Indian Journal of Traditional Knowledge
Vol 22(2), April 2023, pp 273-282
DOI: 10.56042/ijtk.v22i2.46379

Quality risk assessment on traditional immunity booster plants cultivators in Punjab, India

P A Singh[a,b] & A Baldi[b,*]

[a]University Institute of Pharma Sciences (UIPS), Chandigarh University, Mohali, Punjab, India
[b]Department of Pharmaceutical Sciences & Technology, Maharaja Ranjit Singh Punjab Technical University, Bathinda-151001, Punjab, India
[*]E-mail: baldiashish@gmail.com

Received 14 February 2021; revised 12 March 2022; accepted 21 March 2022

In the aftermath of the COVID-19, India has witnessed an increase in the demand for immunity boosting plants. The Ministry of AYUSH, Government of India through National Medicinal Plants Board (NMPB) has decided to emerge medicinal plants as an attractive farming option in view of generating income for farmers. The aim of this work was to identify quality gaps through a descriptive study on the farmers of Punjab cultivating immunity booster plants and also conduct a quality risk assessment study to recognize various critical agricultural materials, processes and their impact on the critical quality attributes to ensure the pre-determined quality of medicinal plants. The use of chemical fertilizers, less availability of quality planting material, poor awareness of agro-climatic suitability, and Good Agricultural and Collection Practices (GACP), were some of the problems in ensuring good quality of immunity booster plants. In order to fill these gaps, quality risk assessment studies identified critical materials and processes such as seed, fertilizers, pesticides, water, soil, authentication, sowing, site selection, phytoremediation, harvesting, drying, etc. that affected various quality attributes *viz.* yield, active constituents, toxicity indicators, physicochemical ranges and microbial load of immunity booster plants. Maintaining consistency is one of the major hurdles in agriculture due to several interfering biological and other factors, hence this quality risk assessment technique would enable farmer to fine-tune parameters by evaluating possible interactions with in-depth understanding.

Keywords: COVID-19, Farmers, Good Agricultural Practices, Immunity-booster Plants, Traditional Medicine

IPC Code: Int Cl.[23]: A61K 36/00

The outbreak of the Severe Acute Respiratory Syndrome (SARS-CoV-2) has led to an infectious disease known as COVID-19[1]. The positive results of medicinal plants and related formulations in managing previous infectious diseases such as SARS-CoV, herpes virus etc. has led the world scientists to explore cost-effective, people-reliable traditional medical interventions to manage COVID-19[2]. The Ministry of AYUSH, Government of India, recommended some immunity-boosting plants like *Curcuma longa* L. (Haldi), *Ocimum sanctum* L. (Tulsi), *Emblica officinalis* Gaertn. (Amla) and their formulations for preventive and prophylactic management of COVID-19[3].

The Ministry of AYUSH through NMPB has initiated to support the cultivation of medicinal plants in view of increasing income of the farmers. Despite enormous favourable conditions such as higher trade opportunities being a border state, conducive climatic conditions, and increasing global demand for herbs, the Indian state of Punjab has less than 1% of the total cultivable area under medicinal and aromatics cultivation[4]. Hence, to meet the greatest benefits from the Ministry of AYUSH, and comply with the qualitative standards required for immunity-booster plants, it becomes imperative for the farmers to adopt agricultural and collection practices producing high-quality medicinal produce. The mountainous land of the *Kandi* area (comprising of the upper region of Pathankot, Hoshiarpur, and Roopnagar districts) is undulating, crisscrossed with choes having deep and scarce groundwater making annual crops not only un-economic but eco-degrading also. Therefore, the farmers are mostly involved in the collection of Amla, Harad (*Terminalia chebula*), Bahera (*Terminalia bellirica*), and other medicinal plants which they sell to local industries and *mandis* (herbal markets). The Amla fruit of the *Kandi* region is highly in demand due to higher ascorbic acid content and Total

