International Journal of Agriculture Sciences
ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 13, Issue 8, 2021, pp.-10863-10870.
Available online at https://bioinfopublication.org/pages/jouarchive.php?id=BPJ0000217

Research Article

ORGANIC PRODUCTION PRACTICES IN INDIA FOR SAFE TO EAT CARDAMOM (*Elettaria cardamomum* Maton)

A.K. VIJAYAN*
National Consultant, the GIZ DPP Project on Spices
Former Scientist at Indian Cardamom Research Institute, Spices Board India (Ministry of Commerce and Industry, Govt. of India), Myladumpara, Idukki, 685 553, India
*Corresponding Author: Email - drvijayanicri@gmail.com

Received: August 02, 2021; Revised: August 26, 2021; Accepted: August 27, 2021; Published: August 30, 2021

Abstract: Cardamom enjoys a unique position in the international spices market, as one of the most sought after spices. In India, small cardamom is cultivated in the states of Kerala, Karnataka and Tami Nadu. The natural habitat of cardamom is the evergreen forests of Western Ghats. Pest and disease management is an important aspect of cardamom plantation management. Good quality of the produce can be achieved through timely harvest and adoption of scientific post harvest practices. Promising small cardamom varieties and improved selections coupled with optimum inputs and technologies can increase yield up to 2000 kg/ ha. Proper scientific management of organic cardamom plantation is the prime reason for successful cultivation. This organic cardamom production technology is recommended for safe to eat cardamom in the country.

Keywords: *Cultivar, diseases, Organic production, Pests, Sustainable, Safe to eat cardamom*

Citation: A.K. Vijayan (2021) Organic Production Practices in India for Safe to Eat Cardamom (*Elettaria cardamomum* Maton). International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 13, Issue 8, pp.- 10863-10870.

Introduction

Cardamom (*Elettaria cardamomum* Maton) is indigenous to the southern stretch of evergreen forests of Western Ghats. In India, small cardamom is cultivated in the states of Kerala, Karnataka and Tami Nadu. It is also cultivated in parts of Guatemala, Tanzania, Sri Lanka, ElSalvador, Vietnam, Laos, Cambodia and Papua New Guinea. Now Guatemala is offering stiff competition to Indian cardamom in the international market. Kerala is the largest producer of small cardamom and constitutes the lion share of Indian and world market. The cardamom of commerce is the dried fruit (capsule) of the plant. It is used as spice for various food preparations, in confectioneries, making perfumes and in several ayurvedic preparations [1].

Climate and Soil

The natural habitat of cardamom is the evergreen forests of Western Ghats [Fig-1]. It grow within an altitude ranging between 600 and 1200 meters above MSL. Though considerable variations both in the total rainfall pattern and its distributions are noticed in the cardamom tracts (900- 4000mm), a well distributed rainfall of 1500-2500mm with not less than 200mm summer showers and mean temperature of 15 to 25°C would be ideal.

Crop botany

A mature cardamom plant may measure two to four meters in height. It is a shallow rooted shade loving plant. Tiller production takes place throughout the year. However; peak period is from January to March.

High yielding varieties, improved selections and clones selected by farmers

Various research institutions working on the crop improvement aspects of cardamom have released a number of elite location specific high yielding clones having yield potential of above 450 kg per hectare (rainfed) and superior capsule characters. In addition to this, there are several high yielding clones selected by cardamom farmers. The most popular and widely cultivated farmer variety is Njallani green gold [Fig-2] & [Fig-3] which has very high yield potential and good quality characters.

Other prominent farmers' selections (Land races) are Palakkudy, Panikulangara - 1, Vally green bold, Elarani, PNS Vaigai, cardamom vander, Kalarickal white cardamom, Ela sundari, Thiruthali [Fig-4] and Kaniparamban [Fig-5].

Propagation

Plants raised from seeds need not necessarily be high yielders even if they are collected from very productive plants due to cross pollination [Fig-6]. The major pollinator is honey bees [Fig-7]. On the other hand, planting through suckers ensures true to the parents with a high productivity if they are collected from high yielding, disease free plants.

Land preparation

The land selected for planting is cleared of all under growth, weeds etc. Old cardamom plants, if any, may also be removed. It should be prepared before commencement of monsoon; pits are left open for weathering for a fortnight and then about 1/3 of the pit should be filled with top soil and 1/3 should be filled with 1:3 mixture of organic manure and topsoil.

Planting

Planting material of high yielding variety suitable for the areas may be selected for planting [Fig-8]. They may be planted in the already prepared and filled pits and plants should be protected from wind by staking. For Mysore and Vazhukka cultivars, plant to plant distances can be 3x3 meters (1111plants per hectare). A spacing of 2.4x2.4meters (1736 plants/ha) is recommended for Tamil Nadu 1.8x1.8 meters spacing (3086 plants per hectare) is suitable for Cv. Malabar in Karnataka.

