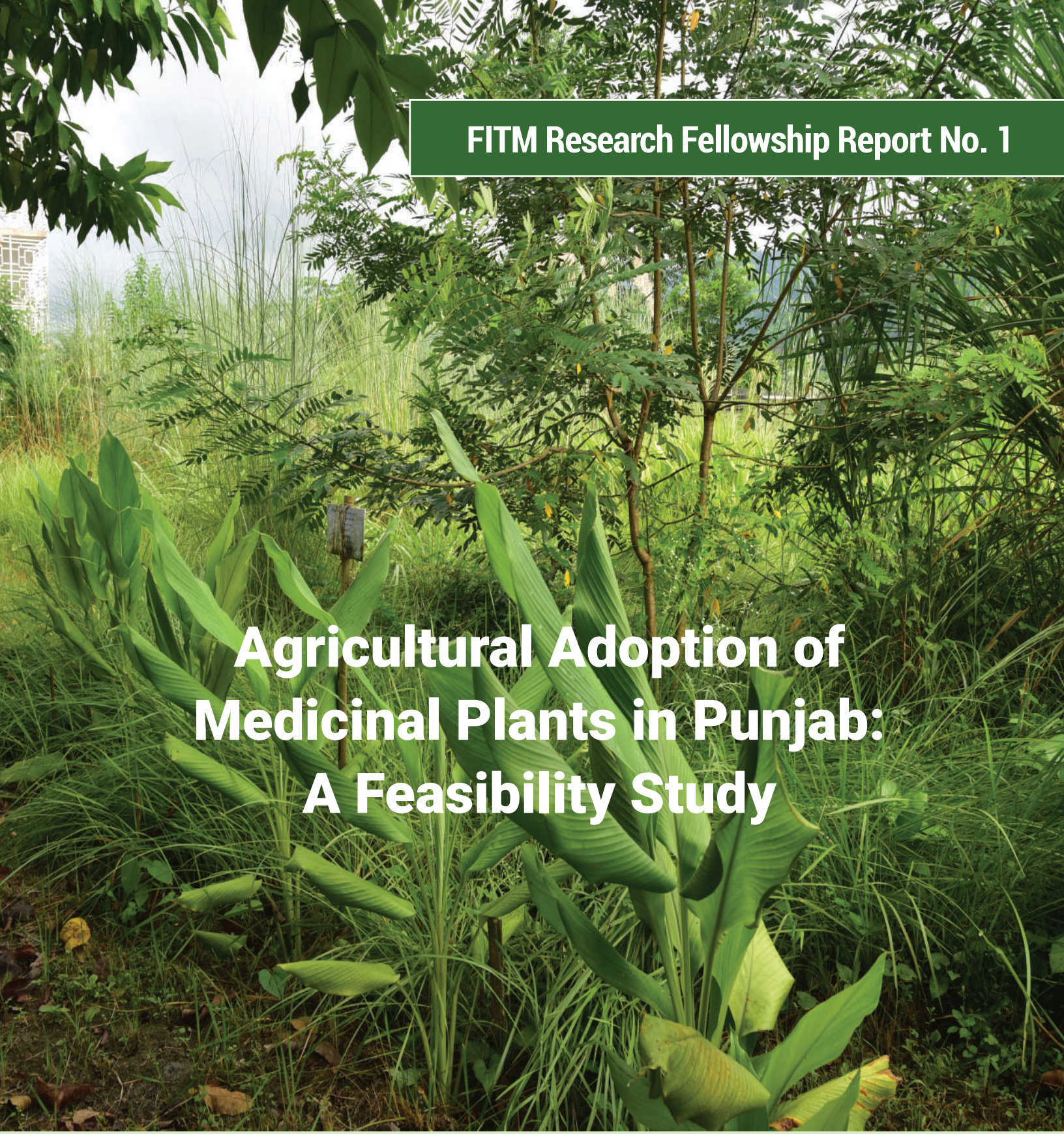

FITM Research Fellowship Report No. 1

Agricultural Adoption of Medicinal Plants in Punjab: A Feasibility Study

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Forum on Indian Traditional Medicine

RIS
Research and Information System for Developing Countries
विकासशील देशों की अनुसंधान एवं सूचना प्रणाली

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Agricultural Adoption of Medicinal Plants in Punjab: A Feasibility Study

Preet Amol Singh

The publication of this Report/Book has been financially supported by the Ministry of AYUSH/RIS. The responsibility of the facts stated or opinions expressed is entirely of the author and not of the Ministry of AYUSH /RIS.

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ISBN: 81-7122-175-0

Published by:

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Acknowledgements

I am grateful to the FITM for providing Doctoral Research Fellowship and technical guidance. I am thankful to Professor Sachin Chaturvedi, Director General, RIS for endorsing the report. I am thankful to Prof. Ashish Baldi, my Ph.D. supervisor and the whole team of Pharma Innovation Lab, Department of Pharmaceutical Sciences & Technology, Maharaja Ranjit Singh Punjab Technical University, Bathinda, Punjab for providing facilities to carry the work. I am grateful Dr J. L. N. Sastry (CEO, NMPB) and Dr Arun Chandan (Regional Director RCFC-North-I, NMPB) for their observations on the present study in the form of messages. I am thankful to Professor (Dr) Tanuja Manoj Nesari, (Director, AIIA, New-Delhi), Dr G.P. Kimothi (NMPB), Dr Kavita Tyagi (NMPB), Dr NB Brindavanam (Consultant NMPB), Mr Jitender Sharma, IFS (Former Principal Chief Conservator of Forests, Department of Forests & Wildlife Preservation, Punjab), Mr Yugraj Singh (DFO), Mr Daljit Singh (DFO), Department of Forests & Wildlife Preservation, Punjab, Professor (Dr) Manmohan Singh (Regional researchstation,PAU,BallowalSonkri,Punjab),DrAnilSood(ScientistSG&Head Agro-ecosystem and Crop Modelling Division Punjab Remote Sensing Centre PAU, Ludhiana), Professor (Dr) Sukhpal Singh (Principal Economist, Department of Economics and Sociology, Punjab Agricultural University), Mr Sumit Bhardwaj (Research Assistant, Department of Economics and Sociology, Punjab Agricultural University), Dr Charanjit Singh (Former Deputy Director, Punjab Pollution Control, Board, Patiala), Mrs Neha Bajwa (ICMR-SRF), Dr Aman Kumar, Principal Scientist, Bio-resource Development Department, DRDC (Dabur Research and Development Centre, Ghaziabad), Mr Jyoti Saroop (Manager, Unati Co-operative Marketing-Cum-Processing Society Ltd., Talwara, Punjab), Mr Pardeep Garg (Managing Director, Herbal Trends, Gidderbaha, Punjab), Mr Satyan Dilawari (Director, Herbal Health Research, Amritsar, Punjab), Mr Lakhwinder Sharma (Department of Statistics, Punjabi University, Patiala), Dr Sunita Garg (Scientist at NISCAIR, New-Delhi) for supporting the project through their much-needed inputs. Last but not least we are thankful to the farmers of Punjab especially Mr Naresh and his team and (Late) Mr Bikramjeet Singh who guided us with their farming experience.

Foreword

Around 80 per cent of the world's population relies directly or indirectly on traditional medicines for primary healthcare need. Most of the traditional medicines are formulated after the medicinal plants are collected and processed. India contains 15 agro climatic zones with diverse number of plant species, of which more than 8000 species have medicinal uses. These medicinal plants have a wide range of uses in Indian society, including the production of medications used in Ayurveda, Siddha, Unani, Homoeopathy, Sowa-Rigpa, as well as in other plant-based pharmaceutical firms. Growing demand for traditional medicinal formulations for managing different ailments are putting undue pressure on our natural resource base as more than 80 per cent of the species are collected from the wild.

Also, the impact of COVID-19, has sparked a greater interest in researching alternate options for medicinal plant-based therapies. Therefore, it is important to discuss strategies that assure balancing the sustainable supply of herbs to the herbal industries and their conservation both in-situ and ex-situ.

The Indian state of Punjab considered as one of the Green Revolution's most popular and successful success stories today faces concerns on depleting ground water and soil health due monoculture of wheat and rice. This has necessitated the need for crop diversification in the state.

The present study discusses the feasibility of adopting medicinal plants by the farmers of Punjab. It highlights digitisation of medicinal plants cultivators using GIS, understanding constraints in medicinal plants adoption, develops monographs for farm-level medicinal plants production, and discusses Good Agricultural Practices to assure supply of good quality herbs. It also highlights agro-economics of economically important medicinal plants and compares it with traditional crops i.e. wheat and rice.

I am sure the present study would enable tapping the potential of medicinal plants sector in the Indian state of Punjab. I congratulate Dr Preet Amol Singh for producing this important report. I hope to see more recipients of FITM Fellowship scholarships produce policy relevant reports in future. I also thank the RIS publication team for designing and publishing the Report.

Professor Sachin Chaturvedi
Director General, RIS

Dr. J. L. N. Sastry
Former CEO, NMPB, Ministry of AYUSH
Government of India

Preface

The increasing interest of the population in complementary and alternative systems, particularly in the Indian Systems of Medicine is leading to a surge in the demand for Ayurvedic, Siddha, and Unani (ASU) drugs which are mostly made from medicinal plant parts. The global market size of herbal sector is likely to touch US $ 746.9 billion in the year 2022 against the estimated global market size US$ 657.5 billion in year 2020. Similarly, the current turnover of the Ayush industry is US$ 18.1 billion suggesting growth of 17 per cent during 2014–2020. Most of the medicinal plants are collected from the wild but recent restrictions imposed on unprincipled collection from forests, and knowledge regarding herbal raw drug sources in the industries has augmented the cultivation of medicinal plants. Now there is a broad consensus that cultivation of medicinal plants provides best prospects for conservation and providing herbal raw material of desired quality. The World Bank has highlighted that though the cultivation of medicinal plants is done on a small scale it is projected to show 'dramatic growth' in the coming decade favouring organic and mixed cropping. There is a prevailing belief that the adoption of Good Agricultural Practices (GAP) is restrictive and obstructs farmer's agriculture practices. On the contrary, the adoption of GAP provides a sustainable production system for both the producers and users.

The Indian state of Punjab has a meager agricultural area under Medicinal and Aromatic Plants (MAP) due to its high reliability of traditional crops, i.e. Wheat and Paddy. There are many reports that indicate this monoculture cropping system leading to the exploitation of natural resources especially the underground water table. Understanding the need for crop diversification, this comprehensive study was undertaken to highlight in-depth insights into the medicinal plants' sector of the state especially focussing on the identification of medicinal plant cultivators, digitalizing farmer's data using Geographic Information System (GIS), and constraints faced by the farmers in medicinal plants adoption through personal interviews. With no policy to regulate the right medicinal plant species in the right location, the study highlighted potential growing areas of thirteen medicinal plants, *viz Aloe vera*, *Emblica officinalis*, *Withania somnifera*, *Glycyrrhiza glabra*, *Asparagus racemosus*, *Andrographis paniculata*, *Ocimum tenuiflorum*, *Curcuma longa*, *Centella asiatica*, *Acorus calamus*, *Rauvolfia serpentina*, *Ocimum basilicum*, and *Chlorophytum borivilianum* considering climatic and land pattern data. Besides drafting comprehensive and robust GAP guidelines for medicinal plants, monographs on GAP *for Curcuma longa, Aloe vera, Emblica officinalis, Ocimum sanctum*, and *Rauvolfia serpentina* based on farmer's agro-practices and reported literature are also mentioned in this book. The identification and mapping of critical material attributes, critical process parameters, and their effect on critical quality attributes during the cultivation of medicinal plants would make this book worth it for medicinal plant stakeholders. Apart from this, the report flags various risk factors involved in the cultivation of medicinal plants and their management for the

first time. Understanding the dynamic nature of the medicinal plant sector that demands re-look for a gamut of demand and supply, the agro-economics study of medicinal plants and traditional crops are included in the study followed by critical observations and recommendations.

The text of the report is laced with images, graphics to highlight various issues pertaining to the objectives of the study. The study is organized into 12 chapters. The authors hope that this work imparts more understanding and knowledge to the subject on various complex issues, and should be helpful to the policymakers, researchers, resources managers, and users for drafting strategies that strengthen the medicinal plants sector in the state. I am grateful to the FITM for providing technical as well as financial support to complete this project.

Preet Amol Singh

List of Abbreviations

A.vera	*Aloe vera* (Linn.) Burm.f.
API	Ayurvedic Pharmacopoeia of India
app.	Application
As	Arsenic
ASTA	American Spice Trade Association, Inc.
AYUSH	Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homeopathy
BC	Backward Class
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
COX	Cyclooxygenase
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

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 Effect Analysis
FPO's	Farmer Producer Organizations
FSSAI	Food Safety and Standards Authority of India
FYM	Farm Yard Manure
g	Gram
GACP	Good Agricultural and Collection Practices
GAP	Good Agricultural Practices
GIS	Geographic Information System
Ha	Hectare
HCH	Hexachlorocyclohexane
Hg	Mercury
HHRC	Herbal Health Research Consortium
HMHD	High Molecular Weight High-Density Polyethylene
HPLC	High Pressure Liquid Chromatography
HPTLC	High-Performance Thin Layer Chromatography
Hrs.	Hours
i.v.	Intravenous
ICAR	The Indian Council of Agricultural Research
ICMR	Indian Council of Medical Research
IITM	Indian Institute of Tropical Meteorology
IMD	Indian Meteorological Department
ISM	Indian System of Medicine
IUCN	International Union for the Conservation of Nature
Kg	Kilogram
KVKs	Krishi Vigian Kendras
m	Meter
MAP	Medicinal and Aromatic Plants
max.	Maximum
mg	Milligram
min	Minimum
mins	Minutes

mm	Millimetre
MPS	Mean Percentage Score
MSP	Minimum Support Price
MT	Metric Ton
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
NHo_1	Null Hypothesis
Ni	Nickel
NMPB	National Medicinal Plants Board
O.sanctum	*Ocimum sanctum* L.
OBC	Other Backward Class
OCC	Occurrence
P.aeruginosa	*Pseudomonas aeruginosa*
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
quin.	Quintals
R.serpentina	*Rauvolfia serpentina* (L.) Benth. ex Kurz.
RCFC	Regional cum Facilitation Centre
RET	Rare, Endangered and Threatened
$R_{f:}$	Retention Factor
RH_1	Alternate hypothesis
RPN	Risk Priority Number
Rps.	Rupees
SC	Scheduled Caste
SEV	Severity
SHGs	Self Help Groups

Spp.	Species
SPSS	Statistical Package for the Social Sciences
ST	Scheduled Tribe
TCM	Traditional Chinese Medicine
Th	Thorium
TLC	Thin Layer Chromatography
TS	Transverse Section
U	Uranium
UV	Ultraviolet
WHO	World Health Organization
Zn	Zinc
µ	Micro
%	Per cent
%w/v	Per cent Weight by Volume
%w/w	Per cent Weight by Weight
<	Less than
>	More than
°C	Degree Celsius

Executive Summary

The increasing demand for herbal raw materials and based products for healthcare and wellness across India and worldwide is leading to high demand for medicinal plant resources both, collected from wild and cultivated. This has raised concerns regarding the need for a sustainable supply of raw herbal drugs thereby focusing the attention of experts on *in-situ* and *ex-situ* conservation of the medicinal plants. The Indian state of Punjab has always led by an example in the area of agriculture and is still celebrated as a success story in implementing the green revolution. The green revolution led to the situation directing the farmers to adopt monoculture of wheat-paddy in the state. With a period, this monoculture cropping pattern is leading to the decline of groundwater levels, soil fertility, and crop yield with the experts suggesting the need for crop diversification.

The cultivation of medicinal plants not only offers opportunities for crop diversification but can be a potential source for income generation. It was in this direction that the need was felt to undertake this comprehensive study whose sole objective was to analyse the feasibility of adoption of the medicinal plants in the state.

The present work comprises 12 chapters that are inter-connected to each other opening a new vista that might be helpful to the concerned policymakers for upscaling the adoption of medicinal plants in the state. The chapter I comprises identification, digitalisation of data, mapping of medicinal plant cultivators on agro-climatic zones of Punjab using Geographic Information System (GIS). It successfully determined the number of farmers cultivating the specific medicinal plant in the specific agro-ecological zone of Punjab highlighting the natural biophysical potential of the specific area. The medicinal plants require specific climate and soil for expressing quality and at present there is no policy to regulate the right medicinal plant species in right location.

The chapter II provides agro-ecological zoning studies considering climatic and land pattern data for highlighting potential growing areas of *Aloe vera*, *Phyllanthus emblica*, *Withania somnifera*, *Glycyrrhiza glabra*, *Asparagus racemosus*, *Andrographis paniculata*, *Ocimum tenuiflorum*, *Curcuma longa*, *Centella asiatica*, *Acorus calamus*, *Rauvolfia serpentina*, *Ocimum basilicum*, and *Chlorophytum borivilianum* in Punjab. This helped identifying optimally suitable, suitable and lesser suitable zones for selected medicinal plants considering different agro-climatic aptitudes of Punjab. The chapter III highlighted technical, marketing, social participation, awareness related constraints faced by the medicinal plant cultivators in Punjab. Primary data was collected after conducting personal interviews with the farmers throughout Punjab. A complex statistical technique such

as Chi-square was applied to define significant relationships between the small and large farmers in context to the different statements related to constraints. This chapter provided ground observations and thorough inputs from the farmers which might help the policymakers to promote the cultivation of medicinal plants in the state. Maintaining consistency is one of the major hurdles in agriculture due to several interfering biological and other factors. Therefore, chapter-IV highlighted critical material attributes, critical process parameters, and critical quality attributes involved in the cultivation of medicinal plants. In view to ensure the quality of medicinal plants, the World Health Organization (WHO) has published Good Agricultural and Collection Practices (GACP) in the year 2003 and suggested the countries develop country-specific guidelines. Chapter-V involved the exploration and comparison of GACP guidelines of WHO and other countries in order to devise more robust and comprehensive GAP guidelines. This can guide the formation of GAP guidelines based on a specific region or nation for developing monographs on medicinal plants. The GAP guidelines developed by research institutions located in the specific geographic area may not meet the exact agronomic requirements of the same crop cultivated in the different agro-climatic regions. Hence, chapters VI to X comprised of GAP monographs of *Curcuma longa, Aloe vera, Phyllanthus emblica, Ocimum tenuiflorum,* and *Rauvolfia serpentina* considering agronomic practices followed by the farmers of Punjab and reported literature published by various concerned research organizations.

The chapter-XI comprises agro-economic studies of selected medicinal plants, their comparison with traditional crops based on cost-return analysis. The study highlighted potential profit involved in the cultivation of selected medicinal plants than the traditional crops if prior marketing is assured.

Before the end of the book, the chapter XII also includes critical observations and recommendations based on the present undertaken study. The recommendations mentioned in the present work might be helpful for the policymakers to introduce medicinal plant cultivation in the state at the commercial level eventually opening the opportunities for crop diversification in the state.

1

Geographical Information System for Mapping of Medicinal Plant Cultivators

1.1 Introduction

Many countries including India have a rich tradition of using medicinal plants as medicines, food supplements, cosmetics, fragrances, for maintaining health hygiene, and quality of life1. Indian System of Medicine (ISM) comprising of Ayurveda, Unani, Siddha, and Homeopathy have used plants for curing both humans and animals (Mukherjee, 2001). As per WHO (World Health Organization), 60-80 per cent of the world's population seeks plants or plant-derived natural products for the prevention and curing of various diseases.[1]

Punjab falls in the agro-climatic zone-VI, known as the "Trans-Gangetic Plains Region" which is further divided into five agro-climatic zones (Sidhu, 2011; Hamadani and Khan, 2015; Hiloidhari *et al*. 2014; Krishan *et al*. 2015). Two-third of the total production of the food grain is contributed by Punjab[2]. Punjab has a meager agricultural area under Medicinal and Aromatic Plant (MAP) cultivation due to various factors involved. However, few progressive farmers have started medicinal plant cultivation in Punjab[2]. In developing countries like India, official information on medicinal plant cultivators is scanty. Geographic Information System (GIS) is an automated system for capturing, retrieving, storing, analysing, and displaying spatial data. It allows mapping of spatial data and facilitates the progression of descriptive to analytical work resulting in the rise of hypothesis (Parker, 1988). In the present chapter, we discuss the exploration of various channels to collect information related to medicinal plant cultivators and characterize, enumerate, and digitally map the medicinal plant cultivators using GIS in Punjab to design an improved system for health services research in the future.

1.2 Methodology

1.2.1. Identification of medicinal plant cultivators

The medicinal plant cultivators' data was collected in between May 2019 and July 2019 from *Collection of medicinal plants data from Government channels.* This included collecting details of medicinal plants cultivators from different concerned government channels. The information gathered from the concerned government institutions are mentioned below:

RCFC-North: The National Medicinal Plants Board (NMPB) through its Facilitation Centres (FCs) provides a service window for growers of medicinal plants for supporting cultivation; handholding support to stakeholders in terms of technology dissemination, trainings, data compilation and maintenance, etc. The facilitation centres work in close co-ordination with the concerned departments of Indian states and also provide

training in the formulation of projects of medicinal plants cultivation, development.

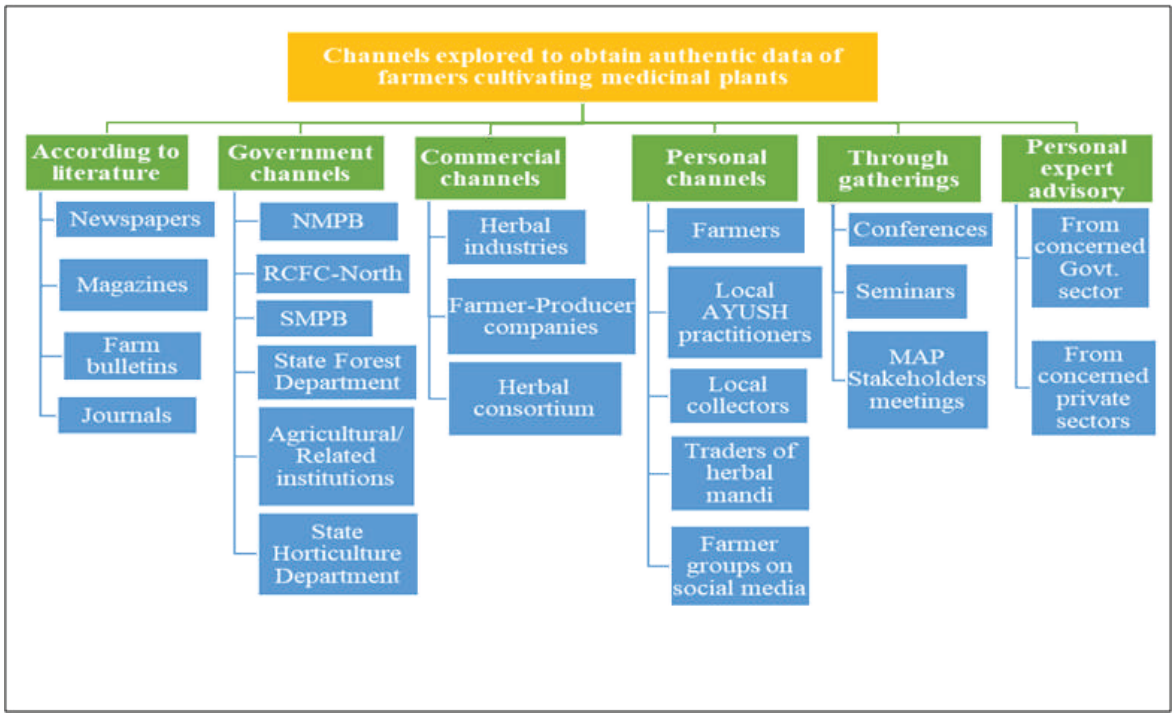
State Forest Department: It has direct linkage with the farmers of the state cultivating medicinal plants. The subsidies provided to farmers for cultivating selected medicinal plants are disbursed to the farmers through state forest department by the NMPB.

State Horticulture Department: The department deals with the spices and aromatic crops like Curcuma longa L. (Haldi) and other spices. The department provides facilities to the growers on priority basis to upscale the adoption of horticultural crops. *KVK's:* Punjab Agricultural University (PAU) Ludhiana, is engaged in providing agricultural extension services through a network of Krishi Vigian Kendras (KVKs) and Farm Advisory Services Centers (FASCs) located in different districts of the state. It has direct link with the farmers and potentiates quick transfer of technology among the farmers of the state and getting first hand feedback of their field problems. *Collection of data from private channels:* Various private channels were explored to gather medicinal plant cultivators information. For this, appointments were made with the concerned officials of different herbal industries, herbal consortium, farmer-producer companies, traders of herbal *mandis*, and other progressive farmers throughout Punjab on personal requests. Seminars and MAP stakeholders meeting conducted by RCFC-North, NMPB were also attended to get substantial data regarding farmers cultivating medicinal plants in Punjab. The outline of various channels explored for information and collection of data is represented in the Fig. 1.1.

1.2.2. Farmer interaction

The information gathered from the concerned organizations was utilised to personally interview medicinal plants cultivators in their respective fields throughout Punjab for geo-

Fig. 1.1: Channels explored to obtain data of farmers cultivating medicinal plants in Punjab



Source: Authors' compilation

tagging and mapping of farmers on digitalized maps (Tongco, 2007).

1.2.3. Spatial distribution of medicinal plants cultivators using GIS

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. A manual digitization method was used, through which X and Y coordinate values were assigned to describe the locations of points. The first layer comprised of basic geophysical structures, viz. major roads, built-up and district boundaries.[1]

The respondents were combined on geophysical characteristics; roads, built-up and district boundaries in the digitalised map. Maps were marked considering the pre-determined five agro-climatic zones of Punjab. This helped in determining the number of farmers cultivating the specific medicinal plant in a specific area and agro-climatic zone of Punjab. Furthermore, demographic information was embedded and stored in specific layers of maps using GIS software Arc. GIS 10.3.

1.3. Results & Discussion

1.3.1 Identification of medicinal plant cultivators

Based on the data collected and participating interest of the farmers, this resulted into identification of 68 medicinal plant cultivators involved in commercial cultivation of medicinal plants like Curcuma longa L., (Haldi) Aloe vera (Linn.) Burm.f. (Ghritkumari), Emblica officinalis Gaertn. (Amla), Ocimum sanctum L. (Tulsi), Rauvolfia serpentina (L.) Benth. ex Kurz. (Sarpgandha). The farmers cultivating specific medicinal plants with area under cultivation is mentioned in Table 1.1

According to the Ayurveda Pharmacopoeia of India (API), the selected medicinal plants have broad spectrum pharmacological properties and have high demand and industrial utilisation as mentioned Table 1.2. According to the report on "Medicinal Plants in India: An Assessment of their Demand and Supply" by the NMPB and Indian Council of Forestry Research and Education, Dehradun, most of the selected medicinal plants were among top 198 medicinal plants covering 95per cent of total herbal raw drugs consumed by Indian herbal industry (Goraya & Ved, 2017).

1.3.2. Spatial distribution of medicinal plants cultivators using GIS

The mapping of farmers on the agro-ecological specific map has been carried out using GIS. Mapping potentiated to determine the number of farmers cultivating the specific medicinal plant in the specific agro-ecological zone of Punjab highlighting the natural biophysical potential of the specific area. Amla is native to tropical and sub-tropical regions. It is native to southeast Asia's moist and deciduous forests

Table 1.1: Number of medicinal plant cultivators with area of cultivation

S.No.	Selected medicinal plants	No. of farmers	Total area of cultivation (Acres)/ No. of plants
1	*Curcuma longa*	24	86.5 acres
2	*Aloe vera*	20	128.5 acres
3	*Emblica officinalis*	15	13,370 plants
4	*Ocimum sanctum*	05	02 acres
5	*Rauvolfia serpentina*	04	03 acres

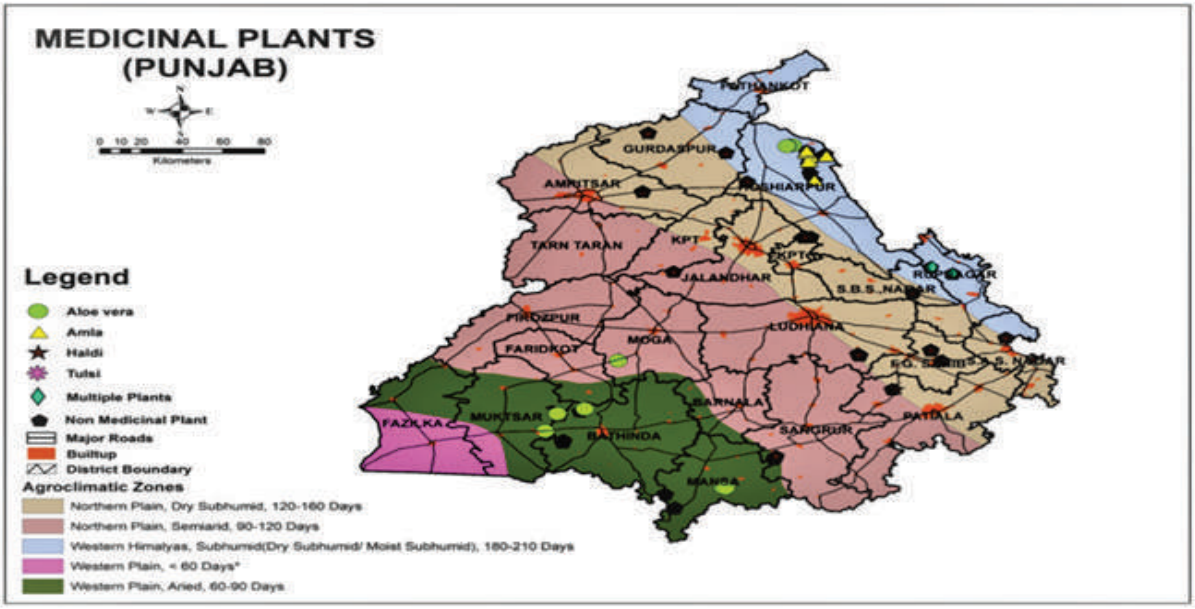
Source: Authors' compilation based on data gathered from the farmers

Table 1.2: Selected medicinal plants and relevant details about their demand and uses

Medicinal plant	Medicinal applications (AYUSH & Allopathy)	Representative formulations (AYUSH & Allopathy)	Rank among cultivated plants on the basis of estimated consumption[1]	Estimated consumption by domestic herbal industry* (MT)	Reference
Aloe vera (Ghritkumari)	Jvara, Udararoga, Kastārtava, Yakrdvikāra, Laxative, In treatment of psoriasis, Acne, Anti-diabetic, Wound healing, etc.	Rajahpravartini Vati, Cukkumtippalyādi Gutika, Juices, Tablets, Tonic, etc.	1	15677.08	(The Ayurvedic Pharmacopoeia of India, 1989; Eshun and He, 2010)
Emblica officinalis (Amla)	Raktapitta, Amlapitta, Prameha, Dāha, vitality and vigor booster, treatment of diarrhea, jaundice, inflammation, dietary source of vitamin C, etc.	Cyavanaprasa, Triphala, Juices, Candies, etc.	2	14178.23	(The Ayurvedic Pharmacopoeia of India, 1989; Tandon and Sharma, 2010)
Ocimum sanctum (Tulsi)	Svasa, Kustha, Kāsa, Krmiroga, Asmari, Pārsva Sula, Hikkā, Chardi, Netraroga, In treatment of bronchitis, Bronchial asthma, Malaria, Diarrhea, Dysentery, Skin diseases, Arthritis, In painful eye diseases, Chronic fever	Tribhuvanakirti Rasa, Manāsamitra Rasa, Muktāpancāmrta Rasa, Muktādi Mahājana, Churnas, Tablets, Pills, Juices, Eye drops, Expectorants, Oils, etc.	10	1362.81	(The Ayurvedic Pharmacopoeia of India, 1989; Gupta *et al.* 2008)
Curcuma longa (Haldi)	Pāndu, Prameha, Vrana, Sitapitta, Tvagroga, Pinasa, Kustha, Visāvikara, Antioxidant, Anti-cancer, Anti-inflammatory, Insecticidal, Nematocidal, Anti-microbial etc.	Haridrā Khanda, Syrups, Tablets, Capsules, Tonics, Juices, Lozenges, etc.	11	1334.13	(The Ayurvedic Pharmacopoeia of India, 1989; Prasad and Aggarwal, 2011)
Rauvolfia serpentina (Sarpgandha)	Jvara, Sula, Apasmāra, Bhrama, Anidrā, Bhutabādhā, Yonisula, Madaroga, Mānasaroga, Krmiroga, Unmāda, Vrana, Raktavita, Visucika, In treatment of snakebite, Hypertension, etc.	Sarpagandhādi Cūrna, Sarpgandhā Vati, Sarpagandhāyoga, Sarpagandhā Ghana Vati, etc.	--	275.34	(The Ayurvedic Pharmacopoeia of India, 1989; Abhijit and De, 2010)

Source: Goraya and Ved, 2017.

Fig. 1.2: Geospatial distribution of medicinal plant cultivators on agro-ecological zones of Punjab



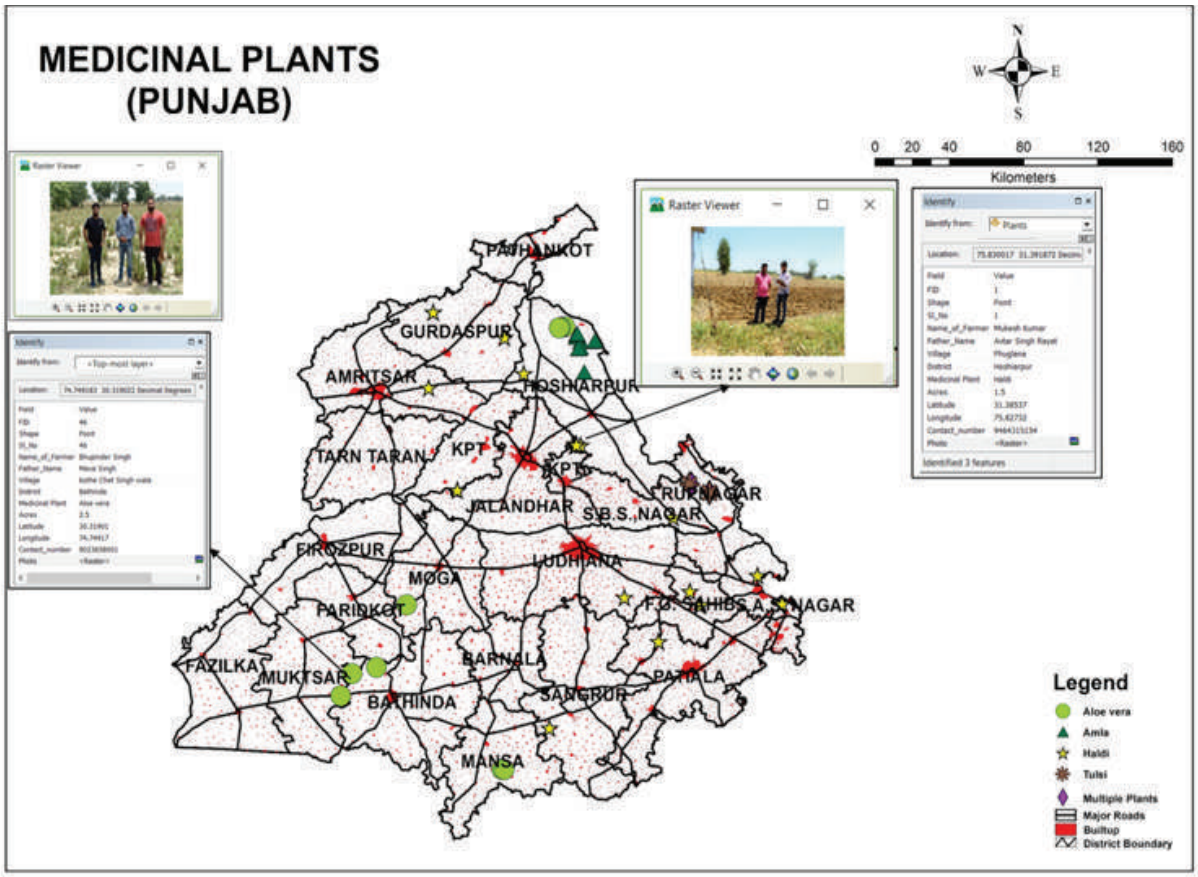
Source: Authors' compilation based on data gathered from the farmers

and is found along the hill slopes ranging 800-1500m and above altitude. In the present study, it was observed that the amla was mostly cultivated in the western Himalayas, subhumid agroclimatic zone of Punjab which can be corroborated to its suitable agro-ecological requirements as per the literature1. Sarpgandha is native to tropical and sub-tropical regions and is found up to an elevation of 1300-1400 m requiring 1100-4500 mm annual rainfall. In the present study, Sarpgandha was found in the agro-climatic zone-I (western Himalayas, sub-humid belt), which is attributed to the plant's suitable agro-ecological requirements (Bhattarai, 2013). Tulsi which is found in the entire Indian subcontinent ranging from the Himalayas (1800m) to Andaman and Nicobar islands, is cultivated in the agro-climatic zone-I (western himalayas, sub-humid belt) corresponding to its suitable agro-ecological conditions (Jat et al. 2014). Ghritkumari originated in Africa due to dry climate, hence it is highly suited for aried and semi aried zones corroborating with the findings of the present study in which it was predominantly found in the western plain aried zone of Punjab (Eshun and He, 2010). Haldi is found in diverse tropical regions from sea level to 1500 m above sea level. Haldi was cultivated in different agro-climatic zones of Punjab especially in the northern plain, dry subhumid zone, and western himalayas, subhumid agro-climatic zones, which represented its natural agro-ecological requirements. The fig. 1.2, represents the geospatial distribution of medicinal plant cultivators in the Punjab.

In developing countries like India, information on medicinal plant cultivators, private health providers, etc. is scanty and also scattered. This is a major hurdle for effective health care planning, linkage with industries, trade and policy development (Deshpande et al. 2004). In this context, the farmer's demographic information was digitalized and embedded on respective maps. Relevant data was inserted in such a way that the detailed information like name of the farmer, photograph of the farmer, father's name, village, district, a medicinal plant cultivated, its area and contact number displayed on each marking on the map when clicked as represented in the **Fig. 1.3**.

In the present study, a systematic survey of medicinal plant cultivators has been carried

Fig. 1.3: Embedded demographic information of medicinal plant cultivators



Source: Authors' compilation based on data gathered from the farmers

out by digitally mapping the cultivators with their socio-demographic characteristics using GIS. Punjab alone has 284 licensed herbal units based on Ayurveda out of 1,95,000 herbal units across India (Goraya and Ved, 2017). Therefore, digital mapping, representing collected data compiled in a virtual image could be used to link clients, farmers, industries, and concerned officials to plan strategies for improved access, trade, and outreach in the future studies. Mapping also potentiated to determine the number of farmers cultivating the specific medicinal plant in a specific agro-climatic zone of Punjab highlighting the natural biophysical potential of the specific area.

1.4. Conclusion

The work was aimed to enumerate and identify farmers cultivating medicinal plants in Indian state of Punjab. In the present study, data was successfully collected and subsequently stored on digital map using GIS for the very first time as no such compilation was previously available. Data explored from different channels resulted into identification of 68 farmers cultivating haldi, ghritkumari, amla, tulsi, and sarpgandha. The study also developed digital maps highlighting the five agro-climatic zones of Punjab to facilitate study related to biophysical potential of specific zone with the selected medicinal plant. It was found that at present haldi was cultivated in every zone of Punjab except western plain. Similarly, tulsi, amla, sarpgandha was cultivated in western Himalayas, sub-humid zone. On the other hand, ghritkumari was dominant on western plain, aried zone corroborating with its suitable agro-ecological requirements followed by western Himalayas, sub humid zone. Furthermore, geo-tagging of farmers was done on respective maps using

GIS Arc.GIS 10.3 application and relevant data was inserted in such a way that the detailed demographic information on each marking on the map was successfully displayed. The study resulting into the digitalisation of farmer's data on respective agro-climatic zone specific maps can be utilised for further studies and generating new hypothesis related to linkage of medicinal plants sector stakeholders for trade, and connectivity.

Endnotes

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[2] On the basis of top 198 medicinal plants covering 95 per cent of total herbal raw drugs consumed by Indian herbal industry (Report on "Medicinal Plants in India: An Assessment of their Demand and Supply" by National Medicinal Plant Board and Indian Council of Forestry Research and Education, Dehradun, compiled by G.S. Goraya and D. K. Ved, 2017).

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2

Agro-Ecological Zoning Based Suitability Study To Identify Potential Growing Areas for Medicinal Plants

2.1 Introduction

India is located to equator's north extending between 8°4′ to 37°6′ north latitude and 68°7′ to 97°25′ east longitude.[1] The country possesses tropical monsoon climate with summers (March-May), winters (January-February), south-western monsoon (June-September) and north-eastern monsoon in southern peninsula (October-December) season.[2] Punjab is an Indian state located between 29′30′′ N to 32′32′′ N latitude and 73′55 E to 76′50 E longitude in the north-west of the Indian subcontinent. Punjab falls in the agro climatic zone-VI, which is called the "Trans-Gangetic Plains Region" (Hamadani and Khan, 2013). Most of Punjab lies in the fertile plain; toward the southeast one finds semi-arid and desert landscape; a belt of undulating hills extends along the northeast at the foot of the Himalayas (Singh and Rath, 2013; Sidhu, 2011).

Punjab is also referred to as one of the most successful celebrated stories of the green revolution bearing good results at the time (Khajuria, 2016). This impression, however, will be diluted, if no management interventions are made on agricultural pattern of Punjab. With time, the momentum of the green revolution started to sustain, and wheat-paddy dominance has led to the overexploitation of groundwater resources, pesticide resistance, declining soil fertility, and increasing vulnerability to human diseases (Kaur, 2010a). In such cases, crop diversification with commercially important crops such as medicinal plants can be helpful. In progress that would persuade the farmers to diversify and adopt the planned cultivation of medicinal plants in a climatically diverse state, the author has devised an agro-ecological zoning model in the present study.

A crop is optimally grown in its preferred conducive environment. Therefore, the idea of this model is to predetermine optimally suitable, suitable, and less suitable areas considering the climatic and land pattern data in context to the bio-climatic requirements for the medicinal plants. The present study utilised principles of agro-climatology as the main tool (Falasca et al. 2012). Based on available bibliographic data, the climatic requirements for selected medicinal plants were identified. In this study crucial parameters like temperature, rainfall, soil texture and soil pH were considered to highlight optimally suitable, suitable and lesser suitable agro-climatic zones for selected MAP in Punjab.

2.2 Methodology

2.2.1. Selection of medicinal plants

Medicinal plants for the study were selected based on their bio-physical requirement suitability in context to the climatic conditions

of the Punjab, feasibility of cultivation, consumption by the herbal industries, estimated annual trade, expert consultation and prior traces of their cultivation in the state.

2.2.2. Collection of meteorological data

To define temperature and rainfall zones, meteorological data was collected from the available meteorological research stations in Punjab. Annual temperature and rainfall records were analysed after obtaining the climatic data from IMD (Indian Meteorological Department) and PAU (Punjab Agricultural University) meteorological research stations present. The temperature records were collected from eight research stations similarly; rainfall data was collected from 11 research stations present in Punjab. Depending upon the availability of meteorological data in the research stations, the period for the meteorological record was selected for the study.

