CHAPTER-3

RESEARCH ENVISAGED & PLAN OF WORK

3.1. PROBLEM FORMULATION

3.1.1. Research Problem

Majority of the farmers of Punjab rely on traditional cropping pattern *i.e.* rice and wheat due to assured market and low risk in their production. There is scattered and very less information available regarding medicinal plants cultivators in the state. This scenario is becoming a barrier to link clients, farmers, industries, and concerned officials to plan strategies for improved access, trade, and outreach. As Punjab is divided into five agro-climatic zones, till now, there is no policy to regulate right medicinal plants in right area. Since, few farmers have started to adopt medicinal plants cultivation through the collective efforts of NMPB and concerned organizations, it is required to determine various technical, trade, social, awareness and attitude-related constraints faced by the small and large farmers of Punjab in order to promote medicinal plants cultivation in the state. In general, agricultural risks are identified at the later stages of plant production, which becomes impossible for the farmers to reverse the un-wanted results, in this context, critical variability alignment analysis and inclusion of suitable quality improvement studies based on scientific rationale are essential to pre-determine the agricultural risks and sustain medicinal plant cultivation by identification of critical agricultural variables and their effect on the quality of medicinal plants. Similarly, the reliability of medicinal plants has been accomplished using widespread testing of medicinal plants which are applied at the delayed phases. The challenge is to devise quality and reliability approaches that can be applied in the early phase of medicinal plants production in order to standardize the farmer's produce.

GAP provides series of technical guidelines to assure the quality of medicinal plants. The GAP guidelines are developed by various countries on the recommendations of the WHO. The GAP guidelines are unique and varied from country to country. So, in order to devise robust guidelines, there is need to draft comprehensive guidelines after exploring the guidelines of WHO and different nations for the quality establishment and sustainable cultivation of medicinal plant keeping in view the region's agro-climatic conditions. Subsequently, lack of standard agro-technology of selected

medicinal plants based on region's ecological conditions, lesser knowledge regarding the importance of standard quality tests, non-availability of intuitive monographs corresponding to agricultural practices followed by the farmers its corroboration with the literature and quality are need of an hour to promote quality-based production of medicinal plants in Punjab.

For a crop to become commercial success there is need to understand economic viability pattern of the crop. For this, agro-economics study model and comparative analyses with the traditional crops will motivate as well as provide in-sights regarding the cost-return structure to the farmers leading to wider adoption of medicinal plants.

The proposed work is purely farmer-centric and will help in filling the gaps related to the zones specific cultivation of medicinal plants. Comprehensive study would act as a baseline study on merging the agro-practices used by farmers and its corroboration with the standard literature for commercial cultivation of medicinal plants in compliance with the requirements of GAP. This study encompasses on-field validation resulting in generation of monographs and farming/training manual for farmers in English and vernacular language along with identification of the constraints faced by the farmers to find out possible solutions to promote cultivation of medicinal plants. A comprehensive and robust set of GAP guidelines are drafted after consulting GAP of various countries and the WHO in order to achieve high-quality medicinal plants. The present study was designed to promote the medicinal plants cultivation keeping in view the economic sustenance of farmer based on integrative knowledge of suitable agro-practices, collection/harvest methodologies, quality evaluation, financial feasibility analysis, and related documentation.

3.2. AIM AND OBJECTIVE

3.2.1. Aim

To promote quality-based production of medicinal plants as a viable alternative farming model for the farmers of Punjab.

3.2.2. Objectives

- To select medicinal plants.
- To conduct agro-climatic feasibility analysis including agro-climatic mapping and zoning to find best suitable zone of the selected medicinal plant.
- To identify medicinal plants cultivators exploring different channels in Punjab.

- To geo-tag medicinal plants cultivators using Geographic Information System (GIS).
- To conduct survey for identification of constraints in medicinal plant cultivation by farmers of Punjab.
- To draft comprehensive GACP guideline after critically assessing and comparing GAP of WHO and other countries like America, Japan, China, UK, and NMPB India for selected plants.
- To conduct critical variable alignment study to understand significant variables affecting the critical quality attribute in question based on scientific rationale and suggestive improvements in agro-practices for quality compliance with specific reference to content of active constituent(s), heavy metal residue and pesticide contamination.
- To standardize farmer's produce for same quality parameters and gap/variability analysis in comparison to industrial standards.
- To draft monographs of selected medicinal plants featuring GAP related documentation for on-field cultivation comprising:
    - Botanical and pharmacological characteristics.
    - Good agricultural practices.
        - Growth and development characteristics.
        - Cultivation method and management.
        - Best collection/harvest practices.
    - Quality control requirements for herbal materials.
        - Suggestive quality parameters of selected medicinal herbs/raw materials as per industrial requirements, standards mentioned in API and reported literature.
- To conduct economic feasibility studies of selected medicinal plants.
- To develop farming manual for selected plants in local language for wider benefits.
- To submit the proposed comprehensive GAP for selected medicinal plants to regulatory agencies.

