Cultivation of medicinal plants in South Africa: A solution to quality assurance and consistent availability of medicinal plant materials for commercialization

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INTRODUCTION

Plants have been of great importance as a source of medicine since the time of human civilization and since then their products are being used for different purposes such as food, shelter, clothing, health care and as agrochemicals (Kamble et al., 2010).

Plant materials used for medicine include the active ingredients of roots, stems, leaves, seeds and barks of trees in various combinations (Ngarivheme et al., 2001). Medicinal plants are plants that have healing properties and contain mixtures of phytochemicals (Secondary metabolites) that may act individually, additively or synergistically used to treat some illnesses (Mohammed and Mundanthra, 2013).

Presently, medicinal plants are gaining popularity globally as a source of raw material for pharmaceuticals and traditional health care systems (Kandari et al., 2012). According to the World Health Organization (WHO), about 80% of the world population relies (solely or partially) on traditional medicine for their primary health care and more than 85% of herbal medicines used in traditional health care systems are derived from different parts of medicinal plants (Phondani et al., 2014).

In this regard, there has been an increasing interest worldwide in traditional system of medicine including South Africa, with substantial increase in the use of herbal-derived medicines, supplements and cosmetics in communities (Fisk et al., 2014).

In the recent decades, there has been an indiscriminate harvesting, over-grazing and uncontrolled commercialization of medicinal plant species from the wild (Barata et al., 2011). Indiscriminate harvesting of medicinal plants has led to an increasing trend in habitat loss locally and globally due to environmental degradation and encroachment of alien invasive species which are adversely affecting the availability of medicinal plant in the wild (Phondani et al., 2016).

In South Africa, millions of people in both rural and urban communities mostly rely on traditional medicine for their...
primary health care needs due to their easy accessibility and affordability of plant materials with good knowledge and know-how amongst the local communities (Mahomoodally, 2013; Oliver, 2013). This is increasingly putting pressure on wild population with little or no mitigative measures like medicinal plant cultivation that may enhance quality, quantity, biomass production and quality control measures such as monitoring of metabolites production and optimization of production techniques.

Importance of medicinal plants

Plants are the primary source of all medicines in the world and provide mankind with new remedies (Beyene et al., 2016).

Medicinal plants are the “backbone” of traditional medicine and are considered to have some important ingredients which can be used in drug development and synthesis. They play a critical role in the development of human cultures around the world and also have a promising future because there are millions of plants around the world with yet to be discovered medicinal activities (Singh, 2015).

Traditional systems of medicine have become a topic of global importance during the past decade. Presently, in many developing countries, a large proportion of the population rely heavily on traditional practitioners, who uses exclusively medicinal plant materials for treatment of various illnesses on the account that medicinal plants are curative with no side effects (Rasool, 2012).

Although there may be the availability of orthodox medicine in these countries, herbal medicines have always upheld fame popularity for historical and cultural reasons (Hosseinzadeh et al., 2015; Vishwakarma et al., 2013).

Medicinal plants have many different characteristics. When used in the treatment of diseases, it can be synergic, supportive and preventive (Rasool, 2012). At the moment, there is an increasing interest in the field of research on the metabolomics profile of medicinal plant species due to the remarkable diversity of both chemical and biological activities of naturally occurring secondary metabolites present in different plant species. This has led to the development of novel and sensitive techniques to detect some of these biologically active ingredients with improved isolation techniques to meet human’s medicinal needs (Hosseinzadeh et al., 2015).

Trade in medicinal plants

Generally, every year more than 500,000 tons of plant materials of about 60,000 plant species are traded based on their medicinal, nutritional and aromatics properties (WHO, 2015). According to Barata et al. (2011), there has been a significant increase in the importation (US$462.8 million) and exportation (US$1034.8 million) of medicinal plants into Europe between the period 1991 to 2002. In the last three decades, there has been a substantial growth in herb and herbal product markets across the world. According to the Secretariat of the Convention on Biological Diversity, the global sales of herbal products were estimated to be US$60,000 million in 2002 (Food and Agricultural Organization, 2007).

