BIO-INTENSIVE PEST AND DISEASE MANAGEMENT IN SMALL CARDAMOM

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PREFACE

I am immensely delighted to know that Dr.G.Sivakumar, Principal Scientist ICAR-NBAIR,Dr.R.Marimuthu, KVK, Idukki, Kerala. Sudhakar.S Scientist-Plant Protection-ICAR-KVK-BSS, Idukki, had written, compiled and prepared the book entitled "Bio-Intensive Pest and Disease Management in Small Cardamom " and releasing the book by me which is useful for farming community, academia, research institutes and agricultural scientists as a new dimension in a traditional and sustainable way of farming in small cardamom plantation. Insect pests have been known to cause losses in crop yields over the years; pesticides have become an integral part of crop production in achieving economical yields and in meeting food security needs. Green revolution technologies have adversely affected different components of environment and subsequently led to intensification of pest problems. Thus, the challenge ahead is to increase crop yields from the existing land resources without harming the environment by developing environmentally benign pest control methods. This goal can be accomplished by adopting eco-friendly bio-intensive integrated pest management (IPM) strategies incorporating ecological and economic factors addressing concerns about environmental quality and food safety. The benefits of implementing bio-intensive IPM can include reduced chemical input costs, reduced on-farm and off-farm environmental impacts, and more effective and sustainable pest management (Reddy, 2014). Moreover, the high cost of discovering, developing and registering new synthetic pesticides and the rapid emergence of pest resistance have contributed to an increased interest in bio-pesticides (Glare et al., 2012) and bio-intensive IPM which will focus primarily on biological knowledge of pests and on their interaction with the crops and other components of the cropping system. Ideally, pest management interventions should take into account the extent of natural regulation and basic ecological information about pests and their crop environment which has become a prerequisite for efficient pest control. I have great pleasure in releasing the book on Bio-Intensive Pest and Disease Management in small cardamom. I congratulate the author and editors for their endeavor and wish them all success in spreading the Bio-Intensive Pest and Disease Management technology to make this world a better place to live in and for the benefit of the future generations.

FOREWORD

We looked for years various technology and looked at possible solution to ensure high yields but these methods, sadly, are not always the “best” solutions. The “Bio-Intensive Pest and Disease Management in Small Cardamom” provides us the system of using fully local materials both for farm inputs and processing methodology. About two decades ago came Green Revolution’s “miracle” seeds a short term for narrow-minded search for higher yields of grains. The widely used of these chemicals landed us in such a mess, obscure as it may seems but the fact remain that the death of our farmers is a result of economic policies that promote modern agriculture. When two third of the country are farmers faces extinction we viewed this as genocide. With this system, we can now grow more food and higher incomes to farmers without destroying the environment and killing our farmers. This paper will focus on the methodology of men and women who has acquired competencies and commitment in giving quality of life to its people. The formula of success is “you walk, the talk” by teaching the technology more widely and challenges the local government unit (LGU) to adopt and embraces the technology. Eventually, bring prosperity for rural communities - adept-free farmer. Bio-Intensive Pest and Disease Management in Small Cardamom system have unleashed the most creative and the most innovative men and women from private sector and local government officials in this country. It created a common ground and unified knowledge and understanding about the many aspect of natural farming technology. It internalized the reason for the need of improving the farming industry as a whole. It created awareness and interest on the need to sustain sub projects that are geared to natural farming technologies. This development approach will have an impact on the rural scenario since activities will involve the use of crops, livestock other indigenous materials and skills of the local residents as the result will eventually also benefit the from the farmers’ increased economic income. Bio-intensive IPM is defined as 'A systems approach to pest management based on an understanding of pest ecology. It begins with steps to accurately diagnose the nature and source of pest problems, and then relies on a range of preventive tactics and biological controls to keep pest populations within acceptable limits. Nothing would give us more joy than to meet others of the same mind. **Authors…..**

INTRODUCTION:

Small cardamom, the 'Queen of Spices,' is commonly cultivated beneath the evergreen forest trees of Western Ghats of South India, Sri Lanka, and Guatemala. Guatemala, where cardamom is grown largely on plantation scale, is the world's premier producer and exporter followed by India. The major consumers of cardamom are India, Saudi Arabia, other Arab countries, Europe, and Japan. The most significant component of cardamom, as a spice, is the volatile oil with its characteristic aroma, described generally as camphory, sweet, and aromatic spicy. This is due to the presence of 1,8 cineole, di-terphenol, terpinyl acetate, limonene, sabinene, and borneol, which makes cardamom oil unique (Lewis et al., 1966). The evergreen forests of Western Ghats in India where natural populations of cardamom still exist is considered the native home of small cardamom. The genus Elettaria consists of seven species distributed in India, Sri Lanka, Malaysia, and Indonesia; of these, only *E. cardamomum* is economically important (Holttum, 1950). In India, the genus Elettaria is represented only by one species, *E. cardamomum.*

Cardamom is a herbaceous perennial (2–5 m in height) having underground (subterranean) rhizomes with aerial leafy stems (tillers) made of leaf sheaths (Figure 9). The suckers grow for approximately 10–18 months before flowering (Madhusoodanan et al., 2002). The growth habit of the panicles and the shape as well as the size of the capsules varies in different cultivars/types of cardamom. Flowers are arranged in clusters known as cincinni, are bisexual, and occur from May to October. Bisexual flowers are self-compatible but cross-pollination is the rule. Honey bees contribute for more than 90% of pollination. Cardamom is a shade-loving plant that thrives well at elevations of 600–1200 m above sea level under an average annual rainfall of 1500–4000 mm and temperature range of 10–35 °C.

Cardamom germplasm is maintained as clonal field repositories in India with more than 1500 accessions. The main focus of cardamom breeding, in addition to high yield, bold capsules, and quality attributes, are resistance to viral and fungal diseases, and drought. The main breeding strategies are selection and

hybridization. Convergent breeding programs designed to bring multiple resistance are in progress (Madhusoodanan et al., 2002).

Cardamom is propagated both through seedlings and vegetatively through suckers. Clonal multiplication of cardamom ensures genetically uniform true-to-type planting material. Seedlings are raised in a nursery under partial shade using seeds from ripe capsules collected from high-yielding and healthy clumps. Cardamom seed has a hard seed coat, and scarification of seed with 25% nitric acid for 10 min followed by thorough washing in water before sowing assures above 80% germination. Soil solarization of seedbeds in cardamom nurseries enhances germination by 25%, reduces weed growth by 82%, and suppresses pest and disease incidence.

Small cardamom (Figure 9) requires a warm and humid climate fairly well distributed annual rainfall of 1500–5000 mm. Cardamom is a surface feeder; 70% roots are at a depth of 15 cm and hence availability of moisture at the root zone is important for good growth and yield. It is also susceptible to wind damage. Cardamom thrives well in moderate shade (50–60% light).

The crop starts flowering during early monsoon showers in India and comes to bearing during July–August, with harvest generally completed by October–November. This highly humid warm climate so congenial to growth and productivity is also congenial for fungal diseases; among them are capsule rot caused by *Phytophthora meadii/P. nicotiana* and clump rot caused by a Pythium–Fusarium complex. The root knot nematode M. incognita is another serious soil-borne pest. Three viral diseases are important, namely, katte or mosaic disease (Figure 9), kokke kandu, and banana bract mosaic virus. A minor viral disease, nilgiri necrosis virus (Naidu and Thomas, 1994) has also been reported (Siljo et al., 2013).

Katte virus is a Potyvirus transmitted by the banana aphid *Pentalonia nigronervosa*. The disease is not fatal but results in a gradual decline in the vigor and productivity of the affected clumps (Venugopal and Naidu, 1984; Naidu and Thomas, 1994). The disease starts as chlorotic spindle-shaped streaks that later merge to produce a mosaic pattern of the disease (Figure 17). Studies on the coat protein and 3′ untranslated sequence of a Karnataka (Sakleshpur) isolate

indicated that the virus is a new member of the genus, Macluravirus, family Potyviridae (Jacob and Usha, 2001). At least six distinct strains of the virus have been reported (Jacob et al., 2003). Both serological and reverse transcription polymerase chain reaction methods are available for the detection of the virus in plants.

Cardamom plants start bearing fruits (capsules) in the second year after planting and satisfactory yield is obtained starting in the third year. It takes 110 days from flowering to fruit maturity. Time and duration of harvest depend on the climate, varietal differences, and irrigation. Fruits are handpicked just before fully ripe to get maximum green color during curing. Capsules are processed within a day after harvest. Processing consists of washing, curing (drying), cleaning, polishing, sorting, grading, and packing. Capsules immediately after harvest are washed in clean water to remove adhering soil. Sometimes capsules are treated with 2% washing soda (sodium carbonate) for 10 min to stabilize the chlorophyll and impart a grass better green color. After washing capsules are dried to a moisture content of 7–20%, in drying houses by heat radiation. Dried capsules are rubbed with coir mat/gunny cloth/steel mesh and sieved to remove the plant debris, and graded according to size and color.

Cardamom (*Elettaria cardamomum L.*) popularly, known as Queen of Spices is native to the evergreen rain forests of the Western Ghats in South India. It is commonly cultivated in Kerala, Karnataka, and Tamil Nadu. Cardamom is used for flavoring various preparations of food, confectionery, beverages, and liquors. Worldwide it is cultivated in Guatemala, Tanzania, Sri Lanka, El Salvador, Vietnam, Laos and Cambodia. In India cardamom is mainly cultivatedin Kerala, Karnataka and Tamil Nadu. Introduction

The term cardamom refers to several plants of genera Elettaria and Amomum in the Zingiberaceae family. The plants of both of these genera are recognized by their spindle-shaped pods with small black seeds and characteristic aroma. Corresponding to the said two genera are two different types of cardamom, one is known as true cardamom, green cardamom, or small cardamom (*Elettaria cardamomum*) and the other is recognized as large cardamom or black cardamom (*Amomum subulatum*) (Bhide, 2010).

