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Cultivation and beneficial uses of *Pelargonium sidoides* DC. – A review

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Background: *Pelargonium sidoides* (*P. sidoides*) DC. (Geraniaceae) is one of several geophytic species of the genus that are important traditional medicines in South Africa. *P. sidoides* has been identified as a potential future economic species known to cure various ailments, including respiratory infections.

Aim: This review was aimed at addressing concerns around the overexploitation of *P. sidoides* in the wild.

Setting: This review provides an overview of *P. sidoides* cultivation and usage.

Method: A comprehensive literature search involving mainly electronic and library sources of information was used to collate and synthesise published data.

Results: According to the findings of the study, there has been a huge increase in demand for the plant and it has been overexploited locally as a result of increased domestic and global demand from native consumers and the pharmaceutical industries.

Conclusion: The review emphasises the necessity of cultivation in ensuring the sustainability of *P. sidoides* in the wild. Cultivation is a crucial component of conservation attempts which is under threat because of increasing urbanisation, habitat degradation, and population growth. Furthermore, producing medicinal plants allows new rural farmers to produce them as a new crop option, reducing unsustainable wild collection and competition with established commercial farmers who mostly raise food crops. Lastly, the study reveals the benefits in cultivating medicinal plants namely the strengthening of primary healthcare through traditional medicine, the preservation of indigenous knowledge, local economic growth, and job creation.

Contribution: The benefits of cultivation and using *P. sidoides* medicinally are reviewed in this essay.

Keywords: Geraniaceae; *Pelargonium reniforme*; *Pelargonium sidoides*; Schwabe; Cultivation; Geraniaceae.

Introduction

Pelargonium sidoides (*P. sidoides*) DC. (Geraniaceae) is one of the estimated 3000 medicinal plant species that have been documented as traditional medicine used across South Africa (Van Wyk, Oudtshoorn & Gericke 1997). About 350 species of medicinal plants are the most commonly used and traded (SANBI 2006). However, Van Wyk (2008) claims that about 38 indigenous species have been commercialised to some extent (Table 1). These plants are available as processed materials in modern packaging and in various dosage forms such as teas, tinctures, tablets, capsules or ointments. Several others are also produced for multi-million rand informal markets (Cunningham 1988; Mander 1998).

The genus *Pelargonium* is a fundamental part of the Cape flora, and the centre of diversity is the South-Western part of South Africa (Lalli et al. 2006). Most of the *Pelargonium* plants cultivated in Europe and North America originated from South Africa (Sayre 2003). They are adapted to a wide Faltitudinal range, spanning from near sea level in the Eastern Cape of South Africa to 2746 m above sea level in the Lesotho highlands (Newton et al. 2013).The species is commonly called geranium, 'umckaloabo', Uvendle (isiXhosa), Kalwerbossie (Afrikaans), i-Yeza lezikali (isiXhosa), Icwayiba (isiXhosa), ikhubalo (isiXhosa), Rabassam or Rabas (Dutch or Afrikaans), and Khoaara e nyenyane (Sesotho). *P. sidoides* is a native plant to South Africa and Lesotho (Brendler & Van Wyk 2008). The plant has well-developed tubers that enable it to survive harsh environmental conditions, and also circumvent the perennial grass fires that occur across its distribution (Van der Walt & Demarne 1989). Numerous studies have been carried out on the antibacterial and

TABLE 1: Thirty-eight commercialised indigenous species.

