AGRO-CLIMATIC, ECONOMIC AND GOOD AGRICULTURAL PRACTICES ADOPTION FEASIBILITY STUDIES ON SELECTED MEDICINAL PLANTS OF PUNJAB

A

THESIS

SUBMITTED TO

MAHARAJA RANJIT SINGH PUNJAB TECHNICAL UNIVERSITY

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IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR IN PHILOSOPHY

IN

PHARMACY

By

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2021

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis, entitled "**Agro-climatic, Economic and Good Agricultural Practices Adoption Feasibility Studies on Selected Medicinal Plants of Punjab**" in fulfillment of the requirements of the award of the degree of Doctor of Philosophy in **Faculty of Pharmaceutical Sciences** and submitted in **Maharaja Ranjit Singh Punjab Technical University, Bathinda** is an authentic record of my own work carried out during a period from Aug., 2017 to Dec., 2021 under the supervision of Dr. Ashish Baldi, Professor, Department of Pharmaceutical Sciences & Technology, Maharaja Ranjit Singh, Punjab Technical University, Bathinda, Punjab, India.

The matter embodied in this thesis has not been submitted by me for the award of any other degree of this or any other University/Institute.

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This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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National Medicinal Plants Board

FOREWORD

Nature has bestowed medicinal plants as a wonderful gift to the human race for curing and preventing a large number of ailments. They are not only used as medicine but in cosmetics, food supplements, hygiene for improving the quality of life. Increased awareness among the population regarding their significant role in maintaining an individual's quality of life, has led to a surge in the demand for medicinal plants. The majority of the medicinal plants are collected from the wild and very few are practiced for cultivation. This worldwide supply of medicinal plants through the wild collection is resulting in shrinking of natural resources, unsustainable collection, and decreased biodiversity leading to species entering the red data book. Therefore, the conservation of medicinal plants both in-situ and ex-situ becomes essential.

The cultivation of medicinal plants with compliance with Good Agricultural Practices ensures rich quality raw drugs. In this context, I am pleased to note the study titled "Agro-climatic, economic and good agricultural practices adoption feasibility studies on selected medicinal plants of Punjab" carried out by the authors through the financial support of Forum on Indian Traditional Medicine (FITM), a platform created by the Ministry of AYUSH at Research and Information System for Developing Countries (RIS), New-Delhi.

This study brings out critical points and addresses objectives that are required in the adoption of medicinal plants in Punjab. The study encompasses the identification of medicinal plant cultivators and subsequently geo-tag their locations and digitalize their demographic data using Geographic Information System (GIS). The study highlights potential growing zones for 13 medicinal plants using climatic as well as land pattern data. Besides this the authors have conducted a survey relating to constraints faced by the farmers of Punjab in medicinal plant cultivation, generating good agricultural practices monographs for medicinal plants viz: Curcuma longa L., Aloe vera (L.) Burm.f., *Ocimum sanctum* L., *Emblica officinalis* Gaertn., *Rauvolfia serpentina* (L.) Benth. ex Kurz *considering farmer's practices and reported literature. The study emphasizes on identification and mapping of critical agricultural variables involved in the cultivation of medicinal plants to avoid risks at later stages of production. The agro-economics of selected medicinal plants carried out in the present study is essential for the farmers of Punjab interested in medicinal plant cultivation. This study is very helpful in strengthening the medicinal plant's sector particularly in Punjab which has a huge potential of adopting the cultivation of medicinal plants as a better farming option. I once again compliment and the authors as well as FITM for this important study.*

With Best Regards

01/03/21

(DR SASTRY J L N)

NATIONAL MEDICINAL PLANTS BOARD
Plants For Health & Prosperity

if the wisdom is herbal,
many ailments are curable
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ABSTRACT

INTRODUCTION

According to the World Health Organization (WHO) estimate, the global herbal industry is projected to be worth US$ 5 trillion by the year 2050 globally. Punjab is an Indian state which falls under trans-gagentic agro-climatic zone of India. Despite favourable climatic conditions and trade opportunities, Punjab has less than 1% of its total cultivable land under medicinal plants cultivation which is far less than its potential. Non-existence of agro-climatic zoning, standard agro-practices, unawareness about Good Agricultural Practices (GAP), marketing and no quality mapping with industrial standards have made the adoption of medicinal plants complex.

