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## Review Article

# *Pelargonium reniforme* Curtis (Geraniaceae Family): Ethnopharmacology of an Endangered Medicinal Plant

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### Abstract

Tuberous roots of *Pelargonium reniforme* Curtis are harvested from the wild and used in traditional medicine. This review aimed at documenting the botany, ethnomedicinal uses, chemical and biological properties as well as prospects for sustainable use of *P. reniforme*. The literature search on existing information on the botany, ethnomedicinal uses, chemical and biological properties and sustainable use of *P. reniforme* was carried out using online databases such as PubMed®, Web of Science, SciELO, Google Scholar, ScienceDirect®, SpringerLink® and Scopus®. *Pelargonium reniforme* is Near Endangered in South Africa and is commercially useful as a source of pharmaceutical products against coughs, colds and respiratory tract infections. The aerial and floral parts and roots of *P. reniforme* contain phenolic acids, phenylpropanoid derivatives, fatty acids, essential oils, coumarins, flavonoids, diterpenes and tannins. The pharmacological evaluations showed that the crude extracts and phytochemical compounds isolated from the species have antimycobacterial, antibacterial, antifungal and antioxidant activities. This study revealed the need for further studies focusing on ethnopharmacological evaluations of *P. reniforme* aimed at documenting the chemical, biological properties and toxicological evaluations, *in vivo* and clinical studies of the species. Furthermore, since *P. reniforme* is categorized as Near Endangered on IUCN Red List categories and criteria due to unsustainable harvesting and exploitation, the species need to be cultivated to meet its increasing demand as a medicinal plant.

**Key words:** Indigenous pharmacopoeia, *Pelargonium reniforme*, materia medica, IUCN Red List, threatened species

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**Data Availability:** All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Medicinal plants are mainly harvested from the wild, with a wide range of species showing some signs of unsustainable harvesting<sup>1</sup>. These plant species are at risk of extinction due to over-harvesting and commercial trade as traditional medicines. Commercial trade in traditional medicines is a major cause for concern among researchers, conservation organizations and traditional healers as some of the harvesting methods employed are unsustainable<sup>2</sup>. The plant collection or harvesting methods used by medicinal plant gatherers or collectors include uprooting of whole plants, particularly herbaceous plants, collection of tubers, bulbs, roots, corms, rhizomes, removal of the bark, cutting of stems, branches, twigs, flowers, fruits, seeds and leaves<sup>2</sup>. Some of the medicinal plants that are threatened with extinction that are collected for commercial trade include *Alepidea amatymbica* Eckl. and Zeyh. (Apiaceae family), *Bowiea volubilis* Harv. ex T.Moore and Mast. (Asparagaceae family), *Clivia miniata* (Lindl.) Verschaff. (Amaryllidaceae family), *Prunus africana* (Hook.f.) Kalkman (Rosaceae family) and *Warburgia salutaris* (G.Bertol.) Chiov. (Canellaceae)<sup>2-4</sup>. Apart from over-harvesting and commercial exploitation, other major threats affecting medicinal plants include habitat loss and degradation through agricultural expansion, urban developments, mining, overgrazing, forestry plantations, fire, invasive alien plant species and harvesting for horticultural purposes<sup>5,6</sup>. Similarly, *Pelargonium reniforme* Curtis (Geraniaceae family) (Fig. 1), commonly known as kidney-leaved pelargonium, endemic to the Eastern and Western Cape Provinces of South Africa is listed in the Southern African traditional medicine pharmacopoeia<sup>7,8</sup>. *Pelargonium reniforme* is categorized as Near Threatened on the International Union for Conservation of Nature (IUCN) Red List of Categories and Criteria of Threatened Species as the taxon is declining in population size as a result of over-collection as traditional medicine and also harvested for commercial trade at both local and international markets<sup>9-11</sup>. The indiscriminate, unsustainable collection and over-exploitation of *P. reniforme* throughout its distributional range have made it necessary to review its botany, ethnomedicinal uses, phytochemistry, biological activities and sustainable harvesting strategies for the species.

## MATERIALS AND METHODS

The literature search for the botanical characteristics, ethnomedicinal uses, phytochemistry, biological activities and sustainable harvesting strategies for *P. reniforme* was done from March, 2023 to May, 2024 using the electronic search for

peer-reviewed scientific publications, published books and book chapters. Online search databases used included Web of Science, Scopus®, SpringerLink®, Google Scholar, SciELO, PubMed® and ScienceDirect®. The keywords used in the search included "*Pelargonium reniforme*", the synonyms of the species "*P. reniforme* Curtis" and the English common name "Kidney-leaved pelargonium". Additional search was also conducted using the keywords "Biological activities of *Pelargonium reniforme*", "Pharmacological properties of *Pelargonium reniforme*", "Ethnobotany of *Pelargonium reniforme*", "Medicinal uses of *Pelargonium reniforme*", "Phytochemistry of *Pelargonium reniforme*" and "Traditional uses of *Pelargonium reniforme*".

