Medicinal plants of Lesotho: A review of ethnomedicinal, pharmacological and conservation studies

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Review

Abstract

Background: Of the approximately 2,076 plant species occurring in Lesotho, about 355 are used for medicinal purposes. Many communities in the country, mainly in rural areas with limited access to health facilities, rely on traditional medicine as primary healthcare. Several publications provide helpful information on plants used for medicinal purposes in Lesotho. These include documentation of the plants, investigation of their therapeutic potential to provide scientific validation for their use, and conservation status. However, a synthesis of all the studies conducted so far has hitherto not been undertaken. The current study aimed to provide a systematic review of ethnomedicinal, pharmacological, and conservation studies undertaken on medicinal plants of Lesotho. The synthesis brings together published and unpublished literature sources, thus providing a comprehensive database for studies conducted on Lesotho medicinal plants. Furthermore, it identifies existing knowledge gaps on research that has been carried out on the species and thus provides opportunities for further research, especially in the search for new natural products.

Methods: Information was gathered from published and unpublished literature sources, with the earliest publication dating back to 1917. Information was gathered through keyword search using accessible literature sources from Google Scholar, Science Direct, Scopus and PubMed. Books, dissertations, theses, technical reports were also searched. Keywords used for the search were Lesotho, in conjunction with medicinal plant and traditional medicine. To be eligible for inclusion in the current review, a literature source was expected to have assessed ethnomedicinal use, biological/pharmacological activity (e.g., antimicrobial activity), phytochemistry, toxicology) or conservation status of any Lesotho plant species used in traditional medicine.

Results: A total of 116 records were identified, of which 76 were included in the review. Thirty-one ethnomedicinal, 14 pharmacological (nine antioxidant, three anti-inflammatory, five antimicrobial activities), six phytochemical, and 15 conservation studies on medicinal plants of Lesotho were scrutinized. It is important to note that some studies evaluated more than one pharmacological activity. Ethnomedicinal studies show that numerous plants are used for medicinal purposes in Lesotho, however studies to scientifically validate their traditional use has remained far behind.

Conclusion: Many of Lesotho's important medicinal plants have been assessed for pharmacological activity, providing scientific proof for their use. However, there are numerous gaps in the number and type of pharmacological and phytochemical studies that have been conducted. These gaps offer endless opportunities for researchers working in these fields. In addition, the conservation status for most of these plants is unknown., therefore, a detailed red data listing of Lesotho plants, particularly those used in traditional medicine, is recommended.

Keywords: ailments; ethnomedicine; safety; traditional medicine, treatment toxicology

Background

A preliminary checklist of the flora of Lesotho has recorded 2,076 species belonging to 674 genera and 172 families (Kobisi 2005), based on records at the National University of Lesotho (NUL) herbarium (ROML). About 355 of these species are used for medicinal purposes (Moteetee & Van Wyk 2011). Indeed, like other developing countries, medicinal plants have been used for centuries in Lesotho (Letšela *et al.* 2002) and continue to be a source of primary healthcare for many people in the country (Moteetee et al., 2019). This is particularly true since healthcare facilities are far from most rural communities, while medicinal plants are readily available and more affordable than modern healthcare. Several publications have provided helpful information on the medicinal uses of various plants found in Lesotho. These include the pioneering work of Phillips (1917), and subsequent studies by Jacot Guillarmod (1971), Schmitz (1982), Maliehe (1997, although medicinal plants were not the main focus of these publications. In addition, broad-based studies that covered parts of Lesotho exist, and these include Watt and Breyer-Brandwijk (1962), Moffett (2010), Van Wyk *et al.* (1997), Van Wyk *et al.* (2009). More recent comprehensive studies documenting medicinal plants of Lesotho are Moteetee and Van Wyk (2011), as well as Moteetee *et al.* (2019). The former recorded 355 medicinal plants used in Lesotho, whereas the latter recorded 437 species utilized for all kinds of medical conditions by Basotho residing in both Lesotho and the Free State Province of South Africa.

On the other hand, several studies have been undertaken to investigate the efficacy of some of the medicinal plants used in Lesotho as a step towards the provision of scientific validation. These studies include investigations of the antimicrobial activity, e.g., Mekbib (2016), and Seleteng-Kose *et al.* (2019) anti-inflammatory, e.g., Shale *et al.*(1999), Shale *et al.* (2004), Kena and Lepheana (2016), as well as antioxidant activity, e.g., Magama *et al.* (2013), Asita *et al.*(2015), as well as phytochemistry, e.g., Qhotsokoane-Lusunzi and Karuso (2001), Mugomeri *et al.* (2014) and toxicity, e.g. Seleteng-Kose *et al.* (2019). Despite many research activities on Lesotho plants used for medicinal purposes, a comprehensive synthesis of such studies has hitherto not been published. The profiling of studies on medicinal plants has been carried out in various countries. For example, Maroyi (2013) reviewed the traditional use of medicinal plants in south-central Zimbabwe. In contrast, Van Vuuren (2008) examined the antimicrobial activity of South African medicinal plants, and Van Wyk (2008) presented a broad review of commercially important southern African medicinal plants. An attempt to provide a synthesis of studies on medicinal plants used in Lesotho was made by Motjotji (2014), however, the study has not been published. Moreover, it summarised a limited number of studies, mainly focusing on the medicinal plant trade in Lesotho. Therefore, the current study aims to provide a comprehensive review of ethnomedicinal, pharmacological (biological and phytochemical) and conservation studies undertaken on medicinal plants of Lesotho to date. The synthesis brings together published and unpublished literature sources, thus providing a comprehensive database for studies conducted on Lesotho medicinal plants. Furthermore, it identifies existing knowledge gaps on research that has been carried out on the species and thus provides opportunities for further research, especially in the search for new natural products.

Materials and Methods

The paper reviews research studies undertaken on Lesotho medicinal plants during 1917-2021, even though significant research activities were observed mainly in the last eleven years. These include ethnomedicinal, pharmacological (antimicrobial activity, anti-inflammatory, phytochemistry, and toxicity), and conservation studies. Information was gathered from literature sources, including published journal articles, scientific reports, dissertations, books, and unpublished sources. To be eligible for inclusion in the current review, a literature source was expected to have assessed ethnomedicinal use, biological/pharmacological activity (e.g., antimicrobial activity), phytochemistry, toxicology, or conservation status of any Lesotho plant species used in traditional medicine., as shown in the PRISMA flow diagram (Figure 1). In addition, different databases such as Google Scholar, Science Direct and Pubmed were searched for published articles using the search terms conservation status, ethnobotany, ethnomedicine, medicinal plants, biological activity, toxicity, coupled with the country name Lesotho. It is important to note that since Lesotho is surrounded by the Republic of South Africa, it shares a substantial number of common medicinal plants. Therefore, some of the broad-based pharmacological studies conducted on South African flora

have covered some of the medicinal plants in Lesotho. However, the current study's primary focus is on Lesotho-specific medicinal plants.