*Corresponding author

Suspended Solids (TSS) value and provides handsome returns to the farmers. Similarly, Tulsi is cultivated by farmers running a farmer-producer company named *Suhavi* for the first time in the Roopnagar district while clusters of Haldi are mostly present in Hoshiarpur, Roopnagar, and Fatehgarh district which is mostly sold in retailing by the cultivators in processed form (powdered). During the survey, it was found that some technical, awareness-related constraints were faced by the farmers cultivating selected medicinal plants. Quality-risk assessment study is a systematic process for the assessment, control, and communication of risks involved in any technical or manufacturing process. Through the inputs from the farmers, and corroborating their inputs and implications with respect to the GACP, the present works highlights critical materials and processes that affect the quality of herbal products so that farmers get good quality produce and enable themselves to avoid risks at later stages of plant production[5-7]. GACP is a set of guidelines drafted by the World Health Organization (WHO) in the year 2003 that ensure the good quality of medicinal plants. In the present study, a comprehensive survey-based analysis was conducted to select immunity-boosting medicinal plant cultivators across Punjab to highlight the quality gaps concerning GAP and subsequently conduct quality risk assessment study to map the Critical Quality Material (CQA), Critical Process Parameter (CPP) with Critical Quality Attribute (CQA) to ensure the predefined quality of the immunity-boosting plants with lesser chances of risks as represented in Figure 1.

Methods

Identification of immunity-booster medicinal plants cultivators and survey design

The participants for the study were identified based on the medicinal plants reported to possess immunity-boosting property as suggested by the Ministry of AYUSH for the management of COVID-19 and their availability in Punjab. Farmers from outside Punjab, not willing to participate in the study, and not involved in immunity-booster plant cultivation were excluded from the study. The forest department, farmer-producer companies, herbal industries, collection centres, herbal market, local farmers were consulted to gather the information regarding immunity-booster plant cultivators.

The data was collected from April 2019 to August 2019 and snowball sampling was followed as a sampling technique. With this criterion, total 44 farmers involved in cultivation of Haldi, Tulsi and Amla were interviewed personally using a semi-structured and pre-tested questionnaire throughout Punjab. The statements related to agro-practices, constraints and awareness of farmers on medicinal plant cultivation was collected, coded, processed and statistical measures such as MPS (Mean Percentage Score), frequency, Chi square was used to conclude. SPSS version 22 was used for statistical calculations in order identify gaps and analyse their impact on quality of herbs through the design based on critical variables.

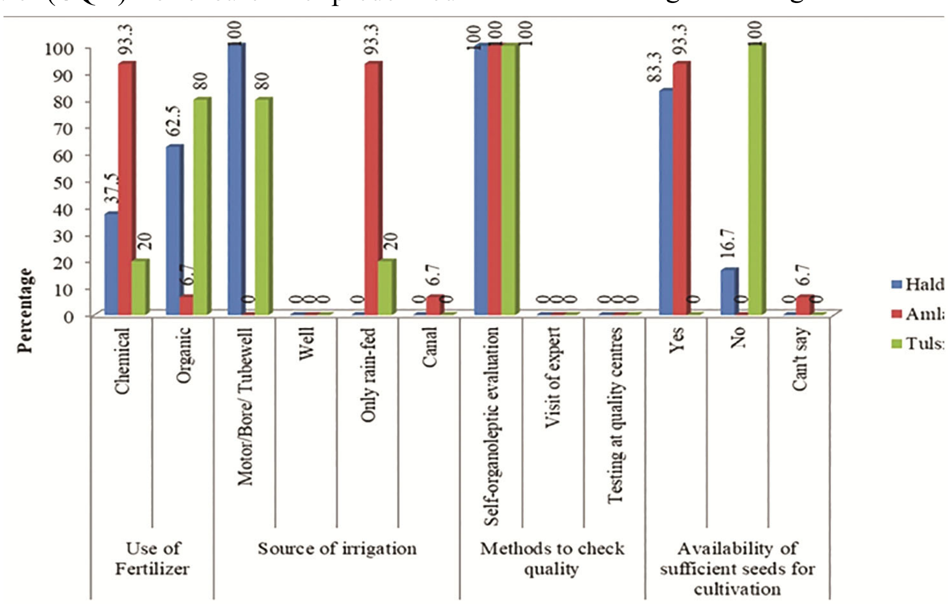

Fig. 1 — Responses regarding the agricultural pattern

Quality risk assessment design based on critical variables

Quality risk assessment was carried out to minimize the level of risks associated to getting low-quality produce. 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 agricultural material or process was rated on the critical quality risk scale that was established on basis of the number of consequences a material or process has on the quality of immunity-booster plants based on the sound literature exploration. 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[6]. The CQA were selected based on empirical data in context to industrial importance and sound literature exploration. The three set of variables mentioned in this scientific design 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[7].

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[8].

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[9].