Every year, about five hundred thousand tons of dried medicinal plants are traded internationally, with substantial quantities in South Africa’s national and local markets. More than 50% of the plants are harvested from the wild, and the demand for these materials keeps increasing (Traffic International, 2015). The utmost form of traditional medicine has always remained the use of herbs which are highly lucrative in the international market. The annual revenue of Western Europe between 2003 and 2004 was US$ 5 billion (Chaudhary et al., 2010).

The trade in pharmaceutical plants is dominated by only a few countries with three international trade centers; Germany, USA, and Hong Kong. Twelve countries make up 80% of both the exports and imports from the world market. The major markets are in the developed countries, while the bulk of pharmaceutical plants are exported from developing countries, not or only little processed from developing countries and they are of wild origin (Barata et al., 2011). The trade also contributes as a source of revenue to millions of families involved in medicinal plants collection, with women often playing the major role of supplying medicinal plant materials to pharmaceutical industries. Although accurate data is lacking, available information indicates that trade is increasingly growing especially in Europe where 90% of commercially used medicinal plant materials are collected from the wild (Traffic International, 2015).

In South Africa, medicinal plant trade is a large and growing industry. It operates in both the formal and informal sectors of the economy which involves a few stakeholders in the Eastern Cape but a greater number of commercial harvesters from Kwa-Zulu Natal, Gauteng and Western Cape provinces (Williams, 2004).

Over-harvesting of medicinal plants

Medicinal plants are being harvested in increasing volume from the wild population all over the world creating pressure on plant diversity and population in the wild. In the recent decades, the demand for medicinal plants has increased from 8 to 15% per year in Europe, North America, and Asia (Ross, 2005; Bentley, 2010).

Furthermore, over 25% of prescribed medicines in developed countries are derived from wild plant species and up to 80% of people in developing countries are totally dependent on herbal medicine for their primary
healthcare (Hamilton, 2004). In South Africa, about 72% of black South Africans rely exclusively on traditional health care system for their survival, which involves the use of medicinal plants (Mander et al., 2007). The increasing demand for herbal drugs and natural health products by the growing population, without putting in place a mitigating measure like medicinal plants cultivation may result in some of these plants going into extinction (Chen et al., 2016).

According to the International Union for Conservation of Nature (IUCN), there are between 50,000 to 80,000 flowering plant species used for medicinal purposes worldwide. Among these, about 15,000 plant species are under threats of extinction from overharvesting from the wild and habitat destruction (Bentley, 2010) and 20% of these wild resources have already been nearly exhausted with the increasing human population and plant consumption (Ross, 2005). Even though these pressures have been known for years, the accelerated loss of species and habitat destruction worldwide has increased the risk of extinction of medicinal plants, especially in South Africa as a result of the high demand by the increasingly large population.

Conservation strategies of wild medicinal plants collection

Extensive studies have been carried out on the conservation and sustainable use of medicinal plants (Larsen and Olsen, 2007; Upreti et al., 2012) and various forms of recommendations have been made regarding their conservation, inventorying and monitoring systems to coordinate both in-situ and ex-situ conservation strategies (Hamilton, 2004).

Ex-situ cultivation is practiced through seed germination and in vitro cloning. Recommendations on medicinal plants conservation have been developed on both in-situ and ex-situ conservation (Huang, 2011) with the knowledge of their geographical distribution and biological characteristics (Chen et al., 2016).

Nurseries and nature reserves are measures put in place to maintain the medicinal efficacy of plants as bioactive compounds can be influenced by intrinsic or extrinsic factors which can then be monitored thereof, while botanical gardens and seed banks are ex-situ conservation strategies for future replanting (Mohammed and Mundanthra, 2013; Maywa, 2016).