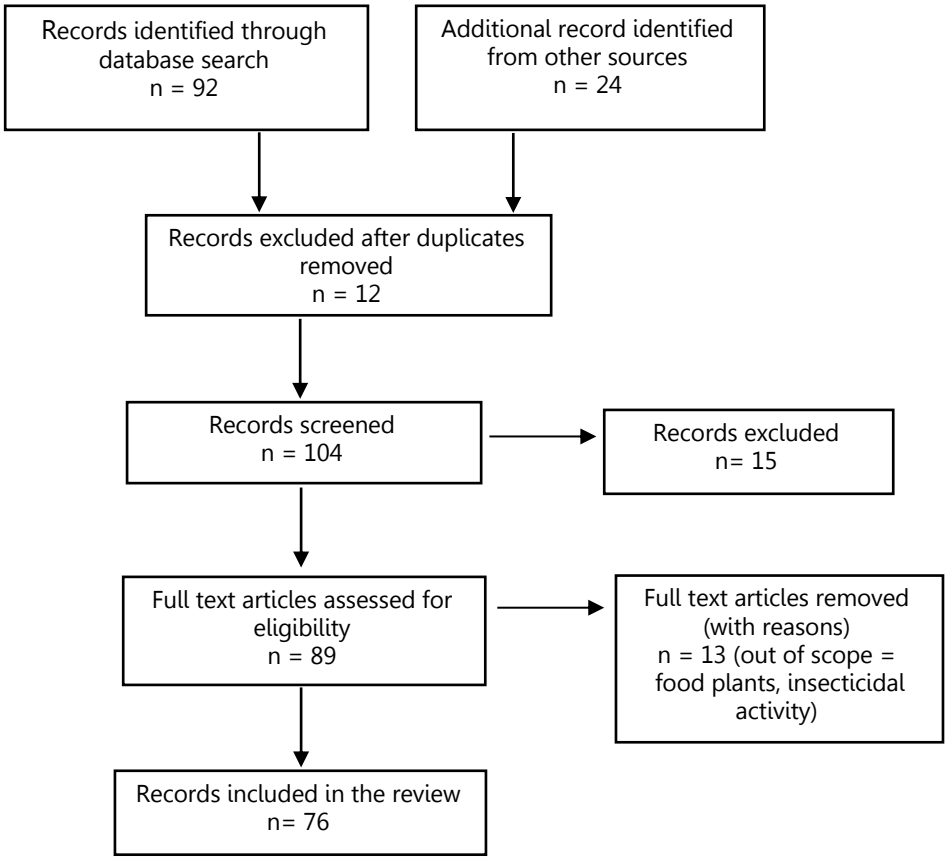

Figure 1. PRISMA flow chart: identification and screening of records for the review

Results and Discussion

Ethnomedicinal studies

A publication by Phillips (1917) pioneered ethnomedicinal studies in Lesotho by documenting the flora of Leribe (one of the ten districts of Lesotho) and the surrounding areas. The publication listed a total of 782 species (representing 348 families), and in some cases, described their ethnobotany which includes medicinal uses. The information was sourced from physical surveys by the author and from Madame Dieterlen's plant collection, which she had collected during her 19-year residency in the Leribe district. Later, Jacot Guillarmod (1971) gave an account of the essential plants known in Lesotho at the time, with a record of 1,537 plant species (representing 95 families and 526 genera). About 600 of these plants were reportedly used for medicinal purposes in the country. After that, Schmitz (1982) gave a detailed description of about 300 flowering plants recorded in Lesotho and their therapeutic use. A publication by Zepp (1982) documented about 50 ferns and fern allies occurring in the country, including an account of their medicinal uses. The list was updated by Cooper-Driver *et al.* (2008) through a physical survey of ferns in the country and documenting 56 fern species, including their medicinal uses. Unpublished research by Ramohlabi (1989) discussed ten plant species reputed to be important medicinally in Lesotho. These are *Artemisia afra* Jacq. ex Wild*, Aloe striatula* Haw. var. *striatula* [now *Aloiampelos striatula* (Haw.) Klopper & Gideon F.Sm)], *Boophane disticha* Herb., *Cotyledon orbiculata* L., *Dicoma anomala* Sond.*, Gunnera perpensa* L., *Mentha longifolia* (L.) Huds., *Pentanisia prunelloides* Walp., *Pollichia campenstris* Aiton and *Tephrosa semiglabra* Sond. A Food Agricultural Organization (FAO) country-wide study (FAO, 1996) provided a list of the topmost preferred indigenous trees and shrubs used for various purposes in Lesotho. Some of these species are used for medicinal purposes, for example, *Euclea coriacea* A.DC, *Rhamnus prinoides* L'Her. and *Cussonia paniculata* Eckl. & Zeyh. Maliehe (1997) documented 60 medicinal plant species commonly used in the country based on his experience as a traditional healer. The publication also recorded therapeutic uses of these species and the parts used, as well as their habitats.

A publication by Shale *et al.* (1999) documented 23 medicinal plants used for inflammations and bacterial infections, with data derived from interviewing traditional healers and herbalists from the Mohale's Hoek and Qacha's Nek Districts, Lesotho. A study by Letšela *et al.* (2003) made an inventory of communal biological resources in and around the Tšehlanyane National Park and Bokong Nature Reserve. Thirty-eight of the recorded species were of medicinal value. The inventory was compiled by undertaking a household survey (149 households were sampled, representing a sampling intensity of 19% in both communities).

Unpublished reports by the then National Environment Secretariat (NES, now the Department of Environment) (2005, 2007) documented invasive alien species occurring in the country based on physical surveys. Of the 31 invasive alien species documented (NES, 2005), only two species, *Datura ferox* L. and *Argemone ochroleuca* Sweet are used for medicinal purposes. A more comprehensive evaluation produced two years later by the National Environment Secretariat (2007), listed 54 invasive alien species, five of which are medicinally important. These include *Phytolacca octandra* L., *Ricinus communis* L., and *Foeniculum vulgare* Mill.

Based on physical surveys, Wybenga (2006) documented 28 wildflower species of Lesotho's Tšehlanyane National Park. Of these, only two were reported for medicinal use, namely, *Alepidea amatymbica* Eckl. & Zeyh. and *Gunnera perpensa*. Later, Moteetee and Van Wyk (2007) discussed the identity and uses of 20 species known as '*Musa-pelo* (translating into bringing back health to the heart) in Lesotho. Plants regarded as '*Musa-pelo* belong to different genera, mainly in the family Fabaceae, and they include *Argyrolobium collimum* Eckl. & Zeyh., *Lessertia depressa* Harv., *Sutherlandia montana* E. Phillips & R.A. Dyer, *Tephrosia capensis* (Jacq.) Pers., *Trifolium burchellianum* Ser. These plants treat fits, circulation problems, stress-related ailments and chronic illnesses, and trauma and sedative to bereaved people under severe psychological duress or stress. The past few years have seen an increase in the number of studies documenting the ethnomedicinal uses of plants occurring in Lesotho, either in the form of literature reviews, own experience, or field surveys based on questionnaires (Moteetee *et al.* 2019). An extensive review of the medical ethnobotany of Lesotho (Moteetee & Van Wyk 2011) compiled a checklist of 355 medicinally important plant species used by Basotho traditional healthcare practitioners. Among the best known and most frequently used medicinal plants recorded were *Artemisia afra* Jacq. ex Willd., *Bulbine narcissifolia* Salm-Dyck, *Dicoma anomala* Sond., *Dianthus basuticus* Burtt Davy, *Helichrysum caespititium* (DC.) Harv., *Mentha longifolia* L. and *Pentanisia prunelloides*. The study also reviewed traditional healing in Lesotho based on literature and the recollections of the authors. An unpublished study by Lebamang *et al.* (2013) recorded 10 medicinal plant species commonly traded in the markets of three districts in Lesotho, namely, Leribe, Mohale's Hoek and Quthing. The study correlates with Moteetee & Van Wyk (2011) in that four species, namely, *Bulbine narcissifolia, Dianthus basuticus, Dicoma anomala* and *Helichrysum caespititum,* were also listed as the most frequently used medicinal plants in Lesotho.

