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Medicinal plant cultivation for sustainable use and commercialisation of high-value crops

Many traditional healing systems are based on natural biological resources, and there is a general shift in most parts of the world towards natural medicine, with direct implications on the demand and supply of medicinal plants. This review highlights the economic importance of medicinal plants, their contribution to healthcare systems, and potential opportunities for rural economic development through cultivation. A systematic literature review with specific search terms related to medicinal plants was used to collect scientific and non-scientific information from peer-reviewed literature and grey literature databases. The findings indicate that trade in medicinal plants is increasing, and although they are considered minor crops compared to major food crops, their value is among the highest in the list of traded plants globally. The trade also serves as a revenue source for many rural livelihoods, with women playing a significant role. Medicinal plants contribute to primary health care in many developing countries, and they are also an essential source of modern drug discovery. Cultivation of medicinal plants offers emerging rural farmers an opportunity to grow these plants as new and alternative crops, thus reducing unsustainable wild harvesting and competition with established commercial farmers who mostly focus on food crops. Furthermore, medicinal plant cultivation should be promoted as one of the options for local economic development and sustainability through job creation, the revival of the rural economy, and income generation for small businesses, such as the transport businesses, involved in the value chain. Land accessibility, financial resources, and direct market access for rural communities can elevate their contribution to the industry. Formalisation of the lower levels of the medicinal plant trade is also recommended.

Significance:

- Cultivation is a viable option for biodiversity conservation of medicinal plants and ensuring a good-quality supply of plant materials.
- Cultivation of medicinal plants – a source of natural products used in product development – can contribute to job creation, income generation, and rural economies in developing countries.
- This review underlines the importance of medicinal plants in product development, the contribution of the industry to economies of different countries, and the potential for cultivation.

Introduction

Plant biodiversity fulfils various needs for daily human livelihoods, including health care.¹ The contribution of medicinal and aromatic plants to the agriculture output is relatively small compared to food crops. Still, their value in terms of volumes traded is among the highest in the list of traded plants. Thus they are amongst the high-value minor crops.² Notwithstanding the potential contribution to national agriculture through commercial cultivation, medicinal plants contribute to primary health care in many developing countries, and they are also an important source in modern drug discovery.³ There is a general shift in many countries from acute disease incidences and management, towards chronic disease incidence, with implications on pharmaceutical demand and supply.⁴ Many traditional healing systems are based on natural biological resources, particularly plants. For example, 20% of India's flora, 18.9% in China, 17.1% in Vietnam, 16.5% in Sri Lanka, 15.5% in Thailand³, and 10% in South Africa⁵ are used as medicinal plants. Guided by the indigenous use of many plant species, several plant-based health supplement products are produced and marketed globally with the resultant increasing demands on good-quality plant raw materials.

Developmental pressure, with related habitat destruction and unsustainable harvesting, result in biodiversity loss.⁶ Cultivation of medicinal plants provides several opportunities, including preservation of indigenous knowledge, access to primary health care through traditional medicine, local economic development, and job creation.^{7,8} The developments mentioned above can be achieved through micro-enterprise development by indigenous and rural communities.⁹ However, the cultivation of medicinal plants can sometimes be unprofitable due to competition with freely accessible wild-harvested plant materials.¹⁰ Commercial wild harvesters can cause significant damage to medicinal plant populations and the environment.⁶ This could be attributed to the pressure to generate income, with less concern for conservation. Recent statistics on medicinal plant trade and consumption are scanty, with limited information as medicinal plant trade is mostly part of an informal economy.⁷ This review highlights the global trade and use of medicinal plants, the effects of cultivation practices on bioactivity, and perspectives on cultivated medicinal plants.

Methodology

A systematic literature review was used to collect scientific and non-scientific information related to the aim of the study. Search terms were created to extract sources from peer-reviewed literature on the Web of Science, Scopus, Science Direct, and grey literature databases such as Google. The search terms were “commercialization of medicinal plants”, “trade in medicinal plants”, “cultivation of medicinal plants”, “use of medicinal plants”, and “acceptance of cultivated medicinal plants”. Scientific articles and non-scientific literature published between 1995 and 2021, at the time of submission of the manuscript, were considered. To minimise non-target articles,

less relevant publications were excluded after scanning through their titles and abstracts. To develop a list of selected medicinal plants and compounds isolated from their different parts for medicinal use, medicinal plants that were already commercialised or had the potential to be commercialised, originating from Africa or naturalised through cultivation, were considered.