Green cardamom (*E. cardamomum*) is distributed in several Asian regions from India to Malaysia. The dried fruits (seed pods) of this perennial herb are marketed as one of the most expensive and valued spices. The small black seeds of cardamom, which are embedded in a thin papery outer shell or pod, have a pleasant aroma and a characteristic, slightly pungent taste (Padmakumari et al., 2010).

Green cardamom has been used all over the world for culinary and traditional pharmaceutical applications. This spice is not only employed as a flavoring and spicy ingredient in several food products, but is also used traditionally as a folk remedy to treat teeth and gum infections, lungs and pulmonary tuberculosis, and digestive and kidney disorders (Hamzaa and Osman, 2012; Saeed et al., 2014). The volatile oils, and other high-value gastroprotective and antioxidant bioactives present in cardamom seeds mainly contribute to its characteristic aroma and role as a functional food, as well as its pharmaceutical and nutraceutical value (Hamzaa and Osman, 2012). The current chapter is mainly designed to highlight the traditional pharmaceutical as well as the food science applications of cardamom and cardamom essential oil.

CLASSIFICATION OF CARDAMOM

Cardamom (Elettaria cardamomum Maton) belongs to the natural order Scitaminae under the family Zingiberaceae. The genus Elettaria consists of a small number of spices distributed in India, Sri Lanka, Malaysia and Indonesia (Holtum, 1950; Wills, 1967; Mabbberley, 1987). Two botanical varieties have been distinguished based on the size of the fruits, one for the wild taxon and one for the cultivated forms:

Elettaria cardamomum var major Thw. comprising the ‘wild’ indigenous cardamom of Sri Lanka, also known as greater oblong cardamom or long cardamom.Elettaria cardamomum var minor Watt (syn *Elettaria cardamomum* var minuscula Burtkill) comprising all the cultivated groups. This cultivated cardamom can be grouped into many cultivar groups, the two most important ones being Malabar and Mysore (Wardini and Thomas, 1999).In addition to the two main varieties, a few more have been recognised. All the varieties and races are interfertile and the observed variations are probably due to natural crossing.

Based on adaptability, nature of the panicle, shape and size of fruits, three types of cultivated small cardamom have been identified, viz., Malabar, Mysore and Vazhukka (Madhusoodanan et al., 1994). Two more varieties, mysorensis and laxiflora, have been recognised based on some morphological characteristics.A lot of confusion prevails over the botanical identity of Sri Lankan wild cardamom and the Indian cardamom varieties mentioned above. Various authors have named cardamom varieties differently:Sri Lankan wild cardamom: *Elettaria ensal Abheywickrama* (E. major Thawaites) (Madhusoodanan et al., 2002);Malaysian and Indonesian: *Elettaria longituba* (Ridl.), (Holttum, 1950).The vernacular name 'cardamom' is also often also used for many other taxa, particularly Amomum species.

BOTANY

Cardamom is an herbaceous perennial (2–5 m in height) with underground (subterrain) rhizomes, with aerial pseudo stems (tillers) made of leaf sheaths. Studies of vegetative growth indicate that suckers continue their growth for a period of about 18 months from time of emergence. The rate of linear growth is at its maximum during June and July, when the suckers have attained an age of about one year. The development of reproductive buds (panicles) can be seen in 89 % of them, indicating that the suckers require about 10–12 months to attain maturity. It takes almost ten months for a vegetative bud to develop and about a year for the panicle to emerge from the newly formed tillers (Sudharsan et al., 1988). Kuruvilla et al. (1992) carried out a round-the-year study on the phenology of the tiller and panicle in three varieties of cardamom. They found that it took around 90–100 days for the emergence of the first flower from the panicles, irrespective of the variety.

The inflorescence is a long panicle with racemose clusters rising from the underground stem, but coming up

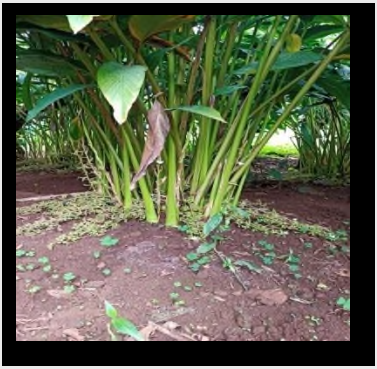
above the soil. Pattanshetty and Prasad (1976) and Parameswar (1973) have made detailed observations on panicle production; its growth, duration of flowering, etc. The linear growth of the panicles extends over a period of about seven months. The rate of growth is at its maximum during April, and is slower during the earlier and later stages. The growth habit of the panicles and the shape and size of the capsules vary in different cultivated varieties/types of cardamom (Table 8.2). These panicles either grow erect (Mysore), prostrate (Malabar) or in a semi-erect manner (Vazhukka). Multiple branching (compound panicle) of panicles appears in certain cultivars. In such cases, the central peduncle undergoes further branching of secondary and tertiary branches producing compound panicle types.

Flowers appear on the panicle after four months and flowering continues for a period of six months. Each flower cluster is a cincinnus (Holttum, 1950). Pai (1965) has concluded from anatomical evidence that the labellum is a double structure, whereas Parameswar and Venugopal (1974) are of the view that the labellum is made up of three modified anthers.Normally, flowering in cardamom is seen throughout the year on panicles produced during the current year, as well as on panicles produced during the previous year. The peak flowering is spread over a period of six months between May and October. The time required from flower/bud initiation to full bloom stage ranges from 26 to 34 days. Capsule development takes about 110–20 days from the full bloom stage (Krishnamurthy et al., 1989).

The early hours of the day are when the maximum number of flowers open. Anthesis follows immediately. In the Mudigere region of Karnataka, flowering commences at 3.30 am and continues until 7.30 am. The dehiscence of anthers takes place immediately followed by anthesis at 3.30 am which continues up to 7.30 am. The maximum pollen bursting occurs between 5.30 am and 6.30 am. The pollen grains are round and mostly found individually. They measure on average 87.6 µ in diameter. By appearance, 85.2 % of the pollen grains are fertile, but a maximum of 70.1 % germinate on an artificial medium, containing 20 % sucrose and 1 % agar. Studies of the viability of pollen grains indicate that only 6.5 % remain viable after 2 hours of storage. After 6–8 hours of storage, the percentage of viability was practically zero (Krishnamurthy et al., 1989). Pollen fertility is maximum at full bloom stage, and low at the beginning and end of the

flowering periods (Venugopal and Parameswar, 1974). With respect to pollen morphology, the three varieties of cardamom are round in shape and the pollen mass appears as a creamy powder. The largest pollen grains are observed in Mysore variety, while the smallest are found in Vazhukka variety.

Even though cardamom has bisexual flowers and is self-compatible, cross-pollination is common. Self-pollination is hindered due to the slight protrusion of the stigma above the stamens. In cardamom, cross-pollination is mediated by the activity of bees (*Apis cerana, Apis indica and Apis dorsata*) who act as pollinators. Cardamom flowers remain in bloom for 15–18 hours per day. Stigma receptivity and pollen viability are at maximum during the morning hours. Receptivity is at maximum between 8 am and 10 am, when 72 % of the opened flowers set fruit. After 10 am the stigma receptivity decreases gradually and only 24 % of the flowers opening at 4 pm set fruit. It is reported that receptivity of the stigma is highest between 8 am and 12 noon (Krishnamurthy et al., 1989; Kuruvilla and Madhusoodanan, 1988). Parvathi et al. (1993) and Belavadi et al. (2000) noticed that the peak receptivity around 12 noon coincides with peak pollinator activity. The active foraging of bees is mainly seen in the morning hours; this activity is instrumental in increasing the fruit set in cardamom.



Cytology

The chromosomal numbers for cardamom are 2n = 48 (Gregory, 1936; Sharma and Bhattacharyya, 1939) and 2n = 52 (Chakravarti, 1948). Cardamom is considered to be a balanced tetraploid. Allied genera such as Globa, Balbifera, Phoemaria, Amomum sps and Alpinia sps also possess 2n = 48 and are considered to be evolved from a common basic number, x = 12. The Mysore and Malabar varieties of cardamom possess 2n = 50 and 2n = 48 chromosomes, respectively, and aneuploidy as well as structural alterations in the chromosome have contributed to the varietal differentiation (Chandrasekhar and Sampathkumar, 1986). Earlier researchers (Chandrasekhar and Sampathkumar, 1986) have reported that cardamom is of amphidiploid origin from wild species, and the two species considered to be the putative parents are the Sri Lankan cardamom E. major and the Malaysian species *E. longituba*.

CLIMATE AND SOIL:

Evergreen forest of Western Ghats with latitude of 600 to 1200 above MSL is best suitable for the cultivation of cardamom. Organic content-rich Forest loamy soil with a soil pH of about 4.2 to 6.8 and low to medium availability of phosphorous and medium to the high availability of potassium are the best suitable soil condition for the growth of cardamom. It also grows on laterite soils, clay loams, and rich black soils having good drainage. Sandy soil is not suitable for growth. Average rainfall about 1500 to 4000 mm and optimum temperature of about 100C to 35oC is the best fit condition for the cardamom cultivation.

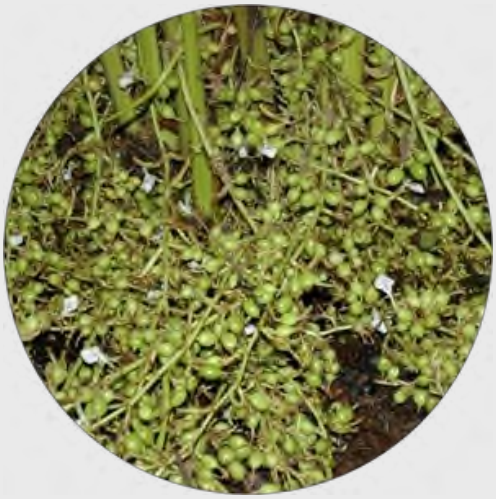
CARDAMOM VARIETIES

There are two main types of cardamom: Small green cardamom (*Elettaria cardamomum*) Large red/black cardamom (*Amomum subulatumRoxb*) The most common type is the small green cardamom while large cardamom is mainly grown in India, with some in Nepal and Bhutan. They both come from the Zingiberaceae family of plants.