METHODS

The selection of medicinal plants was done on the basis of commercial value, feedback received from local farmers, Government officials along with experts from industry and academia. Agro-climatic study was conducted after collecting the annual temperature and rainfall records from the Indian Meteorological Department (IMD) and Punjab Agricultural University (PAU) and agro-eco-subregion based benchmark soils network was utilized for the preparation of digital base maps. All the base maps were superimposed to highlight optimally suitable zone, suitable zone, and lesser suitable zone using Arc. GIS 10.3. Different government, private channels were explored to identify farmers involved in medicinal plants cultivation for geo-tagging and conduct of survey. The base maps were digitalized online and digital information layers were created. The exact location of farmers was marked on the digitalized maps using their latitude and longitude coordinates using GIS. The farmers were interviewed personally using a questionnaire following the purposive sampling technique. Different constraints related to technical, marketing, social participation, awareness and farmer attitude and policy were studied based on Mean Percentage Score (MPS) and Chi-square test was applied to highlight the significant relationship between the farmer's land holdings (small and large farmers) and various constraints. To supplement quality-rich medicinal plants, drafting of comprehensive Good Agricultural and Collection Practices (GACP) guideline was conducted after critically assessing and comparing the GAP of WHO and other countries like America, Japan,

China, The United Kingdom (UK), and India for selected plants. Critical variable alignment study was conducted to understand significant variables and map Critical Materials Attributes (CMA), Critical Process Parameters (CPP) with Critical Quality Attributes (CQA) for e.g. content of active constituent, crop yield, heavy metal content, pesticide residue, physico-chemical ranges, microbial load and suggest improvements. Standardization of farmer's produce for same quality parameters and gap/variability analysis in comparison to industrial standards was conducted using the Failure Mode and Effect Analysis (FMEA) to get rich-quality herbs and avoid risks that are involved in widespread testing of medicinal plants which is mostly costly. Subsequently, monographs featuring GAP related documentation for on-field cultivation were prepared after conducting field visits, farmer interaction and corroborating the inputs with reported literature. The cost-return analysis for selected medicinal plants was performed following descriptive statistics such as average prices of the crops to calculate total variable costs, yield, gross returns, and return over variable costs. The comparative agro-economics analysis was conducted between traditional crops (wheat and rice) and selected medicinal plants. The GAP based farming manuals have been prepared in English and vernacular language (Punjabi).

RESULTS OBTAINED

Based on industrial demand, pharmacological importance, feasibility of cultivation, and expert consultation, thirteen medicinal plants such as *Aloe vera (A. vera), Phyllanthus emblica* (*P. emblica*), *Withania somnifera* (*W. somnifera*), *Glycyrrhiza glabra* (*G. glabra*), *Asparagus racemosus* (*A. racemosus*), *Andrographis paniculata* (*A. paniculata*), *Ocimum sanctum* (*O. sanctum*), *Curcuma longa* (*C. longa*), *Centella asiatica* (*C. asiatica*), *Acorus calamus* (*A. calamus*), *Rauvolfia serpentina* (*R. serpentina*), *Ocimum basilicum* (*O. basilicum*), *Chlorophytum borivilianum* (*C. borivilianum*) were selected for the agro-climatic zoning studies. Among these thirteen plants, five medicinal plants i.e. *A. vera, O. sanctum, C. longa, P. emblica, R. serpentina* were identified that were presently cultivated by the farmers of Punjab which were included in the survey studies. Among these five medicinal plants, *A. vera, O. sanctum, C. longa* were selected for preparing detailed GAP monographs considering their short crop cycle in terms of first harvest than *P. emblica*, and *R. serpentina*.

