CHAPTER-1

INTRODUCTION

Most of the countries have a rich tradition of using medicinal plants as medicines, food supplements, cosmetics, fragrances, for maintaining health hygiene, and quality of life (Veeresham, 2012; Kala *et al.,* 2004). Indian System of Medicine (ISM) comprising of Ayurveda, Unani, Siddha, and Homeopathy, etc. are mostly utilizing plants for curing both humans and animals (Kilmer, 2010; Punjani and Kumar, 2003; Mukherjee, 2001). Ayurveda-the oldest ISM, written 5,000 years ago has reported around 2000 Medicinal and Aromatic Plants (MAP) species followed by Siddha and Unani for their preparations and formulations (Singh *et al.,* 2020a; Kala, 2005). According to modern pharmacopoeias, approximately, 25 per cent of the drugs are derived from plants and several others are the synthetic derivatives of prototype compounds isolated from the plants (Kala *et al.,* 2006). Therefore, one cannot ignore the contribution of traditional systems medicines in strengthening the allopathic system of medicine. Furthermore, worldwide growing recognition of medicinal plants, higher prices and side-effects of allopathic medicines are forcing people to return to herbal medicines (Kala, 2005).

As per World Health Organization (WHO), 60-80% of the world's population seeks plants or plant-derived natural products for the prevention and curing of various diseases (Singh *et al.,* 2018). The total trade of botanicals in world is US $ 32.702 billion out of which Asia accounts for US $ 14.505 billion (44.35%). The annual demand of herbal raw drugs is estimated to 5,11,910 (dry Weight in Metric Tonne) (Wt. in MT) with export value and rural household demand of 1,34,500 (dry Wt. in MT) 1,67,500 (dry Wt. in MT) respectively (Goraya and Ved, 2017). Subsequently, according to the WHO estimate, demand for medicinal plants is likely to increase more than US $5 trillion by the year 2050 (Kala, 2010).

The Asia-Pacific region of the world is rich in diversity of Medicinal and Aromatic Plants (MAPs). Asia, alone has about 8,000 ethno botanical properties containing plant species out of which 25,00 species are used in making of different traditional medicines and about 250 species are commercially traded (Paroda *et al.,* 2013). India and China, the largest countries of Asia have the richest arrays of registered and well-known medicinal plants. The maximum numbers of medicinal plants species are

found in northern part of India. It has been reported that the Himalayas have 8000 species of angiosperms, 600 species of pteridophytes and 44 species of gymnosperms out of which 1748 are medicinal plant species (Kala *et al.,* 2006). Most of the medicinal plants are found around 1800 m elevation range with largest number of species reported from Uttaranchal followed by Sikkim and North Bengal. No other country in the world has this proportion of medicinal plants for the existing flora (Kala, 2010). However, the rising demand of herbals across the world has led to massive exploitation of high value medicinal plants in the wild due to over-harvesting (Kala, 2015). Many poor farmers and communities benefit from the valuable MAP's found in Asia and Pacific region for their livelihood (Paroda *et al.,* 2013). Therefore, any threat to these MAP will not only affect the living status of the farmers and communities but also jeopardize the health of the people in the region (Hamilton, 2004). In order to promote medicinal plant sector in India, Government of India has developed National Medicinal Plants Board (NMPB) under Ministry of Ayurveda, Yoga & Naturopathy, Unani, Siddha and Homeopathy (AYUSH). The main objective of NMPB is to develop suitable mechanism for coordination between different ministries, departments, and implement policies to promotion, conservation and trade of medicinal plants. NMPB has also developed list of prioritized medicinal plants to provide 30 per cent, 50 per cent and 70 per cent subsidies to the farmers of India interested in cultivation of medicinal plants under National AYUSH Mission (NAM) scheme (Kala and Sajwan, 2007).