## RESULTS AND DISCUSSION

**Taxonomical and morphological description of *Pelargonium reniforme*:** The *Pelargonium* L'Héritier genus belongs to the Geraniaceae, commonly known as *Geranium* or *Pelargonium* family. The family Geraniaceae comprises approximately 800 species which are annual or perennial herbs, geophytes, subshrubs or shrubs that are cosmopolitan in subtropical and temperate regions with many species cultivated as ornamentals and container plants<sup>11,12</sup>. Plant species belonging to the genus *Pelargonium* are perennial, sometimes woody or succulent shrubs, subshrubs, acaulescent geophytes, tuberous scramblers, climbers or annual herbs recorded in Central, Eastern, Northern and Southern Africa, Asia, Madagascar, Australia and New Zealand<sup>12</sup>. The genus name *Pelargonium* is based on the Greek term "*pelargos*", the name for stock and this is about the shape of the fruits of most species of this genus which resemble stock. The species name "*reniforme*" is derived from a Latin word that means "kidney-shaped", about the leaf shape of this species which are bluntly heart-shaped to kidney-shaped. Two synonyms, namely *Geranospermum reniforme* (Andrews) Kuntze and *Geranium reniforme* Andrews are associated with the name *P. reniforme*. Two infraspecific taxa, namely *P. reniforme* subsp., *reniforme* and *P. reniforme* subsp., *velutinum* (Eckl. and Zeyh.) Dreyer is recognized<sup>13</sup>. But Victor and Aphane<sup>11</sup> argued that the recognition of two subspecies of *P. reniforme* is not justified as the morphological characters used to delimit the two subspecies are unreliable and too variable. *Pelargonium reniforme* is known and identified by several vernacular or local names, which include "kidney-leaved pelargonium" in English, "rabassam", "rooirabas" or "rooirabassam" in Afrikaans, "iyeza lesikhali", "kubalo" or "umsongelo" in IsiXhosa. *Pelargonium reniforme* is a decumbent or erect subshrub with tuberous roots, growing to one metre in height<sup>11,13</sup>.



Fig. 1: *Pelargonium reniforme* showing the habit, flowers and leaves

Source of photo: Andrian Grober

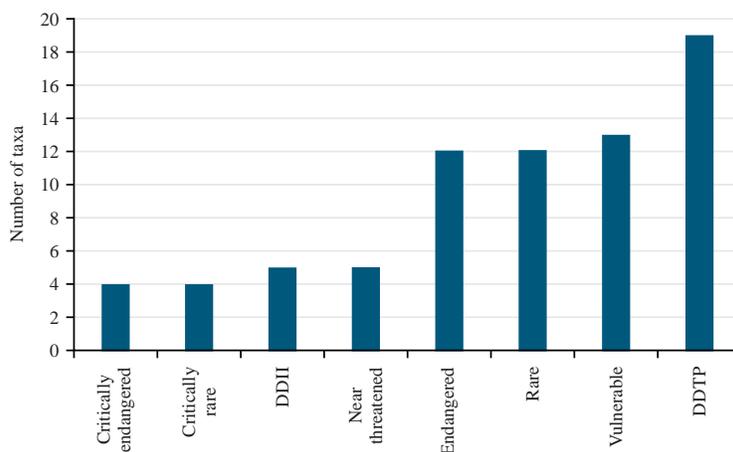


Fig. 2: *Pelargonium* taxa in Southern Africa in different categories of threat

DDII: Data deficient insufficient information and DDTP: Data deficient taxonomically problematic

The leaves are crowded or loosely spaced, ovate to cordate in shape, shallowly lobed, base cordate or reniform with finely toothed margins. The inflorescence is characterized by branches with several pseudo-umbels with small tubular flowers that are pink to purple (Fig. 1). *Pelargonium reniforme* is endemic to the Eastern and Western Cape Provinces of South Africa, recorded in grassland, savanna, the drier coastal

plain, Fynbos-Renosterveld and the Albany thicket biome, an altitude ranging from 20 to 1494 m above sea level<sup>13</sup>.

**Conservation status:** Out of 280 *Pelargonium* species that have been recorded throughout the world<sup>14</sup>, 219 of these species have been recorded in Southern Africa<sup>11,13,14</sup> and 74 of these species are threatened with extinction (Table 1, Fig. 2).

Table 1: *Pelargonium* taxa in Southern Africa that are threatened or are of conservation concern<sup>16</sup>