The agro-climatic zoning model highlighted that zone-I was optimally suitable for most of the selected medicinal plants, followed by zone-II, III, IV, and V. Geo-tagging enabled assessing of farmers on different agro-climatic zones of Punjab and representing their demographics. It was found that 05 medicinal plants such as *C. longa, A. vera, O. sanctum, P. emblica*, and *R. serpentina* were cultivated by 68 farmers across Punjab. It was found that 95.72% of the farmers were not involved in signing contract farming, 78.4% had no processing units, 58.4% lacked knowledge of potential agro-climatic zone to cultivate medicinal plants, 74.47% lacked awareness regarding GAP. The comprehensive drafted GAP guidelines resulted in 12 GAP parameters with 108 sub-parameters. The variable alignment study highlighted seed, site, soil, and water had the highest bearing on the crop yield. Furthermore, in pre-cultivation phase, seed treatment, site treatment, soil treatment, and water treatment had very high impact on crop yield and very less impact on physicochemical ranges. In agro-practices phase, sowing had high impact on crop yield, and very less effect on toxicity indicators. Subsequently, in post-harvest phase, collection has moderate effect on active constituents, drying has moderate effect on microbial load, and storage has moderate effect on active constituents. FMEA successfully enabled standardization of farmers produce in context to crop yield, toxicity indicators, microbial load, active constituents, and physicochemical ranges. Highest severity was given to toxicity indicators followed by microbial load, active constituents, crop yield, and physicochemical ranges. Each agricultural process (authentication, site selection, soil, water, cultivation, crop fertilization, harvest, drying, storage, etc.) and its effect on the critical standardization criteria was evaluated and checklists were suggested to lower the Risk Priority Number (RPN) in order to get good standardized herbal produce. The monograph represented three sections *viz.* botanical and pharmacological characteristics of plants, good agricultural practices, and Standard Quality Certifications (SQC's) tests that were mentioned in Ayurvedic Pharmacopoeia of India (API), Indian Council of Medical Research (ICMR), WHO, and Food Safety and Standards Authority of India (FSSAI). Based on our agro-economics study, *A. vera* has INR. 92,876/- profitability per annum/acre, *O. sanctum* has INR. 35,515/-, and *C. longa* has a profitability of INR.73,725 per annum/acre. The pictorial farming manuals were prepared in local language (Punjabi) for wider dissemination among the farmers.

DISCUSSION

A comprehensive roadmap was required to identify potential growing zones and medicinal plants cultivators in the state, digitalize their information in order to map the farmers on the agro-ecological specific map using GIS. In developing countries like India there is scanty information related to medicinal plants cultivators so digitalization of farmers information would also help to link clients, farmers, industries, and concerned officials to plan strategies for improved access, trade, and outreach in the future studies.

It also highlighted *O. sanctum*, *W. somnifera* as alternate crops for paddy during *kharif* season. Different technical, trade, social, awareness, and policy related constraints highlighted in the study would help the policymakers to devise appropriate solutions to promote medicinal plants cultivation in the state. In agro-economics study, the selected medicinal plants had more annual profitability than wheat and paddy, hence these crops can be adopted by the farmers after following GAP, and market assessment.

Maintaining consistency is one of the major hurdles in agriculture due to several interfering biological and other factors, hence variability alignment study technique would enable farmer to fine-tune parameters by evaluating possible interactions with in-depth understanding. Conventionally, reliability of medicinal plants has been accomplished using widespread testing of medicinal plants adopting probabilistic reliability modeling. These methods were applied at the delayed phase of improvements. Therefore, FMEA would help to standardize the farmers produce in order to avoid quality related issues in the later stages. Experience of a farmer plays a vital role in the success of the crop. The WHO has recommended drafting of region specific GAP monographs of medicinal plants. In accordance to it, monographs were prepared considering the farmers practices, ecological conditions of the state and corroborate the inputs with supportive literature. These monographs can be adopted by the farmers interested in cultivation of medicinal plants at commercial scale.

CONCLUSIONS

The study was designed to promote the medicinal plants cultivation in the state keeping in view the economic sustenance of farmer based on integrative knowledge of optimum zone and condition, financial feasibility analysis, suitable agro-practices, collection methodologies, quality evaluation and related documentation. The study

successfully identified medicinal plants cultivators in the state, digitally mapped farmers and also embedded their demographic profile using GIS. Agro-ecological zoning successfully highlighted potential growing zones for medicinal plants across Punjab. It also highlighted various constraints faced by the farmers. Subsequently, comprehensive GAP guidelines were drafted, the study also identified critical materials and processes effecting quality of medicinal plants. FMEA approach was successfully applied for standardization of farmers produce in order to prevent late stage risks in plant production. The monographs of GAP of selected medicinal plants based on the farmers practices and literature support were drafted and the agro-economics study suggested that *C. longa, A. vera,* and *O. sanctum* has more profitability per annum than the traditional crops.

