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Cues from Sri Lankan Traditional Medicine to the Modern Drug Development Pipeline - for a Sustainable Future

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ABSTRACT

Worldwide, traditional medicine (TM) systems based on cultural and religious beliefs, and geographical regions of origin, possess their own unique practices. The use of herbal preparations in TM follows the basic principle of treating a disease by stabilizing organ systems of the body, with simultaneous targeting of multiple symptoms. Time-tested practices from TM preparations, fed into the development of modern drugs, can drastically reduce its long, arduous turnover time. However, novel drug development research focusses on single compound drugs; yet frequently, it is the synergistic activity of phytocompounds in the original herbal preparation that renders them unique in their therapeutic activity. A recent area of research examines the synergistic activity of several compounds achieving multi drug targets, as a powerful treatment regimen for diseases with complex aetiology.

Blessed with a lavish biodiversity and a rich, unique TM heritage, Sri Lanka is well-placed to identify and produce drugs for a wide range of disorders. Local research on diverse disorders has demonstrated promising results, yet the standardization of effective drugs and supplements which compete with the international market poses a significant challenge. State support as well as the sustainable use of traditional medicinal plants are required. The cultivation of medicinal plants would reduce their harvest in the wild, and help preserve these species from extinction. Thus, a market of high value could be developed for medicinal plant cultivators and the herbal pharmaceutical industry, which would sanction its socio-economic growth and sustainable future.

KEYWORDS:

Sri Lanka, Traditional Medicine, polyherbal preparations, modern drug development, synergism, international pharmaceutical market, translational research

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Introduction

The World Health Organization (WHO) has defined Traditional Medicine (TM) as “the sum total of the knowledge, skills and practices based on the theories, beliefs and experiences indigenous to different cultures, whether explicable or not, used in the maintenance of health, as well as in the prevention, diagnosis, improvement or treatment of physical and mental illnesses” (WHO, 2000). In some countries TM is also termed alternative, complementary or non-conventional medicine. TM systems in different countries vary drastically, depending on religious beliefs, culture, history, and biodiversity from which medicinal material is extracted (WHO, 2000). However, in every TM system, the use of plants to prepare herbal medicines remains an important practice. The WHO defines traditional herbal medicines as “naturally occurring, plant-derived substances with minimal or no industrial processing that have been used to treat illness within local or regional healing practices (Tilburt & Kaptchuk, 2008). World renowned TM systems such as Ayurveda in India, or Chinese, African, South American and Arabic traditional medicine systems use herbal medicine for the primary healthcare needs of 75% of the world’s population (Pan et al., 2014). In countries such as India and Sri Lanka, archaeological proof of using herbal medicine to treat a wide range of disorders has a history of more than 5000 years (Edwards et al., 2012). There is also written evidence such as *Arkaprakasa* (pharmacology and pharmacy) and *Kumaratantra* (paediatric diseases and management) claimed to be documented by King Ravana of Sri Lanka, which are now considered basic reference pharmacopoeias in Ayurveda (Sharma, 2000).

Traditional herbal preparations, although having a long record of use and acceptance by patients, are not within mainstream medical treatment. This is due to the absence of scientific proof and standardization according to international drug manufacturing protocols. However, the WHO general guidelines for Methodologies on Research and Evaluation of Traditional Medicine (WHO, 2000) supports proceeding directly to the clinical evaluation of suitable time-tested medicinal preparations, without carrying out preclinical and toxicological studies. Traditional health practitioners, however, consider it their responsibility to continue with their treatment of patients in need, and generally ignore requests to commercialize their knowledge of herbal preparations handed down from generation to generation.

Modern drug discovery and development has reached an immensely influential level, with the use of cutting edge, high throughput screening devices and computational drug target predictions. Although, an estimated USD 2.6 billion is spent to develop a new treatment, most potential drug candidates are rejected between Phase I trials and regulatory approval (Fleming, 2018). Leading biopharmaceutical companies such as Pfizer, Roche, and Sanofi are already using artificial intelligence (AI) driven systems to invent new drugs which are cheaper and more effective with less turnaround time. Yet, there are no approved drugs produced to date with the help of AI systems, as its use in drug discovery is contentious (Fleming, 2018).

