AGRICULTURE ISSUES AND POLICIES

Cardamom

[*Elettaria cardamomum* (L.) Maton]

Production, Breeding, Management, Phytochemistry and Health Benefits

Kaliyaperumal Ashokkumar
Muthusamy Murugan
M.K. Dhanya
Editors

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Contents

PREFACE

This reference book is based on the history, cultivation, processing, breeding, protection, phytochemistry, and pharmacological importance of cardamom. Cardamom is scientifically known as *Elettaria cardamomum* (L.) Maton and is a member of the Zingiberaceae family. It's a shade-loving plant that grows well at an altitude between 600 and 1400 metres above sea level, with annual rainfall ranging from 1300–4000 mm and temperatures ranging from 10 to 35°C. Cardamom is highly cross-pollinated and depends on honeybees for pollination. Cardamom is classified into three types based on the nature of the panicles, namely, *Malabar* (prostrate panicle), *Mysore* (erect panicle) and *Vazhukka* (semi-erect panicle), a natural hybrid between *Mysore* and *Malabar* varieties. In India, currently, six research institutions, namely, Cardamom Research Station (CRS), Pampadumpara (Kerala Agricultural University, Kerala), ICAR-Indian Institute of Spices Research (IISR), Kozhikode, Kerala; Cardamom Research Centre, Appangala, Karnataka; Indian Cardamom Research Institute (ICRI), Myladumpara, Kerala and its Regional Research Station, Sakleshpur, Karnataka and Regional Research Station, Mudigere (University of Agricultural and Horticultural Sciences) are engaged in research for the improvement of cardamom farming. These research institutions have begun doing routine surveys to exploit desirable genes using a variety of traditional and modern crop improvement techniques. Also, these research centres/institutes are holding enormous genetic wealth of different accessions. Recently, many researchers have used various biotechnological approaches to conduct studies on micropropagation, assess the diversity in germplasm collections, and elucidate the biotic and abiotic stress tolerance mechanisms in cardamom.

Fungal, bacterial and viral diseases pose severe threats to the successful cultivation of this crop. Major pests of cardamom include thrips, shoot and capsule borer, root grub, and whiteflies. Injudicious pesticide applications to manage pests and diseases rises the residue levels in the cured product, limiting its export value. Bio-pesticides control pest in an eco-friendly manner and are considered as the best alternatives to synthetic pesticides. It includes the effective utilization of microbials (bacteria, fungi, virus, and nematodes), macrobials (predators, parasitoids, and parasites), botanicals, organic amendments, semiochemicals, endophytes, and reduced risk pesticides in managing pest and diseases.

Cardamom is grown in the throughout tropical mountains mainly for its capsules and its essential oil. Cardamom capsules/seeds accumulate essential oil and other bioactive metabolites, which contribute to their distinctive aroma and are used in the functional food, pharmaceutical, and nutraceutical industries. More than 100 secondary metabolites have been identified from cardamom essential oil. The essential oil of cardamom capsules possesses predominantly monoterpene constituents, such as 1,8-cineole, α-pinene, α-terpineol, linalool, linalyl acetate and nerolidol and the ester constituent α-terpinyl acetate all of which have therapeutic benefits including antioxidant, anticancer, antidiabetic, anti-inflammatory, antifungal, antiviral and gastroprotective activities. Cardamom capsules contain substantial concentration of flavonoids like catechin, myricetin, kaempferol and quercetin. Lutein is said to be the most abundant carotenoid in small cardamom. According to recent investigations, cardamom phenolic constituents’ flavonoids, alkaloids, terpenoids, and anthocyanins are being used to treat cardiovascular, pulmonary, kidney, and lung disorders. Cardamom capsules are a nutraceutical and functional food that can protect humans from several chronic diseases when taken daily. Cardamom oil is a new potential natural source for food, aroma, cosmetics, and pharmaceuticals.

Since the 4th century BC, Indian Ayurvedic physicians, as well as Greek and Roman doctors, have used small cardamom capsules to treat bronchitis, asthma, and constipation, as well as colds, coughs, diuretics, carminatives, teeth and gum infections, urinary and kidney disorders, congestion of the lungs, pulmonary tuberculosis, irritation of the eyelids, cataract, nausea, and diarrhoea. Cardamom was used to treat constipation, stomach aches, bladder infections, and dysentery in children in traditional Chinese medicine. Cardamom is also used in Ayurvedic medicine to cure food sickness. Cardamom oils are being employed in the production of plant-based hand lotions and soaps. Digestive problems can be treated with powdered cardamom capsules mixed with pulverised cloves, ginger, and caraway. In addition, using cardamom capsules helps to relieve inflammation and headaches.