The global trade in medicinal plants

The development of plant-based drugs has been listed as the next significant development in commercial biotechnologies as it would offer an opportunity to supply low-cost, quality pharmaceuticals to marginalised communities in developing countries.⁴ The trade in medicinal plants occurs at three primary levels: national (within countries), regional (across borders on a continent), and international (the formal export trade).¹¹ At all levels, the value of medicinal plants is not only in financial income but also in health care, cultural identity, and livelihood security. The global trade in medicinal plants is dominated by a few countries, with three international trade centres: Germany, the USA, and Hong Kong.¹²

The formal trade in plant-based medicine has had an attractive return on investment over the past years. The global traditional medicine industry was estimated to be worth USD60 billion in 2006.² In 2014, the worldwide trade in plant-based medicine was worth USD940 billion.⁴ This shows an increase in the global trade from the estimated USD30 billion in 2000.¹³ Accurate estimates in the trade are difficult because medicinal plants are also used for other non-medicinal purposes, and also because the increased global interest in medicinal plants has led to an 'underground' trade which is mostly not recorded.¹³ In general, the reports show an increase in investment in the trade by individual countries, despite differences in the figures reported. For example, compared to USD800 million in 1980⁴ and USD1.6 billion in 1999¹⁴, USD17 billion was spent in the USA on traditional medicine in 2000¹⁵, which was a relative increase of 20–25%. The traditional Chinese medicine industry alone was estimated to be worth USD83 billion in 2012.¹⁵ In India, the trade in herbal products was estimated to be worth USD120 billion in 2015 and is expected to reach USD7 trillion by 2050.¹⁶ In general, Europe imports from Africa and Asia an estimated 400 000 tonnes of medicinal plants per annum, to the value of USD1 billion.^{2,17} The supply of raw materials in Germany was approximately 30 700 tons with a value of EUR84 million (USD 101 938 200) in 2019, with 90% of the plant materials being imported.¹⁸ Pakistan exported therapeutic plant materials valued at USD10.5 million and similarly imported materials valued at USD130 million in 2012.² Overall, high-income countries such as Germany, Japan, and USA, with only 15% of the world population, dominated the formal trade with an increase in shared value from 89.1% in 1985 to 92.9% in 1999.⁴ In contrast, the combined shared value of low-income countries for the same period decreased from 10.9% to 7.1%.⁴ The international status, in terms of demand, of many South African medicinal plant species is increasing. For example, wild ginger (*Siphonochilus aethiopicus* (Schweinf.) B.L. Burtt) and African potato (*Hypoxis hemerocallidea* Fisch., C.A.Mey. & Avé-Lall.) have become more prominent as a growing number of venture companies started utilising them in their formulations.¹⁹

The national and regional trade is characterised by informal markets (Figure 1) managed by harvesters, hawkers, healers, small traditional medicine chemists, and large traditional medicine markets. The majority of people, between 200 000 and 300 000 in South Africa alone, involved in the value chain of this 'hidden economy' come from rural households and disadvantaged socio-economic backgrounds.^{19,20} The informal medicinal plant trade in Africa has a significant socio-economic role as it enables millions of people living in rural areas to generate income.²¹ In 1998, an estimated 20 000 tons of South African medicinal plant materials were traded at a value of USD38 million.²¹ Thirteen years later, in 2011, the total value of the South African bioprocessing segment, which includes primary and secondary processing of indigenous resources, was estimated at ZAR482 million.²² Based on the average 2011 currency exchange rate (ZAR7.27 = USD1²³), this translated to USD66 million. There are, however, variations reported in the value of