2.2.3 Preparation of base maps

The base maps were digitalised online and digital information layers were created using GIS Arc.GIS 10.3 software. The climatic data obtained from the different meteorological stations were utilized for the preparation of temperature and rainfall digital base maps. The thermal regime was defined by the average annual temperature and similarly, the moisture regime was plotted based on annual rainfall data. The research stations from where meteorological data was collected were geo-tagged using their latitude and longitude specifications on digital maps using GIS. On the other hand, an agro-eco-subregion based benchmark soils network was utilised for the preparation of digital soil maps based on texture and pH. In the agro-eco-subregion model, soils in the same family generally required the same management practices and maximum production result acquired from a soil family can be utilized as production targets of other soils belonging to the same family (Chahal, 2005; Kumar *et al.* 2008; Saini *et al.* 1995).

2.3 Results and discussion

2.3.1 Medicinal plants selected

The medicinal plants for the agro-ecological studies were selected based on the consumption by the herbal industries, estimated annual

Table 2.1: Medicinal plants selected for the agro-ecological zoning studies

Medicinal plants	Estimated consumption by herbal industries (Dry weight MT)[1]	Estimated annual trade (MT)*
Aloe vera (L.) Burm.f. (Ghritkumari)	15677.08	>10000
Emblica officinalis Gaertn.. (Amla)	14178.23	>10000
Withania somnifera (L.) Dunal (Ashwagandha)	4198.0	2000-5000
Glycyrrhiza glabra L. (Mulethi)	2832.10	2000-5000
Asparagus racemosus Willd. (Shatavari)	2723.00	2000-5000
Andrographis paniculata (Burm.f.) Nees (Kalmegh)	1828.35	2000-5000

Ocimum tenuiflorum L. (Shyama tulsi)	1362.81	2000-5000
Curcuma longa L. (Haldi)	1334.13	1000-2000
Centella asiatica (L.) Urb. (Brahmi)	781.02	500-1000
Acorus calamus L. (Bach)	590.10	500-1000
Rauvolfia serpentina (L.) Benth. ex Kurz (Sarpgandha)	275.34	200-500
Ocimum basilicum L. (Rama Tulsi)	73.30†	200-500
Chlorophytum borivilianum Santapau & R.R.Fern. (Safed Musali)	25.80†	100-200

Source: Goraya and Ved, 2017.

* Report on "Medicinal Plants in India: An Assessment of their Demand and Supply" by National Medicinal Plant Board and Indian Council of Forestry Research and Education, Dehradun, compiled by G.S. Goraya and D.K. Ved, 2017).

trade, expert consultation and prior traces of their cultivation in the state (Ved and Goraya, 2017). The 13 medicinal plants selected for the study are mentioned in the Table 2.1.

2.3.2 Collection of meteorological data

The climatic data, *viz*. temperature and rainfall obtained from the various research stations is mentioned in table 2.2 and 2.3. The average annual temperature of the state is 23.9°C which is suited for all the selected medicinal plants in the study. The maximum average temperature, i.e. 31.3 was observed in the research station present in the Bathinda district of Punjab represented in zone-IV, similarly the minimum average temperature i.e. 15.5 was observed in the research station present in Amritsar district represented in zone-II. The cropping pattern in Punjab is divided into *Kharif* and *Rabi* season representing the sowing of crops at the beginning and the end of the rainy season respectively (Kaur *et al.* 2010b). Two major crops of Punjab i.e. Rice and Wheat are sown in *Kharif* and *Rabi* season respectively. As per the climatic data, the mean maximum temperature during the *Rabi* and *Kharif* season was 25°C and 38°C respectively. The average annual temperature of the state is 23.9°C. However, the mean maximum and minimum temperature can reach 44°C and 8°C minimum. Long term historical meteorological analysis of Punjab, revealed that the frequency of occurrence frost was limited to only two days in December, five days in January, and one day in February (Kaur *et al.* 2016). The Indian climate is mainly characterized by monsoon rainfall as supported by several studies (Krishan *et al*. 2015). The rainfall data collected from the research stations ranged from 350-above 1000 mm as mentioned in the table 2.3 and most of the rainfall is received during the southwest monsoon occurring from June to September. There is a high variability of rainfall in space and time in Punjab. The annual rainfall variability in Punjab is 25 to 30 per cent while monthly variability ranges between 35 to 230 percent (Kaur *et al*. 2016). The zone-I represented the highest level of rainfall ranging from 1000-1500 mm followed by zone-II, III, IV, and V. The zone-V represented the lowest range of rainfall in Punjab covering south western districts of Punjab such as Fazilka.

Table 2.2: Research stations with temperature ranges in Punjab

Research stations	Location co-ordinates of research stations	Period of collected data	Representing agro-climatic zone	Average minimum and maximum temperatures ranges (°C)	Average temperature range (°C) of the stations
Ballowal Saunkri	31.0993°N, 76.3870° E	1984-2015	Zone-I and II	16.2-30.0	23.1
Amritsar	31.6340°N, 74.8723° E	1970-2018	Zone-II and III	15.5-30.3	22.9
Jalandhar	31.3260°N, 75.5762° E	1971-2015	Zone-II and III	16.4-29.3	22.85
Ludhiana	30.9010°N, 75.8573° E	1970-2018	Zone- II and III	16.7-29.8	23.25
Patiala	30.3398°N, 76.3869° E	1970-2018	Zone-II and III	17.6-30.2	23.9
Bathinda	30.2110°N, 74.9455° E	1977-2015	Zone-IV	16.9-31.3	24.1
Faridkot	30.6769°N, 74.7583° E	2000-2015	Zone-IV	20.3-29.9	25.1
Abohar	30.1469°N, 74.2008° E	2004-2015	Zone-V	17.6-30.2	23.9

Source: Authors' compilation based on data collected from meteorological research stations.

Table 2.3: Research stations with rainfall ranges in Punjab

Station	Location co-ordinates	Period of collected data	Total rainfall (mm)	Representing agro-climatic zone	Total rainfall range (mm)
Ballowal Saunkri	31.0993°N, 76.3870° E	1984-2015	1049	Zone-I & II	1000-1500
Gurdaspur	32.0414° N, 75.4031° E	2002-2018	1063		
Jalandhar	31.3260°N, 75.5762° E	1971-2018	990	Zone-II & III	550-1000
Amritsar	31.6340°N, 74.8723° E	1970-2018	722		
Patiala	30.3398°N, 76.3869° E	1970-2018	774		
Ludhiana	30.9010°N, 75.8573° E	1970-2018	759		
Nawashahr	31.1256° N, 76.1186° E	2004-2018	749		

Bathinda	30.2110°N, 74.9455° E	1977-2018	517	Zone-IV	350-550
Faridkot	30.6769°N, 74.7583° E	2000-2018	468		
Mukstar	30.4762° N, 74.5122° E	2004-2018	368		
Abohar	30.1469°N, 74.2008° E	2004-2015	323	Zone-V	<350

Source: Authors' compilation based on data collected from meteorological research stations.

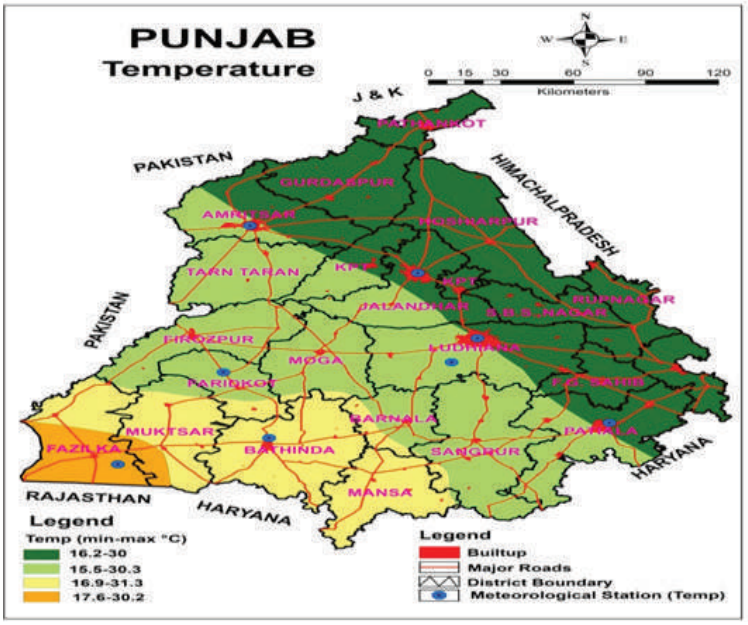
2.3.3 Base maps

As agro-climatic zones are classified on the basis of common ecological parameters, so the temperature range corresponding to the research station present in the specific zone was considered the temperature of the whole agro-climatic zone. The annual average maximum and minimum temperature ranged between 29 to 32°C and 15-20°C respectively in Punjab. The mean annual rainfall in the state and different locations ranged from 400 to more than 1000 mm. The base maps of temperature and rainfall are represented in the Figs. 2.1 and 2.2. The base maps for the soil highlighted that the agro-ecological zone-I comprised of sandy skeleton, loamy sand and sandy loamy soil with pH ranging from 7.5 to 8.2. The zone-II represented sand to loamy sand, to calcareous soils with pH 6.8 to 8.3; zone-III represented sandy loam to clay loam to calcareous soil with pH 7.5 to 9.3; and zone-IV and V corresponded to sandy loamy soils to loam and calcareous soils with pH 8.1 to 8.5. The base maps corresponding to the soil texture are represented in the Fig. 2.3 .

2.3.4. Ecological requirements of selected medicinal plants

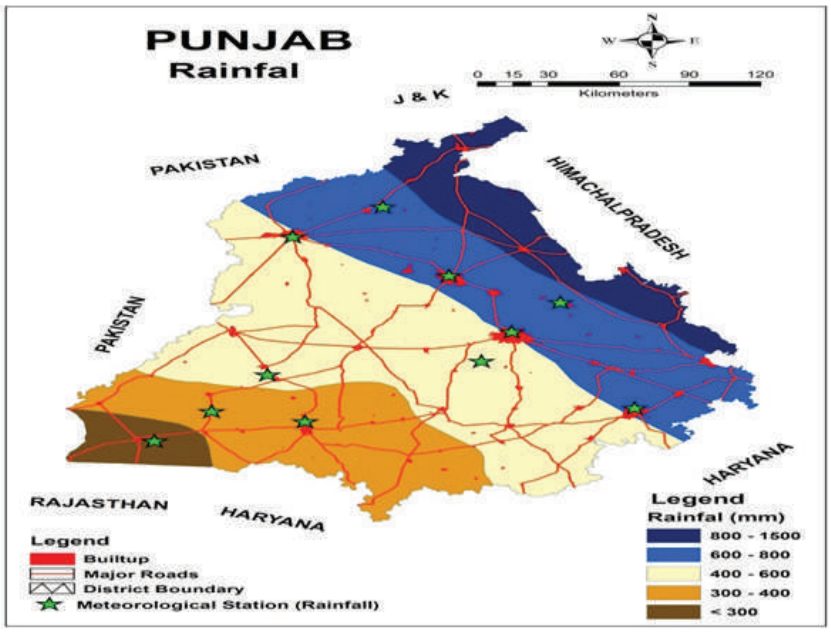
The literature was surveyed to highlight standard climatic and edaphic requirements for the medicinal plants *viz. Ashwagandha, Haldi, Amla, Ghritkumari, Rama Tulsi, Shyama*

Fig. 2.1: Spatial distribution of meteorological research stations representing average maximum and minimum temperature ranges



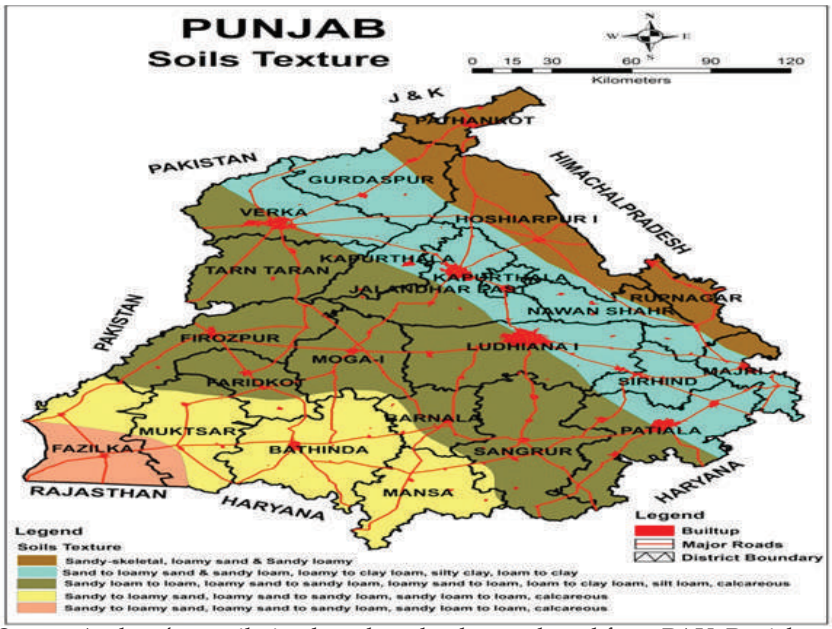
Source: Authors' compilation based on the data gathered from meteorological research stations.

Fig. 2.2: Spatial distribution of meteorological research stations representing rainfall ranges



Source: Authors' compilation based on the data gathered from meteorological research stations.

Fig. 2.3: Soil texture of benchmark soils present in Punjab



Source: Authors' compilation based on the data gathered from PAU, Punjab.

Tulsi, Sarpgandha, Bach, Brahmi, Mulethi, Shatavari, Kalmegh, Safed Musali (FAO, 2007; Anonymous 2008; Anonymous, 2014; Jat *et al.* 2015a; Jat *et. al.*, 2015b; Jat et al. 2015c; Jayashree *et. al.*, 2015; Anonymous, 2016). The optimum ecological requirements for the selected medicinal plants were extracted to correlate with the ranges of temperature, rainfall and soil digital base maps. The standard ecological requirements of the selected medicinal plants are mentioned below in the Table 2.4.

Table 2.4: Standard ecological conditions of selected medicinal plants

Name of the plant	Average annual temp (°C)	Average annual rainfall (mm)	Soil texture	Soil pH	References
Aloe vera	20-40	350-400	Loam to coarse sandy loam	Up to 8.5	(Cousins and Witkowski, 2012; Jat *et al.* 2015b; Bahmani *et al.* 2016)
Emblica officinalis	14-35	700-4200	Loamy soil, calcareous, rocky substratum	Up to 8.5	(Anonymous , 2008; Jalal *et al.* 2018)
Withania somnifera	20-35	600-750	Sandy loamy	7.5-8	(Kumar et al. 2012; Jat *et al.* 2015a)
Glycyrrhiza glabra	5-25	300-1200	Sandy loamy	5.5-8.2	(Anonymous, 2014; FAO, 2007)
Asparagus racemosus	17-40	600-1000	Sandy loam to clayey loam	6-8	(Joshi, 2016; Sharma and Sharma, 2013, Kaur *et al.* 2018)
Andrographis paniculata	14-38	1500-4000	Sandy loam to clayey loam	6.5-8.5	(Patra et al. 2004; Niranjan *et al.* 2010; Anonymous, 2014; Verma *et al.* 2019)
Ocimum tenuiflorum	15-35	700-7600	Sandy loamy	5-8.5	(Makri and Kintzios, 2008; Jat *et al.* 2014; FAO, 2007)
Curcuma longa	20-35	800-1500	Sandy or clay loam	4.5-7.5	(Jayashree *et al.* 2015)
Centella asiatica	28-44	800-1500	Sandy loamy to clayey soil	6- 7.5	(Times-is, 2009a)
Acorus calamus	10-38	430-4200	Clayey loam & sandy loam	5.5-7.5	(Times-is, 2009b)
Rauvolfia serpentina	10-38	1100-4500	Sandy loam	6-8	(FAO, 2007; Bhattarai, 2013)
Ocimum basilicum	7-36	600-4300	Rich loam to poor laterite, sandy loam soil	4.3-8.2	(Jat *et al.* 2014; FAO, 2007)
Chlorophytum borivilianum	15-35	500-1500	Loamy to sandy loamy clay	Not more than 8	(Vijaya and Chavan, 2009; Jat *et al.* 2015c; Tiwari, 2018)

Source: References already provided in the last column.

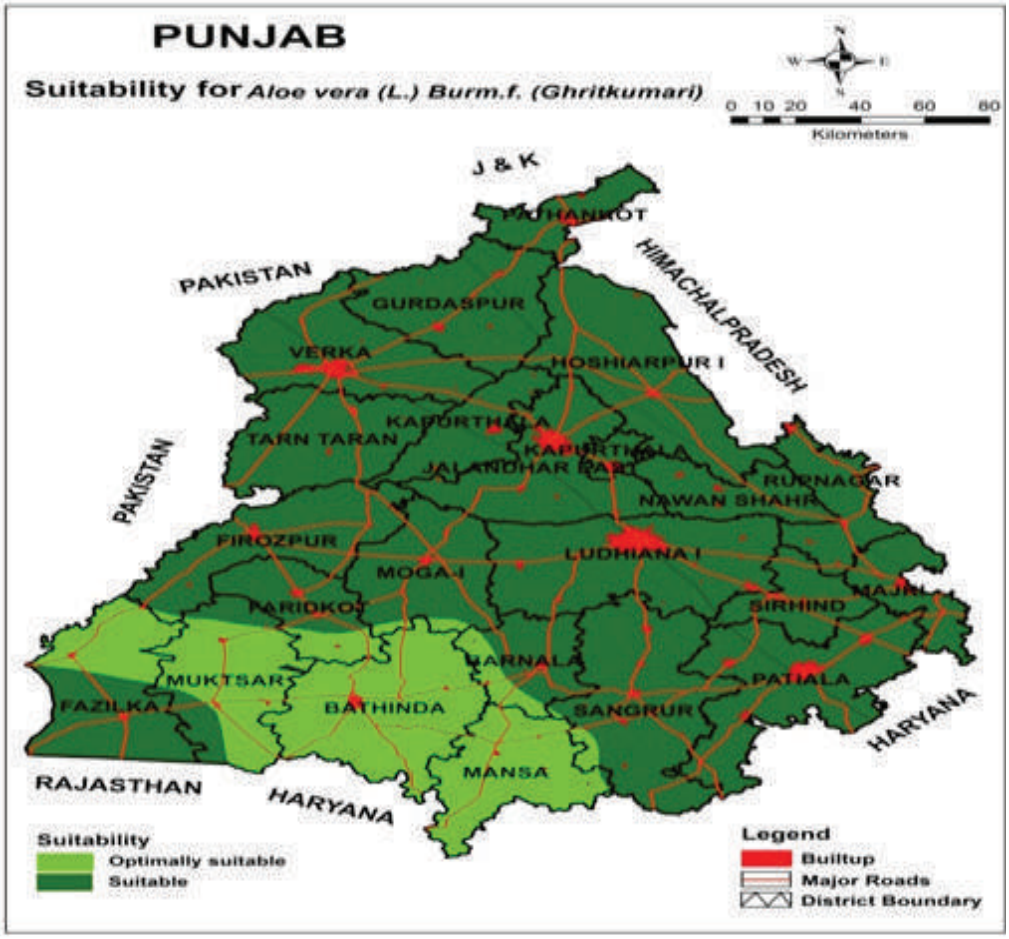
2.3.5. Agro-ecological zoning model

The base maps for temperature, rainfall, and soil were integrated with agro-ecological zones map of Punjab delineated by ENVIS center, Punjab (http://punenvis.nic.in/index1.aspx?lid=5617&mid=1&langid=1&linkid=1257). All the base maps were superimposed to highlight optimally suitable zone (having all the climatic and edaphic parameters common with the bio-meteorological requirements of selected medicinal plants), suitable zone (having only two parameters common with the bio-meteorological needs of selected medicinal plants), and lesser suitable zone (having only one parameter common with the bio-meteorological need of the plant). The suitability studies for the selected medicinal plants are mentioned below.

Aloe vera: It is a perennial plant that requires rainfall ranging from 350-400 mm with coarse sandy loam soil. According to the present agro-ecological zoning model, the zone-IV comprising of Mansa, Bathinda, and Muktsar districts was found to be optimally suitable for its cultivation due to suitable rainfall besides temperature, soil and pH ranges as represented in the Fig. 2.4. However, it can also be grown on zone-V (comprising of Fazilka district) with more irrigation for its optimum growth besides considering suitable soil characteristics.

Emblica officinalis: It is also known as *Phyllanthus emblica* which was found optimally suitable for zone-I and II due to optimum rainfall range (700-4200 mm rainfall) apart from suitable temperature and benchmark soil characters as represented in the fig. 2.5. Due

Fig. 2.4: Potential growing areas of *Aloe vera* in Punjab



Source: Authors' compilation based on the agro-ecological zoning model.

Fig. 2.5: Potential growing areas of *Phyllanthus emblica* in Punjab

Source : Authors' compilation based on the agro-ecological zoning model.

to its suitable temperature and soil conditions across the Punjab, it can be cultivated in all the remaining three zones with more irrigation cycles. It can be preferably cultivated on the boundaries of the agricultural fields to generate extra income and for health purposes.

Withania somnifera : It cultivated as a *Kharif* crop (starting from June and ending October) in India. The mean maximum and minimum temperature during *Kharif* season ranged from 34.4-36.7°C to 22.4-26.7°C which can be correlated to its suitable cultivation during Kharif season in Punjab. It requires rainfall ranging from 600-750 mm, and the *Kharif* season rainfall varied from approximately 262-888 mm across Punjab, which further supported the suitability of zone-II and III for the optimum cultivation of *Withania somnifera* apart from suitable temperature and soil characters. Whereas, zone-V had only temperature regimes suitable for its cultivation so it was considered lesser suitable zone and zone-I and IV were considered suitable due to more rainfall in zone-I and unsuitable soil pH of zone-IV corresponding to the requirements of the plant as mentioned in the Fig. 2.6.

Glycyrrhiza glabra: It is a perennial plant and due to its higher adaptability in diverse climatic requirements, it was found optimally suitable for all the five zones of Punjab as represented in the Fig. 2.7.

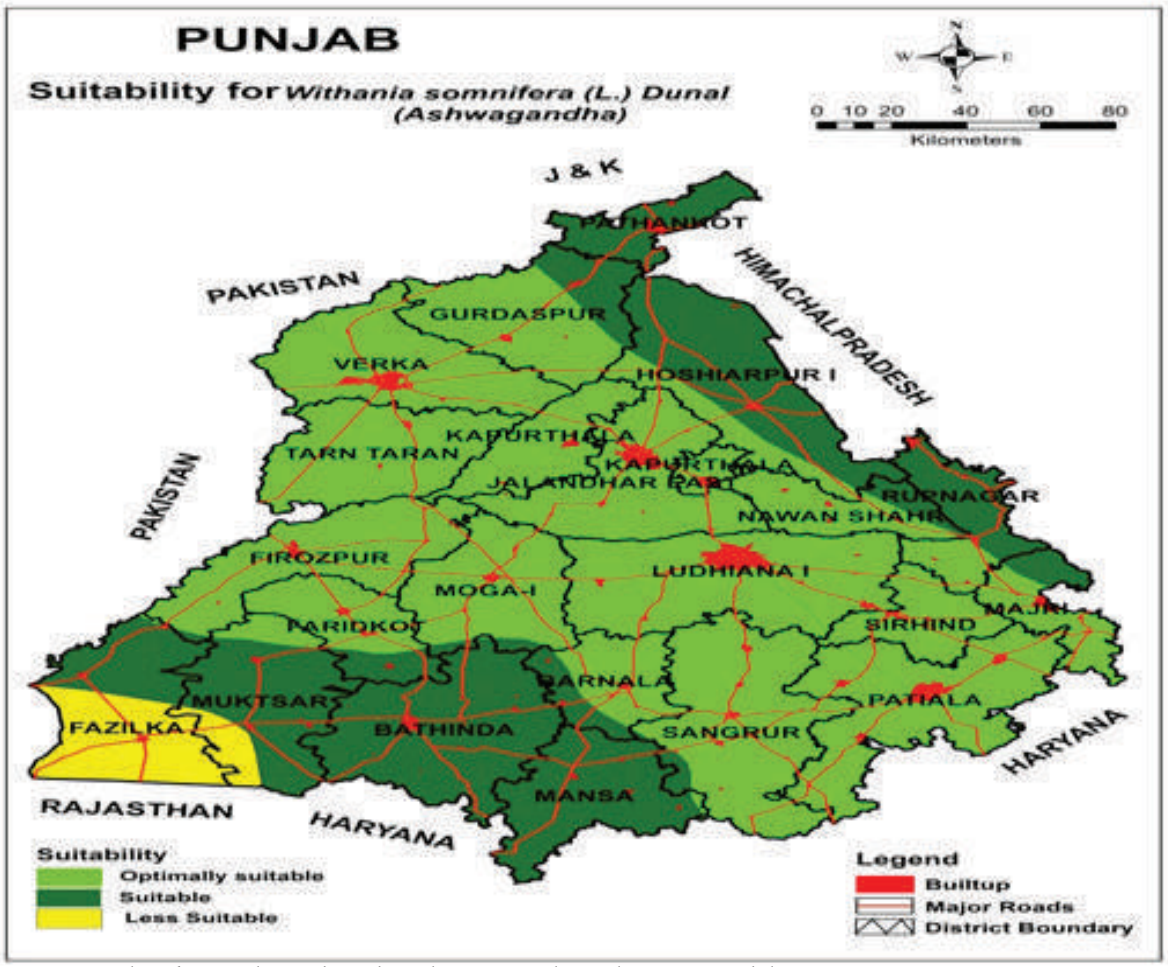
Asparagus racemosus: It is a perennial plant whose roots are consumed for various pharmacological actions. The plant requires

annual rainfall from 600-1000 mm that was optimum to zone-II and III of Punjab. Similarly, sandy loam to clay loam soil with pH 6-8 is best suited for the cultivation of the plant. According to the present agro-ecological zoning model, *Asparagus racemosus* was: Optimally suitable (15.5-30.3°C; rainfall 550-1000mm; Sandy skeleton, loam to clayey loam to silt clay and calcareous with pH range 6.8-9.3) corresponding to agro-climatic zones II, III; Suitable (16.9-30°C; rainfall 1000-1500mm; sandy to loamy sand and calcareous with pH 7.5-8.2) corresponding to zone I; Less suitable (16.9-30.0°C; rainfall 550 to less than 350; sandy to loamy sand and calcareous with pH 8.1-8.5) corresponding to zone IV and V as represented in the Fig. 2.8.

Andrographis paniculata: In most parts of India, it is cultivated as a *Kharif* crop that requires 1500-4000 mm rainfall. Due to its higher requirement of water, it is suitable for the zone-I corresponding to Roopnagar, Hoshiarpur and Pathankot districts of Punjab. Apart from this, it can be cultivated in all the remaining zones of Punjab by adopting higher frequency of irrigation cycles as represented in the Fig. 2.9.

Ocimum tenuiflorum: It is widely cultivated in India due to its adaptability in diverse climatic conditions. According to the present agro-ecological study, it was found optimally suitable for the zones-I, II and III due to favorable temperature (15-35°C), rainfall (700-7600 mm), and soil parameters. Whereas, it was found suitable for the zones IV and V due to lesser rainfall ranges as represented in the fig. 2.10.

Fig. 2.6: Potential growing areas of *Withania somnifera* in Punjab



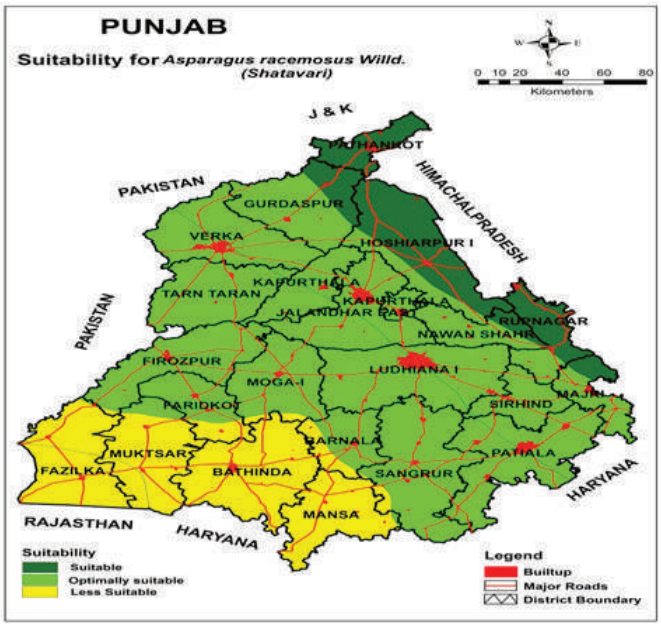
Source: Authors' compilation based on the agro-ecological zoning model.

Fig. 2.7: Potential growing areas of *Glycyrrhiza glabra* in Punjab

Source: Authors' compilation based on the agro-ecological zoning model.

Curcuma longa: It is approximately nine month crop which requires 20-35°C annual temperature for its growth. It was found optimally suitable for the zone-I and II due to suitable temperature, rainfall and soil characteristics. The zone-III was considered suitable due to soil, and temperature ranges corresponding to the requirements of the plants. On the other hand, zone IV and V were marked as lesser suitable because of unfavorable soil pH and rainfall as represented in the Fig. 2.11. However, the plant can

Fig. 2.8: Potential growing areas of *Asparagus racemosus* in Punjab



Source: Authors' compilation based on the agro-ecological zoning model.

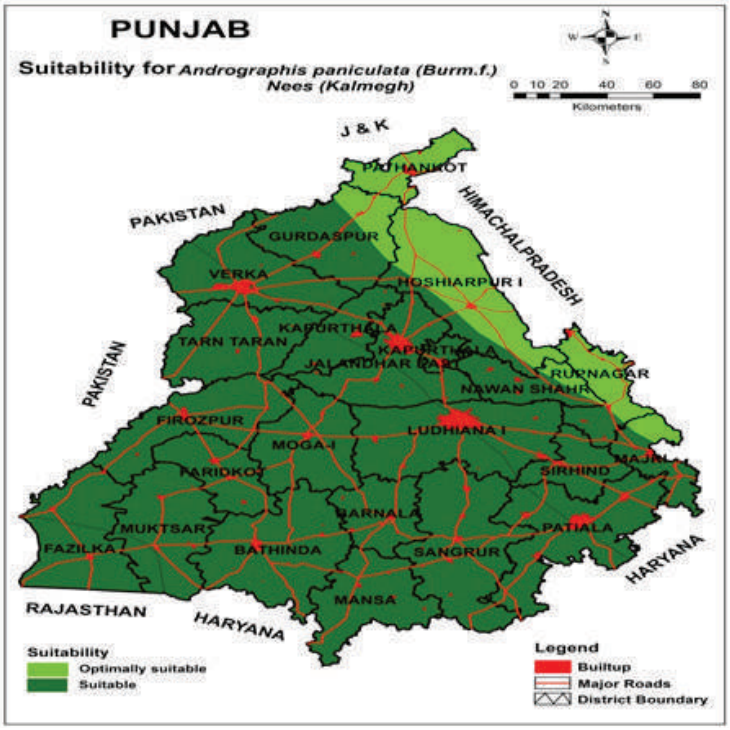
be cultivated in zone-III by increasing the irrigation cycles for the plant. Similarly, certain soil treatments and more irrigation cycles can prompt its cultivation in zone-IV and V as well.

Centella asiatica: The plant is cultivated in the month of June and is harvested after 5-6 months. Therefore, it can also be considered as a *Kharif* crop that requires good amount of rainfall. As discussed earlier, the annual *Kharif* season rainfall varied from approximately 262-888 mm across Punjab. Therefore, the rainfall requirements of the plant (800-1500 mm) can be corroborated with the rainfall ranges of zone-I and II for its optimum cultivation besides suitable temperature and soil ranges. On the other hand, it is lesser suitable for the zone-IV and V due to low rainfall and high soil pH ranges. Whereas, the zone-III was considered suitable because of favorable temperature and soil conditions correlating with the requirements of the plant as represented in the Fig. 2.12.

Acorus calamus: This is a perennial, semi-aquatic and smelly plant. It was optimally suitable for the zones-I, II, and III due to favorable climatic and edaphic requirements. Due to its semi-aquatic nature it can be grown in waste-lands, water logged and marshy soils. It was considered less suitable for the zone-V corresponding to Fazilka district due to lesser rainfall, and more soil pH as represented in the fig. 2.13.

Rauvolfia serpentina: The bio-meteorological requirements and climatic conditions for

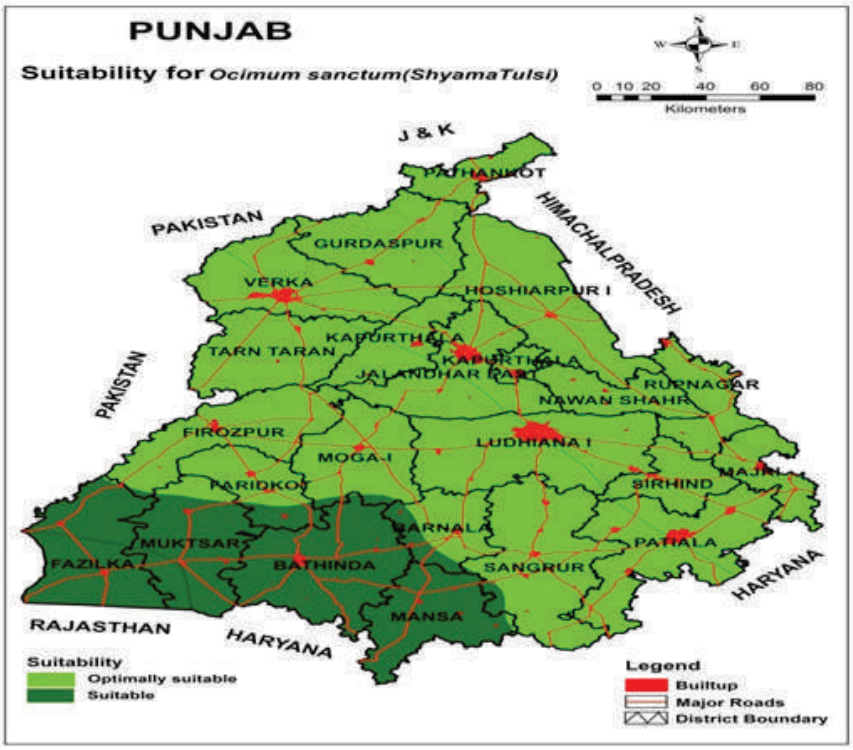
Fig. 2.9: Potential growing areas of *Andrographis paniculata* in Punjab



Source: Authors' compilation based on the agro-ecological zoning model.

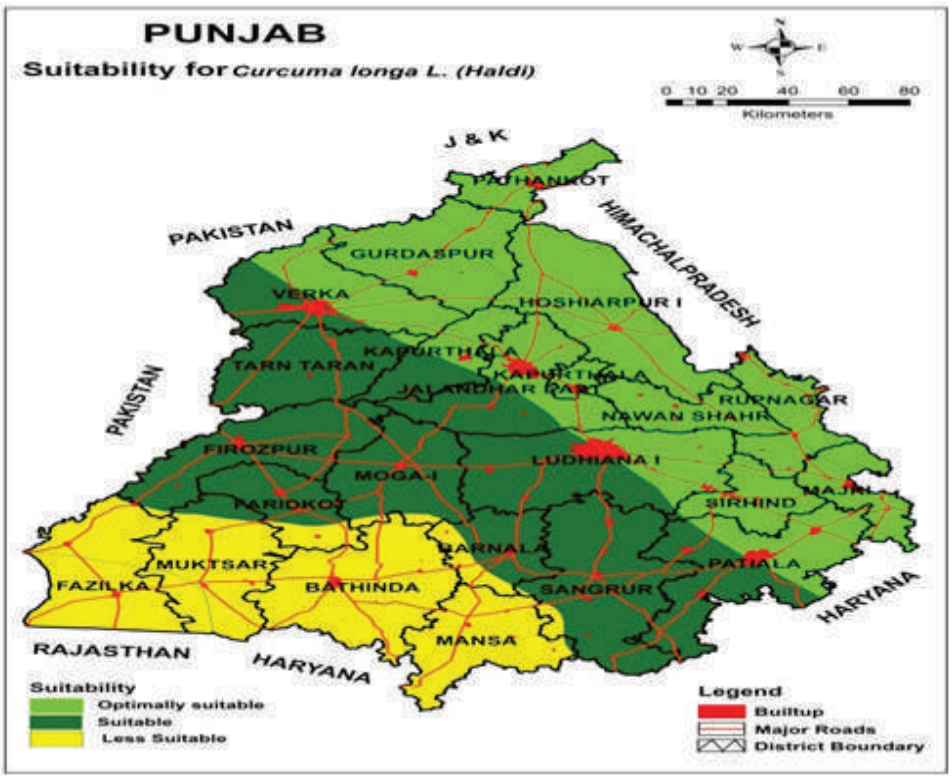
the plant suggested that it was: Optimally suitable (16.2-30°C; rainfall 1000-1500mm; Sandy skeleton loamy sand to sandy loam pH range 7.5-8.2) corresponding to agro-climatic zone I; Suitable (15.5-30.3°C; rainfall 550-1000mm; sandy to loamy sand, silt clay-loam and calcareous with pH 6.8-9.3) corresponding to zone II & III; Less suitable (16.9-31.3°C; rainfall <350-550 mm; sandy to loamy sand and calcareous with pH 8.1-8.5) corresponding to zone IV-V as represented in the Fig. 2.14.

Fig. 2.10: Potential growing areas of *Ocimum tenuiflorum* in Punjab



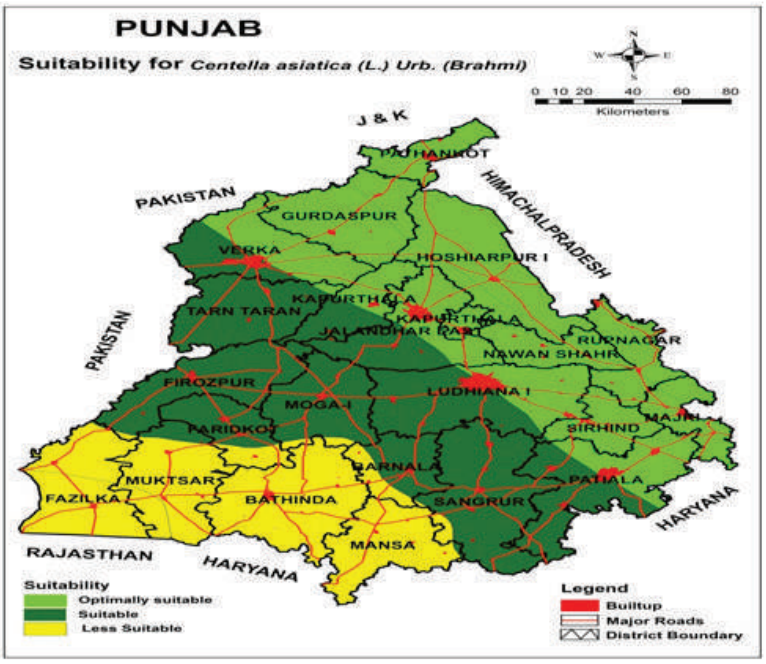
Source: Authors' compilation based on the agro-ecological zoning model.

Fig. 2.11: Potential growing areas of *Curcuma longa* in Punjab



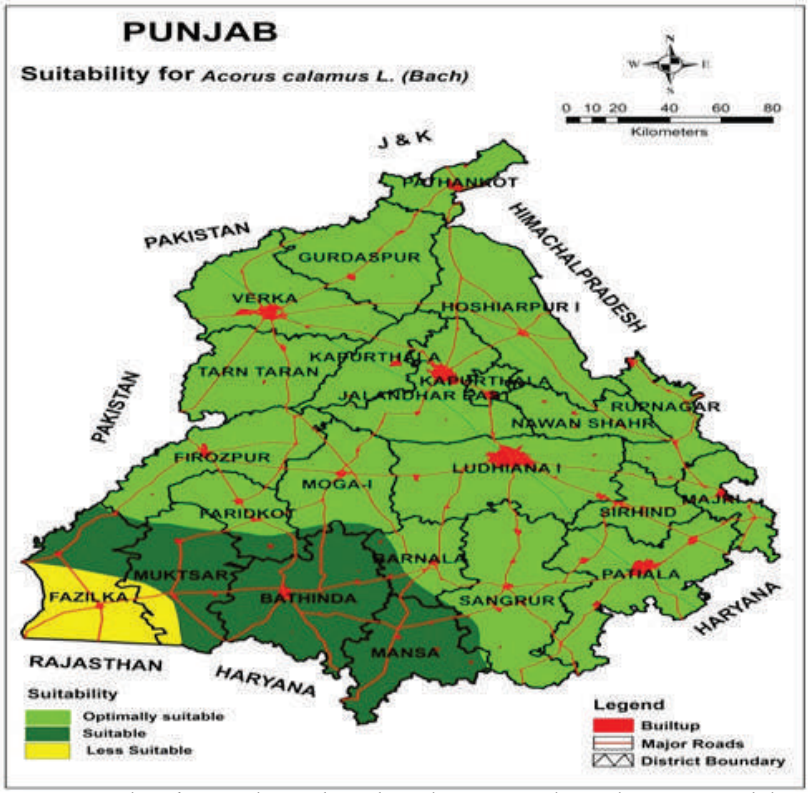
Source: Authors' compilation based on the agro-ecological zoning model.

Fig. 2.12: Potential growing areas of *Centella asiatica* in Punjab



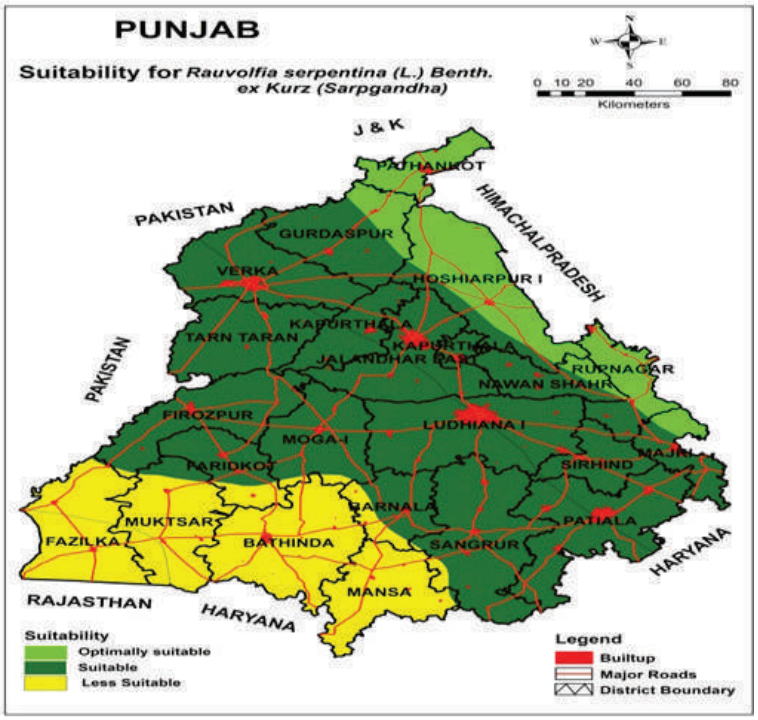
Source: Authors' compilation based on the agro-ecological zoning model.