<i>Pelargonium</i> taxa	Threat category	Conservation concerns or threats
<i>P. adriaanii</i> M.Becker and F.Albers	Vulnerable	Habitat loss, degradation due to mining, overgrazing and trampling
<i>P. aestivale</i> E.M.Marais	Data deficient: Insufficient information (DDII)	Habitat degradation due to overgrazing
<i>P. album</i> J.J.A.van der Walt	Rare	Habitat loss
<i>P. alternans</i> J.C.Wendl. subsp. <i>parviflorescens</i> M.Becker and F.Albers	Rare	Confined to mountain slopes
<i>P. appendiculatum</i> (L.f.) Willd.	Endangered	Habitat loss and heavy grazing
<i>P. asarifolium</i> (Sweet) Loudon	Vulnerable	Habitat loss, degradation, urbanization, agriculture and alien invasive species
<i>P. attenuatum</i> Harv.	Endangered	Habitat loss
<i>P. bifolium</i> (Burm.f.) Willd.	Data deficient: Taxonomically problematic (DDTP)	Poorly known and poorly defined species
<i>P. brevipetalum</i> N.E.Br.	DDTP	Poorly known to determine its status
<i>P. brevirostre</i> R.A.Dyer	DDII	Poorly known
<i>P. bubonifolium</i> (Andrews) Pers.	Rare	Localized and occur in small subpopulations
<i>P. burgerianum</i> J.J.A.van der Walt	Vulnerable	Habitat loss and agricultural expansion
<i>P. burtoniae</i> L.Bolus	DDTP	Taxonomically problematic
<i>P. caledonicum</i> L.Bolus	Critically endangered	Habitat loss, agriculture, fire and infrastructure development
<i>P. calviniae</i> R.Knuth	DDTP	Taxonomically problematic
<i>Pelargonium campestre</i> (Eckl. and Zeyh.) Steud.	DDII	Poorly known
<i>P. caroli-henrici</i> B.Nord.	Rare	Range-restricted species
<i>P. chelidonium</i> (Houtt.) DC.	Endangered	Habitat loss, agricultural expansion, alien invasive plants and overgrazing
<i>P. citronellum</i> J.J.A.van der Walt	Rare	Habitat specialist that occurs as scattered subpopulations
<i>P. confertum</i> E.M.Marais	Rare	Rare and poorly known species
<i>P. connivens</i> E.M.Marais	Vulnerable	Habitat loss, agriculture and overgrazing
<i>P. crassicaule</i> L'Hér.	Endangered	Habitat loss, illegal collection and mining
<i>P. crassipes</i> Harv.	Endangered	Habitat loss and fragmentation due to agriculture
<i>P. curviandrum</i> E.M.Marais	Vulnerable	Habitat loss due to agriculture
<i>P. denticulatum</i> Jacq.	Rare	Rare habitat specialist
<i>P. divisifolium</i> Vorster	Near threatened	Alien invasive plants
<i>P. elandsmontanum</i> E.M.Marais ex J.C.Manning and Goldblatt	Critically rare	Rare species
<i>P. ellaphieae</i> E.M.Marais	Endangered	Habitat loss, urbanization, agriculture and illegal collection
<i>P. exhibens</i> Vorster	Near threatened	Over-harvesting for medicinal use
<i>P. fasciculaceum</i> E.M.Marais	Near threatened	Agriculture
<i>P. fergusoniae</i> L.Bolus	Endangered	Habitat loss, fragmentation, agriculture and alien invasive plants
<i>P. flavidum</i> E.M.Marais	DDII	Rare and poorly known species
<i>P. glabriphyllum</i> E.M.Marais	Rare	Habitat loss, agriculture and over-grazing
<i>P. gracile</i> (Eckl. and Zeyh.) Steud.	DDTP	Taxonomically poorly delimited
<i>P. gracilipes</i> R.Knuth	DDTP	Poorly known
<i>P. grenvilleae</i> (Andrews) Harv.	DDTP	Poorly known species
<i>P. greytonense</i> J.J.A.van der Walt	Vulnerable	Habitat loss, timber plantations and alien invasive species
<i>P. hantamianum</i> R.Knuth	DDTP	Poorly known taxon
<i>P. hemicyclium</i> Hutch. and C.A.Sm.	DDTP	Poorly known taxon
<i>P. heterophyllum</i> Jacq.	Critically endangered	Range-restricted species, habitat loss, agriculture, alien invasive plants and urbanization
<i>P. keerombergense</i> M.Becker and F.Albers	DDTP	Taxonomically problematic
<i>P. laciniatum</i> R.Knuth	DDTP	Taxonomically problematic
<i>P. ladysmithianum</i> R.Knuth	DDTP	Taxonomically problematic
<i>P. leptum</i> L.Bolus	Vulnerable	Over-collection for the horticultural trade
<i>P. longicaule</i> Jacq. var. <i>angustipetalum</i> C.Boucher	Vulnerable	Habitat loss
<i>P. luteum</i> (Andrews) G.Don	DDTP	Taxonomically problematic
<i>P. nephrophyllum</i> E.M.Marais	Endangered	Range-restricted species, agriculture and grazing
<i>P. nummulifolium</i> Salisb.	Critically rare	Known from one inaccessible mountainous area
<i>P. ocellatum</i> J.J.A.van der Walt	Rare	Range-restricted endemic species
<i>P. ochroleucum</i> Harv.	DDTP	Poorly known species
<i>P. ovale</i> (Burm.f.) L'Hér. subsp. <i>hyalinum</i> Hugo	Vulnerable	Alien invasive plants
<i>P. oxaloides</i> (Burm.f.) Willd.	DDTP	Taxonomically problematic
<i>P. pachypodium</i> J.P.Roux	Critically rare	Rare and localized species
<i>P. petroselinifolium</i> G.Don	Vulnerable	Habitat loss and agriculture
<i>P. plurisectum</i> Salter	Vulnerable	Habitat loss and invasive alien species

Table 1: Continue

<i>Pelargonium</i> taxa	Threat category	Conservation concerns or threats
<i>P. pubipetalum</i> E.M.Marais	Vulnerable	Habitat loss and degradation
<i>P. quarcitcola</i> Meve and E.M.Marais	Rare	Range-restricted species
<i>P. reflexum</i> (Andrews) Pers.	Endangered	Habitat loss, agriculture and over-grazing
<i>P. riversdalense</i> Knuth	DDTP	Taxonomically problematic
<i>P. rustii</i> R.Knuth	DDTP	Taxonomically problematic
<i>P. sabulosum</i> E.M.Marais	Endangered	Habitat loss, agriculture, coastal development, mining and alien invasive plants
<i>P. salmoneum</i> R.A.Dyer	DDTP	Taxonomically problematic
<i>P. saxatile</i> J.C.Manning and Goldblatt	Critically rare	Localized habitat specialist, occurring in mountainous areas
<i>P. semitriobum</i> Jacq.	DDTP	Taxonomically problematic
<i>P. sibthorpiifolium</i> Harv.	Critically endangered	Habitat loss and degradation, mining and overgrazing
<i>P. suburbanum</i> Clifford ex C.Boucher subsp. <i>Suburbanum</i>	Vulnerable	Habitat loss, degradation and invasive alien species
<i>P. ternifolium</i> Vorster	Near threatened	Habitat loss, agriculture, fire and invasive alien plants
<i>P. tongaense</i> Vorster	Rare	Habitat specialist being degraded by subsistence farming
<i>P. torulosum</i> E.M.Marais	Rare	Range-restricted species
<i>P. tripalmatum</i> E.M.Marais	Critically endangered	Habitat loss, degradation, overgrazing, trampling and soil erosion
<i>P. viciifolium</i> DC.	Endangered	Habitat loss, agriculture, urbanization and alien invasive plants
<i>P. violiflorum</i> (Sweet) DC.	Endangered	Habitat loss and agriculture
<i>P. weberi</i> E.M.Marais	DDII	Poorly known species, threatened by habitat loss and degradation