This reference book entitled "Cardamom [*Elettaria cardamomum* (L.) Maton]: Production, Breeding, Management, Phytochemistry and Health Benefits" is comprises of twelve chapters contributed by different authors and provide complete information about this wonderful herb. Its occurrence, history, cultivation, post-harvest processing, botany, crop improvement, biotechnology, protection, ethnopharmacological uses, phytochemistry and pharmacological activities are well described with supporting references.

The book contains latest information pertaining to cardamom and its cultivation. The information provided in this book will be very useful for students, academicians, researchers, and scientists, as well as others interested/involved nutraceutical and pharmaceutical industries.

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Editors

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We, the Editors, are thankful all the authors for their valuable contribution and kind support in the editing and composing process. They have all been well supportive as well as responsive in the whole process. The contents of the book have been extensively reviewed by different subject experts, and their opinions resulted in its qualitative improvement. The contribution of the reviewers is much appreciated as, without their support, this book would never have been never possible. Hence, we must pay our sincere thanks to the reviewers for accepting our request and spending their valuable time for reviewing the chapters. We are also thankful to Nova Science Publishers Inc. for inviting us to edit this book on small cardamom, one of the most commercially important and valuable spice in the world. We wish to thank the reviewers/subject experts for sparing their precious time to review the book. Indeed, their valuable opinions/ comments have been found worthy to improve the contents of this book. We are glad to mention the names of our esteemed reviewers who contributed extensively to this book by providing their expertise.

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ACRONYMS

ABTS	2,2'-Azino-Bis (3-Ethylbenzothiazoline-6-Sulfonic Acid)
AMF	Arbuscular Mycorrhizal Fungi
ARE	Antioxidant Response Element
BAB	6-Benzyl Amino Purine
CdMV	Cardamom Mosaic Virus
CEO	Cardamom Essential Oil
CH	Cardamom Hills
CHR	Cardamom Hill Reserves
COC	Copper oxychloride
DENA	Diethylnitrosamine
DES	Diethyl Sulphate
DMBA	7,12-dimethylbenz[a]anthracene
DOX	Doxorubicin
DS	Diclofenac Sodium
EC_{50}	Effective Concentration
EMS	Ethyl Methane Sulphate
EO	Essential Oil
EPN	Entomopathogenic Nematode
EST	Expressed Sequence Tags

IC_{50}	Inhibitory Concentration
ICH	Indian Cardamom Hills
iNOS	Inducible Nitric Oxide Synthase
IPM	Integrated Pest Management
ISSR	Inter Simple Sequence Repeats
LC_{50}	Lethal Concentration required to kill 50% of the population
LDH	Lactate Dehydrogenase
LDL	Low-Density Lipoprotein
MAB	Marker-Assisted Breeding
MBC	Minimum Bactericidal Concentration
M-CSF	Macrophage Colony-Stimulating Factor
MFC	Minimum Fungicidal Concentration
miRNAs	MicroRNAs
MS	Murashige Skoog
NAA	1-Naphthaleneacetic Acid
NGS	Next-generation sequencing
NMU	Nitrosomethyl Urea
NPV	Nuclear Polyhedrosis Virus
NSKE	Neem Seed Kernel Extract
ODC	Ornithine Decarboxylase
PIC	Polymorphic information content
RAPD	Random Amplified Polymorphic DNA
RFLP	Restriction Fragment Length Polymorphism
RKN	Root Knot Nematodes
SNP	Single-Nucleotide Polymorphism
SSR	Simple Sequence Repeat
TN-F	Tumor Necrosis Factor
TPC	Total Phenolic Content
VCAM-1	Vascular Cell Adhesion Molecule 1
WG	Western Ghats
WTO	World Trade Organization

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Chapter 1

HISTORY OF LAND AND AGRICULTURE IN THE INDIAN CARDAMOM HILLS

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ABSTRACT

The cardamom ecosystem consumes enormous pesticides and other production chemicals that throw a negative impact on many key fronts like soil, water, air, and forest compartments. In the last fifteen years, the forests of cardamom hill reserves (CHR) have undergone tremendous changes concerning tree density, species composition and epiphytes diversity. The utilization of plastic shade net has been increased several folds; almost all the cardamom gardens in the CHR use plastic shade nets during the summer seasons, thereby the once impenetrable CHR rain forest is now looking like shade net nurseries. This paper discusses the level of

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degradation due to intensive cardamom farming in Indian cardamom hills based on observations through surveys and experiments done during the past decades. The chapter also elaborates the current situation of landholdings as well as the importance of agroecosystem in these tropical mountains.