Results

Type of immunity-boosting plants cultivators

It was observed that Amla was ultivated in Hoshiarpur district while Tulsi was predominantly cultivated in Roopnagar district of Punjab. Haldi was cultivated throughout Punjab except for few districts, as represented in Table 1.

Analysis of critical quality statements of cultivators

The selected immunity-boosting plant cultivators were subjected to the critical quality statements mentioned in the questionnaire. The statements related to agro-practices, constraints, and awareness were analysed to identify gaps with respect to GACP and subsequently co-relate the responses with the critical variables to understand their impact on the quality of herbs. The statements are mentioned in Figures 1, 2, and 3.

It was found that on average 50.2% of the farmers used government approved chemical fertilizers such as Urea, Di-ammonium Phosphate (DAP) for maintaining the growth of the plants. Most of the farmers except Amla cultivators relied on underground water for irrigating their crops using motors/bore/tube-well submerged in the ground. Amla trees were cultivated in the sub-mountainous zones of Punjab and due to the difficulty and high cost of installing pumps and motors in the area; the farmers relied on only rain-fed irrigation. When using the Chi-square test, it was discovered that farmers growing Amla depended on rain-fed irrigation as opposed to those growing Haldi

Table 1 — Type of immunity-boosting plants cultivated by the farmers in Punjab

Districts	Haldi		Amla		Tulsi	
	f	**%**	**f**	**%**	**f**	**%**
Amritsar	1	4.2	0	0	0	0
Fatehgarh Sahib	3	12.5	0	0	0	0
Gurdaspur	2	8.3	0	0	0	0
Hoshiarpur	5	20.8	15	100	0	0
Kapurthala	1	4.2	0	0	0	0
Ludhiana	1	4.2	0	0	0	0
Mohali	2	8.3	0	0	0	0
Patiala	2	8.3	0	0	0	0
Roopnagar	4	16.7	0	0	5	100
Sangrur	2	8.3	0	0	0	0
SBS Nagar	1	4.2	0	0	0	0
Total	**24**	**100**	**15**	**100**	**5**	**100**

and Tulsi, who relied on underground water for irrigation, with a statistically significant p-value of 0.000638. Lack of authentication by an expert and quality estimation of produce utilizing testing labs were some of the constraints faced by the farmers as represented in Figure 1. Subsequently, the statement pertaining to quality of seed as observed by the farmers was highlighted by the farmers represented in Figure 2.

During the conduct of the survey, it was found that on average more than 95% of the immunity-boosting plant cultivators wanted to refine their adopted agro-technology for ensuring good quality and yield of the crops in order to gain maximum benefits, as represented in Figure 3. The Amla cultivators had lack of drying spaces and most of the farmers had storage areas without controlled environment conditions. The farmers, except Amla cultivators had no linkage with the herbal or related industry for buyback of their produce. Similarly, more than 75% of the farmers were not satisfied with the subsidy amount on medicinal plants as represented in Figure 3.

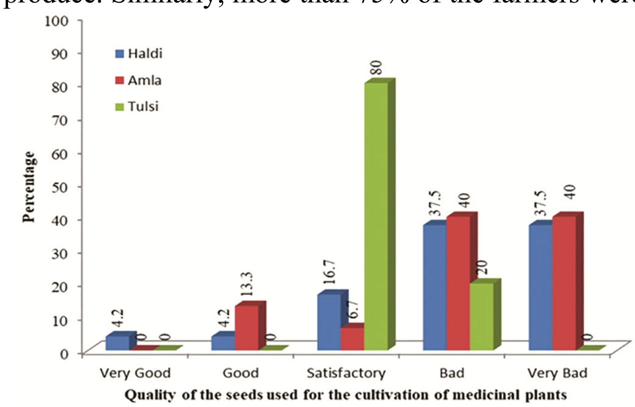

Fig. 2 — Response regarding the quality of seeds for immunity-booster plants

Punjab has five agro-climatic zones based on growing periods, soil dominancy, and climatic requirements[10]. Each immunity-booster plant required specific bio-climatic requirements for normal physiological functioning. It was found that most of the farmers lacked knowledge regarding the best agro-climatic suitability of the plants they were cultivating as mentioned in Figure 3. Similarly, except Haldi cultivators, most of the farmers were not even aware of the GACP of medicinal plants. It was observed that on average 43% of the farmers were not aware of the industrial requirement of the quality of medicinal as presented in Figure 3. Therefore, to circumvent the quality-related issues, a quality risk assessment design ensuring pre-determined quality of the immunity-boosting plants is required which is covered in the next sections of this paper.