Most vital drugs approved in recent decades are reported to be isolated from plants. The naturally occurring, bioactive compounds are termed “phytochemicals”. They are

plant secondary metabolites, which are not required for the immediate survival of the plant, but which can be synthesized to increase its robustness for better survival (Kennedy & Whiteman, 2011). With the first breakthrough in the 18th century when morphine was isolated from the plant *Papaver somniferum*, numerous effective drugs such as salicylic acid (the precursor of aspirin), cocaine, quinine, and digitoxin have been discovered this way (Pan et al., 2009).

The modern drug pipeline relies, however, on single compounds as potential drugs. It does not consider the value of multi-herbal mixtures or whole extracts of a single herbal plant. Traditional medicine preparations, on the other hand, focus on the synergy of a myriad of “phytochemicals”. Even though cues extracted from prominent traditional medicine systems are tested globally, the search for a single compound drug may compromise their effectiveness as suitable treatments for diseases in clinical trials. In TM, polyherbal preparations are considered to exert synergistic interactions increasing bioavailability of the compounds, thereby enhancing the therapeutic effects and reducing toxicity (Jia et al., 2004). In the context of TM, it is believed that a herbal preparation maintains or stabilizes different systems of the body, explaining these multitarget effects by a sequence of compounds in a preparation. It is now apparent that whole extracts or polyherbal mixtures could be effective due to the synergistic activity of the different phytocompounds present, as important bioactivities tend to lose their effectiveness upon fractionation (Caesar & Cech, 2019). However, the phenomenon of antagonistic effects has also been studied, as this could mask important bioactivities in a polyherbal mixture or a whole extract.

The Role of Synergism

In recent years, the study of the synergistic effects exerted by whole plant preparations has been considered extremely important in pharmaceutical pipelines, and advanced techniques in metabolomics and biochemometrics are constantly used to identify underlying mechanisms of actions alongside toxicity and the side effects of such preparations (Caesar & Cech, 2019).

A review of synergistic bioactivities in Chinese TM (CTM) multiherbal preparations on diseases such as cancer, asthma, myocardial ischemia, cardiovascular diseases, hepatic injury and fungal disorders, reported confirmation of synergistic activity in the compounds present in the preparations (Zhou et al., 2016). The review also reported an increased use of proper mathematical or computational methods in detecting synergistic activity of CTM preparations between the years 2000 to 2014 (Zhou et al., 2016). In a study on South African TM, effective anti-gonococcal activity was reported in the use of different combinations of 7 medicinal plants (Vambe et al., 2018). In India, where Ayurvedic literature such as the *Sarangadhar Samhita* concentrated on synergistic activity of ingredients (“*Samyoga*”), there is now a move to focus on a network of pharmacology research to investigate herbal preparations exerting synergistic activity (Mukherjee et al., 2018). In this context, *Lagenaria siceraria*, a food plant used in Indian TM against hyperlipidaemia, and in Sri Lankan TM to treat lactation issues, fractures, and inflammation, was studied and multiple compounds in

the extract targeting multiple sites of relevant pathways building up synergistic interactions were reported (Mukherjee et al., 2018).

Sri Lankan Traditional Medicine

Sri Lanka has a unique system of traditional medicine, supported by archaeological evidence of a complete hospital system and medical instruments similar to those currently in use (Kannangara, 2016). Sri Lankan TM is divided into different traditions, based on geographical regions and practices. It is often mistaken as a descendent of the Ayurveda of India, but there are clear cut differences between Indian and Sri Lankan TM systems. For example, preparation methods and the use of *Arka* (distilled products of herbal preparations) is known to have been introduced to Indian Ayurveda at a later stage – approximately in the 12th Century, whereas the word *Arka-prakasha* is first cited in ancient dialogues of a Sri Lankan story, linking its roots to Sri Lanka (Jalpa & Pandya, 2017). Sri Lankan TM practitioners often use medicinal plants endemic to Sri Lanka, in their herbal preparations. They also replace the rare herbs used in Indian Ayurveda with easily accessible plants in Sri Lanka. For example, instead of *Shalaparni* (*Desmodium gangeticum*) and *Daruharidra* (*Berberis aristate*) used in Indian herbal preparations, they use Aswenna (*Alysicarpus vaginalis*) and *Weniwelgata* (*Coscinium fenestratum*) respectively.

