CRITIQUES ON THE CRITICAL ISSUES OF CARDAMOM CULTIVATION IN CARDAMOM HILL RESERVES, KERALA, INDIA

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Introduction

Small cardamom (*Elettaria cardamomum Maton*) is a mellitophilous perennial pseophyte extensively cultivated in Cardamom Hill Reserves (CHR) of Idukki district. India is one of the largest producers and consumers of cardamom. Few other countries in Asia, Africa and Central America also grow cardamom. The south Indian states namely Kerala, Karnataka and Tamil Nadu are the main producers in India. Among these states, Kerala is the largest producer followed by Karnataka. An approximately 334 square mile (86, 000 ha) area in and around cardamom hills was allotted for exclusive cultivation of cardamom. Cardamom is being cultivated under high management in CHR while in other countries it is not grown under forest condition that too under high input system. The habitat of cardamom (CHR) is one of the two-biodiversity hot spots in India. The peculiarity of CHR and high input farming need careful evaluation and monitoring for the long-term ecosystem sustainability. Therefore this paper tries to analyse the critical issues of cardamom cultivation and attempt to give solution based on scientific analysis as well as experience.

Critical issues

1) Cardamom production and productivity

At present only half of the allotted area (41,412 ha) is being utilized for the cultivation of cardamom averaging a production of 281 kg ha^{-1} during 2002 –'03. Despite the area under cardamom cultivation remaining static, the productivity rose to 281 kg ha^{-1} from 81 kg ha^{-1} during 1993. The export of cardamom during the recent years has come down heavily to a mere quantity of 550 metric tonnes during 2002-'03. However, the internal consumption within the country has substantially increased. Production and productivity profile of cardamom for the last ten-year period is presented in Table 1. There has been a four-fold increase in the yield over a period of just ten years. This quantum increase is mainly due to the intensive farming on high responsive varieties like Njallayani series.

2) Cardamom hills (CHR)

Cardamom hills are the middle altitude ranges that lie between Periyar Tiger Reserves in the South and Kannan Devan Hills in the North. Cumbum and Kothakudy valleys form the eastern

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Table 1 : Area, production and productivity of cardamom since 1993-2003 in CHR

No	Year	Area cultivated (ha)	Yielding area (ha)	Total production (tonnes)	Average yield (kg/ha)
1	1993	43388	31885	2570	81
2	1994	43459	32476	4430	136
3	1995	44237	32520	4720	145
4	1996	44248	32561	5380	165
5	1997	41268	30609	4550	149
6	1998	40867	30668	5290	172
7	1999	41449	30742	4990	162
8	2000	41491	30797	6585	214
9	2001	41288	30665	7580	247
10	2002	41336	30837	8380	272
11	2003	41412	30855	8680	281

(Source: Cardamom Marketing Corporation, Vandanmedu, Idukki district, Kerala)

boundary and Thodupuzha range borders the western side of the cardamom hills. Extreme variation in rainfall and its intensity prevails within this CHR ranging from 1400 mm in Cumbum mettu to 7000 mm in Elapara ranges. Other climatic elements such as atmospheric temperature, relative humidity, wind velocity (4 feet), sunshine hours and climatic controls like altitudes and land slope vary from one place to another in CHR. For instance, coefficient of variation of rainfall of places adjacent to Munnar is 9%, Gavi, 16%; Pampadumpara, 27%; Myladumpara, 29 %; Elappara, 7%; Kumily, 19% and Karunapuram, 30%. Agroclimatiology and climate change of present climate normal period of CHR were well studied by Murugan et al. (2000; 2003 and 2006). Generally tropical moist evergreen forest vegetation predominates in this system except in adjoining hill areas of Cumbum and Kothakudy valleys that are solely dominated by grasslands and shrubs. Soil pH was medium acidic ranging from 5.2 to 6.0. Most soils come under ultisols followed by oxisols and inceptisols. Acidity of these soils is also contributed by the presence of active Al species [Al $(OH_2)^{3+}$] or Al^{3+} besides active hydrogen ions in soil because all the CHR soils are mineral acid in nature which were derived from parent material that are acidic and low in basic cations like Ca, Mg, K and Na. Therefore the soils are nutrient poor and careful management is imperative. Report of the soil analysis performed at Cardamom Research Station, Pampadumpara on heavy metal concentration of representative CHR (under intensive management) soil is given in Table 2. The data revealed high concentration of available copper, cadmium, mercury, chromium and manganese.

Table 2. Heavy metal concentrations in CHR soil under intensive cultivation

Available zinc	0.83 μ /g soil
Available iron	53.00 μ /g soil
Available manganese	2.00 μ /g soil
Available copper	12.00 μ /g soil
Available chromium	4.00 μ /g soil
Available cadmium	7.00 μ /g soil
Available mercury	2.00 μ /g soil

Studies conducted at CRS, Pampadumpara with respect to the micro flora population on cultivated (CHR) and virgin forest (Periyar Tiger Reserve) soil revealed that the population of fungi in virgin soil (14.8 X10^4 cfu/g soil) was low compared to that of cultivated soil (22.6 x10^4 cuff/soil). As far as bacteria and actinomycetes are concerned the population was high in virgin soils than that of cultivated soil. This infers that the change in population of micro flora could be attributed to the intensification of agriculture and application of plant protection chemicals. The results pertaining to this are presented in Table 3. One of the unique features of the CHR is the biodiversity of avian fauna and amphibians. An approximate total of 250 diverse avian fauna species was recorded during 1997-98 and as of now some of them are not seen recently.