3.3. PLAN OF WORK

1. Selection of medicinal plants:
   - *A. vera* (Ghritkumari)
   - *P. emblica* (Amla)
   - *W. somnifera* (Ashwagandha)
   - *G. glabra* (Mulethi)
   - *A. racemosus* (Shatavari)
   - *A. paniculata* (Kalmegh)
   - *O. sanctum* (Shyama tulsi)
   - *C. longa* (Haldi)
   - *C. asiatica* (Brahmi)
   - *A. calamus* (Bach)
   - *R. serpentina* (Sarpgandha)
   - *O. basilicum* (Rama Tulsi)
   - *C. borivilianum* (Safed Musali)
2. Agro-climatic feasibility analysis to find optimally suitable, suitable and lesser suitable zones of the selected medicinal plant.
   - Collection of annual temperature and rainfall meteorological data
     - Indian Meteorological Department (IMD) research stations
     - Punjab Agricultural University (PAU) research stations
   - Reported soil pattern data
     - Soil texture
     - Soil pH
3. Identification of medicinal plants cultivators in Punjab exploring different channels:

Table 3.1: Different channels explored to identify farmers.

Government channels • RCFC North • State Forest Department • PAU	*Commercial channels* • Herbal industries • Farmer-producer companies
Personal channels • Farmers • AYUSH practitioners • Herbal *mandi* • Farmers groups	*Gatherings* • Seminars • Conferences • MAP stakeholder meet
Literature • Newspaper • Magazines • Case reports	*Expert consultation* • Industry experts • Government experts • Subject experts

4. Identification of medicinal plants cultivated by the farmers for survey study
   - *A. vera*
   - *P. emblica*
   - *O. sanctum*
   - *C. longa*
   - *R. serpentina*
5. Geo-tagging medicinal plants cultivators using GIS
   - Preparation of base maps
   - Processing latitude and longitude coordinates
   - Embedding of farmer's demographics in maps
6. Survey for identification of constraints in medicinal plant cultivation by farmers of Punjab
   - Preparation of questionnaire
   - Validation of questionnaire based on chronbach alpha value
   - Selection of sample size
   - Personal interviews with farmers to collect primary data
   - Statistical tools i.e. Mean Percentage Score, Chi-square using SPSS
   - Descriptive analysis of data
   - Inferential analysis of data between small and large farmers
   - Determination of technical, trade, social participation, awareness and attitude related constraints
7. Drafting of comprehensive GACP guidelines for medicinal plants considering guidelines drafted by:
   - WHO
   - America
   - European Union
   - Japan
   - China
   - India
8. Critical variable alignment study to understand significant variables affecting the critical quality attribute of medicinal plant cultivation considering:
   - Critical quality attributes
   - Critical process parameters
   - Critical material attributes
9. Standardization of farmer's produce for same quality parameters and gap/variability analysis in comparison to industrial standards.
   - Application of FMEA for standardization of medicinal plants production
   - Preparation of checklists to avoid risks in medicinal plant production

10. Preparation of GAP related documentation for on-field cultivation of *A. vera, O. sanctum,* and *C. longa* in the form of monographs comprising of quality parameters of plants, agro-practices (farmer's practices and reported literature).
    - Botanical and pharmacological characteristics
        - Scientific and vernacular names of plants
        - Medicinal plant part of interest
        - Geographical distribution
        - Major areas of production
        - Morphological and microscopic characters
        - Chemical composition
        - Pharmacological activity
    - Good Agricultural practices
        - Growth and development characteristics
        - Preferred growing conditions
        - Seeds and cultivars
        - Cultivation methods
        - Rate of seedlings per acre
        - Plant to plant distance
        - Row to row distance
        - Sowing depth
        - Fertilization
        - Field management
        - Intercropping
        - Disease management
        - Best collection/Harvest practices
        - Post-harvest processing
    - Drafting of quality parameters of selected medicinal herbs considering:
        - API
        - ICMR
        - FSSAI
        - WHO

11. Economic feasibility studies of selected medicinal plants:
    - Cost-Return structure of *A. vera, O. sanctum, C. longa*

Table 3.2 Parameters for cost return structure of selected medicinal plants.