Quality risk assessment design

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 immunity-boosting plants based on farmer's inputs and literature exploration. The materials affecting the CQA of plants based on risk assessment scale are mentioned in Table 2.

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

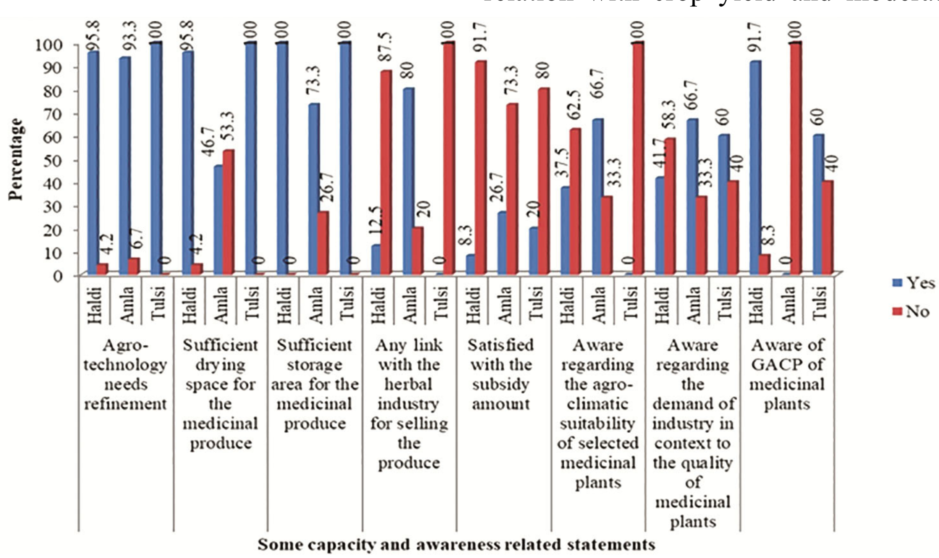

Fig. 3 — Responses to some capacity and awareness related issues

Table 2 — CMA based on quality risk assessment.

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

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

Table 3 — CPP based on quality risk assessment

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

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

toxicity indicators. On the other hand, biological indicators, agricultural equipment's had a negligible bearing on toxicity indicators of the plants.

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[11,12]. 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.

Pre-cultivation phase

Seed treatment: Seed treatment included proper taxonomical authentication with phenotype/chemotype/genotype and breeding history for obtaining good quality immunity-boosting plants. Similarly, proper inspection should be carried out to control intentional and un-intentional adulteration of the seeds[13,14]. Furthermore, seeds must be checked for physical uniformity, seed coat, should be made disease and pest resistance to get optimum yield, active constituents and the produce free from toxicity indicators[15]. The seed treatment had very high impact on the crop yield, followed by active constituents, toxicity indicators, microbial load and physicochemical ranges as mentioned in the Table 3.

Site selection process: 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[16]. Sites near to mining, crematoriums, golf courses, etc., shall be avoided to produce good quality herbs. Feedlot history and domestic animals entry need to be strictly prohibited as it affected the yield of the crop[17]. Concerning these factors and the quality risk assessment study suggested that site selection mostly affected the crop yield followed by toxicity indicators, microbial load, active constituents and physicochemical ranges of immunity-booster plants as mentioned in Table 3.

Soil treatment process: Soil sampling and physicochemical properties of the soil must be carried out to highlight the nutrient requirements of the immunity-booster plants and to check the water movements in soil layers. There should be proper tillage for the activation of the soil microbes, soil structure, and incorporation of fertilizers and soil amendments[18,19]. Similarly, levelling the field must be carried out for the uniform distribution of water, nutrients to the seedlings thereby increasing the yield and good traffic[20]. 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[21,22]. Therefore, 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[23]. Night soil must be avoided to ensure a lesser vulnerability of microbial and aflatoxin contamination of the plants. Based on these factors and their effects on the quality of immunity-booster plants, the soil treatment significantly affected crop yield, followed by microbial load, toxicity indicators, active constituents and physicochemical ranges of immunity-booster plants as mentioned in the Table 3.

Water treatment processes: The first step to assure the quality of the water is to ensure its compliance with the regional and national qualities[5]. 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[24,25]. Lead which is not 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.[5,26]. Therefore, lead pipe fittings should be avoided to control excessive lead presence in the crop[5,27]. The water treatment processes has larger impact on crop yield followed by active constituents, microbial load, toxicity indicators and physicochemical ranges as mentioned in Table 3.