Species	Parts used	Main traditional uses in South Africa (traditional uses elsewhere or modern uses, if different, in brackets)
Adansonia digitata L	Seeds, leaves, roots, flowers, fruit pulp and bark	Fever, diarrhoea, haemoptysis, hiccup remedy (urinary disorders)
Agathosma betulina (P.J.Bergius) Pillans	Leaves	Stomach complaints, bitter tonic, wound-healing, traditional antiseptic and cosmetic (diuretic, urinary tract disinfectant, flavourant)
Aloe ferox Mill	Plant gel, leaves and pods	Bitters: laxative, bitter tonic; gel: wound-healing (health drink, cosmetic)
Artemisia afra Jacq. ex Willd	Leaves	Colds and influenza, stomach ailments, bitter tonic, analgesic, anthelmintic, traditional inhalant for a blocked nose
Aspalathus linearis (Burm.f.) R.Dahlgren	Leaves	Antispasmodic, traditional milk substitute for infants prone to colic, health drink
Athrixia phylicoides DC.	Leaves	Health tea, aphrodisiac
Bulbine frutescens (L.) Willd	Fresh leaf	Wounds, burns, rashes, itches
Carpobrotus edulis (L.) L.Bolus	Leaf juice	Gargle for mouth and throat infections, dysentery, digestive ailments, and tuberculosis
Centella asiatica (L.) Urb.	Leaves and stems	General tonic, leprosy, wounds and cancer (venotonic, prevention of scar tissue formation, adaptogen, acne, allergies)
Cyclopia genistoides (L.) R.Br.	Shoots, stems and leaves	Health drink, digestive, stomachic (antioxidant)
Dodonaea viscosa (Jacq.) var. angustifolia (L.f.) Benth	Leaves	Fever, colds, influenza, stomach ailments, measles, gargle for sore throat and oral thrush, pneumonia, tuberculosis, topical anti-pruritic
Elytropappus rhinocerotus (L.f.) Less.	Young tips	Indigestion, dyspepsia, ulcers, stomach cancer, fumigant against influenza; appetite stimulant, bitter tonic
Eriocephalus africanus L.	Seeds, leaf and its oil	Diaphoretic, diuretic, stomach ache
Euclea natalensis A.DC.	Roots and bark	Bronchitis, chest ailments, pleurisy, asthma, urinary tract infections, toothache, headache, toothbrush sticks
Eucomis autumnalis (Mill.) Chit.	Decoctions of the bulb	Urinary diseases, stomach ache, diarrhoea, enema for low back pain and healing of fractures
Gunnera perpensa L.	Leaves, rhizomes, roots, and stems	Antenatal and postnatal medicine, uterotonic, stomach ailments, menstrual pain, stomach bleeding, rheumatic fever, and topical application for wounds
Harpagophytum procumbens (Burch.) DC. ex Meisn.	Leaves	Antirheumatic, anti-inflammatory, weakly analgesic, bitter tonic, wound-healing
Heteropyxis natalensis Harv.	Roots	Leaves for colds, weaning; roots for nose bleeds and bleeding gums, menorrhagia
Hoodia gordonii (Masson) Sweet ex Decne	Eaten raw, spines must first be removed	Appetite and thirst suppressant
Hypoxis hemerocallidea Fisch. & Avé-Lall.	Roots	Emetic to treat bladder disorders, dizziness and insanity, traditional tonic, prostate hyperplasia
Kigelia africana (Lam.) Benth.	Seeds, bark and fruit extracts	Powdered fruit applied to treat sores, wounds and rheumatism; bark used to treat dysentery and stomach ailments (skin care, cosmetic)
Leonotis leonurus (L.) R.Br.	Flower and leaves	Coughs, colds, influenza, asthma, bronchitis, high blood pressure, headache, viral hepatitis; topically applied to treat skin disorders and cramps
Lippia javanica (Burm.f.) Spreng.	Leaves, stems and twigs	Fever, cough, colds, bronchitis, influenza, measles, rashes, malaria, stomach ailments, headache (insect repellent)
Lobostemon fruticosus (L.) H.Buek.	Leaves	Wound-healing, traditional multi-purpose plaster, ringworm
Mesembryanthemum tortuosum L. (syn. *Sceletium tortuosum*)	Leaves	Hypnotic, sedative
Ocotea bullata (Burch.) Baill	Stem bark	Headache, diarrhoea; emetic for emotional and nervous disorders
Olea europaea L. subsp. africana (Mill.) P.S.Green	Dried leaves and the oil of the fruit	Anti-hypertensive, diuretic, tonic, diarrhoea, sore throat
Pelargonium sidoides DC	Roots	Tuberculosis, diarrhoea (bronchitis, infections of the upper respiratory tract)
Prunus africana (Hook.f.) Kalkman	Bark	Chest pain, benign prostate hyperplasia
Sclerocarya birrea (A.Rich.) Hochst	Roots and bark	Stomach ailments, diarrhoea, dysentery, fever, malaria, general tonic (diabetes)
Securidaca longepedunculata Fresen	Roots	Cough, chest complaints, rheumatism, toothache, headache, wounds and sores
Siphonochilus aethiopicus (Schweinf.) B.L.Burtt	Seeds, leaves and bark	Colds, cough, influenza, hysteria, pain, asthma, dysmenorrhoea, anti-inflammatory, bronchodilatory, traditional antimalarial
Sutherlandia frutescens (L.) R.Br.	Leaves and stems	Adaptogenic tonic, traditional general tonic, traditional cancer tonic, skin disorders, eye disorders, diabetes, numerous other ailments
Trichilia emetica Vahl	Leaves	Stomach ailments, dysentery, kidney ailments, indigestion, fever, parasites; poultices for bruises and eczema; seed oil for rheumatism
Tulbaghia violacea Harv	Leaves and bulbs	Colds, fever, asthma, tuberculosis
Warburgia salutaris (Bertol.f.) Chiov	Stems, burning bark, root bark, dried and ground to a snuff and leaves	Coughs, colds, chest ailments, influenza, rheumatism, malaria, venereal diseases, headache, toothache, gastric ulcers (antibiotic, general tonic)
Xysmalobium undulatum (L.) W.T.Aiton	Roots	Diarrhoea, dysentery, stomach cramps, and headache