Although there is a large number of TM practitioners throughout the country specializing in different disorders such as diabetes, arthritis, fractures, injuries, different types of cancers and eye disorders, it is rarely that patient feedback is gathered and analyzed. Further, neither the preparation methods nor the herbs used in the treatments are disclosed to the general public by most Sri Lankan TM practitioners. Therefore, the potential to scientifically validate and commercialize these products is severely restricted. However, as the herbal preparations have been used for a long time, and TM practices in the country are valued, practitioners do not view scientific validation and commercialization as an obligatory step forward. For the academics amongst TM and Ayurvedic practitioners, however, documenting the effects of herbal preparations in usage, and disseminating this knowledge to the scientific community for the greater good of humanity, is of great importance.

Conservation and Sustenance of Medicinal Plants in Sri Lanka

Countries such as India and China which are the leading exporters of herbal products, focus on sustainable agricultural development to meet the increasing global demand for their standardized, safe and efficient products. They focus on socio-economical sustainability through the organic farming of herbs resulting in high market values for the raw material required for quality products, thereby safeguarding economic growth and social stability (Shahrajabian et al., 2019; Kumar et al., 2021). If the Sri Lankan indigenous herbal preparation and drug development process is streamlined along the aforementioned lines, the achievement of a sustainable future through the flourishing cultivation of medicinal plants can be achieved.

In 2004, the World Bank's Indigenous Knowledge Notes described the methods used in Sri Lanka in the conservation and sustainable use of medicinal plants – a project funded in 1998 with a US \$4.6 million grant by the Global Environment Facility. The project had successfully implemented a) *in situ* conservation, mainly by establishing 5 medicinal plant conservation areas in Bibile, Ritigala, Rajawake, Naula, and Kanneliya; b) *ex situ* conservation by promoting home-gardens and nursery cultivation; and c) providing institutional and informational support to the area on medicinal plants (Mahindapala, 2004). According to a survey carried out in 2002, Sri Lanka has about 1432 medicinal plant species, of which 148 are endemic. The number of threatened species is estimated at 110, prompting action on the sustainable use of medicinal plants (Ratnayake & Kariyawasam, 2007). Several large-scale medicinal plant gardens have been established and at present, maintained by different authorities such as the Ministry of Agriculture, the Ministry of tourism, and the Ministry of health, nutrition and indigenous medicine. The Ganewatte medicinal plant garden is one such garden in the intermediate zone of the country, occupying 22 acres of land, with medicinal plants that help in conservation, economic development and educational programmes (Ganewatte Medicinal Plant Gardens, 2009). In addition, private non-profit organizations such as the Nagenahiru Foundation have established medicinal plant arboretums and herbariums to propagate rare plants, educate, demonstrate, and conduct field research promoting the sustainable use of threatened and rare medicinal plants under the guidance of the National Institute of Traditional Medicine (Nagenahiru Foundation, 2010). A renowned cosmetic herbal product manufacturer, Nature's Beauty Creations, has pledged 100,000 medicinal plants and 5 million medicinal plant seeds by 2025 to the government, as a part of its environment protection campaign *sadaharitha hetak*. The company also possesses the largest privately owned medicinal plant collection, grown and maintained by its agriculture department (Daily FT, 2021).

In the following section, publications on Sri Lanka's TM herbal preparations that have effectively targeted diseases *in vitro*, and during patient treatment are listed. Under each subsection, a summary of research carried out is presented, together with a list of medicinal plants used (either as whole extracts of plant parts or as polyherbal mixtures).

Research Based on Cues from Sri Lankan Traditional Medicine

Tables 1 to 5 present studies on anti-cancer, hypoglycaemic, hypolipidaemic and anti-obesity and anti-inflammatory effects of Sri Lankan TM preparations.

Scientifically validated herbal preparations against oral squamous cell carcinoma (OSCC), laryngeal cancer cells, breast cancer, non-small cell lung cancer, human hepatoma, endometrial carcinoma, cervical adenocarcinoma, and rhabdomyosarcoma are listed in table 1 with stage of study and findings.