Keywords: cardamom, Indian cardamom hills (ICH), cardamom ecosystem, cardamom hill reserves (CHR), pesticides and residues

INTRODUCTION

The cardamom trading across the Indian Ocean was one of the most important activities that brought significant changes in the face of the Indian cardamom sector besides elevating India's fame in international commodity trading. For many reasons concerning their applications and uses, the demand for cardamom across the world has increased manifolds. The trading and business activities of cardamom in India have experienced several ups and downs during the last couple of decades. The steady but increased local market price has been realized despite several complaints in relation to higher levels of pesticide residues. Higher market price instigates most cardamom farmers to go for heavy application of agrochemicals. The economy and trading of cardamom affect the production environment both directly and indirectly. This necessitates critical analysis of the ongoing issues and the status-quo of the cardamom production system in Indian cardamom hills (ICH) that are very pertinent to the agricultural and environmental sustainability of the Indian cardamom hills as well as the livelihood of farmers.

IMPORTANCE OF MOUNTAIN ECOSYSTEM

Mountain regions, together with forests, deserts, polar caps, and coral reefs, cover 20% of the Earth's land surface and are one of the most fragile ecosystems. Mountain forests are important worldwide, nationally, and locally, because they provide a variety of irreplaceable products and services, yet they are threatened by poor management, resource exploitation, and agricultural activities. Mountain ecology and the degradation of watershed areas influence over half of the world's population, but this fact has received comparatively little attention (UN, Agenda 211992). Many tropical mountain (forest) areas are highly productive, but they are increasingly under threat from external economic forces and human population expansion (Price and Kohler, 2000). Conversion of tropical forest into agricultural lands is increasing at an alarming rate, owing to a corresponding rise in demands for food, fodder, and fuel.

The Cardamom Hill Reserves (CHR)

The CHR covers over 1015 sq km (Figure 1; Figure 2), and the extent and intensity of cardamom cultivation in CHR are shown in Figure 2. A total of 107197.4689 hectares of land was allotted, of which legal ownership was issued to nearly 48629 ha as of 1961. The government is much concerned in the process of issuing ownership to the growers until now. The details of the extent of "patta" lands given to cardamom cultivators are not known exactly till now. The forest department has issued around 1281.7419 ha of land, occupying the entire Mathikettan National Park (MNP). The High Range Colony patta was issued for an area of 2968 ha. Farmers' lands that are leased to the Institution accounts to an area of 18.158 ha. Data on the details of the number of pattas issued even as on 1993 are unavailable. Therefore, it is difficult to point out the number of cases under each sector. Farmers occupy leased lands in all the three sub-districts. Udumban Chola registers maximum leased lands (9527.6152 ha) followed by Devikolam (948.5275 ha) and Peermade (293.967 ha). The evergreen forests of Cardamom Hills (CH) were the richest in terms of plant biodiversity within the Western Ghats (WG) (Pascal, 1988). These humid forests had the highest rates of endemism, and the rate of deforestation in these hills has been increasing considerably during recent years due to agricultural activities (Murugan et al., 2017).

Unscrupulous tree felling has resulted from the rapid encroachment of forest lands, which has contributed to the extension of area under cultivation of various crops, creating substantial changes in micro and macro climatic conditions in the CHR region. One of the main causes for the dramatic drop in cardamom acreage was that most of the planters who migrated from Kerala and Tamil Nadu's plains in search of agricultural lands for living had introduced a range of subsistence crops such as rice, tapioca, vegetables, and so on. The cultivation of these crops necessitated the destruction of a significant amount of forest tree growth in the early phases. Although the regulations of land assignment on lease banned the removal of forest trees, the simultaneous control of the revenue in the CHR areas and forest department allowed cultivators to engage in such activity freely. As a result, the introduction of other crops in CHR areas has resulted in the degradation of the CHR forest. Apart from that, tillage operations on steep slopes caused significant soil erosion and fertility loss.

As a result, both large-scale deforestation and declines in soil fertility and productivity, the favourable microclimatic conditions required for normal cardamom growth and development, had nearly irreversibly changed (Miniraj and Murugan, 2000; Murugan et al., 2011). Pest insect and disease attacks have exacerbated the situation in recent years for a variety of causes, including climate change. Overall, human contact with the CHR forest system through extensive cardamom agriculture has undeniably transformed and damaged the cardamom ecosystem.

HISTORICAL AND SOCIO-POLITICAL OVERVIEW OF EARLY PLANTATION AGRICULTURE IN CARDAMOM HILLS (CH)

The CH came under the nominal control of Travancore state in 1755 or 1756 when Travancore conquered the small municipality of Changanacheri. However, there were other sovereignty disputes too. The 'Pooniat Rajah', a Tamil, claimed that most of the current CH area had been his family's territory since the time of the Pandya King (at least since 1537). Thus, the history of CH is interesting and can be divided into distinct periods. Even in the early 1800's numerous cardamom gardens planned by ethnic Tamilians were scattered throughout the High Ranges (HR) adjacent to towns (Bodinayakanur and Cumbum) in the Madras presidency. Until 1860, the hills were inhabited exclusively by tribal populations. Therefore, cardamom farming has a history of more than 400 years. Between 1880 and World War II, timber harvesting in CH continued, but plantation agriculture grew rapidly and became an equally dominant activity shaping and changing the land use. Tea, coffee, cardamom and forest tree plantations displaced the natural forest. Timber smuggling was also a major governmental concern in the mid-1800s, and various methods were tried to limit it. Thus, despite the management efforts, key species (trees) in the forests of the CH were depleted by the end of the 1800s (Sivanandan et al., 1986).