Table 2: Patents associated with *Pelargonium reniforme*

Year	Patent No.	Details of patent
2003	WP03/0287546A1	Method for producing extracts of <i>Pelargonium sidoides</i> and/or <i>Pelargonium reniforme</i> and the use of said extracts
2006	US20060263448	Use of <i>Pelargonium sidoides</i> and <i>Pelargonium reniforme</i> root extracts
2006	US20070014877	Use of extracts from the <i>Pelargonium</i> species
2007	WO2007009446	Method for extracting plants of the genus <i>Pelargonium</i> , extract produced according to said method and use thereof
2007	EP1429795B1	Method for producing extracts of <i>Pelargonium sidoides</i> and/or <i>Pelargonium reniforme</i>
2008	DE102006032326	Use of extracts from <i>Pelargonium sidoides</i> and/or <i>Pelargonium reniforme</i> for manufacturing preparations and preparations containing these extracts
2009	US7611734B2	Use of extracts from <i>Pelargonium</i> species
2010	US2010/0112096A1	Dry extracts of <i>Pelargonium sidoides</i> and <i>Pelargonium reniforme</i>

Majority of these species (25.7%) are categorized as “data deficient” due to taxonomic problems which hinder accurate determination of habitat and distribution range of the species, followed by vulnerable (17.6%), endangered and rare (16.2% each) (Fig. 2). In South Africa, a threatened species that is categorized as least concern (LC) under the IUCN Red List Categories and Criteria version 3.1 can also be flagged as of conservation concern either as critically rare, rare, declining, data deficient as the taxon is insufficiently known (DDII) or is data deficient as the taxon is taxonomically problematic (DDTP)<sup>1,15</sup> (Fig. 2).

**Medicinal uses of *Pelargonium reniforme*:** The rhizomes of *P. reniforme* are sold as sources of traditional medicine in informal herbal medicine markets in the Eastern Cape Province in South Africa<sup>9,10</sup>. Over the years, there has been a concern that the species will be driven to extinction due to over-collection from the wild as a medicinal plant. The ethnomedicinal value of *P. reniforme* became known to the world when the species mixed with a related species, *P. sidoides* DC was developed into herbal tincture known as umckaloabo®. This herbal product umckaloabo® has been

successfully marketed and used by consumers internationally as a natural medicine to treat coughs, colds and respiratory tract infections<sup>10</sup>. Preparations, extraction and use of *P. reniforme* as a proprietary herbal tincture have been protected by at least seven patents in several countries (Table 2).

The fleshy roots or tubers of *P. reniforme* are used either fresh or dried for at least 15 human ailments or diseases (Table 3). The roots of *P. reniforme* are mixed with those of *Anemone vesicatoria* Prantl (family Ranunculaceae) as a remedy for colds and/or influenza<sup>7,17</sup>. Research by van Wyk and Gorelik<sup>18</sup> showed that the roots of *P. reniforme* are mixed with those of *Arctopus echinatus* L. (family Aliaceae) as traditional medicine for syphilis. The roots of *P. reniforme* are used as ethnoveterinary medicine for diarrhea in cows and goats, heartwater in cattle, liver disorders in cattle and sheep and purging in horses<sup>10,19,20</sup>.

**Phytochemical composition and pharmacological properties of *Pelargonium reniforme*:** The aerial and floral parts and roots of *P. reniforme* contain phenolic acids, phenylpropanoid derivatives, fatty acids, essential oils,

Table 3: Medicinal uses of *Pelargonium reniforme*

Medicinal use	Plant part used	References
<b>Human diseases and ailments</b>		
Anaemia	Tuberous roots	van Wyk and Gorelik <sup>18</sup>
Asthma	Not specified	Brendler and van Wyk <sup>10</sup>
Colds	Roots mixed with those of <i>Anemone vesicatoria</i> Prantl (family Ranunculaceae)	Watt and Breyer-Brandwijk <sup>7</sup> and van Vuuren <i>et al.</i> <sup>17</sup>
Colic	Not specified	Brendler and van Wyk <sup>10</sup>
Cough	Roots	Mativandlela <i>et al.</i> <sup>21</sup>
Diarrhea	Tuberous roots	Watt and Breyer-Brandwijk <sup>7</sup> , Brendler and van Wyk <sup>10</sup> , van Vuuren <i>et al.</i> <sup>17</sup> , van Wyk and Gorelik <sup>18</sup> , Mativandlela <i>et al.</i> <sup>21</sup> , Lattè <i>et al.</i> <sup>22</sup> , Appidi <i>et al.</i> <sup>23</sup> and Adewusi and Afolayan <sup>24</sup>
Dysentery	Tuberous roots	Watt and Breyer-Brandwijk <sup>7</sup> , Brendler and van Wyk <sup>10</sup> , van Vuuren <i>et al.</i> <sup>17</sup> , van Wyk and Gorelik <sup>18</sup> , Lattè <i>et al.</i> <sup>22</sup> , Adewusi and Afolayan <sup>24</sup> and Olajuyigbe and Afolayan <sup>25</sup>
Fever	Tuberous roots	Brendler and van Wyk <sup>10</sup> , van Wyk and Gorelik <sup>18</sup> and Adewusi and Afolayan <sup>24</sup>
Inflammation	Not specified	Brendler and van Wyk <sup>10</sup>
Influenza	Roots mixed with those of <i>A. vesicatoria</i>	Watt and Breyer-Brandwijk <sup>7</sup> and van Vuuren <i>et al.</i> <sup>17</sup>
Liver problems	Roots	Adewusi and Afolayan <sup>24</sup>
Syphilis	Roots mixed with those of <i>Arctopus echinatus</i> L. (family Aliaceae)	van Wyk and Gorelik <sup>18</sup>
Tuberculosis	Roots	Brendler and van Wyk <sup>10</sup> , Mativandlela <i>et al.</i> <sup>21</sup> , Lattè <i>et al.</i> <sup>22</sup> and Adewusi and Afolayan <sup>24</sup>
Weakness	Tuberous roots	van Wyk and Gorelik <sup>18</sup>
Wounds	Aerial parts and leaves	Brendler and van Wyk <sup>10</sup> , Lattè <i>et al.</i> <sup>22</sup> , Kolodziej <sup>26</sup> , Lattè and Kolodziej <sup>27</sup> and Bladt and Wagner <sup>28</sup>
<b>Ethnoveterinary medicine</b>		
Diarrhoea in cows and goats	Roots	Dold and Cocks <sup>19</sup> and McGaw and Eloff <sup>20</sup>
Heartwater in cattle	Roots	Dold and Cocks <sup>19</sup> and McGaw and Eloff <sup>20</sup>
Liver disorders in cattle and sheep	Roots	Brendler and van Wyk <sup>10</sup> , Dold and Cocks <sup>19</sup> and McGaw and Eloff <sup>20</sup>
Purging in horses	Roots	Brendler and van Wyk <sup>10</sup>

coumarins, flavonoids, diterpenes and tannins (Table 4). The pharmacological activities of *P. reniforme* such as antimycobacterial, antibacterial, antifungal and antioxidant activities.