the medicinal plant trade. For example, other reports estimated that the total value of the trade was ZAR2.9 billion per annum in 2006²⁴, whereas Myles et al.²⁵ estimated the value to be approximately ZAR520 million in the same period (2006 exchange rate²³: ZAR6.78 = USD1). This could be because the trade is mostly informal and, at times, there is supplementation of the plant materials in South Africa with materials from neighbouring countries such as Botswana, Lesotho, Zimbabwe, and Mozambique.²⁴ Most of the cross-border trade in medicinal plants that was reported between Malawi and other SADC countries such as Botswana, Lesotho, Zimbabwe, Zambia, Mozambique, and South Africa, is illegal²⁶ and thus poorly recorded. For example, although there was no record of trade in *Mondia whitei* (Hook. F.) Skeels – an endangered species of high demand in South Africa – the government of Malawi reported evidence of trade in this species between the two countries.²⁶



Figure 1: (a) Traditional medicine products displayed in a small traditional medicine chemist and (b) dried plant raw materials displayed by hawkers in an informal street market.

Plant secondary metabolites and their global use in medicines

Plant secondary metabolites play an essential role in plants' interaction with the environment, protecting plants against or helping them to survive biotic and abiotic stress.²⁷ The production of secondary metabolites in plants is dependent on growth conditions and the physiological responses of plants to different environmental conditions.²⁸ Plant-specific secondary metabolites include phytoalexins, which are antimicrobial compounds synthesised by plants after infection with microorganisms, and may act individually, additively, or synergistically to improve human health.^{27,29,30} Secondary metabolites play a role in the signalling and regulation of primary metabolic pathways in plants.³¹

Natural products from plants (phytochemicals) play an important role in drug development processes. The use of some medicinal plants has led to the discovery and isolation of drugs used in the treatment of various human diseases and ailments.²⁹ For instance, artemisinin from *Artemisia annua* L. has been successfully used as an effective anti-malarial.^{28,32} Ellipticine from elliptic yellowwood (*Ochrosia elliptica* Labill.) has been used as an anti-cancer drug.²⁸ Extracts from African geranium (*Pelargonium sidoides* DC.), which contains coumarins, have promising lead candidates for developing herbal drugs for HIV management.³³ Some of the phytochemicals from African potato corms – including daucosterol, beta-sitosterol, and hypoxoside – have therapeutic properties³⁴, which have been exploited in the management of HIV/AIDS, cancer, and sexually transmitted diseases^{35–37}. *Aloe ferox* Mill. leaf gel, which contains aloin as an active ingredient, and *Lessertia frutescens* (syn. *Sutherlandia frutescens* L.; Fabaceae) containing pinitol and canavanine, were found to be promising in alleviating or preventing non-communicable diseases such as cancer, neurodegeneration, diabetes, and cardiovascular diseases.^{30,38} The cited examples demonstrate some crucial roles that plant-based medicines can play in managing chronic and acute diseases. Some plant bioactive compounds used in modern therapeutics are listed in Table 1.

Medicinal plants also have potential in combating or managing pandemic diseases of viral origin due to some plant secondary metabolite antimicrobial (antivirus, antibacterial and antifungal) properties or their attenuating effect on the disease. At least four medicinal plants (*Azadirachta indica* A. Juss., *Eurycoma longifolia* Jack, *Nigella sativa* L., and *Vernonia amygdalina* Delile) showed potential in the management of COVID-19 due to their antiviral, anti-inflammatory and immunomodulatory properties.³⁹ Four bioactive compounds, which are arabic acid, L-canavine,

Table 1: Selected medicinal plants and compounds isolated from their different parts for medicinal use

