REPORT ON STRENGTHENING THE VALUE CHAIN BASED ON CINCHONA AND OTHER MEDICINAL PLANTS

Study undertaken for :

Directorate of Cinchona and Other Medicinal Plants
Gorkhaland Territorial Administration
Department of Food Processing Industries and Horticulture
Government of West Bengal

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DEX-DEFT®

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New Delhi - 110019

सत्यमेव जयते

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সুব্রত সাহা
Subrata Saha

রাষ্ট্রমন্ত্রী (স্বাধীন দায়িত্ব)
খাদ্য প্রক্রিয়াকরণ শিল্প ও উদ্যানপালন বিভাগ
পশ্চিমবঙ্গ সরকার
Minister-of-State
(Independent Charge)
Food Processing Industries
& Horticulture Department
Govt. of West Bengal

MESSAGE

Established long back in 1862, during colonial era, the Cinchona plantations of Darjeeling and Kalimpong districts in West Bengal are today, the only commercially grown Cinchona plantations in India.

As such, Cinchona and various other medicinal products and their derivatives, produced by the Directorate of Cinchona and Other Medicinal Plants (DCOMP), under the aegis of Gorkhaland Territorial Administration (GTA) and Department of Food Processing Industries and Horticulture (FPIH), Government of West Bengal, are of great importance considering valuable medicinal properties.

It gives me immense pleasure to know that an exercise to formulate a short, medium and long term plan had been commissioned by the Food Processing Industries and Horticulture (FPIH) Department, Government of West Bengal with the Directorate of Cinchona and Other Medicinal Plants (DCOMP) through the assistance of DEX-DEFT Research and Consulting and several other collaborating institutions.

I sincerely hope that this study will provide a much needed scientific insight in modern plantation management of Cinchona which is the source of "Quinine" – a valuable anti-malarial medicine and also other medicinal plants to make it commercially more viable.

I convey my sincere regards to all members of the study team, field level scientists and research scholars and the officials of FPIH Department, Directorate of Cinchona and Other Medicinal Plants and GTA for this innovative and extensive study and wish every success of this endeavor.

Subrata Saha

(SUBRATA SAHA)

Kolkata
Dated: The 31st May, 2022.

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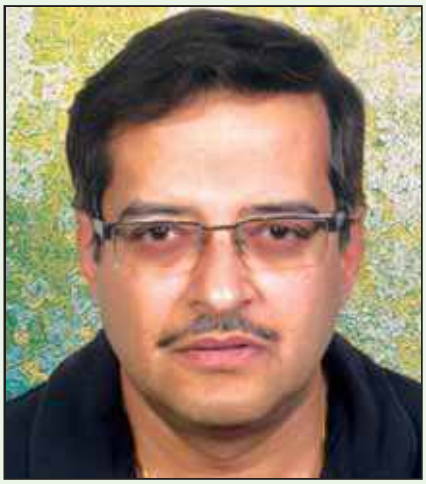
FOREWORD



The Cinchona plantations in West Bengal were established in the year 1862 by the Scottish botanist, Dr. Thomas Anderson, Superintendent of Royal Botanical Garden, (then) Calcutta in the hills of Darjeeling. A few years prior to this, the British introduced Cinchona plantations in the Nilgiri and Anamalai hills of Tamil Nadu. At that time malaria was a scourge affecting many in the subcontinent. Quinine, an alkaloid obtained from the bark of the Cinchona tree was effective for the treatment of malaria. It has also been used to treat other diseases such as varicose veins, influenza etc. The bark also contains other alkaloids including quinidine which have therapeutic properties. The plantations were established with the objective to grow different species of Cinchona from the bark of which quinine was extracted. The Cinchona plantations established in Tamil Nadu were discontinued from 2012. Today, the only Cinchona plantations in India are in the hills of Darjeeling and Kalimpong districts. Apart from India, Cinchona is commercially grown in a handful of countries. The Cinchona plantations are, therefore, a national asset which need to be well preserved and further developed.

The Directorate of Cinchona and Other Medicinal Plants (DCOMP) was set up to protect and expand the Cinchona plantations and also to introduce new crops which are important from the commercial and therapeutic angles. Over several decades, crops like ipecac, citronella, lemon grass, rubber, Mandarin orange, *Taxas baccata,* cardamom, *Swertia chirayita, Artemisia annua,* coffee, black pepper, orchids etc. were introduced in the plantations covering an area of over 26000 acres.

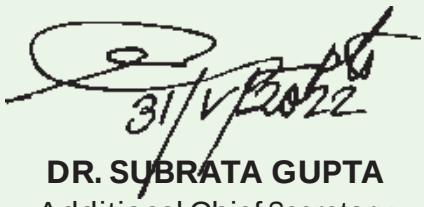
In the decades that followed, it was seen that the quinine content in the Cinchona bark has declined to a level of around 3-6% which is far less in comparison to that obtained elsewhere such as in Indonesia, Ghana, Peru, Costa Rica, Rawanda etc. It was also found that the other commercial crops, in spite of the promise, were not yielding adequate returns in comparison to the investment. There was, therefore, a need to adopt plantation practices which would improve the quinine content and also identify those crops which would suit the climate and soil in the Darjeeling and Kalimpong hills while being commercially remunerative. The government thereafter decided to carry out a detailed study for preparing a short, medium and long term plan for the Directorate of Cinchona and Other Medicinal Plants. This report entitled "**Report on Strengthening the Value Chain Based on Cinchona and Other Medicinal Plants**" encapsulate the findings and conclusion of the exercise carried out by the consulting firm, DEX-DEFT.

Among otherthings, the report suggests practices for better management of the Cinchona plantations to improve the alkaloid yield comparable to the best in the world. It identifies the requirement of

refurbishment of infrastructure and processes for harvesting, storage and processing of Cinchona bark. The study also examines the feasibility of cultivation of other plantation and medicinal crops and creation of other enabling facilities such as testing laboratory.

This report prepared after extensive field study and interaction with different stakeholders is a valuable document which will be used for informing the policy of the Directorate of Cinchona and Other Medicinal Plants and the Government of West Bengal with regard to the activities of the Directorate in the years to come. It is often said that reports produced for the government usually gather dust. Not this one. The Directorate has already embarked on an implementation of several steps recommended in the report in a systematic manner. A huge exercise has been carried out to identify and label 2,00,000 Cinchona trees in certain age groups and their bark samples collected for chemical analysis. From this exercise, it is expected that high yielding trees can be identified which can then be used for vegetative propagation. A parallel initiative has been launched to develop a protocol for tissue culture of Cinchona trees. Once high yielding trees are identified and the protocol is established, the plantation can be renewed over a ten-year period, an ambitious but achievable plan.

I expect this document to be of significant value, not only to the officials of Directorate of Cinchona and Other Medicinal Plants and the Department of Food Processing Industries and Horticulture but also to other stakeholders including enthusiasts, researchers, environment activists and educational institutions.



DR. SUBRATA GUPTA
Additional Chief Secretary
Government of West Bengal

Kolkata
Dated 31 May 2022

ACKNOWLEDGMENTS

This study was an extensive collaborative effort between the Directorate Cinchona and Other Medicinal Plants, West Bengal, Gorkhaland Territorial Administration, the Department of Food Processing Industries and Horticulture, Government of West Bengal, the study team of DEX-DEFT Research and Consulting, and several other collaborating institutions. All participants extended their full cooperation to this study to ensure successful outcomes.

A special mention may be made of the visionary leadership provided by Dr. Subrata Gupta, Additional Chief Secretary, Department of Food Processing Industries and Horticulture, Government of West Bengal to commission this study and dedicate his valuable time by chairing several meetings to (a) understand the findings of the study, and (b) take necessary actions wherever deemed necessary. Our team would like to take this opportunity to also thank Mr. Saurav Pahari, Additional Secretary, Department of Food Processing Industries and Horticulture, Government of West Bengal for guiding the study team on several occasions.

The Directorate of Cinchona and Other Medicinal Plants, West Bengal, as the nodal agency for this study, played key role in supporting timely execution of all components planned in this study.

Our team acknowledges the cooperation they have received from all officials of the Directorate. The exemplary functional leadership provided by Dr. Samuel Rai, Director, to this study is hereby acknowledged with gratitude; without such demonstrated leadership from him this initiative could not have been completed meaningfully, and within stipulated time. Our team sincerely thanks the Director, and all officials and staff of the Directorate for their unstinted support and deeply appreciates the commitment they have shown on this exercise.

Our team would also like to thank all collaborating institutions in this study, and especially acknowledge the valuable contributions made to this study by the Gorkhaland Territorial Administration (Office of the Principal Secretary and Kurseong Engineering Division), Uttar Banga Krishi Vishwavidalaya, Bidhan Chandra Krishi Vishwavidalaya, Jadavpur University, and National Bureau of Soil Survey and Land Use Planning (Kolkata office).

Last, but not the least, high quality inputs and rich information were provided by academicians and functionaries in the private sector through interviews and discussions in several of the study areas; all these contributions are gratefully acknowledged.

Dated 22 February 2022

On behalf of the study team
Partha S Banerjee Ph. D., Director
DEX-DEFT Research and Consulting

CONTENTS

INTRODUCTION

1.1 Structure of this report

This report is being submitted to provide an understanding of the work that has been done in the value chain study for Cinchona and other medicinal plants commissioned by the Directorate of Cinchona and Other Medicinal Plants (DCOMP), under the aegis of Gorkhaland Territorial Administration (GTA) and Department of Food Processing Industries and Horticulture, Government of West Bengal (GoWB). The report has attempted to synthesize insights drawn from (a) the analyses of primary data and secondary information collected through desk research, (b) findings from field missions to Mungpoo and other DCOMP locations, and (c) inputs received from expert consultations in this assignment.

Chapter 1 : (the present chapter) of this report introduces the study, encapsulating its objectives, and outlining the approach adopted for this study. Besides this chapter, the report contains five other chapters, namely:

Chapter 2 : discusses the challenges in the plantations, outlining the need for adopting good practices in plantation management, and making it sustainable.