Major improved varieties of cardamom released so far areMudigere-1 (V); Mudigere-2 (V); PV-1, PV-2 (V),; CCS-1 (Suvasini) (V); ICRI-1 (V); ICRI-2 (V); ICRI-3, TKD – 4 (V), IISR Vijetha (V), IISR Avinash (V), Njalani green gold (V), SKP-14) (V); ICRI-4 (V) etc.

IISR-Vijetha - 1

IISR-Avinash (RR1)



IISR-Kodagu Suvasini

NHY-35

ICRI 1

ICRI 2

ICRI 3

ICRI 4

ICRI 5

ICRI 6

Variety	Centre developed	Year ofrelease	Pedigree/ Parentage	Av. yield(kg/ha/)*	Dryrecovery	Oil %	Salientfeatures
ICRI 1	ICRI**	1992	CS Malabar	325	22.90	8.70	Early maturing, round extra bold dark greencapsules,paniclemediumsized
ICRI 2	-do-	1992	CS Mysore	375	22.50	6.67	Bold parrot green capsules, rot disease tolerant,mediumlong panicle
ICRI 3	-do-	1994	CS Malabar	440	22.00	6.60	Early maturing, rot tolerant, bold parrot greencapsulessuitablefor Karnataka

ICRI 4	-do-	1997	CS Malabar	455	22.76	6.40	Early maturing, bold capsules, medium panicle,suitable for low rainfall areas, relatively tolerant torotandcapsule borer
ICRI 5	-do-	2006	HybridVazhukka	1543	23.15	7.13	First hybrid, early maturing, high yieldermoderatelydroughttolerant,capsule>7mm.
ICRI6	-do-	2006	CS Malabar	1200	19.00	7.33	High yielder, medium maturity, moderatelydroughttolerant, boldcapsules>7 mm
ICRI 7	-do-	2010	HybridMalabar	1400	22.00	8.84	Angular boldcapsules, oleoresin7.99%
ICRI 8	-do-	2014	CS Malabar	655	19.00	7.1	Oval,boldand palegreencapsules
IISR Vijetha	IISR-ICAR*	2001	CS Malabar	643	22	7.9	Resistant to katte virus, bold capsules. Fieldtoleranttothripsand borer.
Mudigere	RRS-UAS***	1984	CS Malabar	300	20	8.0	Moderately tolerant to thrips, hairy caterpillar andwhitegrubs,palegreen,ovalboldcapsule
PV1	CRS-ICAR*	1991	CS Malabar	260	19.9	6.8	Early maturing. short panicle, elongated ribbedlightgreen,longand boldcapsules
IISR Avinash	IISRICAR*	2001	CS Malabar	847	20.8	6.7	Dark green capsules. Tolerant to rhizome rot, andshoot/panicle/capsuleborer.
Njallani	Farmer'sselection	1990s	Selection Vazhukka	1600	25	9.01	High yielder non-pubescent, semi erect, globose extraboldanddark greencapsules.

Kodagu Suvasini	IISRICAR	1997	CS Malabar	1322	22%	8.7%	Highly adapted and produces 89% bold (7.2 mm and above) capsules. Tolerant to thrips and shoot/panicle/capsulebo rer.

Farmers developed Small Cardamom varieties:

1.Njallani Green Gold.

Description of Innovation The farmer innovation Njallani Green Gold variety in 1987 revolutionized small cardamom cultivation in Kerala particularly in Idukki district in production, management and productivity. Njallani belongs to Vazhukka type with high yield potential and ability to respond to better agronomic management. It spread like wild fire to occupy more than 70% of the cardamom area in Idukki in about a decade and lesser percentage of area in other cardamom growing regions. The increase in the cardamom production in Idukki district as well as in Kerala could largely be attributed to this variety. B. Problem Statement Till 1980s mainly Mysore, Malabar and Vazhukka types occupied the cardamom tracts of Idukki district. The productivity of cardamom at the time was less than 200kg/ha. As per the Complete Enumeration Survey on the State Wise Area and Production of Small Cardamom, during 1986-87, the area under small cardamom was 61000ha with a production of 2500 tones. By 1990-91, the area reduced to 44008 ha and the production increased to 3450 tones. This increase in production despite the decrease in the area is mainly attributed to the cultivation of Njallani variety. As per M.S. Swaminathan Committee Report submitted to Government of India, the spread of the variety started in early

1990s and reached the peak by 2002-03. On the assumption that influence of Njallani on the yield and production had become perceptible only from 1995-96 and subsequent 75% of production difference from the base period prior to 1995-96 is contributed by this variety, its revenue contribution to the state is estimated to be @ 150 crores during the last 15 years. C. Process of Technology Development The innovator Rejimon Joseph used to help his father Sri. Sebastian Joseph in cardamom field right from his school days. He experimented with artificial cross-pollination and different planting methods in cardamom. He noticed a cardamom plant with peculiar features in his plantation. He propagated it vegetatively and observed its growth and yield characteristics. It took almost ten years for him to develop the new variety Njallani Green Gold, which is actually a selection from Vazhukka. Sri. P.J. Philip, Deputy Director (Development) of Spices Board took great interest in the innovation and helped in the spread of the technology. All India Radio and leading newspapers also took up the innovation in a big way. The major advantages of the innovation are High productivity i.e. 2000-2500kg/ha as against 250-300kg/ha in case of other varieties⎮ Dark green colour of the capsules.⎮ Bold capsules of 8.5-9.0 mm size amounts to 30% where as in other varieties it is about⎮ 15-20%, seeds/ capsule is 18-36, whereas in other varieties, it is less than 20 In case of Njallani length of panicle varies from 5-9 ft but in other varieties it varies from⎮ 3-5 ft 40-48 racemes /panicle and 17-25 capsules/raceme in Njallani but in other varieties, 20-⎮ 22 racemes/panicle and 7-14 capsules/ raceme. D. Replication and Promotion The variety is spread over 23500 ha area in Idukki district. In Palakkad district, it is being grown in about 2000ha area. In Waynad district, 70% of the hill area under cardamom is occupied by this variety. Mainly newspapers and television channels did the promotion of the innovation. The innovator claims that there is more than 1000 newspaper coverage in Malayalam, English, Kannada and over 100 television coverage on his innovation. E. Recognition a. Institutional acceptance of the innovation: National Innovation Foundation Award in 2001.⎮ Spices Board Special Award in 1995.⎮ b. Recognition in the form of Honours/certificates/awards etc. Spices Board has announced a special grant of RS. 6.0 Lakhs.⎮ Gandhiji Study Centre (NGO) awarded the title 'Elathilakam' and a gold medal.⎮ World Vision of India (NGO) honoured him with a shield.⎮ Certificate of honour from 'krishad' a Karnataka based organization⎮

2.Thiruthali - an improved variety of cardamom:

The area where Joseph lives gets covered with heavy mist particularly during rainy and winter seasons. Joseph observed that even Njallani, the most popular variety of cardamom was not performing well in his place. He then tried many other varieties but without success. He also realised that many high yielding cardamom varieties were highly prone to diseases and pests, which drastically reduced the yield at times. This prompted him to think about developing a variety, which would suit local conditions.

In 2000 he selected the high yielding variety Njallani and other two varities named Vazhukka and Vulga (Malabar Variety). Though low in yield, both Vulga and Vazhukka were known for less maintenance as well as high resistance to pest and disease. These three varieties were planted in a pit with an isolation distance of 5m to reduce the chances for cross pollination. After two years capsules were harvested from these plants and 600 seedlings were raised through seed propagation. These seedlings were then transplanted in an acre of land. When the plants grew, he noticed a special plant with profuse flowering and long panicles (6 feet long) with an average of 4 pinnacles per tiller. It displayed resistance to disease and pests as well. From this mother plant, 30 seedlings were developed and planted. Another 20 seedlings were then developed from each plant. Of these 600 plants, 500 are still growing well in his field in their twelfth year. High yield, good resistance to pests and diseases are the particular features of this variety. It took him six years to stabilize the yield characters of this variety. Presently, he receives a minimum of about 4-6kg of dried cardamom per plant. He says this yield is unique and high among the existing popular varieties. He has been multiplying the variety by vegetative propagation. This has been widely adopted by other cardamom cultivators as well

Thiruthali- the improved cardamom variety

Thiruthali variety, named after his family house, is a high yielding disease resistant variety possessing bold parrot green coloured capsules. It is a Malabar

type variety with a dry yield of 4-6kg per plant and is highly suitable to Santhampara area of Idukki district, Kerala. It gives good yield even under rain fed condition and is mostly suited for areas with less shade (<40%). The medium bold and parrot green coloured capsules fetch good market price. In this variety about 60 - 80 productive tillers per clump, 50- 60 racemes per panicle and 15- 20 capsules per racemes can be observed. Due to the higher number of panicles per tiller, the yield level in the first bearing itself is two to four times higher in comparison with other popular and released varieties. The plant has fibrous stem and is resistant to stem borers, root grubs and incidence of decaying. The management efforts as well as the pesticide and fertilizer requirements are also less than other locally popular varieties. Indian Institute of Spices Research, Calicut and Indian Cardamom Research Institute, Idukki have both observed that this variety has a higher yield than other locally popular and released varieties. IISR, Calicut, while claiming it to be an innovation, recommended recognition for the farmer. Bapooji Krishi Vigyan Kendra Santhanpara, Idukki describes this variety to have a yield potential of 2000-3000 kg/acre (dry weight) with 22% curing weight.

Joseph maintains a nursery of the plants for sale/distribution to other farmers. This variety has slowly spread to many districts of Kerala and neighbouring states of Karnataka and Tamil Nadu. The farmers mention that this variety gives good yield and performs well even under adverse conditions while reducing the overall cost of production by 40 per cent. He claims to have sold more than 2 lakh seedlings to about 1000 farmers in over 2000 acres of land. Joseph mentions that mostly small and medium farmers cultivate his cardamom variety because it requires little inputs. He adds that most of such farmers actually grow cardamom because of this particular variety; else they may have switched over to some other crop. Apart from economic benefit, which he may obtain through the sales, Joseph is happy to see the change in the lives of small farmers. Cherukida karshakarude jeevithathil ee vilavu kondu vanna matta kanumbol njan valareyathikam santhoshavananu, says Joseph. (I am satisfied by seeing the success of small and medium farmers cultivating this variety which has brought change in their life).