India is located to equator's north extending between 8°4' to 37°6' north latitude and 68°7' to 97°25' east longitude. Federal union of India comprises of 28 states and 08 union territories (Chandrachud, 2019; Hiloidhari *et al.,* 2014). India has 329 million hectares geographical area covering larger part of the Southern Asia and making it seventh largest country in the world (Garg, 2012). 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 (Attri and Tyagi, 2010). India has the most alluring ecological conditions in the world possessing nearly rainless Thar desert to Cherrapunjee, the rainiest place on earth and extending to hot-salty Ran of Kutch to everlasting snow bonded Himalayan peaks. It alone hosts two biodiversity hotspots out of 34 in the world (Singh *et al.,* 2020a; Kelkar, 2002).

Punjab is a small state located between 29’30’’ N to 32’32’’ N latitude and 73’55 E to 76’50 E longitude in north-west of Indian subcontinent. The word Punjab was derived from two words Punj (Five) and Aab (Water) means land of five rivers. The rivers are Beas, Sutlej, Ravi, Jhelum and Chenab. At present, only three rivers Beas, Sutlej and Ravi flow in today’s Punjab, the other two are now situated in Pakistan’s Punjab after the partition of India in the year 1947 (Krishan *et al.,* 2015; Singh and Rath, 2013). Punjab has total 50,362 square kilometres total area with population of 2,77,43,338 according to the 2011 Census report of India (Singh and Singh, 2014). Punjab falls in the agro-climatic zone-VI, which is called “Trans-Gangetic Plains Region” and is further divided into five sub-zones (Hamadani and Khan, 2015). 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). After the successful implementation of green revolution in the mid-1960s, Punjab has become the epicenter of wheat-rice cropping pattern, which is now the most preferred agricultural system among farmers (Kaur *et al.,* 2018a; Dutta, 2012; Kaur, 2010). Two-third of the total production of the food grains are contributed by Punjab and it is leading producer of wheat in India (Thakur *et al.,* 2016). Green revolution has led to agricultural development in the state but also gave some serious ecological threats to the state. The wheat-rice cropping pattern became reliant on under water resources, extensive use of chemical fertilizers, pesticides and agricultural machinery leading to lesser returns of farmers and massive exploitation of natural resources (Singh, 2002; Chand, 1999). During the 1980’s, the momentum of green revolution was sustained leading to stagnation of yields thereby increasing the cultivation cost. A wheat grower started to get lower net returns per hectare after incurring higher input costs using modern farming equipment. This led to ‘reverse tenancy’ causing small and marginal farmers to lease their land to large farmers causing decline in number of operational holding (Singh, 2002).

In developing countries, socio-economic needs of quickly expanding populations are the major reason for designating land resources for different uses. Sustainable and rational use of land has become the key issue for policy makers, government and land users for preserving the resources for present and future generations. The major challenge for the policy makers is to flip the trends of land degradation in already cultivated areas by improvising the conditions and re-establishing the land fertility

(FAO, 1996). The diverse agro-climatic conditions in Punjab have the ability to provide suitable environment to vast range of medicinal plants if chosen in a scientific manner through agro-climatic zoning model (Singh *et al*., 2021a,b; Falasca *et al.,* 2012). To circumvent issues related to crop diversification, there is a strong need of precision agriculture that would enable highlighting potential growing areas for new crops to be adopted in the state. In this context, FAO has developed agro-ecological zoning methodology using complex software packages to circumvent problems related to land resources leading to sustainable agriculture. Geographic Information System (GIS) is a tool that allows mapping of spatial data and facilitates the progression of descriptive to analytical work resulting in the rise of hypothesis (Parker, 1988). A crop is optimally grown in its preferred conducive environment. Therefore, the GIS model has the potential to predetermine land potential considering the climatic and land pattern data in context to the bio-climatic requirements for the medicinal plants by generating digitalized maps. The present study utilized principles of agro-climatology as the main tool (Falasca *et al.,* 2012). Based on available bibliographic data, the climatic requirements for the medicinal plants were identified. High industrial demand and feasibility of cultivation in the region makes medicinal plants cultivation a successful farming model. Medicinal plants such as *A. vera, 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) have good industrial demand and cultivation feasibility in Punjab.