Chapter 3 : outlines the measures needed to improve drying and storage facilities.

Chapter 4 : reports findings from a rapid market study of Cinchona based products.

Chapter 5 : focuses on a few other crops (besides Cinchona) where DCOMP can achieve commercial success.

Chapter 6 : sets out the recommendations emanating from this study.

The proceedings of the implementation planning meetings in Kolkata (18 November 2021) and Mungpoo (17 December 2021) are enclosed. Implementation of the recommendations in the interim report are already in progress. Any further set of actions may be initiated based on the progress of implementation works.

1.2 The context

DCOMP has a rich legacy and a glorious history. It was established in the year 1862 by Dr. Thomas Anderson, Superintendent of Royal Botanical Garden, (then) Calcutta. It was established with an objective to grow different species of Cinchona to produce the anti-malarial drug 'Quinine' from its bark. This was the premium institution that served the whole country with Cinchona tree bark to produce anti-malarial drug 'Quinine'. By 1906, the Government Cinchona Plantation comprised: (1) the Rangju Valley block, consisting of the Rangbi and Mungpoo Divisions, which together measure about 900 acres, containing nearly over 2 million plants, of which more than a million and half are *Cinchona ledgeriana* (syn. calisaya), nearly half a million of hybrid, and the remainder of *Cinchona succirubra*; (2) the Rayang Valley block, consisting of the Sitong and Labdah Divisions which together comprise an area of about 600 acres, with over 200,000 plants, more than half of which are *Cinchona succirubra* and hybrid, and the remainder *Cinchona ledgeriana* (syn. calisaya). Another South American species, Ipecac (source of "emetin") was introduced by the British in the 19th century.

Subsequent initiatives, spread over several decades in the British era and in independent India, expanded the activities of DCOMP by introducing new crops like Ipecac (*Cephaelis ipecacaunha),* Citronella *{Cymbopogon nardus),* Rubber (*Hevea brasiliensis),* Mandarin Orange (*Citrus reticulata),* Kiwi *(Actinidia sp.),* Cardamom *{Amomum subulatum), Taxus baccata, Dioscorea,* Orchids (Cymbidium and Tropical), Coffee (*Coffea arabica), Chirata (Swertia chirata),* Black Pepper *{Piper nigrum),* and some temperate fruits. This contributed to production of various medicines like Dioscorea (intermediate in the production process of steroids), Ipecac for production of anti-diarrhoeal medicine "emetin" and *Taxus baccata,* for production of anti- cancer "Taxol".

A few years ago, DCOMP was brought under the Gorkhaland Territorial Administration (GTA) and it now continues to be administered by Government of West Bengal through the GTA. DCOMP is headquartered in Mongpoo, a town located under Darjeeling Sadar Sub-Division of Darjeeling district about 33 km east of Darjeeling town. A summarized institutional profile of DCOMP is given below:

- Plantation units (i) Mungpoo (ii) Munsong (iii) Rongo and (iv) Latpanchor.
- The total area available with DCOMP is 10,538.29 hectare (ha) varying between an altitude of 1,200 ft and (approx) 6,000 ft above mean sea level. Of this, only about 31.5% (3,316.31 ha) is the productive cropping land.
- The climate is humid-temperate with temperature ranging between 30°C (max.) and 08°C (min.), and average rainfall being approx 4,000 mm per annum.
- The soil is typical hilly with high organic matter, acidic in reaction, coarse texture. Water is sourced through lift irrigation from jhoras.
- Cinchona is cultivated in 26.1 % of the total land. The annual production of Cinchona bark is about 200 MT from the areas under cultivation.
- DCOMP has 5,350 daily wage labourers, which is a high number.

1.3 Objectives of this study

DEX-DEFT Research and Consulting (hereinafter "DEX-DEFT") was commissioned by DCOMP to undertake a study "to strengthen the value chains based on Cinchona and other medicinal plants in West Bengal" with the objective of expansion of Cinchona and other medicinal plants production and to look into its commercial viability. As a preparatory work for this study, DCOMP invited DEX-DEFT team (dated 09-12 February 2021) to visit Mungpoo and its other units in Darjeeling and Kalimpong districts to assess the current situation and discuss with the concerned officials. The study commenced with an initial set of objectives. Thereafter, as the study progressed, the objectives of the study were amended to deviate from a typical value chain study to address some of the urgent needs of DCOMP.

The revised objectives of the study were as follows:

i. Suggest better practices to manage the Cinchona plantation to improve the crop yield, and other active pharmaceutical ingredient / alkaloid content as the case may be. The suggestions are to consider priority needs and longer-term measures.
ii. Recommend measures to address urgent issues in the Cinchona plantation and put in place an implementation framework of the recommendations being made. Initiate appropriate mechanisms that could enable DCOMP to foster technical collaborations to improve productivity and quality of produce.
iii. Suggest options for refurbishment of the storage and drying facilities.
iv. Study possibilities for DCOMP to cultivate a few other plantation crops with an aim to sell their produce on a commercial scale.
v. Other recommendations covering enabling functions, such as improvements in testing laboratories and accounting systems.

1.4 Approach to the study

Our staged-approach to the study is illustrated in Figure 1.

Figure 1 : our staged-approach to the study

The key tasks, based on our approach depicted above, are briefly discussed below.

TASK 1	TASK 2	TASK 3	TASK 4	TASK 5
Landscape analysis, literature reviews: As the first task, we conducted desk research and analysis of available data on products of DCOMP. We prepared the context for strengthening the yield from plantations, the value chains as it exists today, and export markets. This, inter alia, includes analyses of current scenarios; India's nutraceuticals exports of quinine and its derivatives, trends in the global as well as domestic markets. Apart from Cinchona we conducted desk research for a few medicinal plants and products of DCOMP already identified in our first mission (dated 09-12 February 2021).	**Primary data collection:** We studied the existing plantation management practices in DCOMP and analyzed the improvement possibilities. Field studies for primary data collection by DCOMP staff were undertaken. Stakeholders in the private sector, public institutions and other relevant players were consulted.	**Study of drying operations, storage facilities and processing units:** We assessed the feasibility of refurbishing drying and storage facilities. A detailed project report was prepared jointly with the GTA Kurseong Engineering Division for further consideration by GoWB. The feasibility of setting up a new processing unit either through a brownfield or as a greenfield investment was considered.	**Implementation arrangements:** Based on findings from Tasks 1-3, we prioritized some urgent actions that were needed to restore the health of the plantation and followed it up to formalize implementation arrangements of these priority actions.	**Reporting:** Findings from this study were presented to DCOMP, GTA and GoWB at Mungpoo and Kolkata. The deliberations guided development of an action plan.

LIMITATIONS OF OUR STUDY:

Our study has relied on desk research, field missions to Mungpoo and other locations, findings of sample testing done by DCOMP and other external laboratories, inputs from DCOMP officials on plantation practices and challenges faced and stakeholder consultations to draw up its recommendations. There has been a paucity of literature from India on Cinchona. Some of the scientific aspects may need to be further studied. These can be referred to the Empowered Technical Expert Committee (E-TEC) of reputed experts that has been recommended to be setup as one of the outcomes of this exercise (Chapter 6, item (ii), page 40).

PLANTATION MANAGEMENT

The present plantation system, comprising Cinchona and other plant species, has had its beginning when "Ground was broken in the Rungbee Valley, in June 1864, at a spot 4,410 feet above the sea level, on the south-eastern slope of a long spur running out from the main ridge of Sinchel."[1] It started with 523 Cinchona plants. Thereafter the plantations grew in acreage and now covers about 26,000 acres of plantations and other facilities. As on date, the DCOMP Cinchona plantation is one of the largest such surviving plantations in the world. The other large, commercial-scale Cinchona plantations are located in the Democratic Republic of Congo and Indonesia.

2.1 Initial findings

The key findings from the first field mission to the plantations (09-12 February 2021), are enlisted below which have, thereafter, been supplemented by inputs obtained during discussions with DCOMP officials:

1. The average quinine content in Cinchona bark needs significant improvement to meet market demand. Technologically sound methods are needed for propagation, nurturing and harvesting of Cinchona bark.
2. There is a need to modernize the existing laboratory facilities. An initial tranche of financial assistance has been received from GoWB, based on which work in this direction has been started by DCOMP.
3. Land use: The cropped area has been reducing. For example, between 2002 and 2021, Cinchona plantation area reduced by 16.9%. Moreover, the land and soil conditions have not been assessed for years. The climate change impact (150+ years) on the agro-ecological system is yet to be assessed.

4. There is no database of the plantation system. The historical data on the Cinchona planation trees are not maintained rigorously. There is a need to develop an integrated database of the physical and plant resources, and activities of the entire plantation system under DCOMP.
5. Storage and drying facilities are old and dilapidated. Degradation of the stored dry bark is impacting the competitiveness of saleable produce. There is a need to refurbish facilities, adopt standard operating procedures on the improved facilities and train the deployed personnel accordingly.
6. There are significant weaknesses in marketing of products based on Cinchona and other medicinal plants: in terms of assuring consistent product quality acceptable to the market, setting competitive prices, promotion and distribution. This is leading to annual harvests lying as idle stock which is degrading. Such findings have been discussed with DCOMP.
7. The quinine factory (based on toluene extraction process) has not been in operation since it was commissioned in 1986. Hence, no value addition is being done and it is unlikely the existing plant equipment can be re-commissioned with reasonable efforts. Modern extraction technologies (using either toluene, or alcohol or aqueous based extraction processes) that can efficiently extract need to be specifically tested with Cinchona bark harvested from DCOMP plantations. Once the process of the chosen extraction technology is proven by setting up pilot plants, such technologies can become more suitable for DCOMP and make their products more competitive.
8. Besides the Cinchona plantations, the study team visited plantation and processing sites for Rubber, Chirata, Ipecac including the closed down diosgenin (extract from Dioscorea) 16-DPA factory at DCOMP Gairibas division, orchid nurseries, and other crop fields.
9. It was agreed by DCOMP that, besides Cinchona, there is a need to focus only on a few more crops suitable for the ecology and achieve commercial success in these crops rather than cultivating a large number of crops as is being done now.
10. The accounts had not been finalized and audited for several years. During the course of this study, the AG Bengal audit was carried out and financial statements till FY20-21 were finalized. The absence of a robust accounting system leads to subjectivity in decision making on product costing, valuation of available stock and compounds other related difficulties.

