. coli*, and *P. aeruginosa* using the broth
microdilution assay. The extracts exhibited activities against E. faecalis and P. aeruginosa with MIC values ranging from 0.6 mg/ml to 2.5 mg/ml and total activities ranging from 3.3 mL/g to 13.3 mL/g [70]. Baskaran et al. [79] evaluated antibacterial activities of the aqueous bulb and root extracts of ex vitro grown D. elata derived from somatic embryogenesis against Bacillus subtilis, E. faecalis, M. luteus, S. aureus, E. coli, K. pneumonia, and P. aeruginosa using microtiter bioassay with neomycin (µg/ml) as a positive control. The extracts exhibited activities with MIC values ranging from 0.4 mg/ml to 6.3 mg/ml [79]. Kandari [80] evaluated antibacterial activities of aqueous, dichloromethane, and ethanol bulb extracts of D. elata subjected to vermicompost leachate at different concentrations against Bacillus subtilis, S. aureus, and E. coli using microdilution assay. The extracts exhibited activities with MIC values ranging from 0.4 mg/ml to 6.3 mg/ml [80]. Matotoka et al. [81] investigated the antifungal activity of aqueous, petroleum ether, dichloromethane, and ethanol bulb extracts of D. elata against C. albicans using the microdilution assay with amphotericin B as the positive control. The extracts exhibited activities with MIC and MFC values ranging from 3.1 to 6.3 mg/ml and 6.3 mg/ml to 12.5 mg/ml [2].

### Antimycobacterial activities

Madisha [50] evaluated the antituberculous activity of ethanol, methanol, hydroethanol, and dichloromethane bulb extracts of D. elata against Mycobacterium tuberculosis, Mycobacterium smegmatis, Mycobacterium peregrinum, and Mycobacterium haemophilus using agar well dilution method and streak plate disc diffusion assays. The extracts revealed varying degrees of activities with the zone of inhibition values ranging from 9.0 mm to 21.0 mm and MIC values ranging from 0.1 mg/ml to 12.5 mg/ml [50]. Madisha [50] also evaluated the antituberculous activity of ethanol and methanol bulb extracts of D. elata against Mycobacterium tuberculosiosis and Mycobacterium peregrinum, M. haemophilus, and Mycobacterium smegmatis using agar well dilution method and streak plate disc diffusion assays. The extracts exhibited activities against tested pathogens with MIC values ranging from 0.1 mg/ml to 1.6 mg/ml [50]. These findings show the potential of D. elata in the treatment and management of respiratory problems such as blocked nose [48], chest pains [46-48], colds [43,44,47], cough [48], and runny nose [50].

### Anticancer activities

Fouche et al. [81] evaluated in vitro anticancer activities of dichloromethane: methanol (1:1) of the whole plant of D. elata against a panel of three human cell lines (breast MCF7, renal TK10, and melanoma UACC62). The extract exhibited total growth inhibition values ranging from 6.3 µg/ml to 29.6 µg/ml. The extracts were screened against human cancer cell lines organized into sub-panels representing leukemia, melanoma, cancer of the lung, colon, kidney, ovary, central nervous system, breast, and prostate. The extract exhibited total

### Table 3: Mineral and phytochemical composition of D. elata

| Mineral and phytochemical composition | Values | Plant parts | References |
|--------------------------------------|--------|-------------|------------|
| Aluminum (mg/kg dry weight)           | 559.8–1595.0 | Bulbs | [70,71] |
| Arsenic (mg/kg dry weight)            | 1.8 | Bulbs | [71] |
| Boron (mg/L)                         | 3.0 | Bulbs | [70] |
| Cadmium (mg/kg dry weight)           | 0.01–0.06 | Bulbs | [71] |
| Calcium (mg/L)                       | 19.0 | Bulbs | [70] |
| Cobalt (mg/L)                        | 0.04 | Bulbs | [70] |
| Copper (mg/kg dry weight)            | 5.6–11.3 | Bulbs | [71] |
| Chromium (mg/kg dry weight)          | 7.8–12.0 | Bulbs | [71] |
| Flavonoids (µg of quercetin equivalent/g extract) | 0.54–15.0 | Bulbs and leaves | [43,71,76] |
| Gallotannin (µg gallic acid equivalent/g dry weight) | 4.0–7.0 | Bulbs and leaves | [76] |
| Iron (mg/L)                          | 0.15 | Bulbs | [70] |
| Iron (mg/kg dry weight)              | 593.0–1634.0 | Bulbs | [71] |
| Lead (mg/kg dry weight)              | 0.2–1.2 | Bulbs | [71] |
| Magnesium (mg/L)                     | 28.0 | Bulbs | [70] |
| Manganese (mg/kg dry weight)         | 60.7–145.8 | Bulbs | [70,71] |
| Mercury (mg/kg dry weight)           | 0.04–0.8 | Bulbs | [71] |
| Molybdenum (mg/L)                    | 0.02 | Bulbs | [70] |
| Nickel (mg/kg dry weight)            | 4.2–10.0 | Bulbs | [71] |
| Phosphorus (mg/L)                    | 24.0 | Bulbs | [70] |
| Potassium (mg/L)                     | 53.0 | Bulbs | [70] |
| Silicon (mg/L)                       | 4.0 | Bulbs | [70] |
| Sodium (mg/L)                        | 56.0 | Bulbs | [70] |
| Sulfur (mg/L)                        | 7.0 | Bulbs | [70] |
| Tannin (mg of gallic acid equivalent/g extract) | 4.5–9.6 | Bulbs and leaves | [43,76] |
| Tin (mg/kg dry weight)               | 31.4–79.8 | Bulbs | [71] |
| Total phenolics (mg gallic acid equivalent/g dry weight) | 0.05–2.5 | Bulbs and leaves | [43,71,76] |
| Total saponins (mg diosgenin equivalent/g dry weight) | 5.0–17.0 | Bulbs and leaves | [76] |
| Total steroidal saponin (mg diosgenin equivalent/g dry weight) | 1.0–4.5 | Bulbs and leaves | [76] |
| Zinc (mg/L)                          | 0.1 | Bulbs | [70] |
| Zinc (mg/kg dry weight)              | 34.1–102.6 | Bulbs | [71] |
growth inhibition values of 1.1 μg/ml against ovarian (OVCAR-3), 1.4 μg/ml against central nervous system cancer; CNSC SF-539 and 1.4 μg/ml against non-small cell lung cancer; NSCLC A549/ATCC [81]. The documented anti-cancer activities may be attributed to bufadienolides as these compounds are known to have anti-cancer activities [62-68].