Irrigation

Irrigation is required generally during summer months and also during periods of prolonged dry spells, if it coincides with the critical periods of plant growth where development of young tillers and panicles takes place. Irrigation can be done at weekly intervals at the rate of 20- 30 liters per plant depending upon the clump size. Fogger/mist irrigation system is used widely in the cardamom plantations to create a suitable microclimate within the plant ecosystem to create a favorable environment for growth, flowering and seed setting.

Fig-1 Cardamom in its natural habitat

Fig-3 Njallani- 15 years old plant

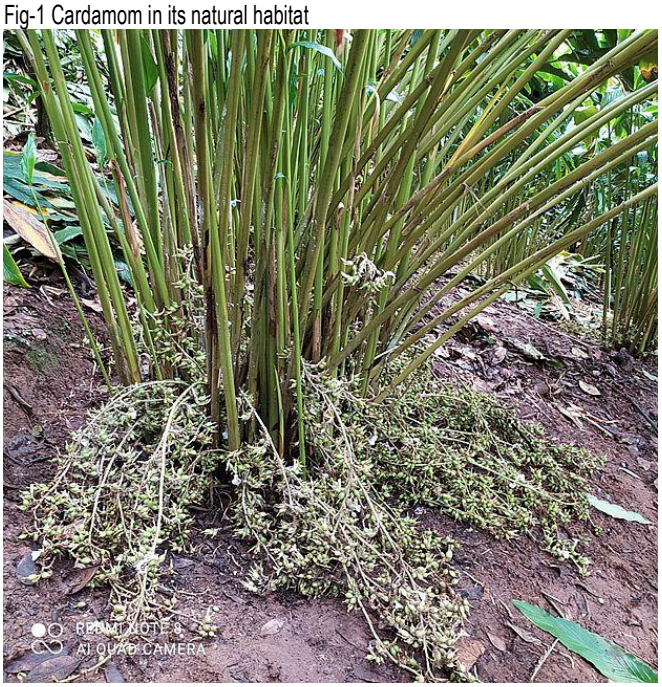

Fig-2 Njallani Cardamom-Farmers' selection

Fig-4Thiruthali cardamom landrace

The frequency of operation of the irrigation systems depends on the microclimate in the plantation and hence has to be standardized for specific local weather situations. Irrigation is to be undertaken with utmost care to avoid excess wetness at the plant base for prolonged periods to prevent occurrence of rot diseases.

Forking and mulching

As far as possible, the entire plantation and particularly the plant base are to be kept under mulch for reducing evaporation loss, suppress weed growth and to maintain optimum soil temperature. It is very essential to keep the plant base mulched (5-10 cm thick), except during periods of heavy monsoon (June to September). Through adopting the best soil management practices, the soils will remain loose and friable.

Trashing and pruning

This operation may be carried out once in a year at any time after the receipt of the pre-monsoon showers, in May. Pruning is the operation undertaken with sharp sickles for removing the dead and hanging leaves from the pseudostem [Fig-9].

Care should be taken not to peel off the leaf sheath from the pseudo-stem. This operation may be done during January and during September, which coincides with the peak thrips population. The resultant plant materials obtained through pruning can be used for mulching.

Earthing up

Whenever, the top soil covering the plant base is washed away and the rhizomes and roots are exposed, earthing-up of the plant base with top soil is recommended during November/December, before the withdrawal of north east monsoon.

Manures and fertilizer application

Cardamom responds to both organic manuring and organic fertilizer application. A soil test based judicious manuring schedule should be followed to achieve optimum production on a sustainable basis. Application of bulk organic manure, concentrated organic manures or both may be adopted based on nutrient requirement/status of the soil under organic cardamom cultivation. Application of mature farmyard manure/ compost @ 5-10Kg per plant may be made during

Fig-5 Kaniparamban cardamom


Fig-6 Seeds of cardamom

Fig-7 Pollination by honey bees

Fig-8 Sucker planting for raising a new plantation

May/June along with rock phosphate (180 grams per plant) and murate of potash (90 grams/plant). Organic manures such as neemcake (one to two kg per plant), bone meal (one kg per plant) or vermicompost (three to five kg per plant) have beneficial effects on root proliferation and plant growth and also help to reduce nematode and root grub infestation. Application of lime/dolomite is essential if pH of the soil is<5.5. Lime is to be applied in two splits during May and September. Organic fertilizers shall be applied only after 15 days of lime application. Zinc deficiency is widespread in cardamom soils and Boron deficiency is observed in certain areas. Application of Zinc to the foliage is found to enhance not only cardamom growth and yield but also the quality of the produce. Hence, it is recommended that Zinc may be applied as a foliar spray as Zinc sulphate@ 250 grams/100 liters of water during April/May and September/October.