- *A. vera* is a draught tolerant plant and is suitable for arid and semi-arid conditions and possesses vast spectrum of pharmacological, drug permeation enhancer, and nutraceutical properties (Patil and Saraogi, 2014; Cousins and Witkowski, 2012).
- *P. emblica* popularly known as Indian gooseberry is extensively cultivated in India and widely reported for possessing exemplary anti-oxidant properties (Jalal *et al.,* 2018).
- *W. somnifera* is a rejuvenating shrub mostly used for curing brain-related disorder (Namdeo and Ingawale, 2020; Kumar *et al.,* 2012).
- *G. glabra* is a perennial legume whose roots are used for curing cough, rheumatism, stomach ulcers, etc. (Anonymous, 2014).

- *A. racemosus* is found throughout India and is used to treat dyspepsia, diabetes, etc. (Kaur *et al.*, 2018b).
- *A. paniculata* is native to South Asian countries and used to treat urinary tract infection, hypertension, etc. (Verma *et al.*, 2019).
- Medicinal plants such as *O. sanctum*, *O. basilicum* that are rich in volatile oils are used as anti-aging, treating kidney stones, anti-septic, viral infections, etc. (Yadav *et al.*, 2013a).
- *C. longa* rhizomes have been widely used to treat viral infections. Ministry of AYUSH has also recommended golden milk for the prevention and prophylaxis of COVID-19 (Singh *et al.*, 2020a).
- *C. asiatica* is a perennial herbaceous creeper that grows on moist soil and is a traditional medicinal herb of Nepal (Times-is, 2009a).
- *A. calamus* is a shallow water plant having sword-shaped leaves that is used for gastrointestinal problems (Times-is, 2009b).
- The leaves, roots, stems of *R. serpentina* are used to possess wide pharmacological properties such as controlling blood pressure, snakebite, etc. (Bhattarai, 2013).
- Similarly, roots of *C. borivilianum* are used for boosting vitality, and treating arthritis, etc. (Vijaya and Chavan, 2009). The medicinal plants selected for the study are represented in Fig. 1.1.

Figure 1.1: Live images of selected medicinal plants.

Furthermore, these medicinal plants are among 95% of total herbal raw drugs consumed by Indian herbal industry and rural households and possessed more than 100 MT consumption, according to a report published by the NMPB (Goraya and Ved, 2017).

GIS based agro-climatic zoning of selected medicinal plants considered crucial parameters like temperature, rainfall, soil texture and soil pH to highlight optimally suitable, suitable and lesser suitable agro-climatic zones in Punjab. GIS is not a new phenomenon, but still, it has not been utilized to its full potential in context to digitization and geo-tagging of the farmer's data based on region's agro-ecological conditions (Singh *et al.,* 2021c). In developing countries like India, official information on medicinal plant cultivators is scanty. This is a major hurdle for effective health care planning, linkage with industries, trade and policy development (Deshpande *et al.,* 2004). There is a requirement for digitalizing and mapping the medicinal plant cultivators using GIS to design an improved system for health services research. Like other developed countries, geo-tagging of farmers on digital maps along with species, production volume, and pricing details can become an avenue for bulk purchase from farmers. In this study, GIS was used to embed medicinal plants cultivator's demographic data for linking clients, stakeholders in the future studies.

Since farmers of Punjab are initiating cultivation of medicinal plants as a new venture, it is obvious that they would have been facing various constraints. Apart from agro-climatic zoning studies, highlighting technical, trade, social, awareness related issues faced by the farmers is a requirement. Highlighting constraints through participatory research would not only give insights into their farming methods but also it would help the policy makers to devise policies that would help in wider adoption of medicinal plants. The present study also encompasses the identification of medicinal plants cultivators after exploring concerned public and private sectors to conduct personal interviews to highlight constraints faced by the small as well as large farmers.