**Anti-inflammatory activities**

Lupt et al. [72] evaluated anti-inflammatory activities of aqueous, ethyl acetate, and ethanol bulb and leaf extracts of *D. elata* using the cyclooxygenase assay with indomethacin as the positive control. The bulb extracts inhibited cyclooxygenase with inhibition ranging from 69.0% to 98.0% which was comparable to 94% exhibited by indomethacin, the positive control [72]. Stafford et al. [82] evaluated anti-inflammatory activities of aqueous, ethanol, and hexane bulb extracts of *D. elata* by assessing their ability to inhibit cyclooxygenase (COX)-1 enzymes. The ethanol extract showed high inhibition level of 96.0% which decreased to 76.0% of the COX-1 enzyme after 90 days of storage while aqueous extract showed 61.0% inhibition which decreased to 0% of the COX-1 enzyme after 90 days of storage [82]. Ndhlala et al. [2] investigated the anti-inflammatory effects of aqueous, dichloromethane, ethanol, and petroleum ether bulb extracts of *D. elata* using COX-1 and COX-2 inhibitory bioassays. The aqueous and ethanol extracts showed percentage inhibition of over 80.0% and 48.0%, respectively, for COX-1 while only the aqueous extract showed moderate inhibition of over 55.0% for COX-2 enzyme [2]. Ncube et al. [83] evaluated the anti-inflammatory activities of aqueous, dichloromethane, ethanol, and petroleum ether bulb and leaf extracts of *D. elata* collected in spring, summer, autumn, and winter seasons by assessing their ability to inhibit COX-1 and COX-2 enzymes. The dichloromethane and petroleum ether bulb and leaf extracts in all seasons except for winter when the leaves are not available showed moderate to high inhibition levels ranging from 58.0% to 94.1% of the COX-1 enzyme. A similar trend was observed for COX-2 enzyme with inhibition levels ranging from 52.8% to 91.2% [83]. These findings support the traditional use of *D. elata* as herbal medicine for back pain [39], body pains [2,3], inflammation [51], muscle pain [41], pain [43,46,51], and swelling [39].

**Antioxidant activities**

Matotoka and Masoko [70] evaluated antioxidant activities of acetone and hexane extracts of *D. elata* bulb using 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging assay. The hexane extracts exhibited antioxidant activities [70]. Matotoka and Masoko [43] evaluated antioxidant activities of an herbal mixture of *D. elata* bulb together with leaves of *M. angustifolia*, *S. viminalis*, and *V. capensis*, *K. wilmsii* (leaves, roots, and twigs), and *H. hemerocallidea* (corn) using the DPPH free radical scavenging assay and ferric reducing power measuring assay with L-ascorbic acid as the positive control. The free radical scavenging activity showed that the herbal concoction exhibited moderate antioxidant activities. The ferric reducing power measuring the reduction of Fe3+ to Fe2+ revealed that the herbal concoction exhibited good reducing activity compared to L-ascorbic acid, the positive control [43]. The documented antioxidant activities of the bulb extracts of *D. elata* are probably due to flavonoids, gallotannins, phenolics, saponins, and tannins which have been isolated from the species [43,71,76].

**Hemagglutinating activities**

Gaidamashvili and Van Staden [84] evaluated hemagglutinating activities of aqueous bulb extracts of *D. elata* toward fresh and glutaraldehyde-treated rabbit erythrocytes using the hemagglutination and hapten inhibition assays. The extracts yielded hemagglutinating activity which was detected in the crude protein extracts at the minimal concentrations of 19.9 mg/ml. The was inhibited by 200 mM lactose along with major inhibition by D(+)-trehalose, >DL arabinose, and D fructose [84]. The documented information on hemagglutinating activities and the identification of proteins from *D. elata* may be useful for future characterization of the species extracts in developing pharmaceutical products.

**Cytotoxicity activities**

Matotoka and Masoko [43] evaluated cytotoxicity activities of an herbal mixture of *D. elata* bulb together with leaves of *M. angustifolia*, *S. viminalis*, and *V. capensis*, *K. wilmsii* (leaves, roots, and twigs), and *H. hemerocallidea* (corn) using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide calorimetric assay with actinomycin D as the negative control. The cytotoxic concentration (CC50) values of all the concoctions were above the highest concentration used (1000 μg/ml) and Actinomycin D; the negative control exhibited CC50 value of 0.6 μg/ml [43]. The documented cytotoxicity activities exhibited by *D. elata* extracts may be attributed to bufadienolides as these compounds are known to have cytotoxic activities [64,65].

**CONCLUSION**

Based on information about *D. elata* that has been documented in this review, there appear to be research gaps on ethnomedicinal uses, and potential toxic components of the species can be managed.

**AUTHOR’S CONTRIBUTIONS**

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

**CONFLICTS OF INTEREST**

The author declares that there are no conflicts of interest regarding the publication of this paper.

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