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[10,28]. During sowing, optimal seed-to-seed and row-to-row distance, seed depth must be maintained according to the plant requirements[5]. 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, physicochemical ranges, and toxicity indicators as mentioned in Table 3.

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[5]. The plants 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. Pruning was essential to remove the dead part of the plant especially Amla, to control and re-direct its growth[29]. According to the mapping, the plant management possessed effect on the yield, microbial load, physicochemical and toxicity indicators of the immunity-boosting plants as mentioned in Table 3.

Crop nutrition: In case of medicinal plants, optimum use of aerobic organic fertilizers, bio-pesticides is recommended. Fully composited organic manures, vermi-compost, poultry manure, green leafy manure must be applied at the initial phase for a complete breakdown. In some cases, if pesticides were essentially required, the smallest effective dosage with the least toxicity must be used[5].Human excreta should not be used or mixed with the fertilizers as it attracts pathogens, diseases, and pests lowering the yield of the plant and increasing the microbial load[5,30]. The crop nutrition highly affected crop yield followed by microbial load, active constituents, toxicity indicators as mentioned in Table 3.

Harvest: The time of the harvest played a critical role in context to the presence of active constituents. 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[5]. Harvesting must be avoided in high dew, humidity, and rainfall. The harvesting process affected active constituents, physicochemical ranges, and microbial load as mentioned in Table 3.

Post-harvest phase

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. Furthermore, collection of immature and undersized fruit must be avoided. 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[31].Collection should be avoided in high moisture conditions, or during rainfall as it is prone to increase the microbial load, and affect the active constituents. Process for collecting the fruits moderately affected active constituents, followed by microbial load, and physicochemical ranges as mentioned in Table 3.

Drying: Essentially low drying temperatures between 30 to 50°C are recommended to protect sensitive active constituents such as eugenol in Tulsi, and volatile oils in Haldi[32]. In general, drying should be done in a manner to prevent discoloration of herbs, and drying under direct sunlight must be avoided to maintain the volatile contents. Shade drying, solar drying, freeze-drying, etc. must be preferred for the selected immunity-booster plants. During drying tarpaulin cloth should be used between the cemented floor and the drying material to prevent crop damage and foreign matter in the medicinal plants. Similarly, drying should be done in such a place where there is no threat from rodents, pests to the drying material. Drying process has effect on microbial load, active constituents, and physicochemical ranges as presented in Table 3.

Storage: It is recommended to process or semi-process selected immunity booster plants in due course of time and storage time must not exceed one year[33]. 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[34]. As mentioned in Table 3, the storage process affected active constituents, microbial load, and physicochemical ranges.

Handling: Harvested material should be thoroughly cleaned to avoid the presence of foreign matter, high moisture content, microbial content, aflatoxin levels, etc. 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 increased the chances for microbial contamination and damage of produce[5]. Inappropriate handling of herbal raw material affects the microbial load, active constituent yield, and physicochemical parameters as represented in mentioned in Table 3.

Discussion

Punjab has become the epicenter of wheat-rice cropping pattern, after the successful implementation of 'Green Revolution in the 1960s[35]. Over time, this cropping pattern has become reliant on underwater resources, extensive use of chemical fertilizers, pesticides, and agricultural machinery is leading to lesser returns for farmers[4,36,37]. In this context, Punjab requires potential crops for diversification in order to maintain sustainable agriculture. There are reports claiming rise in the income of farmers adopting medicinal plants in India. The recent surge in the demand for immunity-booster plants in the aftermath of COVID-19 has increased their commercial value which can lead to high profitability to the farmers of Punjab if the quality is maintained[38]. Punjab has approximately 284 functional herbal licensed units, but lesser awareness among the farmers regarding the agro-climatic suitability, quality requirements, industrial demand, potential buyers, lack of industrial linkage, buyback agreements, prohibited them to adopt immunity-boosters plant cultivation. In this context, agro-ecological zoning-based immunity booster and other medicinal plants can be suggested to the farmers using geospatial modelling techniques to circumvent quality related issues[38,39]. A study was conducted to highlight potential growing zones for immunity-booster medicinal plants *viz.* Tulsi and

Withania somnifera in Punjab. It was observed that Tulsi was optimally suitable for the zones I,II, III and *Withania somnifera* was optimally suitable for zones II and III[38]. To link farmers with the nearby industries, a study has been conducted by Singh and co-workers that created a state-of-art geo-spatial model by tagging the medicinal plants cultivators in different agro-climatic zones of Punjab[4]. Apart from geo-spatial model, it is necessary to encourage formation of large clusters of medicinal plant cultivators in the form of self-help groups, farmer-producer companies to attract industry of the state.