Plant diversity database which is available for an update in all provinces of South Africa has been created in order to produce a national flora that will go life on the world wide web by 2020 (Victor et al., 2014). Through the International Union for the conservation of nature (IUCN) red list category, the South African national biodiversity institute (SANBI) has created a comprehensive national plant red list for South African plants (Raimondo et al., 2009). A mandate was made to monitor plant species listed as threatened and protected species of the National Environmental Management Biodiversity Act (NEMBA) Act N0: 10 of 2004 between 2005 to 2020 by provincial and National Authorities. In 2010, the Department of Environmental affair launched a R20 million conservation project on medicinal plants species in Limpopo to promote and protect endemic medicinal plants species in South Africa through the Indigenous Knowledge System (IKS) of the South Africa Trust. Notwithstanding, the project did encountered financial mismanagement for its collapse. Moreover, despite the tremendous efforts put in place as conservation strategies, the issues of shifting from subsistence to commercial harvesting of medicinal plants materials as an employment opportunity is posing unprecedented extinction threat to the wild population as setback to the aforementioned.

Prospects of medicinal plants cultivation

There is a global increase in the demand of medicinal plant products which is estimated to worth R2.9 billion per annum (Sobiecke, 2014). In South Africa a large business venture has been created in the interest of plant derived medicines with estimated value of R270 million per annum (Dold and Cocks, 2002; Wiersum et al., 2006).

In KwaZulu-Natal, it is estimated that 1.9 tons of the indigenous African ginger containing 52,000 plants is traded annually (Mander, 1998). The aerial part of Khoi-San’s traditional plant “Buchu” is sold at $56/kg and the seeds are sold for R20000.00 per Kilogram (Moolla and Viljoen, 2008).

The ethanolic formulation of Pelargonium sidoides extracts (Eps 7630) called “Umckaloaba” is reported to be the most successful phytomedicine in the world (Van Wyk, 2011; Theisen and Muller, 2012) with a very high market potential especially in Germany recording 80 million Euros per annum (Van Wyk, 2011). The economic benefits of some South African indigenous medicinal plants is an encouragement to promote the cultivation of medicinal plants as a viable option for livelihood enhancement that needs to be addressed especially in rural communities (Lewu et al., 2007a, b). This will significantly contribute to job creation with potentials to improve South Africa’s economy (Moolla and Viljoen, 2008; Street and Prinsloo, 2012).

In this regard, medicinal plants cultivation is gaining attraction as an emerging sector of self-employment to subsistence and commercial farmers (Rashid et al., 2014). Also, there is a growing interest in medicinal plant research focusing on cultivation and processing of medicinal plants by some government agencies and academic institutions especially those that are in high demand within and outside the country. The optimization of propagation techniques will definitely be a remedial action to ensure a sustainable
supply of good quality plant materials to our local communities and plant-based industries contributing towards biodiversity conservation and environmental health (Davis et al., 2012).

Introducing medicinal plants cultivation for commercialization in South Africa

Cultivation of medicinal plants

The cultivation of medicinal plants can be a means of sustainable supply of medicinal plants materials with quality assurance to the market. However, there is little available information in this exercise, with much attention on crop cultivation for food security. Currently, the consumption of herbal medicines is widespread due to the presence of useful compounds within plants of medicinal potential. This has raised a lot of interest in medicinal research with increasing support from government and industries, with the interest most specifically to commercialize the products. Different cultivation practices such as planting date, fertilizer application, irrigation systems and harvesting methods need to be optimized to improve growth, yield and quality of medicinal plant materials. Cultivation of medicinal plants with the use of controlled environments will be a viable alternative that offers the opportunity to overcome the problems that are inherent in herbal extracts such as extract variability, contamination, misidentification, instability and a means to manipulate the yield of bioactive compounds. However, the propagation of some medicinal plants in a new habitat may be challenging due to local adaptation of some medicinal plants to their natural environments (Lewu et al., 2007b) and low germination rate (Vines, 2004).