**Antimycobacterial activities:** Seidel and Taylor<sup>36</sup> evaluated the antimycobacterial activities of hexane extracts of *P. reniforme* roots against *Mycobacterium aurum* and *Mycobacterium smegmatis* using the microdilution technique with isoniazid, doxycycline, ethambutol, streptomycin and clarithromycin as positive controls. The extract exhibited activities against the tested pathogens with minimum inhibitory concentration (MIC) values ranging from 64.0 to 512.0 mg/L<sup>36</sup>. Seidel and Taylor<sup>36</sup> evaluated the antimycobacterial activities of the fatty acids, palmitoleic, oleic and linoleic acids isolated from *P. reniforme* roots against *Mycobacterium fortuitum*, *Mycobacterium aurum*, *Mycobacterium abscessus*, *Mycobacterium smegmatis* and *Mycobacterium phlei* using the microdilution technique with isoniazid, doxycycline, ethambutol, streptomycin and clarithromycin as positive controls. The fatty acids demonstrated activities against the tested pathogens with MIC values which ranged from 4.0 to 256.0 mg/L<sup>36</sup>. Similarly,

Mativandlela *et al.*<sup>21</sup> assessed the antimycobacterial activities of chloroform, ethanol and acetone extracts of *P. reniforme* roots against the drug sensitive *Mycobacterium tuberculosis* strain H37Rv using the BACTEC radiometric assay with rifampicin, ethambutol, streptomycin and isoniazid as positive reference drugs. The extracts demonstrated activities at  $5.0 \times 10^3$  mg/L against the tested pathogens<sup>21</sup>. Kim *et al.*<sup>35</sup> evaluated the antimycobacterial activities of the phytochemical compounds gallic acid, 1-O-(2-(4-methoxyphenyl)ethyl)-6-O-galloyl-glucopyranoside, methyl gallate, quercetin 3-O- $\beta$ -D-glucoside and myricetin isolated from *P. reniforme* roots against *Mycobacterium tuberculosis* and *Mycobacterium fortuitum*. The phytochemical compounds exhibited activities against the tested pathogens<sup>35</sup>.

**Antibacterial activities:** Kayser and Kolodziej<sup>34</sup> evaluated the antibacterial activities of aqueous, butanol and ethyl acetate extracts of *P. reniforme* against *Haemophilus influenzae*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Streptococcus pneumoniae*, *Proteus mirabilis*,  $\beta$ -hemolytic *Streptococcus*, *Klebsiella pneumoniae* and *Escherichia coli* using the twofold dilution technique. The extracts exhibited