Fig. 2.13: Potential growing areas of *Acorus calamus* in Punjab



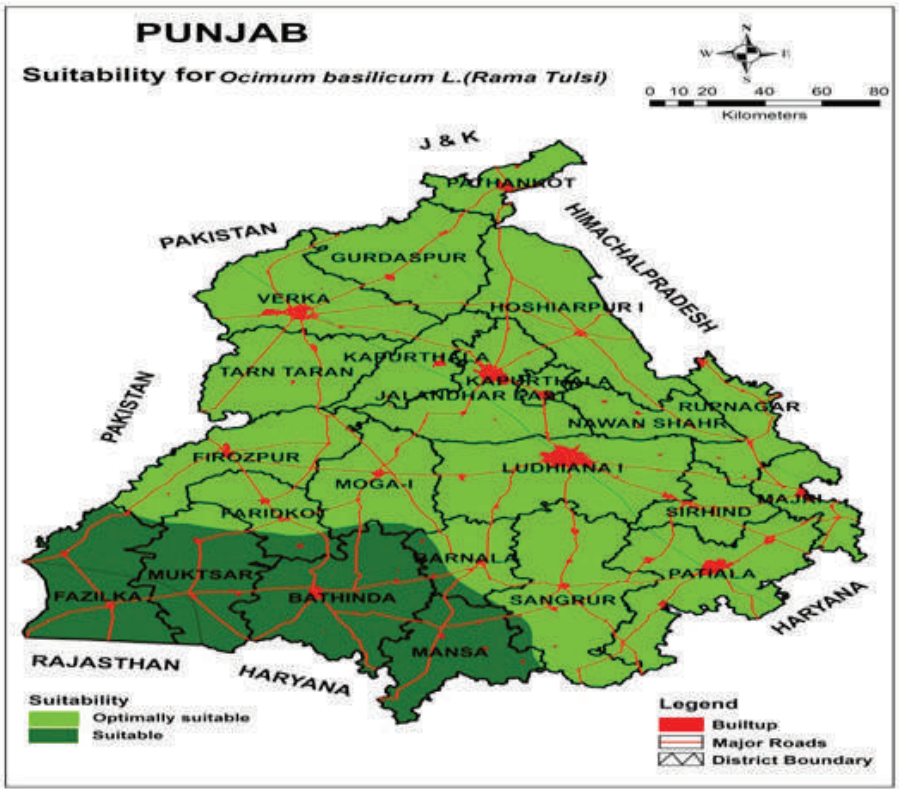
Source: Authors' compilation based on the agro-ecological zoning model.

Fig. 2.14: Potential growing areas of *Rauvolfia serpentina* in Punjab



Source: Authors' compilation based on the agro-ecological zoning model.

Fig. 2.15: Potential growing areas of *Ocimum basilicum* in Punjab

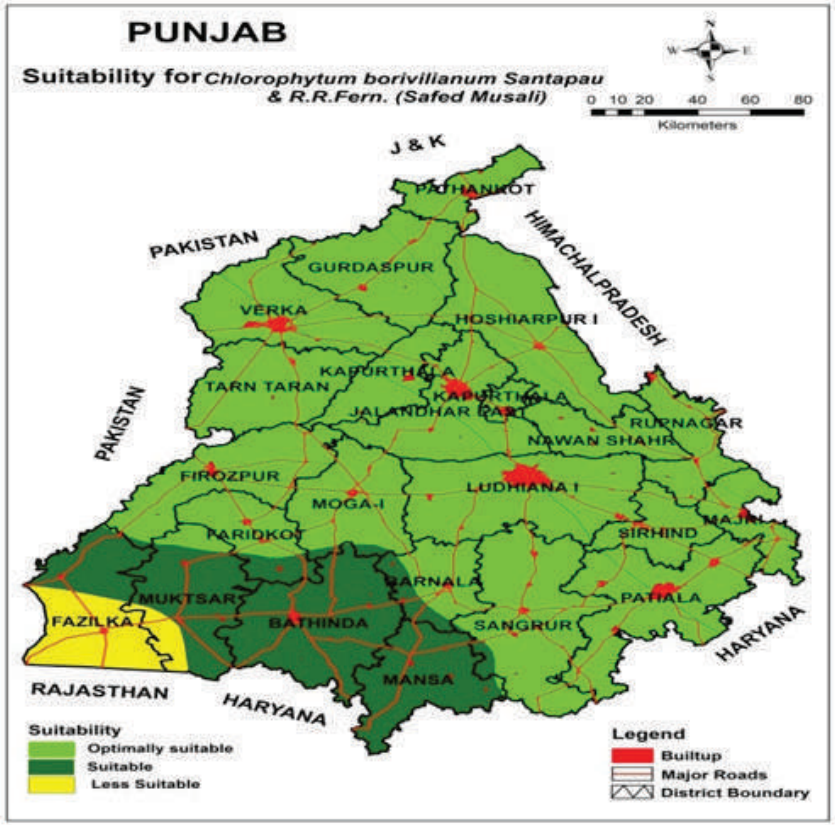


Source: Authors' compilation based on the agro-ecological zoning model.

Ocimum basilicum: Similar to *Ocimum tenuiflorum*, it was also found optimally suitable for the zones-I,II, and III. Subsequently, it was found suitable for the zone-IV and V as represented in the Fig. 2.15.

Chlorophytum borivilianum: The crop is cultivated in the month of June considering the onset of the monsoon and is harvested after 04 months of planting. The mean maximum and minimum temperature during *Kharif* season ranged from 34.4-36.7°C to 22.4-26.7°C in Punjab. Therefore, this plant can be optimally grown during the *Kharif* season with rainfall ranging from 500-1500 mm. Based on the agro-ecological zoning mode, the plant is optimally suitable for the zones-I,II, and III corresponding to Pathankot, Hoshiarpur, Roopnagar, Gurdaspur, Amritsar, Tarn taran, Ludhiana, Jalandhar, Patiala, Moga, Sangrur, Moga districts of Punjab. It was found just suitable for the zone-IV due to higher pH ranges of benchmark soil. The zone-V was highlighted as lesser suitable zone due to higher pH of benchmark soil, and lesser rainfall ranges as represented in the Fig. 2.16. However, appropriate treatments

Fig. 2.16: Potential growing areas of Safed Musali in Punjab



Source: Authors' compilation based on the agro-ecological zoning model.

of the soils, and more irrigation cycles can convert the optimally suitable and lesser suitable zone into optimally suitable zones.

Sustainable and rational use of land has become the key issue for policymakers, government, and land users for preserving the resources for present and future generations. In view of the above, agro-ecological zoning model to highlight potential growing areas of medicinal plants can be an initial step towards diversification (FAO, 1996; Chand, 1999; Kaur et al. 2015). Many studies related to the development of the agro-ecological

zoning model have been conducted in past. In the year 2012, Falasca and co-workers have established a suitable agro-ecological zoning model to determine production areas of castor bean. The study utilized meteorological data such as average temperature, annual rainfall, frost-free days for highlighting suitable production zones of the crop (Falasca et al. 2012). Similarly, potential growing areas for Cyamopsis tetragonoloba, Acrocomia aculeate, Lesquerella fendleri (a multipurpose oilseed crop), Jatropha curcas, Salicornia bigelovii and Camelina sativa, Panicum virgatum and Argania spinosa (L.) Skeels were highlighted in different zones of Argentina (Fischer et al. 2000; Falasca et al. 2012; Falasca et al. 2013; Van Wart et al. 2013; Falasca *et al*. 2015; Falasca et al. 2016; Falasca et al. 2017a; Falasca et al. 2017b; Falasca et al. 2018). Most of the studies on the agro-climatic zoning model were limited to analysing the meteorological data such as temperature, rainfall, frost-free days, etc. for highlighting potential zones, however, the inclusion of significant land pattern data like soil texture and pH could have added more strength to the work. Since benchmark soil network based on soil texture and pH had played a pivotal role in determining the land potential for selected medicinal plants, consideration of both meteorological as well as land pattern data was the major advantage of the present study.

IITM, Pune prepared PRECIS (Providing Regional Climates for Impact Studies) model having simulated baseline (1961-1990) and simulated mid to end century (2021-2100) climatic data for different agro-climatic zones was downscaled to check the projected climatic variability in Punjab. The model analyzed the changes in temperature and rainfall by mid (2021-2050) and (2071-2100) under different scenarios classified as A1B (describing the future world of rapid economic growth), A2 (describing heterogeneous world), B2 (describing world emphasising on local solutions to social, economic and environmental sustainability) and suggested that projected climatic variability in Punjab had no significant effect on the climate in context to the bio-climatic requirements of selected medicinal plants. Hence, it can be assumed that the present agro-ecological zoning model would be suitable up to at least 50 years for the domestication of selected medicinal plants. The present study was limited to the climatic data available at research stations, however, the findings could have been more specific if more meteorological stations were set up in the state.

2.4 Conclusion

Based on international and national available bibliographic data, the climatic requirements for selected medicinal plants were identified. At present, no policy regulates to suggest which medicinal plants are best suited in the right location. In this direction, this study would be helpful to the policymakers in suggesting optimal regions to cultivated selected medicinal plants. However, besides agro-ecological zoning model, the authors strongly recommend adopting Good Agricultural Practices (GAP) of the selected medicinal, prior assurance of the marketing, consultation of experts. This model gives an overview of the probable suitable areas and does not guarantee production in case of any extreme climatic adversity, or change. The comparison based on their suitability is mentioned in the table 2.5. This agro-ecological zoning model can act as a baseline study for other medicinal plants, aromatic plants, and spices with same or different bioclimatic indices and can be used in any part of the world for determining potential growing areas for new crops.

Endnotes

[1] Garg, P. 2012. Energy scenario and vision 2020 in India. Journal of Sustainable Energy and Environment, 3(1): 7–17.

[2] Attri, S.D., Tyagi, A. 2010. Climate profile of India. Environment Monitoring and Research Center, Meteorology department, India. pp. 1–122. https://doi.org/10.1007/s12524-010-0015-9

Table 2.5: Comparison between agro-ecological zones for cultivating medicinal plants

Plant	Zone-I	Zone-II	Zone-III	Zone-IV	Zone-V
Aloe vera	**	**	**	***	**
Phyllanthus emblica	***	***	**	**	**
Withania somnifera	**	***	***	**	*
Glycyrrhiza glabra	***	***	***	***	***
Asparagus racemosus	***	***	***	**	*
Andrographis paniculata	***	**	**	**	**
Ocimum tenuiflorum	***	***	***	**	**
Curcuma longa	***	***	**	*	*
Centella asiatica	***	***	**	*	*
Acorus calamus	***	***	***	**	*
Rauvolfia serpentina	***	**	**	*	*
Ocimum basilicum	***	***	***	**	**
Chlorophytum borivilianum	***	***	***	**	*

Source: Authors' compilation

*** = Optimally suitable; ** = Suitable; * = Less-suitable

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3

Constraints and Motivating Factors for Medicinal Plants Cultivation: A Survey

3.1 Introduction

India has the most alluring ecological conditions in the world and has the richest plant bio-diversities in the world that it alone hosts two biodiversity hotspots out of 34 in the world.1 Punjab is a small northern state of India having 50,362 square kilometers total area and 2,77,43,338 population according to the census report of India.2 Two-third of the total production of the food grains are contributed by Punjab and are a leading producer of wheat in India.3 Punjab has become the epicentre of wheat-rice cropping pattern, after the successful implementation of 'Green Revolution' in the 1960s.4 But over time, this cropping pattern has become reliant on underwater resources, extensive use of chemical fertilisers, pesticides, and agricultural machinery is leading to lesser returns for farmers (Chand, 1999; Singh, 2002).

In this context, resorting to crop diversification shall be beneficial for managing the soil and water resources (Singh, 2002; Singh and Sidhu, 2004; Ali et al. 2012; Kaur et al. 2015). Many farmers and communities benefit from the valuable medicinal plants found in Asia and the Pacific region for their livelihood therefore, adoption of medicinal plants can be a viable alternative to the traditional crops (Paroda et al. 2014; Hamilton, 2004). Despite of conducive climatic conditions, Punjab has meagre agricultural area under Medicinal and Aromatic Plant (MAP) cultivation which is far less than its potential. (Saxena, 2018). However, few farmers in Punjab have started adopting medicinal plant cultivation after the collective efforts made by the Ministry of Ayush and NMPB, India. In this chapter, a survey was conducted through personal interviews using a pre-tested questionnaire to ascertain various constraints faced by the farmers of Punjab in view to promote medicinal plants adoption in the state.

3.2 Materials and Methods

3.2.1. Study area

The present study was conducted in the areas having medicinal plants cultivation in the Indian state of Punjab. As per the study area, the cultivation of Aloe vera was carried out in 128.5 acres, Curcuma longa in 86.5 acres, Phyllanthus emblica in 56 acres (approximately 13,370 tees), Rauvolfia serpentina in 03 acres, and Ocimum sanctum in 02 acres. Most of Punjab lies in the fertile plain; toward the southeast, one finds semi-arid and desert landscape; a belt of undulating hills extends along the northeast at the foot of the Himalayas (Sidhu, 2011; Singh and Rath, 2013, Dutta, 2012; Hamadani and Khan, 2015). Punjab is classified into three regions named Majha, Doaba and Malwa having 22 districts, subdivided into 79 tehsils consisting of blocks with 12, 278

revenue villages (http://censusindia.gov.in/2011census/dchb/DCHB.html?q=Punjab).

3.2.2. Sample size

Total 68 farmers were selected for the study, based on the information gathered from the concerned channels such as Regional-Cum-Facilitation-Centre (RCFC) North-NMPB, state forest department, herbal industries, farmer-producer companies, farmers groups, local herbal practitioners, traders, and local herbal markets.

3.2.3. Inclusion criteria

The farmers involved in the cultivation of medicinal plants in the Indian state of Punjab and the farmers willing to participate in the study were selected for the study.

3.2.4. Exclusion criteria

Farmers not involved in the cultivation of medicinal plants, farmers outside the jurisdiction of Punjab, and medicinal plants cultivators who were not ready to participate in the study were excluded from the study.

3.2.5. Mode of survey

Personal interviews were conducted to collect the primary data using a questionnaire.

3.2.6. Data and sampling technique

The data was collected from April 2019 to August 2019 throughout Punjab and purposive sampling was followed as a sampling technique.

3.2.7. Questionnaire design and validation

The questionnaire was drafted after expert consultations and pre-testing of the questionnaire was carried out by interviewing at least 40 medicinal plant cultivators in Medicinal Plants Stakeholders Meet conducted by RCFC-North (Regional-cum-Facilitation Center), NMPB. Subsequently, modifications were made and it was tested again on ten other farmers. The reliability of the Likert scale was measured using Chronbach's Alpha value. The value measured the reliability of the questions and internal consistency. The questions having Chronbach's alpha value of more than 0.6 were selected for further analysis.

3.2.8. Statistical tools

Different constraints related to technical, trade, social participation, awareness and farmer attitude and policy were studied based on their respective MPS (Mean Percentage Score). Constraints were ranked according to their MPS values. As the data was collected in the form of categorical variables and skewness was observed in the numerical value, the Chi-sqaure test was selected for the study. In the present study, it was hypothesized that there was no significant relationship between the farmer's landholdings on the constraints faced by the farmers. So, to validate the null hypothesis, the Chi-square test was applied to find significant relationships between the farmer's land holdings with every statement of technical, trade, social participation, awareness, and attitude related constraints. SPSS version. 22 software was used for statistical calculations.

3.3 Results and discussion

3.3.1. Type of medicinal plants cultivated by the farmers

The information collected from the concerned organizations resulted in identifying 68 farmers cultivating medicinal plants such as Curcuma longa, Aloe vera, Emblica officinalis, Ocimum sanctum, Rauvolfia serpentina in different districts of Punjab. A total of 24 Haldi farmers were found in almost every district of Punjab, 20 farmers were cultivating Ghritkumari in Bathinda, Shri Mukstar Sahab, Mansa, Roopnagar districts. Similarly, 15 farmers were cultivating Amla in Hoshiarpur district, 04 Sarpgandha, and 05 Tulsi farmers were cultivating in Roopnagar district.

3.3.2. Descriptive analysis of data

The descriptive analysis of the data revealed that 30.9 per cent of the medicinal plant cultivators were aged between 36-45 category followed by 25-35, 56-65, 46-55 categories

having 25 per cent, 20 per cent, and 16.2 per cent respectively. The age category (36-45) had maximum number of farmers cultivating medicinal plants. This finding can be correlated with a study conducted by Kanwat and co-workers that highlighted medium age group level involved in the cultivation of medicinal plants (Kanwat et al. 2012). It was notable among the respondents that 36.8 per cent of the farmers were graduates, 17.6 per cent were post-graduate and only 2.9 per cent of the respondents were illiterate. This finding can be corroborated with a study that highlighted significance of literate farmers in promoting medicinal plants cultivation (Phondani et al. 2016). Caste in India is a determinant factor of economy, power, poverty, inequality, etc. among its population in India (Zacharias and Vakulabharanam, 2011). It was observed that 42.6 per cent of farmers belonging to the general caste category were involved in the cultivation of medicinal plants followed by backward class, other backward class, and scheduled caste categories. Among the selected population, it was found that 41.2 per cent of the farmers were small farmers (owning up to 05 acres of land), and 58.8 per cent were large farmers (owing more than 5 acres of land) that were involved in the cultivation of selected medicinal plants as mentioned in the Fig. 3.1.

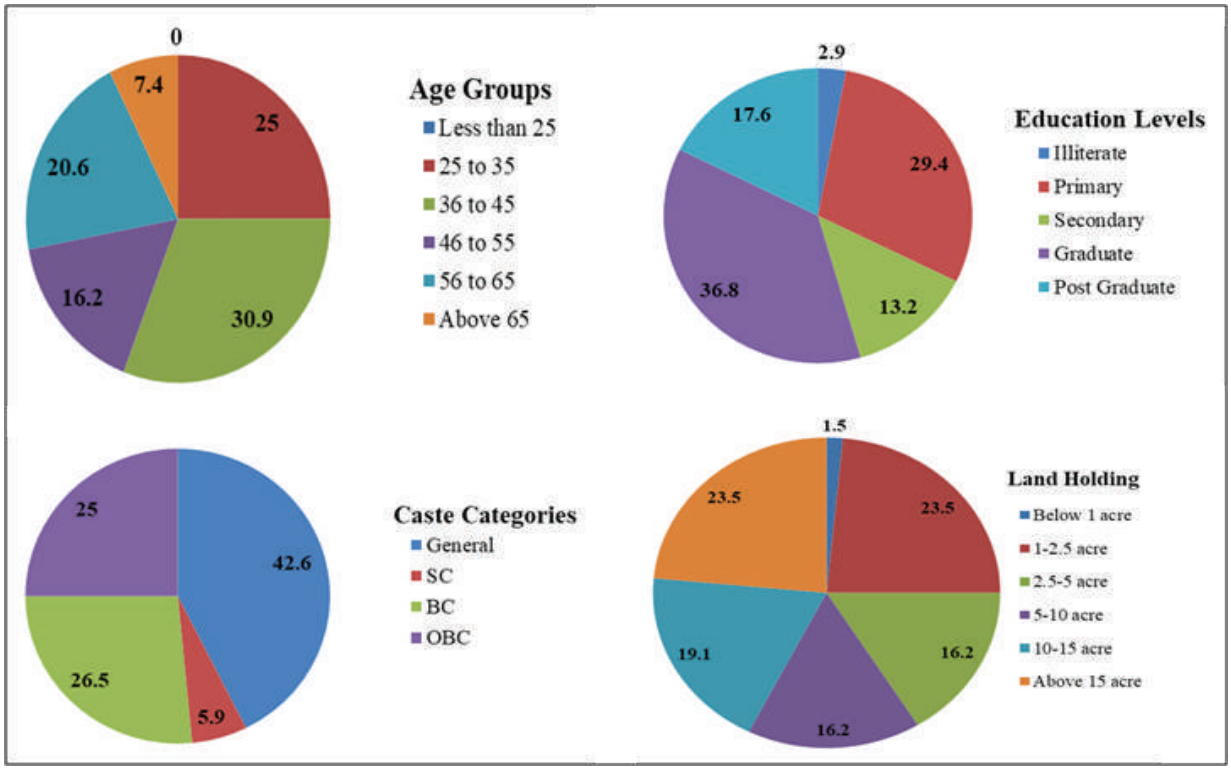
The descriptive analysis of data highlighted that most of the medicinal plant cultivars were young, graduates, large farmers belonging to general caste category. Therefore, awareness regarding the demand and uses of medicinal plants should be translated more to lesser educated farmers through NMPB stakeholders meetings for its wider its adoption.

3.3.3. Statements of the constraints

3.3.3.1. Technical constraints

The technical constraints represented the statements concerning the technical issues faced by the medicinal plant cultivators. All the statements were selected based on the reliability of the questionnaire. The technical

Fig. 3.1: Descriptive analysis of respondent's data



Source: Authors' compilation based on the data gathered from the farmers.

Table 3.1: Technical constraints faced by the marginal/small and large farmer.

Statements of technical constraints	Small Farmer (n1=28)	Large Farmer (n2=40)	Total (n1+n2=68)
	MPS	MPS	MPS
No labelling material for the medicinal plant produce	92.86	77.5	85.18
No processing/distillation units installed at your place	89.29	67.5	78.4
No prior knowledge of suitable agro-climatic zone before cultivating selected MAP	64.29	52.5	58.4
Do not get sufficient seeds for cultivating MAP on proper time	42.86	20	31.43
No proper washing facility for removing earthy material or other contaminants from the produce	17.86	10	13.93
Do not have sufficient storage area for the post-harvested material at your place	10.71	2.5	6.605
Lesser knowledge regarding the characteristics of your soil and water for selected medicinal plants	7.14	2.5	4.82
No refinement needed in your adopted agro-technology	3.57	5	4.285
Do not procure right seeds or planting material from reliable sources	0	7.5	3.75

Source: Authors' compilation.

MPS: Mean Percentage Score

constraints faced by the small and large farmers are represented in Table 3.1.

Different technical constraints faced by the farmers cultivating medicinal plants were accessed based on their MPS and ranking. It was observed that 78.4 per cent of the respondents (both small & large farmers) had no processing or distillation units installed at their place. Lesser availability of processing units resulted in higher processing costs of the medicinal plants. There are few public processing units maintained by the societies which are comparatively cheaper than other commercial processing units. To circumvent the high processing cost of medicinal plants, the government must install more processing and distillation units in different parts of Punjab. Village co-operatives societies can play a significant role in this mechanism with the help of government (Singh, 2006). The findings can be correlated with a study conducted by Kanwat and co-workers that highlighted technical constraints as one of the most prominent perceived constraints by the medicinal plants cultivators in the Rajasthan, India (Kanwat *et al*. 2017). Similarly, packing and labelling equipment or material must be provided by the NMPB through state forest officials to promote farmers for value additions. On the other side, it was observed that 58.4% of the respondents didn't have prior knowledge of suitable ago-climatic zones before cultivating selecting medicinal plants. As Punjab has diverse ecological conditions, agro-climatic

suitability studies of the selected medicinal plant should be translated to the farmers. A complete blueprint regarding potential agro-zones of medicinal plants with reference to Punjab bio-physical attributes should be provided to the farmer. Similarly, 31.43 per cent of the population didn't get sufficient seeds for the cultivation of medicinal plants and 13.93 per cent of the population didn't have proper washing facility for removing earthy materials from the plants. The medicinal plant cultivators have to go far places or other states to get reliable seeds and QPM (Quality Planting Material) that eventually increases the input costs of the farmer (Kala et al. 2006). To circumvent this, various agricultural and all the related organizations of Punjab should be provided with adequate funds and equipped with facilities to provide seeds and QPM to the interested farmers. It was also observed that only 4.285 per cent of the respondents were satisfied by their agro-technology and above 95% of the population thought that their agro-technology needs more refinement according to their suitable agro-climatic zones. Moreover, only 3.75 per cent of the respondents said that they didn't procure seeds from reliable sources.

Marketing constraints

Based on MPS, it was noticed that 95.72 per cent of the farmers were not signing contract farming agreement for cultivation of the selected medicinal plants. There is no regulated existence of a market mechanism to control the supply chain of medicinal plants (Sharma *et al*. 2008). Therefore, self-help groups (SHGs) or marketing cooperatives need to be built at the producer's level. Another method is by establishing a strong official link between the farmers and the herbal industries (Paroda *et al*. 2014). The existence of a 100 per cent buyback contract agreement between the farmers and industry can assure farmers to adopt medicinal plants in Punjab. The proper functioning of the contract can be supervised by the forest officials of Punjab which is the concerned body for promoting medicinal plants with the coordination of NMPB. It was observed that 91.43 per cent of the population did not participate in Kisan mela's or other exhibitions for selling their produce. Kisan mela's provides a direct link between farmer and consumer and also provide great exposure to farmer in updating his knowledge.

It was also observed that 56.25 per cent of the farmers directly sold their produce to the consumers than relying upon any middlemen or traders. Similarly, 71.61 per cent of the farmers cultivating selected medicinal plants said that they didn't manufacture their herbal products; they sell their produce to the buyers without any value additions. Only 33.04 per cent of the farmers strongly disagreed that industry gave them fair prices of their produce. Only 29.65 per cent of the population had basic packing equipment for selling their produce to the consumers, rest most of the population was devoid of the basic packing materials. Out of the surveyed population, 26.62 per cent disagreed that transportation is the major issue in the economics of the medicinal plants. Rest most of the population agreed that transportation is the major issue in the economics of medicinal plants. The marketing constraints are represented in the Table 3.2.

The medicinal plants cultivated by the farmers in Punjab have a huge demand and economical potential. The medicinal plants are utilized for the preparation of different ayurvedic, nutraceutical, and also allopathic formulations. Medicinal plants such as Amla, Haldi has 14178.23 MT and 1316.51 MT consumption by the domestic herbal industry respectively. Similarly, Ghritkumari, Tulsi, etc., has more than 12,000 MT of domestic industrial consumption. On the other hand, Sarpgandha being an endangered species in India fetches a handsome price of Rs. 800-850/kg with 200-500 MT annual trade (Goraya and Ved, 2017). These plants are used for making tablets, juices, tonics, candies, lozenges, eye drops, etc. for the treatment and prevention of a large spectrum of diseases. Popular ayurvedic formulations like HaridraKhanda, Rajahpravartini Vati,

Cukkumtippalyadigutika, Chyavanaprasa, Tribhuvanakirti Rasa, Muktapancamrta, Muktadimahajana, Laksaditaila, etc. are prepared from these medicinal plants (The Ayurvedic Pharmacopoeia of India, 1989). Therefore, cultivating these medicinal plants could provide huge benefits to the farmers of Punjab, if constraints especially related to marketing are addressed by the concerned organizations. Similarly, farmers should be made aware of the significance of value additions and Food Safety and Standards Authority of India (FSSAI) approval for their medicinal products for agri-business ventures. The FSSAI in India is a government body ensuring food quality and safety of spices, juices, herbal products thereby providing satisfaction to every customer (Shukla *et al*. 2014). Hence, farmers should be motivated to apply for FSSAI approval for their respective herbal products.

Table 3.2: Marketing constraints of the respondents

Marketing constraints	Small Farmer (n1=28)	Large Farmer (n2=40)	Total (n1+n2=68)
	MPS	MPS	MPS
No signing of contract farming agreement with the industry/organization before cultivating medicinal plant?	96.43	95	95.72
Don't sell your herbal products at Kisan Mela's/ exhibitions/ seminars/ any other?	92.86	90	91.43
No manufacturing of herbal products/ formulations for consumers?	85.71	57.5	71.61
Do you sell your medicinal produce directly to the consumer?	75	37.5	56.25
No fair price given by the industry for the medicinal produce?	53.57	12.5	33.04
Have basic packaging equipment's for packing your finished product?	14.29	45	29.65
There is high transportation cost for medicinal plants?	35.71	17.5	26.61
Don't want FSSAI approval?	17.86	20	18.93

Source: Authors' compilation.

MPS: Mean Percentage Score

3.3.3. Social participation and awareness related constraints

Social participation plays a vital role in updating the knowledge of the farmers. Therefore, it was necessary to understand the role of social participation in adoption of medicinal plants cultivation in Punjab. In the present study, it was observed that 89.65 per

cent and 64.82 per cent of the farmers were not member of any self-help group or farmer-producer company respectively. There are many self-help groups especially working in the Kandi belt of Punjab that are involved in the collection and processing of different medicinal plants such as Harad, Bahera, Amla, Giloy, etc. to manufacture *Chyawanprash, Triphala* etc. Therefore, awareness regarding successful self-help group and farmer-producer companies should be provided to the farmers through RCFC-North, NMPB, and other concerned organizations. In the present study, 'Suhavi' a farmer-producer company was involved in cultivation of Sarpgandha, Tulsi, *Aloe vera*, Haldi collectively to open a new line of agriculture in Punjab. It was also observed that 72.86 per cent of the population had internet access and only 68.57 per cent of the farmers used internet to update themselves regarding agriculture as mentioned in Table 3.3. Similarly, awareness among farmer plays an important role in adopting new crops. In this study, constraints related to awareness of the farmers were studied and it was observed that 80 per cent of the population was not aware regarding *e.charak* mobile application which is the official mobile app. developed by NMPB, Ministry of AYUSH for all the concerned stakeholders of medicinal plant for trading, agro-techniques

Table 3.3: Social participation and awareness related constraints faced by the farmers

Statements related to social constraints	Small Farmer (n1=28)	Large Farmer (n2=40)	Total (n1+n2=68)
	MPS	MPS	MPS
Not a member of any self-help group	89.29	90	89.65
Have internet connection	60.71	85	72.86
Accessing internet for acquiring updates regarding agriculture	57.14	80	68.57
Not a member of any farmer producer company	57.14	72.5	64.82
Statements related to awareness constraints			
No awareness regarding NMPB's official e.CHARAK mobile app. for latest market prices, agro-techniques of medicinal plants	75	85	80
No awareness regarding Good Agricultural Practices	71.43	77.5	74.47
No awareness regarding the industrial requirement of medicinal plants in context to the quality.	46.43	45	45.72
No awareness regarding the subsidy on medicinal plants for promoting medicinal plant cultivation by NMPB	14.29	42.5	28.4

Source: Authors' compilation.

MPS: Mean Percentage Score

and pricing related updates. Majority of the farmers i.e. 74.47 per cent were not aware regarding GAP. On the other hand only 28.4 per cent of the population was not aware regarding subsidy given on medicinal plant cultivation by NMPB through state forest department officials. It was observed that 45.72 per cent of the population was not aware of the quality of medicinal plants demanded by the industry.

3.3.3. Attitude and policy related constraints faced by the farmers

As mentioned in Table 3.4, 98.22 per cent of the population admitted that more demonstration plots should be installed by the govt. for wider dissemination of the knowledge regarding medicinal plant cultivation. Also, 95.18 per cent of farmers agreed on the establishment of a government mechanism to buy their produce will encourage the cultivation of medicinal plants at a wider level. Among the selected population 94.47 per cent of the respondents agreed to the organic certification of their fields. Most of the Kandi region of Punjab has natural organic land and the belt has great potential for medicinal plants cultivation because of the absence of pesticide residue which is one of the determining factors of herbal formulation in terms of quality (Kaur and Kaur, 2019). So, the farmers should be made aware regarding organic certifications through RCFC-North, India for fetching higher prices for their produce. Farmers were not equipped with a proper agro-technique manual, so the majority of the respondents i.e. 92.68 per cent agreed that providing them with an agro-technique manual will help them cultivate medicinal plants. Good Agricultural Practices of medicinal plants provide medicinal products of desired quality as well as quantity (Singh and Baldi, 2018). Therefore, farmers must be provided with agro-technique manuals regarding good agricultural practices for selected medicinal plants. Extension services must be made robust by establishing state-of-art medicinal plant department in the Punjab Agricultural University (PAU), Ludhiana, India and frequent training programs must be conducted by the PAU in cooperation with the NMPB. Among the selected respondents 84.82 per cent of the farmers said that they were not satisfied with the amount of subsidy given by the government and 44.47 per cent of the farmers only participated in NMPB/other related institute training programs. The NMPB provides subsidies on selected medicinal plants

Table 3.4: Respondents attitude and policy related constraints

Policy and farmer's attitude related constraints	Small Farmer (n1=28)	Large Farmer (n2=40)	Total (n1+n2=68)
	MPS	MPS	MPS
There should be more demonstration plots installed at universities/or related places to disseminate knowledge to interested farmers involved in cultivation of MAP	96.43	100	98.22
Establishment of Government mechanism for buying medicinal produce, will encourage in cultivation of MAP at larger level	92.86	97.5	95.18
You are interested in organic certification conducted by the Government	96.43	92.5	94.47

Table 3.4 Continue...

Table 3.4 Continue...

A proper agro technique manual will help you in MAP cultivation	92.86	92.5	92.68
You are willing to conduct trial for medicinal plant cultivation in your field	85.71	95	90.36
Success stories of medicinal plant adopters will motivate you to increase your land under MAP cultivation	85.71	90	87.86
Mobile app. facilitating quality determination and certification of medicinal plants, will help in determining the quality of the produce	85.71	85	85.36
Not satisfied with the amount of subsidy provided by NMPB on selected MAP	82.14	87.5	84.82
You are getting desired amount of subsidy from the NMPB for cultivating selected MAP	82.14	60	71.07
You are participating in training programmes being conducted by the NMPB/other related institutes on MAP cultivation/processing?	46.43	42.5	44.47

Source: Authors' compilation.

MPS: Mean Percentage Score

per acre through forest officials. The farmers were not satisfied with the subsidies, so it becomes imperative that the amount of subsidy allocated on different medicinal plants by the NMPB be revised for the wider adoption of medicinal plants in Punjab.

Similarly, 90.36% of the population agreed that they would actively participate in the conduction of trail plots in their respective fields if selected by the government. Likewise, 85.36% of the respondents agreed that mobile app. enabling evaluation of the quality of the medicinal would help them in maintaining the quality of the produce and 87.86% of the population said that success stories of farmers involved in medicinal plants cultivation would motivate them to cultivate the crops at a larger level.

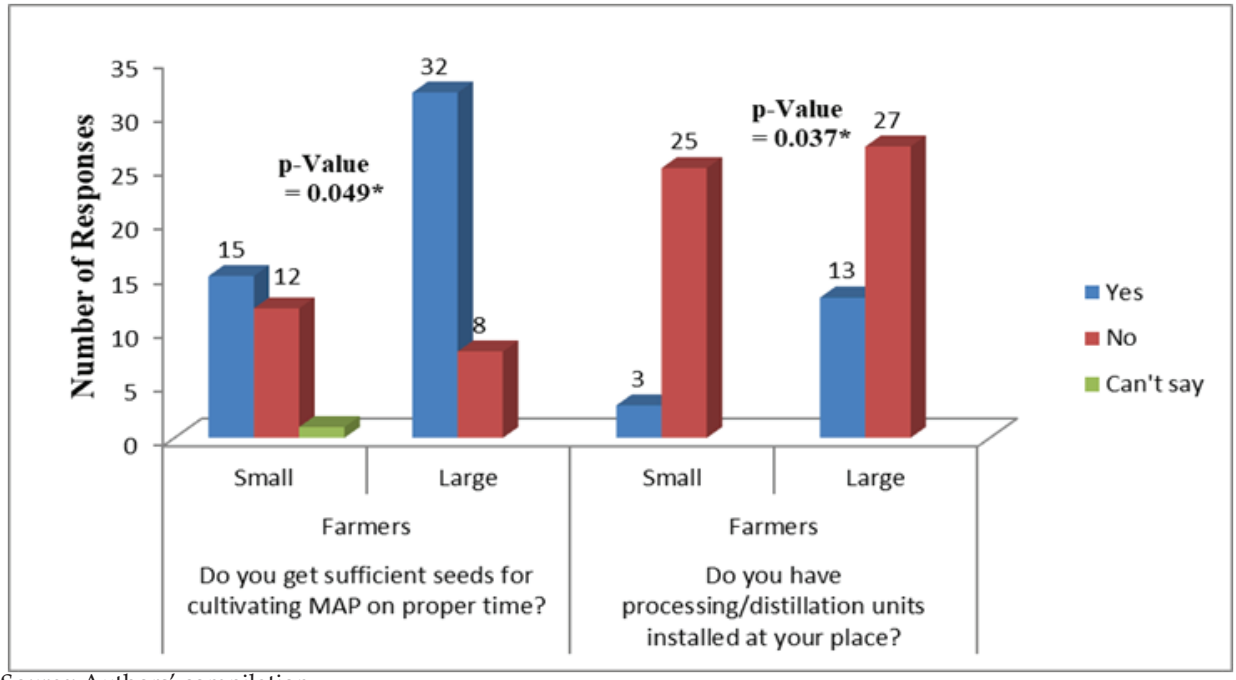
3.3.4. Inferential analysis of data

In this study, significant associations between the dependent and independent variables were carried out using the Chi-square test. In this section, only significant relationships between landholdings and constraints are highlighted.

3.3.4.1. Relationship between farmer's landholdings and technical constraints statement

The null hypothesis was assumed that small and large farmers did not differ significantly in getting sufficient seeds and owing processing units. But in the present study, null hypothesis was rejected and it was observed that there was a significant relationship between the landholdings of the farmers with getting sufficient seeds for cultivation and owing processing units for medicinal plants as represented in the Fig. 3.2. The large farmers are expected to have high annual income than the small farmers and it can assumed that because of high annual income, the large farmers can bear the transportation cost to buy seeds and also own processing units for their crop (Mittal and Mehar, 2016).

Fig. 3.2: Relationship between landholding and significant technical constraints



Source: Authors' compilation.

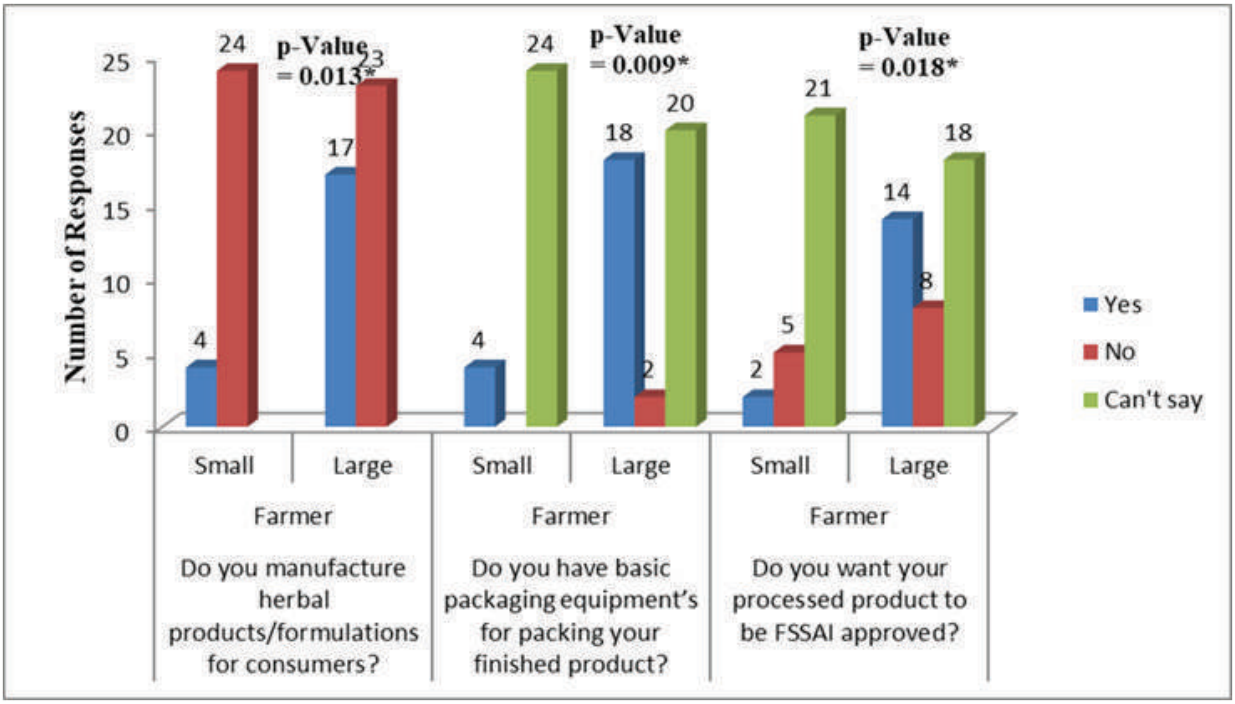
*Result is Significant as p-value < 0.05.

3.3.4.2. Relationship between farmer's landholdings and important marketing constraints statement

The null hypothesis was rejected for three statements corresponding to the marketing constraints. Farmer landholdings had a significant relationship between the manufacturing of herbal products, availability of packing equipment, and willingness for FSSAI approval as mentioned in the Fig. 3.3. It was observed that the large farmers were mostly involved in manufacturing of herbal formulations as compared to the small farmers. This can be corroborated with the fact that the large farmers due to their high annual income owned processing units and basic packaging equipments for the value additions. Most of the small farmers answered 'can't say' for the availability of packing equipment and FSSAI approval of their product. This can be corroborated with a study conducted by Shetty and co-workers that highlighted that more awareness regarding the quality of food, value additions, need for packaging equipment, and role of FSSAI must be disseminated to the farmers for fetching higher costs (Shetty *et al.* 2010). The results can also be correlated with a study conducted by Jairath and Purohit, highlighted that food safety law is poorly implemented for fruits and vegetables. The study also emphasized the need for small farmers and traders to integrate into food quality and safety network by establishing more number of supermarkets. The promotion of awareness programs regarding value additions, quality, and FSSAI needs to be disseminated to the farmers for promoting agri-business (Jairath and Purohit, 2013).

Similarly, a significant relationship was found between the farmer landholding and the type of market channel used by the farmers to sell their medicinal produce. Majority of the farmers included in the study sold their produce directly to the industry and consumer as mentioned in the Fig. 3.4. One of the most

Fig. 3.3: Relationship between landholdings with manufacturing of herbal products, owing packing equipment and willingness for FSSAI approval



Source: Authors' compilation.

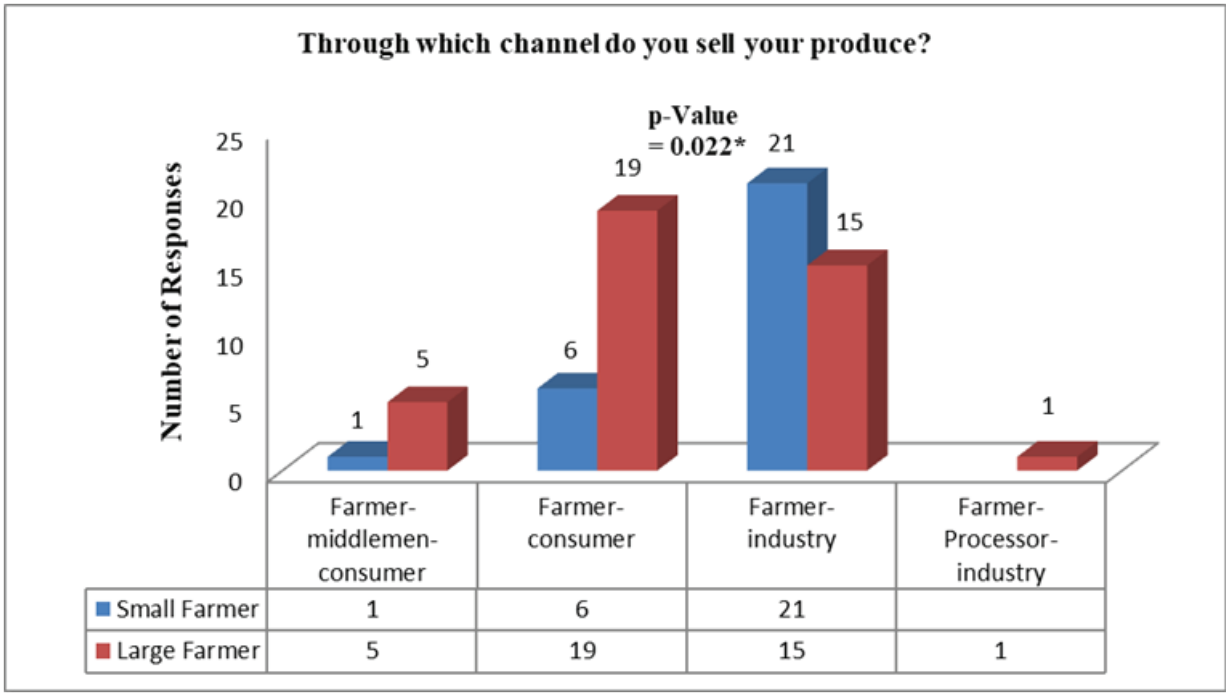
*Result is Significant as p-value < 0.05.

interesting findings of the present study was that the small farmers were directly selling their produce to the consumer (industry) which is not a common mechanism in India. In general, the small farmers are prone to sell their produce to the middlemen which cut their economic share in the marketing process (Ranjan, 2017). Similarly, this study can be correlated with the study conducted by Mitra and co-workers which highlighted that farmers had to bargain with the village middlemen for selling their crops eventually leading to less returns (Mitra, 2018). The small farmers that sold their produce directly to the industry were mostly the Amla growers of Kandi belt. They benefitted by selling their produce directly to the Unati co-operative marketing-cum-processing society situated in Talwara, District Hoshiarpur, India. The result can be corroborated with a study conducted by Dev in the year 2012, which highlights importance of directly linking small farmers with markets including value chains and enhancing employment and food security (Dev, 2012).