Also, specific information about the requirements for seed germination, growth and pollination is usually not available since these plants are introduced into cultivation. Propagation success of new plants in an environment will depend on the understanding of the basic principles of plant propagation which usually takes place through seed and vegetative propagation (Hartmann et al., 2002).

Seed propagation

Seed propagation is a means of large scale multiplication of plants which takes a longer period for plants to reach maturity. It is a less expensive process in which the crop stands a chance to compensate for the time lost in seed germination. Seed germination is a vulnerable stage in the life cycle of plants (Kigel, 1995).

It is the process of reactivation of metabolic machinery of seed which starts with inhibition in completion with radicle emergence from the seed coat giving rise to a seedling. It is a complex phenomenon which is influenced by genetic and environmental factors such as light, temperature, moisture and nutrient availability that are annually unstable (Tang et al., 2015).

The requirements for seed germination (temperature, soil pH, light, moisture and nutrients) vary between plants and among species which greatly influence germinability. In general, seed germination remains the key to modern agriculture as critical event in determining the success of plant species. To meet up with the demand and supply of plant materials for commercialization, a fundamental understanding of the protocol for seed germination is essential to medicinal plant production. Several studies on different plant species have been carried out by some researchers showing the influence of some of these factors on seed propagation (Table 1).

Vegetative propagation

This is the multiplication of plants through vegetative parts; it is a fast, expensive and more labour intensive process with a lot of technical applications compared to seed propagation. Vegetative propagation can be through cuttings, grafting, budding and micro propagation. It is a process of plant multiplication in which a portion or fragment of the plant body functions as a propagule and develops into a new individual (Megersa, 2017).

Among the different methods of vegetative propagation, cutting is regarded as the most preferred and best method as it retains and conserve the genetic diversity of the plant (Dumroese et al., 2016). Cuttings are any vegetative parts of plants that can fully develop to the parent materials when subjected to favorable condition for regeneration (Hartmann et al., 2002).

Several studies on vegetative propagation of medicinal plants have been investigated by some researchers such as: Chandra et al. (2015) who reported highest rooting percentage in the macro propagation of Holostemma Adekodien, tested in vermiculate and vermicompost growth media using different concentrations of IBA and IAA growth hormones.

Danu et al. (2015) investigated the sprouting and rooting percentage of Paris polyphylla Smith, using various soil composition with different concentrations and combinations of IBA and GA3 hormones (50, 100 and 150 mg/L) treatments. Combination of 100 mg/L GA3 and 100 mg/L IBA demonstrated highest sprouting and rooting percentage in soil: loam: sand (3:2:1).

Cultivation of medicinal plants: A solution for biodiversity conservation in South Africa

The cultivation of South African medicinal plants has increased over the years, due to their high demand in the market by herbal practitioners, pharmaceutical industries
and the increasing awareness of medicinal plants conservation. Opportunities have been created for farmers to cultivate medicinal plants which have helped to reduce the issue of competition between farmers (Reiniten and Coetze, 2002). Research projects have been conducted in South Africa on the cultivation and commercialization of indigenous plants materials to reduce pressure of wild plants collection. A handful of indigenous South African medicinal plants are under cultivation in the different provinces (Table 2).

**Cultivation of medicinal plants: A possible solution of product quality and commercialization**

Medicinal plant cultivation is a solution to meet up with the demand in the market and an advantage for pharmaceutical industries and herbal practitioners to have control over their raw materials (Martins, 2014). Providing a reliable identification prevent the risk of contamination, steady supply of plant materials, control of post-harvest handling, effective monitoring of products standard, easy plant certification procedure, minimized batch-batch product variability and provides a platform of agreement between wholesalers and growers (Mathe and Mathe, 2008).