Table 4: Phytochemical composition of *Pelargonium reniforme*

Chemical compound	Formula	Plant part	References
1-O-Galloylglycerol	C <sub>10</sub> H <sub>12</sub> O <sub>7</sub>	Roots	Latté <i>et al.</i> <sup>29</sup>
2"-O-Galloylisovitexin	C <sub>28</sub> H <sub>24</sub> O <sub>14</sub>	Aerial parts	Latté <i>et al.</i> <sup>30</sup>
2"-O-Galloylorientin	C <sub>28</sub> H <sub>24</sub> O <sub>15</sub>	Aerial parts	Latté <i>et al.</i> <sup>30</sup>
4,6-Dihydroxyacetophenone-2-O-β-glucoside	C <sub>14</sub> H <sub>16</sub> O <sub>9</sub>	Roots	Latté <i>et al.</i> <sup>30</sup>
5,6-Dihydroxy-7-methoxycoumarin	C <sub>11</sub> H <sub>10</sub> O <sub>8</sub>	Roots	Latté <i>et al.</i> <sup>31</sup>
6-Hydroxy-5,7-dimethoxycoumarin	C <sub>11</sub> H <sub>10</sub> O <sub>9</sub>	Roots	Latté <i>et al.</i> <sup>31</sup>
6,7,8-Trihydroxycoumarin	C <sub>9</sub> H <sub>6</sub> O <sub>5</sub>	Roots	Latté <i>et al.</i> <sup>31</sup>
6'-O-Galloylsalidoside	C <sub>21</sub> H <sub>24</sub> O <sub>11</sub>	Roots	Latté <i>et al.</i> <sup>29</sup>
6-Hydroxy-5,7-dimethoxycoumarin	C <sub>11</sub> H <sub>10</sub> O <sub>5</sub>	Roots	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
7-Hydroxy-6-methoxycoumarin	C <sub>10</sub> H <sub>8</sub> O <sub>4</sub>	Roots	Latté <i>et al.</i> <sup>31</sup>
8-Hydroxy-6,7-dimethoxycoumarin	C <sub>11</sub> H <sub>10</sub> O <sub>5</sub>	Roots	Latté <i>et al.</i> <sup>31</sup>
8-Hydroxy-5,6,7-trimethoxycoumarin	C <sub>12</sub> H <sub>12</sub> O <sub>6</sub>	Roots	Latté <i>et al.</i> <sup>31</sup>
(α, β)-3,4-Di-O-galloylglucopyranoside	C <sub>20</sub> H <sub>20</sub> O <sub>14</sub>	Roots	Latté <i>et al.</i> <sup>31</sup>
Afzelechin	C <sub>15</sub> H <sub>14</sub> O <sub>5</sub>	Roots	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Brevifolincarboxylic acid	C <sub>13</sub> H <sub>8</sub> O <sub>8</sub>	Aerial parts and roots	Latté and Kolodziej <sup>27</sup> and Latté and Kolodziej <sup>33</sup>
δ-cadinene	C <sub>15</sub> H <sub>24</sub>	Leaves	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Caffeic acid	C <sub>9</sub> H <sub>8</sub> O <sub>4</sub>	Roots	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Catechin	C <sub>15</sub> H <sub>14</sub> O <sub>6</sub>	Roots	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Corilagin	C <sub>27</sub> H <sub>22</sub> O <sub>18</sub>	Aerial parts and roots	Latté and Kolodziej <sup>27</sup> and Latté and Kolodziej <sup>33</sup>
p-coumaroyl-4-O-β-D-glucoside	C <sub>15</sub> H <sub>18</sub> O <sub>8</sub>	Aerial parts	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
(+)-Dihydrokaempferol	C <sub>15</sub> H <sub>12</sub> O <sub>6</sub>	Floral parts	Latté <i>et al.</i> <sup>30</sup>
Ferulic acid	C <sub>10</sub> H <sub>10</sub> O <sub>4</sub>	Roots	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Gallic acid	C <sub>7</sub> H <sub>6</sub> O <sub>5</sub>	Roots	Latté and Kolodziej <sup>33</sup> , Kayser and Kolodziej <sup>34</sup> and Kim <i>et al.</i> <sup>35</sup>
Gallic acid butyl ester	C <sub>11</sub> H <sub>14</sub> O <sub>5</sub>	Aerial parts	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Gallic acid ethyl ester	C <sub>9</sub> H <sub>10</sub> O <sub>5</sub>	Aerial parts	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Gallic acid methyl ester	C <sub>8</sub> H <sub>8</sub> O <sub>5</sub>	Roots	Kayser and Kolodziej <sup>34</sup>
Gallocatechin	C <sub>15</sub> H <sub>14</sub> O <sub>7</sub>	Roots	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Glucogallin	C <sub>13</sub> H <sub>16</sub> O <sub>10</sub>	Roots	Latté and Kolodziej <sup>33</sup>
Glycerol-1-gallate	C <sub>10</sub> H <sub>12</sub> O <sub>7</sub>	Aerial parts	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Heptadecanoic acid	C <sub>17</sub> H <sub>34</sub> O <sub>2</sub>	Roots	Seidel and Taylor <sup>36</sup>
p-Hydroxyphenyl acetic acid	C <sub>8</sub> H <sub>8</sub> O <sub>3</sub>	Aerial parts	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
p-Hydroxybenzyl alcohol	C <sub>7</sub> H <sub>8</sub> O <sub>2</sub>	Aerial parts	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
p-Hydroxyphenyl ethanol	C <sub>8</sub> H <sub>10</sub> O <sub>2</sub>	Aerial parts	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
(+)-isolariciresinol 9'-O-β-glucopyranoside	C <sub>26</sub> H <sub>34</sub> O <sub>11</sub>	Roots	Latté <i>et al.</i> <sup>29</sup>
Isocorilagin	C <sub>27</sub> H <sub>22</sub> O <sub>18</sub>	Aerial parts	Latté and Kolodziej <sup>27</sup>
Isofraxoside	C <sub>16</sub> H <sub>18</sub> O <sub>10</sub>	Roots	Viljoen <i>et al.</i> <sup>37</sup>
Isorientin	C <sub>21</sub> H <sub>20</sub> O <sub>11</sub>	Aerial, floral parts and roots	Latté <i>et al.</i> <sup>30</sup> and Latté and Kolodziej <sup>33</sup>
Isorientin 2"-O-gallate	C <sub>28</sub> H <sub>24</sub> O <sub>15</sub>	Aerial parts	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Isoquercitrin	C <sub>21</sub> H <sub>20</sub> O <sub>12</sub>	Roots	Latté and Kolodziej <sup>33</sup>
Isostrictinin	C <sub>27</sub> H <sub>22</sub> O <sub>18</sub>	Aerial parts	Latté and Kolodziej <sup>27</sup>
Isovitexin	C <sub>21</sub> H <sub>20</sub> O <sub>10</sub>	Aerial parts and roots	Latté <i>et al.</i> <sup>30</sup> and Latté and Kolodziej <sup>33</sup>
Isovitexin 2"-gallate	C <sub>28</sub> H <sub>24</sub> O <sub>14</sub>	Roots	Latté and Kolodziej <sup>33</sup>
Kaempferol 3-O-β-D-galactoside	C <sub>21</sub> H <sub>20</sub> O <sub>11</sub>	Roots	Latté <i>et al.</i> <sup>30</sup>
Kaempferol 3-O-β-D-glucoside	C <sub>21</sub> H <sub>20</sub> O <sub>11</sub>	Roots	Latté <i>et al.</i> <sup>30</sup>
Kaempferol 7-O-β-D-glucoside	C <sub>21</sub> H <sub>20</sub> O <sub>11</sub>	Aerial and floral parts	Latté <i>et al.</i> <sup>30</sup>
Kaempferol 3-O-β-rutinoside	C <sub>27</sub> H <sub>30</sub> O <sub>15</sub>	Floral parts	Latté <i>et al.</i> <sup>30</sup>
Linoleic acid	C <sub>18</sub> H <sub>32</sub> O <sub>2</sub>	Roots	Seidel and Taylor <sup>36</sup>
Luteolin 7-O-β-D-glucoside	C <sub>21</sub> H <sub>20</sub> O <sub>11</sub>	Aerial parts	Latté <i>et al.</i> <sup>30</sup>
Methyl gallate	C <sub>8</sub> H <sub>8</sub> O <sub>5</sub>	Roots	Latté and Kolodziej <sup>33</sup> and Kim <i>et al.</i> <sup>35</sup>
Myricetin	C <sub>15</sub> H <sub>10</sub> O <sub>8</sub>	Roots	Kim <i>et al.</i> <sup>35</sup>
Myricetin 3-O-β-D-glucoside	C <sub>21</sub> H <sub>20</sub> O <sub>13</sub>	Roots	Latté <i>et al.</i> <sup>30</sup>
Naringenin 7-O-β-D-glucoside	C <sub>21</sub> H <sub>22</sub> O <sub>10</sub>	Aerial and floral parts	Latté <i>et al.</i> <sup>30</sup>
n-butyl gallate	C <sub>11</sub> H <sub>14</sub> O <sub>5</sub>	Aerial parts	Latté <i>et al.</i> <sup>29</sup>
Nonadecanoic acid	C <sub>19</sub> H <sub>38</sub> O <sub>2</sub>	Roots	Seidel and Taylor <sup>36</sup>
Octadecanoic acid	C <sub>18</sub> H <sub>36</sub> O <sub>2</sub>	Roots	Seidel and Taylor <sup>36</sup>
Oleic acid	C <sub>18</sub> H <sub>34</sub> O <sub>2</sub>	Roots	Seidel and Taylor <sup>36</sup>
Orientin	C <sub>21</sub> H <sub>20</sub> O <sub>11</sub>	Aerial parts and roots	Latté <i>et al.</i> <sup>30</sup> and Latté and Kolodziej <sup>33</sup>
Orientin 2"-gallate	C <sub>28</sub> H <sub>24</sub> O <sub>15</sub>	Roots	Latté and Kolodziej <sup>33</sup>
p-coumaric acid	C <sub>9</sub> H <sub>8</sub> O <sub>3</sub>	Roots	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
p-coumaraldehyde	C <sub>9</sub> H <sub>8</sub> O <sub>2</sub>	Roots	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>