As no policy exists to regulate right medicinal plant in right area, the rationale and findings of the present study can be used in other parts of the country to ascertain potential growing zones for other medicinal plants based on the region's ecological conditions. The geo-spatial approach used in the present study can provide a luminous light to link consumers and industries directly with the farmers throughout the country. Subsequently, successful farmer's practices in corroboration with the literature can be reported in the form of monographs and disseminated throughout the region using vernacular languages in different parts of the country. This study can be a baseline study for integration of scientific methodologies, successful agro-practices, and documentation as per international norms leading to inputs for future policies for farmer's benefit.

DEDICATED

To

The Farmers and Peasants

ACKNOWLEDGEMENTS

Iamque opus exegi, quod nec jovis ira, nec ignis,
nec poterit ferrum, nec edax abolere vetustas;

(I have now completed a work that neither the wrath of Jupiter, nor fire,
nor sword, nor the devouring of time can destroy)

Soon after I chose to study Pharmacy, I took a conscious decision of doing a Ph.D. Every research scholar may second to these lines that entering a Ph.D. may not be very difficult but completing a Ph.D. takes a toll on social, physical, and mental aspects of a researcher's life. When I was in school days and got fewer marks, my dad use to say that everything one's get in inheritance can be shared by relatives or others but it is only your education that no one can take away from you. For me, achieving a Ph.D. degree was a dream that is coming true today. Completing Ph.D. was my *Opus exegi*. As I believe that every passing-out Ph.D. scholar carves his way and has his own struggle story to inspire, my Ph.D. journey was not at all exceptional from those hardworking, brave and diligent Ph.D. scholars.

The efforts bore fruits with the successful completion of my Ph.D. However, many people share the reward of this effort simply because it would never have been this good without their help. I relate my Ph.D. work with a plant that has been sown, nurtured, watered, shaped, by many professionals to whom I shall remain indebted throughout my life. First and foremost, I would extend my sincere thanks to my guide Prof. (Dr.) Ashish Baldi, Department of Pharmaceutical Sciences and Technology, Maharaja Ranjit Singh Punjab Technical University, Bathinda. The relationship between the student and his supervisor is always priceless as there is a need to combine two wills, each with their circumstances, to achieve best during the Ph.D. I am grateful to my guide for seeding the idea of my research topic and providing all necessary means for growth. As I took the shovel to nurture the seed with soil, and water it, it was my guide who monitored the entire process diligently, provided solutions to the problems such as plague, drought, and hail so that the tree can grow righteously bearing the best fruits. I also remember the good times when we as a team used to struggle, bear the pressure of writing, re-writing, drafting the research ideas to get research projects from various funding agencies. The sleepless nights writing proposals at the department, the patties and samosas that many of the times replaced

our lunch and dinner, we managed to get 05 projects in a year -as rightly said "hard work always pays". Prof. Baldi possesses deep knowledge that helped me to learn and implement a wide spectrum of professional skills.

Behind every successful man is a woman. And if the man is married, then the woman is definitely his wife. I owe a great sense of respect, love to the strength of my life- my wife Neha Bajwa. Apart from managing her own Ph.D. work, taking care of our home, cooking, she stood by me and worked together as a team. Whether it was daily routines or achieving long-term goals, she helped me in every dimension. Things for me changed when our daughter Nehreet was born on 5-September-2020. She is an apple of my eye and all the pressure and tensions vanished on seeing her. Through this acknowledgement, I wish her success, prosperity and best in her life. My parents deserves endless gratitude: my dad Dr. Charanjit Singh Nabha for his constant support in every aspect of my life, wise counseling, and specifically teaching me that positive attitude and patience leads to success. To my family, I give everything, including this.