Cultivation of medicinal plants provides the opportunity to optimize the production of secondary metabolites of interest with information on the best season and time of harvest and ultimately increase volume. Herbal medicines and supplements derived from medicinal plants are usually assessed for quality assurance to ensure their safety before commercialization (Govindaraghavan and Sucher, 2015). Quality assessment measures need to be put in place to address safety and efficacy as well as, consistent monitoring of the entire value chain to ensure the delivery of quality finished products to local and international herbal markets. However, this depends on the processing and storage conditions, which may have an influence on

<table>
<thead>
<tr>
<th>Study</th>
<th>Findings of the study</th>
<th>Sources</th>
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<tbody>
<tr>
<td>Investigated the effects of water and temperature on seed germination and emergence as a seed hydrothermal time model</td>
<td>Temperature diversity influences germination capacity in many species, relating to different strategies adopted as a consequence of the heterogeneity of the habitat and microclimatic seasonality intrinsic to their ecosystems</td>
<td>(Moral, 2013).</td>
</tr>
<tr>
<td>Influence of seed source, pre-chilling, light and temperature on the germination of South African Pelargonium sidoides.</td>
<td>Seed age, temperature, light and pre-chilling conditions had an influence on seed germination of pelargonium sidoides. At temperatures higher than 25°C germination was reduced by 60% and at pre-chilling there was a drop by 29% in seed germination compared to other treatments.</td>
<td>(Lewu et al., 2010).</td>
</tr>
<tr>
<td>Investigated the effects of seed germination and vegetative propagation of bush tea (Athrixia phylloides),</td>
<td>Germination percentage of bush tea differed with the temperature treatments, with the highest (75%) at 20 - 25°C. There was a high germination percentage at constant temperature than at alternate temperature and in a continuous light than alternate light. Condition.</td>
<td>(Araya, 2005).</td>
</tr>
<tr>
<td>Effect of saline water on seed germination and early seedling growth of the halophyte quinoa</td>
<td>Saline water had an influence on growth attributes, an efficient antioxidant mechanism was present in quinoa, activated by salts during germination and early seedling growth and total antioxidant capacity was higher under salt stress than in water. Also, osmotic and ionic stress factors had different degrees of influence on germination and development.</td>
<td>(Panuccio et al., 2014).</td>
</tr>
<tr>
<td>Hydrothermal time models for conidial germination and mycelial growth of the seed pathogen Pyrenophora semeniperda</td>
<td>This study has demonstrated that the hydrothermal time model framework developed to describe the effects of temperature and water potential on physiological processes in seeds can also be successfully applied to germination and growth processes in ascomycete seed pathogen</td>
<td>(Barth et al., 2005).</td>
</tr>
<tr>
<td>Temperature requirements for seed germination and seedling development determine timing of seedling emergence of three monocotyledous temperate forest spring geophytes</td>
<td>The different stages of development, from embryo growth to leaf development, occur continuously in response to different temperatures. Differences in timing of emergence between the three species studied are caused by a subtle difference in temperature effects on germination and seedling development.</td>
<td>(Vandelook and Assche, 2008).</td>
</tr>
<tr>
<td>Interactive effects of salt, light and temperature on seed germination and recovery of a Halophytic grass-Phragmites karka</td>
<td>Toxicity of salts varies with environmental conditions, treated seeds were better in moderate temperatures. The salts did not affect viability of seeds which probably entered into dormancy. During extended exposure to high salinity and temperature stress, seeds were prevented from germination.</td>
<td>(Zehra et al., 2013).</td>
</tr>
</tbody>
</table>