Physical input • Seed/acre (quintals) • Seed treatment • Fertilizers • Plant protection/acre	*Machine labour* • Tillage/acre (hrs.) • Sowing/acre (hrs.) • Harvesting/acre (hrs.)
Irrigation • Irrigation cost (hrs.)	*Human labour* • Fertilizer application • Sowing • Weedings • Harvesting
Post-harvest • Cleaning • Transportation	*Income estimate* • Gross returns/acre
Total expenditure • Variable cost/acre	*Profitability* • Return over variable cost/acre

    - Comparative cost-return analysis between traditional crops and medicinal plants
12. Development of farming manual for selected plants in local language for wider benefits.
    - Considering botanical characters, pharmacological importance, agro-techniques, harvest and post-harvest, model farmers, industry, and checklists to avoid risks at plant production, etc.
13. Submission of the proposed comprehensive GAP for selected medicinal plants to regulatory agencies.

3.4. RESEARCH METHODOLOGIES

- **Selection of medicinal plants**

Different government channels (RCFC-North-NMPB, State Forest Department, etc.) private (farmers groups, NGO's, Farmer-Producer Organization, industries) were explored to identify medicinal plant cultivators for the study. The selection of medicinal plants was done on the basis of medicinal/commercial value, feedback received from local farmers, Government officials along with experts from industry and academia.

- **Agro-climatic feasibility analysis including agro-climatic mapping and zoning to find best suitable zone of the selected medicinal plant**

The annual temperature and rainfall records collected from the Indian Meteorological Department (IMD) and Punjab Agricultural University (PAU) and agro-eco-subregion based benchmark soils network was utilized for the preparation of digital base maps All the base maps were superimposed to highlight optimally suitable zone (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) using Arc. GIS 10.3.

- **Identification of medicinal plants cultivators exploring different channels in Punjab**

Different government channels (RCFC-North-NMPB, State Forest Department, etc.), private (farmer groups, NGO's, herbal mandi traders, farmer-producer organization, industries) were explored to identify farmers involved in medicinal plants cultivation for geo-tagging and conduct of survey throughout Punjab.

- **Geo-tagging 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. Maps were marked considering the pre-determined five agro-climatic zones of Punjab using GIS software Arc. GIS 10.3.

- **Survey for identification of constraints in medicinal plant cultivation by farmers of Punjab**

A total of 68 farmers were interviewed personally by the researcher using a closed and open-end questionnaire following the purposive sampling technique. The pre-tested and reliable questionnaire was drafted and SPSS version. 22 software was used for statistical calculations. Different constraints related to technical, marketing, social participation, awareness and farmer attitude & policy are studied based on their respective MPS. Similarly, the Chi-square test was applied to highlight the significant

relationship between the farmer's land holdings (small and large farmers) and various constraints.

- **Drafting of comprehensive GACP guideline after critically assessing and comparing GAP of WHO and other countries like America, Japan, China, UK, NMPB India for selected plants**

The comprehensive and robust GAP guidelines for medicinal plants were drafted after assessing the GAP guidelines of various countries like China, Japan, America, European Union, India and the WHO to supplement quality-rich raw herbal material.

- **Critical variable alignment study to understand significant variables affecting the critical quality attribute in question based on scientific rationale and suggestive improvements in agro-practices for quality compliance with specific reference to content of active constituent(s), heavy metal residue and pesticide contamination**

An alignment study was carried out to study the inter-relation between following variables:

- CMA for e.g. soil, water, seed material, fertilizers, pesticides, etc.
- CPP involved in various agro-processes such as site treatment, seed treatment, soil preparation, sowing, manure addition, irrigation, protection from weeds/pests, harvesting, storage, etc.
- CQA for e.g. content of active constituent, crop yield, heavy metal content, pesticide residue, physic-chemical ranges, microbial load.

- **Standardization of farmer's produce for same quality parameters and gap/variability analysis in comparison to industrial standards**

The FMEA was adapted for standardization of the farmers produce to get rich-quality herbs and avoid widespread testing of medicinal plants which is mostly costly. This method helped to avoid and measure risks associated with each agricultural process to prevent in-appropriate physicochemical ranges, active constituents, toxicity indicators (heavy metals, pesticide residues), and microbial content at the delayed phases.