Thiruthali variety was recognized in First Farmer Science Congress at Kannur Krishi Vignan Kendra some time back. Joseph also received a certificate of honour from All India Radio for adopting the modern agricultural techniques and Prasar Bharati award from Doordarshan in 2009. A documentary on his variety was also aired in Krishi Darshan programme by Doordarshan Kendra. He also bagged Bapooji Krishi Vigyan Kendra's best farmer award of Idukki district in 2009-10.

"Cardamom landrace Thiruthali is an innovation of high esteems for consideration by any institution for a moderate farmer" mentions the KVK. Joseph, still experimenting, is working on developing another variety – the 'super Thiruthali' with bold capsules, high productivity and adaption to local conditions. Though he is largely satisfied with what he has achieved in his life, there is a worry that troubles him a lot. While he wants to transfer all his accumulated knowledge to the next generation, not many are interest to receive any. He is sad about the fact that while the whole world is dependent on agriculture yet farmers and agriculture are not getting the attention that is due to them. He wishes for a time when farmers' contribution would be recognized. Joseph opines that agriculture needs to be included in school curriculum so that students get sensitized to it and may get interested to take it up as a career later.

3.Pachaikkai Improved Cardamom Variety

In 1986 Ramaiah wanted to establish a cardamom plantation in his three acres of land and started by growing local Malabar variety in a limited area. After few years he started harvesting cardamom pods from his garden. He and his son Murugan observed that a few plants had large sized pods with bright green color. He then expanded his plantation using the seeds from the newly identified clump. He observed parameters such as growth rate of the plant, disease resistance and yield, and found that they were superior as compared to other local varieties such as 'Nallajni' and 'Malabar'. Also the green colour of capsule did not fade out even after a year. The family members called it Pachakkai (green coloured capsule). Later they purchased land and extended the plantation to over another 8 acres by planting with seedlings raised from seeds of this clump of Pachakkai. Ramaiah digs pits of 2 ½' x 2 ½' x 2' size and fills with top

soil, compost and lime after mixing them together before planting the cardamom seedlings.

He manures the seedlings once in a year during the rainy season by using neem seed powder and compost. The plants come to yield about two and a half year onwards and maximum yield starts third or fourth year onwards. The Improved Cardamom Variety This is a high yielding (2000kg/ha (dry)) variety with exceptionally bright green coloured bold capsules, which have more seeds than other varieties. This variety is also drought tolerant and most suitable for lower elevation areas of Tamil Nadu. Owing to the color and bold capsules this variety is much sought after by the traders. It fetches a premium price of Rs 100-150 per kg over the normal cardamom price. The Spices Board has recorded the salient features of this improved cardamom variety. and awarded him a shield for best performing cardamom planter in the region in 1999. Over the last 8 years, many neighboring farmers have gradually adopted this new variety. Many farmers from Kerala and Karnataka have also obtained seeds material from him.

4.Elarajan :

In 1996, for the first time, he observed a white flower plant in his cardamom garden, which he had never heard or seen, and so he isolated it and multiplied it by vegetative propagation. At that time itself a lot people showed interest in it, but he did not want to distribute it, as he wanted to observe the results over a period. By 2001, he had raised around 800 plants, which were similar to the mother plant and bore white flowers. Same year, when experts from Indian Institute of Spice Research were visiting his area to inspect pepper, he invited them to his farm to have a look at his variety. They appreciated him for his efforts to develop this variety.

Thereafter exposure in media started and subsequently he started selling his seeds 2003 onwards.Being financially sound Baby did not face any major problems and always had the support of family, friends and relatives. His wife and daughter-in-laws took personal care of the plants, from irrigation, manuring to performing associated farm practices. His wife specially likes this particular variety because of the enhanced taste and flavour. His three sons have been much interested in evolving a variety out of the white flowered mother plant and their involvement, interest and hard work has been instrumental in the evolution, multiplication and dissemination of this variety over years.

5.Wonder Cardamom:

Sabu Varghese has developed a drought-resistant cardamom variety that he calls Wonder cardamom. This variety can also be grown in rubber plantations at lower altitude. The specialty of the variety is that it has branched panicles. Sabu is a small farmer with five acres of land in Idukki district, a place covered by thick forests where sometimes even sunlight does not penetrate the canopy. Tribal communities are the original inhabitants of this place. Unavailability of cultivable land elsewhere forced the people to migrate to this hilly district. Sabu parents migrated to Valiya thovala from Thodupuza in 1954. Paddy, yam and tapioca were their major food crops but attacks by wild animals and the higher market value of cash crops made them take up the financially lucrative crops like rubber, which was most suitable for the area. Since his childhood, Sabu was drawn to nature and he enthusiastically watched every sprout of plants. He is a cycling and swimming course, he liked to study but he liked better to help his father in farming. Now Sabu lives here with his wife and five young daughters and grows a wide variety of crops including cardamom, pepper, rubber, clove, vanilla, coconut and banana. Cardamom followed by pepper fetch him the highest returns.

6.PNS Vagai:

Surulivel (70), a progressive farmer, has developed and propagated a variety of cardamom having the qualities of high productivity, large sized capsules and high growth rate. His family comprises his wife, son and two daughters. He has been cultivating cardamom and coconut on the 30 acres of land he has in Kerala for the past 40 years.With plans to start cultivation, he bought a piece of dry rocky land in 1969. The land was mostly covered by weeds like Pterolobium hexapetalum and Lantana camara and was not suitable for cultivation. Toiling hard, he moved the big rocks and used them for building rock bunds, which were incorporated with native soil, cow dung and dried leaves. This prevented soil erosion and improved its fertility. As he found the land suitable for cardamom cultivation, he planted many varieties in it. Since cardamom plants require more shade, he planted *Artocarpus heterophyllus* (Jackfruit1) trees between the cardamom saplings.

Genesis

In late sixties, SuruIivel started cultivating cardamom (Mysore type) on his farm. Then in 1986, he came across some other varieties, which grew well in both drought and water logged conditions.His wife who has been quite observant pointed out two plants that outperformed others in the field. He noted

the quantitative and qualitative traits of these plants such as growth, yield, and resistance to pests, diseases and abiotic stress viz. drought tolerance, water logging, aroma, oil content, etc. over the next five years.

A senior scientist of Indian Cardamom Research Institute, visited his field, appreciated his efforts and encouraged him to mass-multiply these two plants by adopting propagation techniques. The words of appreciation from an expert egged him and he started preparing clones of the plants to use them as planting material in his own estate. He isolated planted this variety in one acre of land in 1991. He multiplied the selected lines by vegetative propagation. The planting 3 x 3 x 2 feet pits were filled with lime powder, compost and topsoil. The split suckers were planted in pits and protected from wind by supporting the plants with stakes. Dried leaves were used for mulching to prevent soil erosion and to conserve soil moisture. Then organic manure was applied at three months interval.Five years later in 1996, the plants started yielding. He named the variety as PNS- Vaigai?, PNS standing for his name (P.N.Surulivelu) and Vaigai, which is the name of the river flowing nearby in the Cumbum valley.

Innovation

The PNS- Vaigai seed size is large compared to the local variety Njallani. The yield is higher and consistent: 900-1400 kg/acre from 1996 till date. The number of internodes (average 40-45) is higher than in the locally popular varieties. The rhizomes are bigger, bolder bearing 3-4 inflorescences each, which in turn bear around 25-32 racemes each. The rind (skin of capsule) is thin and hence the recovery percentage is higher than Njallani. In addition, there is no difficulty in post harvesting. In fact, the driage recovery has been higher than in the local variety. The market response for it has also been very encouraging and it has been commanding prices, at least 15-20 percent higher than other local varieties. Since 60-70 percent of the produce is 7 mm and above, the income from per unit of land is also higher than other local varieties. So far he has sold 2,50,000 sapling to many farmers of the region. Now most of the cardamom growers in his area have started growing PNS-Vaigai and a vast area under cardamom cultivation is covered by this variety alone.Apart from receiving public recognition at local level many times, Surulivel also won ICAR Spices Board?s

(Kerala) first prize for achieving the highest productivity in cardamom (3250 kg of dried capsules/ha) during the year 2002-2003 by).

High yielding planting material, maintenance of soil fertility through judicious application of organic manures and systematic soil and moisture conversation practices helped him in reaching the top position among cardamom growers. Given his vast experience and expertise in agriculture, he was invited to NIF?s informal Research Advisory Committee meeting in May 2006 to meet fellow innovators and also participate in the traditional food festival, Saatvik, organised by SRISTI-NIF in November 2006, where the response to his cardamom variety was overwhelming.

7.Panikulangara Green Bold No.1

Our economy is based on agriculture; innovation and innovators are very much essential for the sustenance of agriculture, but unfortunately they are not getting adequate respect and recognition'Progressive farmer Joy Peter (60) has developed a cardamom variety through selection process. The new variety is less prone to biotic and abiotic stresses and its ripe capsules retain green colour and size even after drying.

Farmers of Idukki, from where Joy belongs, are known for their hard work and determination. They struggle and fight with the extreme hardships of natures for survival. Steep slopes, adverse climatic conditions and problems of wild animals are main obstacles faced by these farmers. Joy Peter, who has studied only up to class four, has 50 acres of land. Here he grows plantation crops like cardamom, pepper, coffee, vanilla, clove, nutmeg and arecanut. Of the total area, 20 acres is

devoted to cardamom cultivation alone. In his family, there are seven members including three children (two sons and a daughter), his mother and a sister.Joy Peter's family migrated from nearby Ernamkulam in 1948 when he was 10 years old. His father, a business man, due to business failures, had to sell off their native land and purchase nearly 2 hectares in Adimally, Idukki. Later, his father started the business of spices at Adimally. Since his school was ten km away from his house, Joy discontinued his regular studies and joined his father. He grew up to be a successful farmer and expanded his father's work.Joy Peter specifically narrates an incident, from where he got the inspiration and determination to do well in life. During his school days, after a long walk, he came back to his home when his father asked him to go to the market and purchase grocery. As he too tired, he refused to do so. This irritated his father, who then commented that he was good for nothing and it was waste spending on him. His father did not mean to hurt him intentionally but this comment left a deep impact in young Joy's heart. He then decided to prove himself before every one. That day onwards he started working hard. It was quite emotional when one day his father was praising him for his success that he narrated this incident.