**Table 1: Advances on factors that influences seed germination potential.**
Table 2: Cultivation practice and uses of some South African medicinal plants species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Common name</th>
<th>Propagation</th>
<th>Place of cultivation</th>
<th>Parts used</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Siphonochilus aethiopicus</em></td>
<td>African ginger</td>
<td>Seeds and rhizomes</td>
<td>Mpumalanga, Limpopo</td>
<td>Secondary roots and rhizomes</td>
<td>Flu, cold, malaria, charm, appetite suppressant and sedative</td>
</tr>
<tr>
<td><em>Eriocephalus africanus</em></td>
<td>Wild rosemary</td>
<td>Seeds, cuttings, layering</td>
<td>Western cape, Eastern Cape</td>
<td>Leaves</td>
<td>Asthma, throat and lung infections</td>
</tr>
<tr>
<td><em>Sutherlandia frutescens</em></td>
<td>Cancer bush</td>
<td>Seeds and cuttings</td>
<td>Northern Cape, Eastern Cape, KwaZulu Natal, Western Cape, Mpumalanga</td>
<td>Leaves and young stem</td>
<td>Fever, ulcer, poor appetite, diabetics, cold, flu, gastritis, cough, asthma, rheumatism, urinary tract infection, stress, anxiety</td>
</tr>
<tr>
<td><em>Harpagophytum procumbens</em></td>
<td>Devil’s claw</td>
<td>Seeds, secondary tuber</td>
<td>Northern West, Northern Cape, Free state</td>
<td>Root</td>
<td>Treatment of liver, kidney and bladder diseases, stimulate appetite and for indigestion</td>
</tr>
<tr>
<td><em>Hypoxis hemerocallidea</em></td>
<td>African potato</td>
<td>Seeds</td>
<td>Eastern Cape, KwaZulu Natal, Mpumalanga, Limpopo, Gauteng, North West, Free state</td>
<td>Tuber, leaves and bulbs</td>
<td>Treatment of urinary tract infection, testicular tumor heart weakness</td>
</tr>
<tr>
<td><em>Tulbaghia violacea</em></td>
<td>Wild garlic</td>
<td>Seeds</td>
<td>Rocky grassland of the Eastern cape, KwaZulu Natal, Limpopo</td>
<td>Rhizome, leaves, bulbs flower</td>
<td>Fever, rheumatism, asthma, constipation, cough and cold</td>
</tr>
<tr>
<td><em>Moringa oleifera</em></td>
<td>Drumstick tree</td>
<td>Seeds and cuttings</td>
<td>Limpopo, Free State, Mpumalanga, KwaZulu Natal, Gauteng</td>
<td>Roots, leaves, barks, immature pods</td>
<td>Headache, ulcers, diarrhoea, wounds</td>
</tr>
<tr>
<td><em>Pelargonium sidoides</em></td>
<td>Kalwerbossie</td>
<td>Seeds and cuttings</td>
<td>Eastern cape, Free state, Gauteng</td>
<td>Whole plant</td>
<td>Cough, chest pain, bronchitis, fever, sore throat, dysentery, diarrhoea</td>
</tr>
<tr>
<td><em>Warburgia salutaris</em></td>
<td>Pepper Tree</td>
<td>Seeds and cutting</td>
<td>Limpopo, KwaZulu Natal, Northern Gauteng</td>
<td>Whole plant</td>
<td>Abdominal pain, constipation, cancer, rheumatism, stomach ulcer, malaria, influenza</td>
</tr>
<tr>
<td><em>Eucomis antumnalis</em></td>
<td>Pineapple flower</td>
<td>Seeds and leaf cutting</td>
<td>Limpopo, Mpumalanga, Free State, Eastern Cape, Western Cape, Southern KwaZulu Natal, South Eastern part of Free State</td>
<td>Bulb</td>
<td>Fever, stomach ache, colic, flatulence, syphilis</td>
</tr>
<tr>
<td><em>Aloe ferox</em></td>
<td>Bitter aloe</td>
<td>Seeds and stem cuttings</td>
<td>Nalatal, South Eastern part of Free State</td>
<td>leaves</td>
<td>Arthritis, eczema, hypertension, stress,</td>
</tr>
<tr>
<td><em>Artemisia afra</em></td>
<td>wormwood</td>
<td>Roots and stem cutting</td>
<td>All provinces of South Africa except in the Northern cape province</td>
<td>Leaves, stems and roots</td>
<td>Cough, fever, headache, loss of appetite, intestinal worms</td>
</tr>
</tbody>
</table>

Source: (Mahomoodally, 2013; Street and Prinsloo, 2012; McMaster, 2007; Herbert, 2006; Joffe, 2005).
the quality of final product.

