Summary

This Ph.D. study is on the plant raw drug markets in southern India with particular reference to adulterants and substitutes of the traded medicinal plant species. The main two objectives are:

1. to explore the major raw drug markets in Tamil Nadu and Kerala, identify and enlist range of botanical raw drugs traded.
2. to identify the plant sources of these raw drugs including substitutes, adulterants.

A systematic market survey was undertaken in the selected 6 unregulated plant raw drug markets of two states: i) Tamil Nadu (Madurai, Virudhunagar, Thoothukodi and Dindigul) and ii) Kerala (Palakkad and Thrissur). In the field survey, interviews were conducted with Knowledge Partners (KP) such as primary collectors, traders, pharmacy individuals and ISM practitioners. Frequent market visits were undertaken to collect specimen sold as botanicals, recorded the dynamics of trading system including trade route, regional specificity of raw materials, business as usual practices that affects the Quality Assurance (QA), Good Manufacturing Practices (GMP) and Resource Augmentation (RA) processes of medicinal plants.

Key message of this study: Medicinal plants trade is complex, dynamic and influences the making of commodities that go by the same name.

Key learnings:

1. During the study period 2010 to 2016, an extensive field survey was conducted in two states comprising of six plant raw drug markets viz. 1. Tamil Nadu (Madurai, Virudhunagar, Thoothukodi and Dindigul) and 2. Kerala (Palakkad and Thrissur). Interviews were conducted with identified primary collectors, traders, pharmacy individuals, ISM practitioners related to trade of medicinal plants. Alongside this effort, go downs/retailers/wholesalers/collection points, cultivation trail plots were visited to get better understanding of the trade scenario. The plant raw drug specimen (dried/and fresh forms) were collected from markets, macroscopic
characters were examined to identify the species. Authentication was carried out by the senior taxonomist in FRLHT. The trade names and corresponding scientific names were correlated to each of the botanicals collected during the study. These authenticated materials were deposited in the FRLH herbarium and raw drug repository, FRLHT, Bengaluru. Further these materials were compared with the existing collections in the herbarium.

2. The survey generated an exhaustive list of 779 plant raw drugs corroborated to 298 botanical species traded in the select markets. A ‘ready reckoner of raw drug traded from the study area’ or a ‘catalogue’ with botanical names, trade names, striking features and accession numbers was prepared (Suma et al. 2017).

3. In continuation with the market survey, a special case study was taken up to understand the dynamics and diversity of medicinal plants resources sold in the weekly local market, the Sunday Market (Tilagar tidal) market in Madurai, Tamil Nadu. An ethno-botanical investigation was carried out to document ‘fresh herbs’ dispensed by the Valaiyar communities, who are chiefly folk healers-cum-traders. About 132 plant species was inventoried with their preparation methods and medical uses. These medical uses were subjected to assessment as per Traditional Systems of Medicine (TSM) such as Ayurveda, Siddha and Unani. The study revealed that these local market (Shanties) serve as a Traditional Medicine Service Point (TMSP) similar to Primary Health Care dispensaries. TSMPs not only manage community health at affordable price but also easily adaptable by the community (Suma et al. 2018).

4. Subsequent to the market survey, analysis of the ‘raw drug catalogue’, comprising of 779 botanicals resulted in short listing of a range of 65 trade names with multiple botanical sources. These botanicals were further classified into categories such as: Originals (accepted sources, officinal parts as per AFI, API or Scholarly works); Alternatives (accepted alternative species as per AFI, API or Scholarly works or belonging to the same family of the originals); Substitutes (species beyond the purview of AFI/API or Scholarly work); Replacements (a different species as a make shift arrangement); Deceptive (look alike/bio mimics from
different families); Spurious (unrelated entities, falsified); Context Based Aberrations/false naming (CBA): originals with all parts as admixture of the same species/originals with others species as admixture (this includes those plant parts mixed together belonging to cousin species/members of unrelated botanical families) as blending materials/inert/bulk make up materials/inert materials.

5. During the study, one of the highly traded plant raw drug entity namely Balaa (Sanskrit name) was chosen for pharmacognosy study, due to the multiple plant species being sold in the market. This has resulted in commoditization, controversial identity thus affecting the QA. Approximately 14 species are recorded to be used as Balaa. Study of trichomes (hairs) was undertaken for these species thus leading to development of a simple diagnostic key.