3.3.4.3. Relationship between farmer's landholdings and important social participation and awareness related constraints statement

All the statements related to the social constraints passed the null hypothesis except farmer's landholdings with the availability of internet connection. Considering easy availability of internet connection now days, it was assumed (null hypothesis) that farmer landholding's had no significant relation on the availability of internet facility. But in the present study, it was observed that large farmers had more internet facility than the small farmers. The findings can be correlated with a study conducted by Mittal and Mehar, which highlights less accessibility of the internet among the small farmers but also

Fig. 3.4: Association of farmer's landholdings with type of marketing channel used

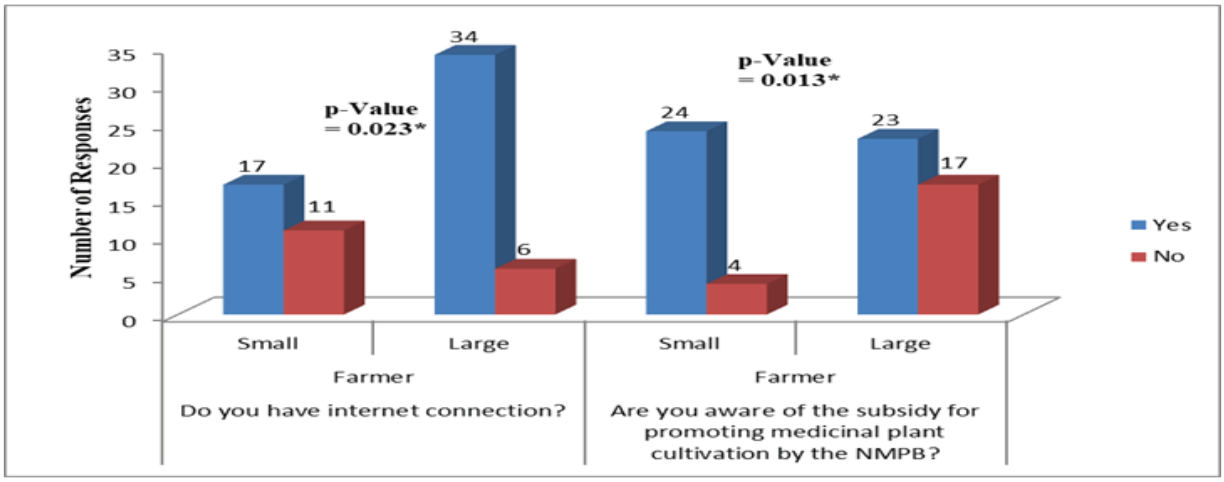


Source: Authors' compilation.

* Result is Significant as p-value < 0.05.

emphasised positive role of internet connection in updating the knowledge and positive growth of the small farmers. Similarly, Cecchini and Scott in the year 2003, highlighted role of Information and Communication Technology to reduce poverty especially among poor people by improving their access to health, education, and government services (Cecchini and Scott, 2003). The awareness of a farmer is a crucial factor in the adoption of new crops; therefore farmer's landholding had a significant relationship with the awareness regarding

Fig. 3.5: Association of farmer's landholdings with the availability of internet and awareness regarding subsidy



Source: Authors' compilation.

* Result is Significant as p-value < 0.05.

subsidy given on selected medicinal plants by the NMPB as mentioned in the Fig. 3.5.

3.3.4.4. Relationship between farmer's landholdings and attitude and policy related constraints

It the present study, all the statements relating to attitude and policy related constraints passed the null hypothesis and no significant relationships existed between the farmer's landholdings and attitude and policy related statements.

3.3.4.5. Determining motivating factors among medicinal plants cultivators

It was observed that 89.03 per cent of the farmers were motivated to adopt medicinal plants cultivation because it had more opportunity in agro-business. The findings are similar to a study that highlighted positive role medicinal and aromatic plants to enhance farm income in Bihar, India (Singh *et al*. 2013). The findings can be corroborated with a study that highlights most of the farmers had favourable attitude towards cultivation of medicinal plants in India (Kanwat, 2011). Similarly, 77.02 per cent and 60.42 per cent of the population highlighted requirement of less irrigation and lesser use of fertilizers as their motivating factor respectively. The medicinal plants such as Tulsi, Aloe vera, Amla, Haldi, and Sarpgandha selected in the study require less irrigation as compared to the paddy which extensively utilizes underground water leading to water exploitation (Bhattarai, 2013; Jat et al. 2014, 2015; Jayashree *et al.* 2015). In a study, 61.58 per cent of the population was motivated to adopt medicinal plants cultivation because of awareness from concerned organizations. Similarly, 52.92 per cent of the respondents highlighted that they adopted medicinal plants because traditional crops were not grown on sub-mountainous zone. It is difficult for the farmers of Kandi belt comprising of sub-mountains to cultivate traditional crops in the area. Hence the farmers cultivate Amla trees on the mountainous area in order to obtain income from their produce. On the other hand 52.83 per cent and 46.04 per cent of the population adopted cultivation of medicinal plants as they wanted to preserve traditional system of medicine and supposedly have good industry linkage. The motivating factors highlighted by the farmers are mentioned in Table 3.5.

Table 3.5: Motivating factors of farmers involved in cultivation of medicinal plants

Motivating Factors	Total
	MPS
More opportunity in agri-business	89.03
Require less irrigation	77.02
Awareness from concerned organizations	61.58
Less use of fertilizers	60.42
Sub-mountainous zone not suitable for traditional crops	52.92
Want to preserve traditional system of medicine	52.83
Good linkage with industry	46.04
Easy to grow	19.17

Source: Authors' compilation.

This wheat-paddy dominance contributed to serious ecological, and soil problems such as a decline in agricultural employment, slowing of productivity growth, overexploitation of groundwater resources, and decline in soil fertility Therefore, understanding the repercussions of these hazards on the farming economy, the government is promoting alternative crops through contract farming, developing infrastructure and linkage with agro-industries for diversification of agriculture.

Conclusion

Primary data was collected through personal interviews using a semi-structured, pre-tested reliable questionnaire following purposive sampling. A total of 68 farmers were involved in the cultivation of medicinal plants. Medicinal plants such as Curcuma longa, Aloe vera, Emblica officinalis, Ocimum sanctum, Rauvolfia serpentina were cultivated by the farmers. The mean percentage score and the Chi-square test was applied for finding significant differences i.e. p-value < 0.05 between the small and large farmers to highlight various technical, marketing, social, and awareness related constraints. It was found that 36 per cent of the cultivators were graduates, large farmers, and belonged to the general caste category. Few processing units, non-availability of quality planting material, packing and labelling equipment, less knowledge regarding agro-climatic suitability, lack of awareness regarding GAP, NMPB e-charak mobile app., and need for agro-technology refinement etc. were some of the constraints faced by the farmers. The significant relationship was found between farmer landholdings in getting sufficient seeds, having distillation units, manufacturing herbal formulation, having packaging equipments, willingness for FSSAI approval, channel to sell the produce, availability of internet and subsidy of medicinal plants given by the NMPB rejecting the null hypothesis.

Historical evidence shows that apart from providing health values, the adoption of medicinal plant cultivation has improved the livelihood status of the cultivators in many countries by generating high-income sources. Subsequently, medicinal plants have an important ecological role that helps check runoff, erosion, purify water, controls flooding. The adoption of medicinal plant cultivation could be fruitful if the constraints highlighted in the study are comprehensively addressed by the concerned policymakers.

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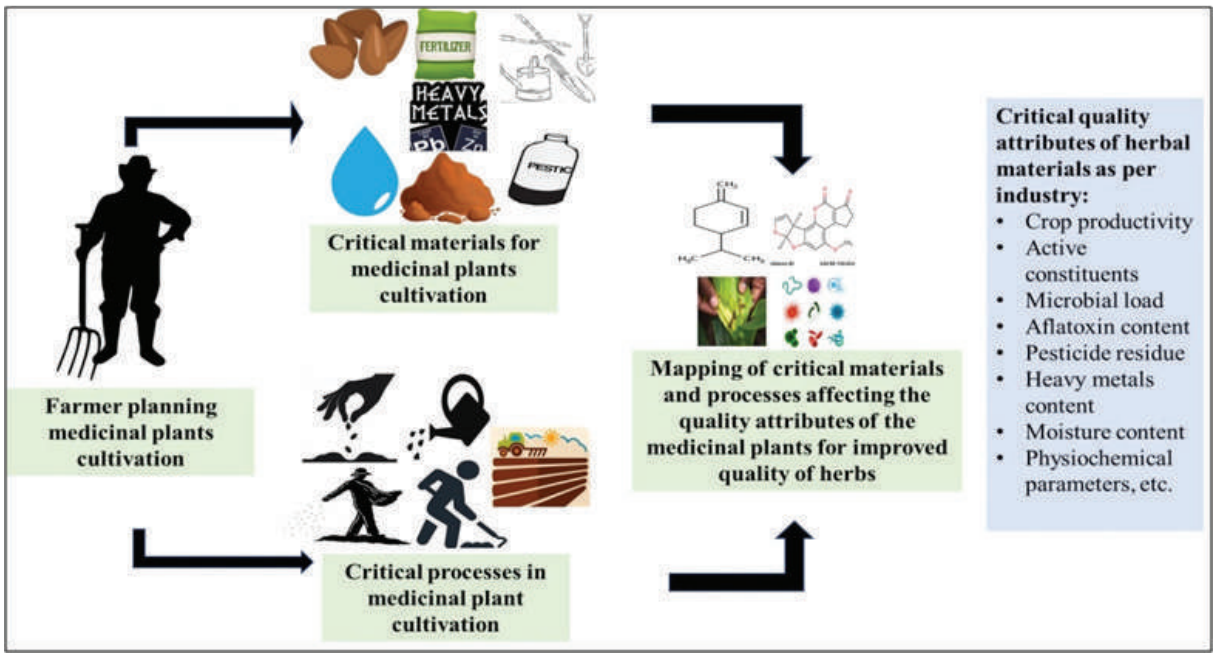
4

Quality by Produce: An Alignment Study of Critical Variables for Medicinal Plants

4.1 Introduction

The cultivation of medicinal plants and its commercial sustenance is substantially dependent on the quality of the produce. Maintaining consistency is one of the major hurdles in agriculture due to several interfering biological and other factors. In general, agricultural risks are identified at a stage when there are lesser chances to manage the risks.1 Therefore, prior understanding of risks in medicinal plants cultivation was essential to facilitate, coordinate and improve science-based decision making ensuring quality of the herbs with low cost inputs. It becomes imperative to highlight and map various agricultural materials and processes in order to maintain the desired quality of medicinal plants while also avoiding risks during its production. This has urged the author to develop a rationale-based methodical approach to comprehend

Fig. 4.1: A layout of design for QbP



Source: Authors' compilation.

the quality of medicinal produce in relation to variables and practices involved.

Quality by Design (QbD) and in this case Quality by Produce (QbP) is a scientific approach that begins with pre-defined quality materials and processes based on sound science and literature to pre-determine the risks to the quality of the herbs.[2] This technique is designed to understand pre-defined effects of various materials and agricultural processes on the quality of medicinal plants in terms of active constituents, yield, microbial load, heavy metals, etc. (Lawrence *et al*. 2014). This study has three set of variables such as Critical quality attributes *(CQA)*, critical process parameters *(CPP)* and Critical material attributes *(CMA)* that are linked to each other defining the quality of the herbs in a scientific manner (Rathore & Winkle, 2009). The method for this alignment study is represented in the Fig. 4.1.

4.2 Methodology

4.2.1. Design of the study based on critical variables

This design provides stringent, comprehensive and farmer-centric strategies of pre-determining the materials and processes affecting the quality attributes for timely risk management. The critical quality attributes were selected based on empirical data in context to industrial importance and sound literature exploration. Risk assessment to quality was evaluated based on scientific knowledge, farmer's inputs allowing selection of CMA and CPP from the potential list of agricultural materials and processes. The critical quality material or process having the highest risk to the quality attributes was termed as very high followed by high, moderate, less, very less, and negligible.
The three set of variables are mentioned below:
CMA: any physical, biological or chemical property of an input material, i.e. water, soil, seed, fertilizer, pesticides, biological factors, etc. required during the agricultural process that has direct effect on the quality medicinal produce.[3]

CPP: processes such as plant identity methods, soil and water treatment processes, site selection, sowing, harvesting, fertilizer application, harvest, collection, drying, storage, etc. whose variability impacts the quality of the herbs and therefore it must be monitored or controlled to avoid risks at the later stages of plant production by ensuring pre-determined quality.[4]

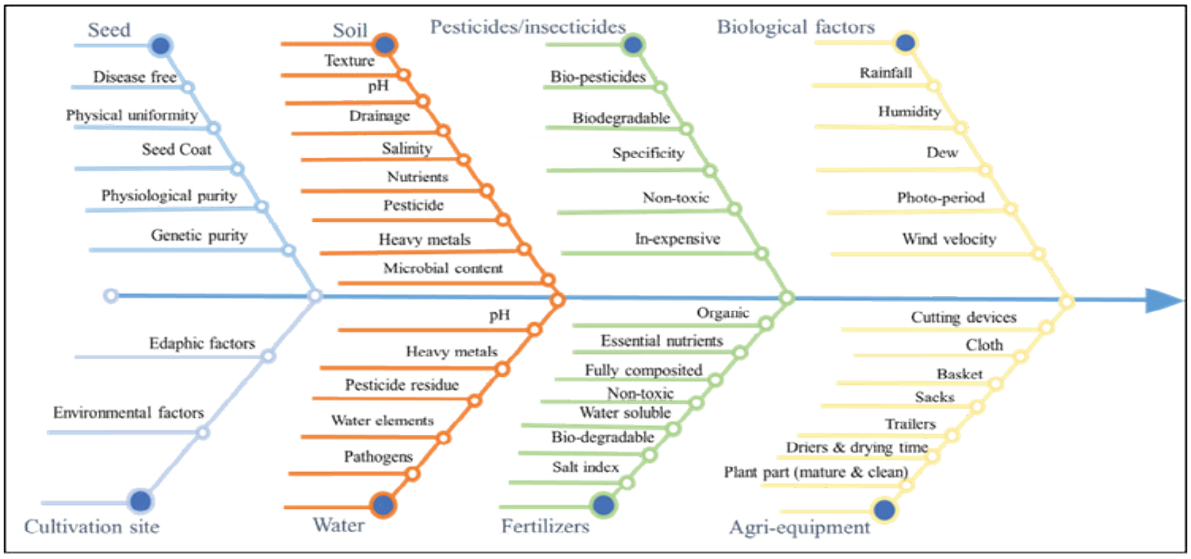
CQA: a physical, biological or chemical property that should be in a desired range or limit ensuring the quality of the raw material, e.g. active chemical constituents, toxicity indicators (heavy metals and pesticide limits), microbial load (aflatoxin levels, microbial contamination related disease), physicochemical ranges (ash values, extractives) and crop productivity, etc. These are the attributes which are highly considered during the trade or by the herbal or related industries.[3] The material or process was classified on the critical quality risk scale. The critical quality material or process having the highest risk to the quality attributes was termed as very high followed by high, moderate, less, very less, and negligible.

4.3 Results and discussion

4.3.1. Critical variable alignment study

The analysis of critical quality statements gathered during the conduct of survey, (mentioned in Chapter 3), highlighted major quality gaps. Hence, it becomes important to analyze critical quality statements of farmers with respect to GAP and suggest comprehensive scientific design for pre-determining the quality of their cultivated produce. In the present design, critical materials, processes involved in medicinal plants cultivation were identified as represented in the Fig. 4.2-4.3.

Fig. 4.2: *CMA* **and their qualities for medicinal plants cultivation**



Source: Authors' compilation.

Fig. 4.3: *CPP* **for medicinal plants cultivation**

Source: Authors' compilation.

Herbal formulations are intended for human administration, therefore, heavy metals, pesticide residues, microbial contamination, aflatoxin levels must be in prescribed limits in the raw herbal plants. Heavy metals such as lead, cadmium should not be more than 10mg/kg and 0.3mg/kg respectively as per the WHO. Likewise, pesticide residues of

Aldrin and dieldrin must not be more than 0.05 mg/kg. Similarly, Escherichia coli, mould propagules, aerobic bacteria, yeasts and moulds, enterobacteria, Salmonellae must be in prescribed limits in raw, pre-treated medicinal plants. Aflatoxins, particularly B1, B2, G1 and G2 in plant materials should be avoided (World Health Organization, 1998, 2011). Likewise, crop productivity, microbial load, aflatoxin level, content of active constituents, toxicity indicators (heavy metals and pesticide residues), physio-chemical parameters, etc. were the major parameters considered by the herbal industries. Therefore, all these parameters must fall in optimum range for wider industrial acceptance. For this, the farmers must be enlightened with critical materials and processes having significant relation with the quality attributes of the plants.

4.3.2. Relationship between CMA and CQA

Materials such as seed, site, soil, water, pesticides, fertilizers, biological indicators, and agricultural equipment were identified as critical materials in the agriculture process for the medicinal plants based on farmer's inputs and literature exploration. The materials affecting the CQA are mentioned in the Table 4.1.

The quality risk assessment study highlighted seed, site, soil, and water had the highest bearing on the crop yield. Similarly, pesticides had a significant relation with crop yield and moderate relation with toxicity indicators. On the other hand, biological indicators, agricultural equipment's had a negligible bearing on toxicity indicators of the plants.

4.3.3. Relationship between CPP and CQA

Every material used by the farmers for the successful cultivation of the medicinal plants passes through several processes that directly affect the quality of the crop. In general, if the materials pass the quality test but fail optimum processes, it results in poor quality crops (Yan *et al.* 2014; Qu *et al.* 2019). The critical processes are divided into three phases, viz. pre-cultivation: comprising of seed, site, soil, and water treatment processes; agro-practices phase: sowing, plant management, crop nutrition, and harvest; post-harvest phase: comprising of collection, drying, storage, and handling of medicinal plants.

4.3.3.1. Pre-cultivation phase

Seed treatment: Proper taxonomical authentication with phenotype/chemotype/genotype and breeding history must be guaranteed for good quality immunity-boosting plants. Similarly, proper inspection should be carried out to control intentional and un-intentional adulteration (Singh *et al.* 2020; Chanda, 2014). Furthermore, seeds must be checked for

Table 4.1: Effect of CMA on CQA

Critical quality attributes	Seed	Site	Soil	Water	Pesticides	Fertilizers	Biological indication	Agricultural equipment's
Crop yield	Very high	Very high	Very high	Very high	High	Moderate	Moderate	Negligible
Microbial load	Moderate	Moderate	High	Moderate	Less	Less	Less	Moderate
Active constituents	High	Less	Very less	High	Negligible	Very less	High	Very less
Physicochemical ranges	Less	Very Less	Less	Very high	Very less	Negligible	Very less	Less
Toxicity indicators	Very less	High	Moderate	Less	Moderate	Negligible	Negligible	Negligible

Source: Authors' compilation.

Very high: 80-100%; High: 60-80%; Moderate: 60-40%; Less: 40-20%; Very less: 1-20%; Negligible: 0-1%.

physical uniformity, should be made disease and pest resistance to get optimum yield.[4]

Site selection processes: A site should be considered after the analysis of the meteorological data for the past 10 years and the bio-climatic needs of the selected immunity-boosting plants. Sites history in context to heavy metals, pesticide residue should be checked by proper soil sampling (Anderson, 2002; Valipour, 2013). Sites near to mining, crematoriums, golf courses, etc., must be avoided for producing good quality herbs. Feedlot history and domestic animals entry need to be strictly prohibited as it affected the yield of the crop (De Freitas Araújo *et al.* 2012).

Soil treatment processes: Soil sampling and physicochemical properties of the soil must be carried out to highlight the nutrient requirements of the plants and to check the water movement in soil layers. There should be proper tillage for the activation of the soil microbes, soil structure, and incorporation of fertilizers and soil amendments (Roger-Estrade *et al*. 2010). It also helps to reduce soil erosion and releasing minerals from the soil to the plants (Rasmussen, 1999).

Similarly, leveling the field must be carried out for the uniform distribution of water, nutrients to the seedlings thereby increasing the yield and good traffic (Agarwal and Goel, 1981). Soil drainage is a natural process that permits water moving across and through the soil because of gravity. In general, poor soil drainage results in a slower germination rate, increase the traffic damage, crop diseases, animal diseases, lesser root development, increase in moulds and weeds affecting the yield of the crops (Seifu and Elias, 2019 and Rhoades, 1974). So, optimum soil drainage must be maintained to avoid deterrent effects on the quality of the produce. In-appropriate soil pH affects plant growth in several ways by leaching the plant nutrients in acidic soil and affecting the bacteria responsible for providing nutrients to plants. Furthermore, to manage heavy metal and pesticide threat, plants such as mustard, marigold, etc., possessing significant phytoremediation properties, must be used (Salt et al. 1998). Nigh soil must be avoided to ensure a lesser vulnerability of microbial and aflatoxin contamination of the plants.

Water treatment processes: The first step to assure the quality of the water is to ensure its compliance with the regional and national qualities (Organización Mundial de la Salud, World Health Organization, 2003). Source of water must be reliable and water should be devoid of pathogens such as Phytophthora, 26 of Pythium, 8 bacteria species, 27 fungi genera, 10 viruses, and 13 plant-parasitic nematodes species causing diseases, aflatoxins, and extraneous matter (Hong and Moorman, 2005). Good mulch under the crop can prevent the soil salinity by maintaining the optimum moisture to the crop (Pang *et al*. 2010). Lead which is neither an essential element has a high tendency to get absorbed and accumulate in different parts of the plants leading to stunted growth, chlorosis, blackening of roots, etc. (Sharma, 2005; Nas and Ali, 2018). Therefore, lead pipe fittings should be avoided to control excessive lead presence in the crop (Singh and Bald, 2018).

4.3.3.2. Agro-practices phase

Sowing: Punjab has different growing periods so optimum climatic requirements of the plants at the time of sowing must be followed after consulting official literature and experts (Coventry et al. 1993; Singh and Rath, 2013). During sowing optimal seed to seed and row to row distance, seed depth must be maintained according to the plant requirements. Inappropriate distances affected crop growth, root density, plant height, number of leaves, plant biomass, weeds, and vulnerability to diseases which eventually affects the yield, microbial load, active constituents, physico-chemical ranges, and toxicity indicators (Ngullie & Biswas, 2017).

Plant management: Seeds or material sometimes tend to show mortality in the initial period, so replenishment of the plant population was necessary to get a better yield (Hatfield *et al.* 2001; Persson, 1980). The plant requires optimum cycles of weeding so that undesired plants do not compete with the principal crops for nutrients especially during the growth period. Similarly, hoeing, topping, pruning, shading must be carried out depending on the plant requirements (Nag and Pradhan, 1992; Aydın and Arslan, 2018). Pruning was essential to remove the dead part of the plant especially Amla, to control, re-direct its growth (Saure, 1987). According to the mapping, the plant management possessed effect on the yield, microbial load, physicochemical and toxicity indicators of the immunity-boosting plants.

Crop nutrition: Optimum use of aerobic organic fertilizers, bio-pesticides is recommended for the medicinal plants. Fully composited organic manures, vermin-compost, poultry manure, green leafy manure must be applied at the initial for phase for a complete breakdown (Organización Mundial de la Salud, World Health Organization, 2003). In some cases, if pesticides were essentially required, the smallest effective dosage with the least toxicity must be used. Human excreta should not be used or mixed with the fertilizers as it attracted pathogens, diseases, and pests lowering the yield of the plant and increasing the microbial load (Strauch, 1991). Fertilisers should be applied by trained personnel only to ensure optimum.

Harvest: The time of the harvest played a critical role in context to the presence of active constituents (Tanko *et al.* 2005). Only the mature part of the plant should be harvested to attain significant chemical constituents. Good harvesting practices should be carried out to avoid the foreign matter, weeds, and toxic plants adjoining the principal crops. Harvesting must be avoided in high dew, humidity, and rainfall (Organización Mundial de la Salud, World Health Organization, 2003).

4.4.3.3. Post-harvest phase

Collection: The collection of medicinal plants strictly falls under regional and national governments in order to check the sustained collection and distribution of medicinal plants (Harnischfeger, 2000). Therefore, prior permission should be sought from the concerned government departments before its collection. In the case of collecting fruits from the trees such as Amla, the collectors should follow the optimum time to obtain maximum active constituents in the plants. Furthermore, avoid the collection of immature and undersized fruit (Tavhare and Nishteswar, 2014). Cutting the branches of the tree to ease the collection of desired plant parts must be strictly prohibited. Shaking the trees to collect fruits should be prohibited to avoid physical damage to the fruits (Pandey and Das, 2014). Fruits should be collected in a scientific manner after consulting experts and pharmacopoeia to get the desired yield, active constituents, lesser microbial, aflatoxin, moisture content, etc.

Drying: Drying is one of the most crucial methods for medicinal plant preservation and due to high investments and energy costs, drying is also a large expense in medicinal plant production. Essentially low drying temperatures between 30 to 50°C are recommended to protect sensitive active constituents of the medicinal plants (Heindl and Müller, 2007) In general, drying should be done in a manner to prevent discoloration of the raw herbs, and drying under direct sunlight must be avoided to maintain the volatile contents present in the medicinal plants. Shade drying, solar drying, freeze-drying, etc. must be preferred for medicinal plants.[5] During drying tarpaulin cloth should be used between the cemented floor and the drying material to prevent crop damage and foreign matter in the

Table 4.2: Effect of CPP on CQA

Pre-cultivation phase				
Critical quality attributes	**Seed treatment**	**Site treatment**	**Soil treatment**	**Water treatment**
Crop yield	Very high	Very high	Very high	Very high
Microbial load	Less	Moderate	High	Moderate
Active constituents	High	Less	Less	High
Physicochemical ranges	Very less	Very Less	Very less	Very less
Toxicity indicators	Moderate	High	Moderate	Less
Agro-practices phase				
Critical quality attributes	**Sowing**	**Plant management**	**Crop nutrition**	**Harvest**
Crop yield	Very high	High	High	Negligible
Microbial load	Moderate	Very less	Moderate	Very less
Active constituents	High	Less	Less	Moderate
Physicochemical ranges	Less	Moderate	Negligible	Less
Toxicity indicators	Very less	Negligible	Very less	Negligible
Post-harvest phase				
Critical quality attributes	**Collection**	**Drying**	**Storage**	**Handling**
Crop yield	Negligible	Negligible	Negligible	Negligible
Microbial load	Less	Moderate	Less	Moderate
Active constituents	Moderate	Less	Moderate	Less
Physicochemical ranges	Very less	Very less	Very less	Very less
Toxicity indicators	Negligible	Negligible	Negligible	Negligible

Source: Authors' compilation.

Very high: 80-100%; High: 60-80%; Moderate: 60-40%; Less: 40-20%; Very less: 1-20%; Negligible: 0-1%.

medicinal plants. Similarly, drying should be done in such a place where there is no threat from rodents, pests to the drying material.

Storage: It is recommended to process or semi-process medicinal plants in due course of time and storage time must not exceed one year for any medicinal plants (Lisboa *et al*. 2018; Yadav *et al*. 2013).

Similarly, there must be controlled environmental conditions in the storage room to avoid moisture, microbial, aflatoxin contamination. Proper packing must be carried out for medicinal plants, i.e. for hard materials, gunny bags and woven sacks should be preferred, for creeper and leaves, high gauge polythene bags should be used, for fleshy material high gauge HMHD (High molecular weight high-density polyethylene) bags should be preferred. An un-authorized person should not be allowed to enter the room (Sumithra and Prasad, 2018)

Handling: Harvested material should be thoroughly cleaned to avoid the presence of foreign matter, high moisture content, microbial content, aflatoxin levels, etc. (Rajeshwari and Raveesha, 2016). The processing equipment should be cleaned and free from pathogens to avoid microbial contamination. During transportation, the raw materials should not be overfilled in the sacks, this increases the chances for microbial contamination and damage of produce3. Likewise, unpacking of the material should be carried out immediately on reaching the processing unit for proper sorting to prevent damage to the crops. Inappropriate handling of herbal raw material affects the microbial load, active constituent yield, and physicochemical parameters. The present study suggested that from all the critical processes, the pre-cultivation phase has a larger bearing on crop yield. Similarly, sowing had a significant bearing on crop productivity, followed by plant management and crop nutrition in the agro-practices phase. On the other hand, harvesting, collection, drying, storage handling had a negligible effect on crop yield and toxicity but specifically affected constituents and microbial load as mentioned in the table 4.2.

4.4 Conclusion

This alignment study identified critical materials such as seed, soil site, water, fertilizers, pesticides, biological indicators, equipment having significant relation with the quality attributes of medicinal plants. Similarly, processes, viz. authentication of seed, maintaining optimum soil drainage and pH, soil sampling, levelling, tillage, water-logging prevention, the optimum time of sowing, seed-row distances, harvesting time, aerobic treated, fully composited and early application of fertilizers, phytoremediation, drying time, drying temperature, storage time, etc. had a significant effect on critical quality attributes of the medicinal plants. The study successfully developed a relationship between CMA, CPP and CQA to enlighten the farmers to pre-determine the quality and subsequently avoid the risks involved in the cultivation of medicinal plants.

The findings will be helpful to ascertain the systematic method of medicinal plant cultivation and application of suitable measures for obtaining maximum productivity with assured quality. Further, the study lays a fundamental basis for the farmers interested in GAP based cultivation of medicinal plants in a more efficient, cost-effective, and scientific manner. This technique would enable the farmer to fine-tune parameters as all possible interactions have been already evaluated with in-depth understanding. This design would become of greater importance for the herbal industries looking to boost their production and reduce throughput times. Apart from medicinal plants, the study can be extrapolated to other agricultural sciences especially spices, aromatics, etc. for continuous improvement of the quality. Hence, the findings may open a new vista in transforming cultivation practices to an inclusive and holistic approach based on scientific intrigue.

Endnotes

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5

Comprehensive GAP Guidelines For Enhancing The Quality Of Medicinal Plants

5.1 Introduction

WHO developed a series of technical guidelines relating to quality control of herbal medicines and GACP guidelines is one of the initiatives of WHO for producing good quality herbs (Saha *et al*. 2018). WHO also stressed that more countries should develop their own guidelines for the quality control of medicinal plants based on the guidelines developed by the WHO (Organización Mundial de la Salud and World Health Organization, 2003). Following the pattern of GACP guidelines for medicinal plants drafted by the WHO, the National Medicinal Plants Board (NMPB) under the ministry of AYUSH have prepared India specific guidelines on GACP (National Medicinal Plant Board, 2009). Similarly, in the year 2006, Good Agricultural and Collection Practice for Herbal Raw Materials, was drafted by the Botanical Raw Materials Committee of the American Herbal Products Association in cooperation with the American Herbal Pharmacopoeia (American Herbal Products Association and American Herbal Pharmacopoeia, 2006). Also, the countries like Japan, China, and even Europe have drafted their own GACP guidelines for the medicinal plants (Organización Mundial de la Salud and World Health Organization, 2003). The GACP guidelines developed by different countries were unique in their own manner and aimed to enhance the quality of herbal raw material.[1,2] In this context, the author necessitated the need to compare the GAP guidelines drafted by the WHO, America, Europe, China, Japan, and India to draft robust and comprehensive GAP guidelines for the medicinal plants. The comprehensive GAP guidelines encourage developing monograph on GAP for medicinal plants for the countries considering their ecological conditions. The monographs shall be made in view to facilitate cultivation of the selected medicinal plants of reliable quality and also ensuring sustainable supply to meet the demands of market (Anonymous, 2009; Bhattarai, 2013). Apart from comprehensive GAP guidelines, we discuss the need for developing monographs on GAP for medicinal plants.

5.2 Objectives of the comprehensive GAP guidelines

- To provide comprehensive and robust GAP guidelines for the medicinal plants.
- To encourage sustainable cultivation of medicinal plants in the country and worldwide and also protect wild resources.
- To encourage developing monographs of GAP for medicinal plants considering

farmers practices, reported literature considering agro-ecological conditions.

- To provide specific practical technical guidelines for the cultivation of selected medicinal plants of good quality.
- To contribute in alleviating the scarcity of selected plant based medicines.
- To ensure quality-rich raw herbal material for achieving efficacious herbal, nutraceutical and cosmetic products.

5.2.1. Utilization

The comprehensive GAP guidelines provide robust and comprehensive parameters to assure the quality of medicinal plants worldwide. It encourages providing detailed technical know-how regarding the good agricultural practices and required measures for their cultivation by developing monographs. Given this, the monographs of selected medicinal plants such as *Curcuma longa, Aloe vera, Emblica officinalis, Ocimum sanctum,* and *Rauvolfia serpentina* mentioned in chapters VI to X of this book were prepared after exploring their GAP reported in standard literature and agro-practices followed by the farmers of Punjab (World Health Organization, 2006; Anonymous, 2009; Bhattarai, 2013). It has been reported that the cultivation of medicinal plants vary from country to country, and the growth of the plant not only depend upon the agro-techniques but also on the ecological conditions of the region. Therefore, the monographs must be used in conjunction with the respective national or international agricultural guidelines.

5.2.2 Pilot test of cultivation in a small area

The medicinal plants are grown worldwide; but this does not mean that all the plants necessarily have desired quality and yield due to varying environmental and edaphic factors. Therefore, a small pilot test of cultivation in a selected site is necessary prior to the cultivation at commercial scale.

5.2.3. Estimation of market demand and potential clients

Before the commercial cultivation of medicinal plants, the market demand and potential clients must be kept in mind for marketing. All over India there are approximately 8610 licensed herbal units out which 284 are present in Punjab. The demand of medicinal plant keeps varying from time to time. However, in context to the medicinal plants selected in the present study, the estimated consumption for *Aloe vera* by the domestic herbal industry is 15,700 MT, followed by 14178.23 MT and 1362.81 MT for *Emblica officinalis* and *Ocimum sanctum* respectively. Similarly, the estimated consumption of *Curcuma longa* and *Rauvolfia serpentina* by the domestic herbal industry is 1316.51 MT and 26.47 MT respectively.

5.2.4. Ensuring the extracting capacity for important chemical constituents from locally grown plants

In many countries, the medicinal plants grow with good yield and many herbal medicines are manufactured with the help of respective government. Therefore, before the large-scale cultivation of the selected medicinal plants, the government should assist in providing technical skills to extract oil and methods for value additions.

5.3 Comprehensive GAP guidelines for medicinal plants

The parameters ranging from seeds and propagation materials, site selection, agro-ecological conditions comprising of soil, water and meteorological specifications, cultivation, land pattern, crop management and nutrition including fertilizers, pesticides, harvest and

post-harvest, personnel, and documentation are encompassed in the comprehensive GAP guidelines for medicinal plants as mentioned below:

5.3.1. Seeds and propagation material

Identity: Supplier of the seed, seedling, cuttings etc. should provide proper taxonomical identity, trade name, cultivar selection/Phenotype/ Chemotype/Genotype and breeding history of the plant either cultivated or wildly collected. The source of the seeds/cuttings should be duly authenticated.

Purity: Seed, seedlings, cuttings (both aerial and underground) propagation material should be free from pests, diseases, extraneous species, sub-standard adulterated material, botanical varieties and strain during production.

Quality: Quality of the propagation material (genetically modified germ plasm), seed should comply with national regulation of the country and with the country in which material may be sold. There should be physico-chemical analysis/marker based analysis for end product used in industry. Material should be resistant to diseases, biotic, abiotic factors and should be certified organic.

Treatment of seeds, seedlings, propagation material: Seeds either collected from wild or cultivated should be mature, fresh and originated from recent harvest. Seed treatment if any should be followed as prescribed. Similarly seedling production should be followed as recommended by the agronomic practices and proper time of transplantation should be kept in mind. In case of cuttings, it should be healthy and of uniform dimensions in terms of length and diameter.

Transportation of seeds: Proper inspection should be made to check disease control on seeds/propagation material during production, transportation and storage. Care should be taken to protect animals from physical and sensory injury during transportation and trapping.

5.3.2. Site selection

Meteorological data including average rainfall, temperature, length of the day, field temperature, duration of sunlight, day and night time difference for the past three years should be consulted for suitability.

Avoid site having hazardous condition (heavy metals, agricultural agent, and industrial waste, contaminated soil with sludge). Pesticides residual and heavy metal analysis can be done when field history is not known. Proper information regarding recent use of pesticides, herbicide, fungicide and rate of its breakdown should be noted.

Corrective measures should be taken to prepare site where environmental contamination is known.

Record information that have relevance to either improving or damaging the crop or site.

Avoid areas near by mine tailings, parking lots, golf courses, waterways, underground storage tanks, graveyard, crematoria or having traceable history of such usage.

As a good indicator for cultivation conditions, plants should be planted where weeds can grow.

Identify crops that will be grown in adjoining sites and their treatment followed.

Cows and domestic animals should be prohibited from entering the site and history of site as feedlot is also to be accessed.

There should be provision of artificial shading for light shade plant.

Site should have optimal level of water holding capacity and water logging prevention.

Ecological, environmental and social impact should also be taken into consideration for benefits of local communities for selected medicinal plant for cultivation.

Potential growing area of a particular medicinal plant should be highlighted utilizing agro-climatic zoning model comprising of at least climatic (temperature, rainfall etc.) and land (soil texture, soil pH etc.) specific indicators to define best agro-climatic zone of the plant.

5.3.3. Soil

There should be no use of night soil.

There should be appropriate amount of nutrients present in soil.

Avoid high soil moisture level for mold and fungal problems.

Soil sampling and physico-chemical analysis of soil should be done to quantify essential soil nutrients prior to planting should and decide further amendments.

Soil type, drainage, moisture, retention, fertility and pH should be considered.

5.3.4. Water

There should be proper identification of water sources (on-farm well, open irrigation canal, reservoir, municipal supply or other sources).

There should be optimal use of water for cultivation.

It should comply with local, regional and national quality standards.

It should have reliable source of water (avoiding salinity, acidity and toxicity).

There should be planned irrigation cycle for optimal growth.

Water harvesting and conservation methods should be applied where ever possible.

Water should be analyzed for heavy metal and residual matter including domestic animals or human materials.

Lead pipe fitting for water must be avoided. Total salt concentration, sodium absorption ratio, bicarbonate and boron concentration should be accessed in accordance to quality of water and target crop.

There should be proper drainage of water and impounding rain water should not be allowed.

5.3.5. Cultivation

Parameters such as rate of seedlings per acre should be taken into consideration.

Plant to plant distance should be optimally decided.

Row to row distance should also be known. Placement of seeds at appropriate depth in moist zone of soil should be considered.

Optimum irrigation cycles should be followed and recorded.

Standard agro-technique for particular plant should be followed drafted by the authorized agencies of the country keeping in mind the agro-ecological conditions of the area where plant is to be cultivated.

5.3.6. Crop management

Replenishment of plant population to compensate mortality losses in reasonable time frame and gestation period of plant should be considered.

Topping, hoeing, bud nipping, pruning, shading, earthing up should be followed depending on the plant selected for the cultivation.

5.3.7. Crop nutrition (Fertlizers/ Insecticides/Pesticides/Fungicides)

Fertilizers for nitrogen fixation and phosphate solubilizing are desired. Organic manure, vermin compost, poultry manure, green leafy manure must be preferred.

Do not use manure or compost based fertilizers with sewage sludge of human feces. Human excreta must be avoided.

Manure should be fully composited.

Fertilizers treated through aerobic process should be preferred.

Monitor undesirable microbial pathogens through periodic testing.

Documentation of fully composted animal manure should be carried out.

Chemical fertilisers approved by the countries should be used with minimize leaching.

Fertilisers should provide buffer zones and planting cover crops to minimize soil erosion.

There must be qualified staff for application of pesticides.

Fertilisers must be applied at early phase for its complete breakdown during harvesting.

Ensure quality of water used for fertiliser application.

Growers should comply with maximum pesticide and herbicide residues limits.

There should be use of bio-pesticides than chemical pesticides. However, pesticides in smallest effective dosage with low toxicity and residue pesticide content should be used.

Documentation of pesticide application must be carried out.

Follow federal, state, local regulations for chemical fertilisers and use fertilisers as labels directions.

5.3.8. Harvesting

Select optimal time for harvesting as harvesting depends upon the part of the plant to be harvested.

Chemical constituents in the plants are responsible for pharmacological/nutraceutical/cosmetology actions, so consultations of pharmacopoeias and other standards of harvest must be studied to assure proper quality and quantity of the active bio-active constituent present in the plant.

Avoid presence of foreign matter, weeds, toxic plants during harvest.

The cloth used as an interface between soil and harvested material should be clean and made of muslin cloth.

Underground parts such as roots, rhizomes should be cleaned from soil as soon as harvested. During harvest, avoid dew, rain and exceptionally high humidity.

In certain cases if harvesting is done in wet conditions it should be transported to indoor dry facility.

Transport harvested medicinal plant promptly in clean and dry conditions.

Place the harvested materials in clean baskets, dry sacks, trailers, hoppers or other well aerated containers for transport subsequently avoid high moisture retention plastic containers.

Overfilling of sacks should be avoided.

Decomposed medicinal material should be identified and discarded during harvest, post-harvest inspections and grading.

5.3.9. Post-Harvest

There should be proper visual inspection, organoleptic evaluation (appearance, damage, size, color, odor, taste) and sorting before primary processing of the collected medicinal plant to avoid cross contamination by untargeted plants and foreign matter.

Primary processing should be accrued out in national, regional quality standards and regulations and norms for producer and purchaser countries.

Standard operating procedures should be followed for evaluation and harvesting material should be unpacked immediately after reaching processing facility and should be protected from rain and moisture.

The plants that require to be processed immediately should be transported immediately to avoid thermal degradation and microbial contamination.

Use of refrigerators, sand boxes and enzymatic measures can be applied.

When materials are required in dry form, moisture levels should be checked according to pharmacopoeia.

Optimum temperature and humidity should be maintained to achieve desired active constituents and parameters such as duration of drying, drying temperature, humidity with context to part of the plant i.e. root, leaf, stem, bark, flower should be recorded.

Drying in sunlight can only be done when specified.

Different drying mechanism i.e. open air drying, drying frames, wire screened rooms, direct sunlight, drying ovens, solar dryers, indirect fire, baking, lyophilization, microwave, infrared devices can be used for drying.

In open air drying, plants should be properly spread for air circulation and drying frames placed in good height for proper circulation.

For direct drying (fire) should be limited to butane, propane or natural gas and temperatures should be kept below 60°C.

Smoke and medicinal plant contact should be avoided.

Use tarpaulin and other appropriate cloth or sheeting during drying in cemented floor.

Rodents, insects should be checked during drying.

Preservatives should be avoided, if used should comply with national norms and well documented.

A label constituting farmer name, farmer agency, plant name, plant part, its quantity, quality (if quality testing is carried out), and harvesting month must be inscribed on every package.