Table 3. Soil micro flora population in forest and cultivated soil (CHR)

No.	Micro flora	Forest soil (cfu/g)	Cultivated soil (cfu/g)
1	Fungi	14.8 x 10^4	*22.6 x 10^4*
2	Bacteria	14 x 10^7	6.5 x 10^7
3	Actinomycetes	7.6 x 10^6	1.7 x 10^6

3) Shade lopping and selective tree felling

Although the trees in CHR area are the property of the forest department, shade lopping is allowed for better infiltration of sunlight to increase cardamom productivity. Though cardamom has been classified as shade loving (Pseophyte) species some high yielding accessions and varieties respond well to yield high under open condition. This is well justified in some of the elite cardamom clones like *Njallani, Vaigai, Palakudi and Kalarickal White Flower* performing better under sunny condition. This shows that high yielding cardamom types especially natural F1 hybrids are more adaptive to high light intensity. From the latest observation it is recorded that at least 70% of total CHR area has been planted with *Njallani*, which is highly responsive to purchased inputs like fertilizers and plant protection chemicals also. The rest of the area grown by other types also prefers high light intensity. Therefore, each single tree in rainforest and the entire CHR, irrespective of potential hot spots has been under severe shade lopping, which paved the way for degradation of erstwhile tropical evergreen forest.

a. Issues associated with unscrupulous shade lopping

1. Practically each tree in CHR is lopped or pruned (main branches) regularly and this leads to degradation of evergreen forests. When this is not checked eventually the CHR will be converted into an open forest under which condition the cardamom cultivation may not be economical and sustainable.

2. Since cardamom is quite often replanted (every 7 years) than other counterparts (tea and coffee) at least 10,000 ha. of forestland is being pruned severely every two years so as to accommodate more planting material and enhanced initial tillering as well as suckering. This leads to severe soil erosion during monsoon periods and more severely during winter monsoon. Soil erosion is more in younger plantations (1.6 to 2.0 tones/ ha/ year) than older ones (0.8 tones/ha/year). This increased soil erosion in younger plantations is mainly due to severe pruning and clean cultivation.

3. Leaching of nutrients and drifting of soil from sloppy lands to low-lying areas and subsequent deposition of such eroded soil in the downstream, impoverishing the productivity of hill soil to a greater extent.

b. **Selective tree felling**

Like any other place in the world, the CHR also experiences the never-ending process of selective tree felling. A maximum tree-felling rate of 1.5% is being witnessed in the recent years. A vicious cycle of maximum cardamom production demanded more curing resulting in enhanced tree felling. With the advent of high yielding *Njallani* variety, the process of tree felling many folds accelerated. Due to seasonal fluctuation in the market value of spice commodities farmers shift to crops that fetch maximum income. A period was there in CHR when farmers were so much interested to take up coffee and black pepper on account of its higher market rate during mid 90's and this has led to severe tree felling in many CHR areas. In addition to this the Eastern slope of cardamom hills in Tamil Nadu right from Kolukumalai to lower camp near Thekkady was worst affected where no tree of economical and ecological significance is now available mainly to deliberate tree felling. Some common trees (notified) of CHR are furnished in Table 4.

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a) Elimination of rare tree species (Irumparappan, Manjakadambu, Unnam, Kumbil, Nangu, Vediplavu, Karuva) has been happening unendingly in CHR system and there by reducing the bio-diversity.

b) Degradation of CHR and reduction in forest tree stand. This leads to change in ecosystem structure and function which ultimately affects the sustainability of the CHR.

c) Increase in area under grasslands and agriculture particularly the bordering areas, thereby alters the microclimatology of CHR. For instance, annual daytime temperature difference between shola forest and grasslands during the period 1994-2003 was found to be 3.2°C. By increasing the grasslands, the temperature would be increased.

Table 4. Common shade trees of cardamom hills

Sl.No.	Common name	Scientific name
1	Kulamavu	*Mangifera axillaris*Desr.
2	Cheru	*Holigarna arnottiana* Hk. F.
3	Choorapplavu	*Nothopegia beddomei Gamble*
4	Ezhilampala	*Alstonia scholaris* (L). R. Br.
5	Ettilamaram	*Schefflera capitata* (Wt. Arn.) H.
6	Valpathiri	*Oroxylum indicum* (L.) Vent.
7	Padri	*Stereospermum colias* (B. H. ex Dillow) M.
8	Kattunelli	*Garuga pinnata* Roxb.
9	Vediplavu	*Cullenia* exarillata Bobyns
10	Irippa	*Cynometra iripa* Kots.
11	Nangu	*Mesua nagassarium* (Burm. F.) Kosterm
12	Cholavenga	*Bischofia javanica* Bl.
13	Porivatta	*Croton zeylanicus* M.A.
14	Vattakumbil	*Mallatus tetracoccus*
15	Venga	*Pterocarpus marsupium* Roxb.
16	Marotti	*Hydnocarpus pentandra* (B. H. Oken)
17	Karuva	*Cinnamomum keralense* Kosterm
18	Kanchiram	*Strychnos nux-vomica* L.
19	Kadaplavu	*Ficus dalhousiae* Miq
20	Irul	*Xylia xylocarpa* Roxb.
21	Pathiri	*Myristica malabarica*
22	Chela	*Ficus tsjahela Burm.* f.
23	Edna	*Olea dioica* Roxb.
24	Analivenga	*Pittosporum dasycaulon* Miq.
25	Irumparappan	*Canthium dicoccum* (Gaertn.)
25	Manjakadambu	*Haldina cordifolia* (Roxb.)
26	Kattunaragam	*Atlantia racemosa* Wt. Arn.
27	Chempoovam	*Dimocarpus longan* Lour.
28	Poovam	*Schlechera oleosa* (Lour.) Oken.
29	Matti	*Ailanthus triphysa*
30	Malamparathi	*Firmiana colorata*
31	Unnam	*Grewia tilifolia* Vahl.
32	Amathali	*Trema orientalis*
33	Kumbil	*Gmelina arborea* Roxb.
34	Madakka	*Xanthophyllum arnotianum*