Under high production technology, where crops are harvested from 18 months onwards, organic fertilizer recommendation for full-grown plantations could be adopted from the second year onwards. Organic fertilizers would be applied in four or more splits after every harvest or combining both soil and foliar application of organic fertilizers. Whenever, the plant growth is affected due to root damage (root grub/fusarium diseases/soil compactness), foliar application of organic sources of DAP (two per cent) + MOP (two per cent) could be adopted.

Schedule for the use of organic source of fertilizers

Age of plants	Rainfed areas (Kg/ha)	Irrigated areas (Kg/ha)
First year of planting	Nitrogen -25 Phosphorus -25 Potassium -50 (2 split application)	Nitrogen -25 Phosphorus -25 Potassium -50 (2 split application)
Second year of planting	Nitrogen -40 Phosphorus -40 Potassium -80 (2 split application)	Nitrogen -60 Phosphorus -60 Potassium -80 (3split application)
Third year of planting	Nitrogen -75 Phosphorus -75 Potassium -150 (2 split application)	Nitrogen -125 Phosphorus -125 Potassium -250 (3 split application)

Shade management

Cardamom is a shade loving plant and trees provide a suitable environment by maintaining humidity and preventing evaporation loss of moisture from the soil. Shade requirements of cardamom plants vary from place to place depending on the slope of land, soil type, rainfall patterns, crop combination etc. Climatic factors will adversely affect the growth, development and production. It is noticed heavy or less shade hinders crop growth and production.

About 50 % shade is found ideal. Lopping of branches of shade trees is very important and should be done before onset of monsoon. But at the same time exposure to direct sunlight causes yellowing of leaves. Therefore, judicious shade management is very important for good growth, timely flowering and for better crop. The foraging behavior of honey bees commence in the morning and continue till evening. However peak forage is encountered from 9 am to 11 pm and this coincides with maximum capsules formation. Tree flowers act as pollen as well as nectar source to bees. The quality as well as the capsule set was related to the number of bee visits. A total of 19 tree species were listed in the cardamom plantations which not only supports the domestication of honey bees but also provides filtered shade, very much suited to the growth and development of cardamom plants. Some of the most ideal shade trees to be grown in the plantations are *Acrocarpus fraxinifolius, Actinodaphne malabarica, Bischofia javanica, Canarium strictum, Mesopsis eminii, Mesua ferrea, Myristica attenuata, Vateria indica, Vernonia arborea, Cedrela toona*, *etc.*

Pests in small cardamom

Small cardamom is infested by many pests, right from the seedling stage to the cured cardamom in storage. Nearly 60 species of insect pests infests cardamom. Based on severity of infestation, these pests are categorized as major and minor pests, the former include thrips, panicle/capsule/shoot borer, root grub and root knot nematode and the latter, mid-rip caterpillar, whitefly, scales, red spider mites, lacewing bugs and aphids.

Major pests

Cardamom Thrips [*Sciothrips cardamomi* (Ramk.)]

Thrips are the most destructive and persistent pest of cardamom and found in all cardamom growing areas. It colonizes and breeds in different parts of the plant such as unopened leaves, leaf sheaths, flower bracts and flower tubes. Adults and nymphs of the insect cause damage to panicles and capsules. Thrips lacerate the surface tissues with mandibles and suck the exuding plant sap. Affected capsules fetch a very low price in the market. Thrips infestation results in nearly 45-48 percent crop loss. Adult insects are greyish brown, 1.25 to 1.5 mm long and with two pairs of fringed wings; females lay minute eggs below epidermis which hatch out into nymphs in 8-12 days.

Shoot/ Panicle/ Capsule borer [*Conogethes punctiferalis* (Guen.)]

Eggs hatch within five-six days. The seed and the capsules become empty. At a later stage the larvae bore into the shoots. They feed the central core of the pseudostem resulting in decaying of the central spindle and the characteristic dead heart symptom develops. A fully grown larva is 30-35 mm long with a pale purple body and black head. After a prepupal period of two-four days, it becomes a brown pupa. Adult emerges in about 11-15 days from pupa through the bore hole. The life cycle is completed within 41- 68 days during summer and prolongs upto 123 days in post monsoon period. Pest infestation is pronounced in three seasons: January- February, May- June and September-October. However, overlapping generations do occur in between. Organic insecticide sprays at late stages of the larvae which bore in pseudostem may not give adequate control of the pest. For effective management, prophylactic application of organic insecticides has to be targeted on early stages of the larvae, which are usually present on panicles/ racemes within 15-20 days after adult emergence in the field. Injection of insecticide/Bacillus thuringiensis (biological insecticide) solution through the bore hole is also a method for controlling larvae in pseudostems.