The storage of medicinal plants must be carried out at optimal conditions i.e. under dry conditions, maintaining proper ventilation, preventing condensation, protected from insects, rodents, and other detrimental factors affecting the quality of medicinal plants. There must be separate places for organic and non-organic medicinal plants.

When there is storage of multiple medicinal plants, care must be taken to prevent their mixing and cross contamination. Therefore distance must be maintained between different medicinal plants.

Appropriate security measures shall be applied for the products that are toxic or poisonous during storage and transportation.

The storage area must be restricted for common people and only authorized personnel should be allowed to enter the storage area. In case of visitors, one should adhere to proper protective clothing and maintain personal hygiene.

Some plants require specific processing for purity and detoxify such as peeling of skins of roots and rhizomes, boiling in water, steaming, soaking, pickling, distillation, fumigation (registered chemical agents only authorized by the regulatory bodies), roasting, natural fermentation, treatment with lime, chopping for their further utilization. Therefore, optimal conditions should be followed for processing of medicinal plants after consultations from pharmacopoeias to acquire best results.

5.3.10. Personnel

The medicinal plant cultivators should have proper knowledge regarding the medicinal plant species identification, climatic requirements, cultivation, harvest and post-harvest mechanisms.

Proper hygiene must be maintained by the medicinal plant cultivators, field workers involved in the different stages of medicinal plants production. Proper training must be given to the medicinal plant cultivators, field workers on hygiene.

An individual allergic to any plant material should not be allowed to stay in contact with that specific medicinal plant. The personnel suspected or known to have suffering any disease or wounds should not be allowed in the process of medicinal plant production.

Protective clothing such as helmets, face masks, goggles, gloves, and overcoats must be provided to the field workers or medicinal plant cultivators for the application of agrochemicals.

Proper training must be given to the medicinal plant cultivators on the need for environment protection, and medicinal plants conservation.

5.3.11. Equipment and materials

The required equipments and utensils must be designed in such a way that should prevent hygienic hazards and are easy to clean, disinfect, and easily assessable for visual inspection. Similarly, the unusable equipments shall be leaf-proof, metal-constructed or impervious material shall be used which is easily cleaned or disinfect.

All the materials used for handling of the medicinal plants must not transmit toxic substances, odor, taste, shall have smooth surface with non-adsorbent properties, and must be resistant to corrosion having the capability to undergo repeated cleaning and disinfection.

The material required for the storage of medicinal plants must comply with the quality requirements for the selected medicinal plants and must be dry, clean and undamaged.

Containers when not in use should be kept clean and in clean area.

Cutting devices, harvesters, machines, equipment's should be kept clean and stored in uncontaminated, dry place free from insects, rodents, birds and other pests.

The equipments (fertilizer and pesticide applicator) used in the agricultural process must be properly calibrated and calibration certificates and related records must be maintained.

5.3.12. Documentation

Proper documentation of different stages of medicinal plant production should be documented with the appropriate dates. Documentation related to seeds or propagation

materials, cultivation site, cultivation process, fertilization (application of fertilisers, type of fertilisers, dose, etc.), management methods, harvest, post-harvest methods must be documented.

Proper auditing shall be conducted by the expert representatives of producers, end users, and authorized regulatory bodies for quality assurance of the medicinal plants and subsequently proper documentation regarding the same shall be maintained.

5.4 Results and discussion

There are reports regarding the presence of unwanted or tacit material in the herbal formulations around the globe. The substances such as pesticides residues, heavy metals, microbes, aflatoxins, etc. have been reported to be present in the herbal medicines. Therefore, need for quality assurance of the herbal medicines have taken a center stage worldwide. The fundamental guiding principle for obtaining the quality of the herbal medicine is the implementation of GAP for medicinal plants (Saha *et al*. 2018). The comprehensive GAP guidelines mentioned above encompasses all the parameters that are mentioned in the different country-specific GAP guidelines for medicinal plants. Special emphasis has been made regarding the quality of the seeds and propagation material in the different GAP guidelines. The GAP guidelines corresponding to America and WHO have described identity, quality, product performance, breeding history of the seeds as an essential parameter. Whereas, India has described the seed/planting material should have pharmacopoeial nomenclature, trade name, botanical name, cultivar selection/phenotype/chemotype/genotype/physico-chemical analysis/marker based analysis. It also lays special emphasis on the marker based analytical confirmation of the seeds for end product used in the industry (Saha *et al*. 2018). On the other hand, GAP guidelines of Europe, highlighted phenotype, chemotype botanical name, cultivar selection for seeds but excluded genotype and physico-chemical parameters of seeds (Committee on Herbal Medicinal Products, 2006).

Similarly, parameters such as identity of planting material obtained from wild sources, obtaining seeds from recent harvest, size uniformity of propagation or root cuttings are specially highlighted in the GAP guidelines of India (National Medicinal Plant Board, 2009). The requirement of species to be resistant or tolerant to diseases is highlighted in the GAP guidelines of Europe as well as WHO and not specifically highlighted in guidelines pertaining Japan and China. The GAP of China has specially highlighted protection of animals from physical and sensory injury during transportation (Organización Mundial de la Salud, World Health Organization, 2003).

The GAP document of Japan highlights one of the unique parameter, viz. cultivation of plants where the weeds can grow as a good indicator of cultivation conditions. It also highlights avoiding of cows in the cultivation site (Organización Mundial de la Salud, World Health Organization, 2003). Similarly, America's GAP of medicinal plants highlights importance of soil sampling, identification of crops that can be grown in adjoining sites, residual pesticides, heavy metal analysis of site with unknown field history, recording information having relevance to either improving and damaging the crop or site, avoiding areas near by mine tailings, parking lots, golf courses, waterways, underground storage tanks, recent use of pesticides, herbicides, fungicides and information of rate of such pesticide breakdown (American Herbal Products Association and American Herbal Pharmacopoeia, 2006). The India's GAP of medicinal plants focusses on collecting meteorological data for the past three years, provision of artificial shading for shade loving plants, field's proximity to reliable source of water, avoiding salinity, acidity and toxicity, water logging prevention, avoiding

site areas near to crematorium, or graveyards, conducting latest soil test report on physico-chemical parameter to decide nature of soil and to do further amendments (National Medicinal Plant Board, 2009).

The WHO guidelines recommend using only the fully composited manure for medicinal plants cultivation. On the other hand, GAP of America recommends use of fertilisers treated through aerobic process and monitor undesirable microbial pathogens through periodic testing. Similarly, it recommends avoiding of lead pipe fitting during irrigation and estimation of pathogenic bacteria in water viz. E.coli, coliforms (American Herbal Products Association and American Herbal Pharmacopoeia, 2006). Estimation of total salt concentration, sodium absorption ratio, bicarbonate and boron concentration in water, replenishment of plant population, topping, hoeing, bud nipping, pruning, shading, earthing up, need for adoption of root production enhancement of leafy biomass are highlighted in the India's GAP guidelines for medicinal plants (National Medicinal Plant Board, 2009). The insertion of water soluble foliar fertilizers within 24 hours of preparation, ensuring the quality of water used for mixing fertilizer is highlighted in the GAP of America (American Herbal Products Association and American Herbal Pharmacopoeia, 2006). Providing buffer zones and planting cover crops and green manure to minimize soil erosion are mentioned in the WHO's GAP document. Use of bio-pesticides for crop protection than pesticides in smallest dosage and use of pesticides in smallest effective dosage with low toxicity and low residue pesticide content are mentioned the GAP document of India and China respectively. Optimal time of harvest, consultation of pharmacopoeias and other standards for harvest, avoiding dew, rain or exceptionally high humidity, need for using only clean cutting devices, harvesters, other machines, sorting of raw herbal produce, etc. are mentioned in the WHO GACP guidelines of the medicinal plants (Organización Mundial de la Salud, World Health Organization, 2003). In addition to following standard agronomic practices of selected medicinal plants, these comprehensive GAP guidelines on medicinal plants would ensure safe and quality-rich herbal materials for efficacious herbal formulations.

The quality of herbs and related products depends upon ecological conditions such as temperature, altitude, rainfall, and characters of soil. Therefore, it becomes important to develop monographs of medicinal plants based on ecological conditions of the specific region in conjunction with other national and international publications in order to obtain good quality herbs. With this in mind, the authors have developed monographs on GAP for selected medicinal plants after consulting the agro-practices of the farmers and corroborating the practices with the reported literature that are mentioned in chapters VI to X of this book.

5.5 Conclusion

Recently, Biological Diversity (Amendment) Bill, 2021 was tabled in the Indian parliament which encouraged the cultivation of medicinal plants and protection of natural resource base. These GAP guidelines for medicinal plants are holistic as well as robust due to inclusion of all the unique parameters mentioned in the GAP guidelines of different countries. In this direction, these guidelines would are holistic and can be considered by the respective subject experts for recommendation to the farmers. These guidelines can be adopted by different nations or regions in order to achieve quality-rich herbal materials considering the region-specific ecological conditions and following standard agronomic practices of selected medicinal plants. Apart from this, it also encourages to develop monograph on GAP of medicinal plants considering the farmers practices, agro-ecological requirements, and reported literature with due consultation of the experts.

The adoption of GAP guidelines provides a safe production system ensuring consumer a right to nutritious, efficacious, affordable herbal medicines. These comprehensive guidelines can be a baseline for the formation of country-specific GAP guidelines considering the successful farmer's practices in the future studies.

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6

Monograph on GAP for Curcuma longa L.

1. Botanical and pharmacological characteristics of Curcuma longa L.

1.1. Name of plant

1.1.1. Scientific name

Latin botanical name: Curcuma longa L.

Family: Zingiberaceae

1.1.2. Vernacular names

Source: Raw image of turmeric captured during field visit.

English: Turmeric
Hindi: Hardi
Punjabi: Haldi
Malyalam: Manjal
Tamil: Manjal
Telugu: Pasupu
Kannada: Arishina
Kashmiri: Ledar

1.2. Medicinal plant part of interest

1.2.1. Plant part used in traditional medicine Rhizomes

1.2.2. Part to be used as raw material for the extraction of curcumin

Dried rhizomes

1.3. Geographical distribution and the major areas of cultivation

1.3.1. Geographical distribution

The plant is found in diverse tropical regions from sea level to 1500 m above sea level. It is speculated to be originated in South-East Asia, while the epicentre of its domestication is certainly Indian subcontinent. The use of turmeric as culinary spice and can be traced back to approximately 4000 years to the Indian Vedic culture. It is likely to have reached China by 700 AD, East Africa by 800 AD, and West Africa by 1200AD. At present, India is a leading producer and exporter of C.longa (Curcuma longa L. will be represented as C.longa in this monograph) in the world1.

1.3.2. Major areas of cultivation

C.longa is cultivated in the tropics and found almost every part of India. Andhra Pradesh is the leading state in India to produce C.longa. It is also widely cultivated in Orissa, Tamil Nadu,

Table 6.1: Morphological characteristics of C.longa

API (The Ayurvedic Pharmacopoeia of India, 1989)	Other reported standard literature (Tandon and Sharma 2010; Indian Herbal Pharmacopoeia, 1998)
Rhizomes half as broad as long. Short branched, root scars and annulations of leaf bases, fractured horny, fractured surface, and central cylinder twice as broad as cortex.	Primary rhizomes are condensed swollen. Longitudinally wrinkled and marked with circular rows. 3 to 5 large depressions scars. Rhizomes are hard, heavy with short fracture. Secondary rhizomes are longitudinally wrinkled exhibiting encircling leaf scars. Rhizomes are hard, heavy with short fracture.

Source: Reference already provided

Table 6.2: Organoleptic characters of *C.longa*

Characters	API (The Ayurvedic Pharmacopoeia of India, 1989)	Other reported standard literature (Tandon and Sharma 2010; Indian Herbal Pharmacopoeia, 1998)
Shape	Oblong, ovate, pyriform, cylindrical, generally short branched	Primary rhizomes: Ovate-oblong, conical, pear shaped. Secondary rhizomes: They are cylindrical curved, tapering bluntly at both ends, occasionally branched.
Size	2-5 cm long and 1-1.8 cm thick	Primary rhizome: 3 to 7 cm long, 2 to 3 cm wide Secondary rhizome: 4 to 10 cm in length 1 to 1.5 cm in diameter
Color	Externally yellow to yellowish brown. Cracked surface orange to reddish brown.	Yellowish orange, internally uniformly dull yellowish.
Odor	Characteristic	Aromatic and somewhat pungent
Taste	Characteristic	Bitter

Source: Reference already provided

West Bengal, Karnataka, Maharastra, Assam, Meghlaya, Gujrat (Jayashree et al. 2015).

1.4. Morphological characteristics rhizomes

The API and other standard literature mentioning the morphological characteristics of C.longa are mentioned in the table 6.1.

1.5. General description of characteristics of plant material

1.5.1. Organoleptic characters

The organoleptic characteristics of C.longa highlighted in the API and other standard literature is mentioned in the table 6.2.

1.5.2. Microscopic characteristics

The microscopic characteristics of *C. longa* highlighted in the API and other standard literature is mentioned in the table 6.3.

Table 6.3: Important microscopic characters of *C.longa*

Type of microscopy	**API** (The Ayurvedic Pharmacopoeia of India, 1989)	**Other reported standard literature** (Tandon and Sharma 2010; Indian Herbal Pharmacopoeia, 1998)
Transverse section	Epidermis is thick-walled, different dimensions of cubical cells. Cortex has presence of slim walled rounded parenchyma cells, collateral vascular bundles. Has disperse oleo-resin cells with brownish content, thin walled cork cells having 4-6 layers, ground tissue cells containing starch grains of 4-5µ in diameter, oil cells containing orange-yellow globules of volatile oils or resinous matter. Presence of spirally thickened vessels.	Presence of cork, cortex, cortical vascular bundle, endodermis, oleoresin cells, stellar vascular bundle. Inner region with endodermis consists all the above mentioned characters including pericycle, phloem, starch grains, stellar vascular bundle, xylem.
Powder	--	Presence of cortical parenchyma cells with starch grains and oleoresin cells, cork in surface view, group of spiral and annular vessels, fragment of reticulate vessel, starch grains.

Source: Reference already provided

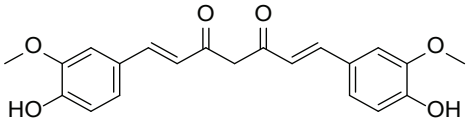
1.6. Chemical composition

1.6.1. The major chemical constituents of C. longa

The major chemical constituents present in the rhizomes of *C.longa* are volatile oil, consisting of turmerone, and colouring agents known as curcuminoids. In standard form, curcumin is varied between 5-6.6 per cent, moisture more than 9 per cent, volatile oils less than 3.5 per cent. The volatile oil contains cinol, zingiberene, d-α-phellandrene, borneol, d-sabinene, and sesquiterpenes (The Ayurvedic Pharmacopoeia of India, 1989).

1.6.2. Physical and chemical properties of curcumin

Chemical structure:



Molecular formula: $C_{21}H_{20}O_6$

Chemical name: (1*E*,6*E*)-1,7-bis(4-hydroxy-3-methoxyphenyl)hepta-1,6-diene-3,5-dione

Molecular weight: 368.4g/mol

Description: Orange-yellow needles.

Solubility: Insoluble in water, ether, and soluble in alcohol, acetic acid, and glacial acetic acid.

Melting point: 183.0°C or 361°F
Detailed quality specifications of curcumin, refer compound summary of curcumin[1].

1.7. Pharmacological activity

C.longa has a long history of medicinal as well as cosmetic use in India and China.

1.7.1. Pharmacological activity of C.longa

In Ayurveda, *C.longa* is known to strengthen the body energy, dispelling worms, regulation of menstruation, expelling gall stones, and relieving gas and arthritis. It is also known to purify blood, and has anti-inflammatory, anti-microbial properties (Prasad and Aggarwal, 2011; Labban, 2014).

1.7.2. Pharmacological activity of curcumin

Curcumin is reported to suppress the formation of edema, decrease the proliferation of cells in a mouse induced with prostate cancer cells, it also exhibit choretic effects. Curcumin also possess anti-inflammatory effects by blocking the cyclooxygenase (COX) enzymes (Beevers and Huang, 2011).

2 Good agricultural practices

2.1 Growth and development characteristics

2.1.1. General description

C.longa is harvested in seven-nine months depending upon the variety and time of sowing if managed properly. The sprouting of rhizomes is difficult below 10°C and above 40°C. Mostly, the optimum range of temperature is responsible for the regulation of seeds and propagules of *C.longa* plants for good germination (Jayashree *et al.* 2015);

2.2. Preferred growing conditions

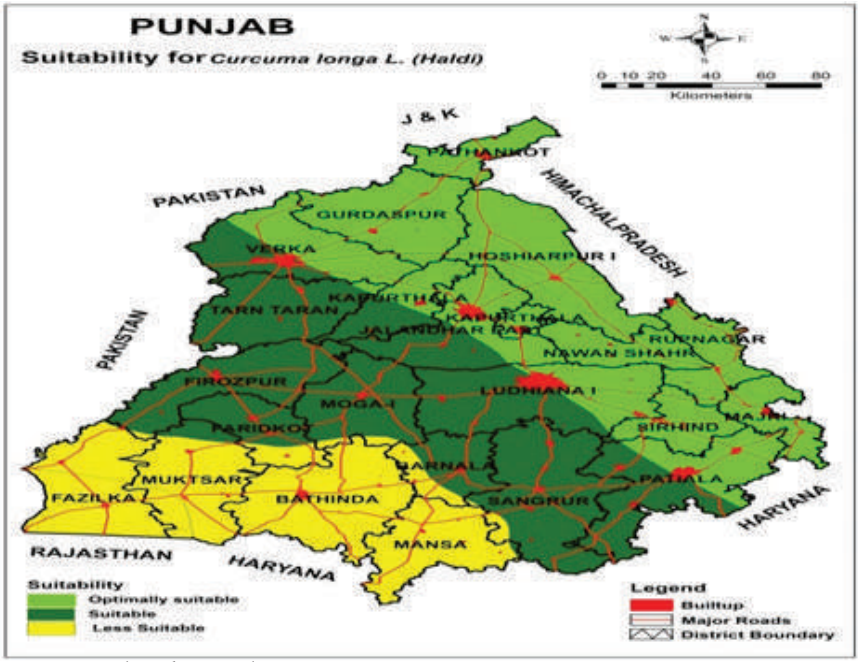
2.2.1. Ecological conditions

The plant can be found at altitudes ranging from sea level to 1500 m above sea level. The optimum annual temperature required for the plant ranges from 20-35°C (Sandeep *et al.* 2016; Sharma and Sharma, 2012; Ishimine *et al.* 2004).

2.2.2. Climatic conditions

It can be grown in diverse tropical conditions. However, annual temperature below

Fig. 6.1: Agro-ecological suitability of turmeric in Punjab



Source: Authors' compilation

10°C and above 40°C is not suitable for its cultivation. It requires an annual rainfall ranging from 800 to more than 1500 mm (Ishimine *et al*. 2004; Jayashree *et al*. 2015).

2.2.3. Soil conditions

It grows best in well-drained sandy and clay loam soils. It can be preferably grown at a range of pH 4.5-7.5 with good organic status (Jayashree *et al*. 2015; Sandeep *et al*. 2016).

2.2.4. Nutrient conditions

Crop requires specific amount of N,P,K doses depending upon the varying soil test values. It is reported that 60 kg Nitrogen, 120 kg K_2O and 50 kg P_2O_5 per hectare is the recommended nutrient dosage in Kerala (Jayashree *et al*. 2015).

2.2.5. Water conditions

Crop requires 12-13 irrigations in Punjab; it can even extend up to 30 irrigations depending upon the region. There should be optimum drainage for the water to prevent excessive water-logging. Water used for irrigation should match national quality standards.

2.2.6. Agro-ecological suitability in Punjab

Considering the above-mentioned agro-ecological parameters, the growing areas of *C.longa* in Punjab is mentioned in the fig. 6.1.

C.longa is optimally suited for agro-climatic zone-I & II corresponding to Western plain and Northern Plain, Dry subhumid regions of Punjab. The zones cover Pathankot, Hoshiarpur, Gurdaspur, Kapurthala, Roopnagar, Sirhind districts of Punjab.

2.3. Seeds

2.3.1. Seeds and cultivar

Generally the cultivator is known by the name of the locality where it is cultivated. Some important cultivators are Allepey, Duggirala, Tekkurpet, Sugandham, Erode local, Amalapuram, Moovattupuzha, Lakdong and Salem. There are certain improved varieties also released by the ICAR-Indian Institute of Spices Research, Kerala, India (Jayashree *et al.* 2015).

2.3.2. Morphology of the seeds of *C.longa*

The seeds should be healthy from the recent harvest. The size of the seed should

Fig. 6.2: Size of turmeric seed during sowing

Source: Raw image of turmeric captured during field visit.

be at least 2-5 cm long and 1-1.8 cm thick. Seeds should be oblong, ovate, pyriform.

2.3.3. Propagation

C.longa can be grown by direct sowing as well as by transplanting. However, transplanting in *C.longa* is not conventional. Therefore, direct sowing is preferred by the farmers. Recently harvested healthy and disease free whole or split mother, and fingers of rhizomes are used for the planting of the turmeric. It is also reported that seed rhizomes should be treated with mancozeb 0.3 per cent for half an hour and dried in shade for 3-4 hours and planted (Jayashree *et al.* 2015). The germination of seeds is observed in 30-45 days after sowing the seed.

2.4. Cultivation method

2.4.1. Selection and preparation of cultivation site

Site should be selected after consulting meteorological and edaphic data. For detailed criteria for selecting suitable site and parameters, refer to the general GAP guidelines mentioned in chapter V of this book. Depending upon the type of soil 3-4 ploughing should be done followed by til thing and leveling. Soil should be brought to desired tilth for growing seed and seedling. Initial flush of weeds should be avoided to ensure weed free young plant. Divide the field according to the field pattern or slope for drainage of water. Generally ridge and furrow method is used for the sowing of *C.longa* seeds. However, few farmers preferred sowing of seeds on beds. Each bed was made 100 cm wide, 30 cm in height with spacing of 50 cm between the two beds. Automatic potato planter consisting of a hopper for each row and cups with chain drive mechanism was used for sowing by some farmers. The graded seeds were picked up by the cups and carried to opener spout and released. If a cup is found empty, seed is released from compensating tray ensuring uniform seed spacing with no missing as mentioned in Fig. 6.3.

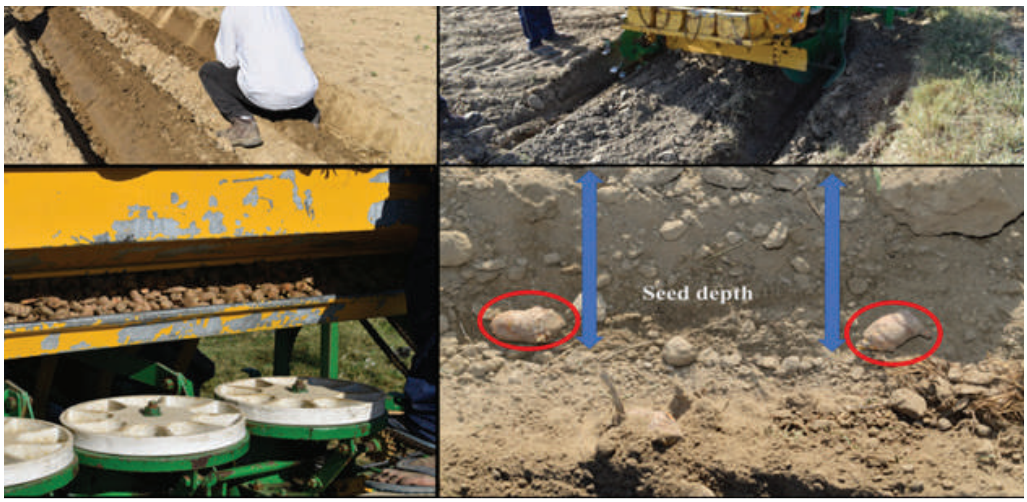
2.4.2. Sowing

Rate of seedlings per acre: 6-7 quintals seeds. Plant to plant distance: 20-25 cm Row to row distance: 30-40 cm Sowing depth: 2.5-3 cm

2.4.3. Fertilization

Compost or farm yard manure approximately 20 tonne/acre is applied during the soil

Fig. 6.3: Cultivation process of Turmeric in Punjab.



Source: Authors' compilation.

preparation by the farmers of Punjab. Based on the pH, hydrated lime 500-1000 kg/ha can also be applied for laterite soils. Farmers also used 50-60 kg Urea, 50 kg DAP and 20 kg muriate of Potash in one acre of land to fulfill required N.P.K level depending upon the type of soil. India has different soil type and agro-ecological conditions throughout, so crop maintenance can be done according to the needs of the soils. Depending upon the soil test reports, there should be supplying of N, P and K as per the requirements which depends upon agro-ecological conditions. The fertilizers must be applied in 2-3 split dosages. In poor zinc soils, zinc fertilizer (25 kg of zinc sulphate/ha) can be applied to get good yield (Jayashree et al. 2015).

2.4.4. Field management Mulching

The crop can mulched with green leaves or with straw of the paddy 40 q/acre just after planting to avoid weeds and reduce evaporation as represented in the fig. 6.7. Mulching can be repeated using lesser proportion of straw after 40 and 90 days after planting as represented in fig. 6.4.

Irrigation: 12-14 irrigations in case of clayey soil and up to 30 irrigations in case of sandy loam soils are required. Irrigations should be frequent in the initial stages of sowing.

Weeding and intercultural operations: Field should be devoid of weeds during the entire period of growth. Weeding: Can be done 2-3 times after planting the seed with gap of 60, 90 and 120 days. Regular inspections should be made so that diseased or dead plants are removed regularly.

Intercropping: During conduct of study in Punjab, it was found that few farmers were involved in intercropping of turmeric with Populus deltoids (poplar tree) due to its shade tolerance as represented in fig. 6.5. However, intercropping with chillies, colocasia, onion, brinjal and cereals like maize, ragi etc. are also reported in literature.

2.5. Pest and disease management

Plant is generally less prone to disease attack.

Fig. 6.4: Farmer of Punjab mulching turmeric using paddy straw

Source: Authors' compilation.

Some pest related disease affecting the leaves of the turmeric post monsoon was observed in Punjab during our study. The infested leaves were rolled up, turned pale yellow and eventually dried. The infested pest can be seen in the fig. 6.6, as mentioned below: However, some of the diseases and their symptoms reported in the literature are as mentioned in the table 6.4. and fig. 6.7. (Jayashree *et al.* 2015).

2.6. Organic production of Turmeric

Crop should be at least 18 months of organic production to claim organic turmeric. If history of the field being organically raised or free of chemicals, the conversion plan could be relaxed. Whole field should be organically raised either as a single crop or a mixed crop. A buffer zone should be created to differentiate organic and non-organic neighboring land and this isolation zone cannot be claimed as organic

Fig. 6.5: Intercropping of *C.longa* with poplar trees by a farmer of Punjab

Source: Authors' compilation.

Table 6.4: Diseases of C.longa

Disease	Causing species	Characterization	Prevention
Leaf blotch	*Taphrina maculans*	Irregular brown spots on either side of the leaves	Spray Mancozeb 0.2%
Leaf spot	*Colletotrichum capsici*	Brown spots of different sizes on the upper surface of the young leaves	Carbendazm (0.5kg/ha) or copper oxychloride (0.2%)
Rhizome rot	*Pythium aphanidermatum*	Lower leaves of the infected pseudo stem show yellowing, becomes soft eventually collapse of plant and decaying of rhizomes	0.3% mancozeb 30 mins before storage and at the time of sowing.

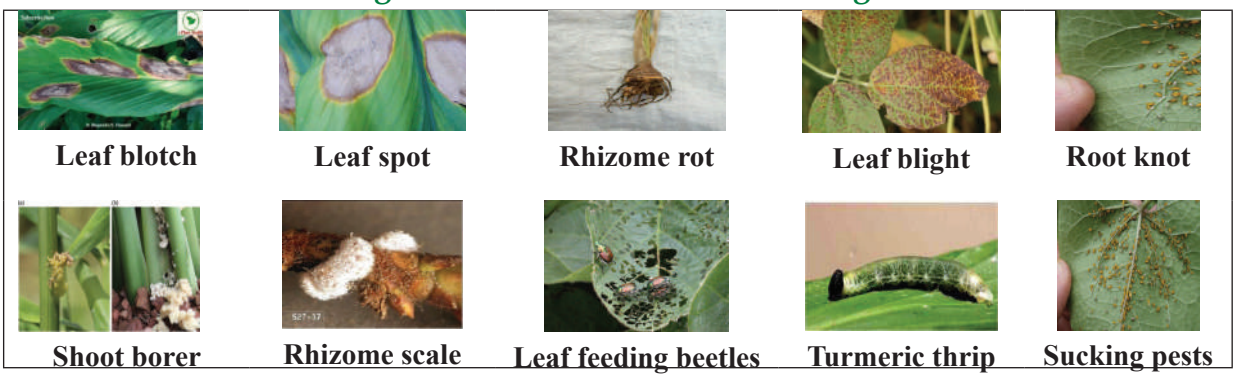
Table 6.4 Continue...

Table 6.4 Continue...

Leaf blight	*Rhizoctonia solani*	Necrotic patches with papery white center spreading on whole surface with blighted appearance	0.2% Bavistin or mixture of Bordeaux 1%.
Nematode pests Root knot	*Meloidogyne spp.* *Radopholus similis* *Pratylenchus spp.*	Damage to turmeric	*Pochonia chlamydosporia* applied to the beds at the time of sowing (20g/bed)
Insect pests Shoot borer	*Conogethes punctiferalis*	Presence of bore-hole on the pseudo stem. The adult is medium sized moth with a wingspan of 20 mm, the wings are orange-yellow with minute black spots	Malathion (0.1%) Lamda-cyhalothrin (0.0125%) at 21 days interval during July to October
Rhizome scale	*Aspidiella hartii*	Adult females are circular with light brown to grey (1mm diameter) appearing on encrustations on the rhizomes. They feed on sap of the rhizomes making the rhizome shriveled.	Timely harvest of rhizomes. Discard severely infested rhizomes before storage. Treat seed with quinalphos (0.075% for 20-30 mins)
Minor pests Leaf feeding beetles	*Lema spp.*	Feed on leaves during monsoon and makes feeding marks on the leaves	Malathion (0.1%)
Lacewig bug	*Stephanitis typicus*	Infests foliage making them turn pale and dry up. It is most common post monsoon period in drier regions	Dimethoate (0.05%)
Sucking pests	--	Infests the leaves affecting their structure	Neem leaves boiled in water for treatment (azadirachtin 2ml/litre of water)
Turmeric thrips	*Panchaetothrips indicus*	Affects leaves causing them to roll and turn pale yellow and dry up. It is also most common post monsoon period in drier regions	Dimethoate (0.05%)

Source: Turmeric extension pamphlet. ICAR- Indian Institute of Spices Research, Kozhikode, India

Fig. 6.6: Common diseases of C.longa



Source: TNAU agritech portal. Accessed on 20-Dec.-2020

(Organización Mundial de la Salud and World Health Organization, 2003). In case of organic production of the crop, the traditional varieties of that particular area should be adapted as they have higher chances of being resistant to diseases, pests and nematodes. All the crop residues, cow dung slurry, grasses, green loppings, etc. available should be recycled through composting. No synthetic chemical fertilizers, pesticides, fungicides should be used under organic system. However, when deficient conditions of essential elements become yield limiting, restricted use of mineral/chemical sources micronutrients are allowed as in limits as prescribed the certifying agency. Oil neem cakes, phosphate solubilizing bacteria and microbial cultures of *Azospirillium* will improve the fertility and yield. Use of biocontrol agents, botanicals, spraying neemgold 0.5 per cent or neem oil 0.5 per cent in July-October is effective against shoot borer (Jayashree *et al.* 2015).

2.7. Harvest and postharvest processing

2.7.1. The best harvesting time, and quality evaluation prior to harvest

Harvesting can be done in 7-9 months after planting the seed. On maturity the leaves of the plant becomes dry and light brown. Harvesting is preferred in dry conditions from January to March. In Punjab, harvesting generally starts from second week of February to March. The harvesting is done either manually or by using a tractor. In manual harvesting the land is ploughed, the rhizomes are lifted with spade and collected by hand picking. In harvesting using tractor, turmeric harvester is used to take raised beds. The rhizomes are collected manually and collected at a place and extraneous matter adhering the crop is removed. The seeds to be utilized in next cultivation should be preserved and stored by heaping in well ventilated rooms. To avoid fungi and scale infestations 0.3 per cent of mancozeb and 0.075 per cent quinalphos are used respectively.

2.7.2. Post-harvest processing method

Turmeric has to be passed through multiple post harvesting processes such as washing, boiling, drying, polishing, grading and storage to enter market.

Boiling: Boiling of turmeric is done before it is dried. Boiling is essential in removal of raw odour of turmeric, reduces drying time and demolish vitality of the fresh rhizomes. Traditional methods of boiling were putting the raw turmeric in a vessel made of galvanized iron sheet and boiling it with water (40-60 minutes for fingers and 90 minutes for mother rhizomes) until froth is formed and white fumes are formed with a characteristic odour. The turmeric was considered to be fully boiled when rhizomes pressed between the finger and thumb is easily broken down and its interior becomes yellow instead of red. It was observed during

our study that turmeric growers in Punjab used different boiling vessels for boiling the raw produce as mentioned in the Fig.6.7. below:

The improved turmeric boiler has trough, inner perforated four drums and lid. The inner drum is provided with hooks for lifting and inspection door. The capacity of the drum is 100 kg and about 55-70 kg of washed rhizome is taken in each drum for boiling. Turmeric boiler has a furnace to produce steam and boil the batches. It takes around 25 minutes to boil the initial batch and about 10-15 minutes for the subsequent batches. The furnace has two opening, one for feeding the fuel and other one for removing the ash. The fuel requirement is 7-75 kg of agricultural waste or leaves of turmeric.

Drying: The cooked finger and balls are dried up seprately under the sunlight. Thick layer of turmeric (5-7 cm) is spread from drying as thin layer adversely affects the colour of the rhizome. During night time the layer should be heaped and covered.It takes around 10-15 days for complete drying of rhizomes. Mould growth should also be taken care of.

Drying can also be done using solar tunnel driers covered by stabilised semi-transparent polyfilm sheet of 200 microns thickness. ***Polishing and Coloring:*** Polishing is done to smoothen the rough surface of the dried turmeric comprising of roots bits. The smoothening is done either manually or mechnically. Manually it is achieved by rubbing the surface of the turmeric with hard surface. Now a days, automatic polishing is achieved in which the dried turmeric rhizomes are put into rotating drum mounted on central axis leading to abrasion of the surface against each other as they roll inside

Fig 6.7: Different boiling assembles used by the framers in Punjab

Source: Authors' compilation.

Fig 6.8: Drying of Turmeric

Source: Authors' compilation.

the drum. Polishing is done till recommended 7-8 per cent is achieved. Usually 5-8 per cent of the weight of the turmeric is the polishing waste. Sometimes undiserable coloring agent is added to the turmeric for polishing, which is not recommended. It takes around one hour per batch for polishing turmeric. During the last phase of the turmeric polishing, turmeric powder is sprinkled over the rotating rhizomes for attractive appearance of turmeric. Cleaned and graded turmeric is packed in gunny bags and stored in cool, dry places protected from light and kept free from extraneous material. Turmeric being a natural product is prone to be affected with contaminants during different stages of processing. As, it is not recommended to apply pesticides on dried produce, so proper inspection should be made and material should be sorted and kept free from pests and other contaminants.

3. Good collection practices

For guidelines required for the collection of medicinal plants, refer to the WHO good

Fig. 6.9: Polishing of Turmeric.

Source: Authors' compilation.

Table 6.5: Physico-chemical parameters of *C.longa*

Physico-chemical parameters	**API** (The Ayurvedic Pharmacopoeia of India, 1989)	**Other reported literature** (Tandon and Sharma, 2010)
Foreign matter	n.m.t. 2 %	n.m.t. 1% by weight
Total ash	n.m.t. 9 %	n.m.t. 9-12 %
Acid insoluble ash	n.m.t. 1 %	n.m.t. 1.5-1.8 %
Alcohol soluble extractive	n.l.t. 8 %	n.l.t. 10 %
Water soluble extractive	n.l.t. 12 %	n.l.t. 11 %
Volatile oil	n.l.t. 4 %	--
Moisture	--	n.m.t. 12 % by weight
Total starch	--	n.m.t. 60% by weight

Source: Reference already provided

n.m.t: not more than; n.l.t: not less than

Table 6.6: Qualitative and quantitative ranges of curcumin in *C.longa*

Major active constituent	**API**	**Other reported literature** (Tandon and Sharma, 2010)	**General method of experimentation**
Curcumin	--	Rf at 0.54 (Reddish brown color). Percentage of curcumin range from 2.85 to 6.5 %	Solvent for extraction using Soxhlet apparatus: Ethanol Solvent system: Toluene: Ethyl acetate: Formic acid (5:1.5:0.5) Visualization: Under UV light at 254 nm For detailed method, refer "*Quality standards of Indian medicinal plants*" [4]

Source: Reference already provided

Table 6.7: Toxicity indicators of C.longa

Toxicity indicators	Ranges (Plotto, 2004; FAO and WHO, 2019; Sharangi and Pandit, 2018, World Health Organization, 1998, 2011)
Aflatoxin	Aflatoxin B1: 5 ppb Aflatoxin Total: 10 ppb
Pesticide residues	Iprobenfos: < 0.01 ppm Profenofos: < 0.05 ppm Triazophos: < 0.01 ppm Ethion: < 0.30 ppm Phorate: < 0.10 ppm Parathoin: < 0.60 ppm Chlorpyrifos: < 1.00 ppm Methyl parathion:< 3.00 ppm
Metal contamination	Lead: n.m.t. 10.0 ppm by weight Copper: n.m.t. 5 ppm by weight Arsenic: n.m.t. 0.1 ppm by weight Zinc: n.m.t. 25 ppm by weight Tin: Nil Cadmium: n.m.t. 0.1 ppm by weight Lead chromate: Nil

Source: Reference already provided

N.m.t: not more than; n.l.t: not less than; ppm: parts per million; ppb: parts per billion

agricultural and collection practices guidelines, 2003[2] and guidelines on good field collection practices for Indian medicinal plants, 2009.[3]

4. Quality control requirements for herbal materials of *C.longa*

4.1. Basic quality requirements for herbal materials

4.1.1. Selection of species or botanical variety

In general, national pharmacopoeias and concerned authoritative institutes should be consulted before selection of varieties. ICAR-Indian Institute of Spices Research has highlighted various varieties and improved varieties of C.longa. The detailed requirements for selection of species or botanical variety are mentioned in the general GAP guidelines described in chapter V of this report.

4.1.2. National quality specification and requirements for herbal materials

National quality specifications on *C.longa* must be consulted in order to achieve optimum quality of the crop. Apart from this monograph, the monographs on *C.longa* are mentioned in the Ayurveda Pharmacopoeia of India (API), and Indian Council of Medical Research (ICMR) for standard quality specifications (Tandon and Sharma, 2010; The Ayurvedic Pharmacopoeia of India, 1989).

4.2. Basic quality specification for herbal materials of C.longa

Table 6.8: Standard requirements of C.longa

ASTA cleanliness specification of turmeric (Plotto, 2004)	• Whole insect, dead: 3 by count • Excreta, Mammalian: 11.1 mg/kg • Excreta, Other: 11.1 mg/kg • Mold: 3% by weight • Insect Defiled/Infested: 2.5% by weight • Extraneous Foreign Matter: 0.5% by weight
ESA (European Spice Association) quality minima for turmeric (Plotto, 2004)	**Whole turmeric** • Total ash(% w/w) max: 8 • Acid insoluble ash (% w/w) max: 2 • Moisture (% w/w) max: 12 • Volatile oil (v/w): 2.5 **Ground turmeric** • Total ash (% w/w) max: 9 • Acid insoluble ash (% w/w) max: 10 • Moisture (% w/w) max: 10 • Volatile oil (v/w): 1.5
Agmark standards for turmeric powder (Plotto, 2004)	**Powder (passed 300 micron sieve)** • Moisture (% w/w) max:10 • Total ash (% w/w) max: 7 • Acid insoluble ash (% w/w) max: 1.5 • Lead max (ppm): 2.5 • Starch max (% w/w): 60 • Chromate test: Negative **Coarse ground powder (passed 500 micron sieve)** • Moisture (% w/w) max: 10 • Total ash (% w/w) max: 9 • Acid insoluble ash (% w/w) max: 1.5 • Lead max (ppm): 2.5 • Starch max (% w/w): 60 • Chromate test: Negative

Source: Reference already provided

%w/w: per cent weight by weight; %w/v: per cent weight by volume; ppm: parts per million

4.2.1. Physico-chemical parameters

The physico-chemical parameters mentioned in the API and other standard literature are mentioned in the Table 6.5.

4.2.2. Qualitative and quantitative estimation of C.longa

The qualitative (R_f) and quantitative ranges of curcumin mentioned in the API and other standard literature are mentioned in the Table 6.6.

4.2.3. Ranges of toxicity indicators in C.longa

The toxicity indicators mentioned in various standard literatures are mentioned in the Table 6.7.

Table 6.9: Agmark specifications of different grades of Turmeric (Plotto, 2004)

Parameters	Limits of Alleppey fingers (Good grade)	Limits of Alleppey fingers (Fair grade)	Fingers other than Allepey (Special grade)	Fingers other than Allepey (Good grade)	Fingers other than Allepey (Fair grade	Rajapore fingers (Special grade)	Rajapore fingers (Good grade)	Rajapore fingers (Fair grade)	Bulbs (Special grade)	Bulbs (Good grade)	Bulbs (Fair grade)
~Flexibility:	Hard to touch	Hard	Hard to touch, metallic twang on break	Hard to touch, metallic twang on break	Hard	Hard to touch, metallic twang on break	Hard to touch, metallic twang on break	Hard	-	-	-
~Broken pieces, fingers<15 mm (not more than % by weight):	5	7	2	3	5	3	5	7	-	-	-
~Foreign matter (not more than % by weight)	1	1.5	1	1.5	2	1	1.5	2	1	1.5	2
~Defectives (not more than % by weight)	3	5	0.5	1	1.5	3	5	7	1	3	5
~Percentage of bulbs by weight, max.	4	5	2	3	5	2	3	5	-	-	-
~Flexibility:	Hard to touch	Hard	Hard to touch, metallic twang on break	Hard to touch, metallic twang on break	Hard	Hard to touch, metallic twang on break	Hard to touch, metallic twang on break	Hard	-	-	-

Source: Plotto, 2004

4.2.4. C.longa standards mentioned in the ASTA, ESA and Agmark

The standard requirements of C.longa as per ASTA, ESA and Agmark are mentioned in the Table 6.8-9.

4.3. Methods for quality analysis

- Refer, *Quality control methods for medicinal plant materials*[2]
- Refer, Appendix(s) *The Ayurvedic Pharmacopoeia of India*[3]
- Refer, Appendix-I, *Quality standards of Indian medicinal plants*[4]

Endnotes

1 Compound summary of curcumin with Pubchem CID: 969516 in Pubchem database, https://pubchem.ncbi.nlm.nih.gov/compound/Curcumin.

2 Organización Mundial de la Salud, World Health Organization. 2003. WHO Guidelines on Good Agricultural and Collection Practices (GACP) for Medicinal Plants, World Health Organization, Geneva, Switzerland, pp.1-67.

3 Guidelines on good field collection practices for Indian medicinal plants. 2009. National Medicinal Plants Board, Department of AYUSH, Ministry of Health and Family Welfare, Government of India in collaboration with WHO Country office for India, New Delhi. pp. 1-34.