Table 1
Cancer Chemopreventive Activity of Sri Lankan Herbal Preparations

Herbal preparation	Cancer type	Stage of study	Findings
1. A mixture of powdered fruits of <i>Embllica officinalis</i> (Indian gooseberry) and <i>Tinospora cordifolia</i> (Heart-leaved moonseed)	OSCC of the buccal mucosa and the tongue	Clinical trial	1) OSCC buccal mucosa with greatly reduced local and overall recurrences 2) OSCC of the tongue, showed statistically significant reduction in nodal and overall recurrences (Dias et al., 2018)
2. Decoction of <i>Adenanthera pavonina</i> L. (red sandalwood) and <i>Thespesia populnea</i> L. (Pacific rosewood)	Laryngeal cancer cells (Hep-2 cell line)	<i>In vitro</i>	Anti-proliferative effects and apoptosis of cells. (Lindamulage & Soysa, 2016)
3. Decoction of <i>Flueggea leucopyrus</i> (Wild) (Purple tephrosia)	Breast cancer (MCF-7, MDA-MB-231 and SKBR-3 cell lines)	<i>In vitro</i>	Cytotoxic effects by inducing apoptosis. (Mendis et al., 2015)
4. A polyherbal mixture containing <i>Nigella sativa</i> (Black cumin) (seeds), <i>Hemidesmus indicus</i> (Indian Sarsaparilla) (roots) and <i>Smilax glabra</i> (Chinaroot) (rhizomes)	Non-small cell lung cancer (NCI-H292 cells)	<i>In vitro</i>	Cytotoxic effects by inducing apoptosis, anti-oxidant activity and colony formation inhibition. (Pathiranage et al., 2020)
5. Aqueous and ethanolic extracts of a polyherbal mixture comprised of <i>Nigella sativa</i> (seeds), <i>Hemidesmus indicus</i> (roots) and <i>Smilax glabra</i> (rhizome)	Human hepatoma (HepG2 cell line)	<i>In vitro</i>	Cytotoxicity (Samarakoon et al., 2010)

Herbal preparation	Cancer type	Stage of study	Findings
6. Non-polar extracts of <i>Garcinia. zeylanica</i> (<i>Ela goraka</i>) and <i>Garcinia quaesita</i> (Indian tamarind), <i>S. castaneifolia</i> barks	Breast cancer (MDA-MB-231 and MCF-7)	<i>In vitro</i>	Inhibition of proliferation of breast cancer stem cells (Rajagopalan et al., 2018)
7. Decoction of the Aerial Parts of <i>Flueggea leucopyrus</i> (Purple tephrosia)	Endometrial Carcinoma (AN3CA cells)	<i>In vitro</i>	Cytotoxicity via apoptosis. (Samarakoon et al., 2014)
8. Polyherbal medicine “ <i>Le pana guliya</i> ”	Hepatocellular carcinoma and human cervical adenocarcinoma (HepG2 and HeLa cells)	<i>In vitro</i>	Cytotoxicity via oxidative stress dependant apoptosis. (Wageesha et al., 2017a)
9. Polyherbal medicine “ <i>Le pana guliya</i> ”	Human Rhabdomyosarcoma cell line (RD), and human breast adenocarcinoma cell line (MCF-7)	<i>In vitro</i>	Strong cytotoxicity activity. (Wageesha et al., 2017b)

Herbal preparations against hyperglycaemia including water and chemical extracts of single and herbal mixtures, powders, and drinks are listed in Table 2, with stage of study, herbal combinations used, and findings.

Table 2
Sri Lankan Herbal Preparations against Hyperglycaemia

Herbal preparation	Study stage	Findings
1. Ethanol and water extracts of <i>Munronia pinnata</i> (<i>Bin kohomba</i>)	Pre-clinical study using Wista rats	Significant hypoglycaemic effects by both extracts (Hapuarachchi et al., 2011)
2. Herbal powder derived from ‘ <i>Thalpathe Piliyam</i> ’	Clinical study using type II diabetic patients	Hypoglycaemic effects similar to the allopathic treatment regime. (Harshamali & Sakunthala, 2019)