Possa *et al.* (2015) recorded a total of 39 species (including those used for medicinal purposes) with idiomatic names expressing certain philosophies of the Basotho society. The names of Sesotho medicinal plants and the etiology behind the name and the use of each medicinal plant were discussed with information derived from interviewing traditional practitioners and general members of the society. The publication by Department of Environment (2014) gives an overview of nine plant species of socio-economic importance in the country: *Alepidea amatymbica, Aloe polyphylla* Schonl. ex Pillans, *Aloe ferox, Dicoma anomala, Hypoxis hemerocallidea* Fisch.Mey. & Ave-Lall., *Pelargonium sidoides* DC., *Merxmuellera macowanii* (Stapf) Conert, *Phytolacca heptandra* Retz. and *Urginea capitata* (Hook.) Baker. All the species are used for medicinal purposes, except for *A. polyphylla*, which is Lesotho's national plant.

A study by Seleteng-Kose *et al.* (2015) identified 38 ailments commonly treated via Lesotho's traditional medicine, a majority of which were found to fall under reproductive, respiratory, degenerative, and digestive ailments (listed in order of prevalence). The information was derived from interviewing traditional practitioners from urban and rural areas of the Maseru District. The study recorded a total of 80 medicinal plants from 44 families, with the Asteraceae having the highest number of species (16), followed by Fabaceae, Asphodelaceae and Poaceae (with four species each). The most frequently mentioned medicinal plants ranking in the top 10 included *Elephantorrhiza elephantina* (Burch.) Skeels, *Pentanisia prunelloides, Hypoxis hemerocallidea, Eriocephalus tenuifolius* DC., and *Salvia stenophylla* Burch. ex Benth. Later, Mugomeri *et al.* (2016a) recorded 54 medicinal species representing 46 genera and 29 plant families. Asteraceae and Asphodelaceae were the most represented families. The study was aimed at establishing a repository and monograph for the herbal medicines in Lesotho. Information was gathered by interviewing 78 local herbalists from four districts (Leribe, Berea, Maseru, and Mafeteng), 84% of whom were men, indicating that the practice of traditional medicine in Lesotho is dominated by males. Another study by

Mugomeri *et al.* (2016b) used questionnaires to explore medicinal herbs used by HIV-positive people in Lesotho and the reasons for their use. The study documented 20 species belonging to 16 families being used in the treatment of HIV related ailments. It was revealed that about 70% of HIV-positive informants were using medicinal herbs for various reasons, such as boosting the immune system and treating gastrointestinal ailments.

A study by Maliehe (2016) investigated traditional healing in Lesotho based on the author's experience as a traditional healer for about 37 years, as well as using ethnography, documentaries, and interviews. The study documented Shamanism in Lesotho, detailing the steps to become a healer and the medicinal plants used to perform associated rituals. The study discussed 51 medicinal plants used in different healing practices in Lesotho. These include *Alepidea amatymbica, Boophane disticha, Buddleja salviifolia* (L.) Lam., *Clematis brachiata* Thunb., *Dicoma anomala, Dianthus basuticus, Eucomis autumnalis*, *Elephantorrhiza elephantina* (Burch.) Skeels, *Hypoxis hemerocallidea, Helichrysum odoratissimum* (L.) Sweet, *Melolobium candicans* (E.Mey.) Eckl. & Zeyh., *Scabiosa columbaria* L. and *Xysmalobium undulatum* (L.) Aiton f.

Moteetee and Seleteng-Kose (2017) documented species used to treat reproductive ailments in Lesotho. The study was based on a previous survey of Seleteng-Kose *et al.* (2015), and the authors' own experiences and observations gathered while growing up in Lesotho. A total of 87 plant species were reported to be used for the treatment of several reproductive problems such as infertility, cleansing and/or toning of the uterus, as well as complications associated with pregnancy, difficult childbirth, treatment of breast and cervical cancer, cysts, fibroids, and testicular tumors. The highest number of species (31) was reported to treat infertility in men and women. The use of medicinal plants during pregnancy is prevalent in Lesotho as indicated by Chatanga *et al.* (2015) who identified the reasons and promoters of medicinal herb usage during pregnancy. This information was obtained from pregnant women who attended antenatal care at one referral district hospital in the Maseru district between March and April 2014. About 47% of the women conceded to using herbs during pregnancy, mainly due to tradition, prevention of placenta previa, as well as for leucorrhea of pregnancy, prevention of abortion and promoting fetal growth. Grandmothers, traditional healers, mothers-in-law, and traditional birth attendants were cited as the significant promoters and providers of traditional herbs.

Moteetee and Seleteng-Kose (2019) recorded a total of 57 plant species utilized for the treatment of various skin ailments, with many of them used for wounds (26 species) and venereal sores (19 species). The plants are distributed in 39 families, with the Asteraceae being the most represented, with seven species, followed by Solanaceae and Asphodelaceae with four species each. Information was sourced from literature and the second author's first-hand experiences while growing up in the rural areas of Lesotho.

A study by Mabaleha *et al.* (2018) reviewed studies on Lesotho medicinal plants of the Asteraceae family based on previous literature. The study discusses 15 medicinal species (e.g., *Artemisia afra, Bekheya setifera, Dicoma anomala, Helichrysum odoratissimum, Othonna natalensis* Sch.Bip. and *Senecio asperulus* DC.) used for the treatment of a wide range of ailments ranging from circulatory, gastrointestinal, respiratory, to reproductive, pain relief and digestive disorders. A year later, Mabaleha *et al.* (2019) documented 43 plant species (both indigenous and exotic) from 26 families and 42 genera used to treat neurological disorders. Information was sourced from interviewing traditional health practitioners in the Berea, Leribe and Maseru districts of Lesotho. The most common families with the highest number of species were found to be Asteraceae (9 species), Fabaceae (5 species) and Rosaceae (3 species). The most frequently cited plant species were *Morella serrata* (Lam.) Killick (26%), followed by *Xysmalobium undulatum* (22%) and *Afroaster hispida* (Thunb.) J.C.Manning & Goldblatt (15%).

A study by Moteetee *et al.* (2019) provided a comprehensive compilation of the ethnobotany of Basotho (residing both in Lesotho and the Free State Province of South Africa). Four hundred and thirty-seven species were reported for utilisation in various medical conditions ranging from the reproductive, urinary tract, degenerative, digestive, and circulatory ailments to wound healing, veterinary and nervous system disorders. Information was gathered from the literature as well as the past experiences of the authors. The study resonates with previous studies in that Asteraceae was the most used family with 115 species, followed by Poaceae (61) and Fabaceae (50). A summary of the various ethnomedicinal studies on Lesotho plants is presented in Table 1.