[1]Source: "A Manual of Cinchona cultivation in India", p.26, Office of the Supdt. of Govt. Printing, Calcutta 1880.

2.2 Making the plantation sustainable

A set of suggestions to make a beginning to make the plantation sustainable are enlisted below. Implementing these suggestions is likely to help upgrade the quality of products harvested from the plantations as well as ensure health of the trees. It must be mentioned here that requisite data support has not been available for drafting these suggestions. For example, there are no clear records of the number of trees in different Cinchona blocks over the years, the bark yield or alkaloid content patterns in different blocks over the years, sound estimates of cost of cultivation for most crops, land quality status, and a few other such critical aspects that indicate the health of the plantation system. Hence, these suggestions are developed from limited data, anecdotal narrations of DCOMP field staff, generally accepted good agricultural practices, scientific knowledge, review of literature and expert consultations.

2.3 Creation of a plantation database

S1. The first suggestion is that an integrated data base of all information starting from the basic natural resources till the level of selling the primary products, or sending to the processing facilities if processing needs to be done. The data base should be modular and scalable. The primary data acquisition system should include mobile-based ones and adapted to the levels of gang-men. This database should be populated backwards from the present and should have a provision for handling data, from about 20 years into the past. The basic system should be in operation in about 12 months and should start acquiring present data and populating the system should be done in three months with whatever data are available over the last 5 years.

S1.1 The main database may, as a sub-system, have a technical knowledge portal which can include Decision Support Systems (DSS). Such DSS may

take a while to be developed but can provide on the spot technical information on plantation operations to various levels of users. Development of the DSS will entail some short and long-term collaborative effort with appropriate institutions.

S1.2 In the longer-term, a plan be developed for real time and low-cost sensor-based data acquisition system especially for monitoring weather parameters, a few soil parameters and chemical parameters, and communicate with either human or machine-based decision makers.

Improving land use

The land use area statement is tabulated in Annex-1 which gives the latest use of the total land available with DCOMP.

S2. It can be seen from Table A.1 of Annex-1 that out of about 26,000 acres belonging to DCOMP about 8,000 acres are cultivated and a maximum of about 1,400 acres can be brought under cultivation assuming that most of the fallow land can be brought under cultivation. So, any future land use plan has to be limited to about 9,000 acres of land only. However, any additional area that is brought under commercial cultivation should improve the sustainability of the plantation and hence it needs to be evaluated accordingly by DCOMP.

S2.1 The area under bamboo has increased from 492 acres in 2002 to 542 acres in 2021. It appears that there could be some compulsions in maintaining the bamboo bushes. In that case some commercial plans (besides nursery use and social obligations) for use of bamboo may be developed. It may be taken forward in collaboration with National Bamboo Mission. Growing some bamboo species, such as Bambusa arundinacea, which are medicinally important may also be planned.

S2.2 A scientific survey of the total plantation area should be carried out using Geographical Information System. A soil survey for land use planning is being carried out with the help of ICAR National Bureau Soil Survey and Land Use Planning, Kolkata Centre. This is necessary because for about one and a half a centuries' the land has been used for repeated plantings, the climate pattern and the landscape has changed, but no systematic survey of soil and land has been done so far. The survey findings can support decisions that need to be taken on efficiently demarcating the prospective sustainable cultivation areas. A plan may then be developed to shape the land suitably, improve the soil health and agro-ecology followed by actions to improve the basic properties, physical, chemical and biological health of the soil.

The land use pattern of DCOMP has changed over the years. The cropping area has reduced by 2.1% between 2015 and 2021: from 8,346.29 acres in 2015 to 8,166.37 in 2021 (Table 1). Importantly, the cultivation area of Cinchona has consistently been decreasing and has reduced by about 16.9% between 2002 and 2021. This reduction has happened despite the present efforts to expand area under Cinchona plantation. This is of concern.

Table 1: Changes in crop area over a period of 19 years

		Crop area (in acres)		
		Year		
		2002	2015	2021
1	Cinchona	**8,214.01**	**7,425.14**	**6,826.22**
2	Ipecac	**50,477**	**79.64**	**92.11**
3	Dioscorea	148.76	8.68	6.75
4	Cardamom	139.15	32.22	124.26
5	Rubber Plantation	100.62	280.90	397.81
6	Taxus Baccata	8.00	59.32	71.62
7	Chirata	-	29.72	39.27
8	Broom Stick	-	23.20	4.00
9	Coffee	3.5	94.34	132.92
10	Citronella	-		25.97
11	Kiwi	-		3.00
12	Medicinal Park	-		3.00
13	Floriculture Area	2.50		6.86
14	Cin/Affo/Rub/Coffee etc. Nursery	81.98	94.34	67.85
15	Mandarin Orange	-	263.57	256.43
16	Subsidiary Crop**		49.56	53.89
Total (1 - 16)			**8,346.29**	**8,166.37**
Non crop area (in acres)				
17	Bamboo	492.57	461.89	541.92
18	Thatch	347.16	151.80	71.08
19	Afforestation	2093.1	2583.79	2551.09
20	Forest/Jungle	4592.08	4328.71	4210.69
21	Fallow/Cultivable	532.16	1192.22	1440.84
22	Mazdoor's Colony	3316.34	3386.67	3297.05
23	Uncultivable (Khola Jhora)	4019.1	4546.39	4452.65
24	Bushy land	-	179.47	177.72
Total (17 - 24)				**16,743.04**
Grand Total (1 - 24)				**24,909,41**

Source: DCOMP, West Bengal

A substantial area has been occupied by Rubber, Mandarin Orange, Coffee and Cardamom among the ten (10) major crops, other than Cinchona. Ipecac was introduced in the 19th century by the British, and the other crops were introduced much later, understandably to make the plantation system viable in the face of falling prospects of Cinchona. However, none of these crops has reached commercially acceptable levels of productivity and quality, and has not given adequate returns to DCOMP. The main factor affecting productivity appears to be the lack of analysis of agro-ecological suitability of the crop (ad hoc choice). This has been compounded by a lack of adoption of *Good Agricultural Practices (GAP)* including uses of quality planting material. Thereafter, limitations in market analysis, deficiencies in costing systems, and weaknesses in marketing strategies have culminated into persistent lack of profitability.

S2.3 Based on the survey reports, market analysis, cost of cultivation and environmental and economical sustainability, it has to be decided how much area has to be reserved for Cinchona and then choose suitable additional crops. As far as possible, the crops should be able to take the ecogeographical advantage of plantation and may be not more than five in number. A suitable combination of annuals and perennials be selected so that till the main Cinchona plantations become commercially viable and even after the subsidiary crops add to DCOMP's economic sustainability.

S2.4 Establishment of or revamping the small primary processing facilities for say, drying and packaging of Chirata or extracting citronella oil may be taken into consideration keeping in view Good Manufacturing Practices.

S2.5 A separate technically competent committee of a national base may be set up for deciding the additional crops with commercial and environmental sustainability being the key deciding factors. The committee should be able to suggest the best sources or methods of obtaining and developing GAPs of planting materials. The committee will also advice about what to do with the existing but long term non-viable plantations such as Rubber. The committee will also suggest collaboration with institutions including Uttar Banga Krishi Viswavidyalaya (UBKV) for providing research support system and technical backstopping for *Good Agricultural Practices (GAP)* and *Organic Farming.*

S2.6 DCOMP has some responsibility towards farmers education and extension. Some land may be allocated for demonstration purposes of cultivation of some important medicinal and aromatic plants for the relevant agro-ecology. The extension activities may be conducted individually and/or jointly with the West Bengal State Department of Horticulture, UBKV or any other suitable institution under suitable mechanism developed by the Director, DCOMP and relevant officials of the partner institutions. The possibility of developing a live museum of the important medicinal and aromatic plants of the Darjeeling Himalayas, especially the endangered ones may be considered.

S2.7 Further, according to the guidelines of Government of India, each district in India ought to have one Krishi Vikas Kendra (KVK). Since Darjeeling was bifurcated into two districts, the earlier KVK is part of the new district of Kalimpong, leaving the present district of Darjeeling with no KVK of its own. Hence, there is a case for establishing a KVK to cater to the extension needs of the present Darjeeling district. DCOMP has adequate land and is well equipped otherwise to become a KVK to fulfil this institutional void in Darjeeling district. DCOMP's KVK application, that originally submitted in 2016 and has repeatedly been followed up, is yet to be approved. If the Darjeeling KVK is approved with DCOMP as the host institute, all extension activities of DCOMP can be routed through the KVK and is likely to become a win-win setup for all stakeholders.

Reviving Cinchona: the central reason for existence of DCOMP

Klaus Roth and Sabine Streller (2012) made a point in relation to Buchler GmbH in Braunschweig Germany (the largest supplier of quinine in the world), which is the key to the success of a Cinchona enterprise: 30-40 kg of quinine is extracted from every ton of bark that is obtained from the Democratic Republic of Congo (DRC).[2] This can be treated as an aspirational benchmark by DCOMP for improving the quality of their harvest. It is understood that market might have been a key external factor for the non-commercial viability of Cinchona at DCOMP, the core issue has been the alkaloid content in the harvested bark that falls far short of the market demand.