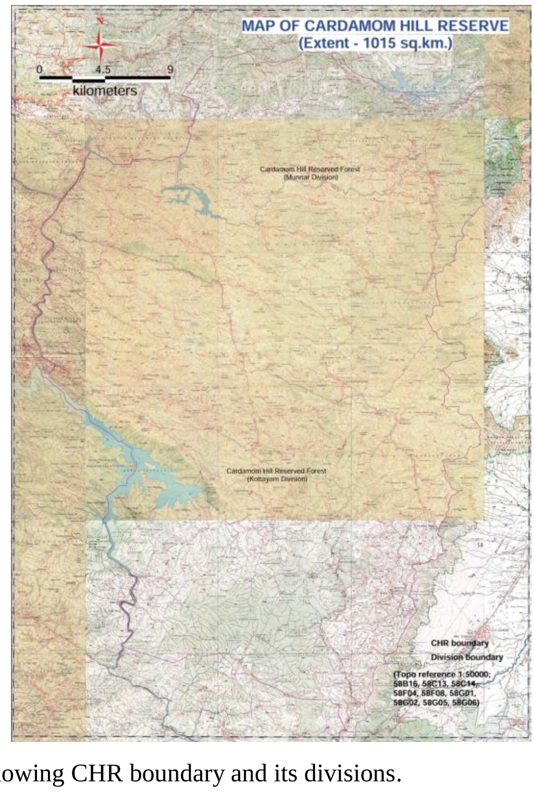

Figure 1. Map showing CHR boundary and its divisions.

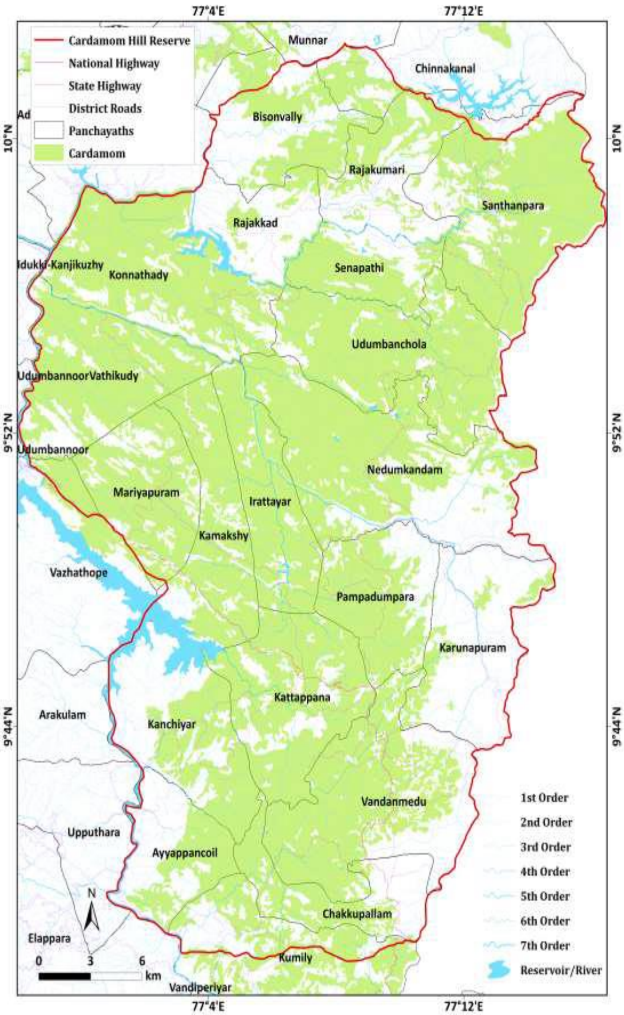

Figure 2. Map showing the area under cardamom, within and outside CHR boundary.

The 'plantation era' was characterized by the widespread European development of coffee and tea plantations as well as the continued development of cardamom plantations. In 1862 the first clearing for coffee was made, and in 1865, the government published rules allowing the sale of lands for the purpose of cultivating coffee and other crops. Much land was given to influential European families in the form of free grants. By 1893, roughly 40,000 acres of land in Travancore had been sold for the purpose of coffee cultivation. Coffee cultivation was facing major problems. Coffee wilt was a serious disease during 1870s and 1880s, and combined with low prices and foreign competition; coffee cultivation had to be suspended on many plantations. Planters then switched to tea in the last two decades of the 1800s. Europeans dominated coffee and tea cultivation in the HR, mainly on the north and south extremes of the cardamom belt. The 'Tamil dominated core cardamom area' lay between these two extreme centers of European tea cultivation (Sivanandan et al., 1986).