d) The following are the changes occurred in climatic elements of CHR system.

(i) Increase in annual average surface air temperature by 0.3°C between 1978-1997.

(ii) Reduction in annual average relative humidity up to 5% over the same period.

iii) Increase in sunshine hours by one hour per day and reduced cloudiness.

(iv) Uneven distribution of rainfall and reduction in number of rainy days during 1997-2005.

(v) Increase in soil surface (top15 cm soil depth) temperature by 0.6°C over the last twenty years (1986-2005). This has lot of implication on soil organic carbon loss which affects manageability of ecosystem and accelerates local warming by influencing soil heat capacity, thermal diffusivity and conductance. These factors in turn influence the local climatology of the system.

(vi) Enhanced loss of soil moisture through increased evaporation between1986-2004. This also directly helps the heat capacity because soil water has twenty times more than soil air.

e) Substantial increase in soil erosion mainly by overland surface run off has been noticed wherever severe shade lopping and selective felling has been practiced. Resistance to overland surface runoff in hill slope is very low because of increased flow energy. Less soil cover and surface condition (Clean cultivation) give little resistance leading to very high soil erosion in tropical rainy environment.

f) Loss of organic carbon from top soil due to less litter fall and increased soil respiration by microorganisms under elevated soil temperature coupled with optimum soil moisture condition. This has lot of implications in the sequestration of carbon dioxide locally. The loss of soil carbon would be environmentally deleterious because storage time of soil carbon is very high and as much as 10-15% of total carbon stored in the world is in the tropical soils. Therefore the loss of soil carbon should be reduced to bare minimum level.

4) Intensive farming

The present trend among the planters is to apply more chemicals to realize the maximum yield. The general recommendation of fertilizer nutrients @ 75:75:150 NP and K ha^{-1} yr^{-1} is no more seen practiced. At this point of time every two months planters go for manuring their cardamom with organic and inorganic source. For every 20-25 days the planters take up sprays of plant protection chemicals. In the so-called well maintained plantations at least 1000-1500 patta of organic manure (one patta= 8-10 kg of cow dung with 30% moisture) has been applied in each year along with (as high as) 1000 kg of synthetic fertilizers containing nitrogen, phosphorus and potassium. Therefore the chemicalisation of CHR is alarmingly high and could be rated as one of the most intensively managed systems in the world. Hence the present chemicalised practices cannot be a sustainable one, which needs thorough scientific investigation and further modification. Increase in number of insect pests and diseases due to recently changed weather conditions and use of inappropriate technology have resulted in higher consumption of pesticides in recent years.

30-40% of Tamil planters use pesticides and fertilizers purchased elsewhere from Tamil Nadu. It is therefore unequivocally understood that the per capita consumption of pesticides in CHR area is very high (>5 kg/ha) than the national average of 288g/ha. These above pesticides are classified as highly toxic to extremely toxic as per WHO and thereby impacting the ecosystem maximum possible. The partition coefficient value of chloropyrifos exceeds 13000 (second highest value after DDT) which mean the pesticide can stay for a longer period in soil particles to degrade the surface soils and contaminate surface waters. Other pesticides like endosulfan, monocrtophos and phorate undergo degradation to yield products that are highly toxic to living systems in soil and water. Therefore immediate involvement on the detailed systematic study for human, aquatic and terrestrial toxicity is unavoidably essential for

Table 5. Pesticides and fertilizer consumption in CHR, Idukki district during 2002-2004 excluding Kumily and Adimali tracts.

No.	Chemicals (Pesticides/fertilizers)	Total consumption 2002- 2003	Total consumption 2003-04	Per hectare consumption 2002-03	Per hectare consumption 2003-04
1	Chlorpyrifos	27620 litres	33584 litres	0.78 litres	0.95 litres
2	Phorate	105839 kg.	73592 kg	3.02 kg	2.10 kg
3	Monocrotophos	28475 litres	21493 litres	0.81 litres	0.61 litres
4	Quinalphos	22199 litres	21256 litres	0.63 litres	0.60 litres
5	Furadan	48514 kg.	40624 kg	1.38 kg	1.16 kg
6	Others including fungicides	20000 kg.	NA	0.57 kg.	NA
7	Fertilizer	5000 tonnes	NA	0.142 tonnes	NA