As gathered from, "A Manual of Cinchona cultivation in India", plants up to 7.5% of total alkaloids "...of which nearly whole is the quinine" were available specially in the species *C. calisaya.* Later, plants having 14% of total alkaloids were found in the species *C. ledgeriana* (S. K. Chatterjee, 1982). In their book "Cultivation and utilisation of medicinal and aromatic plants", edited by C K Atal and B M Kapur, Regional Research Laboratory, Jammu, India (pp. 222-229) these were introduced by Dr. M. Gamine into India in the late 1980s. According to Mausumi Basu (2006) in her thesis submitted to Calcutta University entitled "Cinchona cultivation vis-a-vis propagation of malaria: a geo environmental appraisal in the setting of the Ryang basin", Darjeeling plantations are mostly *C. ledgeriana, C. pubescence* (earlier C. succirubra) and the hybrids Robusta and Hybrida.

The plantations today have hardly any plants with even 5% total alkaloids. A major cause of this drop in alkaloid content could be because vegetative propagation of high-quality plants was stopped somewhere down the path quite early. The vegetative propagation was stopped in contravention to warnings given in the Manual of Cinchona cultivation referred to above. One of the main reasons for the success of Congo and Java plantations even today is their propagation system is almost entirely vegetative.

Today in the DCOMP plantations the trees are grown entirely from seeds and most of the trees are much older than the lifespan envisaged in the Manual: ideally ten years and not exceeding 15

[2]Klaus Roth and Sabine Streller (2012) made this point in their series of articles entitled "From Pharmacy to the Pub-A Bark Conquers the World" Chem. Unserer Zeit 46(4), 228-247

years. After this span, the plantation blocks have to be replanted for environmental and economic sustainability. Attempts at revisiting research into the cultural practices to adapt to the agro-ecological conditions stopped somewhere in the late sixties. The bark yield that can go upto even nine tonnes per hectare has gone down. So, the primary objective of the plantations should be development of a high yielding and high- quality source of bark.

S3. The first job will be clear the plantations that are more than 15 years old and the land has to be scientifically reshaped and rejuvenated.

S3.1 Every plant that is between four and seven years old has to be assessed for alkaloid, quinine and quinidine contents. Any plant with 6% or more total alkaloids needs to be propagated through the method prescribed in the manual. All further plantations must be developed through vegetative propagations (ideally tissue culture) only.

S3.2 UBKV must be mandated to develop micropropagation techniques for Cinchona on a "war footing" in about 15 months. The institution has the basic expertise and infrastructure. In addition, a number of good publications are also available on the topic, especially from Indonesia and Guatemala. However, keeping the urgency in view, the help of dependable private labs may be taken. This initiative will be vital to repopulate the cleared plantations in short span of time. Further, a collaboration between DCOMP and Institute of Biodiversity for Sustainable Development (IBSD) at Imphal under the aegis of Government of India's Department of Bio-Technology may be explored for large scale production of seedlings through micro propagation once the technique is standardised. A suitable Memorandum of Understanding (MoU) may be developed with IBSD for collaboration on other crops also.

S3.3 The possibility of importing high quality lines from Indonesia through the Government of India and the ICAR system may be explored. However, this is likely to be a time consuming and difficult process, requiring DCOMP to be persevering in its pursuit and be willing to commit technical resources from its limited available pool which is already quite stretched.

S3.4 A funded-mandate should be given to Jadavpur University to estimate the quinine and alkaloid content using the Near Infra-Red (NIR) method and fabricate a NIR machine for DCOMP in about eight months. After the method is developed all decisions regarding harvesting, processing and commercialisation should be based on these techniques. A MoU may also be finalized with the Institute of Pesticide Formulation Technology (IPFT) for collaboration in the field of analytical chemistry, and medicinal and aromatic formulations.

S3.5 A joint mandate should be given by the Department of Food Processing Industries and Horticulture to DCOMP and UBKV to develop organic GAP for Cinchona bark yield and alkaloid content. Initially they can start with young plantations and then plan to start with new plantations with selected material.

S3.6 The post-harvest technology group of BCKV Engineering Faculty (being suggested, but other options can also be explored) should be asked to develop a low-cost mobile mechanical bark extraction technology for Cinchona and identify the optimum drying temperatures and techniques for Cinchona and other plants, mechanised powdering, and packaging technologies. The packaging should aim at keeping the powder or dried plan parts without spoilage for at least a year. It is expected that the suggested technique will be cheap and easy to use. A Good Manufacturing Practice (GMP) should be developed from harvesting to packaging. The bark extraction technology should not take more than eight months to standardise. This should be accorded a high priority because till today harvesting is a highly labour-intensive work in the plantations. In fact, one of the main reasons for low price of material from Africa is the relatively low labour cost of bark extraction.

S3.7 Any drying system developed for DCOMP should be a multi commodity one because a majority of the cultivated products of DCOMP will require drying for direct selling or storage and transportation.

S3.8 A seven-year cycle of the Cinchona plantations as is followed in DRC, may be explored because the alkaloid content start declining after the seventh year. However, the optimum bark yield of 5 tonnes or more per hectare should be obtained by that time.

S3.9 Promoting Cinchona bark powder or preparations as an ayurvedic product may be explored with the help of Ministry of AYUSH, Government of India. Promotion of direct bark-based products as consumer goods like gargles may be explored with help of Ayurvedic colleges. In fact, even today Cinchona bark powder preparations are an important herbal product in the European countries.

S3.10 All the quinine extraction enterprises in the world depend primarily on a few dependable sources for guaranteed quality of in-sourced products. There is a need to explore alternative arrangements to the present marketing strategy of yearly auctions through a government-initiated and government-controlled system.

Simultaneous steps should be initiated to increase labour productivity. The policy makers at the political and administrative levels may like to deliberate on findings in the publication Townsend Middleton (2021) *"Becoming-after: The Lives and Politics of Quinine's Remains"* (reference: Cultural Anthropology, Vol. 36, Issue 2, pp. 282-311). This paper is entirely based on DCOMP plantations and vitally related to the labour system and productivity. Enhancing labour productivity is a critical issue in making the plantations survive.

Once the Cinchona plantation system is appropriately **upgraded in about eight years from the commencement of rejuvenation efforts** and becomes capable of supplying quality bark/ bark powder with assurance can the planning for quinine/alkaloid production be initiated. Any hasty attempt is likely not to achieve success.

2.3 Concluding remarks

The present status of the plantations has caused observations such as "What is remarkable, anthropologically, is that India's Cinchona plantations still exist."[3] While any answer to such a conundrum is extremely difficult to provide, it is essential that the strength of continued existence now needs to change to sustainable existence.

From the findings reported in this chapter, it can be concluded that **a set of technical and administrative actions needs to be effectively implemented and progress monitored to make the Cinchona plantation survive and become sustainable.** This may be considered a prioritized imperative.

[3]Source : Townsend Middleton (2021). *BECOMING-AFTER : The Lives and Politics of Quinine's Remains,* Cultural Anthropology, Vol. 36, Issue 2, pp. 282-311

DRYING AND STORAGE

A mission was undertaken to study the drying units and storage facilities at Latpanchor, Mungpoo, Munsong and Rongo along with DCOMP and GTA engineers between 17-Aug-2021 and 20-Aug-2021. The following observations were made.

i. Most of the existing drying sheds and Bark godowns have become dilapidated.
ii. The drying sheds are open and the dried barks reabsorb moisture during high ambient humidity periods.
iii. Godowns have openings that allow moisture ingress throughout the year.
iv. Green barks contain moisture around 60% during harvesting.
v. The moisture content of the bark after natural drying is around 28%.
vi. The moisture content of bark at various storage found to be around 20%.
vii. Average dry bulb temperature during harvesting period is 20° Celsius.
viii. Average relative humidity during harvesting period is 75%.
ix. An average sun hour available during harvesting is about 7 hours.
x. The bulk density of green bark is 200 kgs/m^3.

It is suggested that proper drying and storage procedures are laid out and be followed. As a first step, after de-barking, the Cinchona 'green' bark may be sundried to about 28 percent moisture content. Then, as a next step, the sundried bark may be further dried by (hot air) rotary dryers to achieve the desired moisture content of 8 to 10 percent. One rotary dryer may be installed at each unit-location. The hot air for rotary dryers may be generated as follows:

SOLAR ASSISTED HOT AIR GENERATOR	SOLID FUEL HOT AIR GENERATOR	ELECTRICAL HOT AIR GENERATOR
Typically, in such generators, hot water is produced through solar collectors which in turn generates hot air through heat exchangers. Temperature of the hot air generated, however, cannot always be maintained as it depends on the solar intensity and duration. The operational cost of this option is likely to be the least.	Typically, in such generators, hot air is generated using solid fuel such as coal, wood, or bagasse. Particularly, if chosen for DCOMP operations, the wood of Cinchona trees (by-product after debarking during the harvesting process), can be considered as the solid fuel. The hot air temperature can be maintained by controlling the fuel feed and it will not be limited to sunshine hours as in other fully solar assisted systems. However, pollution control devices will need to be installed along with the hot air generator to comply to environmental norms. The operational cost of this option is likely to be nominal.	In this case, the air is heated with the help of electrical heaters. Its operational cost is likely to be highest among these three options.

The following recommendations for preparing the feasibility report, and the economics (based on solar irradiance data, fuel wood requirement) are to be worked out before implementation.

1. Five unit-locations are chosen to install modern rotary dryers. Conventional drying sheds are not required if rotary dryers are installed in these five locations. The rotary dryers can be used for multiple purposes such as drying Cinchona 'green' bark as well as other medicinal and aromatic plants. The rotary drying units will be primarily powered by solar energy supplemented by debarked (Cinchona) wood fuel as an alternative for cloudy days.
2. After drying in rotary dryer, the dried bark may be stored in go-downs. The existing go-downs are to be re-constructed / refurbished without any openings between the walls and the roof. The go-down walls are to be cement washed (inside and outside) to minimize vapour transmission through the walls. Either silica gel (reusable) may to be placed in the polythene / polythene-lined gunny bags storing the products, or heat pumps be commissioned to reduce deterioration rates during the period of storage.
3. The suggested specifications and tentative cost of the dryers (excluding civil works) to be considered by DCOMP is provided in Annex - 2. As a first step towards implementing the modernized drying and storage system, five sites were selected by DCOMP for the installation of rotary dryers and upgrading of storage facilities. Thereafter, DCOMP, GTA Kurseong Engineering Division (KED), and the study team visited these sites between 01-Dec-21 and 03-Dec-21.
4. Following this, a Detailed Project Report was developed by GTA-KED to set up dryers at the five locations and refurbish go-downs therein which was then sent to the competent authority for approval.