Plant origin	Compounds	Plant parts used	Medicinal uses	Commercial products	References
<i>Agathosma betulina</i> (P.J.Bergius) Pillans	Isomenthone and diosphenol	Leaf	Antispasmodic, urinary tract antiseptic, cholera, rheumatism, gout	Buchu oil, Buchu tea, Buchu powder, Buchu tincture	41, 42
<i>Aloe ferox</i> Mill.	Aloeresin A, aloein and aloin	Leaf	Anti-inflammatory, cosmetic applications	Aloe gel, aloe lumps	43, 44
<i>Artemisia afra</i> Jacq.	Eucalyptol, α -thujone, β -thujone, camphor and borneol	Aerial parts	Respiratory ailments, stomach pains	Tinctures, tablets, herbal teas	44
<i>Artemisia annua</i> L.	Artemisinin	Aerial parts	Anti-malaria	Tablets, tinctures, herbal teas	32, 45
<i>Aspalathus linearis</i> (Burm. f.) R. Dahlgren	Aspalathin and aspalalinin	Leaf	Anti-spasmodic Anti-ageing and anti-eczema	Herbal teas	46
<i>Camptotheca acuminata</i> Decne.	Camptothecin	Bark and stem	Anticancer	Tinctures	47
<i>Cinnamomum camphora</i> (L.) J. Presl	Camphor	Wood	Cough, neurodermatitis, fungal infections	Oil extracts, ointments	48
<i>Coffea arabica</i> L.	Caffeine	Seed	Metabolic stimulant	Hot drinks	49, 50
<i>Curcuma longa</i> L.	Curcumin	Rhizome	Choleretic, anti-inflammatory, antioxidant, arthritis	Oil extracts	51
<i>Erythroxylum coca</i> Lam.	Cocaine	Leaf	Local anaesthetic	Medicinal drugs, tinctures	52
<i>Eucalyptus globulus</i> Labill.	Eucalyptol (<i>Cineole</i>)	Leaf	Cough treatment	Oil extracts, tinctures	53
<i>Gastrodia elata</i> Blume	Gastrodin		Anti-convulsion, analgesic	Tuber powder, tinctures	54, 55
<i>Harpagophytum procumbens</i> (Burch.) DC. ex Meisn.	Harpagoside, harpagide, procumbide	Roots	Anti-inflammatory/analgesic	Tuber cuts/powder, tablets, tinctures	44
<i>Hypoxis hemerocallidea</i> Fisch. & C.A. Mey.	Hypoxoside	Root	Anti-inflammatory, anticancer	Harzol®	44
<i>Lessertia frutescens</i> (L.) Goldblatt & J.C. Manning (<i>Sutherlandia frutescens</i> (L.) R. Br.)	L-canavanine, arginine, GABA and D-pinitol	Seeds and leaves	Diabetes, fever, HIV/AIDS management	Tablets	44, 56
<i>Merwilla natalensis</i> (Planch.) Speta	Proscillarin A	Bulb	Antischistosomal, anti-inflammatory and anthelmintic	Unknown	57, 58
<i>Pelargonium sidoides</i> DC.	Prodelphinidin, coumarins	Tuberous roots	Cough, antibacterial and antiviral	Umckaloabo	44, 59
<i>Siphonochilus aethiopicus</i> (Schweinf.) B. L. Burtt	Siphonochilone	Roots and rhizomes	Cough, asthma, anti-inflammatory	Tablets, tuber powder	60
<i>Warburgia salutaris</i> (G. Bertol.) Chiiov.	Warburganal, polygodial, salutarisolid, muzigadial, ugandensisodial, isopolygodial, mukaadial	Stem bark	Venereal diseases, rheumatism, stomach ulcers, malarial fevers, pneumonia, diarrhoea	Tablets, tinctures	61, 62
<i>Xysmalobium undulatum</i> (L.) W. T. Aiton	Uazarin, xysmalorin, allouzarin, alloxysmalorin	Roots	Diarrhoea, hysteria, syphilis, urinary tract antiseptic, heart failure, malaria, and typhoid fever	UZARA®	63, 64

hypoxoside, and uzarin from *Acacia senegal* (L.) Willd. (syn. *Senegalia senegal* (L.) Britton), *Sutherlandia frutescens*, *Hypoxis hemerocallidea*, and *Xysmalobium undulatum* (L.) W.T Aiton, respectively, all of which are South African medicinal plants, may be exploited as therapeutic agents against SARS-CoV-2 based on their molecular modelling.⁴⁰