Throughout the early period of the plantation era, the Travancore government, despite its hesitancy to grant land outsiders, was legislatively acting in support of plantation development as it frequently sold and gave land to Europeans to cultivate coffee and tea. It also revised its approach to cardamom several times. Cardamom prices declined steadily through the 1850s and early 1860s and then increased between 1880 and 1885, but the new production from Ceylon caused them to crash again. Cardamom was initially a government monopoly, but the government had a difficult time controlling the spice trade in the context of wider price fluctuations. By 1887, low prices forced the government to increase the share it gave cardamom planters and debate the abandonment of the monopoly system. Replacement of the monopoly by a land assessment had far-reaching consequences in HR. It concentrated most trade in the hands of few hundreds of Tamil traders. Cardamom now flowed legally into the adjacent plain towns of Tamil Nadu (Sivanandan et al., 1986). The export and trading of cardamom now within India is done by less than a dozen firms operating mainly from Bombay. Cardamom has been sold through auction centers, and registered cardamom growers can sell their produce via these auction centers. All trading activities, including export, are facilitated and monitored by the Spices Board, Ministry of Commerce and Industry, Government of India.

Control and Current Status of Lands in the CH

Forests in the CH were reserved under the control of the forest department, which was in charge of cultivated areas, and the department had also granted forest lands for cultivation of cardamom because the government did not want to lose its ultimate control over the lands or trees, but needed to give cultivators clearly defined occupancy rights in order to collect taxes. The government retained its rights over land. When the land was cleared for farming, a low tax was assessed first, which then merged with the tree tax as permanent improvements were made. Coffee and tea cannot bear tax due to the non-durable nature of the plant. The same problem of defining tenure to collect taxes was also applied to cardamom once a uniform land assessment replaced the royal monopoly. The government's response, at least in the case of cardamom, was to turn cardamom lands over to revenue department; this presumably happened in 1909, when the cardamom department was a part of the land revenue department. Since the revenue department was in charge of collecting taxes, the control of lands allotted for cardamom cultivation was also placed under it.

The forest department remained in charge of 'forests' i.e., the trees and lands were not suitable for cardamom cultivation. The regulations promulgated in 1900 clearly displayed the contradictory position in which the forest department was placed. The regulation was that the forests in the CH are reserved under the forest regulation. Any interference with them except for the purposes permitted by these rules shall be dealt under the above regulation. Notwithstanding the fact that the forests in the CH are reserved, riots are permitted to fell trees (royal trees excepted) and clear the undergrowth or to open new or improved old gardens, necessitated that they first obtain written permission from the superintendent of the CH. The position of superintendent fell under the cardamom and later land revenue department, but not the forest department. As a result, the forest department had little power to limit authorized tree felling or even to respond to illegal felling. The primary purpose of reserving forest was to limit forest cutting except under forest department sanction and supervision. Therefore, the new rules greatly limited the power of the forest department to control the tree felling of cardamom growers and other planters (Ramakrishna, 1978).

Occupancy rights for cardamom lands were first granted in 1896 on an indefinite basis with the "cardamom tract" in the surveyed area. Later versions permitted lands allocation throughout the PTR and CH reserve forests, rather than just surveyed cardamom tract. Some distinctions were retained between the occupancy rights in the cardamom tract and those outside it; a type of temporary patta (title) was granted outside the tract, while the lands inside were given on lease. In both areas, occupancy was limited to twelve years before the renewal of the rights or land resumption by the government. Initially, the planters were limited to a maximum of 25 acres granted a lease for three years, with the government specifically retaining all rights to land. Later the limit on area opened was removed, and permanent tenure was granted, subjecting only to revisions in the assessment rate every thirty years. In addition to granting occupation rights for cardamom cultivation, the government in 1898 granted the holders of cardamom land the right to open 'waste lands' (grasslands and swamps) for cereal cultivation probably to meet the immediate demand for food grain considering the remoteness of the HR high lands (HL). Lands granted in this manner also fell under the supervision of the superintendent of the CH and were not under the forest department control. Throughout the plantation period, settlements in large areas of HR were minor (Vishvanathan, 1978).