(Source: Office of the Assistant Directors of Agriculture, Nedumkandam and Kattappana)

The consumption of pesticide, particularly, chlorpyrifos had tremendously increased during 2003-2004 than that of the preceding year (Table 5). Other insecticides under examination were sold in lesser quantity for the same period. It is suggested that pesticide consumption had a direct and positive relationship with the market price of cardamom. Among the insecticides, Phorate, Chlorpyrifos and Monocrotophos were the most widely consumed ones. However actual consumption could be on the higher side since ecosystem sustainability. The pesticide regulation should also be uniform among the states and regions so that unwanted pesticides can be avoided considering the severity of the problems in any particular state or region.

a) Application of synthetic fertilizers particularly ammoniacal form of N-fertilizers and murate of potash result in acidification of soil, which further reduces its productivity. Fertilizers containing chloride ions are harmful in acid soil environment due to the amalgamation of chloride to heavy metals.

b) Bioavailability of some toxic heavy metals like cadmium, chromium, and copper in heavily fertilized soils was enhanced which affects certain biological metabolisms of soils. Besides, toxic elements cause some health related problems to higher organisms.

c) Cardamom is found to consume more nutrient elements than its counter part black pepper. Analysis of market available samples of cardamom during 2005 showed very high accumulation of heavy metals (iron, 570ppm; manganese, 1440ppm; zinc, 144ppm; copper, 27ppm; cadmium, 2ppm and lead, 10ppm). On camparison with black pepper, cardamom consumes 14, 4 and 2 times more of manganese, zinc and iron respectively. Presence of cadmium, lead and copper in relatively higher amounts in produces may not be good for the health of human beings.

d) Mercurial fungicides are the most toxic compounds and use of which has been increased among the planters to manage azhugal diseases. Data on the samples collected from treated soils showed a marked increase in its bioavailability.

e) Random sample analysis on the pesticide residue levels in processed cardamom collected from farmers from Pampadumpara village showed levels of quinalphos and monocrotophos above MRL in 20% of samples. Among the pesticides used in cardamom ecosystem, soil insecticides such as phorate, carbofuran and chlorpyrifos had been consumed in large quantities. These chemicals are toxic and highly persistent in soils. Recently, Garcia et al., 2003 proved these compounds to be highly cyto-toxic and specifically targeting immature brain cells.

f) Soil microbial studies like diversity and tolerance to toxic elements and substances in intensive cardamom system in many ways can help to understand the soil metabolism through which nutrients are taken up by cardamom. Such information can be used to overcome soil biodegradation of delicate ecosystem.

g) Application of lime or liming materials in CHR is common, which can accelerate the loss of soil carbon. The liming increases the production of carbonic acid in acid soil, which is highly unstable under rainy environment; therefore, carbonic acid disintegrates into carbon dioxide and water.

h) Since chemical load is high in CHR, studies on input and out put (chemical budgeting) relationship would provide useful information to maintain the ecosystem sustainability.

i) Looking upon the intensity of the cultivation, strengthening environmental contaminant hydrology as well as environmental sociology particularly the quality of potable and eutrophic water resources could be of immense use for the CHR ecosystem ecology.

j) Frequent replanting and striving for continuous higher yield can cause severe soil degradation under which condition rainfed cardamom will face frequent failures.

5) Altered tree species composition in CHR

At the outset of settlement in cardamom hills the process of introducing non-native tree species has been on the rise by inhabitants. Number of high value timber species such as *Kumble, Unnam,* and *Poovam* has been reduced drastically. On the other hand some other species of commercial interest such as coconut, arecanut and trees like *Erythrina sp*. were introduced into CHR system. Species like *Erythrina* and *Vernonia* are not the notified species of this forest and may not be advisable to recommend as shade trees in CHR. In most plantations these tree species are now invariably used and planted together with cardamom and black pepper. In this agro ecosystem, two important aspects need to be considered for species introduction. They are;

a) The species should be of evergreen type and amenable for pruning or lopping.

b) The species should not be a competitor for cardamom.

Considering the above, coconut and areca palms are surface feeders like cardamom and therefore compete for nutrients and water. Hence, in plantations intercropped with coconut and arecanut the yield of cardamom is found to be low. More so areca palms harbours nematodes that infest cardamom as well. Species like Toona ciliata and Erythrina sp. defoliate completely during rainy periods. This leads to enhanced soil erosion and leaching of nutrients making the soil unproductive. Besides, these trees act as alternate hosts of nematodes and adults of root grubs. Nevertheless these tree species dominate CHR at this point of time. Cardamom has been cultivated in traditional and non-traditional areas in Idukki district. Shade lopping in varying degrees and selective tree felling are being carried out routinely in traditional CHR areas. However, in protected non-traditional areas such as Anamalai Reserve Forest (Near Eravikulam National Park) and Periyar Tiger Reserve (Gavi) cardamom has been cultivated under restricted shade lopping and selective tree felling resulting in bare minimum deforestation and degradation of forest.