6. In continuation with the pharmacognosy studies, additionally DNA barcoding study with specific ITS2 and MatK markers were taken up for the select commercial products claiming to have Sida cordifolia L. correlating to Balaa ingredient. Popular selected products such as Balaa kwatha, Balaa choorna, Rasanadi choorna, Kachoradi choorna were chosen for the study. None of the samples showed presence of Sida cordifolia. The study warrants for the Next Generation Sequencing (NGS) of the popular all the Balaa candidate plant species, thus helping in pharmaco-vigilence and QA of the raw materials used at production level.

The Ph.D. work is presented as chapters divided into (1) Introduction (2) Review of literature on the trade aspects of botanicals (3) Overall methodology (4) Complexities in the select plant raw drug markets of Tamil Nadu and Kerala (5) A case study of the ‘Fresh Plant Drugs’ dispensed in the Tilagar tidal market of Madurai, Tamil Nadu, as a Traditional Medicine Service Points for managing Primary Health Care (6) Many Modes of Making a Plant Drug Commodity (7) Application of pharmacognostic tools that will ease in identification of Balaa group of resources using anatomy (8) Application of ITS2 and matK barcode markers to authenticate presence of Balaa in select traditional formulations (9) Conclusions.
1. **Introduction:**

Herbal sector is one of the fastest growing sectors across the world catering to wide range of industries for pharmaceuticals, nutraceuticals, cosmetics, plant extracts and domestic traditional systems of medicine industries. Adding to this growth is the ever increasing belief in the use of natural products/herbal medicine. The annual turnover of India’s herbal industry is now estimated at Rs. 20,000 crores (2014-15) as compared to Rs. 8,800 crores in 2005-06 (Ved and Goraya, 2008). The value of exports of botanical drugs, including extracts has gone up from Rs.516 crores (2004-05) to Rs. 3,211 crores (2014-15). Value of exports of plant extract has gone up from Rs.161 crores (2004-05) to Rs. 1,500 crores (2014-15). However 80% of exported plant extracts are listed under miscellaneous category, under the prevailing system of ITC (HS) codes, without specifying the specific plant species (Goraya and Ved, 2017). Moreover, as per World Health Organization (WHO) standards, 80% of the world population depends on Traditional Medicine for managing primary health care (WHO, 2013). This has resulted in the demand for medicinal plants from the wild and non-forest areas.

With this back ground, the present study is focused to deepen the understanding of complexities in botanicals trade at selected regional and local markets of Tamil Nadu and Kerala states. The dissertation work presents the complexities in trade, commoditization of botanicals in the market, alternatives and substitutes as in business as usual, value addition, short fall species, management interventions, development of a handy diagnostic key to distinguish various species using anatomy tools and additional application of DNA bar coding techniques through select marker methods to identify use of genuine materials in the herbal products.

2. **Objectives:**

The overall aim of the study is to understand and appreciate the dynamism in botanical trade and its complexities. Through this process, deepen the understanding of making of the plant based raw drugs/commodities.
The two main objectives are:

1. explore the major raw drug markets in Tamil Nadu and Kerala, identify and enlist range of botanical raw drugs traded.
2. identify the plant sources of these raw drugs including substitutes and adulterants.

3. **Scope**: This study may help
   a) to know the market dynamism, operational forces and complexities at local level.
   b) to know the reasons for making commodities based on logic of trading communities and demand scenario.
   c) to identify and generate a list of species that warrants further research and inclusion in the herbal pharmacopeia as new alternatives, substitutes and better originals.
   d) to identify conservation concern species that are traded.
   e) to develop simple diagnostic key to distinguish between similar looking plant entities based on taxonomical and anatomical characters.
   f) to generate a list of species with short supply as perceived by the trading and industrial communities.
   g) to know the species that are in commercial cultivation and identify potential species for larger cultivation.

4. **Review of literature**: 
   The literature on market studies were obtained from various published sources such as scientific papers, semi and technical reports from international, national and regional/local levels. This chapter helped in selection of markets in Tamil Nadu and Kerala of southern India. The study enabled in understanding of the alternatives/substitutes concept in *Ayurveda Plant Materia Medica* and business as usual practices. This facilitated in prioritizing the trade name “Balaa” and its botanical complexes as the focus of this study, which also involved in-depth pharmacognostic study and development of diagnostic key as explained.
5. **Overall Methodology:**
   Thorough understanding of the technical aspects in conjunction with the socio-cultural milieu of the use of the botanicals is required for the study. A review on the various methods (Jaeger *et al.* 1999; Lang, 2012; Stokols, 2006.) helped to frame research strategy for the present study. This approach visualized integrating disciplines like ethno-botany, taxonomy, social sciences, Ayurveda, pharmacognosy including anatomy and use of molecular techniques.