Herbal preparation	Study stage	Findings
3. Hot water extract of <i>Tragia involucrate</i> L. (<i>Wel Kahambiliya</i>)	Pre-clinical study using Streptozotocin induced diabetic rats	Significant reduction in blood glucose level, triglycerides, and very low-density lipoprotein cholesterol and increases high density lipoprotein cholesterol levels (Palli et al., 2017)
4. Malewana Madhumeha Choorna polyherbal hot infusion	Biochemical assays	Strong antioxidant, free radical scavenging activity, α -amylase enzyme inhibition activity. (Keshala et al., 2021)
5. A polyherbal mixture composed of leaves of <i>Murraya koenigii</i> L. (Curry leaves tree), cloves of <i>Allium sativum</i> L. (Garlic), fruits of <i>Garcinia quaesita</i> Pierre (<i>Rath goraka</i>) and seeds of <i>Piper nigrum</i> L. (Pepper)	Pre-clinical study using streptozotocin induced diabetic rats	Significantly lower glycated haemoglobin, significantly increased serum insulin concentration, β -cell restoration in the pancreas, restoration of lipoproteins. (Liyanagamage et al., 2021)
5. Herbal drink of <i>Syzygium Cumini</i> (Malabar plum) bark extract	Biochemical assays	Antiglycation and antioxidant effects (Perera et al., 2014)
6. Boiled aqueous extract of <i>Nyctanthes arbor-tristis</i> L (Night-flowering Jasmine) flowers	Pre-clinical study using male mice	Significant reduction of fasting and random blood glucose levels, decreased levels of total cholesterol and triglycerides, and inhibition of glucose uptake by the intestine. (Rangika et al., 2015)
7. Methanolic extract of <i>Aporosa lindleyana</i> (<i>Kabella</i>) leaves	Pre-clinical study using Sprague-Dawley rats	Significant reduction of fasting and random blood glucose levels and no toxic signs in rats (Samanmali et al., 2014)
8. Aqueous leaf extract of <i>Passiflora suberosa</i> (Corky passion vine)	Pre-clinical study using male mice	Reduction of fasting and random blood glucose levels. Tri glycerides, total cholesterol and glucose uptake from the intestine. (Sudasinghe & Peiris, 2018)

Herbal preparations such as water and chemical extracts from herbs and “choorna” against hyperlipidaemia and obesity are listed in Table 3.

Table 3
Sri Lankan Herbal Preparations against Hyperlipidaemia

Herbal preparation	Study stage	Findings
1. Cold water extract of new herbal formulation consisting of <i>Allium sativum</i> (Bulb) (Garlic), <i>Piper nigrum</i> (Nuts) (Pepper), <i>Murrayakoenigii</i> (Curry leaf tree) (Leaves)	Clinical trial	Significant decrease in serum cholesterol levels; triglycerides, LDL and TC:LDL ration. (Pushpamali & Chandrasiri, 2016)
2. Crude methanolic extract of <i>Emblica officinalis</i> fruits (Indian gooseberry)	Preclinical study using cholesterol induced Wistar rats	Significant decrease in total cholesterol, triglycerides and LDL and significant increase in HDL (Dissanayake et al., 2017)
3. Traditional herbal “choorna” consisting of <i>Nigella sativa</i> (Black cumin), <i>Saussurea lappa</i> (Indian costus root), <i>Zingiber officinale</i> (Ginger), <i>Allium sativum</i> (Garlic), <i>Cassia fistula</i> (Pudding pipe tree) and <i>Cassia senna</i> (Indian Senna)	Clinical trial using overweight and obese patients	Significant decrease in the BMI of patients (Jayasena & Dissanayake, 2020)

A hexane extract of polyherbal preparation consisting of seeds of *Piper nigrum* L., leaves of *Murraya koenigii* L. Sprengel, cloves of *Allium sativum* L. and the dried fruit rinds of *Garcinia quaesita* Pierre had demonstrated hypoglycaemic as well as hypolipidemic activities in vivo in streptozotocin-induced diabetic rats (Sampath et al., 2021).

Table 4 lists herbal preparations such as powders, ointments, decoctions, pills, and water extracts used against inflammatory conditions.