Variability of rainfall in these areas (traditional and non – traditional areas) was studied by Murugan et al. (2000) using available data on rainfall and surface air temperature collected over 50 years and 20 years respectively. Coefficient of variation of rainfall for traditional CHR area varied from 27-52% whereas in non-traditional areas it varied from 7.4-19%. Analysis of instrumental data in relation to intensity of shade lopping and degradation of tropical forest revealed certain interesting properties. They are as follows:

a) Climate is relatively constant in protected and non-traditional areas than traditional CHR. Under similar conditions in Sri Lanka the variability in rainfall is minimum due to less frequent shade lopping and other human interventions into the forest system.

b) Stability on climatic elements could be achieved by superimposing appropriate agricultural practices so as to conserve the fragile forest ecosystem and reduce cost of production. Massive afforestation programme in the degraded CHR area and in the eastern most slopes of cardamom hills in Tamil Nadu will have positive impact on ecological enrichment of CHR. To make the system more sustainable, some versatile tree species are really required. In our study a species from central American forest is found more suitable to this ecosystem. It is botanically called as Andira inermis belonging to family "Papplionaceae." This is a dominant tree found throughout the stretch right from Panama to Costa Rica in Coffee plantations. The qualities of this tree species are:

i. It is an ideal legume shade tree for tropical rain forest with very good timber value.

ii. It has medicinal value (Pods are used in health care) also.

iii. The flowers are attractive (pink coloured) and hence it has ornamental and esthetic value.

iv. The lopped biomass can be used as green manure to enrich soil fertility. Studies conducted during early years on the growth and development in this species in Munnar, Idukki district showed encouraging results. Therefore such versatile tree species can give shade, timber and can improve soil fertility of the ecosystem. Introduction of unwanted tree species in to ecosystem should be stopped so that further degradation of tropical forest environment and soil can be checked. All possible alternate energy sources for curing cardamom should be attempted so that tree felling for the purpose of curing cardamom can be avoided.

6) Soil fertility management

Forest trees in CHR act as storehouse of nutrients but make soil poor in nutrient availability temporarily due to the accumulation of these nutrients in whole tree system. However, these accumulated nutrients will be made available to surface feeders like cardamom only upon litter fall and further its decomposition. Despite the fact continued higher yield of cardamom has been realized since many years. This is mainly due to the unknown biological metabolism of soil that is prevailing in this tropical forest soils. Studies on biological metabolism of soils would unravel many new concepts for the recommendation of appropriate levels of nutrients for various crops. Besides, the topographical and climatological factors decide the fertilizer use efficiency. In general

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the fertilizer use efficiency is very low in hill soils especially under rainy environment. Since the research priorities should therefore be focused on the following aspects.

a) Increasing fertilizer use efficiency
b) Nutrient enrichment and heavy metal contamination in soil and water
c) Biological metabolism of soil and ionic concentration of nutrient elements in specific soil volume during various growth stages of crop.
d) Integrated nutrient management
e) Role of microorganisms in enriching fertility and phyto-remediation of contaminated soil.
f) Ecological farming
g) Application of lime or liming materials in CHR is common and which can accelerate the loss of soil carbon. The liming increases the production of carbonic acid in acid soil, which is highly unstable under rainy environment; therefore, carbonic acid disintegrates into carbon dioxide and water. Detailed studies on liming is very much needed as far as cardamom nutrition and soil carbon loss are concerned.

7) Organic farming

Organic farming in strict sense in nutrient poor acid soils of CHR has very little scope because of the following reasons:

a) Utilization of on-farm crop residue is one of the main components in organic farming as manure is not possible to enrich soil fertility as the source material is obtained from nutrient poor topsoil. If the source residue is from tree waste then it can be used as manure.
b) Possibilities for successful crop rotation, cover cropping and relay cropping are very remote in CHR system because of non-availability of sun light and space.
c) One of the components in organic farming viz., incorporation of microorganisms may have positive role to a limited extent in CHR acid soils. Application of *Trichoderma* and *Azospirillum* is encouraged in successful organic farming. The organisms not only supplement nutrients but also ward off soil borne diseases.

8) Biotic stresses

Extensive cultivation of a sole variety, *Njallani*, as well as over dependence on the application of chemicals (the only means of pest management at this point of time) in insect pest and disease management of cardamom has a greater say on the ecological stability of this fragile ecosystem. The recent change in climate and degradation of forest had resulted in increased intensity as well as number of pests and diseases in CHR. On one side there is tremendous depletion of valuable genetic resources leading to a phenomenon called as genetic erosion sidelining the potential of other cardamom cultivars. Elimination of natural enemies and other antagonistic organism is noted as the other factor due to drenching of toxic chemicals such as mercurial fungicides (Emisan) and carbofuran (Re labelled carbamate nematicide). To further add emergence of new insect pests such as mites, ro mealy bug and diseases such as stem rot and ro rot pose a great threat for cardamom production in days ahead that is already subjected to a wide array of chemicals. To manage the CHR ecosystem, Integrated Pest Management is found to be appropriate, the details of which is discussed here under.

Integrated pest management in cardamom

Cardamom is subjected to more than 16 rounds of pesticide application per annum inclusive of certain mercurial fungicides against diseases like clump rot which all the more appear due to over feeding and watering around cardamom rhizosphere. The surface feeding and responsive nature have attracted to feed the crop even at weekly intervals where the plant system is forced to yield more and more beyond its capability. It is quite interesting to note that cardamom having itch symptoms due to infestation by thrips are being preferred in certain west Asian countries understanding its freedom from pesticide residues. Time is not far that our exported produce is likely to be returned if it failed to be in accordance with international quality as outlined by *Codex Alimentarius Commission* with regard to the residue content. At this point of time, the market is purely internal and without any quality standard, market value is ascertained based on colour, boldness and itch free nature of capsules.