Globally, more than 25% of pharmaceutical drugs are of plant origin.¹¹ Between the years 2000 and 2005, five medicinal plant-based drugs were developed in the USA, and seven more were in clinical trials.³ In Germany, more than 90% of the citizenry reportedly used herbal medicines alongside pharmaceutical drugs.¹⁵ Alternative and complementary medicine, which relies on extracts from plant materials, gained popularity in America, where more than 62% of the populace was reportedly using plant-based remedies.¹⁹ Close to 50% of the Australian and French populations reportedly used traditional medicine.¹⁶ In China, approximately 40% of the consumed medicine was attributed to traditional herbal medicine.¹⁷ The Chinese government made public their intentions to integrate traditional Chinese medicine into their healthcare system by 2020.¹⁵ The intentions popularised the value of plant-based medicine in treating human ailments. Ayurvedic medicine ('Ayurveda' for short), which is one of the oldest holistic healing systems developed more than 3000 years ago in India, uses over 1200 medicinal plant species and has been included in the national healthcare system in India.^{15,16} The national health policy of Bhutan, a landlocked country in South Asia, integrates the traditional medicine system into its healthcare system, with the traditional medicine hospitals providing a free healthcare service.³ At least 90% of the Ethiopian population was reported to be using herbal remedies for primary health care.³⁰

Cultivation effects on the medicinal value of medicinal plants

The increasing threat of extinction coupled with the scarcity of several medicinal plants, such as *Warburgia salutaris* (G. Bertol.) Chiov. and *Siphonochilus aethiopicus*, as well as the related genetic loss warrants cultivation as a solution.⁶⁵ The commercialisation of selected medicinal plants and their medicinal value is driving and directing medicinal plant cultivation research (Figure 2); for example, research on understanding the growth requirements and genetics of medicinal plant species. Cultivation is a crucial element in conservation strategies due to increasing urbanisation, habitat loss, population growth, and industrial developments.⁶⁶ Cultivation of medicinal plants can provide opportunities for improving purity and quality, consistency and bioactivity, and biomass production of raw materials.⁶⁵ Sustainable production of a number of innovatively developed plant-based products is often hampered by the inconsistent supply of high-quality plant raw materials. Cultivation can improve biomass production for sustainable supply without negatively affecting the bioactivities of the medicinal plants through the manipulation of the growing conditions. For example, the cultivation of *P. sidoides* under well-watered conditions increased the total biomass significantly, without significant alteration in the content of active compounds.⁵⁷ Similar results have been reported, where greenhouse cultivation of *P. sidoides* did not result in significant reductions in umckalin concentrations compared to the wild-collected plant material.⁶⁸

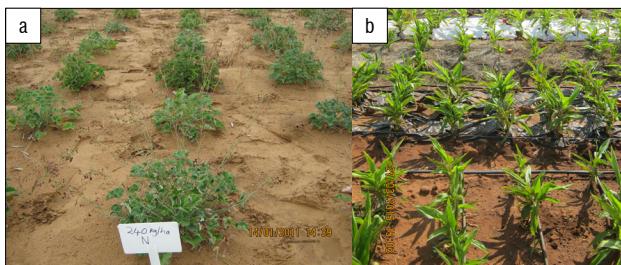


Figure 2: Cultivation research: (a) fertiliser application trials on *Pelargonium sidoides* and (b) mulching trials on *Siphonochilus aethiopicus*.

Additionally, in vitro cloned and greenhouse-acclimatised *P. sidoides* plants retained their phytochemical composition, based on phenolic compound profiling.⁶⁹ Greenhouse-grown, tissue-culture-derived tubers of

Harpagophytum procumbens (Burch.) DC. ex Meisn. had a significantly higher total iridoid content than wild-harvested tubers.⁶⁶ Active compound concentrations can be affected by a number of factors such as the ecotype, age of plant, size, and season of collection.⁶⁶ Although the tubers were collected from different sites, the results indicated that cultivation could maintain the active compound content of the medicinal plant. Application of chemical fertilisers and irrigation improved the concentrations of the potent volatile compounds in *Siphonochilus aethiopicus*.⁷⁰ A study by McAlister and Van Staden⁷¹ showed that high levels of nitrogen, phosphorus, and potassium are necessary for increasing the biomass of *Hypoxis hemerocallidea*. However, once the plants are established, the nutrient application can be discontinued to increase the hypoxoside concentrations. This perhaps suggests that hypoxoside synthesis is enhanced when plants are under nutrient stress conditions, providing an opportunity to manipulate the growing conditions by altering the nutrient supply during plant growth.