MARKET STUDY FOR CINCHONA

"The isolation (1820), proof of structure (1908), and synthesis (1944) of the principal component of Cinchona bark all represented distinct triumphs for chemistry. So far, every effort at developing the crowning achievement, however—an economical industrial-scale synthetic route—has fallen short, nor is one in sight. So now, as always, we are left to rely upon the world's best quinine synthesizer:"

The presence of alkaloids makes Cinchona widely produced and traded medicinal plants across countries. There are nearly 30 chemical components extracted from the bark of the trunk, the most important ones are quinine, quinidine, cinchonidine, and cinchonine.

There are two ranges of uses for alkaloids of Cinchona. These are as follows:

1. Finished Pharmaceutical Products (FPP) for the treatment of malaria.
2. Active Pharmaceutical Ingredients (API) for tertain diseases, food and beverage, flavour & fragrances, and chemical industry.

4.1 Cinchona Trade Statistics

The annual world production of Cinchona bark is estimated to be about 8,000 to 10,000 tonnes, with global alkaloid content ranging from 6% to 7%, which results in an annual production of 400 to 500 tonnes of Cinchona alkaloids[4]. Major producers include Democratic Republic of Congo, Indonesia, and Sri Lanka. Our study of production volumes that is exported from these countries and the alkaloid[4] content of the Cinchona bark produced is given in Table 2 below.

Table 2: Production Volume of Cinchona Bark and their Alkaloid content

Country	Production Volume (Tonne)	Alkaloid Content (%)
Dem Republic of Congo	-	6.3[5]
Indonesia	100 - 150[6]	4 - 4.5[7]
Sri Lanka	-	4 - 8

Source: Various publicly available sources

[4]Hussain, D. A. (1991). Economic Aspects of Exploitation of Medicinal Plants. In O. Akerele, V. Heywood, & H. Synge, Conservation of Medicinal Plants Cambridge

[5]information gathered from stakeholder consultancy.

[6]Reference: https://www.sinkona-indonesia.com/quinine-heritage/

[7]See Cinchona pubescens VAHL, 1790

India has continuously led the export of Cinchona alkaloids and its derivatives (Table 3). Importantly, the statistics reveal that export volume surged in 2020, owing to an increase in demand for quinine, possibly as a result of the COVID-19.

Table 3: Top exporters for Alkaloids of Cinchona and their derivatives

						Figures in Tonnes
Ranks	**Country**	**2016**	**2017**	**2018**	**2019**	**2020**
1	India	265	257	196	267	400
2	Indonesia	117	1136	93	109	118
3	Netherlands	127	107	88	131	88
4	Madagascar	68	59	35	70	71

Source: ITC calculations based on UN COMTRADE and ITC statistics[8]

We further calculated the Revealed Comparative Advantage (RCA) of Cinchona alkaloids from 2016 to 2020 and found RCA>1 (see Table 4). This reveals that Cinchona's products in India have outperformed the competition in the global market by gaining a competitive advantage. Therefore, there is an international demand.

Table 4: India's RCA for Alkaloids of Cinchona and their derivatives

2016	2017	2018	2019	2020
21.47	23.38	24.37	22.80	34.18

Source: Calculations based on data accessed from the ITC database.

However, it is likely the Indian export depends on the import of raw material, but no segregated data could be found for quantifying such import. Our discussions with processors revealed that both Republic of Congo and Democratic Republic of Congo (DRC) could be the major sources of such raw material import into India. This was backed up by limited import data available in the public domain (Zauba) of past years.

In addition, the domestic market demand from the import database for the Cinchona alkaloids reveals that India stands seventh in worldwide imports although there is a decline after 2019 (Table 5). Hence, Cinchona has a domestic market in India as well as an export market which far exceeds DCOMP's production capacity. If DCOMP is able to ramp up high quality production of dried bark having around 4 percent of quinine content, and is able to competitively price its products, it could substitute imports of Cinchona bark into India and become a reliable supplier to domestic processors of value-added Cinchona products. A value chain can thus be established by DCOMP to begin fulfilling domestic demand and, upon achieving success in India, subsequently scale up to export to target European markets.

[8]Reference: https://www.trademap.org/

Table 5: Top importers for Alkaloids of Cinchona and their derivatives

Figures in Tonnes

Rank	Country	2016	2017	2018	2019	2020
1	Netherlands	79	62	1	60	63
2	China	37	44	32	36	53
3	USA	100	99	107	157	85
4	Ireland	24	26	27	27	37
5	UK	26	19	64	113	30
6	Romania	20	11	10	3	57
7	India	39	157	38	27	17

Source: Calculations based on UN COMTRADE and ITC statistics.

4.2 Challenges of Cinchona product sales

In India, Cinchona is mainly cultivated by DCOMP. The plantations are spread over about 6,865.46 acres of land distributed across four units in the Darjeeling and Kalimpong districts. DCOMP records show that around 200 tonnes of Cinchona dry bark can be made available annually, but is not harvested due to paucity of sales and lack of storage space which is occupied by unsold stocks (Table 6).

Table 6: The stock position of DCOMP, 2017-2020

Figures in Tonnes

Unit	2016-2017		2017-2018		2019-2020		2019-2020	
	Produce	Sale	Produce	Sale	Produce	Sale	Produce	Sale
Mungpoo	394.36	0.50	438.97	00.71	489.41	0.45	521.54	16.20
Munsong	353.75	201.00	198.85	0.00	246.35	0.00	258.56	0.00
Latpanchor	227.62	160.00	104.25	0.00	125.95	0.00	137.15	0.00
Rongo	860.09	25.00	77.27	0.00	93.71	0.00	101.53	0.00
Total	**1061.84**	**386.50**	**819.36**	**00.71**	**955.44**	**0.45**	**1018.79**	**16.20**

Source: DCOMP, West Bengal. Note: Figures are for dry Cinchona bark.

According to an initial analysis done by DCOMP on 32 samples of Cinchona dry barks, the alkaloid content ranged between less than 1 percent to about 3 percent[9], but a sounder analysis is now needed. Low alkaloid content is a constraint of DCOMP produce which impacts the sale of Cinchona dry bark. Importantly, despite a rise in India's overall exports (increase in derived demand for import of dried bark is expected to have happened), DCOMP only recorded 16.20 tonnes of sales in the year 2019-2020.

[9]Memo no-542/GOF/2021 issued by Quinologist, DCOMP.

The causes of DCOMP's low sales were analysed following the 4Ps (Product, Price, Promotion, and Place) diagnostic tool in classical marketing. Figure 1 depicts the findings against each of the 4P variables.

Figure 2: Diagnostics for low sales of DCOMP products

Source: DEX-DEFT Analysis.

*Notes: * Product quality can be improved by cleaning stems before bark harvesting.*

*** More attention is required during drying and storage for making it a clean product out of this process.*

i. There is demand of Cinchona-based products in the market and DCOMP is effectively the sole producer in the country. However, the high price[10] and poor quality[11] of DCOMP's Cinchona-based product hinders buyer offtake. Weaknesses in storage and drying process of Cinchona bark degrades the product quality and further impacts the competitiveness of buyer's value chains, making them reluctant to lift older stocks.

ii. In terms of promotion, DCOMP needs to do much more than what is being done at present. The private agents are the buyers and information asymmetries exist. Analyses shows that India is the topmost exporter of Cinchona products but a gap exists between this export information and the import information of dried bark into the country, as well as with the information that is available with DCOMP.

iii. This automatically leads to a dysfunctional marketplace for DCOMP. While Cinchona-based products have an available market, DCOMP is unable to benefit from it owing to its inefficient marketing processes, and product quality.

[10]Conversations with the stakeholders reported that the quality of DCOMP is not up to the mark and overpriced as compared to the world market.

[11]Meetings with the officials of the DCOMP revealed that due to the lower proportion of the alkaloid present in the Cinchona bark they are unable to meet the market demand.

4.3 Concluding remarks

India is the top exporter of Cinchona-based products (alkaloids and derivatives other than quinine) and has certain advantages. Some trade statistics also pointed out that India imports Cinchona bark and other Cinchona-based products, the demand for which can be fulfilled by DCOMP as import substitution. Hence, the demand exists in both domestic and international markets. In India, DCOMP is the main producer of Cinchona products. However, they can only sell limited amount of Cinchona bark due to its low alkaloid content. Thus, though Cinchona has a readily available market, DCOMP is unable to benefit as its product is low in quality, overpriced and lacks proper channels for distribution and promotion.

Once the suggested plantation management improvement measures are robustly implemented, it will begin to get consistently reflected in the quality of dried Cinchona bark outputs and its quinine content. This may take about five years and is likely to result in increased sales either through auctions or through direct marketing channels. At that time, DCOMP may be given more autonomy in marketing its products. The mandate on DCOMP to sell through auctions that are governed by a set of prescriptive rules restrict its ability to be responsive with alacrity to market conditions. A dedicated marketing cell, supervised by a senior officer recruited suitably for this role, may be set up. This cell can continuously scan the landscape, scout for sales opportunities, strike deals with intermediate buyers and processors, initiate prompt action on sales, and be empowered to take pricing decisions keeping the best interest of the institution in view.

FOCUS ON A FEW OTHER PLANTS

This chapter focuses on a few plants, other than Cinchona, where DCOMP can achieve commercial success. Such focus could be on mandarin orange, citronella and lemon grass, and chirata. Artemisia can be introduced as a new crop in near future, and DCOMP can begin to focus on indigenous medicinal orchids on a trial basis.