Source: Van Wyk, B.-E., 2008, 'A broad review of commercially important southern African medicinal plants', *Journal of Ethnopharmacology* 119 (2008), 342–355.https://doi.org/10.1016/j.biocon.2018.09.018

antifungal properties of the species, and the medicinally active ingredients are found in the bitter-taste roots of the plants (Mativandlela, Lall & Meyer 2006).

However, the rich resource of medicinal plants is decreasing at an alarming rate because of over- exploitation (Afolayan & Adebola 2004). Among many of the species which are unsustainably harvested and exploited is *P. sidoides* (Lewu, Adebola & Afolayan 2007). Like many other medicinal plants, *P. sidoides* has experienced extensive wild harvesting because of the increasing international demand (Moyo & Staden 2014), thus, leading to localised overexploitation of its wild populations in Southern Africa. The species has popular usage for the treatment of respiratory related ailments, such as bronchitis and asthma (Lawal et al. 2020), hence, the widespread traditional knowledge associated with the plant

and its uses across cultural groups and geographical areas (Hutchings et al., 1996). *P. sidoides* stands apart from the rest of the genus, not only because of its dark, maroon-red to black petals, but also because that it has been developed into a highly successful, evidence-based medicinal plant (Van Wyk & Brendler 2008).

Methods

A comprehensive literature search involving mainly electronic and library sources of information were used to collate and synthesise published data

Review findings

Historical background of *Pelargonium sidoides*

Pelargonium sidoides commonly called geranium are native to South Africa, and in the 17th century, they made their way to Europe, where they remain popularly planted as ornamentals (Southern Living Editors 2022). It is understood that there are between 250 and 300 species from which several thousands of cultivars have developed (Brendler & Van Wyk 2008). These plants, often referred to by their original Khoi-Khoi name *rabas*, were among the first to be recorded by early travellers such as van der Stel (1685) and Thunberg (1773). Of the 35 indigenous medicinal plants that have been accurately recorded at the Cape in the period 1650–1800, no fewer than six are species of *Pelargonium* (Scott & Hewett 2008). Although the indigenous knowledge about this plant has not yet been thoroughly recorded, it is believed that knowledge has been in existence for a long time (Brendler & Van Wyk 2008). In 1897, an Englishman, Charles Henry Stevens who was diagnosed with tuberculosis came to South Africa in search of a cure. He met a traditional healer Kijitse in South Africa who gave him a mixture made from the *Pelargonium* roots, which amazingly cured him (Secheyahe 1930). After 3 months, Stevens started gaining weight and left Cape Town to England with a stock of the tubers. Upon his return to England, he was declared healthy by his doctor. Stevens then set about commercialising a remedy based on the healer's preparation which he called 'Stevens' Consumption Cure' or alternatively 'umckaloabo' (Van Niekerk & Rachel Wynberg 2012). Stevens created the term 'umckaloabo' to describe the plants. He brought his excitement from healing and his newfound tincture over to Europe and started marketing it as 'Stevens' Cure'. Accordingly, it is claimed to be a derivation from isiZulu *umKhuhlane*, a term for various ailments with symptoms like fever, cough, among others, and *uHlabo*, stinging breast pain (Brendler & Van Wyk 2008). Though he had support from some quarters, controversy ensued about the efficacy of the remedy, leading the British Medical Association to accuse him of quackery and fraud, and ordering him to pay substantial costs (BMA 1909). Nonetheless, Stevens continued to market the remedy with some success until his death in 1942, after which his son sold the company (Newsom 2002). Subsequently, 'umckaloabo' was tested and its healing properties were verified by Dr Sechehaye of the University of Geneva in the 1930s (Bladt & Wagner 2007). These findings and further studies prompted the establishment of JSO–Werks Regensburg (ISO-Arzneimittel), that began importing *P. sidoides* and *P. reniforme* roots from South Africa for the production and sale of 'umckaloabo' (Vonarburg 2007). ISO-Arzneimittel later became a part of the Schwabe group. The true botanical origin of 'umckaloabo' remained unidentified until 1974 when it was identified as *P. reniforme*. In 1998, it was announced that the true origin could also be *P. sidoides*. Various studies on the pharmacological activity and the clinical efficacy of 'umckaloabo' on a range of respiratory conditions have been published (Kolodziej 2007). 'Umckaloabo' was later developed into a fully licensed herbal medicinal product (EPs® 7630 'umckaloabo'), and Linctagon® in Germany and South Africa respectively, to treat infectious diseases of the respiratory tract.