Motivation for experimentation

Being a man with scientific outlook, curiosity, and keen observation, he spent most of his time experimenting in the field so as to substantially incre-ase the production and income from his farm. He used to grow and experiment with arecanut and coconut crops on his farm. But since cardamom was more profitable, he decided to concentrate on cardamom plantation. In 1990s most of the cardamom varieties grown were traditional ones, viz., Malabar and Vazhuka. He heard about Njallani variety and tried to cultivate it. But because of the low altitude, the yield was not good. Also it was more susceptible to thrips and stem borer. Still he was able to cultivate 300 to 400 Njallani variety plants by clonal propagation. He was well aware of the efforts of Sebastian Joseph (NIF awardee 2001) in developing Njallani variety. This inspired him to start experiments to develop a locally adaptable variety.

Developing Panikulangara Green Bold No.1

Joy was growing Mysore, Malabar and Vazukka varieties of cardamom in his field. The Vazukka variety was grown in between the other two varieties. In 1993 out of grown cardamom plants (Vazukka variety) he noted two plants having special characters of thick and long leaves, and vigorous growth. He closely observed these plants for two years. He then collected the seeds from these two plants and he got around 1 kg of cardamom from these two plants. He separated two clones each from two plants and planted them nearby his kitchen for close observation. By 1998 he was able to separate 12 clones and obtain 70 plants by clonal propagation by 1999.

From these 70 plants he was able to develop another 1000 plants. Most important characters that he found in this variety was increased and uniform production of tillers. The variety was adaptable to less altitude, drought conditions and was less prone to pest attack too. The tillers were branched and 95% berry setting was observed in this developed variety. He then gave his house's name 'Panikulangara' to this variety and started commercializing it in 2000.

The Panikulangara Green Bold No.1 variety

Productive tillers in Panikulangara Green Bold No.1 are comparatively higher than Mysore and Malabar varieties. As the capsules of innovator's variety are bolder (80% of the capsules are of more than 8mm size) than Mysore and Malabar varieties, farmers growing this variety (Panikulangara Green Bold No.1) have the advantage to get more profit. The variety is less prone to thrips, borers and Azukal disease, so it can be grown without much care. It is also a short duration variety (75 days after flowering).

Lack of adequate irrigation facilities is a major constraint for cardamom cultivation in Idukki district. But Joy Peter's variety performs well under rainfed condition and hence it is suitable to be grown in the areas where there is a lack of irrigation facilities. Significant differences in the characters viz., yield per plant, capsule's shape & colour and its duration are observed in Panikulangara Green Bold No.1 after selection from a land race, Vazhukka type.

This new variety Panikulangara Green Bold No.1 was formally released by the former Director of Development, Spices Board in 2000. That year itself he sold more than 6000 clones. Farmers from different parts of Kerala, Tamil Nadu and Karnataka approached him. Media also gave quite a bit of publicity to this variety. Local KVK also studied the variety and felicitated him. Scientists from Kerala Agricultural University also visited his farm. Till date he has given more than one lakh seedlings all over Kerala.

Subsequently, NIF requested experts to evaluate the variety and verify the innovator's claims. Indian Cardamom Research Institute in its report mentions that the variety is tolerant to drought and seems to be resistant to stem borer also. The variety is more greenish, requires less shade (40%) and bearing tillers range between 110-120 numbers. The yield per plant is 6-8 kg and the capsules retain an attractive green colour after drying. Also its dry recovery percentage is 4.5:1kg.

Director Research, Indian Cardamom Research Institute, Spice Board, in his report mentions that the quality characters of the capsules like colour, size, oil content, oleoresin, etc are at par with other landraces and released varieties.

Cardamom Research Station, Kerala Agriculture University mentions that this variety responds well under average management conditions. The variety is free from blight disease even in less shade area and is moderately tolerance to thrips, stem borer and other leaf diseases. The capsules retain attractive green colour after drying. They also compared this variety to the locally popular Njallani variety and found that it has more no of tillers (150-200 as compared to 90-100), productive tillers (70-80 as compared to 45-50), panicles (3-4 as compared to 2-3), panicle length (100cm as compared to 60cm). However the number of capsules/panicle (235) is lesser than in Njallani variety (265). It also has the advantage over Njallani variety in having moderate tolerance to thrips, stem borer and other leaf diseases. Njallani variety is highly susceptible to all.

Diffusion, Awards and Recognition

So far Joy Peter has sold more than one lakh seedlings all over Kerala. The success of Panikulangara has given him courage and confidence to continue his

research. In his farm he found another plant, locally known as malainchi (wild ginger), which was very similar to cardamom. The plant can be grown in less shade and is disease resistant. He has developed a cross between Panikulangara and wild ginger. The cross showed vigorous growth underless sunlight condition. A common disease of cardamom, azhkal (rotting of shoots) was not observed in this variety. He has undertaken its clonal propagation and given the name Panikulangara No 2. He has also started selling this variety along with Panikulangara No 1. Till date, he has sold about 23 thousand seedlings. He is also preparing an improved cardamom curing house.

8. Panikulangara No 2

Mr. Joy Peter a progressive cardamom farmer from Idukki district in Kerala said that our economy is based on agriculture and innovative farmers are very much essential for food sustenance, but unfortunately they do not get enough respect and recognition. Possessing a scientific bent of mind and curious nature, he spent most of his time experimenting in the field so as to substantially increase the production and income from his farm. He used to grow and experiment with arecanut and coconut crops. But since cardamom was more profitable, he decided to concentrate on it. Colour retention The new cardamom variety developed by him named Panikulangara Green Bold No.1 (PGB-1) retains its green colour and size even after drying and yields 6-8 kg of capsules per plant.In his 50 acres Mr. Joy grows pepper, coffee, vanilla, clove, nutmeg and arecanut in 30 acres and cardamom in 20 acres.Earlier, the farmer cultivated traditional Mysore, Malabar, and Vazukka varieties of cardamom. of the capsules are of

more than 8mm size) than Mysore and Malabar varieties, farmers growing this variety (Panikulangara Green Bold No.1) have the advantage to generate more profit. Mr. Joy started commercializing the variety from the year 2000 and so far has sold more than a lakh of seedlings to farmers in Kerala, Karnataka, and Tamil Nadu.The Indian Cardamom Research Institute, Spice Board, in its report mentions that the tillers (in PGB-1) are comparatively higher than traditional varieties. It is less prone to thrips, borers, and azukal disease and can be grown without much care. Drought resistant The report further adds that being a short duration variety, 75 days after flowering, it is tolerant to drought and resistant to stem borer also. The crop requires less shade and bears 110-120 number of tillers. The yield per plant is 6-8 kg of

capsules that retain an attractive green colour even after drying. Lack of adequate irrigation facilities poses a major constraint for cardamom cultivation in Idukki district. But the (PGB-1) grows well under rainfed condition and hence is suitable to be grown in the areas where there is a lack of irrigation facilities. Better than others Cardamom Research Station, Kerala Agriculture University mentions that the (PGB-1) variety is blight disease resistant and moderately tolerant to thrips, stem borer, and other leaf diseases. The number of tillers is more and capsules less compared to the traditional Njallani variety. The success of (PGB-1) spurred Mr. Joy to continue research and the farmer developed a cross between (PGB-1) and a wild ginger variety and named it Panikulangara No 2

9.White flowered cardamom variety

The cardamom variety developed by Baby, belongs to Vazhuka type cardamom cultivars bearing purely white flowers, has high productivity than other cardamom plants and can be grown in waterlogged areas as well. The variety has wider adaptability to different shade conditions apart from having high production with good quality that is even higher than other Mysore and Vazhukka cultivars viz., Njallani, Green-bold, Palakkudi and Veeraputhara varieties, which are locally popular. It has sturdy plants, robust tillers and deeper root system, which makes it resistant to various biotic and abiotic stresses. The prominent features of the variety developed by Baby are (a) single tiller planted in the nursery giving rise to 30 tillers, (b) variety having seed last ratio of around 23-26, (c) recovery ratio of one kg dry cardamom from four and half kilograms of green cardamom (d) single plant yielding nearly 4 - 5 kg dry cardamom with size varying from 6 mm to 8 mm and (e) the oil percentage being 8.9 percent as

against 6-7 percent in common varieties. The distribution of this variety started in 2003 when seeds were provided to 200 to 300 farmers from Idukki and surrounding districts of Kerala and border districts of Karnataka covering about 1000 acres of land. As a result, it has now diffused in Idduki, Wayanad (Kerala) and Chikmangalur (Karnataka) and some parts of Tamil Nadu. This variety has aroused the interest among the researchers, as it was believed that the peculiar color of cardamom flower attracts the insects for pollination, but now presence of white colored flower of Baby's variety negates the whole concept.

10. Pappalu - pest tolerant cardamom variety

This is a high yielding variety with an average yield of 2000-2500kg of dry weight of cardamom in a year per hectare. The variety registers 25% dry weight recovery and shows tolerance to thrips, stem borer, root grub and capsule rot. The panicles are long (130- 147 cm), ovoid in shape and has higher seed per capsule. The variety exhibits early flowering than the parent plant and a longer

cultivation period than the other varieties

11.Arjun variety of cardamom

The Arjun variety of cardamom is suitable for cultivation at high elevation area of about 3000 ft from sea level. It gives a dry yield of about 2000-3000kg/hectare. The variety is resistant to thrips and stem borer. About fifty percent of the capsules exhibits comparatively bigger size (10 mm length and 8 mm width) and the recovery percentage are also high.