Table 4
Sri Lankan Herbal Preparations against Inflammatory Conditions

Herbal preparation	Study stage	Findings
1. “Sudarshana Powder” consisting of 53 herbal ingredients	Pre-clinical trial using adjuvant induced arthritic rats.	Significant reduction of foot pad and ankle joint thicknesses and white blood cell counts. Reduced erythema and oedema in the ankle joints and the foot pads. Normalized body weight. (Weerakoon et al., 2016)

Herbal preparation	Study stage	Findings
2. Ointment produced using <i>Curcuma albiflora</i> (Turmeric)	Clinical trial	User satisfaction on disease symptoms were 31 times greater than the placebo. (Herath et al., 2018)
3. <i>Rasna Sapthakaya</i> decoction	Clinical trial	Significant reduction of erythrocyte sedimentation rate and significant increases of Haemoglobin, packed cell volume and red blood cell count. (Perera, 2018)
4. Traditional medicine pill consisting of <i>Aloe vera</i> , <i>Centella asiatica</i> (Gotukola) and <i>Strychnos potatorum</i> (Clearing nut)	<i>In vitro</i> test using egg albumin	Significant anti-inflammatory effects compared to the reference drug. (Sarvaka et al., 2016)
5. Aquous root extract of <i>Syzygium Caryophyllatum</i> (South Indian plum)	<i>In vitro</i> test using egg albumin	Significant anti-inflammatory activity. (Heendeniya et al., 2018)

Other than the aforementioned research on anti-inflammatory effects of traditional herbal medicine, a study reported a total of 43 herbal plants used in anti-inflammatory preparations in which *Coriandrum sativum* was reported by most of the participants recruited within the Gampaha district (Napagoda et al., 2018).

Herbal preparations used against different conditions such as sun burns, urolithiasis, chronic sinusitis, and fertility and urinary issues with study stage and findings are presented in Table 5.

Table 5

Sri Lankan Herbal Preparations against Miscellaneous Disorders

Herbal preparation	Disorder	Study stage	Findings
1. Herbal paste consisting of <i>Brassica campestris</i> (Field mustard), <i>Acorus Calamus</i> (Sweet flag), <i>Symplocos racemose</i> (Lodra), Rock Salt	Sun burnt skin	Clinical trial	A significant increase in skin fairness was reported after treatment. Of the total participants 78% showed increase in skin fairness level (Abegunasekara & Wijesinghe, 2020)

Herbal preparation	Disorder	Study stage	Findings
2. Methanol extract of roots of <i>Asparagus falcatus</i> (Sicklethorn)	Urolithiasis	<i>In vitro</i>	Prevention of crystal nucleation by 13.26%; aggregation by 36.5%, dissolved weight of the calculi by 5.19%. These results are similar to those demonstrated by the positive control. (Napagoda et al., 2019)
3. <i>Pitawakka nawaya</i> decoction consisting of <i>Phyllanthus amarus</i> (Gale of Wind), <i>Terminalia chebula</i> (Chebulic myrobalan), <i>Pygmaeopremna herbacea</i> (Bharangi), <i>Pipper chavya</i> (Chavya), <i>Solanum trilobatum</i> (Purple fruited egg plant), <i>Tinospora Cordifolia</i> (heart-leaved moonseed), <i>Zingiber officinalae</i> (Ginger), <i>Pipper Nigrum</i> (Black pepper), and <i>Piper longum</i> (Long pepper)	Chronic sinusitis	Clinical trial	Reduction of heaviness of the head in 6.3%; headache in 11.8%; mild headache in 7.7%; itching inside ear in 14.3%; nasal obstruction in 6.7%; nasal discharge in 5.9% and abnormalities of smell in 66.7%. (Maragalawaththa et al., 2010).
4. <i>Pala Kalyana Ghritha</i> poly herbal formula	Fertility Issues	Pre-clinical study using Sprague Dawley rats	Significant increase in testicular weight and serum testosterone levels. (Perera et al., 2018)
5. Cold water extract of <i>Spilanthes acmella</i> fresh flowers	Urinary issues	Pre-clinical study using albino rats	Significant diuretic activity similar to furosemide. (Ratnasooriya et al., 2004)

The Way Forward

Synergistic activity among phytochemicals seems to play a major role in the therapeutic properties of traditional herbal preparations. As such, expensive and time-consuming experiments to identify a single bioactive phyto compound for a specific

disorder or disease may be unnecessary, if it is feasible to select a compendium of phytocompounds with effective therapeutic bioactivity in drug development. Collaborative multidisciplinary research in the field of drug discovery using novel screening platforms (e.g., use of stem cell lines) and traditional medicine systems may generate fruitful outcomes in the identification and production of therapeutics. For example, traditional medicine practitioners and institutes can maintain open access data bases for herbs used in TM, together with their properties, which can be readily accessed by researchers for drug development.¹ TM practitioners, in turn, can collaborate with modern medical institutes in using novel technology such as artificial intelligence to model disease-oriented drug targets for complex TM preparations. Exploring hitherto undisclosed areas in Sri Lankan Indigenous Medicine for critical diseases such as pneumonia associated with viral diseases such as SARS, MERS and Covid-19 would be another angle worth investigating.