Root grub [*Basilepta fulvicorne* (Jacoby)]

Female root grubs are bigger than males. They are seen on cardamom leaves during morning and evening hours but do not feed on cardamom. The minute creamy white grubs hatch out from eggs, fall on the ground, reach the root zone and start feeding the roots. Grubs have two periods of occurrence, the first during April-July and the second during September to January.

Nematodes (*Meloidogyne* spp.)

Egg, larva and adult are the different stages in the life cycle of the pest. Second stage larvae infect rootlets and induce formation of giant cells called galls. Larvae moult thrice and form adults. Female secretes a gelatinous matrix into which eggs are extruded. Frequent change of nursery beds will help to reduce nematode infection in nurseries. In case of infection in nurseries, application of neem oil cake per six square meter bed will control the pest. In plantation, 500-1000 grams of neem oil cake per plant in May-June and /or September bring down nematode infestation. Increasing the root biomass with application of compost/ vermicompost result in sustained management of the pest.

Organic Management of Pests (OMP)

Organic management of pests (OMP) is an important method for cardamom pest management under organic cultivation [Table-1]. Effect of pesticides on the environment are very serious, impacts include biodiversity loss, as well as soil degradation and pollution. Sustainable cultivation practices were followed under integrated pest management for cardamom in the country [Table-2] and the risk molecules are listed [Table-3]. Some of them are classified as important pests that need a clear understanding of their biology. Considering the vulnerable stages in their life cycle the following components of pest management are followed in cardamom under organic farming.

1.Cultural control
2.Biological control
3.Physical control
4.Mechanical / manual removal
5.Host plant resistance

Biological control of cardamom root grub

Entomo pathogenic nematodes (EPN) and Entomo pathogenic Fungi (EPF) such as *Metarhizium anisopliae* and *Beauveria bassiana* are effectively used for management of root grub in cardamom. Application of EPN infected Galleria larva (cadaver) at plant base has been found to reduce root grub infestation up to 95 percent. EPN survives in moist soil and hence they persist longer in soil resulting in sustainable management of root grub.

Diseases and their management

Cardamom is affected by a number of diseases caused by various pathogenic fungi, bacteria, viruses and nematodes, in main plantations as well as in nurseries. As many as twenty five fungal, bacterial, viral and nematode diseases have been reported till date.

Capsule rots (Azhukal disease):

Capsule rot or 'Azhukal' is the most serious fungal disease of cardamom. Disease symptoms develop mainly on the capsules, young leaves, panicles and tender shoots. The first visible symptom appears as discolored water soaked lesions on young leaves or capsules. Infected capsules show water soaked discolored areas; they turn brownish and later such capsules decay and drop off. During favorable climatic conditions the diseases aggravate and infection extends to panicles and tender shoots. It has been shown that as high as 40percent crop loss can occur in severely disease affected plantations. The disease severity is uniform in the three major cardamom types Mysore, Vazhukka and Malabar.

Disease management

Phytophthora meadii Mc Rae has been widely observed as causing capsule rot disease. As the outbreak of disease is during the monsoon season, disease management measures have to be initiated sufficiently in advance *i.e.* before the primary infection starts.

The factors responsible for the constraints in achieving satisfactory disease control include lack of phytosanitation, effective and timely application of organic schedule for management of diseases, and the continuous rain that makes any application ineffective. Two to three rounds of fungal biocontrol agents as prophylactic application after proper phytosanitation effectively controlled the spread of the disease.

Fig-9 Trashing and pruning in cardamom


Fig-10 Harvesting in Cardamom


Fig-11 Freshly harvested capsules


Fig-12 Processed cardamom capsules

Biological control of capsule rot

Bioagents play an important role in an eco-friendly system of disease management to fight against the plant pathogens in a totally safe manner avoiding the use of expensive and hazardous chemical fungicides. Field control of capsule rot disease using *Trichoderma viride* and *Trichoderma harzianum* was achieved and has further developed a simple carrier come multiplication medium for *Trichoderma* application in the field. Today, field control of capsule rot (Azhukal) disease of small cardamom has become effective, environmentally safe and cost effective due to the biocontrol potential of *Trichoderma* sp.

Rhizome rot

Rhizome rot (Clump rot) is a common disease occurring in cardamom plantations during the monsoon period. The disease is widely distributed throughout cardamom plantations in Kerala and Karnataka states and in heavy rainfall areas of Tamil Nadu such as the Anamalai hills. The symptoms of rotting develop at the collar region of the pseudo stem (tillers) which become soft and brown coloured. At this stage the affected tillers fall off emitting a foul smell. The panicles and young shoots attached to this are also affected by rot. The rotting extends to the rhizome and roots also.

Falling of shoots resulting from rhizome rot infection becomes severe during July-August months. Rhizome rot is caused by *Pythium vexens* de Barry and or *Rhizoctonia solani* Kuhn or *Fusarium oxysporum* Sehlecht.