When bulbs of cultivated *Bowiea volubilis* Harv. ex Hook. f. plants were compared to the wild-harvested ones sold in markets, there was no wide variation in the biological activities.⁷² *P. sidoides* extracts from greenhouse-acclimatised plants demonstrated similar antimicrobial and antioxidant properties compared to the extracts from wild-collected plants, supporting the feasibility for large-scale cultivation.⁶⁹ The above studies indicate that the bioactivity of medicinal plants could be increased or maintained through the manipulation of agronomic practices.

Although cultivation of medicinal plants is recognised as being important for the development of the formal medicinal plant industry⁷³ and as a conservation strategy, there remains a paucity of information on the response of several commercially important medicinal plants to cultivation practices. Yet, as illustrated above, different agronomic practices, including irrigation, spacing, fertilisation, and plant growth management, influence not only yield but the quality of cultivated medicinal plants. Hence, the use of standardised and optimised cultivation procedures for each commercially important species becomes important to ensure a consistent supply of good-quality medicinal plant raw materials for the industry. However, some species are difficult to cultivate because of certain biological features or ecological requirements.⁷⁴ Other medicinal plants, particularly those whose underground parts are used medicinally, may take a long time to reach maturity, and some growers may not be able to afford to wait more than a year before harvesting due to economic feasibility challenges that may arise with initial capital investment requirement.⁷⁴ Research can play a significant role in technology development and transfer as a contribution to the medicinal plant industry and supporting the development of cultivation sites which can create jobs and revive rural economies. Availability of and access to plant materials can also contribute to the preservation of the indigenous knowledge related to various medicinal plants through continued use and generational information dissemination.

A paradigm shift on the use of cultivated medicinal plants?

Many users of traditional medicine view cultivated medicinal plants with much uncertainty, and this is because they are aware of the effect of the environment on the 'medicinal power' of the plants.⁷⁵ Many refer to the risk of 'metaphysical' dangers destroying the 'medicinal power' of medicinal plants cultivated outside their natural environment.²⁴ For example, nitrogen application resulted in reduced and unstable quantities of the active compounds in *Salvia miltiorrhiza* Bunge compared to the content in wild populations.⁷⁶ Such results highlight the need for further investigations into environmental factors or stimulus of secondary metabolites, such as water stress, soil type, and shading, which could influence the active ingredient quantities. Nonetheless, traditional healers and traditional knowledge holders are also aware that traditional health care is at risk because medicinal plants are becoming scarce.^{76,77} For example, traditional healers in Zimbabwe recommended the cultivation of two threatened species, *Warburgia salutaris*, and *Alepidea amatymbica* Eckl. & Zeyh., to meet future demands of the species.⁷⁸ Furthermore, as many as 98 medicinal plant species were listed as being 'allowed' to be cultivated, whereas 68 were 'not allowed' to be



cultivated by traditional healers in KwaZulu-Natal and Gauteng Provinces of South Africa.⁹ Cultivation of medicinal plants has been recommended in many platforms, by traditional health practitioners, leading to efforts by the South African government to develop medicinal plant nurseries in various provinces.

Kelatwang⁷⁵ reported that 77% of the traditional healers interviewed appreciated a decline in populations of medicinal plants, a further indication of their understanding of the risk of extinction of some medicinal plants. About 69% of traditional healers interviewed in a survey by Dzerefos et al.⁷⁹ perceived a decrease in populations of medicinal plants, and the development of medicinal plant nurseries was recommended as the majority (58%) of the traditional healers mentioned that nursery-grown plants were acceptable for use. It seems that traditional health practitioners are now accepting cultivated medicinal plants, as 83% of those interviewed by Nefhere⁸⁰ showed interest in cultivating the plants, whereas 80% were willing to buy cultivated medicinal plant species. Similarly, 74% and 83% of the traditional healers and traders, respectively, accepted cultivation as a solution for declining medicinal plant populations.¹⁰ Furthermore, 88% of street traders and vendors of medicinal plants were willing to buy cultivated medicinal plants.⁸⁰ Due to the time requirement of cultivation, 58% of the interviewed traditional healers and traders recommended farmers for commercialising medicinal plant cultivation.¹⁰