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 (Bansal *et al.,* 2016; Bansal *et al.,* 2014). 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, Singh and Baldi, 2018). Following the pattern of GACP guidelines for medicinal plants drafted by the WHO, the 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 GACP guidelines for the medicinal plants (Organización Mundial de la Salud and World Health Organization, 2003). 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). The basic components of Good Agricultural Practices (GAP) are mentioned in Fig. 1.2. The GACP guidelines ensure sustainable cultivation, development of region-specific GACP monographs while providing technical know-how regarding its cultivation, provide the best quality herbal material and avoid scarcity of medicinal plants. In order to ensure the best GACP guidelines come into practice, comprehensive GACP guidelines must be devised with time.

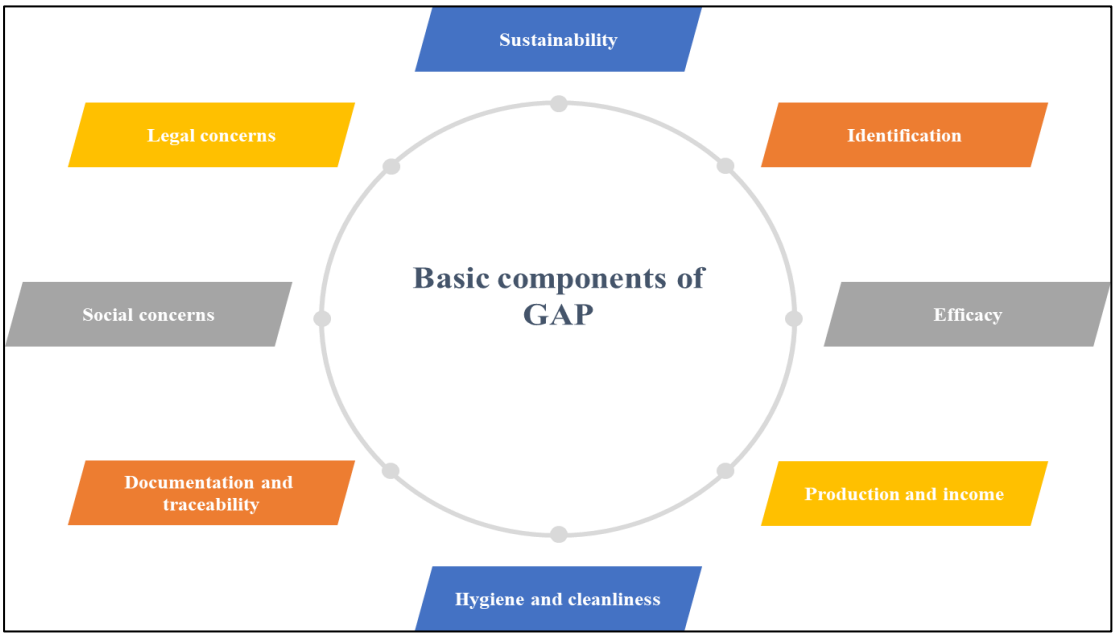

Figure 1.2: Basic components of Good Agricultural Practices.

Research institutes are focusing to develop GACP monographs for medicinal plants considering the agro-ecological conditions of the region (Jat *et al.*, 2015a,b,c, 2014; Jayashree *et al.*, 2015; Bhattarai, 2013; Anonymous, 2009).

Farming and cultivation has always based on prior experience of the farmer and not much scientific explorations has been done so far to understand the intricacies of complex interactions of so many factors involved. Age old practices and refinements in agriculture have obviated much requisite of this. However, cultivation of medicinal plants and its commercial sustenance is substantially dependent on quality of the produce. This has urged us to develop a rationale based methodical approach to comprehend quality of medicinal produce in relation to variables and practices involved. In general, agricultural risks are identified at a stage when there are lesser chances to manage the risks (Ngathou *et al.*, 2006). 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 and also avoid risks. This rationale must attract the attention of the experts to develop a rationale-based methodical approach to comprehend the quality of medicinal produce in relation to variables and practices involved as represented in Fig. 1.3.