6. **Study design:**
   The study design primarily focuses on the comprehensive ethno-botanical documentation of medicinal plant resources traded and the dynamism, including the application of pharmacognostic tools to authenticate the raw materials found in the market. Data was collected through interviews using open-ended questionnaires from identified Knowledge Partners (KP).

7. **Steps involved in the study:**
   The main aim of the study is to facilitate the process of Quality Assurance (QA) of herbal drugs and authentication of plant materials traded and used in ISM industries. The following describes the materials and method applied to undertake the entire study.

   **Step 1: Identification of the study areas:**
   Trade study was limited to Tamil Nadu and Kerala states in southern India, where quantum of trade is more than 5,000 MT per annum as per the trade study conducted (Sasidharan and Muraleedharan, 2003; Harilal, 2008; Ved and Goraya, 2008). From these two states, six markets were identified based on earlier works and consultation with trade experts and latest studies.

   **Step 2: Identification of knowledge partners (KP):**
   The Knowledge Partners (KP) for the study was identified based on interactions with individual experts/agencies working in the area of trade in Tamil Nadu and Kerala. The KPs included primary level collectors, herbalists,
traders (wholesale and retail merchants), pharmacy staff and industries. The middle men provided information on trade dynamics.

**Step 3: Building rapport with the community and individuals respondents:**
In this step, initially the key respondents and communities were contacted via non-government organization (The Covenant Centre for Development, Madurai) and Grama Mooligai Company Limited (GMCL), Madurai, a Community-Based Enterprise company in the study area. Through the link established, desired information including trade transactions was elicited through frequent contacts and visits.

**Step 4: Market survey:**
One of the key objectives of this study is to systematically document the existing knowledge about the diversity of medicinal plants species traded in the select raw drug markets of Tamil Nadu and Kerala, southern India. Regular visits to the market (shops, whole sale units, go downs, collection centres), enabled the preparation of a comprehensive resource inventory. An open-ended questionnaire was used to collect information. To ensure the data consistency and reliability, recall techniques, personal observations, recording oral history and repeated questioning were employed (Alexiades and Sheldon, 1996; Yow, 2005). The survey was conducted for the period from Jan 2011 till Dec 2016.

In this study, a list of botanicals traded in the selected southern India markets were compiled from the field documentation. The list was further subjected to identification of high volume traded drugs based on the all India trade study conducted during 2006-08 (Ved and Goraya, 2008). An inventory of 298 botanical species and their 779 botanicals (different parts) were recorded. Authenticated specimens were deposited in the FRLH herbarium, Bangalore. Besides these, market dynamics with regard to market centres, their specialities, trade route, preferred soil type for certain medicinal plants, quality materials etc. was also documented for select species.
Step 5: Documentation of fresh herbs sold in Tilagar tidal market (a special case):

In this study, an initiative has been made to document the unorganized system of healthcare service offered by the local shanties, especially at the Tilagar tidal market, in Madurai City of Tamil Nadu, which is popular for dispensing “Plant Drugs” and “Remedies”. During 2011-2013, recurrent visits were also made to this market, and all the five shop owners belonging to Valaiyar (Moopanar) community were interviewed to document the diverse medicinal plant species that are dispensed along with the prescriptions. Through ethno-botanical documentation, 136 species were recorded as being used for managing health care by a traditional snake catcher’s communities. This is the first time documentation of such a market in Madurai.

Step 6: Preparation of herbarium and raw drug voucher specimen:

Samples of fresh plant drugs sold in the market were procured, processed into herbarium and raw drugs voucher specimen as per the international protocols (Bridson and Forman, 2010; Jain and Rao, 1977) and deposited at FRLH herbarium for authentication.

Step 7: Authentication of the reference materials/voucher specimen:

The specimen were systematically identified by referring to regional, national and international flora (Matthew, 1983; The Plantlist: Version 1.1; 2013) and further authenticated by expert taxonomists at the FRLH herbarium, FRLHT, Bengaluru. These specimens were given accession numbers.