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7

Monograph on GAP for Aloe vera (Linn.) Burm.f.

1. Botanical and pharmacological characteristics of *Aloe vera* (Linn Burm.f.

1.1. Name of plant

1.1.1. Scientific name

Latin botanical name: *Aloe vera* (Linn.) Burm.f.
Family: Xanthorrhoeaceae

1.1.2. Vernacular names

English: Indian aloe
Hindi: Kunvar pathu
Punjabi: Kamaar
Tamil: Thazahai
Malayalam: Chenninayakam
Kannada: Lolesara
Kashmiri: Musabbar

Source: Raw image of Aloe vera captured during field visit.

1.2. Medicinal plant part of interest

1.2.1. Plant part used in traditional medicine

Leaves

1.2.2. Part to be used as raw material for the extraction of aloe-emodin

Leaves

1.3. Geographical distribution and the major areas of cultivation

1.3.1.Geographical distribution

A.vera (*Aloe vera* (Linn.) Burm.f. will be represented as *A.vera* in this monograph) originated in Africa due to dry climate. It also grows in dry regions of Asia, Europe, America and it can withstand constant drought except in temperate region.[1]

2.3.2. Major areas of cultivation

In India it is widely cultivated in Rajasthan, Andhra Pradesh, Gujrat, Maharastra and Tamil Naidu.[2]

1.4. Morphological characteristics of A.vera

The API and other standard literature mentioning the morphological characteristics of *A.vera* are described in the table 7.1.

1.5. General description of characteristics of plant material

Table 7.1: Morphological characteristics of *A.vera*

Macroscopic	**API** (The Ayurvedic Pharmacopoeia of India, 1989)	**Other reported standard literature** (Tandon, 2011; Indian Herbal Pharmacopoeia, 1998)
Dried Juice	Surface dull, opaque with slightly vitreous appearance	Brittle and solid
Fresh leaves	--	Flat or slightly concave on the upper surface and tapering towards the apex where a strong spine is located and smaller ones at the margins.

Source: Reference already provided

1.5.1 Organoleptic characteristics

The organoleptic characteristics of *A.vera* highlighted in the API and other standard literature is mentioned in the Table 7.2.

1.5.2. Microscopic characteristics

The microscopic characteristics of *A.vera* highlighted in the API and other standard literature is mentioned in the table 7.3.

1.6. Chemical composition

1.6.1. The major chemical constituents of A.vera

The major chemical constituents investigated in the plant are emodin, aloe-emodin, aloin, emodin, aloesin.[3]

1.6.2. Physical and chemical properties of emodin

Table 7.2: Organoleptic characters of *A.vera*

Characters	**API** (The Ayurvedic Pharmacopoeia of India, 1989)	**Other reported standard literature** (Tandon, 2011; Indian Herbal Pharmacopoeia, 1998)
Shape	Dried juice: Compact irregular masses	Dried juice: Opaque pieces of varying shapes. Fresh leaf: Simple, sessile, succulent, subulent, flat or slightly concave on the upper surface and strongly rounded on the lower, broad at base.
Size	Dried juice: Irregular	Dried juice: Opaque pieces of varying sizes. Fresh leaf: 20-30 cm in length, 5 to 10 cm in width.
Color	Dried juice: Dark chocolate brown to black	Dried juice: Dark brown to blackish color. Fresh leaf: Dark green occasional white blotches at places, white base. When broken colorless mucilaginous mass, when exposed becomes yellowish.
Odor	Dried juice: Characteristic	Dried juice: Unpleasant
Taste	Dried juice: Nauseous and bitter	Dried juice: Nauseating and extremely bitter. Fresh leaf: Bitter fluid.

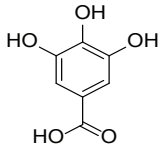
Source: Reference already provided

Table 7.3: Important microscopic characters of *A.vera*

Type of microscopy	API (The Ayurvedic Pharmacopoeia of India, 1989)	Other reported standard literature (Tandon, 2011; Indian Herbal Pharmacopoeia, 1998)
Transverse section	--	TS of leaf is boat shaped showing outermost chlorenchymatous region. Important descriptors in the TS of leaves should include acicular crystal of calcium oxalate, cuticle, epidermis, juice cells, mesophyll, mucilage, pericycle, phloem, stomata, spine, vascular bundle and xylem.
Powder	Shows innumerable crystalline, yellowish brown to chocolate, colored particles of varying size.	--

Source: Reference already provided

Chemical structure:



Molecular formula: $C_{15}H_{10}O_5$

Chemical name: 1,3,8-trihydroxy-6-methylanthracene-9,10-dione

Molecular weight: 270.24 g/mol

Description: Orange powder or needles

Solubility: It is soluble in alcohol, insoluble in water

Melting point: 257.0 °C

Detailed quality specifications of emodin, see compound summary of emodin.[4]

1.7. Pharmacological activity

Traditionally, it is used to treat wounds, burns, and inflammation.

1.7.1. Pharmacological activity of A.vera

The recent studies highlights that the plant possesses anti-cancer, anti-diabetic, anti-microbial properties. Apart from this, it provides protection against skin problems, digestive diseases, bone related and cardiac problems. It acts as laxatic, aphrodisiac, stomachic, astringent, antidotal, cathartic, anthelmintic and hepatic stimulant. Its gel is used in various skin ailments, gonorrhea, piles, jaundice, menstrual suppressions and treatment of burns and bruises.

1.7.2. Pharmacological activity of emodin

Emodin possesses anti-viral, anti-allergic, anti-diabetic, anti-bacterial, anti-osteoporotic, neuroprotective, immunosuppressive, anti-cancer, and hepato-protective properties. It aslo possess good laxative property (Dong *et al.* 2016).

2. Good agricultural practices

2.1. Growth and development characteristics

2.1.1. General description

Therefore, it can be grown in almost all part of India. Its water requirement is low therefore; it can be cultivated in arid to semi-arid areas.

2.2. Preferred growing conditions

2.2.1. Ecological conditions

Some studies suggest that A.vera can tolerate -3°C minimum and 40°C maximum temperature. It can tolerate excessive draught conditions, except in temperate climate (Jat *et al.* 2015; Bahmani *et al.* 2016).

2.2.2. Climatic conditions

The climatic conditions of India, suits the plant. For the ideal growth, annual temperature range of 20-40°C and 350-400 mm annual rainfall is required (Cousins and Witkowski, 2012).

2.2.3. Soil conditions

Growth is faster under medium fertile soils such as cotton soils. It can also be grown in marginal to sub-marginal soils having low fertility. Loam to coarse sandy loam soil is preferred. It can be preferably grown up to pH 8.5 with high sodium and potassium salts (Jat *et al.* 2015)

2.2.4. Nutrient conditions

Crop requires specific amount of N,P,K doses depending upon the varying soil test values. Use of farm yard manure, vermi compost, green manure and poultry manure shall be used to fulfill the requirements of nutrients.

2.2.5. Water conditions

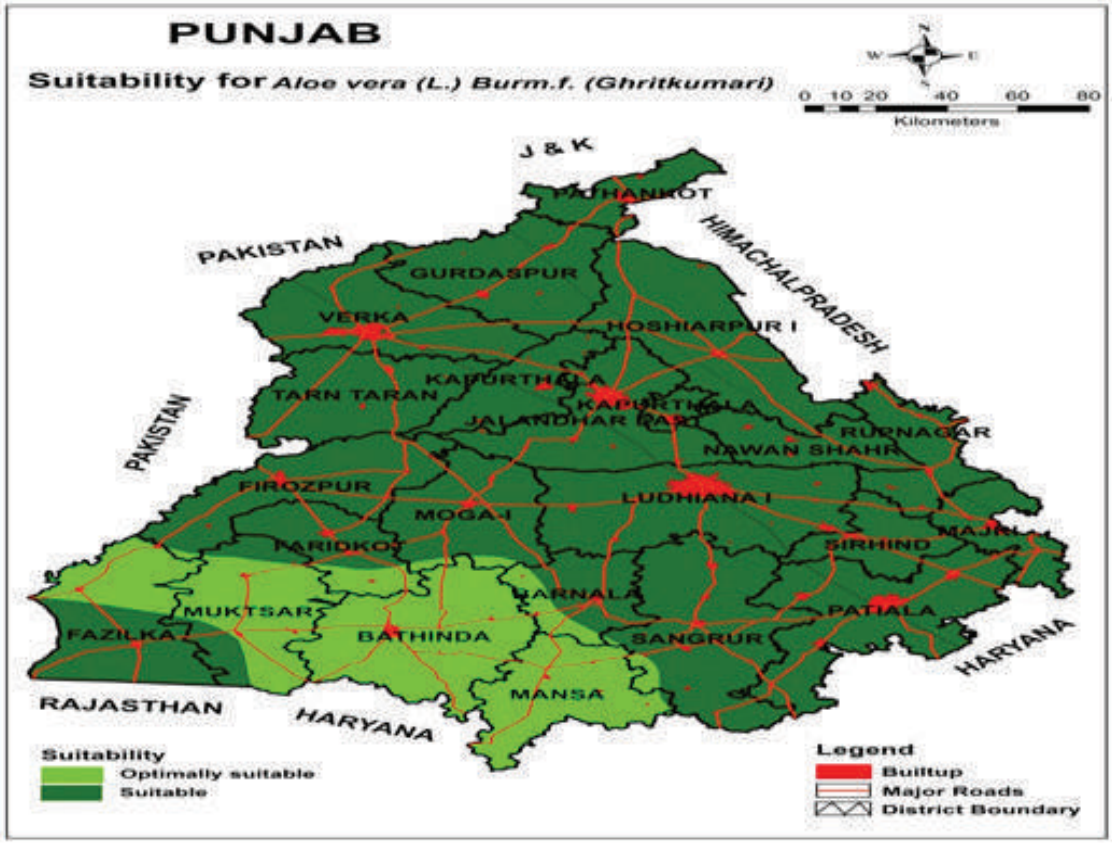
It requires less irrigation but irrigation at critical points of cultivation must be given. Water used for irrigation must comply with national requirements of water used for irrigation (Organización Mundial de la Salud and World Health Organization, 2003).

2.2.6. Agro-ecological suitability in Punjab

Considering the above-mentioned agro-ecological parameters, the growing areas of *Aloe vera* in Punjab is mentioned in fig. 7.1.

Aloe vera is highly suitable in agro-climatic

Fig. 7.1: Agro-ecological suitability of *Aloe vera* in Punjab



Source: Authors' compilation.

zone-IV which is called as western plain aried zone comprising of Mukstar, Bathinda, Mansa and some part of Faridkot districts of Punjab.

2.3. Seeds

2.3.1. Seeds and cultivar

Generally For commercial cultivation, India has released varieties of aloe for commercial cultivation. The genotypes with high level of aloin such as IC 111267, IC 111269, IC 111271, IC111279, IC 111280, IC 112532, IC 112521, IC 111273, IC 112531, IC 112517, IC 112527, INGR 06023, INGR 13043 and INGR 06024 released by ICAR-Delhi can be used as planting source (Jat *et al.* 2015).

2.3.2. Morphology of the suckers of A.vera

Suckers should have 4-7 leaves with height up to 20-30 cm.

2.3.3. Propagation

The plant is mostly propagated through suckers (lateral shoots). The mother plant produces 3-4 suckers in the growing period. The propagation material used by the farmers of Punjab is mentioned in the fig. 7.2.

Fig. 7.2: Size of *Aloe vera* during sowing

Source: Raw image of Aloe Vera captured during field visit.

2.4. Cultivation method

2.4.1 Selection and preparation of cultivation site

Site should be selected after consulting meteorological and edaphic data. For detailed criteria for selecting suitable site and other parameters, refer to the general GAP guidelines mentioned in Chapter V of this report. The roots of A.vera do not penetrate much deep, therefore land should not be disturbed deeper. Depending upon the type of soil 2-3 ploughing should be done followed by leveling. Divide the field according to the field pattern or slope for drainage of water. Initial flush of weeds should be avoided to ensure weed free young plant for initial 20-30 days. Suckers should be planted in the month of July to August, for irrigated land it can be cultivated anytime in the year except the months of winter November-February.

Fig. 7.3: *Aloe vera* field

Source: Authors' compilation.

2.4.2. Sowing

Rate of suckers per acre: 17,000-19,000
Plant to plant distance: 40-50 cm
Row to row distance: 40-50 cm
Sowing depth: 12-15 cm

2.4.3 Fertilization

Compost or farm yard manure approximately 15 tonne/acre is applied during the soil preparation by the farmers of Punjab. Subsequently, 10tonne/acre of farm yard manure is applied in the second, third, fourth year of planting. Wood ash can be applied in the pits during field preparation for good growth.

2.4.4. Field management

- **Irrigation:** Irrigation is required just after transplantation of suckers. However, 3-5 irrigations are required in a year except monsoon season. If monsoon is abundant one time irrigation is also sufficient.

- **Weeding and intercultural operations:** Field should be devoid of weeds during the entire period of growth. Initial weeding should be done during land preparation and first hoeing should be followed in a month after weeding. Subsequently 3-5 weeding are required manually with light hoeing for beneficial outputs. Regular inspections should be made so that diseased or dead plants are removed regularly.

2.5. Prevention and control of plant diseases and pests

Plant is not much prone to diseases in India. But due to efficient water holding capacity of soil, plants are prone to get fungal infections in the roots. For this, some farmers of the Punjab use Trichoderma: a bio control agent for the treatment. However, leaf spots, mealy bug are reported in some parts of the India. Termite problem can be eradicated by light irrigation. The Fig. 7.4, represents leaf spot disease in the A.vera.

Fig.7.4: Leaf spot disease on aloe leaf

Source: Authors' compilation.

2.6 Harvest and postharvest processing

2.6.1. The best harvesting time, and quality evaluation prior to harvest

Aloe vera harvesting is labour intensive job. The leaves of aloe are cut from its base by the workers. First harvesting is done after 10-11 months of planting. The first harvesting yields from 25-35 ton per acre. Subsequently, three harvesting are taken from second, third, fourth and fifth year. On average 60 ton per acre is the yield of the plant from second to fifth year. The best time to harvest plant is during morning and evenings at early flowering to get good active constituents. The Fig.7.5 represents harvesting of A.vera leaves in the Punjab.

Fig. 7.5: Farm women worker harvesting *Aloe vera* in Punjab

Source: Authors' compilation.

2.6.2. *Post-Harvest processing method*

The plant is required to be processed immediately so immediate transport is required to avoid thermal degradation and microbial contamination. The fig. 7.6-7.8 represents processing of *A.vera* leaves in the herbal unit in Punjab. Use of refrigerators, sand boxes and enzymatic measures can be applied. Preservatives should be avoided, if used they should comply with national norms and well documented. The *A.vera* leaves are transported to processing unit and dried aloe juice as a medicine is prepared by transversely cutting the leaves at the bases and allowing gel to drain out in a vessel. The collected juice is allowed to concentrate by evaporation or by boiling. Similarly, the pulp of the leaf is used particularly in cosmetics industry, so the left over leaves after exudation are cut open and gel is removed by using blunt knives. The gel is stirred

Fig.7.6: (A) Loaded trolley of *Aloe vera* leaves in unit (B) Unpacking of leaves at herbal industry in Punjab

Source: Authors' compilation.

Fig. 7.7: A worker washing freshly harvested *Aloe vera* leaves in Punjab.

Source: Authors' compilation.

vigorously in a blender to make a homogeneous mixture which is then filtered using muslin cloth and allowed to centrifuge to get gel.

3. Good collection practices

For guidelines required for collection of medicinal plants, refer to the WHO good agricultural and collection practices guidelines, 2003[5] and guidelines on good field collection practices for Indian medicinal plants, 2009.[5]

4. Quality control requirements for herbal materials of A.vera

4.1. Basic quality requirements for herbal materials

4.1.1. Selection of species or botanical variety

In general, national pharmacopoeias and concerned authoritative institutes should be consulted before selection of varieties. The Directorate of Medicinal and Aromatic Plants Research (DMAPR), Boriavi Anand, Gujrat must be consulted for more details. The detailed requirements for selection of species or botanical variety are mentioned in the general GAP guidelines described in chapter V.

4.1.2. National quality specification and requirements for herbal materials

National quality specifications on A.vera must be consulted in order to achieve optimum quality of the crop. Apart from this present monograph, the monographs on A.vera are mentioned in the Ayurveda Pharmacopoeia of India (API), and ICMR for standard quality specifications. Furthermore, FSSAI has also prescribed some quality parameters for A.vera which is also included in the monograph.

4.2. Basic quality specification for herbal materials of A.vera

4.2.1. Physico-chemical parameters

The physico-chemical parameters mentioned in the API and other standard literature are mentioned in the Table 7.4.

Table 7.4: Physico-chemical parameters of A.vera

Physico-chemical parameters	**API** (The Ayurvedic Pharmacopoeia of India, 1989)	**Other reported literature** (Tandon, 2011)
Foreign matter	Dried Juice: n.m.t. 2 %	Dried Juice: Nil Leaf: Nil
Total ash	n.m.t. 5 %	Dried Juice: n.m.t. 3.5 % Leaf: n.m.t. 1.0%
Acid insoluble ash	Dried Juice: n.m.t. 2 %	Dried Juice: n.m.t. 0.4% Leaf: n.m.t. 0.002%
Alcohol soluble extractive	Dried Juice: n.l.t. 80 %	Dried Juice: n.l.t. 83.0% Leaf: Not less than 0.45 %
Water soluble extractive	Dried Juice: n.l.t. 60 %	Dried Juice: n.l.t. 60.0 % Leaf: n.l.t. 1.5 %
Moisture Content	Dried Juice: n.m.t. 10 %	--

Source: Reference already provided
n.m.t: not more than; n.l.t: not less than

Table 7.5: Qualitative and quantitative ranges of emodin in *A.vera*

Major active constituent	API	Other reported literature (Tandon, 2011)	General method of experimentation
TLC	--	TLC of leaf: Emodin spot at R_f at 0.61 (Green color). TLC of dried juice: Aloin spot at Rf at 0.63 (Reddish orange)	Solvent for extraction using Soxhlet apparatus: Alcohol as solvent. Solvent system: Toluene: Ethyl acetate: Formic acid (5:1:0.5) Visualization: Under UV light at 254 nm. For detailed method, refer *"Quality standards of Indian medicinal plants"*[7]
HPTLC	--	Aloin was found to be 0.521 % in dried juice. Emodin was found to be 0.0131 % in leaves.	Dried juice: extraction using Soxhlet apparatus: Alcohol as solvent. Solvent system: Ethyl acetate: Methanol: Water (10:1.35:1) Visualization at: Spraying TLC plate with 10% ethanolic potassium hydroxide reagent. For detailed method, refer *"Quality standards of Indian medicinal plants"*[8]

Source: Reference already provided

4.2.2. Qualitative and quantitative estimation of A.vera

The qualitative (R_f) and quantitative ranges of emodin mentioned in the API and other standard literature are mentioned in the Table 7.5.

4.2.3. Ranges of toxicity indicators in A.vera

The toxicity indicators mentioned in various standard literatures are mentioned in the Table 7.6.

4.3. Methods for quality analysis

- Refer, Quality control methods for medicinal plant materials.[9]
- Refer to Appendix(s) *The Ayurvedic Pharmacopoeia of India.*[10]
- Refer, Appendix-I, *Quality standards of Indian medicinal plants.*[11]

Endnotes

1 Eshun, K., He, Q. 2010. Aloe vera: a valuable ingredient for the food, pharmaceutical and cosmetic industries—a review. Critical reviews in food science and nutrition. 44(2):91-6.

2 Jat, R.S., Reddy Nagaraja, R., Manivel, P. 2015. Good agricultural practices for aloe. ICAR- Directorate of Medicinal and Aromatic Plants Research, Boriavi, Anand, 1-8.

3 Sánchez, M., González-Burgos, E., Iglesias, I., Gómez-Serranillos, M.P. 2020. Pharmacological update properties of Aloe vera and its major active constituents. Molecules, 25(6): 1-37.

4 Compound summary of emodin with Pubchem CID: 3220 in *Pubchem* database, https://pubchem.ncbi.nlm.nih.gov/compound/Emodin.

5 Organización Mundial de la Salud, World Health Organization. 2003. WHO Guidelines on Good Agricultural and Collection Practices (GACP) for Medicinal Plants, World Health Organization, Geneva, Switzerland, pp.1-67.

6 Guidelines on good field collection practices for Indian medicinal plants. 2009. National Medicinal Plants Board, Department of AYUSH, Ministry of Health and Family Welfare, Government of India

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11 *Quality standards of Indian medicinal plants.* 2011. Vol-IX, Appendix-I. Indian Council of Medical Research, New-Delhi, India. pp. 379-390.

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World Health Organization. 2011. Quality control methods for herbal materials. Geneva, Switzerland. pp. 1-200.

8

Monograph on GAP for Emblica officinalis Gaertn.

1. Botanical and pharmacological characteristics of *Emblica officinalis Gaertn*

1.1. Name of plant

1.1.1. Scientific name

Latin botanical name: *Emblica officinalis* Gaertn.
Family: Phyllanthaceae

Source: Raw image of *Emblica officinalis* captured during field visit.

1.1.2. Vernacular names

English: Emblic Myrobalan
Hindi: Amla, Aonla
Punjabi: Aula, Amla
Tamil: Nellikkai, Nelli
Malayalam: Nellikka
Kannada: Nellikayi
Urdu: Amla, Amlaj

1.2. Medicinal plant part of interest

1.2.1. Plant part used in traditional medicine

Fruit

1.2.2. Part to be used as raw material for the extraction of gallic acid

Fruit

1.3. Geographical distribution and the major areas of cultivation

1.3.1. Geographical distribution

It is widely found in India, China, Sri Lanka and Malaysia. In India, it is found throughout in Assam and is widely found in Madhya Pradesh, Odhisa, Tamil Naidu, Uttar Pradesh, Rajasthan, Manipur, Jammu & Kashmir, Himachal Pradesh, and Andaman & Nicobar islands. *E.officinalis* (*E.officinalis Gaertn*. will be represented as *E.officinalis* in this monograph) is widely found on the sides of road adjoining forests.

1.3.2. Major areas of cultivation

E.officinalis is mostly cultivated in Uttar Pradesh, Gujrat, Maharastra, Andhra Pradesh, Rajasthan, Tamil Naidu, Karnataka and Himachal Pradesh.[1]

1.4. Morphological characteristics of roots of E.officinalis

The Ayurvedic Pharmacopoeia of India (API)

Table 8.1: Morphological characteristics of *E.officinalis*

Macroscopic analysis	API (The Ayurvedic Pharmacopoeia of India, 1989)	Other reported literature (Tandon and Sharma, 2010)
Fresh fruit	Fleshy, smooth with six prominent lines with a few dark specks	Compact, heavy, fleshy drupe, smooth shining shows 5-8 longitudinally running furrows and minute light coloured specks
Dried fruit	Shriveled and wrinkled external convex surface to concave. Rough texture	Tough and cartilaginous and almost unbreakable in by hand

Source: Reference already provided

Table 8.2: Organoleptic characters of *E.officinalis*

Organoleptic analysis	API (The Ayurvedic Pharmacopoeia of India, 1989)	Other reported literature (Tandon and Sharma, 2010)
Shape	Fresh fruit: Globose. Dried fruit: Curled pieces	Fresh fruit: Almost globular Dried fruit: Tough
Size	Fresh fruit: 2.5-3.5 cm in diameter Dried fruit:1-2 cm long or united as 3-4 segments	Fresh fruit: 3 to 4 cm in diameter. Dried fruit: 1 to 2 cm in length and 1 cm in breadth.
Color	Fresh fruit: Greenish turning to light yellowish and pinkish when matured. Dried fruit: Bulk grey color to black. Surface shows few whitish specks.	Fresh fruit: Yellowish green. Dried fruit: Greyish white, dark brownish or black in color.
Odor	Fresh fruit: Odorless Dried fruit: Specific	Fresh fruit: Odorless Dried fruit: Characteristic
Taste	Fresh fruit: Sour to astringent followed by sweet taste; Dried fruit: Sour and astringent.	Fresh fruit: Bitter and sour, followed by delicately sweet astringent feeling Dried fruit: Bitter and sour.

Source: Reference already provided

and other standard literature mentioning the morphological characteristics of *E.officinalis* are mentioned in the Table 8.1.

1.5. General description of characteristics of plant material

1.5.1. Organoleptic characteristics

The organoleptic characteristics of *E.officinalis* highlighted in the API and other standard literature is mentioned in the Table 8.2.

1.5.2. Microscopic characteristics

The microscopic characteristics of *E.officinalis* highlighted in the API and other standard literature is mentioned in the Table 8.3.

1.6. Chemical composition

Table 8.3: Important microscopic characters of *E.officinalis*

Microscopic analysis	API (The Ayurvedic Pharmacopoeia of India, 1989)	Other reported literature (Wallis 2003; Indian Herbal Pharmacopoeia, 1998; Tandon and Sharma 2010)
Transverse section	*Fresh fruit:* TS shows epicarp with layer of epidermis and 2-4 layers of hypodermis. Tabular shape epidermal cell covered with thick cuticle. Mesocarp consisting of parenchymatous cells with intercellular spaces. Presence of collateral fibrovascular bundles in mesocarp consisting of xylem and phloem; xylem fibres elongated with narrow lumen and pointed end; mesocarp contains irregular silica crystals. *Dried fruit:* Epicarp with epidermis cell. Presence of cuticle, mesocarp cells with parenchymatous cells. Ramified vascular elements and presence of stone cells and pitted vascular fibres.	*Fresh fruit:* Presence of epicarp and mesocarp and pericarp covered with thick cuticle. The TS of pericarp shows stone cells, sclereids. Presence of vascular bundle in pericarp. Sclereids, fibres, hypodermis, starch grains, stone cells, spiral vessels, thick walled fibres are also present.
Powder microscopy	Epidermis with thick walled isodiametric parenchyma cells. Occasionally short fibres and tracheids.	Shows epidermal cells, parenchyma cells, isolated sclereids, prismatic crystals of silica, pitted vessel, starch grains, group of stone cells, fibres.

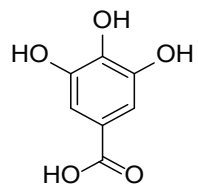
Source: Reference already provided

1.6.1. The major chemical constituents of E.officinalis

The major chemical constituents investigated in the plant are ascorbic acid and tannins (Tandon and Sharma 2008).

1.6.2. Physical and chemical properties of gallic acid

Chemical structure:



Molecular formula: $C_7H_6O_5$

Chemical name: 3,4,5-trihydroxybenzoic acid

Molecular weight: 170.12 g/mol

Description: White or slightly yellow crystalline solid, odourless

Solubility: Soluble in oxygenated solvents, 1 g is soluble in 87 ml of water

Melting point: 258-265°C

Detailed quality specifications of gallic acid, refer compound summary of gallic acid.[2]

Pharmacological activity

It is important dietary source of vitamin C which plays an important role in the human body.

1.6.3. Pharmacological activity of E.officinalis

It is used in jaundice, diarrhea, inflammation, antidiabetic, antibacterial, hypolipidemic, antiulcerogenic, antioxidant, gastroprotective, hepatoprotective, and possess chemopreventive properties (Tandon and Sharma 2008; Dasaroju and Gottumukkala, 2014).

1.6.4. Pharmacological activity of ascorbic acid and gallic acid

The compound is responsible for the treatment and prevention of scurvy. It is also a potent anti-oxidant agent that fights against bacterial infections. It helps in the formation of bones, teeth, skin, connective tissue and fibrous tissue. Ascorbic acid is not formed or stored in the body so it must be taken from the diet. It is found mostly in citrus fruits and vegetables. Gallic acid possesses anti-microbial, anti-cancer, and it is protective against gastrointestinal disorders, cardiovascular diseases, neuropsychological disorders, and metabolic disorders (Raghu et al. 2007; Tandon and Sharma 2010; Kahkeshani *et al.* 2019).

2. Good agricultural practices

2.1. Growth and development characteristics

2.1.1. General description

It is a deciduous tree with a height ranging 15 m. The life expectancy of the tree is approximately 15 years. The flowers are yellow in colour present in axillary clusters. The plant is evergreen shrub having more than 100 species. It is native to tropical and sub-tropical regions. It is native to southeast Asia's moist and deciduous forests (Khan, 2009; Kavitha *et al.* 2021).

2.2. Preferred growing conditions

2.2.1. Ecological conditions

It is found in dry and moist deciduous forests. It is also found along hill slopes ranging 800-1500m and above altitude. It has a high draught tolerance but prefers good drainage (Jalal et al. 2018; Wali *et al.* 2015; Kavitha *et al.* 2021).

2.2.2. Climatic conditions

Being a sub-tropical crop, it prefers dry sub-tropical climate. It survives on very low temperature; however it grows optimally in an annual temperature range of 14-35°C with 700-4200 mm annual rainfall (Jalal *et al.* 2018).

2.2.3. Soil conditions

It prefers slightly acidic to saline soil. It can be grown in heavy or light soil except purely sandy soil. It can grow on calcareous soil and rocky substratum soil, however well drained loamy soil is best for higher yield. It can be preferably grown up to pH 8.5. (Kumar *et al.* 2012; Jalal *et al.* 2018).

2.2.4. Nutrient conditions

Only organic fertilizers are preferred for the cultivation of the plant. The one year old plant requires 10 kg FYM, 200 g N, 500g P and 200 g K that should be given to per plant per year (TNAU, 2013; Reddy, 2019).

2.2.5. Water conditions

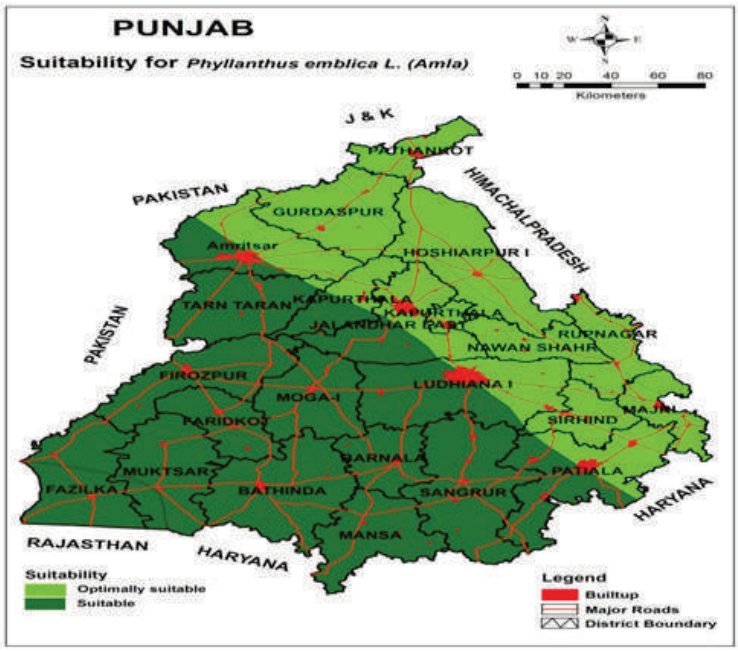
Water used for irrigation must comply with national requirements of water. It requires no irrigation during rainy season and less water during winter season.

2.2.6. Agro-ecological suitability in Punjab:

Considering the above-mentioned agro-ecological parameters, the growing areas of *E.officinalis* (it is also known as Phyllanthus emblica L.) in Punjab is represented in the fig. 8.1

Based on the agro-ecological zoning model, the plant is found optimally suitable for agro-climatic zone-I & II, also representing sub-mountainous zone of Kandi belt in Hoshiarpur district of Punjab. From Kandi belt, it extends towards Jalandhar and Sirhind districts of Punjab.

Fig. 8.1. Agro-ecological suitability of E.officinalis in Punjab



Source: Authors' compilation.

2.3. Seeds

2.3.1. Seeds and cultivar

The most popular varieties found in India are Banarasi, BSR 1, Francis, Chakaiya, Kanchan (NA 4), Krishna (NA 5, NA 6, NA 7 and NA 10, Narendra Aonla 6,7,10 and Navyakrit. The information regarding the varieties can be obtained from the CIMAP, Lucknow (TNAU, 2013; Wali *et al.* 2015).

2.3.2. Morphology of the seeds of E.officinalis

The size of the fruit is approximately 0.5 cm. The color of seed is dark brownish to black. Dispersal of seeds is by wind, insects, mammals other pollinators (Reddy, 2019; Kavitha *et al.* 2021).

2.3.3. Propagation

The plant is propagated through seeds, budding and softwood grafting. The quality of the plant depends solely on the seeds. In Punjab, especially in sub-mountainous Kandi region, wild *E.officinalis* having smaller size fetches more value than the Banarasi variety which is bigger in size as represented in the fig. 8.2.

2.4. Cultivation method

2.4.1. Selection and preparation of cultivation site

Land is prepared by ploughing, harrowing and leveling. It is essential to remove weeds during the initial periods as weeds compete with the nutrients required by the principal plant. Pits are prepared 15-30 days before planting and exposed to sunlight. Divide the field according to the field pattern or slope for drainage of water.

2.4.2. Sowing and nursery management

Sowing: The seeds collected from wild or cultivation should be mature, fresh, and originated from the recent harvest. Seeds must be sown in nursery beds uniformly. Sometimes it is observed that the trees propagated from seeds bear inferior quality plant with long gestation period. So, it is recommended to

Fig. 8.2: Size variability between Banarasi variety (A) and wild variety (B)

Source: Raw image of *Emblica officinalis* captured during field visit.

do shield budding in one year old plant with superior strain yielding good quality fruits.

Nursery management: Nursery is raised in the starting month April-June. The seeds are sown on well prepared nursery beds supplemented with decomposed farm yard manure. Seeds must be uniformly distributed and proper moisture must be maintained till the seeds are germinated. The nursery of E.officinalis is represented in the Fig. 8.3.

2.4.3. Transplanting

Transplanting is done when the seedling are 40 days old obtaining 12-15 cm in length.

Spacing: 400-500 cm

Pits: 100 cm

2.4.4.Fertilization

Farmers used 4 tonne/acre farm yard manure on average in Punjab. However, it is reported that each pit should be filled with surface soil mixed and well rotten farmyard manure and neem cake 500-1000 g. 10 kg farmyard manure, 100g N, 50g

Fig. 8.3: Nursery of E.officinalis in Hoshiarpur district of Punjab

Source: Authors' compilation.

P and 100g K should be given to one year old plants (Wali *et al.* 2015; Reddy, 2019).

2.4.5. Field management

- **Irrigation** The plant requires no irrigation during rainy season and less water during winter season. However plant needs water after every 10-20 days during summers. Irrigation is required during flowering period i.e. May to April. Drip irrigation can also be used than conventional method of irrigation.
- **Weeding and intercultural operations** Weeding is done after one month when the weeds start to compete with the principal crop for nutrition and sunlight.
- ***Taining and Pruning*** Two to four branches seen in the opposite directions with wide crotch angle, should be allowed to grow in early years. In March-April unwanted braches are cut. In next year 4-6 branches are allowed to grow. Regular pruning is not generally required in the fruit bearing plant. Broken or damaged, overlapping, infested branches of the plant need to be cut off regularly.
- ***Mulching*** Mulching with paddy straw or sugar cane trash can be done to suppress the inflow of weeds and to maintain moisture.

2.5. Prevention and control of plant diseases and pests: No serious pests or diseases have been reported for this plant on the selected cultivars in Punjab. To prevent diseases, bio-pesticides are used that are made from neem (kernel, seeds & leaves), chitrakmool, dhatura (Anonymous, 2009). Some of the reported pests, diseases and the symptoms of *E.officinalis* are mentioned in the Table 8.4., and Fig. 8.4. The *E.officinalis* field in the Pathankot district is represented in the Fig. 8.5.

2.6. Harvest and postharvest processing

2.6.1. The best harvesting time, and quality evaluation prior to harvest

During harvesting of the plant, minimum damage should be done to the plant. Fruit should not be damaged during collection or harvesting. Cutting the branches of the plant to ease harvesting of the fruit must be avoided. Harvesting should be done at right phonological stage and appropriate developmental stage of the plant to obtain optimum quality of the principal active constituents. Harvesting in Punjab generally starts from November to December. Plant is harvested after 7-8 years of planting but the budded clones may start giving first harvest on third to fifth year. Harvesting is done during the early and late hours of the day. The fruit are first light green color but becomes dull green when fully matured. The phenological stage during collection should be duly documented and collectors should also seek the advice of an expert at herbal processing unit to

Table 8.4: Diseases of *E.officinalis*

Insect pests	Management
Leaf rolling caterpillar	Through clean cultivation and avoiding over crowded branches.
Shoot gall maker	
Mealy bug	
Pomegranate butterfly	
Ring rust	Timely management and clean cultivation
Fruit rot	
Leaf rot	

Source: Sengupta, 2020

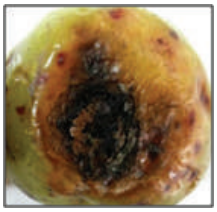
Fig. 8.4: Common diseases of *E.officinalis*

Leaf rolling caterpillar

Shoot gall maker

Mealy bug

Ring rust



Fruit rot

Pomegranate butterfly

Source: Sengupta, 2020

Fig. 8.5: *E.officinalis* field in Pathankot district of Punjab.

Source: Authors' compilation.

understand the optimum time of collection. Harvesting should be avoided during rain, high humidity and mist as the produce will be prone to fungal attack. If harvesting in the wet conditions in inevitable, provisions should be there to dry the produce as soon as possible.

2.6.2. Post-harvest processing method

Sorting of fruits should be carried out after the harvesting. Sorting includes separation of immature fruits, and damaged fruits that may downgrade the quality of the produce. The post-harvested fruits can be processed to make to make juices, candies, pickles, and fruit murabba. The sorting of low grade and high grade fruits of *E.officinalis* carried out by a herbal industry in Punjab is represented in the Fig. 8.6.

3. Good collection practices

3.1. General regulatory requirements during collection from wild

- During collection of fruits from the wild, one should bear in the mind that forests in

India are regulated by the both central and state governments. Therefore, forests being concurrently regulated, one should adhere to all the laws regulated by central and state governments.

- Collectors should seek written permission from all the local authorized agency for collection, transit and sell of produce. The documentary proof should be kept in safe custody.

Fig. 8.6: (A) Low grade fruit (B) High grade fruit

Source: Authors' compilation.

- India is signatory to many international treaties and forest conservation and biodiversity conventions, so international laws where ever applicable must be respected time to time. One to adhere to the international regulations such as Convention on International Trade in Endangered Species of Wild Flora & Fauna (CITES) during collection from wild. For importing, local secretariats of CITES, TRAFFIC (The wild trade monitoring network) and International Union for the Conservation of Nature (IUCN) may be consulted.

- The collectors of medicinal produce should also be aware of national regulations amendments from time to time. Indian Forest Act 1927, The wildlife (Protection) Act 1972, The forest (Conservation) Act 1980, The Biological Diversity Act 2002, The Scheduled Tribes and Other Tradtional Forest-Dwellers Act 2006 must be consulted as they contain provisions for collection of medicinal plant produce from the forests.

3.2. General environmental considerations during collection from wild

- The increasing demand of medicinal plant has resulted in exploitation of forests. So regulators (forests and wild life field officials) and collectors must be aware of the current conservation status of the plant species.

- Rare, Endangered and Threatened (RET) status of the plant species in respective areas should be known. Collection of senstive endemic plant should adhere to legal and ecological prescriptions to ensure prevention of threat to species.

- Collection of *E.officinalis* from the wild should be done from the areas where its frequency of occurrence is sustainable. Harvesting should be done in limits, and certain percentage of its population should be left so to allow regeneration.

For the detailed guidelines on the collection of medicinal plants, refer to the Good Field Collection Practices for Indian Medicinal Plants, 2009.[3]

4. Quality control requirements for herbal materials of *E.officinalis*

4.1. Basic quality requirements for herbal materials

4.1.1. Selection of species or botanical variety

In general, national pharmacopoeias and concerned authoritative institutes should be consulted before selection of varieties. Regional research laboratory, CIMAP Lucknow, India shall be consulted. The detailed requirements for the selection of species or botanical variety are mentioned in the general GAP guidelines described in chapter V of this book.

4.1.2. National quality specification and requirements for herbal materials

National quality specifications on *E.officinalis* must be consulted in order to achieve optimum quality of the crop. Apart from this present monograph, the monographs on *E.officinalis* are mentioned in the API, and Indian Council of Medical Research (ICMR) for standard quality specifications (The Ayurvedic Pharmacopoeia of India, 1989; Tandon and Sharma, 2010).

4.2. Basic quality specification for herbal materials of E.officinalis

4.2.1. Physico-chemical parameters

The physico-chemical parameters mentioned in the API and other standard literature are mentioned in the table 8.5.

4.2.2. Qualitative and quantitative estimation of E.officinalis

The qualitative (Rf) and quantitative ranges of gallic acid mentioned in the API and other standard literature are mentioned in the table 8.6.

4.2.3. Ranges of toxicity indicators in E.officinalis

The toxicity indicators mentioned in various standard literatures are mentioned in the Table 8.7.

Table 8.5: Physico-chemical parameters of *E.officinalis*

Physico-chemical parameters	API (The Ayurvedic Pharmacopoeia of India, 1989)	Other reported literature (Tandon and Sharma, 2010; Indian Herbal Pharmacopoeia, 1998)
Foreign matter	Fresh fruit: n.m.t 2 % and dried fruit: n.m.t 3 %	Fresh fruit: Nil Dried fruit: Nil
Total ash	Fresh fruit: n.m.t. 7 % Dried fruit: n.m.t. 7 %	Fresh fruit: n.m.t. 1.0 % Dried fruit: n.m.t. 12.0 %
Acid insoluble ash	Fresh fruit: n.m.t. 2 % Dried fruit: n.m.t. 2 %	Fresh fruit: n.m.t. 0.05 % Dried fruit: n.m.t. 2 %
Alcohol soluble extractive	Fresh fruit: n.l.t. 40% Dried fruit: n.l.t. 40%	Fresh fruit: n.l.t.10.0 % Dried fruit: n.l.t. 31.0 %
Water soluble extractive	Fresh fruit: n.l.t. 50 % Dried fruit: n.l.t. 50%	Fresh fruit: n.l.t. 11.0 % Dried fruit: n.l.t. 46.0 %
Moisture Content	Fresh fruit: n.l.t. 80 %	--

Source: Reference already provided
n.m.t: not more than; n.l.t: not less than

Table 8.6: Qualitative and quantitative ranges of gallic acid in *E.officinalis*

Major active constituent	API	Other reported literature (Indian Herbal Pharmacopoeia, 1998; Tandon and Sharma, 2010)	General method of experimentation
TLC	--	TLC of fresh fruit: Gallic acid spot at Rf at 0.41 (Green color). TLC of dried fruit: Gallic acid spot at Rf at 0.41 (Green)	Fresh and dried fruit: Extraction using Soxhlet apparatus and alcohol as solvent. Solvent system: Toluene: Ethyl acetate: Formic acid (5:3.5:0.5) Visualization: Under UV light at 254 nm For detailed method, refer Quality standards of Indian medicinal plants[4]
HPTLC	--	Fresh fruit: Gallic acid was found to be in range from 0.015 to 0.022 % in fruit samples. Dried fruit: Gallic acid was found to be in range from 3.87 to 5.46 %	Fresh fruit: Extract powdered drug with alcohol using Soxhlet apparatus scanning densitometrically at 254 nm. For detailed method, refer, Quality standards of Indian medicinal plants[5]

Source: Reference already provided

Table 8.7: Toxicity indicators of *E.officinalis*

Pesticide residues (World Health Organization 1998; FAO and WHO 2019).	Aldrin and dieldrin not more than 0.05 mg/kg. Total residue consumed should not be more than 1 % from the medicinal plant material
Microbial contamination (World Health Organization, 1998, 2011).	**For crude plant:** *Escherichia coli*, maximum 10^4 per gram; mould propagules, maximum 10^5 per gram. **For pre-treated plant:** aerobic bacteria, maximum 10^7 per gram yeasts and moulds, maximum 10^4 per gram; *Escherichia coli*, maximum 10^2 per gram; other *Enterobacteria*, maximum 104 per gram; *Salmonellae*, none **Plant materials for internal use:** aerobic bacteria, maximum 10^5 per gram; yeasts and moulds, maximum 10^3 per gram; *Escherichia coli*, maximum 10 per gram; *Enterobacteria*, maximum 103 per gram; *Salmonellae*, none.
Heavy metal residue (World Health Organization, 1998, 2011)	Lead: n.m.t. 10mg/kg Cadmium: n.m.t. 0.3mg/kg
Aflatoxins (World Health Organization, 1998, 2011)	Avoid Aflatoxins B1, B2, G1 and G2 in plant materials

Source: Reference already provided

n.m.t.: not more than; n.l.t.: not less than

4.3. Methods for quality analysis

- Refer, *Quality control methods for medicinal plant materials*[6]
- Refer, Appendix(s) *Ayurveda Pharmacopoeia of India*[7]
- Refer, *Quality standards of Indian medicinal plants*[8]

Endnote

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9

Monograph on GAP for Ocimum sanctum L.