Table 1. Summary of ethnomedicinal studies of Lesotho plants

Ethnomedicinal study	**Focus of the study**	**Source(s) of data**	**Number of medicinal plant species recorded**
(Phillips 1917)	Flora of Leribe plateau and the surrounding areas	Physical surveys and literature review,	782 species (348 families) used for various purposes, inclusive of medicinal
(Jacot Guillarmod 1971)	Flora of Lesotho	Physical surveys, literature review and experience of the author	1,537 species used for various purposes, including medicinal (95 families)
(Schmitz 1982)	Wild flowering plants of Lesotho	Literature review and plant collections by various authors	300 species, inclusive of medicinal plants
(Zepp 1982)	Ferns of Lesotho	Physical surveys	50 species of ferns and fern allies, inclusive of medicinal plants
(Ramohlabi 1989)	Medicinally important plants of Lesotho	Interviews	10
(FAO 1996)	Plant genetic resources in Lesotho	Physical surveys	Nine shrub and tree species
(Maliehe 1997)	Medicinal plants commonly used in Lesotho	Experience of the author as a traditional healer	60
(Shale *et al.* 1999)	Plants used for inflammations and bacterial infections	Interviews	23 (13 families)
(Letšela *et al.* 2003)	Inventory of communal biological resources in and around Tšehlanyane National Park and Bokong Nature Reserve	Household survey	38
(National Environmental Secretariat 2007)	Status of invasive alien species in Lesotho	Physical surveys	31 (including medicinal plants)
(Wybenga 2006)	Wildflowers of Tšehlanyane National Park	Physical surveys	28 angiosperms (inclusive of medicinal plants)
(National Environment Secretariat 2007)	Inventory of invasive alien species and their distribution in Lesotho	Physical surveys and literature review	54 (inclusive of medicinal plants)
(Moteetee & Van Wyk 2007)	Plants known as '*Musa-pelo* in Lesotho (treating the heart and associated ailments)	Literature review and first author's own experience	20
(Cooper-Driver *et al.* 2008)	Ferns and fern relatives in Lesotho	Physical surveys	56 ferns, inclusive of medicinal plants
(Moteetee & Van Wyk 2011)	Traditional practices and *materia medica* of Lesotho	Literature review, experiences, and recollections of the first author	355 (84 families)
(Lebamang *et al.* 2013)	Medicinal plants commonly traded in the markets of three districts in Lesotho, namely, Leribe, Mohale's Hoek and Quthing.	Interviews and physical surveys	10
(Possa & Khotso 2015)	Naming of Basotho medicinal plants	Interviews	20
(Department of Environment 2014)	An overview of plant species of socio-economic importance in the country	Literature review	Nine
(Seleteng-Kose *et al.* 2015)	Medicinal plants used for treating common ailments in the country's traditional medicine	Interviews	80

Ethnomedicinal study	Focus of the study	Source(s) of data	Number of medicinal plant species recorded
(Mugomeri *et al.* 2016a)	Herbal medicines used in Lesotho	Interviews	54 (29 families)
(Mugomeri *et al.* 2016a)	Medicinal plants used for the treatment of HIV-related ailments	Interviews	20 (16 families)
(Maliehe 2016)	Medicinal plants used in Shamanism	Author's own experience and interviews	51
(Moteetee & Seleteng-Kose 2016)	Medicinal plants used for the treatment of reproductive ailments	Interviews, authors' own experiences and observations, as well as literature review	87
(Moteetee 2017)	Plants for magic by Basotho	Literature review and author's experience and recollection	197
(Moteetee & Seleteng-Kose 2017)	Medicinal plants used for the treatment of skin ailments	Interviews (based on authors' own experiences and observations, as well as literature review)	57 (39 families)
(Mabaleha *et al.* 2018)	Lesotho medicinal plants of the Asteraceae family	Literature review	15
(Mabaleha *et al.* 2019)	Medicinal plants used for neurological disorders	Interviews	43 (26 families)
(Moteetee *et al.* 2019)	Ethnobotany of Basotho (in Lesotho and Free State Province of South Africa)	Literature review, survey, and experience of the authors	712 species used for various purposes, 437 of which are used for medicinal purposes

Broad-based publications which included medicinal plant use by the Basotho (the people of Lesotho) include Watt and Breyer-Brandwijk (1962), which gives information on the medicinal uses, chemistry, pharmacological effects, and toxicology of the flora of southern and eastern Africa. A book by Moffett (2010) provided comprehensive documentation of medicinal plants used by the Basotho. The publication collated all the available literature as well as information from discussions with traditional healers in Qwaqwa in the Free State province of South Africa and parts of Lesotho.

Pharmacological studies

Several pharmacological studies have been carried out, particularly in the past ten years, to assess the efficacy of various medicinal species of Lesotho, focusing on biological and phytochemical assessment (Table 2).

Biological activity studies

The studies include Shale *et al.* (1999), which assessed the antimicrobial activities and anti-inflammatory properties of 12 species against various micro-organisms (*Micrococcus luteus, Bacillus subtilis, Staphylococcus aureus, S. epidermidis, Escherichia coli, Pseudomonas aeruginosa* and *Klebsiella pneumoniae*). *Malva parviflora* L. inhibited most test pathogens, including *E. coli,* which had resistance to most other plant extracts. Shale (2003) assessed the antibacterial and anti-inflammatory activity of 15 medicinal plants used traditionally in Lesotho. Extracts from *Afroaster hispida, Eriocephalus punctulatus* L., *Haplocarpha scaposa* Harv., *Malva parviflora, Rumex acetosella* L., *Solanum aculeatissimum* Jacq and *Chenopodium* sp. exhibited high antibacterial activity, whereas *Asparagus microraphis* (Kunth)Baker, *Rhynchosia adenodes* Eckl. & Zeyh. and *Watsonia* sp. showed high anti-inflammatory activity. Shale *et al.* (2004) monitored the effect of storage on antibacterial and anti-inflammatory activity of three plants used as traditional medicines in Lesotho, namely, *Asparagus microraphis, Eriocephalus tenuifolius* and *Malva parviflora*. The highest antibacterial activity was detected in roots of *M. parviflora* stored at room temperature, while COX-1 anti-inflammatory activity of *M. parviflora* (leaves and roots), *E. tenuifolius* (leaves) and *A. microraphis* (leaves and roots) also generally increased with the length of storage. Magama *et al.* (2013) assessed antioxidant and free radical scavenging properties of four medicinal plants used in Lesotho's traditional medicine, namely, *Berkheya setifera, Camellia sinensis* (L.) Kuntze*, Leucosidea sericea* Eckl. & Zeyh. and *Trifolium burchellianum*. Methanolic extracts of the four plants scavenged DPPH free radicals, with a modest correlation between total phenolics content and antioxidant activity observed in *L. sericea* and *B. setifera* having the highest phenolics content. The two species were also more potent in all the antioxidant assays undertaken in the study.