12.Thadathil gold

Salient features A high yielding variety of cardamom developed by the farmer through selection. Major morphological characteristics shape Panicle growth habit Panicle length Capsule shape Matured capsule colour Recognitions : Medium : Lanceolate : Semi-erect : Long : Ovoid : Pale green

Cardamom cultivation:

Cardamom is propagated mainly through seeds and also through suckers each consisting of at least one old and a young aerial shoot. Seedlings are normally raised in primary and secondary nurseries. Raised beds are prepared after digging the land to a depth of 30-45cm. The beds of 1m width and convenient length raised to a height of about 30cm are prepared. A fine layer of humus-rich forest soil is spread over the beds. A seed is to be collected from well ripe capsules. Immediately after harvesting, the husk is removed and the seeds are washed repeatedly in water for removing the mucilaginous coating. Seeds should be sown immediately after extraction. One kg of seed capsules may produce 5000 seedlings. Sowing may be taken up during November-January and is done in rows. Seedbeds are to be dusted with chloropicrin or Carbon disulphide. The germination commences in about 30 days and may continue for a month or two. After germination, the mulch is to be removed. Manuring at the rate of 90g nitrogen (N), 60g phosphorus (P2O5) and 120g potash (K2O) per bed of 5x1m size, in three equal split doses at an interval of 45 days is recommended to produce healthier seedlings. The first dose of fertilizer may be applied 30 days after transplanting in the secondary nursery. Pits of 45x45x30cm size are dug in April-May and filled with a mixture of top soil and compost or well decomposed farm yard manure. In sloppy land, contour terraces may be made and pits may be taken along the contour and a close planting (2mx1m) is advisable along the contour. The planting is carried out during the rainy season commencing from June.

Seedlings are to be planted upto the collar region for better growth. Cloudy days with drizzle are ideal for planting. Generally in Kerala and Tamil Nadu, the seedlings are transplanted in March-May at a spacing of 20x 20 cm and mulched immediately. Beds are to be covered with an overhead pandal and should be watered regularly. In order to overcome the dry spell during summer, it is necessary to irrigate the crop to get maximum production as it helps in initiation of panicles, flowering and fruit set. They may be irrigated at an interval of 10-15days till the onset of monsoon. It is an important cultural practice in cardamom. Fallen leaves of the shade trees are utilized for mulching. Sufficient mulch should be applied during November-December to reduce the ill effects of drought, which prevails for nearly 4-5 months during summer.

Exposing the panicle over mulch is beneficial for pollination. The first round of weeding is to be carried in May-June, the second in August-September and the third in December-January. Trashing should be done for the cardamom plants, it consists of removing old and drying shoots of the plant once in a year with the onset of monsoon under rainfed conditions and 2-3 times in high density plantations provided with irrigated facilities. It is very sensitive to moisture stress. Shade helps to regulate soil moisture as well as temperature and provides congenial micro-climate for cardamom. Excess shade is also quite detrimental and shade has to be regulated so as to provide 50-60% filtered sunlight. After the monsoon is over, a thin layer of fresh fertile soil, rich in organic matter may be earthed up at the base of the clump, covering up to the collar region be scraping between the rows or collecting soil from staggered trenches/check pits. This encourages new growth.

Table 1. Commonly available shade trees in cardamom plantations

Sl. No.	Species	Popularname (Malayalam)	Family
1.	*Sesbaniasesban*	Chithagani	Fabaceae
2.	*Pterocarpusmarsupium*	Venga	Fabaceae
3.	*Macarangapeltata*	Vatta	Euphorbiacaeae
4.	*Mesuaferra*	Vainavu	Clusiacea
5.	*Ficusretusa*	Kalathi	Euphorbiaceae
6.	*Mallotusalbus*	Vattakumbil	Euphorbiacaeae
7.	*Albizziaamara*	Nenmenivaka	Fabaceae
8.	*Cedrellatoona*	Chandanavayambu	Meliaceae
9.	*Clerodendronviscosum*	Peringalam	Verbenaceae
10.	*Cassia fistula*	Kanikkonna	Fabaceae
11.	*Albizzialebbeck*	Vaka	Fabaceae
12.	*Artocarpushirsuta*	Anjili	Moraceae
13.	*Acrocarpusfraxinifolius*	Kurangatti	Fabaceae
14.	*Adinacordifolia*	Manjakadambu	Rubiaceae
15.	*Dalbergialatifolia*	Veeti	Fabaceae
16.	*Albizziaodoratissima*	Pulivaka,Chelavaka	Fabaceae
17.	*Artocarpusheterophyllus*	Plavu	Moraceae
18.	*Brideliaretusa*	Mulluvenga	Phyllanthaceae

19.	*Vernoniaarborea*	Karana	Compositae
20.	*Canariumstrictum*	Kunthirikkapayin	Burseraceae
21.	*Careyaarborea*	Pezhu	Lecythidaceae
22.	*Culleniaexarillata*	Vediplavu	Malvaceae
23.	*Dalbergiapaniculata*	Velleetti	Fabaceae
24.	*Dysoxylummalabaricum*	Vellaakil	Meliaceae
25.	*Eugeniahemispherica*	Tholnjaval	Myrtaceae
26.	*Maesaindica*	Neerunchi	Myrsinaceae
27.	*Hopeaparviflora*	Thampakam	Dipterocarpaceae
28.	*Hydnocarpuslaurifolia*	Marotti	Achariaceae
29.	*Lanneagrandis*	Uthi	Anacardiaceae
30.	*Litseazeylanica*	Akil	Lauraceae
31.	*Lagerstromialanceolata*	Ventheku	Lythracaea
32.	*Cinnamomumzeylanicum*	Vayana	Myrtaceae
33.	*Erythrinaindica*	Murikku	Fabaceae
34.	*Calophyllumwightianum*	Cherupunna	Clusiaceae
35.	*Gmelina arborea*	Kumbil	Lamiaceae

Table2.Listofidealshadetreesincardamomplantations

Sl. No.	**Species**	**Popular name(Malayalam)**	**Family**
1.	*Vernoniaarborea*	Karana	Compositae
2.	*Sesbaniasesban*	Chithagani	Fabaceae
3.	*Maesaindica*	Neerunchi	Myrsinaceae
4.	*Cedrellatoona*	Chandanavayambu	Meliaceae
5.	*Ficusretusa*	Kalathi	Euphorbiaceae
6.	*Cassia fistula*	Kanikkonna	Fabaceae
7.	*Cinnamomumzeylanicum*	Vayana	Myrtaceae
8.	*Erythrinaindica*	Murikku	Fabaceae
9.	*Clerodendronviscosum*	Peringalam	Verbenaceae
10.	*Dalbergialatifolia*	Veeti	Fabaceae
11.	*Albizzialebbeck*	Vaka	Fabaceae
12.	*Artocarpushirsuta*	Anjili	Moraceae

Conventional and Bio-intensive IPDM in Small Cardamom:

Pest management is an ecological matter. The size of a pest population and the damage it inflicts is, to a great extent, a reflection of the design and management of a particular agricultural ecosystem. We humans compete with other organisms for food and fiber from our crops. We wish to secure a maximum amount of the food resource from a given area with minimum input of resources and energy. However, if the agricultural system design and/or management is faulty—making it easy for pests to develop and expand their populations or, conversely, making it difficult for predators and parasites of pests to exist—then we will be expending unnecessary resources for pest management. Therefore, the first step in sustainable and effective pest management is looking at the design of the agricultural ecosystem and considering what ecological concepts can be applied to the design and management of the system to better manage pests and their parasites and predators. The design and management of our agricultural systems need re-examining. We've come to accept routine use of biological poisons in our food systems as normal. But routine use of synthetic chemicals represents significant energy inputs into the agricultural system, and carries both obvious and hidden costs to the farmer and society. Attempting to implement an ecology-based discipline like IPM in large monocultures, which substitute chemical inputs for ecological design, can be an exercise in futility and inefficiency.IPDM, as it was originally conceived, proposed to manage pests though an understanding of their interactions with other organisms and the environment. Most of the 77 definitions for IPDM listed in The Database of IPDM Resources (DIR) website, , despite some differences in emphasis, agree with this idea and have the following elements in common:

A conception of a managed resource, such as a cropping system on a farm, as a component of a functioning ecosystem. Actions are taken to restore and enhance natural balances in the system, not to eliminate species. Regular monitoring makes it possible to evaluate the populations of pest and beneficial organisms. The producer can then take steps to enhance natural controls (or at least avoid or limit the disruption of natural controls) of the target pest(s).An understanding that the presence of a pest does not necessarily constitute a problem. Before a potentially disruptive control method is employed, appropriate decision-making criteria are used to determine whether or not pest management actions are needed. A consideration of all possible pest management options before action

is taken. A philosophy that IPDM strategies integrate a combination of all suitable techniques in as compatible a manner as possible; it is important that one technique not conflict with another. However, IPM has strayed from its ecological roots. Critics of what might be termed "conventional" IPM note that it has been implemented as Integrated Pesticide Management (or even Improved Pesticide Marketing) with an emphasis on using pesticides as a tool of first resort. What has been missing from this approach, which is essentially reactive, is an understanding of the ecological basis of pest infestations.