In order to take stock of the entire scenario the concept of integrated pest management is emphasized for the production of clean produce at low price and so it favoured by ethnic and yogic centres of the country. In IPM, all available and known pest management strategies are aligned rationally in as compatible way as possible in order to keep the pest population at levels that may not cause economic damage. In this concept a pest residue is always left behind for the natural enemies to take care IPM permits judicious use of pesticides at time of necessity. On a perennial crop like cardamom, this integrated approach is likely to yield encouraging results with least setback on the ecosystem.

a) Cultural control

1) De-trashing (removal of older and dried leaves) as well as destruction of dried tillers prior to the application of insecticides will not only expose the hiding immature and adults of cardamom thrips, *Sciothrips cardamomi* , but also enhance the efficiency of the insecticide applied as well, ie. the requirement of spray fluid is reduced to one-half. Elimination of diseased materials is also accomplished in this process of phytosanitation, which helps to reduce the initial spore load of fungi to minimum.

2) Periodical ragging of the plantation and destroying infected cardamom due to katte disease and Nilgiri Necrosis so as to avoid spread of the disease to near by area.

3) Suckers need be collected from gardens free from viral diseases and other soil borne diseases.

4) Planting of cardamom suckers just prior to Southwest monsoon is very ideal. Late planting will invite problems due to shoot and capsule borer, nematodes and root grub even if it coincides with Northeast

monsoon. Inadequate tillering is observed in late planted cardamom.

5) Pruning shade trees immediately after the onset of first monsoon in order to allow infiltration of 40% light will reduce problems due to capsule rot and clump rot. Shade intensity less than 50% is highly suited for the outbreak of root grub during summer and *chenthal* disease during post monsoon period. Plantation should have as many shade trees as possible to replenish soil organic matter and to provide home for nesting birds and beneficial insects.

6) Avoid planting of jack and dadaps in cardamom plantations, as they are the alternate hosts for root grub adults and root knot nematodes, respectively.

7) Excess application of nitrogenous fertilizers makes the plant succulent and problem due to shoot and capsule borer and whitefly become unmanageable. Application of inorganic fertilizers @ 100: 100: 175 NPK Kg/ha in three or four splits along with 1000 g/plant of good quality neem cake is optimum for cardamom growth and productivity.

8) Ensure adequate drainage facility to avoid water stagnation in root zone

9) Replenishment of nutrients after infestation by root grubs so as to induce root proliferation and care should be taken for avoiding secondary infection due to pathogens through prophylactic application of fungicides.

10) Windy area, locations with steep slopes as well as soil with low organic matter are not suitable for cardamom cultivation.

11) Earthing up with topsoil is advised as and when the roots are exposed.

12) Application of slurry containing cow dung mixed with organic cakes and fermented for 48 hours is found to boost tillering in cardamom.

c) Mechanical control

1) Collection of adult beetles of root grub feeding on jack, mango and fig trees using sweep nets results in suppression of grub population.

2) Trapping and monitoring of whitefly adults using yellow sticky trap coated with viscous castor oil. More than one whitefly per square cm is the threshold to initiate control measure.

3) Installation of bird perches to attract birds of ecological importance in biological control.

4) Country made tin scarers to repel off wild boars.

5) Dry rubble embankments across the slope and along the contour will conserve nutrient layer in top soil and enhance water use efficiency.

6) Forking the soil around the base of cardamom clump mechanically damages the root grub and enhances better penetration of insecticides employed against it. Soil aeration achieved in this process improves root proliferation as well.

d) Physical control

1) Irrigation @ 15-20 litres per day per plant during peak summer around the root zone will create microclimate for better tillering,

panicle initiation and avoidance of root grubs. This is because the increase in soil temperature by 2°C in the top 20 cm soil and sunshine hours >6 hours a day enhance root grub multiplication.

2) Break in monsoon and thereafter increase in temperature and relative humidity will favour whitefly outbreak. Careful monitoring and need based management strategy are advocated against this.

3) Rainy period is not ideal time for breeding of cardamom thrips and hence application of insecticides is not recommended during that period. However, such a condition is highly favourable for capsule and root rot pathogens for which prophylactic application of fungicides is advised.

e) Behavioral control

1) Use of pheromones in the monitoring of cardamom shoot and capsule borer adults and thereafter-correct timing of insecticide application is recommended. The pheromone component is identified as hexadecenal in two isomeric forms.

2) Allomonal behaviour of root grubs on biomulches of wild *Helianthus* sp. and kairomonal activity of adult beetles on jack leaves are being studied.

3) Spraying with neem oil , fish oil insecticidal soap, tobacco and garlic decoction exhibited repellency to the chief pollinating agent, honey bees and thereafter resulted in reduced yield.

4) Avoid cultivation of alternate host plants for katte disease and shoot borer damage like *Ammomum* sp., turmeric, ginger, and castor in the immediate vicinity of cardamom plants.

5) To maintain soil temperature during summer provides adequate shade and mulch younger plants with slash weeded materials. Avoid clean cultivation during initial period of establishment so as to maintain soil temperature and conserve soil moisture.