5.1 Mandarin Orange

Mandarin orange is known as the mandarin or mandarine. It is one of the premier commercial citruses grown in India. Citrus industry in India is the third largest fruit industry of the country after mango and banana. Mandarin orange, which is commonly known as "suntala", is the pride fruit of Darjeeling hills due to its pleasant aroma and taste. Other than West Bengal, many states in India (such as Arunachal Pradesh, Assam, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala etc.) are producing mandarin orange. However, the oranges cultivated in Darjeeling (West Bengal), Sikkim, Assam, Meghalaya, and Manipur are similar with tight skin, excellent quality, flavour and juice which is completely different from the varieties cultivated in other states. It is used for table purposes, in fruit salads, gelatins, puddings, or on cakes etc.

The Table 7 reveals the total production of the fruit by DCOMP. The average production of DCOMP is 26,965 pieces in 2017-2020 by utilising 270.20 acres of cultivation land. The production of mandarin orange is irregular.

Table 7: Production of mandarin oranges in DCOMP

Sl. No.	Year	Total production (pieces of fruit)
1	2019-2020	9,484
2	2018-2019	31,360
3	2017-2018	14,350
4	2016-2017	42,664
Average	**For four years**	**26,965**

Source: DCOMP, West Bengal.

The quantity produced is insufficient to commercialise the fruit. DCOMP has potential to produce at least 10 lakh pieces of fruit in a year (when trees attain full maturity) within the available cultivation area.[12] However, the highest production reported so far was 42,664 pieces of fruits in the year 2016-2017 with an average production of 26,965 pieces of fruits in four years. Even the allotted 270.20 acres of land for harvesting is under-utilised in all four units.

[12]Assumptions: each tree can produce 400-600 pieces of fruit on attaining full maturity, about 180 trees can attain full maturity per acre of land, and DCOMP maintains the present 270 acres of orchard without expanding any area.

Labour-intensive practice : Though DCOMP has a significant amount of workforce misalignments exist between its establishment strength, those available and skilled to work on orange orchards and actual deployment at times of need. Low availability of workforce for nurturing and maintenance are one of the reasons for DCOMP not being able to scale up production.

Nutrition management : DCOMP is well aware about the requirement of nutrition management, but face difficulties in accessing the citrus plots. The terrain permits only manual head-loads to be taken to the plots. There is also a need to streamline timely fund flows to avoid procurement disruptions. Equally important is the issue of workforce management. It is essential that a group of workers be identified for specialized training. Once trained, these specialized workers are assigned clear targets by the Assistant Manager, backed up by strict delegation of responsibilities, expecting them to perform assigned tasks with commensurate accountability.

Similar arrangements for workforce training, followed by task assignments, responsibility delegation and performance accountability need to be instituted for other crops identified for commercial scale-up.

Irrigation systems : Action has already been initiated through installation of sprinkler system of irrigation with fertigation facilities in a few sites at Latpanchor and Mungpoo. It is suggested that drip irrigation system may also be tried which will reduce the requirement of water and nutrients per unit area.

Diseases and pests : The remedies of diseases and pests are well-known but the reasons for DCOMP not being able to follow are similar to the ones for nutrition management. The problems of the major soil borne disease gummosis can largely be remedied by inarching (labour and skill intensive) and increasing organic carbon in the soil. DCOMP needs to attempt regular green manuring for this purpose.

Keeping the above points in view, DCOMP may submit its own orange orchard rejuvenation plan to GoWB detailing the proposed activities. Production of tissue culture seedlings with micro grafting and appropriate disease indexing will be a prerequisite. Earlier than later a tissue culture facility will be required to be established at Mungpoo not only for tissue culture of Cinchona plants but also for supplying disease for planting material of mandarin orange, orchids and other plants. Separately, as a part of its extension activities, DCOMP needs to submit another proposal to GoWB for rejuvenating the existing mandarin orange orchards of farmers. DCOMP may collaborate with UBKV for this purpose. In case UBKV does not have the capacity to fully service DCOMP's extension area needs, or firming up arrangements between DCOMP and UBKV are taking longer than anticipated, then DCOMP may explore additional partnerships with other capable institutions as deemed appropriate.

5.2 Citronella and Lemongrass

For the purpose of this study, citronella (will mean Java Citronella *Cymbopogon witerianus*) and lemongrass will mean *C. flexuosus.* Citronella is an important Aromatic Plant product of DCOMP and essential oil is extracted by steam distilling the citronella grass which is a multi-harvest perennial crop. The essential oils from both of citronella and lemongrass have a good market value (domestic and export) a synthesis of the important component molecules or similar molecules of these oils have been posing a significant challenge.

The pricing structure is based on a complex classification of oil types but in general lemongrass oil has a little edge over citronella oil. The price of citronella oil is determined to a good extent by its citronellal content and that for lemongrass oil by its citral content. In India the major use of lemon grass oil is for its citral which is used as the starting molecule for Vitamin A synthesis. Lemongrass leaves and oil have a direct culinary use. The oil has lesser use in perfumery, toiletry and aroma therapy. Citronella oil is not edible and has use in insect repellents, perfumery, toiletry and aroma therapy. These two crops can be very important cash crops and can be grown even up to 1000 m height in the Darjeeling hills.

DCOMP has about 35 acres under citronella and lemongrass; and between them lemongrass has a much lesser area under cultivation. The plantation is old. On an average, the economically viable life of the perennial grasses varies between three to five years. Thus, the area under cultivation of these grasses needs to be replaced by new plants of higher yield, and with varieties of higher quality suitable for the DCOMP farms as well as for farmers in the Darjeeling hills. The two varieties referred to in the following table could be explored. Whatever essential oil is available from the old clumps should extracted. The leaves after extraction can be good manure after composting.

There is a paucity of literature and published data comparing the profitability of citronella and lemongrass farming, in general, and specifically for North Eastern Himalayas and Darjeeling Hills. Basic information (to the extent available) on these two grasses is provided in Tables 8 and 9, but no general conclusions can be drawn from them.

Table 8 : Basic information on Citronella varieties

Yield	National Horticulture Board (NHB) web site (Average values)	Council for Scientific and Industrial Research (CSIR) web site	High yielding; Jor Lab C5 (a Java variety) info from CSIR-North East Institute for Science and Technology publications
Herbage Yield	1st year: 15-20 t/ha 2nd and 3rd years: 20-25 t/ha declines after that		25 - 28 t/ha
Oil Yield	1st year: about 100 kg/ha 2nd and 3rd years: 150 kg/ha Under favourable conditions: 200 - 250 kg/ha	The varieties for North East Region yield 90 kg oil/ha under rainfed conditions	200 - 350 kg/ha
Oil Content	About 1%		1.1% -1.3%
Citronellal	32% - 45%		32.5% - 38.0%

The exact mix of citronella and lemon grass to be grown in DCOMP areas needs to be worked out through experimentation. As the renewal of existing 35 acres under the two aromatic grasses will require about 22,000 slips per acre. Non-availability of such huge number of slips of improved varieties will make replanting more than 7 acres a year difficult, at least for the first two years. However, from the third year onward, DCOMP farms will be able to generate the required quantity of planting material.

Table 9 : Basic information on Lemongrass varieties

Yield	National Horticulture Board (NHB) web site (Average values)	Council for Scientific and Industrial Research (CSIR) web site	High yielding; Jor Lab L8 (a C. flexuosus variety) info from CSIR-North East Institute for Science and Technology publications
Herbage Yield	25 - 30 t/ha		29 - 31 t/ha second year onwards
Oil Yield	150 kg/ha under irrigated condition	175-200 kg/ha 2nd year onwards Varieties for North East Region yield 90 kg oil/ha under rainfed conditions	200 - 350 kg/ha
Oil Content	About 0.2% - 0.4%		1.0% -1.2%
Citral	—		75% - 80%

Thus, in the first and second years DCOMP can start with 50:50 mix of the two grasses but a large portion of the planting should be laid out in an experimental design in different locations of the farm, in order to : (a) evaluate the comparative performance and profitability of the two grasses; (b) work out the agronomic requirements; and (c) understand the stress patterns. By the end of the third year the required information will be available, after which a proper mix can be worked out.

In the third and fourth years some experiments should be laid out to examine the feasibility of these two crops to be grown as intercrops in plantations such as coffee, rubber, Cinchona (at least the early stage), and orange (at least the early stage) without detriment to the main crops.

All planting material should be procured after testing the source for total oil content and citral (lemongrass) or citronellal (citronella) content.

DCOMP should aim at being the major supplier of quality planting material particularly to the farmers in the Darjeeling Hills and in general for farmers in West Bengal and other states in India. So at least 50 percent of the plantation should be grown with constant checking of quality parameters and developing disease free quality planting material. This may be more profitable than selling essential oil.

Sprinkler or drip irrigation facilities should be developed because oil yield is always more under adequately irrigated crops. Proper GMP for clean and quality oil production should be developed, which may require post-harvest engineering interventions in collaboration with organisations like the Engineering College at Ranipul under the Central Agricultural University Sikkim. Assuring good quality planting material will need large scale testing for oil content and components for which sensor based rapid systems based on NIR needs to be developed.

5.3 Chirata

Chirata (Swertia chirayita) holds a place of pride in the Indian system of medicine. It forms a valuable household remedy used primarily as blood purifier, carminative, digestive, expectorant, febrifuge, fever, gout, bronchial asthma etc. This species also acts on the central nervous system as a stimulator and is used for dyeing cotton cloth yellow as well as in liquor industry for imparting a bitter taste. It is one of the 32 medicinal plants identified as a priority by the National Medicinal Plants Board of India. Most of the chirata obtained in India is from the wild though it is an endangered species. Besides this, India imports chirata from countries like Nepal, Vietnam, Afghanistan. Table 10 indicates the quantity imported from the top 5 countries :

Table 10 : Quantity imported from top 5 countries

					Figures are in Tonnes
Country	**2016**	**2017**	**2018**	**2019**	**2020**
Vietnam	4,723	7,655	7,791	16,271	59,352
Afghanistan	4,463	4,171	4,599	5,551	8,683
Nepal	3,775	3,105	2,583	1,749	4,470
Indonesia	1,701	2,162	4,886	4,334	2,922
China	1,902	1,612	1,830	2,904	2,889
Total	**16,564**	**18,705**	**21,689**	**30,809**	**78,316**

Source : ITC calculations based on UN COMTRADE statistics.