Table 2: A summary of pharmacological (biological, toxicity, cytotoxicity, genotoxicity, and phytochemical) studies on Lesotho medicinal plants

Pharmacological study	**Focus of the study**	**Assay followed**	**No. of medicinal plants assessed**	**Biological activity**
Mokhobo (1976)	Toxicity of plants associated with herbally-induced hepatitis	Liver biopsies full blood count, ESR, determination of urea, electrolytes, serum glutamic oxalo-acetic transaminase, prothrombin index, serum proteins, serum alkaline phosphatase, serum bilirubin, full urinalysis (including urobilin and urobilirubin), and chest radiographs	10	*Senecio* species were found to be the principal source of hepatotoxic alkaloids, especially pyrrolizidines.
Shale *et al.* (1999)	Antibacterial activity Anti-inflammatory activity	Disc diffusion bioassay Cyclo-oxygenase bioassay	23	*Afroaster hispida, Haplocarpha scaposa, Malva parviflora, Rumex acetosella, Solanum aculeatissimum, Chenopodium* sp. were found to have the highest activity *Asparagus microraphis, Rhynchosia adenodes* and *Watsonia* sp. were found to have the highest activity gentiobioside
Qhotsokoane-Lusunzi & Karuso (2001)	Secondary metabolites in *Bulbine narcissifolia*	NMR spectroscopy	1	Detection of acetosyringone, chrysophanol, knipholone, isoknipholone, 10,7′-bichrysophanol, and chrysalodin in addition to two new anthraquinone glycosides, knipholone-8-O-β-d-gentiobioside and chrysalodin-10-β-d-
Shale (2003)	Medicinal plants used traditionally in Lesotho	Disc-diffusion bioassay (for anti-bacterial activity) Cyclooxygenase-1 (COX-1) bioassay (anti-inflammatory activity)	15 medicinal plants (antibacterial activity) and 13 plants (anti-inflamma	High antibacterial activity was observed for *Afroaster hispida* (roots), *Eriocephalus punctulatus* (leaves), *Haplocarpha scaposa* (leaves and roots), *Malva parviflora* (roots), *Rumex acetosella* (leaves), *Solanum aculeatissimum* (leaves) and *Chenopodium* sp. (roots). *Asparagus microraphis*, *Rhynchosia adenodes* and *Watsonia* sp. (both leaf and root extracts) showed high anti-inflammatory activity.

Pharmacological study	Focus of the study	Assay followed	No. of medicinal plants assessed	Biological activity
			tory activity)	
Mabaleha & Yeboah (2004)	Physicochemical properties and FA compositions of seed oils from six legume cultivars of *Phaseolus vulgaris*, grown in Lesotho	HPLC	1	The oil content of the beans was very low compared to those in *P. vulgaris* cultivars grown in other parts of the world.
Shale *et al.* (2004)	Effect of storage on antibacterial and anti-inflammatory activity of *Asparagus microraphis, Eriocephalus tenuifolius, Malva parviflora*	Disc-diffusion bioassay (antibacterial) COX-1 (anti-inflammatory)	3	The highest antibacterial activity was detected in roots of *M. parviflora* stored at room temperature. However, storage temperatures did not influence the rate of loss of antibacterial activity in *E. tenuifolius* leaves. *A. microraphis* retained their high COX-1 anti-inflammatory activity throughout the twelve-month experiment period. The results, therefore, indicated that the plants have a reasonable long shelf-life
Asita & Mokhobo (2013)	Evaluation of *Eriocephalus punctulatus* smoke condensate for cytotoxicity and the induction of genotoxicity	*Allium cepa* assay	1	Smoke condensate of *E. punctulatus* significantly decreased the mitotic index of *Vicia faba* root tip meristem cells, indicating that the plant induced genotoxicity.
Magama *et al.* (2013)	Antioxidant and free radical scavenging properties of four medicinal plants used in Lesotho's traditional medicine, namely: *Berkheya setifera, Camellia sinensis, Leucosidea sericea* and *Trifolium burchellianum*	The stable free radical DPPH method of Blois (1958) with some modifications	4	Methanolic extracts of the four plants scavenged DPPH free radicals, reduced Fe3+ to Fe2+, scavenged hydrogen peroxide and contained phenolics. *L. sericea* and *B. setifera* were found to be more potent in all the antioxidant assays undertaken in the study
Mugomeri *et al.* (2014)	Phytochemical content of *Euclea coriacea, Hypoxis hemerocallidea, Pelargonium sidoides, Senecio asperulus* and *Xysmalobium undulatum*	Qualitative and FTIR-spectroscopy	5	Diterpenes and phytosterols were found in *E. coriacea*, *H. hemerocallidea* was found to have diterpenes, flavonoids and phytosterols. Phytosterols, flavonoids and glycosides were detected in *Senecio asperulus, P. sidoides* and *X. undulatum.*

Pharmacological study	Focus of the study	Assay followed	No. of medicinal plants assessed	Biological activity
Asita *et al.* (2015)	Modulation of Mutagen-Induced Genotoxicity in *Dicoma anomala* and *Chenopodium album*	*Allium cepa* assay	2	Both plants were found to be cytotoxic and genotoxic at higher concentrations. However, the lower concentrations of *C. album* extract were neither cytotoxic nor genotoxic
Mekbib (2016)	Anti-pathogenic activity of 23 plant species used to control citrus pre-harvest diseases and human aliments	An *in vitro* antimicrobial activity screening against 12 pathogens (food borne and human)	23	Broad-spectrum antimicrobial activity was observed in *Mirabilis jalapa, Solanum incanum, Tagetes minuta* and *Withania somnifera.*
Kena & Lepheana (2016)	Antimicrobial activity *Artemisia afra* and *Rhamnus prinoides* against three fungal pathogens of *Amaranthus hybridus* namely *Alternaria alternata, Fusarium oxysporum* and *F. solani.*	Disc-diffusion bioassay	2	*R. prinoides* showed maximum inhibition against the three test pathogens, whereas *A. afra* had the highest inhibition activity was against *A. alternata*.
Magama & Asita (2017)	Central antinociceptive activity of *Chenopodium album*	Hot plate nociception test in mice	1	*C. album* leaf extract was found to be non-toxic at oral doses of up to 5000 mg/kg. However, the plant possessed significant dose-dependent central antinociceptive effects at the dosage range of 50- 150 mg/kg bw
Asita *et al.* (2017)	Cytotoxicity, genotoxicity and modulation of cyclophosphamide- and EMS-induced GT in *Helichrysum caespititum* and *Xysmalobium undulatum*	*Allium cepa* assay	2	Individual effect of *X. undulatum* was found to be mildly anti-genotoxic. One or more concentrations of *H. caespititium, X. undulatum* and ascorbic acid were both cytotoxic and genotoxic
Mabaleha *et al.* (2018)	Biological activities of Lesotho medicinal plants of Asteraceae family	Review of previous literature	16	A wide range of metabolites have been reported from Asteraceae, with the commonest being terpenoids, flavonoids and their derivatives. Extracts from plants such as *A. afra, B. setifera, E. panctulatus* and *H. odoratissimum* were reported to have antioxidant properties on DPPH and ABTS cations