Move to Bio-intensive IPDM in Small Cardamom:

Bio-intensive IPD incorporates ecological and economic factors into agricultural system design and decision making, and addresses public concerns about environmental quality and food safety. The benefits of implementing bio-intensive IPM can include reduced chemical input costs, reduced on-farm and off-farm environmental impacts, and more effective and sustainable pest management. An ecology-based IPDM has the potential of decreasing inputs of fuel, machinery, and synthetic chemicals—all of which are energy intensive and increasingly costly in terms of financial and environmental impact. Such reductions will benefit the grower and society. Over-reliance on the use of synthetic pesticides in crop protection programs around the world has resulted in disturbances to the environment, pest resurgence, pest resistance to pesticides, and lethal and sub-lethal effects on non-target organisms, including humans. These side effects have raised public concern about the routine use and safety of pesticides. A systems approach to pest management based on an understanding of pest ecology. It begins with steps to accurately diagnose the nature and source of pest problems, and then relies on a range of preventive tactics and biological controls to keep pest populations within acceptable limits. Reduced-risk pesticides are used if other tactics have not been adequately effective, as a last resort, and with care to minimize risks.This "bio-intensive" approach sounds remarkably like the original concept of IPDM. Such a "systems" approach makes sense both intuitively and in practice. The primary goal of bio-intensive IPM is to provide guidelines and options for the effective management of pests and beneficial organisms in an ecological context. The flexibility and environmental compatibility of a bio-intensive IPDM strategy make it useful in all types of cropping systems. Even conventional IPDM strategies help to

prevent pest problems from developing, and reduce or eliminate the use of chemicals in managing problems that do arise. Results of 18 economic evaluations of conventional IPM on cotton showed a decrease in production costs of 7 percent and an average decrease in pesticide use of 15 percent. Bio-intensive IPDM would likely decrease chemical use and costs even further.

Insect pests have been known to cause losses in crop yields over the years; pesticides have become an integral part of crop production in achieving economical yields and in meeting food security needs. Green revolution technologies have adversely affected different components of environment and subsequently led to intensification of pest problems. Thus, the challenge ahead is to increase crop yields from the existing land resources without harming the environment by developing environmentally benign pest control methods. This goal can be accomplished by adopting eco-friendly bio-intensive integrated pest management (IPM) strategies incorporating ecological and economic factors addressing concerns about environmental quality and food safety. The benefits of implementing bio-intensive IPM can include reduced chemical input costs, reduced on-farm and off-farm environmental impacts, and more effective and sustainable pest management (Reddy, 2014). Moreover, the high cost of discovering, developing and registering new synthetic pesticides and the rapid emergence of pest resistance have contributed to an increased interest in bio-pesticides (Glare et al., 2012) and bio-intensive IPM which will focus primarily on biological knowledge of pests and on their interaction with the crops and other components of the cropping system. Ideally, pest management interventions should take into account the extent of natural regulation and basic ecological information about pests and their crop environment which has become a prerequisite for efficient pest control. Consumer awareness on pesticide residues in food commodities has necessitated decreased usage of these chemicals and shifted the focus on adoption of bio-intensive pest management practices in agroecosystems. Hence, research interest has shifted from pesticide management to a bio-intensive systems approach based on biological knowledge of pests and their interactions with crops. Bio-intensive IPM should be ‘a sustainable approach’ to manage pests utilizing cultural, host plant resistance, bio-control (predators, parasitoids or pathogens), bio-rationales, bio-pesticides and molecular approaches to ensure favorable economic, ecological and

sociological benefits. This review highlights important aspects of bio-intensive IPM with focus on successful examples of its practical deployment. Cultural and behavioral approaches Cultural management Cultural mechanisms include: impediments to pest colonization of the crop; the creation of adverse biotic conditions that reduce survival of individuals or populations of the pest; modifications of the crop in such a way that pest infestation results in reduced injury to the crop and enhancement of natural enemies by manipulating the environment (Ferror, 2013). Bajwa and Kogan (2004) highlighted that cultural practices produce negligible undesirable ecological consequences and are primarily aimed at prevention and reduction of pest outbreaks. But these are relatively slow acting and proper timing of the tactic is prerequisite for adequate results and hence cannot resolve pest outbreaks. Moreover, implementation of cultural control tactics requires thorough knowledge of pest ecology and its interaction with cropping system and these are often pest, crop and region specific. Cultural management approaches include the alteration of planting time, seed rate, plant spacing, tillage, intercropping, trap cropping, crop rotation, sanitation, nutrient and water management.

Behavioural management Semiochemicals: Insect behaviour is elicited in response to visual, auditory, tactile, olfactory and gustatory senses and chemicals involved in communication are termed as semiochemicals. Semiochemicals are subdivided into allelochemicals and pheromones depending on whether the interactions are interspecific or intraspecific. In tritrophic interaction, these semiochemicals produce different responses such as attraction, repulsion, deterrence and stimulation which govern prey-predator interactions (Ananathakrishnan, 2002). Pheromones: During the past few decades, pheromones of hundreds of insect species have been chemically elucidated and used in IPM programmes for monitoring, mass trapping and for mating disruption. The most widespread and successful applications of sex pheromones have been in detection and population monitoring and these have been used to mediate reproduction (Flint and Doanne, 2013). In addition to sex pheromones, aggregation, alarm, dispersal and trail pheromones also have potential use in pest management programmes. Insect populations with pheromones are managed by two principle techniques i.e. mating disruption and mass annihilation. Mating disruption causes disorientation and communication

disruption between the sexes, and thus delays, reduces, or prevents fertilization of females. Mass annihilation includes mass trapping and killing. In a study, mass trapping, without the use of insecticides, has led to more than 50 per cent increase in marketable fruits of brinjal, which has been attributed to the combined effects of mass trapping of brinjal fruit and shoot borer and enhanced impact of natural enemies (Cork et al., 2005). Allelochemicals: Herbivores and plants have coevolved and developed certain mutualistic and antagonistic interactions amongst them. Among the most effective weapons developed by plants against insect damage are the noxious phytochemicals that adversely affect the survival, growth, development and behavior of insects (Dhaliwal and Arora, 2006). Parasitization of *Helicoverpa zea* eggs by *Trichogramma pretiosum* was relatively higher in tomato plots but almost non-existent in adjacent plots of corn (Whitman and Nordlund, 1994). The aphid parasitoid, Diaeretiella rapae is attracted by isothiocynates that are typically present in these plants (Baer et al., 2004). Most plants emit relatively few volatiles until their tissues are damaged and damaged tissue causes the release of these stimuli. Egg parasitoids may orientate using oviposition induced plants cues while larval parasitoids can exploit cues induced by larval feeding (Moraes et al., 2005). Many studies have shown that damaged plants are much more attractive to natural enemies than undamaged plants (Whitman and Nordlund, 1994). The females of *Cotesia plutellae*, a primary solitary larval endoparasitoid and a specialist of *Plutella xylostella*, are primarily attracted by green leaf volatiles produced by wounds caused by herbivores or mechanical injury (Liu and Jiang, 2003). Push - pull strategy: Several authors have suggested that a method based on combination of deterrents and attractants/ stimulants might increase the efficacy over individual component with the basic principle of attracting the pest to a non-valued resource in a stimulo-deterrent diversion (Miller and Cowles, 1990) or push-pull strategy (Pyke et al., 1987). These strategies involve the behavioral manipulation of insect pests and their natural enemies that make the protected resource unattractive to the pests (push) while luring them toward an attractive source (pull) from where the pests are subsequently removed (Cook et al., 2007). Thousands of farmers in East and South Africa are using push-pull strategies to protect maize and sorghum from the attack of stem borers. Molasses grass, when intercropped with maize, not only reduced stem borer infestation, but also increased parasitism by Cotesia sesamiae (Khan et al.,

2011). It has been reported that the onion fly, Delia antiqua can be deterred from laying eggs on seedling onions by cinnamaldehyde and stimulated to lay eggs on worthless cull onion bulbs that are planted in the same field (Cowles and Miller, 1992). These strategies have been employed against Helicoverpa in cotton, colorado potato beetle in potato, pea leaf weevil in beans, pollen beetle in oilseed rape, onion maggot on onions, thrips on chrysanthemum, bark beetles on conifers and also for veterinary and medical pests (Cook et al., 2007). Bio-control and bio-insecticides Natural control is the primary regulating force of the pest populations and includes effects of natural enemies (predators, parasites and pathogens) and other biotic (food availability and competition) and abiotic factors (weather and soil) (Sharma, 2012). Bio-intensive IPM seeks to strengthen the role of biological control agents for management of insect pests. Some of the agricultural practices have the potential to enhance or decrease the functional biodiversity of bio-control agent. Therefore, the practices that enhance the sustainability of these bio-control agents should be promoted (Dhaliwal and Arora, 2006). In a study, classical biological control was applied on 350 million hectares, with a very high benefit-cost ratio of 20-500:1. More than 5,000 introductions of about 2,000 species of exotic arthropod agents for control of arthropod pests in 196 countries or islands have been made during the past 120 years, and more than 150 species of natural enemies have been commercially utilized (Van Lenteren et al., 2006). Predators Insects form an integral part of various food chains, thus can contribute significantly as biocontrol agents. The insects that prey on other insects and mites belong to Coleoptera, Neuroptera, Hemiptera, Odonata etc. (Dhaliwal and Arora, 2006). Manipulation of predator complexes for biological control in cropping systems requires knowledge of predator taxonomy and biology, specificity and rates of predation (Van Driesche et al., 2008). Avian predators: Insectivorous birds are important in controlling the populations, behaviour and evolution of their invertebrate prey (Triplett et al., 2012). Whelan et al. (2008).conducted a large number of studies on top-down effects of birds on herbivorous insects. The most exciting example in this case is reduction in caterpillars and fruit damage and increase in fruit yield by an astonishing 66 per cent from 4.7 to 7.8 kg apples per tree in Dutch apple orchards as reported by Mols and Visser (2002). Triplett et al. (2012) have reported economic benefits from control of insect pests by avian predators in agricultural landscapes (Table 1). Arthropod predators: Insects

belonging to different orders like Dermaptera, Mantodea, Hemiptera, Thysanoptera, Coleoptera, Hymenoptera and Diptera have potential use in biocontrol (Table 2). Mani and Krishnamoorthy (2008) reported that the coccinellid beetle, Cryptolaemus montrouzieri has provided spectacular control of heavy infestations of mealybugs and some soft scales. Dhandapani et al. (2003) observed that conservation of parasitoids like *Erythmelus empoascae* and *Stethymium empoascae*, was effective against *Amrasca bigutula bigutula* in okra while Bracon hebetor, *Rogas testaceus* and *Microbracon lefroyi* are effective against Earias species. *Aphelinus flavipes* parasitizes *Aphis gossypii* and *Eurytoma spp*. parasitizes *Myzus hibisci*. *Stethorus punctum* has been found as an effective bio-control agent of mite in Pennsylvania apple orchards (Biddinger et al., 2009). National Bureau of Agricultural Insect Resources (NBAIR), Bangalore have developed endosulfan, acephate and fenvalerate resistant strain of *Chrysoperla zastrowi arabica* that was also effective against sucking pests of cotton under pesticide sprayed conditions (Venkatesan et al., 2011). Still, improvement of networking among the world's biological control community and further construction of easily accessible databases on all the studied natural enemies will certainly prove useful in identifying an effective biocontrol agent (Shankar and Abrol, 2012).