Disease management

Dense shade increases rot disease infection despite regular bio-fungicides and organic pesticide applications. On the other hand, regulated shade reduces disease incidence by making the microclimate unfavorable for the pathogen. The disease is usually observed in areas previously affected by rhizome rot disease. Therefore, phytosanitation plays a major role in disease management. Presence of inoculums in the soil and plant debris, overcrowding of plants, and thick shade are congenial conditions for disease development. Therefore, any organic disease management schedule has to be followed with these points in mind.

Table-1 *Cultural operations and prophylactic treatments for control of pests and diseases in organic cardamom production*

SN	Time of application	Organic Inputs	Cultural Operations and benefits	Target pests / diseases
1	January 3rd week	-	1. Pruning of dry leaves, 2. Mulch the plant base, 3. Remove and compost diseased plants and/or plant parts.	-
2	February1stweek	Panchagavya spray	Promotes plant growth	Thrips, borer and other foliar pests
3	March 1st week	Pest repellent plant extract spray	-	Thrips, borer and other foliar pests
4	April 1st week	Amruth solution spray and drench	Tonic / growth hormone and micronutrients.	Thrips, borer and other foliar pests
5	May1st week	Panchagavya spray Thrips, borer and other foliar pests	Promotes plant growth	Thrips, borer and other foliar pests
6	May4th week	1. *Pseudomonas* (1-3% as foliar spray and basal application), *Trichoderma* (1-3% as basal application) 2. *Paecilomyces* (25-40 g per plant) mixed with FYM 3. Neem oil cake at plant base @ 500 g per plant	1. Trashing, 2. Shade regulation, 3. Remove the mulch from the plant base, 4. Remove and compost diseased plant and/or plant parts, 5.Provide drainage in low lying areas.	Rhizome rot, capsule rot, foliar diseases, root grubs, nematodes and *Fusarium* pathogen
7	June 1st week	1.Amruth solution spray and drench 2.Apply EPN@4 cadavers + *Metarhizium* 25-40g/plant mixed with FYM	Tonic / growth hormone and micronutrients.	Thrips, borer and root grubs
8	June 3rd week	1.PGPR mixture spray & drench 2.*Metarhizium* and *Paecilomyces* (25-40 g each per plant) mixed with FYM	-	Thrips, borer, root grubs, nematodes and *Fusarium* pathogen
9	August 1stweek	Panchagavya spray	Promotes plant growth	Thrips and bore
10	August4thweek	1. *Pseudomonas* (1-3% as foliar spray and basal application), *Trichoderma* (1-3% as basal application) 2. *Paecilomyces* (25-40 g per plant) mixed with FYM 3. Neem oil cake at plant base @ 500 g per plant	1. Trashing, 2. Shade regulation, 3. Remove the mulch from the plant base, 4. Remove and compost diseased plant and/or plant parts, 5.Provide drainage in low lying areas.	Rhizome rot, capsule rot, foliar diseases, root grubs, nematodes and *Fusarium* pathogen
11	September1st week	Apply EPN@4 cadavers per plant + *Metarhizium* 25-40 g/plant mixed with FYM	Pruning of dry leaves; Remove and compost diseased plants and/or plant parts	Thrips, borer & root grub
12	October1st week	Amruth solution spray and drench	Tonic / growth hormone and micronutrients	Thrips, borer and other foliar pests
13	November1st week	Panchagavya and pest repellent plant extract / neemasthram	Growth promotion	Thrips & borer
14	December1st week	*Pseudomonas* (1-3% as foliar spray and basal application), *Trichoderma* (1-3% as basal application)	-	Rhizome rot, capsule rot, foliar diseases, Root grubs, nematodes and *Fusarium* pathogen
15	December3rd week	Amruth solution spray and drench	Tonic / growth hormone and micronutrients	Thrips, borer and other foliar pests

Table-2 *Cultural operations and treatments for control of pests and diseases in sustainable cardamom production*