As noted in the introduction, methods for the conservation and sustainable use of medicinal plants have already been established in Sri Lanka. However, understanding how to maintain this process is important. Figure 1 summarizes the factors and outcomes of the sustainable use of medicinal plants.

Figure 1

Schematic Presentation on Sustainable Management of Medicinal Plants

(Image Source: Astutik *et al.*, 2019)

Note: Extracted from Astutik, S., Pretzsch, J., & Ndzifon Kimengsi, J. (2019). Asian medicinal plants' production and utilization potentials: A review. *Sustainability*, 11(19), 5483.

Therefore, it is important to carry out in-depth evidence based translational research on traditional medicine preparations, according to international standards, which may pave the path for appropriate dissemination of knowledge in the field of drug discovery.

As only 3.3% of medicinal plants are commercially cultivated globally, with the rest collected from the wild, Sri Lanka would benefit if medicinal plant cultivation elicited more government support (Astutik et al., 2019). As important is the recognition of the novel initiatives by private sector herbal product manufacturers to conserve and promote the sustainable usage of medicinal plants. Guidance by state institutes such as the Institute for Indigenous Medicine of the University of Colombo, the Gampaha Wickramaarachchi University of Indigenous Medicine, and other alternative medicine institutes would be a boon to the industry in its conservation management efforts. To avoid over exploitation of medicinal plants and prevent repetitive research, updated websites listing the medicinal plants of Sri Lanka with current research outcomes such as reported bioactivities, scientific validations, and clinical trials should be maintained. Data collected by state universities from research related to medicinal plant conservation should be used by the government to take these projects to the next level of implementation. Using inexpensive, human cellular platforms such as human stem cells isolated from biological waste (postpartum tissue and surgical waste) to screen traditional preparations and medicinal plants for their claimed bioactivities such as bone, cartilage, muscle, liver protection and regeneration would mark a future, hybridized, novel state of the art technology (Udalamatththa et al., 2016). Anti-cancer traditional preparations could be validated and commercialized with the use of cancer stem cell platforms within a shorter time-period. As genome sequencing methods are well established in modern medicine, personalized medicine treatment could be promoted by investigating the effectiveness of herbal preparations on diseases caused by multifactorial genetic aetiologies.

State support for such activities should be fostered by the State Ministry of Indigenous Medicine under the purview of the Ministry of Health, Sri Lanka. Such a strategy would enable local scientists and local drug companies to compete with global pharmaceutical giants, which could be advantageous to the Sri Lankan economy. Figure 2 demonstrates this with cues from TM, the time period for the development of a drug may surmount by at least 10 years.

Figure 2

Comparison of Drug Discovery Time Lines Based on Modern Technology and with Cues from Traditional Medicine

Conclusions

This article discussed time tested herbal remedies and whole plant extracts used in Sri Lankan Traditional Medicine for the treatment of a wide range of diseases/disorders. When tested *via* modern scientific platforms or clinical studies these may lead to a considerably shorter turnover time and less expenditure in the development of modern drugs. The article also stressed that these remedies may be more effective and non-toxic because whole or crude preparations, with several phytochemicals acting synergistically on multiple molecular targets, are better than an isolated single compound which is the goal of current drug development. The use of novel technology to screen for important bioactivity, reporting scientific findings, proceeding with preclinical and clinical studies, and drug development with several compounds or whole preparations would be advantages to countries such as Sri Lanka, where invaluable and effective traditional medicine solutions for a wide range of diseases have been in use. If accepted by the global market, a socioeconomically sustainable future could be at hand for Sri Lankan cultivators of medicinal plants and local pharmaceutical industrialist, as there would be a continuous demand for quality, fresh medicinal plant material for the production lines. This would also create an uninterrupted flow of foreign exchange into the country.

1. National monographs of herbs used in Sri Lanka and Pharmacopeia are currently available (Astutik *et al.*, 2019).

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