During the settlement phase (1940-1965), the government first granted exclusive cultivation rights (known as 'kuthakapattam') in the state forest areas (Chandrasekharan, 1973). Under these rules up to five acres of land could be distributed to individuals for food crops cultivation on a short-term lease ('kuthakapattam') basis. Food shortages and famine in 1941-44 led to regular demands to open large forest areas for food crops cultivation. Land grants for cardamom cultivation in the CH reserves continued throughout this time. In 1940, a limit of 60 acres was placed on the amount of land that an individual could be allotted, and in 1942, the government stopped all registries of cardamom lands but continued to allow occupation (as with the grow-more-food campaign) on a short-term lease basis. The lease term was revised regularly and finally fixed in 1959 at 20 years. There was a great demand for cardamom lands throughout the war years and post-independence period, and a larger area was occupied. Early settlers were driven by the opportunity to develop cardamom, coffee and tea plantations on the rich forest soils. Most of the early settlers were Tamil Kannadigas or Europeans. The successive governments of Kerela built roads, paths both to assert the sovereignty over the area and enforce their control over the region's forest, water, and the wealth of plantation. Most of the Indian population was Tamil Kannadigas, but a few Malayalis, particularly Syrian Christians, held mid-level jobs on European plantations (Sivanandan et al., 1986).

The long history of encroachment and settlement in the HR high lands has left tenure rights highly confused. The forest department officially owns the trees in many areas, while the revenue department owns the land. Planters occupy much of this land. Some of the planters own large cardamom estates. The land may be encroached and without official occupational rights; it may be under long term cardamom lease; it may have some form of more permanent title. Estate owners often have landed in all the three categories. The situation for smallholders and recent migrants is more complex. The land, or portion of it, may have been initially granted under a short-term lease for food production; it may have been granted as a cardamom lease to an estate and illegally sold to the smallholder; it may have encroached, or it may have a clear title deed. There are numerous variations from no title to clear title (Vishvanathan, 1978; Sivanandan et al., 1986). Presently, the majority of the cardamom growers have official papers for their lands.

Nevertheless, the entire CHR area is now legally compelled. As a whole, every tree in the CHR area has been modified structurally and functionally. The structure and composition of the CHR have been affected drastically. Three species (Vernonia arborea, Artocarpus heterophyllus and *Toona ciliata*) contribute more than 50% of the total individuals. Ecologically important tree species are absent now, except few endemic and endangered species like *Actinodaphne malabarica*, *Saraca asoca* and *Kingeodendron pinnatum*. Most valued trees like *Cullenia exarillata* and *Palaquium ellipticum* are vanishing fast from the cardamom hills. Nearly 95% of the

CHR's epiphytes have been eliminated by shade removal. Among the notified shade trees of the CHR, about 24% of the species are endemic, in which 12 species are endemic to the southern Western Ghats, and seven species are endemic to the Western Ghats. Seven tree species come under IUCN red list category: *Actinodaphne malabarica*, *Dalbergia latifolia*, *Kingiodendron pinnatum*, *Saraca asoca*, *Aglaia apiocarpa*, *Dysoxylum ficiforme* and *Neolitsea fischeri*. *Kingiodendron pinnatum* is the only endangered species recorded from CHR.

CURRENT STATUS AND CHALLENGES OF INTENSIVE FARMING

The ICH lay between Chokka Nadu Hills (CNH) and PTR in the north and south. The Cumbum valley (Tamil Nadu) and the river "Periyar" form the respective eastern and western boundary of CHR. The highest peak in the ICH could be as high as 1700 MSL (Kallippara malai peak). Very intensive cardamom farming is the prominent agricultural activity in the entire CHR, contributing more than 65-70% of the total cardamom production in India. Currently, cardamom occupies nearly about 45,000 ha, which is only 55% of the total allotted lands in the CHR. It means the area under cardamom cultivation over the last few decades has declined. However, the productivity of cardamom has increased over ten folds since 1900. Originally, cardamom was an under-storey crop of tropical rainforest patches and must therefore be a shade loving crop. Many shade-loving annuals and biennials, including cardamom, proliferates and produce profuse tillers and suckers under less shaded or shade-less environments. C4 species like cardamom have a greater photosynthetic rate and quantum yield at higher air temperatures than C3 plants, and this relative advantage disappears at lower temperatures. Generally, C4 plants of tropical and subtropical forests and grassland species have a positive response to the frequent application of nitrogenous and phosphorous fertilizers, especially under increased ambient temperature, to sustain a greater growth rate and higher nutrient demand.