Intensive cropping in Punjab has led to extensive inflow of chemical fertilizers and pesticides in the soils and there are reports of heavy metal contamination in certain areas of Punjab. Herbal formulations are intended for human administration, therefore, heavy metals, pesticide residues, microbial contamination, aflatoxin levels must be within prescribed limits in the immunity-booster plants for industrial acceptance. Heavy metals such as lead, cadmium should not be more than 10 mg/kg and 0.3 mg/kg respectively as per the WHO. Likewise, pesticide residues of aldrin and dieldrin must not be more than 0.05 mg/kg. In order to overcome heavy metal and pesticides threat, farmers of Punjab must conduct soil sampling and resort to phytoremediation techniques using mustard, marigold, etc. plants as intercrops. Similarly, *Escherichia coli*, mould propagules, aerobic bacteria, yeasts and moulds, enterobacteria, *Salmonellae* must be within prescribed limits in raw, pre-treated immunity-booster plants. Aflatoxins, particularly B1, B2, G1, and G2 in immunity booster plants should be avoided by complying with the regional requirements of water for irrigation and avoiding excessive moisture, sludge, and water-logging[40-43]. Besides this, the concerned institutions such as Indian Council for Agricultural Research (ICAR), The Council of Scientific and Industrial Research-Central Institute of Medicinal and Aromatic Plants (CSIR-CIMAP) and also NMPB must co-ordinate to ensure sufficient availability of authenticated Quality Planting Material (QPM) to the interested farmers and also provide standard agro-technique manuals for the selected immunity-booster plants through their extension services in order to obtain high-quality produce.

Conclusion

The descriptive study highlighted poor quality seeds, extensive use of chemical fertilizers, poor knowledge of agro-climatic suitability, lack of industrial linkage, poor awareness of the quality of medicinal produce as some of the major bottlenecks. Therefore, to circumvent these quality gaps, the present study identified critical materials such as seed, soil site, water, fertilizers, pesticides, biological indicators, equipment having significant relation with the quality attributes of immunity-boosting 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 immunity-boosting medicinal plants.

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.

Acknowledgements

The authors are grateful to Dr. Arun Chandan, Regional Director, RCFC-North-NMPB, Ministry of AYUSH for his valuable inputs. The authors are thankful to Ms. Sanjna Aggarwal, Mr. Pranesh Muthuchami, Ms. Ishita Varma, Kritika Khanna from RIS, New Delhi for their inputs. The authors are also grateful to the farmers of Punjab for sparing their valuable time for this survey. The responsibility of the facts stated or opinions expressed is entirely of the author’s and not of the FITM, Ministry of AYUSH or RIS.

Funding

This work has been financially supported by Forum on Indian Traditional Medicine (FITM), Ministry of AYUSH and Research & Information System for Developing Countries (RIS). FITM Doctoral Research Fellowship is awarded to one of the author’s, Mr. Preet Amol Singh for this work.

Conflict of Interest

Authors declare that they do not have any conflict of interest.

Authors' Contributions

P A S has collected the primary data, interpreted the results, written the manuscript. A B conceptualized the study.

Consent to Participation

Signed "consent to participate" certificate was taken from the farmers participating in the survey.

References

1 Zheng Y Y, Ma Y T, Zhang J Y & Xie X, COVID-19 and the cardiovascular system, *Nat Rev Cardiol*, 17 (5) (2020) 259-260, https://doi.org/10.1038/s41569-020-0360-5.

2 Chaturvedi S, Kumar N, Tillu G, Deshpande S & Patwardhan B, AYUSH, modern medicine and the COVID-19 pandemic, *Indian J Med Ethics*, (2020) 1-4, DOI:10.20529/ IJME. 2020.058.

3 Singh P A, Bajwa N & Baldi A, Possible role of traditional systems of medicine to manage COVID-19: A review, *Isr J Plant Sci*, 68 (1-2) (2021) 3-28, DOI: https://doi.org/ 10.1163/22238980-bja10021.