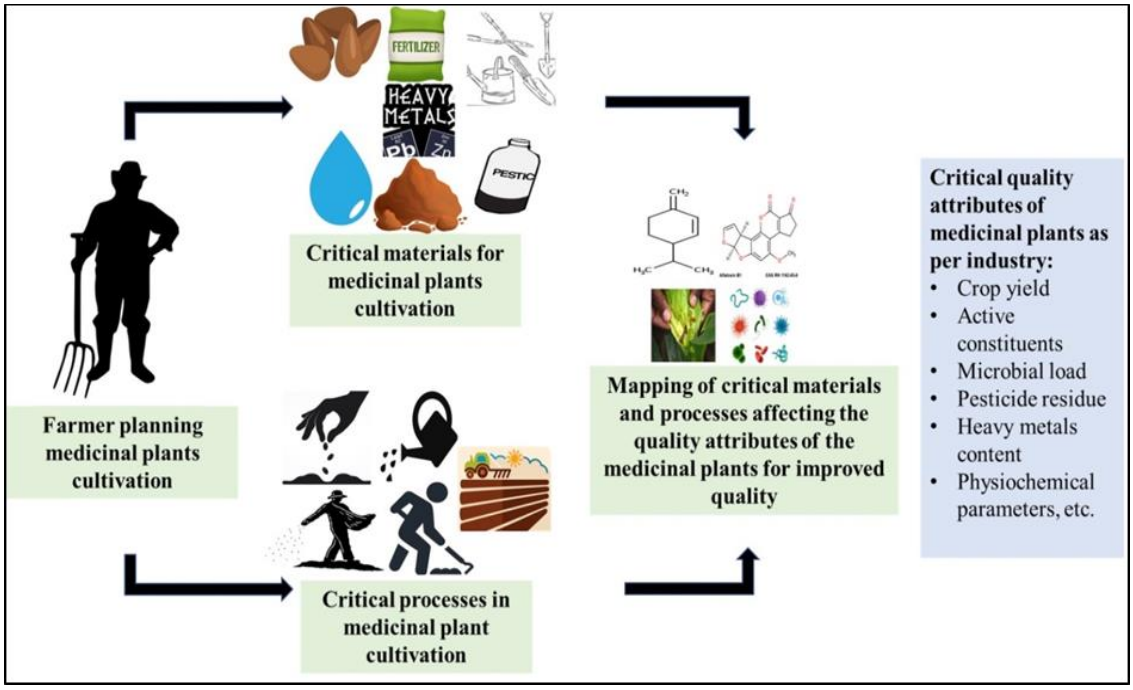

Figure 1.3: Critical variable alignment study.

This variable critical alignment study utilizes a scientific approach that begins with pre-defined quality materials and processes based on sound science and literature to pre-determine the 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). Customers are placing high demands on the industry for high quality of medicinal products. The companies are feeling it difficult to maintain high quality and reliability especially in the case of medicinal plants which are prone to attract microbes, degradation, physicochemical ranges, etc. (Ekor, 2014). Therefore, it becomes necessary to highlight critical quality gaps so that certain standards, improvement methodologies that enhance the quality of medicinal plants as per the requirements of the AYUSH industry may be suggested to the farmers. 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 results may open a new vista in transforming cultivation practices to an inclusive and holistic approach based on scientific intrigue.

Conventionally, reliability of medicinal plants has been accomplished using widespread testing of medicinal plants adopting probabilistic reliability modeling (Sultana *et al.,* 2017; Mishra and Aeri, 2015). These methods are applied at the delayed phase of improvements. The challenge is to devise in quality and reliability in the early phase of medicinal plants production (Dasgupta, 2003). There are many risk management tools such as process mapping, preliminary hazard analysis, hazard analysis of critical control points, hazard operability analysis, and Failure Mode and Effect Analysis (FMEA) that can be utilized for the standardization of farmer's produce by evaluating each agricultural process in a cost-effective and timely manner (Das *et al.,* 2014). In the present work, FMEA approach has been utilized for the standardization of farmer's produce to ensure quality-quantity improvements strategies based on the scientific approach.