6) *In situ* incorporation of marigold (*Tagetus* sp.) is found to have pronounced effect on suppression of nematode population due to release of alpha terpenyl alkaloids.

f) Host plant resistance

1) Varieties having stem girth less than 2.5 cm, 20 cm from base as well as those with pink coloured tillers are found to be tolerant to shoot borer.

2) Malabar varieties are found tolerant to drought and infestation by thrips owing to unique disposition of panicle lying totally prostrate on the ground. Volatile oil content is also higher in these varieties but is susceptible to soil borne pathogens.

3) PV-2, a new bold capsuled high yielding vazhukka variety was found to be relatively tolerant to shoot borer and clump rot.

4) RR-1, a hairy cardamom variety was tolerant to clump rot and certain NKE accessions such as 3, 28 and 31 are katte resistant.

g) Biological control

1) Larval-pupal parasitoids of shoot and

capsule borer, *Agrypon* sp. and *Temeluchus* sp. can be conserved in the system when judiciously intervened with chemical insecticides at appropriate time. The gregarious mosquito like parasitoid and a housefly like parasitoid can be utilized for augmentation.

2) *Verticillium* sp. can be better studied for utilization against cardamom whitefly. Two strains of which have been identified under sporulation.

3) Green muscardine fungus, *Metarrhizium anisopliae* can be employed against cardamom root grubs and *Beauveria bassiana* against adult beetles. Entomopathogenic nematodes belonging to the genera *Steinernema* sp. and *Heterorhabditis* sp. are also found effective against root grubs.

4) Crow-pheasant feeds on shoot borer caterpillar and reduced the population considerably. Conservation of such bird species in cardamom ecosystem is very important.

5) Predatory and parasitic mites are also recorded against thrips. Conservation of *Chrysoperla carnea*, an effective predator against cardamom thrips is best warranted.

6) Application of *Trichoderma* sp. as prophylactic measure is very effective against soil borne pathogens. Optimum soil moisture and adequate soil organic matter are the two prerequisites for its successful establishment in soil. Potassium phosphonate 0.3% can be applied when capsule rot symptoms are observed even after incorporation of *Trichoderma* sp.

7) Use of *Pseudomonas fluorescence* has produced encouraging results in the reduction of *Chenthal* disease and additionally it is a growth promoter and suitable for inclusion in organic farming .

h) Chemical control

1) Prophylactic foliar application of 1% Bordeaux mixture prior to the onset of monsoons as well as drenching of copper oxychloride (0.2%) is recommended against soil borne pathogens.

2) Spraying Mancozeb (0.1%) and drenching carbendazim (0.2%) are advised for the management of *Chenthal* disease and root tip rot respectively.

3) Immature shedding and yellowing of capsules due to *Fusarium* infection can be checked by foliar application of Carbendazim (0.2%).

4) Seven rounds of insecticide application per year are quite sufficient for the management of thrips as well as shoot and capsule borer. Insecticides such as Monocrotophos (0.075%), Fenthion (0.075%), Profenophos (0.05%) and Triazophos (0.04%) need to be applied prior to the onset of monsoon. No insecticides should be repeated in a year and cocktailing of insecticides will induce outbreak of secondary insect pests. Bee safe insecticides like Phosolone (0.07%) and Quinalphos (0.05%) are recommended during and after monsoon periods. Spray fluid should be targeted on

¾ th of tiller as well as on entire panicle.

5) Soil insecticides should be drenched around the plant base for the suppression of root grubs during March-April (Chlorpyrifos 0.05% or Imidacloprid 0.75ml/ litre) and September –October (Phorate 30g/plant or Carbofuran 90g/plant) through monitoring of adult beetles. Ensure adequate moisture when granular insecticides are incorporated.

6) Systemic insecticide (Acephate 0.075%) is sprayed only on the undersurface of the leaves for the management of whitefly and complete avoidance of synthetic Pyrethroids is advocated.

7) Root zone application with Carbofuran 90 g /plant (30 cm away from outer tiller) and 1kg neem cake are recommended during first week of May and September in nematode endemic spots.

i) Use of genetic engineering tools for combating biotic and abiotic stresses.

Use of novel biotechnological tools for engineering pest tolerant varieties to combat biotic stresses is of course gaining momentum these days. In a world purely dominated by Bt toxin, other means of genetic manipulation is being explored. One such potential area is the use of proteinase inhibitors for genetic transformations. Protease inhibitors (PIs) are one group of pest resistant proteins being targeted for expression in cultivated plants. PIs form stoichiometric complexes with specific proteolytic enzymes, thus preventing their catalytic function. Since, PIs are primary gene products they are excellent candidates for engineering pest resistance into plants. When expressed in plants, PI can bind with key digestive proteases of insects feeding on the plants, disrupting their digestion and reducing growth and survival. It may be possible that control of larval stages of shoot and capsule borer could be achieved by producing cardamom cultivars that express insecticidal proteins such as PIs. PIs such as aprotinin, soyabean trypsin inhibitor produced encouraging data, as these proteinaceous PIs suppressed the trypsin and elastase of cardamom shoot and capsule borer midgut proteases in a very significant manner. In *vitro* and *in vivo* luminal protease analysis evinced reduction of enzyme activities by PIs. Dr. Borovsky has identified and characterized the peptide hormones that down-regulates expression of trypsin-like serine proteases, which are primary insect digestive proteases. The initial peptide hormone under development is called Trypsin Modulating Oostatic Factor (TMOF). Failure of insects to digest protein leaves the insect satiated while starving them of essential amino acids required for protein synthesis, egg development, and reproduction. In essence, after ingestion of TMOF the insect is unable to feed or reproduce and quickly starves to death. Exploratory studies should be attempted to evaluate such new compounds against major insect pests of cardamom.