- **Drafting monograph of selected medicinal plants featuring GAP related documentation for on-field cultivation**

Agro-technologies of medicinal plants depend upon ecological conditions and vary from region to region. On-field cultivation adoption analysis was conducted to develop GAP monographs of *C. longa, A. vera, and O. sanctum* that comprised of

land selection, seeds, land preparation, crop management, fertilization, harvest, post-harvest conditions of medicinal plants after conducting field visits, farmer interaction and corroborating the inputs with reported literature to avoid un-predicted yield and quality of the selected medicinal plants. Scientific rationale was developed considering farmer's collection/harvest practices and its corroboration with the literature. The monographs were divided into three parts *viz.* botanical and pharmacological characteristics, good agricultural practices, and quality control requirements for herbal materials. The SQC's of *A. vera*, *O. sanctum, and C. longa* involving morphological, microscopical, physico-chemical, qualitative, quantitative, microbial load, toxicity indicators, etc. along with their acceptable limits prescribed by API, ICMR, FSSAI, and WHO, etc.

- **Economic feasibility studies of selected medicinal plants**

The agro-economics study was conducted for the selected medicinal plants *viz: A. vera, O. sanctum, and C. longa*. 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. The comparative agro-economics analysis was conducted between traditional crops (wheat and rice) and selected medicinal plants.

- **To develop farming manual for selected plants in local language for wider benefits**

The GAP based farming manuals have been prepared in English and vernacular language (Punjabi) and submitted to the RCFC-North-NMPB for its wider translation to the farmers of Punjab.

The proposed research methodologies successfully helped in providing a comprehensive roadmap to promote the quality-based production of medicinal plants as a viable farming alternative in Punjab that is known for following mono-cropping agriculture patterns. The findings of geo-spatial study provided a digitalized framework for the identification and accessing of the locations of medicinal plants cultivators throughout Punjab. The adopted research methodologies for agro-climatic zoning study highlighted optimally suitable, suitable, and lesser suitable agro-climatic zones for the cultivation of selected medicinal plants after accessing annual temperature, rainfall, soil texture, and soil pH data and converting the data into digitalized maps.

The statistical tools such as MPS and Chi-square test used in the participatory research involving personal interviews with medicinal plants cultivators using a semi-structured questionnaire highlighted potential constraints faced by the small and large farmers. Keeping in view the quality perspective of medicinal plants, comprehensive GAP guidelines, scientific approach-based critical variable alignment study, and standardization of farmer's produce using FMEA keeping in view the active constituents, yield, physico-chemical parameters, microbial load, and toxicity indicators helped in pre-determining the agricultural risks and provided quality-quantity improvements techniques involved in the production of medicinal plants. WHO recommends drafting of region-based GAP monographs, therefore, in the present study, detailed monographs comprising of botanical and pharmacological characters, good agricultural practices, and suggestive quality parameters (reported in API, ICMR, FSSAI, and WHO) of selected medicinal plants have been prepared to keep in view the adopted farmer's agro-practices and its corroboration with reported literature for the welfare of interested farmers. Apart from this, the agro-economics study based on the cost-return structure of selected medicinal plants and its comparative analysis with traditional crops *viz.* wheat and rice provided insights into the economic aspects involved in the medicinal plants' cultivation and would eventually build confidence among farmers to adopt medicinal plants cultivation as a potential alternative farming option. For the wider dissemination, the GAP monographs were also prepared in vernacular language (Punjabi) and distributed to farmers and concerned regulatory bodies such as RCFC-North (NMPB) and FITM.

3.5. THE EXPECTED OUTCOMES

1. This study may open new vista in adopting cultivation of medicinal plants as an alternative solution and help farmers to move away from traditional cropping pattern.
2. This study would necessitate the need for adopting precision agriculture using advanced computational methodologies for sustainable agriculture in Punjab.
3. In developing countries like India, there is scanty information related to medicinal plants cultivators so digitalization of farmers information would also help to link clients, farmers, industries, and concerned officials to plan strategies for improved access, trade, and outreach in the future studies

4. The study will provide insights to the farmers regarding critical quality gaps and potentiate the farmers to grow quality enriched medicinal plants as per industrial standards which will boost their income.
5. The GAP monographs that are drafted after reporting the successful agro-practices and their corroboration with literature will act as guiding documents for the farmers keeping in view the region's agro-ecological conditions.
6. This model study can be extrapolated on other medicinal plants for wider adoption of medicinal plants cultivation in the state,
7. The suggestive recommendations mentioned in the chapter 6 of this study can act as a policy document at national level to link concerned stakeholders, provide technical, quality, and economic guidance to promote medicinal plant cultivation.
8. This study will open a debate to integrate scientific methodologies, successful agro-practices, documentation as per international norms leading to inputs for future policies for farmer’s benefit.