Pharmacological study	Focus of the study	Assay followed	No. of medicinal plants assessed	Biological activity
Seleteng-Kose *et al.* (2019)	Antimicrobial activity, phytochemistry and cytotoxicity of plants used for treatment of sexually transmitted infections (STIs)	MIC assay (antimicrobial activity)	20 (antimicrobial)	*Bulbine narcissifolia* and *Helichrysum caespititium* displayed noteworth activity against two and three test pathogens respectively
		Qualitative analyses (phytochemistry)	8 (phytochemistry)	*Eurphobia clavarioides* was found to have a majority of the screened phytochemicals (alkaloids, flanonoids, terpenoids, saponnins and tannins)
		Brine shrimp lethality assay (cytotoxicity)	12 (cytotoxicity)	Five plants were found to be toxic (*Agave americana, Aloiampelos striatula, Berkheya setifera, Cyathula uncinulata, Parapodium costatum*)
Pillai *et al.* (2019)	Radical scavenging of *Rhamnus prinoides*	DPPH radical scavenging assay	1	Low scavenging activity in *R. prinoides*, indicating promising antioxidant activity
Matamane (2020)	Radical scavenging of *Urtica urens*	DPPH radical scavenging assay	1	Different extracts from *U. urens* exhibited a wide range of radical scavenging activity
Mokoroane *et al.* (2020)	Radical scavenging *Aloiampelos striatula*	DPPH radical scavenging activity	1	Water extract showed the highest scavenging potential
Matamane *et al.* (2021)	Phytochemical profile of *Pseudognaphalium undulatum* and its radical scavenging activity	2,2- diphenyl-1-picrylhydrazyl (DPPH) assay, hydrogen peroxide (H2O2) assay, ferric reducing power assay and standard analytical methods	1	Low scavenging activity and presence of saponins, tannins, terpenoids, phenolics, flavonoids, sterols and reducing sugar
Molefi & Pillai (2021)	Radical scavenging of *Searsia dentata*	DPPH assay and ferric reducing power assay	1	Low scavenging activity in *S. dentata*
Mpopo et al. (2021)	Radical scavenging activity of *Searsia burchellii*	DPPH assay	1	Both the leaves and roots exhibited promising radical scavenging activity
Sixtus & Pillai (2022)	Radical scavenging of *Leucosidea sericea*	DPPH and ferric reducing power assays	1	Low scavenging activity, showing significant scavenging potential

A study by Mabaleha *et al.* (2018) reviewed the biological activities of Lesotho medicinal plants of the Asteraceae family. The study indicated that extracts from plants such as *Artemisia afra, Berkheya setifera, Eriocephalus panctulatus* and *Helichrysum odoratissimum* possess antioxidant properties. The study resonates with Magama *et al.* (2013), where antioxidant and free radical scavenging properties were reported for *B. setifera.* In addition, anti-inflammatory activity was reported for *B. setifera, D. anomala, Haplocarpha scaposa, Helichrysum* sp., *Schkuhria pinnata* (Lam.) Thell. and *Senecio asperulus*. Extracts of most plants under review also showed anti-diabetic properties. This property validates the extensive use of *A. afra, D. anomala, E. panctulatus, H. scaposa* and *S. pinnata* by diabetic patients in Lesotho (Magama *et al.* 2013). Indeed, *A. afra* has been used to keep the urine free from sugar in the case of diabetes mellitus (Watt & Breyer-Brandwijk 1962). A publication by Seleteng-Kose *et al.* (2019) investigated 20 plant species used for the treatment of sexually transmitted infections (STIs) in Maseru, Lesotho for antimicrobial activity against three prevalent causative pathogens of STIs (*Gardnerella vaginalis*, *Oligella ureolytica* and *Neisseria gonorrhoea*), as well as *Candida albicans. Bulbine narcissifolia* and *Helichrysum caespititium* displayed noteworthy antimicrobial activity against more than one of the test pathogens, whereas *Senecio asperulus* was found to display noteworthy activity against *N. gonorrhoea*.

Several studies assessed antioxidant activity of different plants. For example, Pillai *et al.* (2019) determined DPPH radical scavenging activity of leaves from *Rhamnus prinoides* using DPPH radical scavenging assay. The plant was found to have promising antioxidant activity. A year later, Matamane *et al.* (2020) evaluated the DPPH radical scavenging activity of *Urtica urens*. In the same year, Mokoroane *et al.* (2020) assessed DPPH radical scavenging activity of *Aloiampelos striatula*. Its water extract showed the highest scavenging potential and identified as the most potent. A study by Molefi and Pillai (2021) assessed antioxidant activity of leaves and stem bark extracts from *Searsia dentata* using DPPH radical scavenging activity and ferric reducing powers. The extracts showed relatively lower scavenging activity, revealing that *S. dentata* could be a valuable source of antioxidants. In the same year, Sixtus and Pillai (2022) assessed the antioxidant activity of *Leucosidea sericea* using DPPH and ferric reducing power assays. The study revealed significant scavenging potential. Moreover, a study by Mpopo *et al.* (2021) assessed the DPPH radical scavenging activity of *Searsia burchellii*. Both the leaves and roots of the plant exhibited promising radical scavenging activity even though the leaf was identified as the most potent.

Phytochemical studies

Phytochemical studies were pioneered in 2001 by Qhotsokoane-Lusunzi and Karuso (2001), who evaluated secondary metabolites from roots of *Bulbine narcissifolia* using NMR spectroscopy. Several chemical compounds were identified in the study including acetosyringone, chrysophanol, knipholone, isoknipholone, 10,7′-bichrysophanol, chrysalodin, anthraquinone glycosides, knipholone-8-*O*-β-D-gentiobioside and chrysalodin-10-β-D-gentiobioside. A study by Mabaleha and Yeboah (2004) determined physicochemical properties and fatty acid compositions of seed oils from six legume cultivars of *Phaseolus vulgaris* L. grown in Lesotho to compare their dietary lipids with those in *P. vulgaris* cultivars grown in other parts of the world. The results revealed that the oil content of the beans was very low, whereas acid values were significantly higher. Mugomeri *et al.* (2014) screened five species from Lesotho Herbal Medicines Repository (LHMR) for their chemical content using qualitative and FTIR-spectroscopy. The plants (*Euclea coriacea* A.DC., *Hypoxis hemerocallidea, Pelargonium sidoides, Senecio asperulus* and *Xysmalobium undulatum*) were found to contain a wide range of phytochemicals, namely, diterpenes, flavonoids, glycosides and phytosterols. Another study by Mabaleha *et al.* (2018) reported that antioxidant properties of members of the Asteraceae family found in Lesotho are attributed to the flavonoids and other polyphenolic compounds that have been isolated from them. In addition, extracts from plants such as *Artemisia afra, Bekheya setifera*, *Eriocephalus panctulatus* and *Helichrysum odoratissimum* have been found to possess antioxidant properties on DPPH and ABTS cations. Seleteng-Kose *et al.* (2019) screened eight species for phytochemical composition using qualitative methods such as colour change and precipitation. Of these, *Euphorbia clavarioides* Boiss. was observed to have most of the screened phytochemical classes (five of the seven, namely, alkaloids, flavonoids, saponins, terpenoids and tannins). Later Matamane *et al.* (2021) determined the phytochemical profile of *Pseudognaphalium undulatum*, as well as its radical scavenging activity. The plant was found to have saponins, tannins, terpenoids, phenolics, flavonoids, sterols and reducing sugar. In addition, the plant showed promising antioxidant properties.