Botany of *Pelargonium sidoides*

Pelargonium sidoides is a perennial evergreen plant with velutinous, rosulate, fairly aromatic and velvety leaves arranged in a basal cluster (Van der Walt & Voster 1988). Flowers of *P. sidoides* plant are mostly present from October to January (Motjotji 2011). The species is rare in gardens but represented by the cultivar 'Alta of Roses' with a more upright habit, rougher but strongly aromatic foliage and deep to red in colour flowers (Mthembu 2017). It is a popular and convenient ornamental plant, and it is also one of the species of *Pelargonium* cultivated as a source of essential oils (Van der Walt 1977).

Pelargonium sidoides usually grows in short grasslands and sometimes with shrubs and trees on stony soil varying from sand to clay-loam, shale or basalt. Though evergreen, they die back during droughts and winter. *Pelargonium sidoides* survives harsh environmental conditions because of its well-developed tubers or rhizomes (Mativandlela et al. 2006; Van der Walt & Demarne 1989). *Pelargonium sidoides* is a geophyte and has condensed underground, root-like stems which are the main locus of the active ingredients that makes this plant so popular (Van der Walt & Vorster 1988; Dreyer & Marais 2000). At first glimpse, the plant is hard to distinguish from a closely related species, *P. reniforme* (White et al. 2008). There has been some confusion about the correct identity of *P. sidoides*, mainly because Harvey and Sonder (1860) included it (as a variety) within a broad concept of *P. reniforme*. Both species are very similar in appearance *However, P. sidoides* forms a rosette-like plant with crowded leaves. It is very similar to some forms of *P. reniforme,* but easily distinguished by its deep red, rather than pink petals (Mativandlela 2005). *Pelargonium reniforme* can only be found in the dry flats and grasslands (where there is not enough regular raifall to support the growth of the plant) extending between Knysna and Umtata (Van der Walt 1977). *Pelargonium sidoides* root wood is dark brown, while that of *P. reniforme* has markedly lighter root wood or that appears yellow (Bladt 2007).

The thickened underground root system penetrates deep into the ground and seems to be a special adaptation which enables the plant to survive grass fires which occur

throughout much of its habitat range (Motjotji 2011). In cross section, young tubers are white, followed by the pink stage and gradually change to the deep red colour at maturity (Van Niekerk 2009). *Pelargonium sidoides* is endemic to South Africa and Lesotho (Brendler & Van Wyk 2008; Seleteng-Kose, Likoetla & Motjotji 2023). It grows naturally in summer rainfall areas with average annual rainfall ranging from 200 to 800 mm per annum (Mativandlela 2006).

Uses of *Pelargonium sidoides*

The tuberous, woody roots of *P. sidoides* are traditionally used in the Eastern Cape Province of South Africa for their medicinal properties (Gerardy 2002), particularly among the Xhosa people who use infusions of the roots for the treatment of diarrhoea, dysentery, colds, and lung infections including tuberculosis (Bladt 1977). The traditional knowledge associated with this plant and its uses is widely spread across cultural groups and geographical areas (Hutchings et al. 1996). Despite the fact that the information about this plant has not yet been thoroughly documented, it is believed that knowledge has been in existence for a long time (Brendler & Van Wyk 2008). Recent research has shown that an extract from the roots of this medicinal plant activates human monocytes, stimulating the innate immune defence (Witte et al. 2015). Decoctions and infusions of the roots enjoy a wide reputation among traditional healers and are highly valued by the Southern African native population. They are admired for its curative and palliative effects in the treatment of respiratory tract infections, gastrointestinal disorders, bronchitis, common cold and sinus infection, while the aerial parts are employed in wound healing (Hutchings 1996). In addition to being both hydrating and regenerative for skin diseases, it may be used to treat shingles, herpes, eczema, dry skin, and athlete's foot (Miller 2002).