4 Singh P A, Sood A & Baldi A, Determining constraints in medicinal plants adoption: A model geospatial study in the Indian state of Punjab, *J Appl Res Med Aromat Plants*, 25, 100342, https://doi.org/10.1016/j.jarmap.2021.100342.

5 Mejàre I, Axelsson S, Dahlën G A, Espelid I, Norlund A, *et al*., Caries risk assessment, A systematic review, *Acta Odontol Scand*, 72 (2) (2014) 81-91, DOI: 10.3109/ 00016357.2013.822548.

6 Sumit K, Shikha T, Deepika T & Ashish B, A quantitative approach for pharmaceutical quality by design patterns, *Invet Rapid: Pharm Anal Qual Assur*, 4 (2012) 1-8.

7 Krull S M, Ammirata J, Bawa S, Li M, Bilgili E, *et al*., Critical material attributes of strip films loaded with poorly water-soluble drug nanoparticles: II. Impact of polymer molecular weight, *J Pharm Sci,* 106 (2) (2020) 619-628, DOI: 10.1016/j.xphs.2016.10.009.

8 Rathore A S, Roadmap for implementation of quality by design (QbD) for biotechnology products, *Trends Biotechnol*, 27 (9) (2009) 546-553, DOI: 10.1016/j.tibtech.2009.06.006.

9 Patel H, Parmar S & Patel B, A comprehensive review on Quality by Design (QbD) in pharmaceuticals, *Int J Pharm Sci Rev Res*, 21 (1) (2013) 223-236.

10 Singh N K & Rath S S, Epidemiology of ixodid ticks in cattle population of various agro-climatic zones of Punjab, India, *Asian Pac J Trop Med*, 6 (12) (2013) 947-951, DOI: 10.1016/S1995-7645(13)60169-8.

11 Yan B, Li Y, Guo Z & Qu H, Quality by design for herbal drugs: A feed-forward control strategy and an approach to define the acceptable ranges of critical quality attributes, *Phytochem Anal*, 25 (1) (2014) 59-65, DOI: 10.1002/ pca.2463.

12 Qu J, Zhang T, Liu J, Su Y & Wang H, Considerations for the quality control of newly registered traditional Chinese medicine in china: A review, *J AOAC Int*, 102 (3) (2019) 689-694, https://doi.org/10.5740/jaoacint.18-0301.

13 Singh P A, Bajwa N, Naman S & Baldi A, A review on robust computational approaches based identification and authentication of herbal raw drugs, *Lett* Drug *Des Discov*, 17 (2020) 1066-1083, DOI: 10.2174/ 1570180817666200304125520.

14 Chanda S, Importance of pharmacognostic study of medicinal plants: An overview, *J Pharmacogn Phytochem*, 2 (5) (2014) 1-15.

15 Gahukar R T, Evaluation of plant-derived products against pests and diseases of medicinal plants: A review, *Crop Prot*, 42 (2012) 202-209, DOI: 10.1016/j.cropro.2012. 07.026.

16 Anderson S, Identifying important plant areas, *Plantlife Int London,* (2002) 5-51

17 De Freitas Araújo M G & Bauab T M, Microbial quality of medicinal plant materials, *Latest Res Qual Cont*, (2012) 67-81, DOI: 10.5772/51072.

18 Roger-Estrade J, Anger C, Bertrand M & Richard G, Tillage and soil ecology: partners for sustainable agriculture, *Soil Till Res,* 111 (1) (2010) 33-40, https://doi.org/10.1016/ j.still.2010.08.010.

19 Rasmussen K J, Impact of ploughless soil tillage on yield and soil quality: A Scandinavian review, *Soil Till Res*, 53 (1) (1999) 3-14, https://doi.org/10.1016/S0167-1987(99)00072-0.

20 Agarwal M C & Goel A C, Effect of field levelling quality on irrigation efficiency and crop yield, *Agric Water Manag*, 4 (4) (1981) 457-464, https://doi.org/10.1016/0378-3774 (81)90033-0.

21 Seifu W & Elias E, Soil quality attributes and their role in sustainable agriculture: A review, *Int J Plant Soil Sci,* 26 (3) (2019) 1-26, DOI: 10.9734/IJPSS/2018/41589.