Product quality depends on active ingredients which are influenced by intrinsic and extrinsic factors. These factors bring about major changes in metabolites creating differences in the final content during every production. It is therefore of utmost importance to understand the dynamics in secondary metabolite for consistency in chemical profiles as well as, biological activities of medicinal plants. Recently, some scientific investigations have been carried out on the synthesis of plant secondary metabolite in response to various factors that deviate from the optimal production of plant secondary metabolites (Table 3).

Challenges in medicinal plant cultivation

Medicinal plants are widely used traditionally throughout human development in the treatment of various illnesses as a source of primary health care in most communities. However, the source of plant material is mostly dependent on the wild, except recently, where there is a growing attention towards medicinal plants cultivation for biodiversity conservation, enhancement of secondary metabolite of interest, product quality and for assurance of steady supply of plant materials. However, this is associated with some unforeseen challenges that may arise without expectations.

In medicinal plant cultivation, the future for some less known species are unpredictable; some of them being perennial will require several years for maturity before harvesting and therefore investment in them could represent a considerable commercial risk (Canter et al., 2005). Medicinal plant cultivation goes with a series of questions like the accessibility of plant materials in the wild, disease susceptibility, labour cost and adaptation to a new environment may be slow. In a situation where there is an excess of a particular medicinal plant in a very large population in the wild, it becomes very easy for medicinal collectors to harvest these materials with little or no cost in the wild to sell at cheaper prices. This makes it difficult and unworthy to such a plant to be cultivated with the application of labour cost of cultivation to sell at a higher price of which buyers will prefer to buy at cheaper price from those collectors from the wild.

Agro-environmental conditions of cultivated medicinal plants are usually not the same to that of the wild habitat. However, secondary metabolite biosynthesis is induced by the extra-optimal influence of biotic and abiotic factors where optimal environment will tend to increase biomass production, rather than the synthesized secondary metabolite usually needed to cope with stress (Pavarini et al., 2012).

Also, post-harvest processing and market availability are very critical because their negligence would lead to an irreversible quality loss of raw materials. Thus, good processing conditions will help to increase the market value of medicinal plant products.

Influence of regulatory policy on safety and quality of medicinal plants products

The use of many plants products as food or dietary supplement is associated with some problems of classification in some countries (Martins, 2014). As a result, quality tests and production standards tend to be less controlled and, in some cases, traditional health practitioners may not be licensed. The safety of medicinal plant product is imperative to the general public (Kasilo and Trapsida, 2011). All manufactured herbal products are required to be licensed as “traditional herbal medicinal product” (Raynor et al., 2011; UNESCO, 2013). Like orthodox medicines, it is compulsory that they are accompanied by a comprehensive information like precaution, prescription, side effect, storage and regulatory information (Martins, 2014).

However, in the developing countries where many unregistered and poorly regulated herbal products are sold freely on the market with little or no restraint, license cannot be obtained for some herbal medicines. Furthermore, the myth that natural products are not poisonous and are devoid of adverse effects often lead to wrong usage and unrestrained intake which may result in poisoning and acute health problems. This is not limited to developing countries, but also exists in highly developed countries, where the general public often resorts to “natural” products without any proper information on the side effects; especially in the case of excessive use (UNESCO, 2013).

In South Africa, advances have been made in the quality control of medicinal plant products by creating a Medicinal Control Council to ensure the quality control of herbal medicines, promote the safety of high-quality traditional medicine, and to contribute in the capacity building of traditional healers (Felhaber and Gericke, 1996).