The total quantity imported indicates that chirata is in high demand in India. At present DCOMP cultivates chirata in 38.52 acres of land in Darjeeling district, and the following Table 11 shows the current yields. The production quality can be improved and quantity produced is insufficient to make the product commercially viable on a national scale. Thus, DCOMP needs to focus more to scale up Chirata production.

Table 11 : The average yield of DCOMP, 2016 - 2021

Unit	Dry Chirata (whole plants) in Kg		
	2015-2016	**2016-2017**	**2020-2021**
Mungpoo	304	496	283

Source: DCOMP, West Bengal.

There is no standardized cultivation practice available for Chirata in India, primarily because of its demanding agro-ecological requirement, most cultivators' non-familiarity with the species, and dearth of seeds. IBSD Imphal made some good effort to develop cultivation practices for Sikkim, but the farmers did not pick it up due to long waiting period, lack of sufficient seeds and availability of land at the appropriate elevation. In the Western Himalayas it has not been very successful so far and so *Swertia cordata* is being taken up there. IBSD has been able to complete the seed-to-seed cycle of *S. chirayita* in the Khasi hills after two years of attempt. Hence, it is necessary that a GAP be developed for *S. chirayita* in DCOMP in collaboration with IBSD.

Some of the higher altitude areas of the 84 acres earmarked for expansion of Cinchona during 2022 may be allocated to chirata cultivation in addition to the present area already under chirata cultivation. Green manuring may be done in the remaining area within the 84 acres till Cinchona expansion through vegetative propagation is taken up. Good seed production in separate seed plots should be intensively taken up, that too at the earliest. Equally important is to undertake chemical analysis of the chirata produced in DCOMP at an appropriate laboratory.

5.4 Ipecac

Ipecac is used as an expectorant, an emetic in the treatment of amoebic dysentery. Emetine hydrochloride has been used extensively as an anti-protozoan in the treatment of amoebiasis, pyorrhoea alveolaris and other amoebic diseases. The emetic action of the alkaloids is valuable and the crude drug extract in the form of ipecac emetic mixture is an important preparation used for drug overdose or poisoning. The emetic mixture is often a standard component in poison antidote kits. Even though use of ipecac has declined, its extracts are still components in a number of compound expectorant preparations. DCOMP produces ipecac in 87.95 acres of plantation land. Tables 12 and 13 together gives a picture of average yields of dry Ipecac root in DCOMP and expenses incurred by DCOMP on its cultivation, respectively.

Table 12 : The average yield of DCOMP, 2017 - 2019

Unit	Dry Impecac root (in Kg)		
	2016-2017	2017-2018	2018-2019
Mundgoo	–	1188	542
Munsong	260	260	143
Rongo	–	1145	774
Latpanchor	169	–	20
Total	429	2,593	1,479

Source: DCOMP, West Bengal.

Table 13 : DCOMP Expense on Ipecac cultivation

Year	Amount (in Rs)
2016-17	16,45,33,541
2017-18	15,21,92,543
2018-19	24,74,18,462
2019-20	13,64,39,722
Average	16,10,55,269

Source: DCOMP, West Bengal.

The above data clearly shows that the cost of ipecac production is very high. Further, with almost no sales of ipecac roots from DCOMP in the last three years, it raises the question of continued viability of maintaining the ipecac plantations within DCOMP. Hence, it is recommended that ipecac cultivation be significantly scaled down and be grown only to the extent for which dried ipecac can be sold; at present this is about 200 kgs of dried ipecac roots a year.

5.5 Artemisia

Artemisia annua has similar medicinal use to Cinchona. Artemisia is more popular now than Cinchona as a source of anti-malarial drug. The extract artemisinin (from *Artemisia annua*) has been widely used as a first line of treatment for malaria. Additionally, artemisinin is known to have antibacterial, antifungal, antileishmanial, antioxidant, antitumor, and anti-inflammatory activity.

The uses of *Artemisia annua* and artemisinin is expanding in the livestock industry. The expansion is based on current reports of anti-protozoal, anti-bacterial and antioxidant activities of the plant, its extracts, and its essential oil. Essential oil obtained on steam distillation of the fresh aerial parts is widely used in the pharmaceutical, cosmetic, and flavoring industries. In the coming years, there is a potential to scale up the cultivation within DCOMP. *Artemisia annua* may be introduced in the next planting

season. For the said purpose Central Institute of Medicinal and Aromatic Plants (CIMAP) under the aegis of Government of India's Council for Scientific and Industrial Research was consulted by DCOMP and an agreement is being finalized to commence work.

Further, attempts can also be made by DCOMP to utilize the wildly and abundantly growing and abundantly available *Artemisia vulgaris*. Collaboration and knowhow can be sought from IBSD Imphal who has identified a molecule from the species which can act against stored-grain pests. The next stage of work being planned by IBSD is to utilize the insect repellent action of *vulgaris* in addition to the traditional uses of human ailments.

5.6 Indigenous Medicinal Orchids

The Detailed Project Report for introducing Indigenous Medicinal Orchids shall be prepared by DCOMP and submitted to appropriate authorities as soon as possible. It will be preferable for DCOMP to work on dual purpose orchids, such as those having ornamental and medicinal properties. Further, DCOMP may work with GTA to explore opening outlets at tourist locations to promote its products. This can include exploring opening Medicinal Plant Tourism Facility (using Ipecac farming facilities) near GTA Dalgaon Resort in Rango Division as well as explore opening a sales outlet for tourists visiting GTA Dalgaon Resort.

5.7 Concluding remarks

DCOMP has plantation areas in mandarin orange, citronella, chirata, and has been planting these over the past few years. As of now, the quantity produced is insufficient to commercialise these products on a national scale with commercial success. Crops now proposed to be introduced such as artemisia, indigenous medicinal orchids have medicinal and/or aromatic values and DCOMP is well-equipped to begin cultivating them. With proper planning and diligent implementation of good plantation practices, DCOMP can scale up the area under these crops, improve productivity to achieve commercial success in these crops. The Empowered Technical Expert Committee that may be formed as a suggested outcome of this study (Chapter 6, item 8 (ii), page 40) needs to validate the recommendations being made and chart out an action plan.

This chapter has analysed the current situation, and issues, as well as suggestions to scale up the production in near future. At the same time, it is important for DCOMP to periodically keep checking the market demand and earned value from all commercial products. Ensuring product quality and maintaining competitive prices through improved efficiencies can help DCOMP realize value chain benefits when its products get marketed well.

RECOMMENDATIONS

The recommendations emanating from this study are outlined below. Some of the recommendations are now being implemented, and further actions may be initiated based on the progress of works.

1. Improving land use: expansion, increasing productivity, geographical survey, scientific soil and land use survey

i. At present DCOMP has about 8,000 acres under cultivation, which can be expanded to 9,000 acres. Further efforts can then be made to increase the productive crop area by including another (approx.) 1,000 acres of cultivatable fallow land that is available within the overall plantation area.

ii. Findings from an initial soil analysis during the course of this study, using DCOMP's own resources, raised some concerns. Hence, it was recommended that a comprehensive soil survey be undertaken using professional expertise.

iii. Thereafter, based on the recommendations made in the interim report, DCOMP has signed a Memorandum of Understanding (MoU) with ICAR National Bureau of Soil Survey & Land Use Planning (NBSS&LUP) Kolkata center to undertake a soil survey in DCOMP plantation area of about 10,000 acres.

iv. All field work by NBSS&LUP for soil sample collection needs to be completed before the monsoons and DCOMP may provide logistics support to NBSS&LUP survey team at the plantations.

v. DCOMP may request NBSS-LUP to complete their soil survey and land use planning report by August 2022. Besides the topics that are usually covered by NBSS-LUP in their reports, this report from NBSS-LUP to DCOMP should include mapping and land shaping recommendations as well.

2. Plantation survey, creation of modular and scalable database

A random sample survey of two lakh Cinchona plants (one sample comprising bark from ten trees) from the entire plantation is nearly complete. Procurement by DCOMP of dryers, grinders, and other items to support sample preparation work at the divisions is completed on time.

On conclusion of the plantation survey and sample collection activities, the sample preparation activities are to be undertaken at the divisions. This would mean drying of collected bark samples, grinding, packing and sealing, tagging and labelling of the samples is to be done at the divisional level. This activity is expected to be completed within 15 March 2022.

Firming up arrangements between DCOMP and UBKV for HPLC testing of samples has been on a slow track. It is taking longer than anticipated and hence it is suggested that DCOMP may explore additional partnerships with other capable institutions as deemed appropriate.

A modular and scalable plantation database needs to be developed. The data collection and mobile based data input for Latpanchor unit (as a pilot) needs to be completed by 31 March 2022. Thereafter, the coverage of the plantation database may be extended to other units at Mungpoo, Munsong and Rango by 31 March 2023.

3. Planning for vegetative propagation of Cinchona

Tissue culture

i. Initial visit by UBKV scientists to DCOMP has been completed on 03 December 2021. Works to standardize protocol for tissue culture will be completed by November 2022. It is recommended that a meeting be held between UBKV and DCOMP during March 2022 to review progress of work and actions be initiated accordingly.

ii. DCOMP will provide tissue of plants with high quinine content to UBKV for mass multiplication, from June 2022 onward.

iii. DCOMP is also exploring the possibility of getting tissue cultured plants from a private firm Pallishree, Arambagh. The firm has collected tissue samples from DCOMP and they will develop the culture protocol pro bono.

iv. A collaboration with IBSD may also be explored.