SN	Time of application	Insecticide/ Fungicide per 100 liter of water	Cultural Operations and benefits	Target pests/ diseases
1	January3rdweek	-------	1. Pruning of dry leaves, 2. Mulch the plant base, 3. Remove and compost diseased plants and/or plant parts.	-
2	February1stweek	Quinalphos spray @ 150 ml	-	Thrips and bore
3	March1stweek	Diafenthiuron spray @ 80 g	-	Thrips, borer and other foliar pests
4	April1st week	Flubendamide @ 15 ml	-	Borer
5	May 1st week	Quinalphos spray @ 150 ml	-	Thrips and borer
6	May4th week	Spray and drench Copper oxychloride @ 200 g / Fosetyl – AL @ 200 g	1. Trashing, 2. Shade regulation, 3. Remove the mulch from the plant base, 4. Remove and compost diseased plant and/or plant parts, 5.Provide drainage in low lying areas.	Rhizome rot, capsule rot and foliar rot diseases
7	June 1st week	Apply EPN@4 cadavers per plant + *Metarhizium* 25-40 g/plant mixed with FYM	-	Thrips, borer and root grubs
8	June3rd week	Diafenthiuron spray @ 80 g	-	Thrips, borer and other foliar pests
9	August 1st week	Flubendamide @ 15 ml	-	Borer
10	August4th week	Spray and drench Copper oxychloride @ 200 g / Fosetyl – AL @ 200 g	Provide drainage in low lying	Rhizome rot, capsule rot and foliar rot pathogens
11	September1stweek	Spray and drench Copper oxychloride @ 200 g / Fosetyl – AL @ 200 g	Trashing, Remove and compost diseased plant and/or plant parts	Rhizome rot, capsule rot and foliar rot pathogens
12	September1stweek	Apply EPN@4 cadavers per plant + *Metarhizium* 25-40 g/plant mixed with FYM	-	Thrips, borer and root grubs
13	October1st week	Quinalphos spray @ 150 ml	-	Thrips and borer
14	November1stweek	Flubendamide @ 15 ml	-	Borer
15	December1st week	Spray and drench Copper oxychloride @ 200 g	-	Rhizome rot, capsule rot and foliar rot diseases
16	December3rdweek	Diafenthiuron spray @ 80 g	-	Thrips, borer and other foliar pests

Application of *Trichoderma viride* and *Trichoderma harzianum* is effective to reduce rhizome rot incidence in plantations. A formulation of *Trichoderma harzianum* in a carrier medium consisting of farmyard manure and coffee husk mixture has been developed for field application in the integrated disease management system. Two rounds of pre monsoon and two rounds post monsoon soil application of *Trichoderma* biocontrol agent (1-3%) fortified vermicompost along with spraying of bacterial biocontrol agent Pseudomonas (1-3%) is very effective for controlling the disease.

Colletotrichum leaf blight

The leaf blight disease is caused by *Colletotrichum gloeosporioides* (Penz.) Penz and Sacc. The disease spread is faster in partially deforested areas and less shaded plantations. Though it was reported as a minor disease of limited spread, presently the situation is alarming as the disease is spreading to newer areas and is becoming a major problem.

Disease management

Bacterial biocontrol agent Pseudomonas (2-3%) is effective for controlling the disease the disease spread in the field.

Leaf blotch

The disease appears during monsoon season *i.e.* from June to August months, normally under heavily shaded conditions. Thick shade, continuous rainfall and high atmospheric humidity predisposed plants to infection. During the rainy period, round, ovoid or irregular water soaked lesions develop on middle leaves, usually near the leaf tips or at the midrib areas. These areas enlarge in size, becoming dark brown with a necrotic centre. In moist weather, a thick, grey colored fungal growth is seen under the side of these blotched areas. The periphery of the lesion shows a dark band of water soaked zone as the lesions spread. However, the lesion spread is limited in size following a dry period. Leaf blotch is a fungal disease caused by *Phaeodactylium alpiniae* (Sawada) (Ellis).

Disease management

Application of bacterial biocontrol agent Pseudomonas (2-3%) or Effective microorganisms (EM solution) is effective for controlling the disease spread in the field.

Fusarium infections of small cardamom

The cultivation of small cardamom and maintenance of healthy plants have become difficult tasks due to the incidence and spread of Fusarium infections since 2006. Fusarium infection in small cardamom have been reported in the form of capsule infection in the field, seed rot and seedling wilt in nurseries, stem rot & stem lodging in plantations, rhizome rot, root tip rot and foliar yellowing. The disease incidence was observed to be severe in plantations 4-6 years of age during October – March months. The causal organism is identified as *Fusarium oxysporum* Sehlecht.

Pseudostem rot

This disease is generally seen during the post- monsoon period and may last up to summer months. Round to oval shaped brown lesions develop on the pseudostem. These later elongate and as infection proceeds the deeper layer of the pseudostem gets discolored.

The pseudostem breaks at this point. The disease is caused by *Fusarium oxysporum*. Two to three rounds of application of fungal biocontrol agents as prophylactics after proper phytosanitation effectively controlled the spread of the disease.