Conclusion

The high and growing interest of medicinal plant products as a means of primary health care system in both developed and developing countries gives a prospect to medicinal plants as a suitable substitute for crop cultivation, an option for a source of employment and livelihood enhancement, with little or no competition in product quality, efficacy and commercialization process. The manipulation and optimization of secondary metabolites of interest will rest be assured for a consistent supply of plant materials, price affordability and efficacy in their functions. Propagation process will be accompanied with modern technology to meet up with the high demands of
### Table 3: Factors that influence the synthesis of secondary metabolites in plants.

<table>
<thead>
<tr>
<th>Studies</th>
<th>Finding of the study</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality from the field: The impact of environmental factors as quality</td>
<td>Biotic and abiotic stresses are tools to increase health related properties of plant materials and understanding elicitation of induced metabolites and their lifetime is fundamental to quality assessment of secondary metabolite production. Notwithstanding, quality is indeed growing out in the field, harvesting and processing methods.</td>
<td>(Ncube et al., 2012)</td>
</tr>
<tr>
<td>determination in medicinal plants</td>
<td>Bioactive compounds in RGT seedlings could be enhanced significantly through co-culture with fungus <em>Aspergillus</em> sp. However, there is the need for further research for larger scale bioactive secondary metabolites production.</td>
<td>(Ding et al., 2018)</td>
</tr>
<tr>
<td>The improvement of bioactive secondary metabolites accumulation in Rumex</td>
<td>Secondary production in the root and rhizomes of <em>Synopodophyllum hexandrum</em> are greatly influenced by environmental factors contributing to a geographical differences in different production location.</td>
<td>(Liu et al., 2013)</td>
</tr>
<tr>
<td>gmelini Threz through co-culture with endophytic fungi</td>
<td>Secondary metabolites of the plant materials assessed for seasonal variation showed concentration differences as well as differences in antimicrobial activities.</td>
<td>(Thanga, 2011)</td>
</tr>
<tr>
<td>Influence of ecological factors on the production of active substances</td>
<td>Environmental factors such as temperature, humidity, light intensity, water, mineral and carbon dioxide influences the growth of plants secondary metabolites production. Drought and freezing temperatures can cause adverse effects on growth of plants and their productivity.</td>
<td>(Ramakrishna and Ravishankar, 2011)</td>
</tr>
<tr>
<td>in the anti-cancer plant <em>Synopodophyllum hexandrum</em> (Royle) ST Ying</td>
<td>Higher alkaloid levels were recorded for plants under salt or drought stress, with levels of ergonovine being higher than those of ergine. Concentrations of both alkaloids increased over the plant growing period.</td>
<td>(Zhang et al., 2011)</td>
</tr>
<tr>
<td>Seasonal variation in the production of secondary metabolites and antimicrobial activity of two species used in Brazil traditional medicine</td>
<td>Growing conditions had an influence on the quali-quantitative profile of the secondary metabolites, with hydroponics culture having significant increase in the active principal components.</td>
<td>(Sellami et al., 2013)</td>
</tr>
<tr>
<td>Influence of abiotic stress signal on secondary metabolites in plants</td>
<td>Cultural practices such as fertilization and planting density have an influence on growth and productivity, with fertilization improving growth, total polyphenol, tannins and antioxidant content of herbal tea. Nitrogen fertilization increases the production of new shoots and content of nitrogenous compounds, plant density also increases productivity.</td>
<td>(Tshivhandekano et al., 2005)</td>
</tr>
</tbody>
</table>
pharmaceutical industries to quality medicinal plant materials. In addition, there will be problem-solving such as mis-identification, contamination, pest infestation, harvesting scarcity in supply and processing methods of plant materials.

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REFERENCES


Academia Journal of Medicinal Plants; Tanga et al.