On the other hand, pharmaceutical companies need consistency in the quality and market value of herbal products.³⁰ Appropriate standard operating procedures and proper management of raw materials through cultivation have been advocated as a strategy for quality assurance because medicinal plant materials can be collected from the same area and grown under the same conditions over a period. The optimisation of propagation and cultivation techniques will ensure the supply of good-quality planting materials for local growers and the supply of good-quality harvested materials to the industry.¹⁴ Cultivation of medicinal plants is of great interest to pharmaceutical companies as it allows for the sustainability of supply, reliability in botanical identification of the plant materials, and guaranteed chemical homogeneity. At the same time, it allows for optimisation of secondary metabolite production through manipulation of the growing plants' environment.^{14,24,76} Cultivation can also provide an opportunity for increasing the yields of secondary metabolites. As an example, the 'trichome management' technique not only increased biomass yields of leaves and stems and the related glandular trichome density, but it also increased the production and alkaloid (camptothecin) yield in trichomes of *Camptotheca* species.⁷⁶ The need for increased cultivation is a reality. For example, in Germany, 750 farmers were reported to be cultivating medicinal plants in a total area of 12 240 ha, and this area was reported to be only 12% of the area required to meet the industry needs¹⁸ as domestic consumption was increasing.

Recommendations and conclusion

South Africa is faced with challenges in job creation, enterprise development, and revival of the economy. The medicinal plant industry can play a critical role in addressing these challenges as farming is a labour-intensive sector. The medicinal plant industry makes significant contributions to the economies of developing countries, such as South Africa. This contribution is through job creation, rural economy revival, and income generation for small businesses, such as the transport businesses, involved in the value chain. Furthermore, rural communities use medicinal plants for primary health care, as they are affordable and accessible. Cultivation of medicinal plants, which are in most cases harvested unsustainably from the wild, offers opportunities over and above the conservation of the species. These opportunities include more jobs, as more people will be needed to maintain the cultivated fields, increased income, and improved livelihoods of communities. Better prices can also be negotiated because quality and traceability can be guaranteed. However, land, financial resources, and direct market access for rural communities should be addressed as these can also unlock the industry. Research efforts optimising practices for improved yield without compromising quality should be intensified with appropriate funding support for technology development

and transfer. In South Africa, different research institutions, government departments – such as the Departments of Science and Innovation (DSI), Trade, Industry and Competition (DTIC), Small Business Development (DSBD), Forestry, Fisheries and Environment (DFFE) – in collaboration with knowledge holders, are already putting in significant efforts in an attempt to formalise the medicinal plant industry. However, there is room for improvements, especially to ease the administrative and compliance burden placed on researchers. Government regulations should be balanced to protect the environment but also to promote sustainable use of natural resources. With enough support, research findings can inform conservation and biodiversity management strategies for effective protection and efficient use of South African biodiversity.

Oversupply of medicinal plant materials can have a negative impact on prices. Therefore, production needs to be managed in relation to market demand. It is also essential to formalise the local medicinal plant trade, especially because traditional health practitioners are starting to accept cultivated medicinal plants so that the contribution to the economy can be recognised. The local trade can be used to develop the emerging growers of medicinal plants, such that they can understand the industry and then graduate to the cross-border trade and ultimately to the international trade where they can supply international pharmaceutical companies.

Competing interests

We have no competing interests to declare.

Authors' contributions

M.M.M.: Conceptualisation; writing – the initial draft. C.P.d.P.: Critical review; commentary; writing –revisions. H.T.A.: Conceptualisation; review of the draft. S.O.A.: Critical review. S.N.M.: Inputs in writing the initial draft. K.M.P.: Inputs in writing the initial draft. P.W.M.: Critical review, commentary; writing – revisions.

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