Step 8: Data digitization and curation for analysis:

The data gathered were systematically compiled and computerized using Microsoft Excel and Access version 10. The database comprised of trade names (regional or Sanskrit names), binomial nomenclature, habit, habitat, specific botanical sources, annotated notes on striking features of the raw drugs.
Step 9: **Botanical correlations with vernacular and trade names:**
Further, the botanical correlation with Tamil/Malayalam/trade names, were carried out using multi-dimensional databases on Indian medicinal plants species (FRLHT Database).

Step 10: **Tagging of botanical names to medical systems:**
Additionally, the usage of these plants in other medical systems viz. Ayurveda (A), Siddha (S), Unani (U), Folk (F), Tibetan (T), Modern (M) and Traditional Chinese Medicine (C) were also tagged (envis.frlht.org). The inventory of medicinal plants recorded was overlapped with the database on Indian Medicinal Plants nomenclature browser to connect to the plants recorded in various Indian Systems of Medicine (ISM).

Step 11: **Folk Medicinal uses and classical references:**
In the special case study pertaining to Tilagar tidal market, medicinal uses recorded were closely examined by the physicians of Indian Systems of Medicine (ISM), who are familiar with Local Health Traditions (LHT) adopting the Documentation and Rapid Assessment methodology (Hafeel et al. 2004; Shankar et al. 2004). The experts consulted various classical medical publications related to medicinal uses of the studied species for direct or indirect references. Besides these, physicians also contributed their experience of using these species for treating health conditions.

Step 12: **Identification of alternatives/substitutes in the practice:**
In order to understand the demand and supply chain, it is important to know the alternatives used in the practice to meet the need in the herbal sector. In this process, based on field level documentation as explained in step 5, personal communication with traders, ISM physicians, collectors, industries and published sources including classical literature related to concept of alternatives, especially in Ayurveda resulted in listing of alternatives and substitutes. Additionally, during 2015, a consultative workshop of multi-stake holder (included collectors, traders and manufacturer) conducted which helped in expanding the list of alternatives/ substitutes as per business-as-usual.
Through this process, approximately 65 trade name complexes with their multiple species were derived.

**Step 13: Prioritization of Balaa complex:**

From the exhaustive list of species that are traded in the market, an attempt has been made to prioritize one of the well-known Ayurvedic drug complexes Balaa, called as Kurunthoti in Malayalam. In the Ayurveda concept of Pratinidhi Dravyas (alternatives) for Balaa complex, there are more than 5 species as per scholarly works. Many of these are accepted alternatives as per concepts specified in classical texts, scholarly works and Pharmacopeia. The multiple species used shows taxonomic affinities; regional complexities in Kurunthothi/Balaa trade (Kollamal, 1972; Sivarajan and Balachandran,1994). Annual consumption of Balaa as raw drug by the medicine manufacturing units in North Kerala shows 6,96,943 tons of Balaa/Kurunthoti (Sida rhombifolia L. spp. retusa (L.) Borss. (Sasidharan and Muraleedharan, 2003). At all India level, Sida rhombifolia L. (Balaa) was recorded to be in high volume consumption (>5,000-10,000 MT (Harilal, 2008). Wide range of products for nerve disorders depend largely on Balaa classical and proprietary medicines. Hence, this group was chosen for pharmacogonosy study.

**Step 14: Application of pharmacognostic tools to ease in identification of genuine Balaa materials.**

Ensuring usage of right material for preparation of traditional herbal formulations is a biggest challenge and responsibility for all the stakeholders in the trade. Through employing selected pharmacognosy tools such as taxonomy, anatomy, microscopy, a practical indented diagnostic key for identification was developed to differentiate multiple species complex for one trade name Balaa. Along with this, molecular tools were also employed to verify whether simple or compounded formulations claiming to have Balaa (S. cordifolia), really had it at all. The following paragraphs describe briefly the steps involved in the process.
a. **Anatomical characters analysis:**
Leafy and stem materials was studied under the microscope after processing as prescribed in standard methods (Krishnamurthy, 1988). They were studied under the microscope (Olympus BX 41, Tokyo) and the photographic images were captured were utilized to develop a diagnostic key using trichome characters in comparison to earlier works (Metcalf and Chalk, 1972 and 1985).