Based on research, proven efficacy and safety, clinical trials and patents, products from *P. sidoides* are marketed in Germany with great success, with annual turnover rising from €8 mil. in 2001 to €80 mil. in 2006 (Brendler & Van Wyk 2008). After years of clinical research, a drug internationally known as 'umckaloabo' (taken from the plant's local name in South Africa) is now manufactured using the roots of *P. sidoides* (Brendler & Van Wyk 2008). 'Umckaloabo' received a full market authorisation by the German Drug Regulatory Agency in 2005 and is listed in European Pharmacopoeia. The drug is marketed in Germany by Spitzner Arzneimittel (Kolodziej 2007). The health benefits of this medicinal plant continue to stimulate more interest and demand, especially in developed countries. For example, *P. sidoides* has been formulated into phytopharmaceuticals, namely EPs® 7630 ('umckaloabo' ®, Dr. Willmar Schwabe GmbH & Co. KG Pharmaceuticals, Germany) and Linctagon® (Nativa, South Africa), which originate from the roots of the species (Moyo & Van Staden 2014). Furthermore, Helfer et al. (2014) also mention that *P. sidoides* root extract has shown anti-HIV-1 properties.

Propagation of *Pelargonium sidoides*

Propagation of the species could be considered one way of reducing collection pressures on the wild populations (Government gazette 2013). Field research has shown that *P. sidoides* can be easily propagated from seed, stem cuttings, root cuttings and leaf cuttings (Mofokeng 2015; Pholo et al. 2013). Plant tissue culture techniques provide options for mass propagation of plant species for conservation and plant improvement purposes (Moyo et al. 2013). Each of these methods has strengths and limitations for large scale propagation (Keret 2020). Though the seeds germinate with ease, it is currently not the solution for large scale propagation (Moyo 2014). The availability of large quantities of seed is problematic since pollination outside of the natural habitat of the plant is nearly non-existent (Miller 2002).

The study of Moyo et al. (2013) was to develop a clonal propagation system for *P. sidoides* using explants from mature plants, with particular emphasis on the regeneration potential of N^6-benzyladenine and kinetin compared to *meta*-topolin, *meta*-topolin riboside, and *meta*-methoxytopolin riboside. The study was able to successfully develop a micropropagation system for *P. sidoides* from mature plants. Another study by Moyo et al. (2013) cloned *P. sidoides* plants *in vitro*, acclimatised under greenhouse conditions, and evaluated them for their phytochemical contents and pharmacological activity. Similarities in phenolic profiles were identified confirming the chemical signatures that characterise *P. sidoides* plants. Extracts of greenhouse-acclimatised and wild plants exhibited comparable antimicrobial and antioxidant properties. Results of this study offer promising prospects for the conservation of *P. sidoides* through large scale cultivation (via micropropagation) as well as plant part substitution. Moyo et al. (2013), Grierson and Afolayan (2005) in their study demonstrated the possibility of propagating *P. sidoides* through the use of its vegetative aerial parts. Plant propagation of the species from petioles and inflorescence shoots was achieved by direct and successful embryo to plantlet conversion. Although seed propagation of the species may be limited by their inherent low seed viability and germination potential (Godefroid Van de Vyver & Vanderborght 2010; Colling et al., 2010), the plant has high resprouting capacity when cuttings are used, thus, making it easy to propagate and produces leafy regrowth within weeks or months.

Cultivation of *Pelargonium sidoides*

The World Health Organization (WHO 1993) recommended that medicinal plants be cultivated, wherever possible, as the source of supply for the market. Commercial *Pelargonium* cultivation has several distinct advantages, most especially, ensuring supply of roots of the correct species that have documented medicinal efficacy (White et al. 2008). Cultivation of *P. sidoides* as a conservation strategy can increase yield without affecting its bioactivity, while providing nourishment for the rural communities (Mofokeng et al. 2020). Commercial growing would ensure a reliable supply of the resource to buyers (Schippmann, Leaman & Cunningham 2002).