The massive increase in cardamom productivity has been mainly due to the introduction of a variety called "green gold" which is highly responsive to fertilizers and other plant protection and production chemicals. While only a few of the high yielding varieties opened great opportunity to increase the yield several folds, the management practices also demanded the heavy application of crop nutrients as well as crop protection chemicals besides very low shade levels. The majority of the farmers apply far higher quantities of fertilizers and crop protection chemicals than the recommended application rates. Planters who realize maximum potential yield, apply twelve rounds of drenching and foliar nutrients of water-soluble fertilizers (both macro and micronutrients) every season and more than twelve rounds of pesticides; half-a-dozen rounds of flowering hormones (nitrobenzene and seaweed-based) besides 4-5 rounds of pesticide drenching. Manures like cow dung and the mixture of oilseed cakes and bone meal are also dumped annually to the tune of 8-10 tones. To alter the soil acidity, nearly two tons of liming materials have been added. Such intensive practices lead to robust growth with an increased number of leaves as high as 28 per tiller, eventually resulting in early flowering and harvesting within a season (12 months). These practices yield heavily up to 5-6 kg (dry) per plant on some favourable seasons. But all of these intensive practices add to production cost (Rs.10 lacs ha^{-1}), which is unimaginable for other low-value crops like millet and vegetables. Increased fertilizer-nutrient supplies led to increased vulnerability to pest insects and disease-causing micro-organisms, which triggered increased crop protection chemicals in large amounts. The recommended seven rounds of crop protection chemicals in a year were always ignored to go up to 15 sprays a year. Such intensified production practices and too many of too much crop protection chemicals over the last 15 years have caused serious environmental and ecological upsets in CHR. The tree density in the CHR has gradually declined over the last four centuries, and the reduction in tree canopy went up to 2.5% in recent years. While the yield of cardamom moved up to a greater level, the productive life span of cardamom clump reduced to one-third of the expected average (12-

14 years), consequently asking for frequent replanting, more soil and tree canopy work leading to lesser sustainability of the system.

The number of holdings of cardamom fields has increased significantly over the past few decades owing to the partitioning of compound family properties into nuclear family properties. The ever-increasing cost of production ranging from Rs.5,75,000- 10,00,000 per ha is a real problem. The existence and future sustainability of cardamom depend more upon ecological sides than the production economy and net return of cardamom. With variable yield under constantly changing managements, the estimated production cost of every kilogram of cured cardamom can vary between Rs.600-800, and this huge cost for intensive cardamom production is undertaken by every planter irrespective of the size of the holding. Increased labour days and cost on the seasonal scale and the considerable rise in inputs and energy prices mainly contribute to production cost. Practically, organic cardamom farming is near impossible in ICH because planters and growers never want to lose yields. Plantation crops such as cardamom and tea are often grown with high levels of agrochemicals and manures. These inputs may pollute the environment when not used judiciously, and repeated use of such production and protection chemicals could be a point of concern, particularly regarding pesticide residues and heavy metal accumulation in the soil and water compartments. For most spice and plantation crops in many countries, yields on plantations are twice as high as on smallholder fields, although the differences between smallholders and plantations can be as high as 500 per cent. In cardamom, yield variations between smallholders and plantations are very low; sometimes, the yield levels of smallholders can be twice as high as the yield level of the plantation. This is mainly because of uniformity and the high density and intensity of farming practices followed in the smallholdings. This has led to a significant increase in the working days as high as 90 days in a season. Until two decades ago, no work in the cardamom plantations was performed from January to March, and this period was considered holidays for the workers.

The monoculture cardamom system typically results in greater yield losses from the insect pest complex that is less diverse but more abundant. The rates of pesticide use and accumulation in the produces and environment are different for the humid tropics because of the longer growing season and higher temperatures. Sustaining and improving the production capacity of cardamom plantations is therefore important, and maintenance of the soil resources is a key issue for sustainable production. To manage the cardamom ecosystem that has been intensively managed for quite some period, needs more important measures that will figure and rule out unnecessary practices and challenges that can cause a negative impact on long ecosystem sustainability.

HISTORY, BENEFITS AND RISKS OF PESTICIDES IN CARDAMOM ECOSYSTEM

Controlling crop diseases, weeds, nematodes, insect pests, rodents, and other pests that would otherwise compete with us for food and fibre drove humans to achieve high output. We employ "pesticides" to control these pests. These were pest-prevention, pest-control, pest-repellent, and pest-mitigation products (US FIFRA,). Pesticides have only one thing in common: they are used to control pests. Aside from that, they come from practically every chemical class known. Pesticides were created to be poisonous to living beings, therefore they are dangerous by definition. The toxicity of a chemical and the amount of exposure to that substance have always determined its risk. However, pesticide hazards, whether genuine or imagined, may induce adjustments in how these chemicals are utilised. Pest management plans that are environmentally sound, practical, and profitable are being developed by scientists and legislators. Environmental concerns and economic realities will be reconciled in the best pesticide programmes. Pests must be controlled, and farmers must make a profit. Agriculture has been practised by humans for almost 10,000 years, but farmers have only been severely reliant on synthetic chemical fertilisers and pesticides in the last 50 years or so (Horrigan et al., 2002). Pesticides had been used in agriculture for a long time. The ancient Romans used sulphur to kill insect pests and salt to control weeds. Farmers in the United States were utilising arsenate, nicotine sulphate, and sulphur to suppress insect pests in field crops by the nineteenth century. Despite this, the results were frequently disappointing due to crude chemistry and application procedures. Planters of cardamom began using synthetic insecticides in the 1970s.