Dr. J.L.N. Sastry (CEO, NMPB) is a walking encyclopedia in the field of medicinal plants. It is a great honor for me that he took time from his busy schedule to acknowledge my research work in the form of a foreword page. I once again thank and extend my sincere gratitude to Dr. Sastry sir.

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I record a cordial acknowledgement for all my teachers from school to university. I place my special thanks to my friends and batch mates for being my stress busters through their wonderful company. Last but not the least; I am thankful to the farmers and peasants of Punjab for guiding me throughout the work.

(Preet Amol Singh)

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Ziziphus jujuba

LIST OF PUBLICATIONS DURING Ph.D.

ARTICLES DURING Ph.D. TENURE (Total Impact Factor: 25.6)
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1. **Singh PA**, Sood A, Baldi A. Determining Constraints in Medicinal Plants Adoption: A Model Geospatial Study in the Indian State of Punjab, *Journal of Applied Research on Medicinal and Aromatic Plants*, 2021, 12 (3), 1-10. **Impact factor (3.4). [Scopus Indexed].**

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3. **Singh PA**, Sood A, Baldi A. Highlighting Agro-Ecological Zones to Upscale the Production of Immunity-Booster Plants in Punjab, *Research Journal of Agricultural Sciences*, 2021, 12 (3), 865–870. **NAAS rating (4.0). [Listed in UGC-Care].**

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11. Bajwa N, **Singh PA**, Sodhi RK, Baldi A, Jyoti K, Chandra R, Madan J. Chronicle of Nanomicelles in Drug Delivery: from Bench to Bedside. In: Nanomaterials: Evolution and Advancement towards Therapeutic Drug Delivery, Part-I. Chapter: 5. **Bentham Science** edited by Surendra Nimesh, Nidhi Gupta, Ramesh Chandra. 2021, pp. 161-210.

12. Bajwa N, **Singh PA**, Baldi A, Jyoti K, Chandra R, Madan J. Scale-up, Preclinical and Clinical Status of Poly (Lactide-Co-Glycolide) and its Copolymers based Drug Delivery Systems. In: Nanomaterials: Evolution and Advancement towards Therapeutic Drug Delivery, Part-II. Chapter: 7. **Bentham Science** edited by Surendra Nimesh, Nidhi Gupta, Ramesh Chandra. 2021, pp. 246-292.

PAPER PRESENTED AT CONFERENCES/SEMINARS

International Conference

1. Delivered oral presentation on topic entitled "Devising Artificial Intelligence System using Complex Datasets for Identification and Authentication of Potential Indian Spices" at SPER, Nepal International conference held at Kathmandu University, Nepal on 7-8 June 2019.

National Conferences and Seminars

Oral presentations

2. Delivered oral presentation titled "Computational Approaches Based Quality Determination of Selected Medicinal Plants" at International Conference on Herbal Medicines: Research and Commerce-Global Perspectives at L.M. College of Pharmacy Ahmedabad held on 27^{th} – 29^{th} Dec, 2018.

3. Delivered oral presentation titled "Development of Agro-climatic Zoning Model for Selected Medicinal plants in Punjab" at National conference on Water & Soil Resource Management for Sustainable Agriculture & Biodiversity Conservation organized by Department of Agricultural Sciences, Swami Vivekanand Group of Institutes, Banur, Punjab, India on 8-9th November 2019. **[Won Award]**.

Poster presentations

4. Presented a paper titled "Modeling an Agro-ecological Zoning Methodology to Highlight Potential Growing Areas of Selected Medicinal Plants in Punjab" at SFEC-2020, 7th International Congress of Society for Ethnopharmacology, India, held at Jamia Hamdard, New-Delhi from 15-17th February, 2020.

5. Presented paper titled "Cultivation of Medicinal Plants as Available Alternative for Uplifting Farmer's Income in Punjab" at national seminar on Agrarian Crisis in Punjab in Panjab University Regional Centre, Shri Mukstar Sahib, Punjab, India on 29th March 2019.

6. Presented paper titled "Developing an Agro-climatic Zoning Model and Identification of Constraints to Access Possibilities of Medicinal Plants Cultivation in Punjab" in ICP (International Conference of Pharmacy) on the theme "Pharmacy: Realigning the Focus on Health" organized by School of Pharmaceutical Sciences, Lovely Professional University held on 13-14th September 2019.