Consumers would be assured that the material was obtained in a legitimate manner and thus, provide an opportunity for sustainable production and increased income generation for the rural poor communities providing plant material for the informal as well as commercial markets (Mofokeng et al. 2020). The most prominent advantage of cultivation over wild harvest is the potential for reducing the quantity of material extracted from the natural environment (White 2006). Cultivation requires that participants have secure land tenure, a degree of assurance that a future market exists, and the economic stability to be able to wait for the product to mature (Belcher & Schreckenberg 2007). Communities may also stand to benefit more broadly (i.e., beyond the harvesters themselves to include other community members) if advances such as improved infrastructure accompany cultivation (Wynberg 2006). Cultivation is a crucial element in conservation strategies because of increasing urbanisation, habitat loss, population growth, and industrial developments (Bairu, Amoo & Van Staden 2011). At present, cultivation of *Pelargonium* in southern Africa is not widespread (Van Niekerk & Wynberg 2012).

Mofokeng et al. (2020) study confirms that *P. sidoides* can be successfully cultivated to reduce harvesting pressure on wild populations and that increased plant population under cultivation with well-watered conditions can increase yield significantly, compared to rainfed conditions in the wild. Information on the cultivation of medicinal plants such as *P. sidoides* is, however, very limited, and therefore further research is needed. In addition, it has been reported that less active ingredient is found in the cultivated crop as compared to that collected in the wild (White 2007). Cultivated plants receive intensive care until they are harvested (McGregor 1976).

Wild harvest of *Pelargonium sidoides*

The increasing commercial demand for *P. sidoides* on the international market has led to localised uncontrolled, indiscriminate, and sometimes illegal harvesting of wild plants (Moyo & Van Staden 2014, Wynberg et al. 2012). In 2009, the medicinal plant was classified as 'Declining' on the Red Data list of South African plants (Newton et al. 2009), which was later re-classified to 'Least Concern' in 2013 (Moyo & Van Staden 2014). The escalation in demand can cause irreparable reductions to wild populations (Colling et al. 2010), which may result in a biodiversity threat to *P. sidoides*. There is currently a lack of information on the impacts of wild harvesting of *P. sidoides* on the ecosystem in which it occurs (Government gazette 2013). There has been a great increase in demand for the plant for both local uses and international pharmaceutical producers; therefore, the number of the collectors and its rate of harvesting have increased in recent years (Van Wyk & Prinsloo 2018). Based on science, proven efficacy and safety, clinical trials and patents, products from *P. sidoides* are marketed in Germany with great success, with annual turnover rising from €8 mil. in 2001 to €80 mil. in 2006 (Brendler & Van Wyk 2008). Parceval South African Company dries and desiccates the roots before exporting them to Schwabe in Germany, where Umckaloabo is manufactured. In Germany, a 100 mL bottle of Umckaloabo syrup costs 30, 68 Euros (R380.85) (African Centre for Biosafety 2008).

Pelargonium sidoides in the wild is the main source of raw materials, hence making the wild stock susceptible to over-exploitation (White et al. 2008). A variety of harvesting tools such as pickaxes, spades or any other sharpened metallic tools are used for uprooting the plants to collect the tubers during harvest (Motjotji 2011). However, at a local level, instances have been recorded of damage caused to local ecosystems through uncontrolled and illegal harvesting being carried out by untrained harvesters (Newton 2009). It has been reported that in the Grahamstown area (Eastern Cape Province, South Africa), approximately 14 000 hectares of farm, municipal, and government land had been repeatedly stripped of *P. sidoides* species, beyond possibilities of re-growth and regeneration (Mayet 2010). De Castro et al. (2010) verified previous observations that local extinctions occur when harvesting is done too regularly. Because of the frequent and strong harvest pressure, less than 20% of the plants at three of the 61 locations studied recovered following harvest.

Over the years, the species has experienced extensive wild harvesting by plant gatherers for personal use and income generation, which has resulted in localised population declines (Williams, Victor & Crouch 2013). Most of the gatherers are from rural communities, with no other source of income and thus, rely heavily on natural resources for sustenance (Mofokeng et al. 2020). Although harvesting and sales of *P. sidoides* from the wild brings financial returns to the people, the consequences of uncontrolled harvesting may affect the availability for future generation (Ghimire, McKey & Aumeeruddy-Thomas 2004).