Table 4: Continue

Chemical compound	Formula	Plant part	References
p-hydroxybenzoic acid	C <sub>7</sub> H <sub>6</sub> O <sub>3</sub>	Roots	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Palmitoleic acid	C <sub>16</sub> H <sub>30</sub> O <sub>2</sub>	Roots	Seidel and Taylor <sup>36</sup>
Pelargoniin A	C <sub>40</sub> H <sub>30</sub> O <sub>26</sub>	Aerial parts	Latté and Kolodziej <sup>27</sup>
Pelargoniin B	C <sub>26</sub> H <sub>22</sub> O <sub>18</sub>	Aerial parts	Latté and Kolodziej <sup>27</sup>
Pelargoniin C	C <sub>26</sub> H <sub>24</sub> O <sub>18</sub>	Aerial parts	Latté and Kolodziej <sup>27</sup>
Pelargoniin D	C <sub>27</sub> H <sub>24</sub> O <sub>19</sub>	Aerial parts	Latté and Kolodziej <sup>27</sup>
Pelargoniin E	C <sub>40</sub> H <sub>28</sub> O <sub>26</sub>	Aerial parts	Latté <i>et al.</i> <sup>29</sup>
Pentadecanoic acid	C <sub>15</sub> H <sub>30</sub> O <sub>2</sub>	Roots	Seidel and Taylor <sup>36</sup>
Phyllanthusiin C	C <sub>40</sub> H <sub>30</sub> O <sub>26</sub>	Aerial parts and roots	Latté and Kolodziej <sup>27</sup> and Latté and Kolodziej <sup>33</sup>
Phyllanthusiin E	C <sub>13</sub> H <sub>8</sub> O <sub>8</sub>	Aerial parts	Latté and Kolodziej <sup>27</sup>
Phyllanthusiin E methyl ester	C <sub>14</sub> H <sub>10</sub> O <sub>8</sub>	Aerial parts	Latté and Kolodziej <sup>27</sup>
Protocatechuic acid	C <sub>7</sub> H <sub>6</sub> O <sub>4</sub>	Roots	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Quercetin	C <sub>15</sub> H <sub>10</sub> O <sub>7</sub>	Roots	Latté and Kolodziej <sup>33</sup>
Quercetin 3-O-β-D-glucoside	C <sub>21</sub> H <sub>20</sub> O <sub>12</sub>	Roots	Latté <i>et al.</i> <sup>30</sup> and Kim <i>et al.</i> <sup>35</sup>
Quercetin 7-O-β-D-glucoside	C <sub>21</sub> H <sub>20</sub> O <sub>12</sub>	Aerial and floral parts	Latté <i>et al.</i> <sup>30</sup>
Reniformin	C <sub>28</sub> H <sub>40</sub> O <sub>6</sub> S	Roots	Mativandlela <i>et al.</i> <sup>21</sup> and Latté <i>et al.</i> <sup>29</sup>
Rutin	C <sub>27</sub> H <sub>30</sub> O <sub>16</sub>	Aerial, floral parts and roots	Latté <i>et al.</i> <sup>30</sup> and Latté and Kolodziej <sup>33</sup>
Salidroside-6"-O-gallate	C <sub>21</sub> H <sub>24</sub> O <sub>11</sub>	Aerial parts	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Scopoletin	C <sub>10</sub> H <sub>8</sub> O <sub>4</sub>	Roots	Viljoen <i>et al.</i> <sup>37</sup>
Scopoletin isomer	C <sub>10</sub> H <sub>8</sub> O <sub>4</sub>	Roots	Viljoen <i>et al.</i> <sup>37</sup>
δ-selinene	C <sub>15</sub> H <sub>24</sub>	Leaves	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Shikimic acid 3-O-gallate	C <sub>14</sub> H <sub>14</sub> O <sub>9</sub>	Roots	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Shikimic acid 3,5-di-O-gallate	C <sub>21</sub> H <sub>18</sub> O <sub>13</sub>	Aerial parts	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
β-sitosterol	C <sub>29</sub> H <sub>50</sub> O	Roots	Kolodziej <sup>26</sup> , Kolodziej <sup>32</sup> and Kayser <i>et al.</i> <sup>38</sup>
β-sitosterol-3-O-β-D-glucoside	C <sub>35</sub> H <sub>60</sub> O <sub>6</sub>	Roots	Kolodziej <sup>26</sup> , Kolodziej <sup>32</sup> and Kayser <i>et al.</i> <sup>38</sup>
Sterculic acid	C <sub>19</sub> H <sub>36</sub> O <sub>2</sub>	Roots	Seidel and Taylor <sup>36</sup>
Strictinin	C <sub>27</sub> H <sub>22</sub> O <sub>18</sub>	Aerial parts	Latté and Kolodziej <sup>27</sup>
(+)-Taxifolin	C <sub>15</sub> H <sub>12</sub> O <sub>7</sub>	Aerial and floral parts	Latté <i>et al.</i> <sup>30</sup>
Taxifolin 7-O-β-D-glucopyranoside	C <sub>21</sub> H <sub>22</sub> O <sub>12</sub>	Floral parts	Latté <i>et al.</i> <sup>30</sup>
Tetradecanoic acid	C <sub>14</sub> H <sub>28</sub> O <sub>2</sub>	Roots	Seidel and Taylor <sup>36</sup>
Umckalin	C <sub>11</sub> H <sub>10</sub> O <sub>5</sub>	Roots	Viljoen <i>et al.</i> <sup>37</sup>
Vanillic acid	C <sub>8</sub> H <sub>8</sub> O <sub>4</sub>	Roots	Kolodziej <sup>26</sup> and Kolodziej <sup>32</sup>
Vitexin	C <sub>21</sub> H <sub>20</sub> O <sub>10</sub>	Aerial parts and roots	Latté <i>et al.</i> <sup>30</sup> and Latté and Kolodziej <sup>33</sup>
Vitexin 2"-gallate	C <sub>28</sub> H <sub>24</sub> O <sub>14</sub>	Roots	Latté and Kolodziej <sup>33</sup>