Benefits of Pesticides

The economic consequences of a pesticide prohibition have been estimated based on studies on pesticide benefits. These "what if" scenarios deal with the most extreme scenarios, but they only provide a starting point for putting pesticides into context. Cardamom production will likely decrease as a result of the pesticide restriction, and consumer prices would rise even higher, making producers less competitive. Pesticide application in cardamom on a seasonal scale per hectare basis creates 7-8% of the job in the sector. An estimate of crop losses of cardamom to pest may vary widely, but the maximum loss can reach up to 70%. The efficiency of crop protection in cardamom was higher than in food crops. Despite a clear increase in pesticide use in cardamom for the last two decades, yield losses have not significantly reduced during the period. The distribution of pesticides on cardamom is even, for example, almost all pesticides available in the state are being used in cardamom. Chemical pest control has contributed to dramatic increases in yields of cardamom. As high as 80% yield reduction can occur in cardamom farming, if its pests were not managed properly. Almost all areas of cardamom acreage have been treated with chemical pesticides. Thrips and borers in combination damaged 55% of the capsules (both qualitative and quantitative damage) when no spraying of pesticides was taken up. The insecticides thiamethoxam, lufenuron, fipronil and thiacloprid successfully reduced capsule damage while chromofenozide, tebufenocide and acetamiprid did not reduce the damage percentage.

Risks of Pesticides and Their Residues

The publication of Rachel Carson's book "Silent Spring" in 1962, shattered the public trust in pesticide use. Carson provided a picture of the harmful effects of pesticide misuse on the environment and human health. Carson, more than anybody before her, had highlighted the dangers of pesticides, despite the fact that the quality of her reporting had been severely challenged (Carson, 1962). Farmers were more prone and are at higher risk for certain malignancies than the general population, according to epidemiologic researches from various nations (Pearce and Reif, 1990; Blair and Zahm, 1995), since farmers were exposed to pesticides at a higher rate than the general public. The number and incidence of health-related problems associated with pesticide exposure in the cardamom sector have been increasing among farming communities. This has been revealed from the local hospital registries.

Pesticide residues were also observed to be higher in cardamom soils and products by Murugan and his team (2008; 2012, and 2017). Pesticides were chosen because the carcinogenic risk related with a number of pesticides had been proven in animal bioassays. The International Agency for Research on Cancer concluded that there was limited or sufficient evidence for carcinogenicity in experimental investigations for nearly half of the chemicals studied (IARC, 1987). Pesticide poisonings and deaths are on the rise in the cardamom industry each year. Humans are exposed to pesticides through residues on or within food, polluted drinking water, and the air they breathe (NRC, 1993). It has been observed that toxic pesticide residue levels were very high in cardamom capsules collected from farmers and market survey, which led to the drastic reduction in cardamom export from India. This has serious economic implications and consequences at all levels. Some of the pesticides used in cardamom, depending on persistence and volatility, that are dispersed locally impact human and other species in the locality, straight from their points of release. If this pattern of pesticide use from the past continues, the pesticide consumption which has increased over 20 years, would be larger than that at present by 2030.

Uses on Cardamom

Farmers have increasingly utilised stronger pesticide concentrations, increased the frequency of pesticide treatments, and employed multiple pesticides together to battle various insect infestations, in addition to the increasing quantities of the pesticides used. Cardamom alone has accounted for about 55% of Kerala's total pesticide use. However, India and all other developing countries lack a pesticide reporting system, therefore no credible data on pesticides that are used in different states for different crops are available.

Cardamom is one of the most vulnerable crops in the tropics; if no crop protection measures are used against significant insect pests (capsule and shoot bores, thrips, and root grubs) and disease-causing pathogens (rot diseases), losses might be as high as 75-80%. Cardamom is one of the most pesticide-intensive crops in the planet (Murugan et al., 2017). Planters cannot afford to lose even a kilogramme of their crop, as one kilogramme of cured cardamom can cost upwards of Rs. 5000-7000 on the local market. As a result, pesticides may play a key part in agronomic and socio-environmental sustainability; they were viewed as cutting-edge concerns that needed to be researched for the overall sustainability and stewardship of the ecosystem. Due to greater input costs and rising labour expenses, the current estimates in the cardamom agroecosystem show that cardamom productivity has to be raised. Given both formal and informal data to date, the pesticide usage necessitates a thorough review of the existing situation, as well as experiments, for which numerous aspects affecting pesticide usage (both directly and indirectly) must be thoroughly studied. Comprehensive IPM tactics are rarely used in cardamom plantations. While biological controls are generally safer for the environment than pesticides, the majority of non-chemical controls represent a risk to the ecosystem and public health. A careful assessment of the benefits and dangers of all combined regulated technologies, including non-chemical biological controls, is at the heart of all IPM initiatives. Because, the advantages and dangers vary depending on the agroecosystem involved and these analyses must be carried out for individual case scenarios or regions (particular pest complex, crop, climate