Current legislative measures in South Africa and Lesotho generally require permits for harvest, transport and export. However, legislative and institutional constraints in Lesotho and the lack of effective management systems in both countries have resulted in the issuing of few permits and confusion about the permit issuance procedure (Newton et al. 2008). The increased rate of wild harvesting diminishes the natural population, thus, making the exploitation of *P. sidoides* unsustainable.

Water requirements of *Pelargonium sidoides*

Water is an important factor affecting plant growth, yield and distribution of different species (Mofokeng et al. 2015). Plant response to water scarcity might take the shape of physiological problems, such as decreased transpiration and root development (Shao et al. 2008). However, water shortage is a serious concern for water scarce countries; South Africa being water scarce country, where drought (temporary or permanent drought) is already posing a threat. This is because of significant uncertainties about the level of water supply for future generations (Fereres & Soriano 2007). The study of Hall (2021) mentions that *Pelargonium* plants are

drought-tolerant and do not need to be watered too frequently. Soil should be sufficiently dry before watering again, but it is important that roots do not dry out completely. However, there is no cultivation guidelines for *P. sidoides*. Hence, the water requirement of *P. sidoides* is not known.

Another study by Mofokeng et al. (2017) showed that *P. sidoides* plants can employ several survival strategies when exposed to water stress. During a prolonged exposure to water stress, the plants reduced plant growth and stomatal conductance, and were therefore not affected by terminal water stress. This is an important finding since the harvested roots are always supplied in a dry state. Thus, *P. sidoides* farmers can save on irrigation costs by reducing watering rate and frequency, as there was no significant difference in dry root yield.

Research on the effect of water stress reported that water deficit did not result in a significant increase in umckalin concentration in *P. sidoides* cultivated under greenhouse condition. Rather, the control plants (well-watered) yielded umckalin concentrations similar to that of wild harvested plants from high rainfall area, with an advantage of higher growth rates (Brendler & Van Wyk 2008; White 2006; White et al. 2008). The regrowth of replanted shoots from which a standard proportion of the root was harvested showed that water availability affected shoot survival but not root regrowth rate. However, the regrowth rates were found to be low, questioning the viability of wild harvest (White 2006). Ingarfield (2018) reported that a certain level of water deprivation (plants watered every 24 days) gave highest values of polyphenols. Whereas, medium to low watering resulted in higher leaf content in *P. sidoides*. All these information are important to understand the potential manipulation of the plants at different stages of development.

Conclusion

The increased rate of wild harvesting diminishes the natural population, thus, making the exploitation of *P. sidoides* unsustainable. Enhancing propagation and encouraging cultivation, especially at the village level, is one of the most effective ways to prevent overexploitation of plant natural resources. *P. sidoides* has been used as a phytomedicine for many different human illnesses for a very long time. These plants' tubers are a plentiful source of phenolic acids, proanthocyanidins, and coumarins, which are essential to their beneficial characteristics. With the demand for items containing *Pelargonium* increasing, it is anticipated that management of the resource through actions like cultivation would increase. This study emphasised the value of growing *P. sidoides* since it will not only ensure the species' conservation and long-term usage but also enhance rural harvesters' quality of life. The ability for natural regeneration appears to be outpaced by the rate of harvesting. However, while cultivation could aid in addressing ecological difficulties, equitable problems may not always be solved by it. It is doubtful that rural populations would be able to cultivate *Pelargonium* without considerable subsidies and support since cultivation requires significant inputs, such as seedlings, fertiliser, water, and land. Therefore, it is necessary to spread the knowledge about the matter, because participants in cultivation must have stable economic standing, a degree of certainty that a future market exists, and secure land tenure in order to wait for the product to develop.

In addition, water is also required for a successful cultivation. In a nation like South Africa that struggles with water shortages, information on *P. sidoides* usage of water is still quite limited. In order to create proper irrigation management that will assure maximum output, it is crucial to understand the water demands of crop. This will relieve some of the burden on the natural populations.

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Competing interests

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Authors' contributions

Y.M. contributed to conceptualisation, methodology, formal analysis, writing – original draft, project administration, data curation, and writing – review and editing. M.N.L. and A.R.M. contributed to conceptualisation, methodology, writing – review and editing, and supervision. F.L. contributed to conceptualisation, methodology, visualisation, writing – review and editing, supervision, and funding acquisition.

Ethical considerations

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Data availability

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Disclaimer

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