22 Rhoades J D, Drainage for salinity control, *Drainage Agric,* 17 (1974) 433-461.

23 Salt D E, Smith R D & Raskin I, Phytoremediation, *Ann Rev Plant Biol*, 49 (1) (1998) 643-668.

24 Hong C X & Moorman G W, Plant pathogens in irrigation water: challenges and opportunities, *Crit Rev Plant Sci*, 24 (3) (2005) 189-208, DOI: 10.1080/07352680591005838.

25 Pang HC, Li Y Y, Yang J S & Liang Y S, Effect of brackish water irrigation and straw mulching on soil salinity and crop yields under monsoonal climatic conditions, *Agric Water Manag*, 97 (12) (2010) 1971-1977, https://doi.org/10.1016/ j.agwat.2009.08.020.

26 Nas F S & Ali M, The effect of lead on plants in terms of growing and biochemical parameters: A review, *Ecol Environ Sci*, 3 (4) (2018) 265-268.

27 Singh P A & Baldi A, Good Agricultural Practices: A prequisite approach for enhancing the quality of Indian herbal medicines, *Biomed J Sci Tech Res,* 5 (5) (2018) 1-4, DOI: 10.26717/BJSTR.2018.05.001268.

28 Coventry D R, Reeves T G, Brooke H D & Cann D K, Influence of genotype, sowing date, and seeding rate on wheat development and yield, *Aust J Exp Agric*, 33 (6) (1993) 751-757, DOI: 10.47856/ijaast.2021.v08i3.002.

29 Saure M C, Summer pruning effects in apple—a review, *Scient Horticulturae,* 30 (4) (1987) 253-282, https://doi.org/ 10.1016/0304-4238(87)90001-X.

30 Strauch D, Survival of pathogenic micro-organisms and parasites in excreta, manure and sewage sludge, *Rev Sci Technol,* 10 (3) (1991) 813-846, DOI: 10.20506/ rst.10.3.565.

31 Pandey A K & Das R, Good field collection practices and quality evaluation of medicinal plants: prospective approach to augment utilization and economic benefits, *Res J Med Plant*, 8 (1) (2014) 1-19.

32 Müller J & Heindl A, Drying of medicinal plants, In: Medicinal and aromatic plants – agricultural, commercial, ecological, legal, pharmacological and social aspects, Bogers, R J Craker, L E Lange (eds.), Springer, p. 237-252.

33 Lisboa C F, de Castro Melo E & Donzeles S M L, Influence of storage conditions on quality attributes of medicinal plants, *Biomed J*, 2 (2018) 3, DOI: 10.26717/ BJSTR. 2018.04.001097.

34 Sumithra G, Prasad P V N R, A review on good storage practices of raw drugs: classical and contemporary, *Int Ayurved Med J*, 6 (9) (2018) 2110-2114.

35 Dutta S, Green revolution revisited: the contemporary agrarian situation in Punjab, India, *Social Change*, 42 (2) (2012) 229-247, https://doi.org/10.1177/004908571204200205.

36 Chand R, Emerging crisis in Punjab agriculture: Severity and options for future, *Econ & Pol Weekly*, 34 (13) (1999) A2-A10, https://www.jstor.org/stable/4407788.

37 Singh S, Multi-national corporations and agricultural development: a study of contract farming in the Indian Punjab, *J Int Dev*, 14 (2) (2002) 181-194, https://doi.org/ 10.1002/jid.858.

38 Singh P A, Sood A & Baldi A, Highlighting agro-ecological zones to upscale the production of immunity-booster plants in Punjab, *Res J Agril Sci*, 12, (2021) 865-870, http://rjas.org/ Article/Article/3686.

39 Singh P A, Sood A & Baldi A, An agro-ecological zoning model highlighting potential growing areas for medicinal plants in Punjab, *Indian J Pharm Edu Res*, 55 (2), (2021) S492-S500, doi:10.5530/ijper.55.2s.120.

40 World Health Organization, Quality control methods for medicinal plant materials, Geneva, 1998.

41 World Health Organization, Quality control methods for herbal materials, Geneva, 2011.

42 Rajeshwari P & Raveesha K A, Mycological analysis and aflatoxin B 1 contaminant estimation of herbal drug raw materials, *Afr J Tradit Complememt*, 13 (5) (2016) 123-131, doi: 10.21010/ajtcam.v13i5.16.

43 Panda S & Thami J K, An ethnomedicinal field survey report on traditionally used plants by the Nepalese of Alubari jungle busty in Darjeeling Himalaya as potential immunity booster and fever-related herbal drugs, *Indian J Tradit Know,* 21 (1) (2022) 157-167.