7. Presented a paper titled "Novel Bilayered Formulation for Sequential Release of Desmopressin Acetate and Tolterodine Tartrate: An Effective Way to Manage Nocturnal Enuresis" at 6th World Congress on Nanomedical Sciences-ISNSCON-2018, Chemistry-Biology Interface 2019 and Conference on Science and Technology for Future of Mankind held at Vigyan Bhawan, New-Delhi on 7-10 Jan, 2019. **[Won Award]**.

8. Presented a paper titled "Robust Artificial Methods for Identification and Authentication of Indian spices" at 23rd Annual National Convention of Association of Pharmaceutical Teachers of India (APTICON-2018) held at Jaipur from 5-6th October, 2018. **[Won Award]**.

9. Presented a paper titled "A Novel Technique to Authenticate Spices Using Complex Computational Approaches" at Integrated Conference on Ayurveda, Agriculture & Pharmaceutical Sciences at Arogya Sangoshthi sponsored by Ministry

of AYUSH and Namo gange trust, held at Lovely Professional University, Jalandhar, Punjab on 13-14th October, 2018. **[Won Award]**.

10. Presented a paper titled "Computational Authentication of Herbal Drugs: One Stop Solution Technique for Quality Standardization and Identification of Adulterants" at 70th Indian Pharmaceutical Congress (IPC), held at Amity University, Noida from 21-23 Dec, 2018.

11. Presented a paper titled "HPTLC Fingerprinting Profiling and Validated HPLC Method for the Determination of Betulin in the Stem Bark of *Tectona grandis*" at 69th Indian Pharmaceutical Congress (IPC) held at Chitkara University, Rajpura, Punjab from 22-24th December, 2017.

LIST OF ABRREVIATIONS

A. annua	*Artemisia annua* L.
A. calamus	*Acorus calamus*
A. paniculata	*Andrographis paniculata*
A. racemosus	*Asparagus racemosus*
A. vera	*Aloe vera* (Linn.) Burm.f.
AHP	American Herbal Pharmacopoeia
AHPA	The American Herbal Products Association
APCI	Atmospheric Pressure Chemical Ionization
API	Ayurvedic Pharmacopoeia of India
app.	Application
As	Arsenic
ASTA	American Spice Trade Association, Inc.
ASU	Ayurvedic, Siddha, and Unani
AYUSH	Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homeopathy
B. campestris	*Brassica campestris*
B. carinata	*Brassica carinata*
B. juncea	*Brassica juncea*
B. napus	*Brassica napus*
B. nigra	*Brassica nigra*
BC	Backward Class
C. asiatica	*Centella asiatica*
C. borivilianum	*Chlorophytum borivilianum*
C. longa	*Curcuma longa* L.
Cd	Cadmium
CIBRC	Central Insecticides Board and Registration Committee
CIMAP	Central Institute of Medicinal and Aromatic Plants
CITES	Convention on International Trade in Endangered Species of Wild Flora & Fauna
cm	Centimetre
CMA	Critical Material Attributes

COVID-19	Coronavirus Disease- 2019
COX	Cyclooxygenase
CPF	Chlorpyrifos
CPP	Critical Process Parameters
CQA	Critical Quality Attributes
Cr	Chromium
CSIR	The Council of Scientific & Industrial Research
Cu	Copper
DAP	Di-ammonium Phosphate
DDT	Dichloro-diphenyl-trichloroethane
DET	Detection
DMAPR	The Directorate of Medicinal and Aromatic Plants Research
DPPH	2,2-diphenyl-1-picryl-hydrazyl-hydrate
E. coli	*Escherichia coli*
E. officinalis	*Emblica officinalis* Gaertn.
ESA	European Spice Association
FAO	The Food and Agriculture Organization
FASCs	Farm Advisory Services Centers
FCs	Facilitation Centres
FDA	Food and Drug Administration
Fe	Iron
FMEA	Failure Mode and Effect Analysis
FPO's	Farmer Producer Organizations
FSSAI	Food Safety and Standards Authority of India
FTIR	Fourier Transform Infrared
FYM	Farm Yard Manure
g	Gram
G. glabra	*Glycyrrhiza glabra*
GACP	Good Agricultural and Collection Practices
GAP	Good Agricultural Practices
GC	Gas Chromatography
GIS	Geographic Information System