activities against the tested pathogens with MIC values ranging from 0.6 to 7.5 mg/mL<sup>34</sup>. Kayser and Kolodziej<sup>34</sup> also evaluated the antibacterial activities of the phytochemical compounds gallic acid and gallic acid methyl ester isolated from the roots of *P. reniforme* against *Haemophilus influenzae*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Streptococcus pneumoniae*, *Proteus mirabilis*, β-hemolytic *Streptococcus*, *Klebsiella pneumoniae* and *Escherichia coli* using the twofold dilution technique with penicillin G and erythromycin as positive controls. The phytochemical compounds exhibited activities against the tested pathogens with MIC values ranging from 250.0 to 2000.0 µg/mL<sup>34</sup>. Mativandlela *et al.*<sup>21</sup> evaluated the antibacterial activities of acetone, ethanol and chloroform extracts of *P. reniforme* roots against *Haemophilus influenzae*, *Streptococcus pneumoniae* and *Moraxella catarrhalis* using the agar dilution assay. The extracts exhibited activities at 5.0 × 10<sup>3</sup> mg/L against the tested pathogen<sup>21</sup>.

**Antifungal activities:** Mativandlela *et al.*<sup>21</sup> evaluated the antifungal activities of acetone, ethanol and chloroform

extracts of *P. reniforme* roots against *Aspergillus niger*, *Rhizopus stolonifer* and *Fusarium oxysporum* using the agar dilution assay with amphotericin B as positive control. The extracts exhibited activities at 5.0 × 10<sup>3</sup> mg/L against the tested pathogens<sup>21</sup>.

**Antioxidant activities:** Latté and Kolodziej<sup>33</sup> evaluated the antioxidant activities of the flavonoids and tannins isolated from *P. reniforme* roots using a luminol-dependent chemiluminescence and 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging assays with ascorbic acid as positive control. The phytochemical compounds exhibited activities in both assays with half Maximal Inhibitory Concentration (IC<sub>50</sub>) values ranging from 2.6 µM to 202.3 Mm<sup>33</sup>. Adewusi and Afolayan<sup>24</sup> evaluated the antioxidant activities of aqueous extracts of *P. reniforme* roots using the DPPH and 2,2-azinobis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS+) free radical scavenging assays with butylated hydroxytoluene (BHT), vitamin C and rutin as positive controls. The extract exhibited antioxidant activities in both assays<sup>24</sup>.

## CONCLUSION

The present review summarizes the botany, medicinal uses, phytochemical and pharmacological properties and sustainable use of *P. reniforme*. As the active ingredients of *P. reniforme* vary depending on the plant parts and origin of the specimen, phytochemical profiling protocols of the species should be standardized. *Pelargonium reniforme* is threatened due to over-collection for local use in traditional medicine. The species is also harvested in large volumes for commercial production of herbal tincture umckaloabo®, which is marketed and used by consumers internationally as a natural medicine to treat coughs, colds and respiratory tract infections. The population of *P. reniforme* is declining in its natural habitat since the species is a slow-growing geophyte and also several months are required for the species to recover from repeated harvesting. There is, therefore, a need for the cultivation of this threatened medicinal plant to stabilize and strengthen the existing herbal medicine market. Other conservation strategies include the use of leaves and aerial parts as sources of traditional medicines instead of the tuberous roots, especially if these organs have similar phytochemical and pharmacological properties.

## SIGNIFICANCE STATEMENT

This study contributes to the existing knowledge about the morphological characteristics, medicinal uses, phytochemical and pharmacological properties and sustainable use of *P. reniforme* as a medicinal plant and also for commercial production of a herbal tincture umckaloabo®, which is marketed and used by consumers internationally as a natural medicine to treat coughs, colds and respiratory tract infections. Since *P. reniforme* is categorized as Near Threatened, this calls for strict regulations on collecting the species as a source of traditional medicines. Future research should focus on validating the medicinal uses of *P. reniforme* through elucidation of its chemical composition, pharmacological properties, toxicological evaluations, *in vivo* and clinical research.

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