Table-3 *Risk molecules in Cardamom*

Risk Molecules in Cardamom (As on 20.8.2019)				
	Minimum Residual Levels (ppm)			
SN	Molecules	European Union	Environmental Protection Agency - USA	Remark
1	2,4-D	0.1	<0.01	Permitted
2	Acetamiprid	0.1	<0.01	Permitted
3	Anthraquinone	0.02	<0.01	To be listed under the prohibited chemicals
4	Bifenthrin	0.03	<0.01	To be listed under the prohibited chemicals
5	Buprofezin	0.05	<0.01	To be listed under the prohibited chemicals
6	Carbendazim	0.1	<0.01	Permitted
7	Carbendazim/Benomyl (sum)	0.1	<0.01	Permitted
8	Carbofuran (Sum)	0.05	<0.01	To be listed under the prohibited chemicals
9	Carbosulfan	0.05	<0.01	To be listed under the prohibited chemicals
10	Chlorfluazuron	0.01	<0.01	To be listed under the prohibited chemicals
11	Chlorpyrifos (-ethyl)	0.01	<0.01	To be listed under the prohibited chemicals
12	Chlorpyrifos (-methyl)	0.01	<0.01	To be listed under the prohibited chemicals
13	Copper oxychloride	40	<0.01	Permitted
14	Cyfluthrin	0.1	<0.01	Permitted
15	Cyhalothrin, lambda- (incl. Cyhalothrin, gamma-)	2	<0.01	Permitted
16	Cypermethrin	3	<0.01	Permitted
17	Deltamethrin	15	<0.01	Permitted
18	Diafenthiuron	0.01	<0.01	To be listed under the prohibited chemicals
19	Difenoconazole	0.3	<0.01	Permitted
20	Dithiacarbamates	0.1	<0.01	Permitted
21	Ethion	5	<0.01	Permitted
22	Fenvalerate (all isomers	0.1	<0.01	Permitted
23	Fenvalerate(RR-/SSIsomers)	0.1	<0.01	Permitted
24	Fenvalerate(RS-/SRIsomers)	0.1	<0.01	Permitted
25	Fipronil (sum)	0.005	<0.01	To be listed under the prohibited chemicals
26	Flubendiamide	0.02	<0.01	To be listed under the prohibited chemicals
27	Folpet/PI(Sum calculated as Folpet)	0.1	<0.01	Permitted
28	Fosetyl-Al	40.0	<0.01	Permitted
29	Hexaconazole	0.05	<0.01	To be listed under the prohibited chemicals
30	Imidacloprid	0.05	<0.01	To be listed under the prohibited chemicals
31	Metalaxyl M	0.1	<0.01	Permitted
32	Methomyl	0.05	<0.01	To be listed under the prohibited chemicals
33	Monocrotophos	0.05	<0.01	To be listed under the prohibited chemicals
34	Nitrobenzene	0.01	<0.01	To be listed under the prohibited chemicals
35	Novaluron	0.01	<0.01	To be listed under the prohibited chemicals
36	Permethrin	0.1	<0.01	Permitted
37	Phenthoate	0.01	<0.01	To be listed under the prohibited chemicals
38	Phosalone	2	<0.01	Permitted
39	Phthalimide (PI)	0.1	<0.01	Permitted
40	Profenofos	3	<0.01	Permitted
41	Propiconazole	0.05	<0.01	To be listed under the prohibited chemicals
42	Quinalphos	0.05	<0.01	To be listed under the prohibited chemicals
43	Tebuconazole	0.05	<0.01	To be listed under the prohibited chemicals
44	Thiacloprid	0.05	<0.01	To be listed under the prohibited chemicals
45	Thiamethoxam	0.05	<0.01	To be listed under the prohibited chemicals
46	Thiodicarb	0.05	<0.01	To be listed under the prohibited chemicals
47	Triazophos	4	<0.01	Permitted

Root tip rot

This disease also occurs during the post monsoon period. The severity is more during summer. Spraying and soil drenching with two to three rounds of application of fungal biocontrol agents as prophylactics after proper phytosanitation effectively controlled the spread of the disease. The application of biocontrol agents may be repeated at 15 to 20 days intervals.

Viral diseases

The four viral diseases of small cardamom are mosaic virus or katte, Nilgiri necrosis virus, vein clearing virus (kokkekandu), and banana bract mosaic virus. Katte is widely distributed in all cardamom growing tracts and is a major production constraint for cardamom in India. Occurrence of these viral diseases is a matter of concern to the cardamom industry.

Use of virus free planting materials, removal of infected host plants, creating awareness among farmers, preventing the movement of diseased plant materials to check introduction of viruses to new areas regular phytosanitation, removal of virus sources, early detection through ELISA, use of resistant varieties are the methods/approaches required to manage the viral diseases in nurseries and plantations.

Management of viral diseases

Viral diseases of plants are cancerous in nature and are difficult to cure. Early identification of the diseased plants and reducing the spread are the easy ways to tackle the problem.

Hence, from an environmentally safe and economically viable perspective the following measures would be adopted for effective management of the diseases.