Toxicity, cytotoxicity, and genotoxicity studies

Toxicity studies conducted on Lesotho plants date as far back as 1976, even though there was little activity until 2013, as indicated in Table 2. The pioneering work of Mokhobo (1976) emanated from an incident in which 12 patients were admitted with herbally-induced hepatitis in Queen II hospital in Maseru, Lesotho, after taking some herbal preparations. The plants taken by the patients included *Albuca trichophylla* Baker*, Brunsvigia radulosa* Herb.*, Elephantorrhiza elephantina, Hypoxis cooperi* T.Moore*, Gunnera perpensa, Phytolacca heptandra, Ledebouria revoluta* (L.f.) Jessop*, Scabiosa columbaria, Senecio coronatus* (Thunb.) Harv. and *Xysmalobium undulatum*. The nature and the severity of the histological changes correlate with the clinical manifestations and the immediate prognosis. The study revealed that some species are used in various traditional medications even though they contain toxins. For example, *Senecio* species were the principal source of hepatotoxic alkaloids, especially pyrrolizidines, which could have resulted in the prognosis in the admitted patients.

Asita and Mokhobo (2017) evaluated smoke condensate of *Eriocephalus punctulatus* for cytotoxicity and the induction of genotoxicity in the onion (*Allium cepa* L.). The results revealed that none of the concentrations of the

smoke condensate of *E. punctulatus* significantly decreased the mitotic index of *A. cepa* root tip meristem cells, indicating that the plant induced genotoxicity. Moreover, Asita *et al.* (2015) investigated the modulation of mutagen-induced genotoxicity in two plants used for medicinal purposes in Lesotho, namely, *Dicoma anomala* and *Chenopodium album* L. Both plants were found to be cytotoxic and genotoxic, indicating that they can cause severe problems and damage to cells if they are improperly used. Magama and Asita (2017) evaluated *C. album* for central antinociceptive activity using inbred NIH albino mice. The toxicity tests showed that *C. album* leaf extract was not toxic at oral doses of up to 5000 mg/kg. However, the plant possessed significant dose-dependent central antinociceptive effects, similarly increasing the pain threshold to Aspirin, indicating similar efficacy to the drug. In the same year, (Asita *et al.* 2017) investigated two medicinal plants (*Helichrysum caespititum* and *Xysmalobium undulatum*) and ascorbic acid for cytotoxicity, genotoxicity and modulation of cyclophosphamide- and EMS-induced GT using the *Allium cepa* assay. Mixtures of the three were significantly more genotoxic than the individual extracts, which indicated a synergistic interaction. Among the extracts, the individual effect of *X. undulatum* was found to be mildly anti-genotoxic. Two years later, Seleteng-Kose *et al.* (2019) evaluated the toxicity of 12 species using the brine shrimp lethality assay. Five plant species, namely, *Agave americana* L. (leaves), *Berkheya setifera* (leaves), *Parapodium costatum* E.Mey. (roots), *Aloiampelos striatula* (leaves) and *Cyathula uncinulata* (Schrad) Schinz (roots) were found to be toxic (% mortality > 50 % after 24 hours).

Conservation studies

Conservation studies are essential since they provide critical information on the extent of the threat facing biodiversity to avoid over-exploitation and possible extinction of biological resources. This is particularly important because medicinal plants are heavily harvested in Lesotho to supply local and international markets (Motjotji 2011, Mojakhomo 2012, Masupha *et al.* 2013, Mugomeri *et al.* 2016b) This is also evidenced by several '*muthi'* stalls in the informal markets of major towns such as Maseru and Maputsoe (Mojakhomo 2012, Masupha *et al.* 2013, Mugomeri *et al.* 2016b). In fact, (Masupha *et al.* 2013) reported that more than 86% of traditional practitioners in Lesotho admitted to experiencing declining sources of plants and animals used in the preparation of traditional medicines. Moreover, Department of Environment (2009) indicated that with the emergence of HIV pandemic, the use of indigenous herbs has intensified because of the assumed potency in managing the viral conditions. Much of these herbs are harvested from the rural areas usually smuggled and sold in urban areas. Despite the high usage of these medicinal plants, information on their conservation status is limited (Mabaleha *et al.* 2018, Newton *et al.* 2008, Motjotji 2011). The few studies that have been undertaken in Lesotho have either investigated conservation status of a limited number of plants or they have sourced information from previous literature (particularly provided by South African studies) e.g., Chakela (1999) without much evidence from physical surveys in the country. In addition, many of these studies were not focusing specifically on medicinal plants but were broadly assessing plants that were believed to be under threat. On the other hand, the neighbouring South Africa is the only African country which has comprehensive data on the conservation status of its flora (http://redlist.sanbi.org/).

A publication by Talukdar (2002) recorded the conservation status and red data listing of 94 Lesotho plants, based on available literature. Of the 94 species, 60 are data deficient, these include *Elephantorrhiza elephantina,* and *Hypoxis hemerocallidea* which are heavily harvested for medicinal purposes in the country (Maliehe 2016). Therefore, there is urgent need to assess their conservation status since the plants are highly threatened. It is important to note that there is contradicting information on the conservation status of some plants.

A publication by Newton *et al.* (2008) assessed the impact of harvesting *Pelargonium sidoides* in Lesotho as well as its Red Data List status, in an effort towards the development of a non-detriment finding exercise for the species. The study revealed that small clusters of this species occur throughout a relatively large area (approximately 2,100 km^2) of Lesotho's total land area of 30,532 km^2. However, it was determined that the annual harvest and the slow re-growth of the ligno-tubers limited repeat harvesting cycles to at least seven years. It was therefore deduced that the harvest levels are detrimental to the species in Lesotho. In comparison to South Africa, the species is reported to have a huge distribution range of 480,000 km^2, however, it is under severe harvesting pressure and its populations are estimated to be declining (Newton *et al.* 2008). Even though the conservation status of the species was not determined in Lesotho, it was classified as least concern-declining in South Africa (SANBI 2008). Several other studies investigated the impacts of harvesting operations on *P. sidoides* wild populations, and these include Van Niekerk (2009) and Motjotji (2011). The former investigated the impacts of commercial cultivation of *P. sidoides* and the contribution of its trade to the livelihoods of harvesters from the Eastern Cape province and Quthing district in Lesotho. The latter investigated the rate of tuber recovery in *P. sidoides* plants as well as the impacts of wild harvest on its tuber recovery in an effort towards sustainable harvest of the species. The study revealed that even a single return harvest event within a 10 to 15 years post-harvest period can negatively affect wild populations of *P. sidoides* due to its slow rate of tuber recovery. Even though no conservation status of the species was given in both studies, it is evident that harvesting of *P. sidoides* is causing a significant decline in the population of the species.