GMP	Good Manufacturing Practices
H&MP	Herbal and Medicinal Plants
Ha	Hectare
HCH	Hexachlorocyclohexane
Hg	Mercury
HHRC	Herbal Health Research Consortium
HMHDP	High Molecular Weight High-Density Polyethylene
HPLC	High Pressure Liquid Chromatography
HPTLC	High-Performance Thin Layer Chromatography
h	Hours
i.v.	Intravenous
IC_{50}	The Half Maximal Inhibitory Concentration
ICAR	The Indian Council of Agricultural Research
ICMR	Indian Council of Medical Research
IDMA	Indian Drugs Manufacturer Association
IITM	Indian Institute of Tropical Meteorology
IMD	Indian Meteorological Department
INR	Indian Rupee
ISM	Indian System of Medicine
IUCN	International Union for the Conservation of Nature
Kg	Kilogram
KVKs	Krishi Vigyan Kendras
L	Litres
L.S.	Longitudinal Section
LC-MS	Liquid Chromatography-Mass Spectrometry
m	Meter
MAP	Medicinal and Aromatic Plants
max	Maximum
MCF-7	Michigan Cancer Foundation-7
mg	Milligram
min	Minimum
mins	Minutes

mL	Millilitres
mL/min	Millilitres per Minute
mm	Millimetre
MPS	Mean Percentage Score
MS	Mass Spectroscopy
MSP	Minimum Support Price
MT	Metric Ton
NGO	Non-Government Organisation
n.l.t	Not Less Than
n.m.t	Not More Than
N.P.K.	Nitrogen Phosphorus Potassium
NABARD	National Bank for Agriculture and Rural Development
NABL	National Accreditation Board for Testing and Calibration Laboratories
Ni	Nickel
nm	Nanometre
NMPB	National Medicinal Plants Board
O. basilicum	*Ocimum basilicum*
O. sanctum	*Ocimum sanctum* L.
OBC	Other Backward Class
OCC	Occurrence
P. aeruginosa	*Pseudomonas aeruginosa*
P. emblica	*Phyllanthus emblica*
PAU	Punjab Agricultural University
Pb	Lead
pH	Potential of Hydrogen
ppb	Parts per Billion
ppm	Parts per Million
PPVRFRA	Protection of Plant Varieties and Farmers' Right Authority
PRECIS	Providing Regional Climates for Impact Studies
QbP	Quality by Produce
QCI	Quality Council of India

QPM	Quality Planting Material
QRM	Quality Risk Management
q	Quintals
R. serpentina	*Rauvolfia serpentina* (L.) Benth. ex Kurz.
RA	Rosmarinic Acid
RCFC	Regional cum Facilitation Centre
RCT	Randomized Clinical Trails
RET	Rare, Endangered and Threatened
R_f	Retention Factor
RPN	Risk Priority Number
Rs.	Rupees
RRL	Regional Research Laboratory
s	Seconds
SAP	Sustainable Agricultural Practices
SC	Scheduled Caste
SEV	Severity
SHGs	Self Help Groups
SOP	Standard Operating Procedures
Spp.	Species
SPSS	Statistical Package for the Social Sciences
ST	Scheduled Tribe
T.S.	Transverse Section
TCM	Traditional Chinese Medicine
Th	Thorium
Ti	Knol Khol
TLC	Thin Layer Chromatography
U	Uranium
UA	Ursolic Acid
UK	The United Kingdom
US	The United States
UV	Ultraviolet
W. somnifera	*Withania somnifera*

WHO	World Health Organization
Wt.	Weight
Yp	Yield Potential
Zn	Zinc
µ	Micro
µg/mL	Micro gram per Millilitres
µL	Microliters
%	Per cent
% w/v	Per cent Weight by Volume
% w/w	Per cent Weight by Weight
°C	Degree Celsius
$	Dollar