1. Monitor the plantation every month particularly during the rainy season and carefully identify the diseased plants.
2. The diseased plants may be uprooted and destroyed as and when they are seen. They should be taken to an isolated place, chopped into small pieces and buried in pits for quick decomposition. As an alternative, mass uprooting and composting of infected plants at the village / area level could be taken up for eradication of the disease.
3. Never collect planting materials from an infected garden or apparently healthy plants from severely infected gardens.
4. Establish nursery about 500 m away from main plantation in order to avoid aphid colonization
5. Maintain clean clumps by removing old tillers with loosened leaf sheath so that aphids will not colonize.
6. During plantation monitoring, especially prior to harvesting, the plantation must be inspected carefully for identification of diseased plants.

These plants may be uprooted and destroyed on priority. The knife and other implements used for the purpose should not be used on healthy plants since disease could be transmitted through sap. Dip the implements in hot water for half an hour to kill the inoculums before going to the healthy plants for harvesting or cleaning.

Harvesting and curing

Good quality of the produce can be achieved through timely harvest and adoption of scientific post harvest operations. Harvesting of capsules at the correct maturity stage is a prerequisite for improving the quality of the produce [Fig-10]. The capsules should be harvested when they attain physiological maturity (Karinkai) to fully ripened stage to allow the capsules for the proper seed development and to obtain higher recovery [Fig-11]. Recovery is highest (24 per cent) in the fully ripened capsules.

Cardamom curing may be defined as the process in which moisture of freshly harvested capsules is reduced from 80 percent to 10-12 percent through indirect heating. Drying is the most important unit operation that determines the colour of the end products. Apart from quality in terms of colour, flavor components such as 1-8 cineole, terpenyl acetate, linalool etc are also important. After keeping cardamom trays in the racks, the curing room is closed and heating is done by burning firewood in the furnace. The hot air passed through the pipes placed a few centimeters above the floor enhances the room temperature to 45 to 55°C and this temperature status should be maintained for three to four hours initially. At this stage the capsules sweat and with the enhanced temperature, give off moisture. The ventilators are opened for sweeping out water vapour from the drying fruits. After the complete removal of water vapour, ventilators are closed and the temperature inside the chamber should be maintained again at 45 -55°C for about 18 to 24 hours. The temperature is again raised to 60 - 65°C for another one or two hours for completing the curing process. Efficient and largely automated cardamom dryers have been designed and manufactured by several private entrepreneurs using alternate sources of fuel such as Kerosene, Liquid Petroleum Gas (LPG), and diesel cardamom or using a combination of fuels. Dried capsules have to be polished either manually or with the help of machines before marketing. For efficient retention of green colour during storage, cardamom should be dried down to a moisture level of 10-12 per cent [Fig-12]. Use of 300 gauge black polythene lined gunny bags improves the storage efficiency.

Future prospects

Promising farmer's selections and improved varieties of small cardamom coupled with optimum inputs and sustainable practices can increase yield up to 2000 kg per hectare [2]. Demand can be raised by adding new value added products from small cardamom. Income of the farmers can be doubled by using the healthy, good planting materials, application of farm yard manure, weed management, irrigation during dry period, diseases and pests management. Proper scientific management of plantation is the prime reason for successful sustainable cultivation. The major causes of low productivity in some regions are lack of improved planting materials, pests and diseases, lack of proper shade management, moisture stress conditions and climate change. The future of cardamom is bright and there are great opportunities for the farming community to produce safe to eat cardamom in the country following sustainable and organic production practices.

Application of research: The future of cardamom is bright and there are great opportunities for the farming community to produce safe to eat cardamom in the country following sustainable and organic production practices. Proper scientific management of plantation is the prime reason for successful sustainable cultivation.

Research Category: Cardamom production technology

Acknowledgement / Funding: Author is thankful to Spices Board, Govt of India, Cochin, Kerala and Ministry of Economic Co-operation and Development, Federal Republic of Germany under its DevelopPPP de program for providing necessary facilities. Author is also thankful to Indian Cardamom Research Institute, Spices Board India (Ministry of Commerce and Industry, Govt. of India), Myladumpara, Idukki, 685 553, India

****Principal Investigator or Chairperson of research: Dr A.K. Vijayan**
University: Indian Cardamom Research Institute, Spices Board India (Ministry of Commerce and Industry, Govt. of India), Myladumpara, Idukki, 685 553, India
Research project name or number: Research station study

Author Contributions: Sole Author

Author statement: Author read, reviewed, agreed and approved the final manuscript. Note-Author agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Idukki, Kerala, India.

Cultivar / Variety / Breed name: Cardamom (*Elettaria cardamomum* Maton)

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

References

[1] Madhusoodanan K.J. Pradip Kumar K. and Ravindran P.N. (2002) *In: Cardamom The genus Elettaria, Eds. P.N. Ravindran and Madhusoodanan, K.J, Taylor & Francis, London.*
[2] Vijayan A.K. (2021) *International J. of Agriculture Sciences*,13 (8), 0840-10844.