Apart from the advantages of risk management and quality-quantity improvement studies through FMEA, the quality of the medicinal plants is confirmed through testing. Therefore, besides critical alignment studies and FMEA, it is also important to aware farmers regarding the Standard Quality Certification's (SQC's) of their

medicinal produce. Reference texts for medicinal plants are the standard documents that are referred by the herbal scientists to check the quality of the herbal samples. It comprises of vast number of quality parameters with the appropriate ranges for an individual plant (Singh et al., 2018b,c; Verma and Singh, 2008). In the case of India, API is the most referred text by the scientists comprising of medicinal plant standards describing the quality, purity, and strength of an individual plant that is manufactured, sold, and distributed by the licensed producer. It is divided into two parts: i) monographs of medicinal substance from natural origin ii) parameters for compound herbal formulations obtained from the schedule I- books under Drugs and Cosmetics Act, 1940. The Indian Drug Manufacturers' Association, Mumbai, and Regional Research Laboratory, CSIR, Jammu Tawi has published the Indian Herbal Pharmacopoeia in the year 1998 comprising of medicinal plants monographs (Yadav and Dixit, 2008). Similarly, the ICMR (Indian Council of Medical Research), New Delhi has developed monographs of medicinal plants that are published in the different volumes of the Medicinal plants of India (Tandon and Sharma, 2015, 2014, 2013, 2012, 2010; Tandon, 2011). Apart from this, the Food Safety and Standards Authority of India (FSSAI) have described some essential quality limits for turmeric. The spice board of India has also highlighted mandatory tests that are required for the export of turmeric to different countries. Besides this, the ASTA (American Spice Trade Association, Inc.), ESA (European Spice Association), Agmark have different standards for the quality evaluation of turmeric during the trade (Plotto, 2004). 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. The WHO has also described some critical quality control parameters such as the limit of pesticide residues, heavy metals, etc. in the medicinal plant materials with the appropriate ranges (WHO, 2011, 1998).

With all these multiple quality-related standard documents having diverse parameters and ranges, it is essential to draft a single intuitive document for a medicinal plant encompassing quality parameters that are mentioned in different texts. In order to address this, GAP related documentation in the form of monographs can prove beneficial. Comprehensive monographs of selected medicinal plants covering botanical, pharmacological, GAP, quality parameters related parameters would be beneficial to the farmers. Given this, in the present study, the monographs of selected medicinal plants *viz*. *A. vera, C. longa,* and *O. sanctum*, have been prepared after exploring standard literature and agro-practices followed by the farmers of Punjab (Jat *et al.*, 2015b; Jayashree *et al.,* 2015; Jat *et al.*, 2014; Bhattarai, 2013; Anonymous, 2009; World Health Organization, 2006).

At present, 199.97 lakh metric tonnes (MT) of paddy has been procured in Punjab by the government of India during 2020-21, which is 19% more than the target of 168 lakh metric tonnes and 26% more than the procurement done during the corresponding period of 2019-20 (The Tribune, 2020). The Ministry of AYUSH, has expressed to emerge medicinal plants 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 INR. 5000/- crores for the farmers (Singh *et al.,* 2021a; Phondani *et al.,* 2016; Singh, 2004). Before planning the cultivation of medicinal plants, it is necessary to conduct agro-economics study especially the cost-return structure involved in the medicinal plants adoption. Subsequently, a comparative cost analysis study between the traditional crops and medicinal plants was conducted in the present study.

In contrast, the present work provides a comprehensive roadmap to promote medicinal plants in the state by identifying progressive farmers, mapping farmers on digitalized maps, defining suitable growing zones for commercial important medicinal plants, assessing constraints faced by the farmers in the cultivation of medicinal plants, suggesting comprehensive GACP guidelines, quality-quantity improvements methodologies, drafting GAP monographs considering farmer's practices and reported literature, agro-economics, and suggestive quality parameters described in different standard texts.