b. **Exo-morphological and taxonomical studies:**
Specimen collected was closely examined using tools like hand lens, microscope to observe some of the key characters like shape, texture, colour, size, appearance, odour and taste. Further, these specimens were compared with specimen deposited at FRLHT herbarium for authentication. This effort is included in the ‘Medicinal Plants Raw Drugs Catalogue’ which forms part of the ‘Market Information System (MIS) of botanicals traded in a specific market’.

c. **Molecular studies of selected single/combined drugs formulations and species:**
Besides these, selected single/combined drugs formulations available in the market were chosen based on their label mentioning *S. cordifolia*, the accepted source of *Balaa* (API, 1999). Internal Transcribed Spacer (ITS) 2 and Maturase K (matK) markers based DNA barcoding technique were employed (Murray and Thomson 1980; Chen et al. 2010; Rai et al. 2012).

**Step 15: Sharing knowledge: Capacity building of the beneficiaries about the raw drug identification, sources and related aspects:**
Apart from publication in journals, attempts were made to reach out to Indian Systems of Medicine community through participation in invited talks, consultative meetings, participate in the All India Trade Study, conducted by ICFRE and NMPB during 2015-16.
8. **Conclusions:**

The present study is at micro-level concentrating on the prioritized plant raw drug markets and hence throws light at local level. Through this study, an effort was made to develop a ‘Medicinal Plants Raw Drugs Catalogue’ which forms part of the ‘Market Information System (MIS) of botanicals traded in a specific market’. Moreover, the catalogue connects to the voucher specimen deposited at National Herbarium. This serves as a ready reckoner for the trading communities to authenticate their traded plant materials. Such efforts need to be encouraged for all the markets at regional and local levels.

As an inseparable and integral part of the trade study, one of the well-known local shanties, the *Tilagar tidal* market, in the Madurai was taken up as a case study. This market has a few shops managed by herbalist-cum-traders, belonging to *Valaiyar* communities, who are committed to provide cost effective and adaptable ‘Traditional Medicine Health Care Service’, through dispensing ‘fresh green herbs’. It co-exists with other medical health care systems in the city. Such Traditional Ecological Knowledge and Services, have to be fostered for ‘health for all’ and Sustainable Development Goal 3.

The study attempted to understand the factors that affect the commoditization of drugs in the market with regard to regional manifestations, sourcing issues, pharmacological or biological similarities or neutral additions. These resulted in categorization of the commodities thus deepening the understanding of issues related to controversial drugs/entities and enrich the pharmacopeia. In the study, Pharmacognosy tools and DNA fingerprinting studies facilitated the process of identification of the plant drug *Balaa* and its botanical sources. The complete gene sequencing of the well-known trade names and accepted botanical entities is recommended for pharmacovigilence and QA besides the conventional application of taxonomy.

While understanding the complexities in trade, a few of the commodities representing 23 species were identified as ‘Potential Geographical Indicators (GI)’ based on the choice of the traders and manufacturers. These are valued as the premium quality material and priced high from the specific regions. Such
potential GI commodities can be further studied for its value chain and encouraged in the agricultural crop improvement programs.

In the study, it was recorded that 80% of the rural households attached to the traders are women beneficiaries, thus indicating the livelihood opportunity for the local communities. This may further be promoted under ‘Green Skill Development Program’ initiatives of Government of India for sustainable collection of medicinal plants resources, value addition and marketing medicinal plants produce at local/regional levels.

Through this study, nearing 75 short fall species were identified, which are rare and also of conservation concern through interactions with various stakeholders in different forums. Further, resource augmentation measures can be developed based on the shortfall analysis to meet the demand from the industries. During the study, there are anomalies related to cultivation of unofficial plant species as original drugs, which misleads the users and affects the quality. Measures may be taken by National Medicinal Plant Board (NMPB) to check the spurious materials under cultivation. Also promote incentive driven need based crop improvement and commercial production.

9. **Scientific papers/ Semi-technical /popular write-ups and national and international presentations/ reviews:**

A. **Scientific papers (3):**


B. **Online resources (1):**


C. **Semi-technical/ popular write-ups (3):**


D. **Scientific Review published in (1):**


4. **Paper presentation (5):**


2. Suma TS. Multi-dimensional databases on Indian Medicinal Plants, traded and conservation concern species. In Scoping Workshop on IT-based Monitoring of
Indian Bio-resources at National Biodiversity Authority, Chennai and GIZ, India. 13-14th, Feb. 2018., organized jointly by National Biodiversity Authority and GIZ, Chennai, India


5. In Press (1):