1 Botanical and pharmacological characteristics of Ocimum sanctum L.

1.1. Name of plant

1.1.1. Scientific name

Latin botanical name: *Ocimum sanctum* L.
Family: Lamiaceae

Source: Raw image of *Ocimum sanctum* captured during field visit.

1.1.2. Vernacular names

English: Holy basil
Hindi: Tulasi
Punjabi: Tulasi
Tamil: Tulasi, Thulasi, Thiru
Malayalam: Tulasi, Tulasa
Kannada: Tulasi, Shree tulasi, Vishnu tulasi
Urdu: Raihan

1.2. Medicinal plant part of interest

1.2.1. Plant part used in traditional medicine

Leaves, whole plant

1.2.2. Part to be used as raw material for the extraction of eugenol

Leaves, whole plant

1.3. Geographical distribution and the major areas of cultivation

1.3.1. Geographical distribution

O.sanctum (*Ocimum sanctum L.* will be represented as *O.sanctum* in this monograph) is found in the entire Indian subcontinent from Himalayas (1800m) to Andaman and Nicobar islands. It can be found in the Southeast Asian tropics [1].

1.3.2. Major areas of cultivation

Traditional cultivation of the plant can be traced around Mathura to fulfill the need of Vrindavan temple. It is widely cultivated in Uttar Pradesh and in southern India (Jat *et al*. 2014).

1.4. Morphological characteristics of O.sanctum

The Ayurvedic Pharmacopoeia of India (API) and other standard literature mentioning the morphological characteristics of *O.sanctum* are mentioned in the Table 9.1.

1.5. General description of characteristics of plant material

1.5.1. Organoleptic characteristics

The organoleptic characteristics of *O.sanctum* highlighted in the API and other standard literature is mentioned in the Table 9.2.

Table 9.1: Morphological characteristics of *O.sanctum*

Macroscopic analysis	**API** (The Ayurvedic Pharmacopoeia of India, 1989)	**Other reported literature** (Indian Herbal Pharmacopoeia, 1998; Gupta *et al.* 2008)
Leaves	Petiolate and thin petiole is 1.5-3 cm long, hairy on surface	Both surfaces pubescent; venation reticulate, veins more prominent at lower side. Slightly grove on upper surface, slender hairy.
Whole plant	Erect, 30-60 cm high, much branched, annual herb. Flowers are crimson or purplish color.	Biennial or triennial plant, reaches heights upto 30-77 cm. Flowers purplish or crimson, fruits are sub-globose with small black markings.

Source: Reference already provided

Table 9.2: Organoleptic characters of *O.sanctum*

Organoleptic analysis	**API** (The Ayurvedic Pharmacopoeia of India, 1989)	**Other reported literature** (Gupta *et al.* 2008; Indian Herbal Pharmacopoeia, 1998)
Shape	Shape of leaf is Elliptic-oblong, obtuse or acute, entire or serrate, pubescent on both surface, thin petiole.	Shape of the leaf is elliptic and oblong.
Size	2.5-5 cm long, 1.6-3.2 cm wide.	2 to 2.5 cm long, 1 to 1.5 cm wide.
Color	Green to yellowish.	Upper surface green and lower pale green.
Odor	Aromatic.	Aromatic.
Taste	Characteristic.	Slightly pungent and mucilaginous.

Source: Reference already provided

1.5.2. Microscopic characteristics

The microscopic characteristics of *O.sanctum* highlighted in the API and other standard literature is mentioned in the Table 9.3.

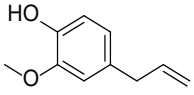
1.6. Chemical composition

1.6.1. The major chemical constituents of O.sanctum

The major chemical constituents investigated in the plant are eugenol, and carvacrol (Gupta *et al*. 2008).

1.6.2. Physical and chemical properties of eugenol

Chemical structure:



Molecular formula: $C_{10}H_{12}O_2$

Chemical name: 2-methoxy-4-prop-2-enylphenol

Molecular weight: 164.2 g/mol

Description: Colourless or pale yellow or amber-color liquid. It has a clove like odour

Table 9.3: Important microscopic characters of *O.sanctum*

Microscopic analysis	API (The Ayurvedic Pharmacopoeia of India, 1989)	Other reported literature (Wallis, 2003; Gupta *et al.* 2008)
Transverse section	Petiole shows number of covering and glandular multicellular trichomes. Layers of collenchymatous and parenchymatous cells and three vascular bundles consisting of xylem and phloem. Midrib has epidermis trichomes and vascular bundles. Lamina has epidermis and presence of trichomes, anomocytic stomata, palisade layers, closely packed parenchyma with chloroplast and oleo-resin.	T.S. of leaf comprises of collenchyma, epidermis, glandular trichomes, lower epidermis, obliquely cut vascular bundles, palisade, phloem, upper epidermis and xylem.
Powder microscopy	Polygonal and wavy walled epidermal cells in surface view, glandular trichomes, palisade and spongy parenchyma and anomocytic and diacytic stomata.	Powder shows covering trichomes, glandular trichomes, sessile glandular trichomes, cupshaped trichomes, fragments of spiral, annular, reticulate and pitted vessel. Cicatrix, obliquely cut vascular bundles, palisade, stomata are also present.

Source: Reference already provided

Solubility: It is soluble in glacial acetic acid, miscible in chloroform, alcohol, and oils.
Boiling point: 253.889° C at 760 mm Hg
Melting point: -9.222222°C
Detailed quality specifications of eugenol, refer compound summary of eugenol.[2]

1.7. Pharmacological activity

In Ayurveda, O. sanctum is mentioned as "Mother medicine of nature", "The Queen of herbs". It is considered to prevent diseases, stress, and promote wellbeing, general health and longevity in an individual.[3]

1.7.1. Pharmacological activity of O.sanctum

Used in bronchial asthma, bronchitis, skin diseases, diarrhea, dysentery, painful eye diseases, arthritis, malaria, insect bite, and chronic fever (Jat *et al.* 2014). It is a potent adaptogen and reported to possess anti-viral, anti-bacterial, anti-fungal, anti-protozoal, anti-inflammatory, anti-carcinogenic properties.

1.7.2. Pharmacological activity of eugenol

Eugenol has potent anti-oxidant and free radical scavenging properties. It shows dose-dependent anesthetic affects at concentration of 50-60 mg/

kg i.v. It possesses inhibitory activity against both gram positive and negative bacteria's. Eugenol at concentration of 1000µg/mL inhibits the growth of *P.aeruginosa*. It is reported to have strong anti-inflammatory effect because of its property to block COX-2 enzyme (Nejad *et al.* 2017).

2. Good agricultural practices

2.1. Growth and development characteristics

2.1.1. General description

Tropical and sub-tropical climate is suitable for its cultivation; therefore, it can be grown in the entire Indian sub-continent tropics (Jat *et al.* 2014).

2.2. Preferred growing conditions

2.2.1. Ecological conditions

It can grow on vast range of soils with tropical and sub-tropical climate. The plant is moderately tolerant to drought and frost. It can also be grown on partially shaded areas (Makri and Kintzios, 2008).

2.2.3. Climatic conditions

It grows optimally, in an annual temperature range of 15-35°C with 700-7600 mm annual rainfall (Jat *et al.* 2014).

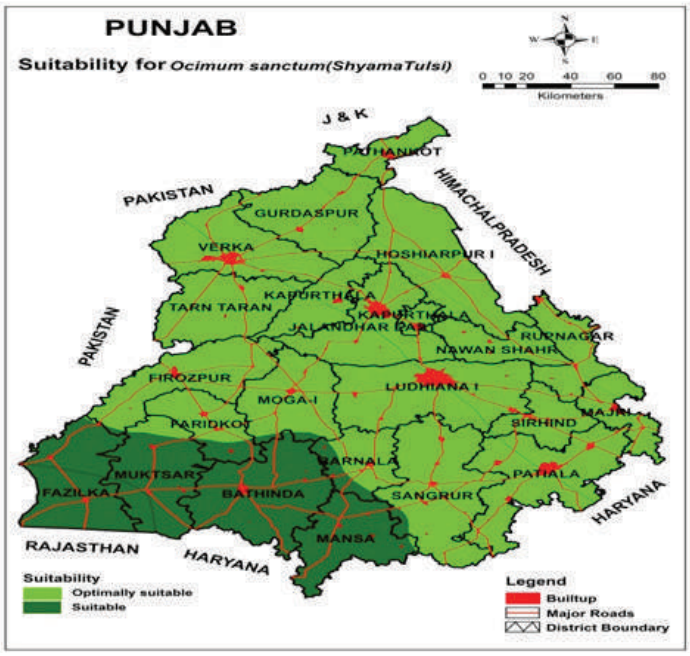
2.2.3. Soil conditions

It grows best in well-drained sandy-loamy soil. However rich loam, saline, alkaline to moderately acidic soils and poor laterite are also suited. Water-logged soil can lead into root-rot disease. It can be preferably grown at a pH range of 5-8.5 (Makri and Kintzios; Jat *et al.* 2014)

2.2.4. Nutrient conditions

The approximate recommended dose of fertilizers required this crop is 30 kg of K2O, P2O5 and 60 kg N per hectare. Cobalt and manganese at 50 and 100 ppm concentration respectively is said to increase the oil content (Jat *et al.* 2014)

Fig. 9.1: Agro-ecological suitability of *O.sanctum* in Punjab



Source: Authors' compilation.

2.2.5. Water conditions

Water requirement depend on the soil's moisture content and season. In *kharif* season, it requires 3-4 irrigations while the plant may require up to 15-20 irrigations per year. Water used for irrigation must comply with national requirements of water used for irrigation.

2.2.6. Agro-ecological suitability in Punjab

Considering the above-mentioned agro-ecological parameters, the growing areas of *O.sanctum* in Punjab is mentioned in the fig. 9.1.

Observing the agro-ecological suitability of *O.sanctum*, it is found to be highly suitable for agro-climatic zones I,II & III comprising from Kandi belt to Pathankot, Hoshiarpur, Gurdaspur, Jalandhar and extending towards Moga, Barnala, Ferozpur and Sangrur districts of Punjab.

2.3. Seeds

2.3.1. Seeds and cultivar

There are seven *Ocimum* species and there are nine varieties named CIM Ayu, CIM saumya, CIM angana, CIM jyoti, CIM Kanchan, CIM surabhi, CIM sharada, CIM snigdha, CIM sharada stocked at CSIR-CIMAP. Central Institute of Medicinal and Aromatic Plants, Lucknow must be contacted regarding the released the varieties CIM-Ayu and CIM-Kanchan.

2.3.2. Morphology of the seeds of O.sanctum

The seeds must be fresh from the stock of pedigree. Seeds of *O.sanctum* are brownish-reddish-yellow in color with shining globose-subglobose seed coat which becomes mucilaginous when wet (Jat *et al.* 2014).

2.3.3. Propagation

The plant is mostly propagated through seeds which must be fresh.

2.4. Cultivation method

2.4.1. Selection and preparation of cultivation site

Land is prepared by ploughing, and leveling. It is essential to remove weeds during the initial periods. The land must be free from heavy metals, and excessive chemical fertilisers.

Fig 9.2: Preparation of nursery and field for *O.sanctum*.

Source: Authors' compilation.

2.4.2. *Sowing and nursery management*

Sowing

The seeds are scattered on the nursery beds manually with 2 cm depth. As seeds are small in size, it can be mixed with the sand for sowing.

Nursery management

Nursery can be raised in the starting month of June. Beds are formed for raising the nursery and must be supplied with farm yard manure or vermi-compost. 50-100 g of seeds is sufficient to raise seedlings for 1 acre land. The Fig. 9.2 represents the farmers preparing nursery and fields for *O.sanctum* in the Punjab.

Transplanting

Transplanting is done in the month of August or when seedlings are six weeks old having 4-6 leaves.

2.4.3. *Transplanting*

Rate of seedlings per acre: 8000-12000
Plant to plant distance: 40-45 cm
Row to row distance: 40-45 cm
Sowing depth: 5 cm

Table 9.4: Diseases of *O.sanctum*

Insect pests	Indications	Treatment
Leaf roller	Roller stick to the under surface of leaves causing them to roll back length wise.	Boil neem leaves for spraying or spray Azadirachtin 10,000 ppm
Tulsi lace wing	Caused by *Cochlochila bullita*	
Diseases	**Causing organism**	**Treatment**
Powdery mildew	*Oidium spp.*	Spraying wet sulphur 4g/l
Seedling blight	*Rhizoctonia solani*	Drenching the nursery bed with Bavistin 1%
Root rot	*Rhizoctonia batalicola*	

Source: Jat et al. 2014

2.4.4. Fertilisation Compost or farm yard manure approximately 9-11 tonne/acre is applied during the soil preparation by the farmers of Punjab.

2.4.5. Field management

- **Irrigation:** Generally, 3-4 irrigations are sufficient if only one harvest is required. If plant is grown for a year, then 15-20 irrigations per year are required.
- **Weeding and intercultural operations** Field should be devoid of weeds during the entire period of growth.
- ***Weeding*** Three weeding are required and first weeding is done after 30 days of planting when the weeds start to compete with the principal crop for nutrition and sunlight. Second weeding can be done after one month followed by third weeding based on visualizing the weeds. Hoeing is required at two months after planting.

Fig. 9.3: Tulsi field in Punjab.

Source: Authors' compilation.

2.5. Prevention and control of plant diseases and pests: No serious pests or diseases have been observed for this plant by the selected cultivars in Punjab. However, there can be chances of root rot due to water logging. Therefore, proper drainage of soil must be maintained. Some of the reported pests, diseases, symptoms of O.sanctum are mentioned in the table 9.4. (Jat *et al*. 2014).

2.6. Harvest and postharvest processing

2.6.1. The best harvesting time, and quality evaluation prior to harvest

First harvesting is done after 80-90 days of transplanting. In Punjab, this is considered as a *Kharif* plant and only one harvesting is carried out. The harvest is done at a full bloom stage during sunny day as represented in the fig. 9.3. Harvesting is avoided in the next day after rainfall. Plant are cut 15-20 cm above the ground level. If the plant is cultivated for the whole year, then the first harvesting is done at the end of third month after planting and subsequent harvesting after 60-80 days interval.

2.6.2. Post-Harvest processing method

The harvested crop is allowed to wilt in the clean area for 4-6 hours to reduce the moisture. The leaves are dried for further processing. Oil is extracted from the leaves and the whole plant using steam distillation. The distillation unit should be cleaned and the collected oil should be passed from anhydrous sodium sulphate 15-20g per litre to remove the moisture. The oil should be stored in amber colored glass bottles or stainless steel containers to avoid degradation of oil (*Jat et al*. 2014).

3. Good collection Practices

For guidelines required for the collection of medicinal plants, refer to the WHO good agricultural and collection practices guidelines 2003[3] and guidelines on good field collection practices for Indian medicinal plants, 2009.[4]

4. Quality control requirements for herbal materials of O.sanctum

4.1 Basic quality requirements for herbal materials

4.1.1. Selection of species or botanical variety

In general, national pharmacopoeias and concerned authoritative institutes should be consulted before selection of varieties. Directorate of medicinal and aromatic plants research-ICAR, Anand, Gujrat, India must be consulted. The detailed requirements for

Table 9.5: Physico-chemical parameters of O.sanctum

Physico-chemical parameters	API (The Ayurvedic Pharmacopoeia of India, 1989)	Other reported literature (Gupta et al. 2008; Indian Herbal Pharmacopoeia, 1998)
Foreign matter	n.m.t. 2 %	n.m.t. 2.0 %
Total ash	n.m.t. 19 %	n.m.t. 17.7 %
Acid insoluble ash	n.m.t. 3 %	n.m.t. 2.8 %
Alcohol soluble extractive	n.l.t. 6 %	n.l.t. 8.0 %
Water soluble extractive	n.l.t. 13 %	n.l.t. 19.0 %

Source: Reference already provided
n.m.t: not more than; n.l.t: not less than

Table 9.6: Qualitative and quantitative ranges of eugenol and urosolic acid in *O.sanctum*

Method	API (The Ayurvedic Pharmacopoeia of India, 1989)	Other reported literature (Gupta *et al.* 2008)	General method of experimentation
TLC	Carvacarol, Caryophyllene, Nerol and camphene with violet to blue color	Urosolic acid and eugenol spot at Rf 0.50 and 0.74 respectively. (Urosolic acid: Purple; Eugenol: Brown)	**API:** TLC of alcoholic extract of drug. Solvent system: Toulene: Ethyl acetate (9:1) on exposure to Iodine solution, and spraying vanillin-sulphuric acid reagent. For detailed method, refer, The Ayurvedic Pharmacopoeia of India [5] **Gupta *et al.* 2008:** Reflux powdered drug with methanol on water bath. Solvent system: Toulene: Ethyl acetate: Formic acid (7:3:0.3) Visualization with spraying plate with anisaldehyde-sulphuric acid reagent with heating the plate at 100°C. For detailed method refer, Quality standards of Indian medicinal plants [6]
HPTLC	--	Eugenol (4.0 % w/v) and Urosolic acid (0.91 to 2.0 % w/v)	Solvent system for HPTLC of Eugenol: Toulene: Ethyl acetate: Formic acid: Methanol (3: 2: 0.4: 0.4). Scanning at 280 nm. Solvent system for HPTLC of Ursolic acid: Toulene: Ethyl acetate: Formic acid: (7: 3: 0.3). Scanning at 530 nm and derivatization with anisaldeyde-sulphuric acid reagent by heating 100°C till colored bands appears. For detailed method, refer, Quality standards of Indian medicinal plants[7]

Source: Reference already provided

Table 9.7: Toxicity indicators of *O.sanctum*

Pesticide residues (World Health Organization, 1998, 2011)	Aldrin and dieldrin not more than 0.05 mg/kg. Total residue consumed should not be more than 1 % from the medicinal plant material
Microbial contamination (World Health Organization, 1998, 2011)	**For crude plant:** *Escherichia coli*, maximum 10^4 per gram; mould propagules, maximum 10^5 per gram. **For pre-treated plant:** aerobic bacteria, maximum 10^7 per gram yeasts and moulds, maximum 10^4 per gram; *Escherichia coli*, maximum 10^2 per gram; other *Enterobacteria*, maximum 10^4 per gram; *Salmonellae*, none **Plant materials for internal use:** aerobic bacteria, maximum 10^5 per gram; yeasts and moulds, maximum 10^3 per gram; *Escherichia coli*, maximum 10 per gram; other *Enterobacteria*, maximum 10^3 per gram; salmonellae, none
Heavy metal residue (World Health Organization, 1998, 2011)	Lead: n.m.t. 10mg/kg Cadmium: n.m.t. 0.3mg/kg
Aflatoxins (World Health Organization, 1998, 2011)	Avoid Aflatoxins B1, B2, G1 and G2 in plant materials

Source: Reference already provided
n.m.t.: not more than; n.l.t.: not less than

the selection of species or botanical variety are mentioned in the general GAP guidelines described in chapter V of this report.

4.1.2. National quality specification and requirements for herbal materials

National quality specifications on *O.sanctum* must be consulted in order to achieve optimum quality of the crop. Apart from the present monograph, the monographs on *O.sanctum* are mentioned in the API, and Indian Council of Medical Research (ICMR) for standard quality specifications (The Ayurvedic Pharmacopoeia of India, 1989; Gupta *et al.* 2008).

4.2. Basic quality specification for herbal materials of O.sanctum

4.2.1. Physico-chemical parameters

The physico-chemical parameters mentioned in the API and other standard literature are mentioned in the Table 9.5.

4.2.2. Qualitative and quantitative estimation of O.sanctum

The qualitative (Rf) and quantitative ranges of eugenol mentioned in the API and other standard literature are mentioned in the Table 9.6.

4.2.3. *Ranges of toxicity indicators in O.sanctum*

The toxicity indicators mentioned in various standard literatures are mentioned in the Table 9.7.

4.3. Methods for quality analysis

- Refer, *Quality control methods for medicinal plant materials.*[8]
- Refer to Appendix(s) *The Ayurvedic Pharmacopoeia of India.*[9]
- Refer, Appendix-I, *Quality standards of Indian medicinal plants.*[10]

Endnotes

1 Jat, R.S., Reddy Nagaraja, R., Manivel, P. 2014. Cultivation of Ocimum. ICAR- Directorate of Medicinal and Aromatic Plants Research, Boriavi, Anand. pp.1-8.

2 Compound summary of eugenol with Pubchem CID: 3314 in Pubchem database, https://pubchem.ncbi.nlm.nih.gov/compound/Eugenol

3 Kumar, A., Rahal, A., Chakraborty, S., Tiwari, R., Latheef, S.K. and Dhama, K. 2013. Ocimum sanctum (Tulsi): a miracle herb and boon to medical science–A Review. *International Journal of Agronomy and Plant Production,* 4(7): 1580-89.

4 Organización Mundial de la Salud, World Health Organization. 2003. WHO Guidelines on Good Agricultural and Collection Practices (GACP) for Medicinal Plants, World Health Organization, Geneva, Switzerland, pp.1-67.

5 Guidelines on good field collection practices for Indian medicinal plants. 2009. National Medicinal Plants Board, Department of AYUSH, Ministry of Health and Family Welfare, Government of India in collaboration with WHO Country office for India, New Delhi. pp. 1-34.

6 *The Ayurvedic Pharmacopoeia of India.* 1989. Part-I, Vol-II, Government of India, Ministry of Health and Family Welfare, Department of AYUSH, New-Delhi. pp.170-176

7 *Quality standards of Indian medicinal plants.* 2010. Vol-V, Indian Council of Medical Research, New-Delhi, India. pp. 278-279.

8 *Quality standards of Indian medicinal plants.* 2010. Vol-V, Indian Council of Medical Research, New-Delhi, India. pp. 280-282.

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11 *Quality standards of Indian medicinal plants.* 2010. Vol-VIII, Appendix-I. Indian Council of Medical Research, New-Delhi, India. pp. 359-373.

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World Health Organization. 1998. Quality control methods for medicinal plant materials. pp. 1-114.

World Health Organization. 2011. Quality control methods for herbal materials pp. 1-200.

10

Monograph on GAP for Rauvolfia serpentina (L.) Benth. ex Kurz

1 Botanical andpharmacological characteristics of *Rauvolfiaserpentina* (L.) Benth. ex Kurz

1.1 Name of plant

1.1.1. Scientific name

Latin botanical name: *Rauvolfia serpentina* (L.) Benth. ex Kurz.
Family: Apocynaceae

Source: Raw image of Rauvolfia serpentina captured during field visit.

1.1.2. Vernacular names

English: Rauvolfia root
Hindi: Chhotaa Chaand, Dhavalbaruaa
Tamil: Sarppaganti
Malayalam: Amalpori
Kannada: Sutranaabhu

1.2. Medicinal plant part of interest

1.2.1. Plant part used in traditional medicine

Roots

1.2.2. Part to be used as raw material for the extraction of reserpine

Roots

1.3. Geographical distribution and the major areas of cultivation

1.3.1. Geographical distribution

R.serpentina (Rauvolfia serpentina (L.) Benth. ex Kurz. will be represented as R.serpentina in this monograph) is native to Asia, Australia, Africa, south and central America (Bhattarai, 2013).

1.3.2. Major areas of cultivation

R.serpentina is native to India, Burma, Bangladesh, Malaysia and Sri Lanka. It is distributed in foot-hills of Himalayan range. It is found all over India but is mostly found in Himachal Pradesh, Jammu and Kashmir, Uttaranchal and Uttar Pradesh etc.1

1.4. Morphological characteristics of roots of R.serpentina

The API and other standard literature mentioning the morphological characteristics of *R.serpentina* are mentioned in the table 10.1.

Table 10.1: Morphological characteristics of *R.serpentina*

Macroscopic analysis	**API** (The Ayurvedic Pharmacopoeia of India, 1989)	**Other reported literature** (Tandon and Sharma, 2010)
Dried Roots	Roots are prominent and tuberous. Rarely branched with irregular longitudinal fissures.	Surface is rough, short, brittle wiry rootlets or the scars left by them, Longitudinally wrinkled or ridged. Fractured smooth surface.

Source: Reference already provided

Table 10.2: Organoleptic characters of *R.serpentina*

Organoleptic analysis	**API** (The Ayurvedic Pharmacopoeia of India, 1989)	**Other reported literature** (Tandon and Sharma, 2010; Indian Herbal Pharmacopoeia, 1998)
Shape	Sub cylindrical, curved, stout.	Cylindrical to subcylindrical, tortuous, stout.
Size	8-15 cm long and 0.5 to 2 cm in thickness. Rootlets are 0.1 mm in diameter.	4 to 5 cm in length and 5 to 20 mm in diameter.
Color	Greyish-yellow to brown	Yellowish brown and buff
Odor	Slight	Indistinct
Taste	Bitter	Bitter

Source: Reference already provided

Table 10.3: Important microscopic characters of *R.serpentina*

Microscopic analysis	**API** (The Ayurvedic Pharmacopoeia of India, 1989)	**Other reported literature** (Wallis 2003; Indian Herbal Pharmacopoeia, 1998)
Transverse section	Stratified cork comprising of 18 layers suberized lignified and unlignified cells. Phelloderm parenchymatous cells with starch grains and calcium oxalate crystals. Pholem fibres are absent and phloem parenchyma mostly filled. There is presence of hilum but fibres, stone cells are absent.	Shows cork, cortex, phloem, xylem. Presence of cork cambium, growth ring, latex cells, medullary rays, phelloderm, prismatic crystals of calcium oxalate, starch grains, xylem vessel are important descriptors.
Powder microscopy	Simple to compound starch grains, calcium oxalate prisms and clusters, lignified tracheids, xylem fibres irregular in shape. Stone cells phloem fibres absent.	Consists of stratified cork, cork in surface view, group of tracheid and vessel, starch grains, calcium oxalate crystals, xylem fibres and latex cells.

Source: Reference already provided

1.5. General description of characteristics of plant material

1.5.1. Organoleptic characteristics

The organoleptic characteristics of *R.serpentina* highlighted in the API and other standard literature is mentioned in the Table 10.2.

1.5.2. Microscopic characteristics

The microscopic characteristics of R.serpentina highlighted in the API and other standard literature is mentioned in the table 10.3.

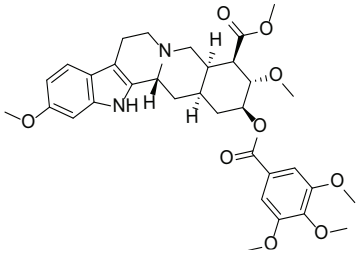
1.6. Chemical composition

1.6.1. The major chemical constituents of R.serpentina

The major chemical constituents investigated in the plant are reserpine, reserpinine, serpentinine, and ajmalicine (Tandon and Sharma, 2010).

1.6.2. Physical and chemical properties of reserpine

Chemical structure:



Molecular formula: $C_{33}H_{40}N_2O_9$

Chemical name: methyl (1R,15S,17R,18R,19S,20S)-6,18-dimethoxy-17-(3,4,5-trimethoxybenzoyl) oxy-1,3,11,12,14,15,16,17,18,19,20,21-dodecahydroyohimban-19-carboxylate

Molecular weight: 608.7 g/mol

Description: White or cream or light yellow crystalline powder which is odourless and bitter in taste

Solubility: It is soluble in glacial acetic acid, chloroform, methylene chloride, benzene, methanol, acetone

Melting point: 264-265°C

Detailed quality specifications of reserpine, refer compound summary of reserpine.[2]

1.7 Pharmacological activity

It is used in India as a folk medicine for centuries to treat snake bite, insect bites, malaria, febrile conditions, febrifuge, dysentery, uterine stimulant, abdominal pain and cure for insanity. It is also useful in curing high pressure, anxiety, traumas, excitement epilepsy, mental agitation and eight schizophrenic disorders (Abhijit and De, 2010).

1.7.1. Pharmacological activity of R.serpentina

The root of the plant is used to lower the blood pressure. It is also used to treat mental disorders including bipolar disorders, schizophrenia, and insomnia. It is reported to possess anti-autism properties in children aged 3.5 to 9 years. It is used in the treatment of breast cancer, migraine and improve psychogenic and pruritic dermatosis.[3]

1.7.2. Pharmacological activity of reserpine

In the year 1952, (Novartis) published detailed report on the chemistry and pharmacology of reserpine. Also in the same year, reserpine was introduced as Serpasil drug to treat tachycardia, hypertension, thyrotoxicosis. The oral bioavailability of reserpine ranges from 50-70 per cent. It is used to prevent strokes and problems related to kidney.[4]

2. Good agricultural practices

2.1 Growth and development characteristics

2.1.1. General description

The plant is evergreen shrub having more than 100 species. It is native to tropical and sub-

tropical regions. It is native to southeast Asia's moist and deciduous forests (Bhattarai, 2013).

2.2. Preferred growing conditions

2.2.1. Ecological conditions

It is found almost up to an elevation of 1300-1400 m. It can grow well up to 38°C annual temperature. It grows on vast range of soils but prefers slightly acidic to neutral fertile soil with good drainage.

2.2.2. Climatic conditions

It grows optimally, in an annual temperature range of 10-38°C with 1100-4500 mm annual rainfall.

2.2.3. Soil conditions

It prefers clay-loam, silt loam or sandy loamy soil for good cultivation with pH range 6-8 with good drainage.

2.2.4. Nutrient conditions

Fully composite farm yard manure is required to maintain N,P,K requirements of the plant. Bone meal, ammonium sulphate and leaf mould can also be applied.

2.2.5. Water conditions

Water used for irrigation must comply with national requirements of water. Irrigations must be done on regular intervals with proper drainage to avoid water logging.

2.2.6. Agro-ecological suitability in Punjab

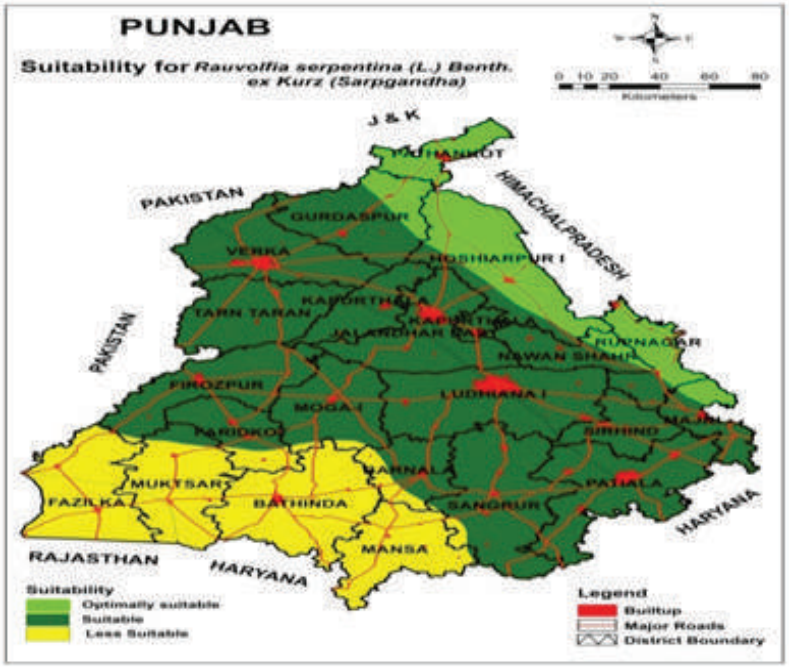
Considering the above-mentioned agro-ecological parameters, the growing areas of R.serpentina in Punjab is represented in the fig. 10.1.

Observing Based on agro-ecological zoning, Sarpgandha was found optimally suitable for agro-climatic zone-I comprising of Kandi belt to Pathankot, Hoshiarpur and Roopnagar districts of Punjab. Subsequently, it was least suitable for western plain, aried agro-climatic zones i.e. -I & IV comprising of Bathinda, Mukstar, Mansa and Fazilka districts of Punjab.

2.3. Seeds

2.3.1. Seeds and cultivar

Fig. 10.1: Agro-ecological suitability of *R.serpentina* in Punjab



Source: Authors' compilation.

Germination rate of seeds is highly variable (5-30%) even when heavy seeds are chosen for sowing purpose. The healthy and heavy seeds are soaked in water for 24 hours before sowing. Varieties like RS-1, CIM Sheel, RI-1, Sarpgandha are reported by CSIR-CIMAP, Lucknow, India, regional research laboratory, Jammu Tawi (J&K), and tropical forest research institute, Jabalpur, Madhya Pradesh (Anonymous, 2009; Bhattarai, 2013).

2.3.2. Morphology of the seeds of R.serpentina

The fruits of the plant are round in shape having approximately 5 cm diameter. The seeds are cream brownish to blackish in color varying from light to heavy seeds (Bhattarai, 2013).

2.3.3. Propagation

The plant is mostly propagated through seeds, root cuttings, stem cuttings and root stumps. However, propagation through seeds is the best method for commercial cultivation (Anonymous, 2009).

2.4. Cultivation method

2.4.1. Selection and preparation of cultivation site

Site should be selected after consulting meteorological and edaphic data. Land ploughing shall be carried out depending upon the type of soil. Generally 2-3 ploughing should be done followed by tilthing and leveling as represented in the fig. 10.2. Farm yard manure, vermi compost, green manure, etc. should be applied to the field before transplanting. Soil should be brought to desired tilth for growing seedling. Initial flush of weeds should be avoided to ensure weed free young plant. Divide the field according to the field pattern or slope for drainage of water.

2.4.2. Sowing and nursery management

Sowing

Heavy seeds must be chosen that can be separated from light seeds by simple water flotation. The healthy seeds are soaked in water for 24 hours before sowing.

Nursery management: Nursery shall be raised in the month of May. Nursery measuring 250 square feet with 30 cm in height shall be

Fig. 10.2: Land preparation

Source: Authors' compilation.

prepared and shade net can be used to prevent excessive sunlight. Seeds are sprouted after 21 days of sowing. Approximately 2 kg seeds are required for seedlings required for 1 acre of land. In root cutting, the roots ranging from 5-6 cm long are cut and planted in the well manured nursery beds with proper watering. In approximately three weeks, sprouting of plant is observed and these can be planted during rainy season to field. In case of stem cuttings, healthy stems are cut measuring from 15 to 22 cm. The cuttings are planted in nursery beds maintaining good moisture. Raising nursery can also be done by root stumps method, in which approximately 5 cm of roots with portion of stem above collar having 4-8 leaves are directly transplanted. Beds are formed for raising the nursery and must be supplied with farm yard manure or vermi-compost (Anonymous, 2009).

2.4.3. Transplanting

Transplanting is done in the month of July-August or when seedlings are six weeks old having 4-6 leaves. Seedlings of 10-15 cm height are considered optimum, however it can extend up to 30 cm. Similarly, the plant spacing and seedling depth is represented in the fig. 10.3.
Rate of seedlings per acre: 16,000-20,000
Plant to plant distance: 30-35 cm
Row to row distance: 60-65 cm
Sowing depth: 10 cm

2.4.4. Fertilization

Compost or farm yard manure approximately 14-16 tonne/acre shall be applied during the soil preparation. 20 Kg of bone meal, 2.5 kg of ammonium sulphate and 40 kg of leaf mould can also be mixed with manure during transplantation. One handful of mixture to each hole is sufficient.

Fig 10.3: Cultivation of *R.serpentina.*

Source: Authors' compilation.

2.4.5. Field management

- **Irrigation:** Transplantation is generally done during rainy season. First irrigation should be done just after transplanting and at regular intervals till the seedlings get established. Total 9-10 irrigations are required for proper production of the plant. During hot and dry season 2-3 irrigation in month is sufficient. While on other seasons one month interval gap is required for irrigation.

- **Weeding and intercultural operations:** Field should be devoid of weeds during the entire period of growth. Weeding: Approximately 2-3 weedings and 2 hoeings are recommended. The first weeding shall be after 30 days of planting when the weeds start to compete with the principal crop for nutrition and sunlight.

2.5. Prevention and control of plant diseases and pests

No serious pests or diseases have been reported for this plant by the selected cultivars in Punjab. Seeds can be treated with trichoderma: a bio-pesticide to avoid microbial infestation. However, some diseases, treatment, and symptoms reported for this plant as mentioned in the table 10.4. (Bhattarai, 2013).

2.6. Harvest and postharvest processing

2.6.1. The best harvesting time, and quality evaluation prior to harvest

The plant is harvested during 18 month after transplantation as it gives maximum concentration of alkaloid. Uprooting the crop is recommended coinciding with the shedding of leaves during autumn season. Roots may go 40 cm deep during harvest (Bhatarai, 2013). Roots should be collected with bark intact and secondary roots or fibrous roots should be properly handled

Post-Harvest processing method: The harvested roots should be made free from the soil and extraneous matter, and properly washed to cut into 12 to 15 cm pieces for drying using air drying. The dried roots are stored in polythene lined gunny bags in cool dry place for protection against mould.

3. Good collection practices

For guidelines required for the collection of medicinal plants, refer to the WHO good agricultural and collection practices guidelines, 2003[5] and guidelines on good field collection practices for Indian medicinal plants, 2009.[6]

4. Quality control requirements for herbal materials of R.serpentina

4.1. Basic quality requirements for herbal materials

4.1.1. Selection of species or botanical variety

Regional research laboratory, Jammu Tawi (J&K), CIMAP Lucknow and tropical forest research institute, Jabalpur, Madhya Pradesh shall be consulted. The detailed requirements for selection of species or botanical variety are mentioned in the general GAP guidelines described in chapter V of this book.

Table 10.4 : Diseases of *R.serpentina*

Disease	Management
Leaf spots cause by *Cercospora rauvolfiae* Chupp & Muler. and *Alternaria tenuis*.	By flooding
Mosaic	
Root knot appearing as gall due to nematodes	
Fungus attack on leaves affecting flower and fruits	

Source: Bhattarai, 2013

4.1.2. National quality specification and requirements for herbal materials

National quality specifications on *R.serpentina* must be consulted in order to achieve optimum quality of the crop. Apart from thid monograph, the monograph on R.serpentina are mentioned in the API, and ICMR for standard quality specifications.

4.2. Basic quality specification for herbal materials of R.serpentina

Table 10.5: Physico-chemical parameters of *R.serpentina*

Physico-chemical parameters	API (The Ayurvedic Pharmacopoeia of India, 1989)	Other reported literature (Tandon and Sharma, 2010)
Foreign matter	n.m.t. 2 %	n.m.t. 2.0 %
Total ash	n.m.t. 8 %	n.m.t. 9.0 %
Acid insoluble ash	n.m.t. 1 %	n.m.t. 3.0 %
Alcohol soluble extractive	n.l.t. 4 %	n.l.t. 4.5 %
Water soluble extractive	n.l.t. 10 %	n.l.t. 9.0 %

Source: Reference already provided
n.m.t: not more than; n.l.t: not less than

Table 10.6 : Qualitative and quantitative ranges of reserpine in *R.serpentina*

Major active constituent	API (The Ayurvedic Pharmacopoeia of India, 1989)	Other reported literature (Tandon and Sharma, 2010)	General method of experimentation
TLC	Reserpine spot at Rf. 0.82 (Reddish brown color)	Reserpine spot at Rf at 0.58 (Yellowish orange).	**API:** TLC of methanol and ammonia extract of the plant using solvent system: Toulene: Ethyl acetate: Diethylamine (70: 20: 10) and spraying with Dragendorff reagent. For detailed method, refer, *The Ayurvedic Pharmacopoeia of India* [7] **Tandon and Sharma, 2010:** Maceration of powdered root overnight with ammonical chloroform. Solvent system: Toulene: Ethyl acetate:Diethylamine (7:2:1.5). Visualization with modified Dragendorff's reagent followed by 10 % methanolic sulphuric acid solution. For detailed method, refer, Quality *standards of Indian medicinal plants* [8]
HPTLC	--	Percentage of reserpine ranges from 0.12 to 0.47	Extraction of powdered roots with methanol using soxhlet apparatus followed by extraction with chloroform and basification with ammonia. Scanning at UV light at 266 nm. For detailed method, refer, *Quality standards of Indian medicinal plants* [9]

Source: Reference already provided

Table 10.7: Toxicity indicators of *R.serpentina*

Pesticide residues (World Health Organization, 1998; 2011)	Aldrin and dieldrin not more than 0.05 mg/kg. Total residue consumed should not be more than 1 % from the medicinal plant material
Microbial contamination (World Health Organization, 1998; 2011)	**For crude plant:** *Escherichia coli*, maximum 10^4 per gram; mould propagules, maximum 10^5 per gram. **For pre-treated plant:** aerobic bacteria, maximum 10^7 per gram yeasts and moulds, maximum 10^4 per gram; *Escherichia coli*, maximum 10^2 per gram; other *Enterobacteria*, maximum 10^4 per gram; Salmonellae, none. **Plant materials for internal use:** aerobic bacteria, maximum 10^5 per gram; yeasts and moulds, maximum 10^3 per gram; *Escherichia coli*, maximum 10 per gram; other *Enterobacteria*, maximum 10^3 per gram; Salmonellae, none.
Heavy metal residue (World Health Organization, 1998; 2011)	Lead: n.m.t. 10 mg/kg Cadmium: n.m.t. 0.3 mg/kg
Aflatoxins (World Health Organization 1998; 2011)	Avoid Aflatoxins B1, B2, G1 and G2 in plant materials

Source: Reference already provided

n.m.t.: not more than; n.l.t.: not less than

4.2.1. Physico-chemical parameters

The physico-chemical parameters mentioned in the API and other standard literature are mentioned in the table 10.5.

4.2.2. Qualitative and quantitative estimation of R.serpentina

The qualitative (R_f) and quantitative ranges of reserpine mentioned in the API and other standard literature are mentioned in the Table 10.6.

4.2.3. Ranges of toxicity indicators in R.serpentina

The toxicity indicators mentioned in various standard literatures are mentioned in the Table 10.7.

Methods for quality analysis

- Refer, *Quality control methods for medicinal plant materials.*[10]
- Refer, Appendix(s) *The Ayurvedic Pharmacopoeia of India.*[11]
- Refer, Appendix-I, *Quality standards of Indian medicinal plants.*[12]

Endnotes

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[7] *The Ayurvedic Pharmacopoeia of India.* 1989. Part-I e-book, Vol-V. Government of India, Ministry of Health and Family Welfare, Department of AYUSH, New-Delhi. pp.194-195.

[8] *Quality standards of Indian medicinal plants.* 2010. Vol-VIII, Indian Council of Medical Research, New-Delhi, India. pp. 276-277.

[9] *Quality standards of Indian medicinal plants.* 2010. Vol-VIII, Indian Council of Medical Research, New-Delhi, India. pp. 277-278.