A judicious intersection on all these human made ill effects reflects the un-sustained approach on the whole aiming at enormous yield at any cost. Farmers are ready to undertake any operation so as to maximize yield. Application of ghee, milk products and fermented substances are being practiced in many estates. Plants are subjected to intoxication by such alcoholic tonic and few gardens had come out with improved performance. All such unscientific practices and overexploitation deteriorate the system and may be the coming generation will have to experience all hardships. As a means of striking balance to counteract the damages caused by human intervention the following proposals are projected herewith.

a) Minimizing genetic erosion
b) Integrated insect pest and disease management
c) Use of genetic engineering tools for combating biotic and abiotic stress.

9) Minimizing genetic erosion

Sixty per cent of the CHR in high ranges of Idukki district is exclusively cultivated by a farmer's cultivar Green Gold, *Njallani*. This is a natural hybrid of *vazhukka* type and highly responsive to all inputs as well as an excellent yielder. It is highly susceptible to all biotic and abiotic stresses. There are reports highlighting 2.5-3.0 kg of dry capsule yield from one clump. The performance of this cultivar is more localized confined to *Mali, Anavilasam* tracts where the yield realized was the highest. However, the yield potential in other tracts was not inferior compared to other cardamom varieties. The variety is so responsive that application of any insecticide would result in better flowering and capsule set. Hence, farmers practice indiscriminate application of insecticide for results beyond expectations bringing out killing all natural enemies in the ecosystem.

Cardamom is a cross pollinated crop. An amalgamation of all three cardamom types *viz.*, Mysore, Malabar and *Vazhukka* should be encouraged for cultivation irrespective of their performance. Genetic variability will ensure consistent yield and act as a barrier to invasion by insect pests due to dilution of semiochemicals involved in host selection process. Such a deorientation from the host finding process will deter host selection and prevent sustained feeding. This is a boon to tritrophic interaction favouring the natural enemies at the disadvantage of insect pests.

There are ample evidences suggesting the increase in shoot and capsule borer, *Conogethes punctiferalis* incidence due to mono- variety cropping of Green Gold cultivar and increased application of nitrogenous fertilizers. Due to excess application of N-fertilizers the shoot become very succulent for easy penetration and feeding of shoot borer larvae. Mono - variety -cropping leads to epidemic of diseases and thereafter complete wipe out of cardamom may not be ruled out. A rise in cardamom mosaic virus (*Katte*) in CHR is a classical example to that. It was generally understood that Malabar types are tolerant to infestation by thrips, *Sciothrips cardamomi* on account of the chemical composition of capsules and unique(prostrate)disposition of panicles. Moreover, Malabar type cardamom is drought tolerant but susceptible to capsule rot caused by *Phytophthora meadii*. Quality profile of Malabar type cardamom is the highest. Mysore types are extra sensitive to the changes in weather fluctuations and vagaries in monsoon will greatly influence the yield of capsules. This type is more or less infrequent in CHR due to poor yielding nature. On the contrary natural hybrid *Vazhukka* cardamom is highly successful in this part of CHR producing more yield and insensitive to climatic variations. The disposition of panicle (intermediate) is highly suited for easy harvesting and tolerant to capsule rot fungus, *Phytophthora meadii*. Perhaps the effective methodology to restore the genetic resources of cardamom is to assign such responsibility to research institute that maintain a gene bank of cardamom germplasm. *In vitro* techniques to cryopreserve the material are highly warranted. Efforts are now being initiated in this direction and CRS, Pampadumpara is looking for biochemical markers for tolerance to biotic and abiotic stresses and standardizing protocols for *in vitro* conservation as well as micro propagation of various cardamom accessions. The station has priorities to conserve a gene pool of cardamom types and molecular characterization of all types based on genetic markers. PCR based molecular characterization is being attempted. A total of 121 cardamom accessions are being conserved in the gene bank of CRS, Pampadumpara.

Conclusion

With the advent of high yielding varieties and intensive cultivation practices, cardamom productivity increased to about 281 kg/ha during 2003. Heavy metal accumulation in CHR soils revealed higher accumulation of available copper, cadmium, mercury, chromium and manganese. Micro-flora population studies evinced lower population of fungi and higher population of bacteria and actinomycetes in virgin soil than that of intensively cultivated soil. It was found that the consumption of pesticides in high ranges was well above the national average of 288 g/ha. The concept of leaving pest residue for the natural enemies to survive and multiply was emphasized along with need based and judicious use of plant protection chemicals. An amalgamated cultivation of all cardamom types in each plantation or field rather than sole variety concept is outlined. Research institutes need be assigned full responsibility for the restoration of genetic resources of cardamom and adequate facilities are to be generated for *in vitro* conservation. To check further degradation of ecosystem (CHR) careful management of soil, forest, pests and diseases of cardamom is imperative otherwise whole CHR ecosystem structure and function could be altered to irreversible levels. This would further pave way for more degradative agriculture.

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