Mojakhomo (2012) assessed the exploitation of medicinal plants in the *muthi* market in the Maseru district. The publication recorded 49 medicinal plants sold in the *muthi* market, 10 of which were reported as priority species for conservation concern in the country, and these were *Alepidea amatymbica, Dicoma anomala, Eucomis autumnalis, Elephantorrhiza elephantina, Gunnera perpensa, Hypoxis hemerocallidea, Ledebouria cooperi, Pentanisia prunelloides, Merwilla plumbea* (Lindl.) Spera and *Xysmalobium undulatum*. It is important to note that *A. amatymbica* and *D. anomala* were reported as the most popular species in the *muthi* market. In addition, a study

by Maliehe (2016) revealed that several medicinal plants are becoming scarce, even though specific conservation statuses were not given. These are *Agapanthus campanulatus* Leighton*, Albuca trichophylla, A. amatymbica, Asclepias cucullata* (Schltr.) Schltr., *Afroaster hispida, D. anomala, Tulbaghia acutiloba* Harv.*,* and *Telunina* sp. In the same year, a study by Mugomeri *et al.* (2016a) reported conservation statuses of 52 medicinal plants used in Lesotho, based on previous literature, mainly (Motjotji 2011, Mojakhomo 2012, SANBI 2020). Of the 52 species, seven were found to be threatened (e.g., *Aloiampelos striatula, Hypoxis hemerocallidea, Euphorbia clavarioides*), two declining (*Gunnera perpensa, Eucomis autumnalis*), 30 Least Concern, three not threatened and 10 not evaluated. Seleteng-Kose *et al.* (2015) recorded conservation statuses of 80 plant species commonly used in Lesotho's traditional medicine, based on Raimondo *et al.* (2009). Of the 80 species, five (*D. anomala, E. elephantina, L. lanceolata, P. prunelloides* and *T. capensis*) were reported as declining, 69 as least concern, whereas seven were not evaluated. Mabaleha *et al.* (2018) provided conservation information on members of the Asteraceae family occurring in the country, with data from Talukdar (2002). The study reported that *D. anomala* was the only species that had Vulnerable status (VU A2d), whereas most of the species were either Least Concern or Data Deficient. However, a list of specific species being referred to in the latter has not been provided in the study. A summary of conservation studies on Lesotho plants, based mainly on literature, and to a limited extent, on physical surveys, is given in Table 3.

Table 3. Conservation status of some medicinal plants of Lesotho

Study	**Focus of study**	**Method used**	**No. of plants assessed**	**Notes on conservation status**
Mcvean (1977)	Nature conservation in Lesotho, focusing on legislation and conservation areas	Physical surveys and literature	Varying number of species in different areas	There is need for small species reserves, e.g., Makhaleng area had high populations of *Aloe polyphylla,* hence is an ideal spiral aloe reserve
Chakela (1999)	Conservation status of 53 plant species occurring in Lesotho,	Literature review	53	1 species extinct (*Smodingium argutum*), 1 endangered (*Aloe polyphylla*), 6 vulnerable, 22 rare
National Environmental Secretariat (2000)	*Psilotum nudum*	Physical survey	1	The plant is known from only one locality in the country (Roma), and is regarded as Lesotho's rarest plant
Talukdar (2002)	Conservation status of Lesotho flora	Literature review	94	1 plant extinct, 7, critically endangered, 4 endangered, 14 vulnerable, 8 lower risk, 60 data deficient
Newton *et al.* (2008)	Impact of harvesting *Pelargonium sidoides* in Lesotho as well as its Red Data List status	Physical survey and literature	1	Current harvest levels are detrimental to *P. sidoides* in Lesotho. However, its conservation status was not determined in Lesotho, but is classified as least concern-declining in South Africa
Van Niekerk (2009)	Impacts of commercial cultivation of *Pelargonium sidoides* and the contribution of its trade to the livelihoods of harvesters	Physical survey and interviews	1	*P. sidoides* trade contribute to welfare of harvesters and traders, but epitomises many inequities in biodiversity trade
Motjotji (2011)	The rate of tuber recovery in *Pelargonium sidoides* and impacts of harvest on its tuber recovery	Physical survey	1	*P. sidoides* has a slow rate of tuber recovery
Mojakhomo (2012)	Assessment of uncontrolled exploitation of medicinal plants for Muti market in Maseru, Lesotho	Interviews and physical survey	49	10 plants were identified as heavily exploited hence of conservation concern.
Mugomeri *et al.* (2016a)	Conservation status of medicinal plants used in Lesotho	Literature review	52	7 species threatened, 2 declining, 30 least concern, 3 not threatened, 10 not evaluated

Study	Focus of study	Method used	No. of plants assessed	Notes on conservation status
Mabaleha *et al.* (2018)	Conservation information on members of Asteraceae family occurring in Lesotho	Literature review	1	*Dicoma anomala* listed as vulnerable
Seleteng-Kose *et al.* (2019)	Red data listing of medicinal plants commonly used in Lesotho's traditional medicine	Literature review	80	4 plants reported as declining, 69 least concern, 7 not evaluated

Conclusions

To the best of our knowledge this synthesis is the first of its kind, it brings together published and unpublished literature sources, thus providing a repository for studies conducted on Lesotho medicinal plants. Although some of the unpublished sources, e.g., reports from government agencies, have not been subjected to peer-review processes, they have proven to be reliable as they contain information that corroborates published data. Although several ethnobotanical field surveys have been conducted in Lesotho, some areas, especially in the northern (i.e., those in the Butha-Buthe and Mokhotlong districts) and the north-eastern (i.e., Thaba-Tseka district) parts of the country, have been neglected. It is therefore recommended that these areas should also be surveyed for the documentation of existing indigenous knowledge, specifically on medicinal plant use.

The study revealed that although studies have been conducted to evaluate the pharmacological properties of several Lesotho medicinal species, they focussed mainly on antimicrobial, anti-inflammatory, and antioxidant activities. It is important to note that these studies were limited in both scope and the number of species studied, for example, an evaluation of antioxidant activities of one species, or antimicrobial screening of selected species used for the treatment of sexually transmitted infections. This suggests that a wide array of other therapeutic effects, such as adaptogenic, antacid, antidiabetic, anti-cancer, anti-tumour, anti-ulcer, anti-viral, aphrodisiac, abortifacient, blood purification, uterotonic, etc., have remained unstudied, yet they are implicated in the ethnomedicinal uses of these species. In addition, the studied biological activities were only done using *in vitro* assays, while *in vivo* studies are lacking. It is recommended that the unstudied biological activities of the medicinal species should be undertaken to unravel their therapeutic potential, using both *in vitro* and *in vivo* models.

The phytochemistry of the Lesotho medicinal plants is one of the least researched areas, with only six studies recorded in this review. Of these, two studies used spectroscopic techniques to assess the chemical composition, namely, nuclear magnetic resonance and Fourier transform infrared, while the other three utilized simper qualitative analyses which only detect presence or absence of certain groups or elements. Only one study isolated and characterised chemical compounds from one medicinal species. In addition, the six studies collectively evaluated 21 species, suggesting that most of the Lesotho medicinal species are yet to be assessed for their chemical composition. It is an established fact that these secondary metabolites exhibit a wide array of bioactivities and can be used as lead compounds in drug discovery, or directly as drugs. It is therefore imperative that the unstudied species are evaluated for their phytochemistry, the bioactive compounds should also be isolated and screened for their biological activities.

Lesotho does not have an up-to-date national red data list for its flora, and like other southern African countries, relies on the conservation statuses based on studies conducted in the neighbouring South Africa, since many of the plants occur in both countries. The current study shows that there is a dire need for a comprehensive and systematic assessment of the conservation status of medicinal species in Lesotho, considering that some of the important species were reported to be "becoming scarce". The results from such assessments will inform conservation strategies for plant biodiversity in the country. Such strategies should include implementation of the appropriate training programs about the conservation and sustainable use of medicinally important plants for the local communities.

Declarations

Ethical approval and consent to participate: The study does not require ethical clearance as it is based on literature review.

Consent for publication: Not applicable

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