Classical methods

v. DCOMP is attempting to standardize vegetative propagation of Cinchona by methods such as cutting and layering, which can become an alternate option.

4. Uproot old Cinchona trees, replace entire plantation over the next 8 years

i. It is recommended that no large-scale uprooting of trees be undertaken till October 2022. However, a sample of ten (10) trees per block in 40, 30, 20 years range are to be fully uprooted in the immediate term. Thereafter, the root and bark alkaloid contents of the uprooted trees should be checked by HPLC methods. These results will give an initial glimpse of the state of alkaloid content in overly-aged trees and how further uprooting plans can be formulated over the next few years.

ii. While uprooting a sample of ten (10) trees per block in 40, 30, 20 years it was seen the old blocks are infested with large numbers of invasive trees.

iii. This requires discussions and coordination between DCOMP and Forest Department to sort out land record and related issues. GTA will step in to facilitate and actively sort out issues that may crop up. Once these arrangements are sorted out, it will then streamline felling of trees in Cinchona blocks.

iv. The Cinchona blocks which are more than 30 years old and less-dense need to be first uprooted. Green manuring plants is to be planted wherever uprooting is done. For the first year of large-scale uprooting to replace the plantation, DCOMP may need some additional implements and machines. Procurement of these implements would be a one-time investment, and the list of implements with their actual costs would need to be worked out by DCOMP subsequently.

v. The expansion of Cinchona plantation by 84 acres planned from June 2022 using Cinchona saplings obtained by adopting existing seed propagation techniques needs to be put on hold till vegetative propagation methods are established.

5. Strengthening laboratory facilities, forging partnerships for testing

i. At present there are two laboratory set ups at Mungpoo: one for Govt. Quinine Factory and the other for R&D. There should be no specially designated R&D group. All staff needs to be integrated into one Main Laboratory unit under Director DCOMP. In future, when the factory is rebuilt, there may be one small, functional lab at the factory site to do chemical analysis for process quality control. All other analytical chemistry will be undertaken at the Main Laboratory. The deployment of staff and officials will be optimized by Director DCOMP.

ii. The progress of procurement of laboratory equipment is slow and needs to be expedited. One possibility is to appoint an external specialist who is experienced in commissioning such laboratories. The external specialist should be willing to be based at Mungpoo for 2-3 months to supervise setting up a basic laboratory with equipment being procured by DCOMP and civil works being completed by GTA-KED. The specialist can work in coordination with a three-member advisory committee having a representative from UBKV, a representative from DCOMP and any other technical expert who may be appointed by DCOMP.

6. Collaboration with BCKV

An exploratory study on selection of an extraction technology that is suitable for DCOMP Cinchona bark is needed before preparing a Detailed Project Report to set up a processing unit.

It is also advisable that a pilot extraction process be setup and run with the selected technology to confirm the process parameters and other technical design aspects that need to be considered.

BCKV has agreed, in-principle, to undertake the technology selection and pilot study. A time frame of 18 months could be considered to be given to BCKV for completing this pilot study. As a first step, BCKV would forward a detailed proposal on this subject to DCOMP. On the basis of this proposal further discussions may happen between DCOMP and BCKV culminating in a memorandum of under-standing being signed.

BCKV needs to commence the work to (a) develop a protocol for Cinchona green bark drying, (b) develop implements for de-barking of Cinchona trees, and (c) studies on further mechanization possibilities in DCOMP plantations.

BCKV also needs to develop Good Manufacturing Practices for post-harvest primary processing / extraction and packaging of Other Medicinal Plants in consultation with DCOMP. This initiative can begin with Chirata, Citronella and Lemon Grass.

7. Streamlining accounting, inventory write-offs if needed

i. The product cost accounting formats used to collect data at the unit level for FY 2020-2021 for each of the crops cultivated needs to be continued for FY 2021- 2022 as well. From the next year FY 2022-2023, it is recommended that product costing data needs to be captured for each crop cultivated at the division level.

ii. A chartered accountant firm is being appointed by DCOMP to develop a Standard Operating Procedure (SOP) for implementing a product costing system for each of the crops cultivated at the division level. The SOP needs to be accompanied by implementation guidelines and a transition plan of the costing system.

iii. Inventory of old stock (Cinchona dry bark): Re-sampling is being done of Cinchona dry bark lying in the go-downs and drying sheds. The quinine estimation (by seeking the help of UBKV) is expected to be completed soon.

iv. Inventory of old stock Cinchona dry bark and Ipecac root lying with DCOMP to be disposed-off through a floating auction. The entire lot may be put up for auction permitting phased lifting of stocks by the winning bidder.

8. Other recommendations

i. Explore importing Cinchona planting material from either Indonesia or the Democratic Republic of Congo through Government of India. However, this may require DCOMP to go through protracted procedures. This may become a difficult process and will need a persevering 'champion' from DCOMP to see it through. This exploration may be initiated after getting a clear idea about the best quality of plants available in the present plantation through the survey of two lakh Cinchona trees that is presently underway in DCOMP plantations.

ii. Setup five member Empowered Technical Expert Committee (E-TEC) of reputed experts drawn from a national base. The Chairman and Members of E-TEC are to be appointed by GoWB. Director DCOMP is to be the Member-Secretary and UBKV nominee is to be a member of the E-TEC. The Committee will work with DCOMP over the next five years.

The Terms of Reference of E-TEC is to be decided by GoWB, and the crops for commercial cultivation by DCOMP are to be selected by E-TEC. For example, the rubber plantation in DCOMP is not profitable and the stocks are not being sold. Hence, continued cultivation of rubber is not advisable. On the other hand, the potential of *Texas baccata*, Large Cardamoms, Kiwi, and Coffee may vary and not all of them may be recommended to be taken forward for commercial cultivation. Thus, the Terms of Reference of E-TEC may include questions that such as:

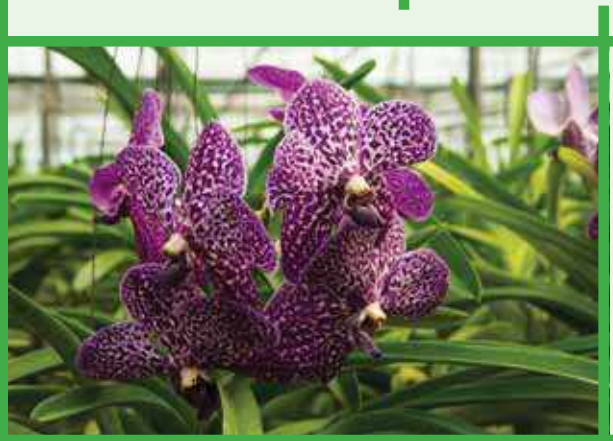
(1) Which crops, being presently cultivated, are to be continued for cultivation? Of these, which crops are to be taken forward for commercial cultivation?

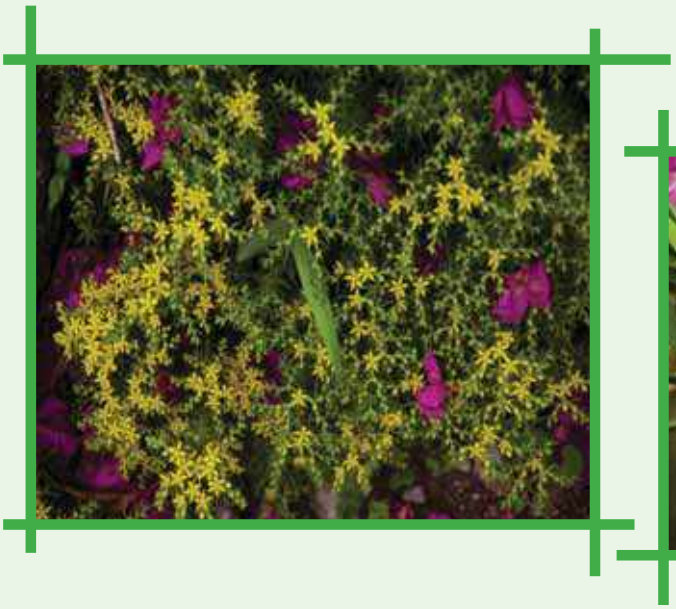
(2) Which crops, being presently cultivated, are to be discontinued, what will be the discontinuation timeline, and what will be the best use of the area that is under plantation for these crops?

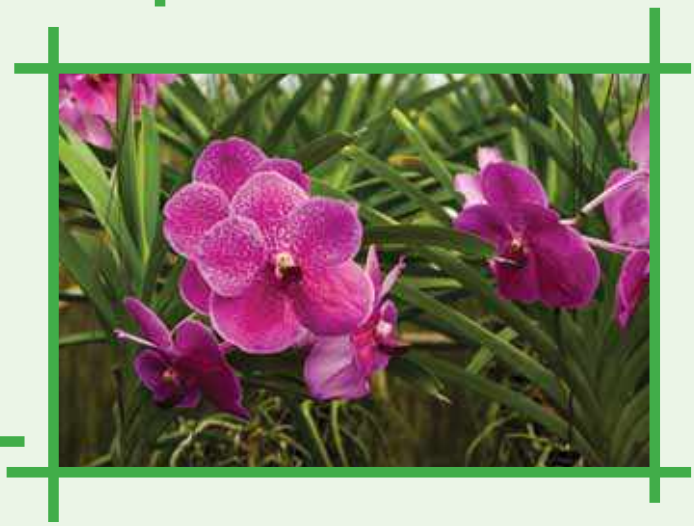
(3) What new plants with emphasis on medicinal and aromatic plants can be introduced in DCOMP plantation? While deciding on these, E-TEC may keep in view the suggestions made in Chapter 5 of this report.

(4) What will be the plan for developing GAP and GMP of the crops to be grown? What should be the marketing strategy to achieve commercial success?

iii. Promoting Cinchona bark powder for ayurvedic products and nutraceuticals may be explored with the Ministry of AYUSH, and ayurvedic colleges in West Bengal.







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