[10] *Quality control methods for medicinal plant materials.* 1998. World Health Organization, Geneva. pp. 1-114.

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11

Agro-Economic Analysis: A Farm-Level Assessment for Cultivation of Medicinal Plants

12.1 Introduction

Punjab is an agricultural state and is mostly dependent on agriculture.[1] Recently 199.97 lakh metric tonnes (MT) of paddy has been procured in Punjab by the government of India during 2020-21, which is 19 per cent more than the target of 168 lakh metric tonnes and 26 per cent more than the procurement done during the corresponding period of 2019-20.[2] In this situation, it is imperative to aware and motivate farmers on shifting from the traditional cropping pattern to commercially important alternative crops.[3] In this regard, adoption of potential medicinal plants can be good competitor to the traditional crops (Phondani et al. 2011). The Ministry of Ayush, Government of India has expressed medicinal plants to emerge as an attractive farming option and has decided to support the cultivation of medicinal plants in 2.25 lakh hectares in view of generating an income of Rs.5000/- crores for the farmers.[4] In order to meet the great benefits, it is necessary to provide a roadmap related to agro-economics of medicinal plants production to the farmers of Punjab. The present report has provided the farm-level agro-economics study of the selected medicinal plants, i.e. *Curcuma longa, Aloe vera, Ocimum sanctum, Emblica officinalis and, Rauvolfia serpentina* that are presently cultivated by the farmers. The objective of this study is to estimate the cost-return structure of the selected medicinal plants. Furthermore, the study also encompasses comparative study of the selected medicinal plants with the traditional crops.

12.2 Methodology

The study was conducted on the selected medicinal plants cultivators during the year 2019 in Punjab. To meet the objectives of the study, the agro-economics inputs were processed after collecting the primary data through personal interviews using a semi-structured, pre-tested questionnaire from the farmers as mentioned in Chapter 3 of this report. Total 68 farmers cultivating *Curcuma longa, Aloe vera, Ocimum sanctum, Emblica officinalis,* and *Rauvolfia serpentina* were selected in the study. The collected data was thoroughly checked, compiled and tabulated. The per acre cost and returns involved in the cultivation were calculated at current prices. The actual expenses in cash and kind incurred in production by owner which included human labour, machine labour, value of seeds, insecticides, pesticides, manures, fertilizers, irrigation, miscellaneous expenses was studied in the present study. The cost-return analysis was processed following descriptive statistics such as average prices of the crops to calculate total variable costs, yield, gross returns, returns over variable costs (Kaur *et al.* 2018). The study also presents

some qualitative and exploratory findings on production and marketing aspects of these crops.

12.3 Results and discussion

The variable costs such as seeds, seed treatment, fertilizers, plant protection, machine labour costs, irrigation, human labour, post-harvest costs were included in the study to estimate gross returns per acre, variable cost per acre, and return over variable cost/acre. In Punjab, the average labour cost per day was Rs.320/ day and each labour worked for 8 hrs./day which costed him around Rs.40/hrs. Similarly, the average cost of the fertilizer was estimated to be Rs.250/tonne. The machine labour which mainly exercised tillage, sowing, harvesting using machinery costed Rs.450/hrs. on average. In Punjab, irrigation is a free process that is supported by the government, however, Rs. 250/acre has been allocated to this subhead for wear and tear of the motors and bore wells. As mentioned earlier in the previous chapters, *Curcuma longa, Aloe vera, Emblica officinalis, Ocimum sanctum,* and *Rauvolfia serpentina* were cultivated by the farmers. The cost-return structures of selected medicinal plants are mentioned below:

12.3.1. Cost-Return Structure of Curcuma longa

The cost-return analysis was analyzed after calculating the input costs of each agricultural process to its processing costs. The costing structure of *Curcuma longa* involves cost of seeds, sowing, machine, fertilizers application, cost of plant protection, irrigation, weeding, harvesting. After harvesting, post-harvest management of *Curcuma longa* also has significant share in the production costs of *Curcuma longa*. The post-harvest management of turmeric included cleaning, polishing, grinding of *Curcuma longa*. During the survey, it was found that 98 per cent of the farmers sold *Curcuma longa* in processed form (powder) directly to the costumers. Only three farmers out of the total *Curcuma longa* cultivators sold raw *Curcuma longa* to local mandi or processing units like Fapro, Hoshiarpur at Rs.8-10/kg while the processer sold *Curcuma longa* for Rs.120-180/ Kg in retail. Therefore, it was concluded that the farmer cultivating as well as processing the *Curcuma longa* had more returns on the variable costs than the one selling raw *Curcuma longa*. In the present study, the agricultural as well as the post-harvest cost-returns have been analyzed as mentioned in the Table 11.1. On average, 110 quintals of *Curcuma longa* was the total wet yield out of which 17.6 quintal was the dry yield from one acre of land. From the total production cost, 53% is the share of post-harvest management of *Curcuma longa*. The selling price of their produce ranged from Rs.100/kg to Rs.200/kg depending upon the demand and quality of the produce. The farmers earned net profit of Rs.73,725/- by incurring Rs.1,02,275/- as variable cost. The returns from the *Curcuma longa* are only possible if standard agricultural practices are followed, grown on optimum climatic conditions, and assuring prior marketing.

12.3.2. Cost-Return Structure of Aloe vera

Aloe vera is a five year crop and the first cutting of the crop is taken after 10-11 months of the plantation (Jat *et al.* 2015). From second year to fifth year three cuttings per annum are done by the farmers. On average, one cutting yields 20-30 tonnes of leaves from 1 acre of land. At present, most of the farmers of Punjab received Rs.2.5/ kg rate of Aloe vera leaves from industries. The farmers cultivating *Aloe vera* directly sold the produce to the interested industries such as the Unati co-operative marketing-cum-processing society ltd. situated at Talwara, Hoshiarpur and Herbal trends, Gidderbaha, Punjab. The cultivation of *Aloe vera* is hugely labour extensive as approximately 50-77 per cent is the share of labour cost in the whole agricultural process. The gross returns of the crop was Rs.75,000/- out of which Rs.45,619/- was the variable cost and Rs.29,381/- was the return over the variable cost for the first year. On average, 60 tonnes of leaves are harvested in

Table 11.1: Agro-economics of *Curcuma longa*

S.No.	Particulars	Quantity	Value (Rs.)	Share in agricultural process
A	**Income estimate**			
	Gross return/acre	Rs.100/kg selling price of powder × dry yield	1,76,000	--
B	**Expenditure estimate**			
1.	**Physical input**			
	Seed/acre (quintals)	6.5	6.5×3600 = 23,400	30.85%
	Seed treatment	--	400	
	Fertilizers Farm yard manure)/ acre (tonnes) Urea, DAP, and Potash fertilizers/acre	20 Less than 50 kg	20×250 = 5,000 2,250	
	Plant protection/acre (mostly bio-pesticides, fungicide, weedicide)	--	1200	
2	**Machine labour** • Tillage/acre (hrs.) • Sowing/acre (hrs.) • Harvesting/acre (hrs.)	3.5 hrs. 4.5 hrs. 2.5 hrs.	450/hrs.=1,575/- 450/hrs.= 2,025/- 450/hrs.= 1,125/-	4.52%
3	**Irrigation (hrs.)**	13 irrigations = 32.5 hrs.	250/-	0.23%
4	**Human labour** • Fertilizer application • Sowing • Weedings • Harvesting (hrs./acre)	16 hrs. 64 hrs. 160 hrs. (2 times, 10 labours one time) 72 hrs. (9 labours)	640/- 2,560/- 6,400/- 2,880/-	11.93%
	Post-harvest			
1.	Wet yield (quin./acre)	110	--	52.44%
2.	Dry yield (quin./acre)	17.6	--	
3.	Cleaning	48 hrs. (6 labours)	1,920/-	
4.	Boiling	200/quin.	22,000/-	
5.	Polishing	500/quin.	88,00/-	
6.	Grinding	1000/quin.	17,600/-	
7.	Transportation	--	3,000/-	
8.	Packing cost	--	1,000/-	
	Miscellaneous		500/-	
	Variable cost/acre		1,02,275	
C	**Profit (Rs.)**			
	Return over variable cost/acre		73,725/-	

Source: Authors' compilation.

three cuttings in one acre of land for the second year with Rs.1,08,750/- as returns over variable cost. The cost-return analysis for the second year remained same for the third, fourth and fifth years as mentioned in the Table 11.2. It is advisable to cultivate *Aloe vera* on optimum agro-ecological conditions, adopting standard agricultural practices and assuring marketing before its cultivation for generating economic benefits (*Jat et al.* 2015).

12.3.3. Cost-return structure of Emblica officinalis

Emblica officinalis is a perennial crop found in the sub-mountainous area covering upper regions of Hoshiarpur and Pathankot districts of Punjab (Rawat *et al.* 2013). There is shortage of water in this area because of its land pattern (Bala, 2014). Crops like wheat and maize are grown in this region and additionally farmers collect fruits of *Emblica officinalis* from their sub-mountainous field. The crop depends on rain fed for water requirements; however some farmers hire labours that use water drums loaded in trolleys for irrigating their crops. The *Emblica officinalis* growers bear the transportation charges and sold their produce directly to the nearby Unati-co-operative marketing-cum-processing society ltd. situated at Talwara, Punjab. Only three farmers from the selected respondents relied on middlemen that collected fruits from their field and gave them 50% of their returns from the variable cost. The rate of the *Emblica officinalis* fruits keeps on changing as per the demand. At present, Emblica officinalis collected from the region is sold at Rs.18/kg and one acre of fruiting *Emblica officinalis* trees yielded 88.2 quintal of fruits on average as mentioned in the table 11.3. Furthermore, on average 70kg fruits are collected by one labour in a day. The farmers purchased one sapling at Rs.10. During the collection of *Emblica officinalis*, seven labours for 18 days were required in one acre of land that shares 78 per cent of the total agricultural cost. The total average return over the variable cost is Rs.88299/- per season from one acre of the fruiting trees (above 5 years of age).

12.3.4. Cost-return structure of Ocimum sanctum

Ocimum sanctum is cultivated in the month of July and harvested in the month of October or November (Jat *et al.* 2014). Nursery is raised and the saplings are transplanted in the field. *Ocimum sanctum* required three manual weedings, 3-4 times irrigation depending upon the rainfall. One acre of *Ocimum sanctum* yielded 3.5 quintal of dried leaves whereas 15 quintal is the yield of dried whole plants. At present, dried leaves of *Ocimum sanctum* are sold at

Table 11.2: Agro-economics of *Aloe vera*

S.No.	Particulars	Quantity	Value (Rs.)	Share in agricultural process
A	**Income estimate**			
	Gross return/acre	Rs.2.5/kg selling price of fresh leaves × yield	75,000/-(1st year)	--
B	**Expenditure estimate**			
1.	**Physical input**			
	First year			
	Suckers/acre	18,000	18,000 × 1 = 18,000/-	40.9%
	Fertilizers (farm yard manure)/acre (tonnes)	15	15×250= 3750	
2	**Machine labour** • Field preparation (hrs.)	4.5	450/hrs.=2025/-	3.81%

Table 11.2 Continue...

Table 11.2 Continue...

4	**Human labour** • Fertilizer application • Sowing • Weedings • Harvesting (hrs./acre)	24 hrs. 160 hrs. 320 hrs. (4 times/ year and 10 labours/ acre) 160 hrs.	960/- 6400/- 12,800/- 6400/-	50.03%
3	**Irrigation (hrs.)**	5 irrigations/year = 62.5 hrs.	250/-	0.47%
	Transportation	--	2000/-	3.76%
	Miscellaneous		500/-	
	Yield (tonne/acre)	30		--
	Subsidy by NMPB per acre (30% of 24889 production cost)		7,466.7/-	
	Variable cost/acre		45,619/-	
C	**Profit (Rs.)**			
	Return over variable cost/ acre		29,381/-	
	Second year			
A	**Income estimate**			
	Gross returns/acre	Rs. 2.5/kg selling price of fresh leaves × yield	1,50,000/-	
B	**Expenditure estimate**			
	Physical input			
	Fertilizer (farm yard manure)/ acre (tonnes)	10	10×250= 2,500/-	6.0%
	Irrigation	62.5 hrs.	250/-	0.60
	Human labour • Weedings (hrs.acre) • Cuttings (hrs./acre)	320 hrs. (4 times/ year and 10 labours/ acre) 480 hrs. (3 cuttings/ year and 20 labours/ cutting)	12,800/- 19,200/-	77.57%
	Transportation	--	6,000/-	14.5%
	Miscellaneous		500/-	1.21%
	Yield (tonne/acre)	Approximately 60 tonnes leaves from three cuttings in one year		
	Variable cost for second year/acre		41,250/-	
C	**Profit (Rs.)**			
	Return over variable cost/ acre/annum		1,08,750/-	
The cost-return structure for second year remains approximately same for the year three, four and five.				

Source: Authors' compilation.

Table 11.3: Agro-economics of *Emblica officinalis*

S.No.	Particulars	Quantity	Value (Rs.)	Share in agricultural process
A	**Income estimate**			
	Gross return/acre	Rs.18/kg selling price of fresh fruits × yield	1,58,760/-	
B	**Expenditure estimate**			
1.	**Physical input**			
	Planting material/acre	150 saplings	1 0 × 1 5 0 = 1,500/-	4.49%
	Fertilizers Farm yard manure)/acre (tonne) Urea (kg/acre)	4 Less than 50 kg	4×250= 1,000/- 280	
	Plant protection/acre (bio-pesticides, fungicide, weedicide)	--	900/-	
3	**Irrigation (hrs.)**	--	3,200/-	3.90%
4	**Human labour** • Fertilizer application • Sowing • Field management • Plucking (hrs./acre)	16 hrs. 320 hrs. (40 labours, 10 days) 256 hrs. (32 labours, 8 days for 1st and 2nd years) 1008 hrs. (126 labours; 1 labour collects average 70 kg fruit; 7 labours in 1 acre for 18 days)	640/- 12,800/- 10,240/ 40,320/-	78.16%
	Transportation	--	10,500/-	12.82%
	Miscellaneous	--	500/-	0.61%
	Yield/acre	On average 88.2 quintal of *Emblica officinalis* fruits. On average 58.8 kg from one fruiting free.		
	Subsidy by NMPB per acre (30% of 38066 production cost)		11,419/-	
	Variable cost/acre		70,461/-	
C	**Profit (Rs.)**			
	Returns over variable cost/acre		88,299/-	

Source: Authors' compilation.

Rs.150/kg and whole plant is sold at Rs.50/kg. There is no major disease attack on the crop so no insecticides or pesticides are required during its cultivation. The gross returns of *Ocimum sanctum* are 52,500/- out of which Rs.16,985/- is the variable cost after deducting subsidy amount provided by the NMPB (National Medicinal Plants Board). The returns over the variable cost are Rs.35,515/- from one acre. The farmers cultivating *Ocimum sanctum* in

Punjab sold Ocimum sanctum directly to herbal industries. The cost-return structure for *Ocimum sanctum* is mentioned in the Table 11.4.

12.3.5. Cost-return structure of Rauvolfia serpentina

Rauvolfia serpentina is 18 month crop that is cultivated in the month of July. Its harvesting is carried out during the early autumn next year. The NMPB provides 50 per cent subsidy, i.e. Rs.18,301/- on the production cost (as set by the NMPB) of this plant. The crop has a good demand and fetched Rs.600-1100/kg for the dried roots. For its cultivation in one acre, the farmers required 2 kg of seeds which valued about Rs. 8,000/-. The nursery is raised

Table 11.4: Agro-economics of *Ocimum sanctum*

S.No.	Particulars	Quantity	Value (Rs.)	Share in agricultural process
A	**Income estimate**			
	Gross return/acre	Rs.150/kg. selling price of dried leaves × yield	Rs.52,500/-	
B	**Expenditure estimate**			
1.	**Physical input**			
	Seed/acre	300 g	500/-	13.48%
	Fertilizers (farmyard manure)/ acre (tonnes)	10	10×250= 25,00/-	
2	**Machine labour** • Field preparation	4.5 hrs.	2,025/-	9.09%
4	**Human labour** • Nursery preparation • Fertilizer application • Transplantation • Weeding • Harvest • Leaf drying	32 hrs. (4 labours) 16 hrs. (2 labours) 82 hrs. (10 labours) 72 hrs. (three times, 9 labours) 80 hrs. (10 labours) 80 hrs. (five days, 10 labours)	1,280/- 640/- 3,280/- 2,880/- 32,00/- 32,00/-	65.0%
	Irrigation	3-4 times	250/-	1.12%
	Transportation	--	2,000/-	8.98%
	Miscellaneous		500/-	2.24%
	Yield/acre (dry leaves)	3.5 quintal		
	Subsidy by NMPB per acre (30% of 17569.2 production cost)		5,270.7/-	
	Variable cost/acre		16,985/-	
C	**Profit**			
	Returns over variable cost/ acre		35,515/-	

Source: Authors' compilation.

followed by the transplantation. The cultivation of *Rauvolfia serpentina* is labour extensive as 66.30 per cent of the total agricultural cost is shared by the labour cost. In 18 months, it required 9-10 irrigations and there is no major disease attack on the plant. The values related to yield, gross returns, returns over variable cost are mentioned in the Table 11.5. The farmers cultivating *Rauvolfia serpentina* in Punjab sold their produce to AYUSH herbals, Nagrota, Himachal Pradesh which was facilitated by the RCFC-North. The gross returns were Rs.4,87,500/-, out of which Rs.39,129/- was the variable cost and Rs. 4,48,371/- was the return over variable cost.

12.3.6. Cost return analysis of prevalent traditional crops in Punjab

Two-third of the total production of the food grains are contributed by Punjab and is a leading producer of wheat in India (Thakur *et al.* 2016). The major reason behind dominance of wheat and paddy monoculture in the state is the zero risk in crop production, and its

Table 11.5: Agro-economics of *Rauvolfia serpentina*

S.No.	Particulars	Quantity	Value (Rs.)	Share in agricultural process
A	**Income estimate**			
	Estimated gross return/acre	Rs.750/kg. selling price of dried roots × yield	4,87,500/-	
B	**Expenditure estimate**			
1.	**Physical input**			**% share in agricultural process**
	Seed	2 kg	8,000/-	25.42%
	Seed treatment	--	50/-	
	Fertilizers (farmyard manure) tonne/acre	15	1 5 × 2 5 0 = 3,750/-	
	Bio-insecticide	--	300/-	
	Nursery shed	--	2,500	
2	**Machine labour** • Field preparation	4.5 hrs.	2,020/-	3.48%
4	**Human labour** • Nursery preparation • Fertilizer application • Transplantation • Weeding • Harvest • Drying	96 hrs. 16 hrs. 120 hrs. 480 hrs. (2 times a crop cycle) 160 hrs. 80 hrs. (2 labours a day for 5 days)	3,840/- 640/- 4,800/- 19,200/- 6,400/- 3,200/-	66.30%
	Irrigation	9-10 times	250/-	0.43%
	Estimated transportation cost	--	2,000/-	3.48%

Table 11.5 Continue...

Table 11.5 Continue...

	Miscellaneous	--	500/-	0.87%
	Estimated Yield/acre (wet)	24 quintal		
	Estimated Yield/acre (dry)	6.5 quintal		
	Subsidy by NMPB per acre (50% of 36602.5 production cost)		18,301/-	
	Variable cost/acre		39,129/-	
C	**Profit (Rs.)**			
	Returns over variable cost in 18 months		4,48,371/-	

Source: Authors' compilation.

marketing. Besides this, there is 100 per cent assured procurement of these crops in the *mandis* providing farmers a minimum support price (MSP). Punjab has the best marketing system for wheat and paddy crops which is developed by strengthening the infrastructure of the *mandi's*. There are *mandis* every five to six kilometres in Punjab. These *mandis* employ up to 300,000 labourers in transportation, sorting and packing. These *mandis* procure from about 2 million farmers (*Inputs: Article by Arvind Shukla, Gaon Connection, 15/Dec./2020*). The department of economics and sociology, Punjab Agricultural University, Punjab has prepared an executive brief on the district wise cost of cultivation of important crops in Punjab (Kaur *et al*. 2018). The average cost-return analysis of wheat and paddy is mentioned in the Table 11.6.

Table 11.6: Cost Return analysis of the common traditional crops in Punjab

Crops	**Wheat**		**Paddy**	
Physical input	**Cost (Rs./acre)**	**Share in variable cost**	**Cost (Rs./ acre)**	**Share in variable cost**
Seed	981	54.9%	690	43.4%
Chemical fertilizers	2049		1514	
Organic manure	41		82	
Pesticides & Insecticides	723		1396	
Diesel oil	968		1343	
Irrigation	234	2.7%	1459	12.60%
Labour	856	35.24%	3110	38.31%
Human labour				
Machine labour	2198		1324	
Repair maintenance and other operations	616	7.10%	651	5.62%
Variable cost	8666		11,574	
Yield (kg/acre)	1780		2598	
Gross return	31,167		37613	
Return over variable cost	21,668		24612	

Source: Authors' compilation.

Though this extensive cropping pattern has made India grain surplus but on the other hand has led to serious ecological problems, decline in agricultural employment, slowing of productivity growth, over exploitation of ground water resources and decline in soil fertility (Chand, 1999). According to a report, 15,000 litres of water is used to produce one kg of paddy, while requirement is just 600 litres as per Indian Agricultural Research Institute.

The present study emphasised on the agro-economics of the selected medicinal plants and recommends adoption of these medicinal plants in the suitable agro-ecological area after assuring or generating market. This objective behind this study was to highlight cost-return analysis of these medicinal plants so that they can be a strong competitor to the traditional crops in context of feasibility of cultivation and economics. Cultivation of paddy requires intensive irrigation for its cultivation leading to huge underground water exploitation. In general, the selected medicinal plants required less irrigation and are lesser prone to disease attack as compared to paddy. Medicinal plants such as Ocimum sanctum can replace paddy in the Kharif season with more returns on variable costs than paddy if proper marketing channel is established. Similarly, Curcuma longa that was cultivated in the month of April to May and harvested in the month of January can be rotated with the maize crop that is cultivated in the month of February and harvested in June. The cultivation of Aloe vera has annual returns over variable cost of Rs.1,08,750/- for consecutive five years if cultivated on suitable land and assuring its market. This can be potential crop having good opportunities in agribusiness for the farmers especially the farmers that can own processing units or have processing units nearby their agricultural fields. Medicinal plant such as Emblica officinalis can be cultivated in the sub-mountainous region having shortage of water and irrigation facilities. Besides cultivation of wheat and maize in the region, the cultivation of Emblica officinalis can generate additional income to the farmers. This is advantageous to the land where there is a limited carrying of major agricultural processes. Similarly, Rauvolfia serpentina which is 18 month crop can be partially cultivated in a proportion of land with other cash crops or other crops get more profits. The comparative agro-economics analysis between

Table 11.7: Comparative cost-return analysis between traditional crops and medicinal plants

Particulars	Wheat (Rabi)	Paddy (Kharif)	*Curcuma longa* (9 month crop)	*Aloe vera*		*Emblica officinalis* (Perennial)	*Ocimum sanctum* (Kharif)	*Rauvolfia serpentina* (18 months crop)
				1st yr.	2nd to 5th yr.			
Yield (quin./ acre)	17.8	25.98	17.6 (dry yield)	300	600/annum in three cuttings	88.2	3.5	6.5 (dry yield)
Gross return	31,167	37613	1,76,000	75,000/-	1,50,000/-	1,58,760/-	52,500/-	4,87,500/-
Variable cost	8666	11,574	1,02,275	45,619/-	41,250/-	70,461/-	16,985/-	39,129/-
Return over variable cost	21,668	24612	73,725/-	29,381/-	1,08,750/-	88,299/-	35,515/-	4,48,371/-
Profitability per annum	**46,280/-**		**73,725/-**	**92,876/-**		**88,299/-**	**35,515**	**2,98,914/-**

Source: Authors' compilation.

the traditional crops and selected medicinal plants in described in the Table 11.7.

Conclusion

The agro-economics of selected medicinal plants such as *Curcuma longa, Aloe vera, Emblica officinalis, Ocimum sanctum, Rauvolfia serpentina* was carried out. The agro-economics inputs were processed after collecting the primary data through personal interviews using a semi-structured, pre-tested questionnaire from the farmers. The actual expenses in cash and kind incurred in production by owner which included human labour, machine labour, value of seeds, insecticides, pesticides, manures, fertilizers, irrigation, miscellaneous expenses was followed in the present study. The cost-return analysis was processed to calculate total variable costs, yield, gross returns, returns over variable costs. Furthermore, the agro-economics of most prevalent crops in Punjab, i.e. wheat and rice was compared with that of selected medicinal plants. As per the study, *Curcuma longa* had Rs. 73,725/- returns over variable returns, *Aloe vera* had Rs.92,876/- returns annually on average for five years, *Emblica officinalis* had Rs.88,299/- returns over variable cost for one season, *Ocimum sanctum* had Rs.35,515 returns over variable cost, and *Rauvolfia serpentina* had Rs. 2,98,914/- for one crop cycle.

The selected medicinal plants had more returns than the traditional crops. The most prevalent marketing channel was found directly between the farmers and the consumers/industry. Cultivation of *Ocimum sanctum* can be a good alternative to paddy after assured marketing. Cultivation and collection of *Emblica officinalis* fruits in sub-mountainous region of Punjab can be beneficial for the farmers of the region in terms of its demand and price given by the industry. Also, *Emblica officinalis* can be explored for intercropping with different plant species for sustainable agriculture. Cultivation of *Aloe vera* can be carried out in Punjab especially in arid areas only after signing contract agreement assuring guaranteed 100 per cent buyback. Multilayer farming of medicinal plants with different types of vegetables, pulses and fruits must be explored by the agricultural research institutions in order to generate maximum returns to the farmers.

Endnotes

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12

The Way Forward

India has a strong traditional base in using herbal-based products for healthcare and therefore has a great opportunity to meet worldwide expectations through enhancing the exports of quality-based herbal raw material and strengthening the sector within the country. The sector requires fair trade practices, generating marketing, adopting *ex-situ* conservation methods of medicinal plants, resorting to Good Agricultural Practices (GAP) for generating quality herbal raw material, and mass awareness regarding potential medicinal plants among the general public, especially in the Punjab state which has nearby 1 per cent agricultural area under medicinal plants cultivation. The Biological Diversity Amendment Bill, 2021 was passed by the Indian parliament with one of its objective being the promotion of medicinal plants cultivation. Though, National Medicinal Plants Board (NMPB) is playing a stellar role in promoting the medicinal plants sector across India through various promotional and awareness programs. The Regional-cum-facilitation Centres (RCFC) established by the NMPB is providing luminous light to aware, adopt, and train the farmers interested in medicinal plants. The farmers of the Indian state of Punjab have a unique cropping pattern, *i.e.* monoculture of Wheat and Rice which provides them an assured market, with zero risks in production. Hence, more efforts are required to shift farmers from traditional crops to medicinal plants. Based on the present study, we summarize some observations and recommendations in sections 12.1. and 12.2. that might help as way forward for the concerned stakeholders in order to promote the adoption of medicinal plants.

Observations

Background on Punjab agriculture

- The cultivable area of Punjab is 4.20 million hectares (83.4 per cent of total geographical area). Punjab has become the epicenter of wheat-rice cropping pattern, after the successful implementation of the 'Green Revolution' (farmech.dac.gov.in).

- The green revolution improved the economy of the farmers, but with time their economic condition started deteriorating, along with the depletion of natural resources and environmental degradation.

- On average, two farmers and one laborer have been committing suicide daily since 2000. Of the 10 lakh farming families in 1991, about 5 lakh were small ones in Punjab. In just one decade, these small farmer families came down to 3 lakh. Under the capital intensive system of farming, 2 lakh families had given up farming in the state.[1]

Ecological status

- At present, 199.97 lakh metric tonnes of paddy has been procured in Punjab by the government of India during 2020-21, which is 19 per cent more than the target of 168 lakh metric tonnes and 26 per cent more than the procurement done during the corresponding period of 2019-20.[2]

- The highly water-intensive paddy crop was not indigenous to Punjab and its widespread cultivation necessitated intense exploitation of groundwater sources. Flood irrigation and application of chemical fertilizers incentivised by government policies aimed at enhancing production damaged soil and its fertility over years.

- The water table in the paddy growing areas has alarmingly gone down. According to a report, 15,000 litres of water is used to produce one kg of paddy, while the requirement is just 600 litres as per the Indian Agricultural Research Institute.

Need of diversification in the states

- The *Johl* committee[3] (1986 and 2002) realized the unsustainability of the wheat-paddy cropping pattern and recommended a series of measures for restructuring and diversifying agriculture, the most significant of which was shifting 20 per cent of the area under agriculture to non-paddy crops.

- The committee also emphasised that commitment of central and state governments in terms of technological, institutional, and assured price support for alternative crops was critical for achieving the desired objective.

- Recently, the government of Punjab has set a diversification plan with the finance minister setting aside Rs. 200 crore for this purpose.[4]

- Scope of adoption of medicinal plants in the state

- Reports are revealing the growth of the herbal raw sector riding on the growth of herbal, wellness and nutraceutical industry in India. Apart from the collection of medicinal plants, the cultivation of medicinal plants was increased in the country. The major driving force behind this growth is the herbal units that are involved in making extracts, and specific formulations that required a high volume of limited species of good quality.

- Given the current level of farming technology and practices, promoting medicinal plants and horticulture crops based on their agro-ecological suitability, standard agro-techniques, and assured marketing can be a potential alternative to the traditional crops.

- Most of the medicinal plants are not only less water-intensive but also essential to meet the increasing demands of industry in the state.

- There is a huge scope of integrating medicinal plants into the traditional cropping system. There is a tradition of practicing a mixed farming system comprising medicinal plants and traditional crops in the South Asian states indicating its scope in Punjab as well. Another advantage of incorporating medicinal plants in the traditional cropping system is their ease of incorporation due to a large number of species and choice of plants such as trees, shrubs, herbs.

Recommendations

Marketing of medicinal plants in Punjab: Challenges and opportunities

- In order to promote medicinal plant cultivation in the state, the recommended crops must compete with traditional crops

such as Paddy and Wheat, which have almost zero risks in cultivation and marketing. The agro-economics study mentioned in Chapter-11 of this report highlighted medicinal plants such as *Haldi, Ghritkumari, Amla, Tulsi*, and *Sarpgandha* having more returns than the traditional crops. Hence, other potential medicinal plants driven by their market demand and economic value (must give higher returns to the farmers as compared to the traditional crops that are supported by the minimum support price) shall be suggested to the farmers.

- During the field visits and general interaction, it was observed that some farmers stressed that providing subsidies has less value if there are no potential buyers and marketing of medicinal plants. In contrast, many farmers showed their willingness to cultivate medicinal plants if informed regarding the potential buyers. Despite 284 licensed herbal industries in Punjab according to NMPB report, there is a huge gap between farmer and the industry which needs to be bridged. Hence, more transparent trade practices ensuring an efficient link between the producer and the end-users, and monitoring the demand and supply of medicinal plants in the trade chain shall be helpful. The backward linkages (farm inputs) and forward linkages (processing and value additions) of agriculture should be set up in the public domain.

- A comprehensive network must be built in the state which may aware farmers regarding the nearest herbal industries, mandis, its demand, and the quality requirements. NMPB's e.charak mobile app., and other trading mobile apps. or a website for medicinal plant stakeholders involving online bidding of herbal produce based on the quality can be useful. The most important is the need for the policies that align all stakeholders' viz. Farmer, buyer, industry, government, processing units.

- Punjab has one of the strong marketing networks for wheat and paddy because of mandis. There are mandis every five to six kilometers in Punjab. These mandis employ up to 300,000 laborers in transportation, sorting, and packing. These mandis procure from about 2 million farmers.[5] Therefore, the concept of the formation of herbal mandi's can be explored utilizing the existing infrastructure of mandi with the help of the state government and linking potential buyers for marketing of medicinal plants in the state.

- Majith mandi, Amritsar is the largest mandi after the Khari Baoli, New Delhi. The mandi has approximately 35 traders and 70 major medicinal entities (annual trade volume 20,000 MT) are traded from the mandi.[6] Apparently, a mandi-level centralized record-keeping system for the trade shall be built for efficient trading of the medicinal plants.

- The collection center such as HHRC-Amritsar, supported by the Ministry of AYUSH can be explored for providing quality certifications of the farmer's produce for quality-based marketing.

- The present study highlighted the need for a written contract agreement between the farmers and the end-users (industries). There is a need to build confidence among the farmers and the industries to sign a contract agreement before initiating the cultivation of medicinal plants. The contract between the company and the farmers must be farmer-friendly and simple to understand by a farmer. A standard model draft for contract agreement must be made

and its regulation must be carried out by the NMPB with the help of the state forest department or state agriculture department to assure guaranteed 100 per cent buyback of the farmers produce. The regulatory body must assure that the agreement between the farmer and the industry was practical to implement. The demand for medicinal plants must not affect the agreement conditions and the duly amount must be paid to the farmers. To promote medicinal plants based products, The National Bank for Agriculture and Rural Development (NABARD) shall significantly support interested farmers by providing them fair loans under farmer-producer organizations for starting agri-business.

Mechanism for promotion of cultivation of quality medicinal plants in Punjab

- *Digitalization of medicinal plants cultivators and related stakeholder data:* In India, information regarding medicinal plant cultivators, and herbal or related industries is not scattered but also scanty. This is a major hurdle for effective health care planning, linkage with industries, trade, and policy development. There is a need to identify model farmers involved in the cultivation of medicinal plants and subsequently, digitalize their information to avoid scattering their data in different departments.

- As represented in Chapter-1 of this present study, a digitalized network of model farmers would ensure linkages of farmers, promote interaction leading to the promotion of medicinal plant cultivation in the state. Apart from this, the mapping of farmers on the agro-ecological specific map using GIS would lead to determine the number of farmers cultivating the specific medicinal plant in the specific agro-ecological zone of Punjab highlighting the natural biophysical potential of the specific area. This model based on digital mapping can be brought to the public domain to link clients, farmers, industries, and concerned officials to plan strategies for improved access, trade, and outreach.

- *Domestication of medicinal plants based on agro-ecological zoning model*: At present, there is no policy that regulates suggestion of right medicinal plants in the right location. Considering five different agro-ecological zones of Punjab, it is necessary to aware the farmers regarding the agro-ecological suitability of the potential medicinal plants in the state. The medicinal plants based on the agro-ecological zoning studies shall be suggested to the farmers and made public through digital platforms, seminars, conferences, and medicinal plants stakeholders meetings conducted by the NMPB. Based on the climatic and land pattern data, the authors have highlighted 13 potential medicinal plants such as *Sarpgandha, Shatavari, Safed Musali, Brahmi, Bach, Mulethi, Ashwagandha, Ghritkumari, Rama Tulsi, Shyama tulsi, Kalmegh, Amla*, and *Haldi* that can be adopted by the farmers in different agro-climatic zones of Punjab. Apart from these 13 medicinal plants, other medicinal plants based on the agro-ecological studies and market demand can be suggested to the farmers in future studies.

- *Value additions, primary processing, and product development:* In the present study, except *Haldi* farmers that sell their produce in powder form, all the other farmers sell the produce without processing. Farmers have a long history of selling their produce as sourcing material at times even without drying leading them to fetch low price. Under such conditions value additions is the answer for good economic sustenance and sustainable supply of the

sourcing material. Farmers must be made aware at least regarding the small scale agri-business opportunities that lead to manufacture herbal based products such *Amla* pickles, *Triphala churna, Chyavanprash*, candies, medicinal plant based oils, etc. Farmer producer companies and self-help groups can augment value additions, primary processing, and product development.

- *Farmer Producer Companies and Self Help Groups:* There is less participation of farmers in farmer-producer companies and self-help groups except a few in the present study. Farmer producer companies and Self Help Groups have a significant role in generating good income for the farmers especially the small farmers who do not have large marketable surplus individually (both inputs and produce) to get the benefit of economies of scale. The farmers must be made aware and motivated to establish farmer-producer companies for value additions and product development. NMPB and RCFC-North-I can take a lead role in the mass awareness among the farmers.

- *Promotional events:* NMPB has played an important role in promoting the cultivation of medicinal plants by conducting medicinal plants stakeholders meetings. However, with the increase and projected growth of the medicinal plant sector, more promotional events related to local anchoring of cultivation and selection of species shall be conducted. Similarly, more extension services regarding the NMPB, Ministry of AYUSH's 'Central sector scheme on conservation, development, and sustainable management of medicinal plants' shall be disseminated to the farmers across the state through frequent medicinal plants stakeholders meetings.

- *Clusters of medicinal plants cultivators:* Farmers should be motivated at the mass level regarding the formation of large clusters of medicinal plant to attract the industries and similarly, processing equipment such as boiling, grinding, polishing, drying, distillation must be provided at village block level to facilitate the farmers for value additions.
- *Identification of alternative potential crop cycles:* Rice and Wheat are considered cash crops that are cultivated in *Kharif* and *Rabi* season respectively. After every end of the season, farmers get their assured income. In order to compete with the existing traditional crop cycle, alternative competitive medicinal plants based on *Kharif* and *Rabi* season shall be identified and suggested to the farmers with the help of various agricultural institutes. The cultivation of Haldi which a nine-monthly crop can be rotated with the maize to replace water gulping paddy crop in Punjab. Medicinal plants such as *Tulsi*, *Kalmegh*, *Safed musali* can be potential *Kharif* crops if their market is assured before their cultivation. Multilayer farming of medicinal plants with different types of vegetables, pulses, and fruits that may complement each other in many ways such as providing shade canopy, litter, increasing the moisture-holding capacity of the soil while nurturing microflora must be explored by the agricultural research institutions in order to generate maximum returns to the farmers. Cultivation of medicinal plants such as *Amla* and other medicinal tree species on the boundaries of the field can be fruitful for the farmers. Mixed farming of medicinal plants with the traditional crops can be fruitful leading to soil improvement and enhancing livelihood if species are selected carefully.

- *Organic certifications:* The majority of the farmers in Punjab used both organic and chemical fertilizers to meet the N, P, K demands of the soil. The chemical fertilizers used are government-recommended, *viz.* Urea, DAP, and Potash. Most of the Kandi region of Punjab has natural land and the belt has great potential for medicinal plant cultivation. So, farmers should be motivated to adopt medicinal plants in the region, and subsequently, organic certifications should be provided to the farmers accordingly with the help of government support. Farmers must be made aware of the adoption of phytoremediation plants to circumvent heavy metal and pesticide residues if any.

- *GACP:* There is a prevailing belief that the adoption of GACP is restrictive and obstructs farmer's agriculture practices. On the contrary, the adoption of GACP provides a sustainable production system for both the producers and users. Hence, farmers must be made aware and motivated to adopt GACP with the help of the Quality Council of India (QCI). Furthermore, less information is available regarding the propagation and agro-techniques of the majority of the medicinal plants in India. This trend suggests the need for the dissemination of good agricultural collection practices methodologies based on the state's agro-ecological conditions to the farmers.

- *QPM providers:* Farmers faced shortages of seeds or Quality planting material (QPM) as discussed in the chapter II of this book. There are also increasing concerns regarding the authenticity of the planting material. Research organizations shall explore and identify more elite cultivars for the release at their institute level or through Central Varietal Release Committee. More species shall be explored to register under Protection of Plant Varieties and Framers' Right Authority (PPVRFRA) registration domain. Furthermore, QPM/seeds should be produced at a high scale at various agricultural research centers and shall be made available to the farmers on subsidized rates at nearby places to avoid transportation costs.
- *Testing labs:* According to the present study, farmers lacked the crucial knowledge regarding the requirements of the industry in context to the quality of raw herbal produce. Therefore, more AYUSH and National Accreditation Board for Testing and Calibration Laboratories (NABL) testing labs shall be established in the state, and subsequently, the farmers must be made aware of these laboratories for evaluating the quality of produce in order to promote quality-based trade.

- *Rural employment:* The agro-economics study mentioned in chapter XII of this book highlighted the cultivation of medicinal plants as a labor extensive job; therefore its adoption has the potential to generate more rural employment.

- *Government funding:* Funds are provided by the NMPB to establish collection centers, therefore farmers should be motivated and cooperative collection centers, storage, and processing centers shall be established. These centers shall be established in villages through the support of *panchayats*.

- *Research:* Research should be promoted to explore the feasibility of the cultivation of more medicinal plants. The agro-techniques should be drafted by active researchers with the help of the regional agricultural universities/ICAR institutions/NMPB. The Punjab Agricultural University (PAU) Ludhiana and its research stations

can provide great help in drafting agro-techniques of medicinal plants based on demonstration plots. An exclusive department of medicinal plants must be established in the PAU with the cooperation of NMPB, and related ICAR institutes.

- *Planning:* The promotion of cooperatives/ state farming, micro and macro-level planning of medicinal plant production, and consumption requirements should be prepared. Government should establish '*Kisan-Aushadh-Kendra*' providing a one-stop solution to the farmers for purchase, obtaining QPM, storage, processing, quality testing, product development and technology, entrepreneurship support, facilitation, industry linkage, and consultancy. The policies shall be planned in such a way enabling a stepwise 05-year plan to achieve the target of converting 20-25% of farmers towards medicinal plant cultivation. To achieve this target, various activities *viz.* promotional events, demonstrations, interactive seminars, etc. should be executed. An integrative package/ scheme must be declared by the Ministry of AYUSH involving the inclusion of all the related government departments (PAU Ludhiana, state agriculture department, state forest department) in order to promote medicinal plants cultivation.

Endnotes

1 Inputs: Article published by Prof. Sukhpal Singh, Principal economist, Punjab Agricultural University, Ludhiana, Punjab, in the Tribune, 01/Mar./2021.

2 The Tribune. 2020. Free farmer, empowered farmer. Ministry of Agriculture and Farmer Welfare. 21/ November/2020.

3 Inputs: Article titled "Either there wasn't an economist in Swaminathan panel, or he didn't know economics", published in The Print, 16/March/2018.

4 Inputs: Article titled "Diversification plan set to take off, finally" published in *The Tribune*, 01/ March/2020.

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Dr. Singh is pharmacognosist by profession and is working on domestication of medicinal plants along with traditional medicine and knowledge related policy-interventions. Dr. Singh has served as a researcher in Forum on Indian Traditional Medicine (FITM) a platform created by Ministry of Ayush at Research and Information System for Developing Countries (A think-tank policy institute under Ministry of External Affairs) for pragmatic policy framing interventions. He has also worked on "Structuring, Analysis and Research Studies of Medicinal Plants Data submitted under Drugs and Cosmetics Rules, 1945, Scheduled T(a)" to National Medicinal Plants Board (NMPB), Ministry of AYUSH, India. He was among two scholars in India to be awarded with FITM doctoral fellowship for research work "Agro-climatic, economic and good agricultural practices adoption feasibility studies on selected medicinal plants of Punjab". He has more than 40 publications on in international and national journals with impact factor above 60. His recent work on nano-carrier COVID-19 vaccine got published in Advanced Drug Delivery Reviews having impact factor of more than 17. He has 04 patents to his credit including one granted by Federal Republic of Germany. He has presented more than 30 papers in International and national conferences. He has won many research awards including from American Chemical Society. He is frequently authoring articles in newspapers such as Deccan Herald, The Tribune, Hindustan Times. He is life member of Indian Science Congress, IPGA, APTI. He is alumnus of Jamia Hamdard, New Delhi and Pt. Bhagwat Dyal Sharma University of Health Sciences, Rohtak, Haryana. He completed his Ph.D. from Maharaja Ranjit Singh Punjab Technical University, Bathinda, Punjab. At present, he is serving as an Assistant Professor in University Institute of Pharma Sciences (UIPS), Chandigarh University, Punjab.

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The FITM Fellowship Programme encourages young doctoral and post doctoral scholars to undertake social science research on traditional medicine. Selected reports of Research Fellows are also published by RIS.

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