Parasitoids Eighty-six families belonging to six orders of insects have been reported to be dominated by parasitoid species, the most important ones being from Hymenoptera and Diptera (Table 2). Tachinidae stand out as the most significant parasitoids amongst thirteen families of Dipteran order that are parasitic to arthropods. Parasitic wasps of Braconidae family have been extensively utilized as endoparasitoids of aphids, larvae of Lepidopterans, and Coleopterans, eggs and larvae of Lepidoptera and Cyclorrhaphous Dipterans (Van Driesche et al., 2008). Ten *Trichogramma spp*. have been mass reared extensively for augmentative release against Lepidopteran pests of corn, sugarcane, cotton, vegetables and other crops. The superior strains of *T. chilonis* have been developed by artificial selection for adaptation to high as well as low temperature regime at NBAIR, Bangalore. The high temperature adapted strain can be utilized at temperatures above 350C and is useful against various insect pests of sugarcane, cotton and vegetable crops during hot months (Singh, 2003). Under Punjab conditions, this strain has also proved superior in reducing the

incidence of sugarcane stalk borer, *Chilo auricillius* and early shoot borer, *Chilo infuscatellus* (Singh et al., 2007). Under field conditions, an endosulfan-resistant strain of T. chilonis termed as "endogram" strain has shown higher parasitism *in H. armigera* eggs on tomato by 260.4 per cent as compared to susceptible strain under sprayed conditions (Jalali and Venkatesan, 2011). An endoparasitoid, *Encarsia flavoscutellum* brought from sugarcane growing areas of Sankeshwar and other neighboring districts of Northern Karnataka is a classical example in biological control of sugarcane woolly aphid, *Ceratovacuna laniger* (Mallapur et al., 2008).

Entomopathogens Insect pathogens are important components of natural enemy complex with some groups such as microsporidia may not always maintain host densities below economic thresholds, but suppress the rapid increase of pest populations. This can be achieved by inoculative releases of the pathogen or by changing cultural practices to promote multiplication of the pathogen (Shankar and Abrol, 2012). Some of these microbial insecticides are registered with the Central Insecticide Board and Registration Committee in India for the control of different insect pests (Table 3). The most broadly used bio-pesticide in pest management is *Bacillus thuringiensis* (Bt). The first commercial product 'Sporeine' was produced in France in 1938 but it was not until 1970 that it emerged as a successful biopesticide with the discovery of the potent strain HD1 of *B. thuringiensis var kurstaki* (Sanchis, 2011). The major drawback of Bt is the rapid photo degradation of foliar sprays on the crop and to overcome this problem, the delta endotoxin genes have been inserted into a number of crop plants. Recent advances in molecular biology have provided the necessary tools for genetic improvement of entomopathogens to overcome their major limitations (Arora, 2015). Microsporidian species include *N. fumiferanae* and *N. pyrausta* infesting spruce budworm and European corn borer respectively. Species in the genera Steinernema and Heterorhabditis are amenable to mass production and application in a variety of pest control programmes (Shankar and Abrol, 2012). Chemical approaches Bio-rational and reduced risk insecticides Botanicals: Botanical pesticides are those compounds or materials derived from plants (excluding synthetic analogues) that demonstrate useful toxicity to pests involved in agriculture, animal husbandry, and human health problems. Presently, there are four major types of botanical products (pyrethrum, rotenone,

neem, and essential oils) which are used for insect control, along with three others in limited use (ryania, nicotine, and sabadilla). Plant extracts of some rice varieties proved highly toxic to important rice pests such as *Chilo suppressalis*, *Nilaparvata lugens* and *Sogatella furcifera* but were safe to predators such as *Cyrtorhinus lividipennis* (Arora and Dhaliwal, 1994). According to Purohit and Vyas (2004), 2121 plant species are reported to be useful in pest management, out of which 1005 species have insecticidal properties, 384 antifeedants, 297 repellents, 27 attractants and 31 with growth inhibiting properties. Microorganism-derived bio-rationales: These have been developed mostly from soil microorganisms by fermentation process and have proved useful as reduced risk pesticides for management of insect pests. Spinosyns: The spinosyns, derived by the fermentation of soil actinomycetes, *Saccharopolyspora spinosa* are very effective against different insect-pests of crops, ornamentals, forestry, greenhouse and household. The most effective insecticide of this group is spinosad which is a mixture of Spinosyns A and D (Kirst et al., 1992) and has shown activity against Lepidopteran, Coleopteran, Dipteran, Hymenopteran and Thysanopteran insect-pests. Avermectins: They are a group of macrocyclic lactones isolated from fermentation of the soil microorganism *Streptomyces avermitilis*. Abamectin acts specifically on phytophagous mites, but also on agromizid leafminers, ants, cockroaches, and selected lepidopteran pests (Lasota andDybas, 1991). Milbemectin acts against a wide range of mites such as two-spotted spider mite, *Tetranychus urticae, T. cinnabarinus*, and the citrus red mite *Panonychus citri* (Sankyo, 1997). Pyrrole insecticides: They are derived from natural product, dioxapyrrolomycin, isolated from a strain of Streptomyces. Among these, chlorfenapyr is effective against loopers, thrips, fruitworms, hornworms, diamond back moth and Helicoverpa. It was first registered in USA under the trade name Phantom® for control of termites, cockroaches and nuisance ants. Reduced - risk pesticides: These are are synthetic or natural compounds that affect those targets within the insect body which are unique to insects e.g. integument, endocrine and communication systems etc. They are preferable to conventional ones because of their target specificity to pests, effectiveness at low rates and non-persistent nature. Insect growth regulators: The chemicals that affect growth and development of insects are called insect growth regulators (IGRs). They disrupt or mimic the insect hormone ecdysone which induces moulting and metamorphosis. Examples of

IGRs include insect hormones (moulting and juvenile hormones) and their analogues and chitin synthesis inhibitors (CSIs). Williams (1967) was first to explore the possibility of the use of Juvenile Hormone (JHs) which further led to the synthesis of Juvenile hormone ananlogues (JHAs). Singh and Suri (2013) studied the effectiveness of JHAs, Methoprene, Hydroprene, Fenoxycarb and Pyriproxyfen and some moulting hormones. The first chitin synthesis inhibitor was a benzoylphenylurea named diflubenzuron, which has been reported to be quite effective against many agriculturally important insect pests. Novaluron acts by both ingestion and contact and is found to be highly effective against many important lepidopteran insect pests. Sublethal concentrations of lufenuron affected various morphological, biological and physiological parameters of *P. xylostella* (Josan and Singh, 2000). Other biorationals: These include the following biorational compounds: Pymetrozine: It is a pyridine azomethine and is active primarily against sucking insects such as aphids and whiteflies. Pymetrozine has been shown a powerful toxicant against aphids, whiteflies, and planthoppers (Zhang, 2011). Oxadizines: This group includes indoxacarb which has been proved effective against important lepidopteran homopteran and coleopterans insect pests such as Heliothis and *Helicoverpa spp*., *Spodoptera spp*., *Trichoplusia spp*., *Lygus spp*., *Empoasca spp*., and the Colorado potato beetle, L. decemlineata (Arora and Singh, 2011). Phenyl pyrazoles: Fipronil belongs to this group and has been developed by Rhone Poulene in 1987. It acts by disrupting the insect central nervous system by blocking the passage of chloride ions through the GABA receptor and glutamate chloride channels (GluCl), components of the central nervous system (Bloomquist, 2001). It is highly effective against diamondback moth (P. xylostella), Spodoptera and Heliothis species, and Colorado potato beetle, and against household pests, such as termites and cockroaches (Hamon et al., 1996). Tetronic acid derivatives: Spiromesifen belongs to this new class of spirocyclic tetronic acids that successfully acts against whiteflies and mites (Nauen and Konanz, 2005). Spirodiclofen has been found effective against mites in apple and pear orchards besides with a good selectivity against predators, parasitoids, syrphids, lacewings and earwigs (Maeyer and Geerinck, 2009). Tetramic acid derivative: Spirotetramat belongs to the chemical class of ketoenols. It interferes with lipid biosynthesis, leading to death of juveniles within two to ten days after application (Palumbo, 2007) and has shown effectiveness against a wide

spectrum of sucking insects. Diamide: Flubendiamide is a phthalic acid diamide with mode of action as ryanodine receptor agonist, which activates ryanodine-sensitive intracellular calcium release channels in insect neurons. It has larvicidal activity by disrupting calcium ion balance, which causes rapid cessation of feeding. Chlorantraniliprole also belongs to the anthranilic diamides, which activate the insect ryanodine receptors affecting calcium release during muscle contractio (Lahm et al., 2007).

INSECT PESTS OF SMALL CARDAMOM

(i) Shoot and Capsule Borer, *Dichocrocis (=Conogethes) Punctiferalis Guen*

Pest infestation is observed from the seedling stage to the harvesting stage. Almost all the plant parts like shoots, panicles and capsules are infested by the caterpillars. Nature of Damage and Symptoms The caterpillars bore into stem of tender plants, young tillers, panicles and capsules in the plantations. Young larvae bore into the pseudostems of young and mature plants, feed on their xylem vessels affecting the translocation of nutrients. This leads to the drying of central leaf tip which is known as the "dead heart" symptom. Later, they also feed on the panicles leading to drying up of the entire panicle and also bore the immature capsules, feed on the tender seeds within and make the capsules empty. The fresh infestation of the pest is indicated by the conspicuous oozing out of excreted frass at bored holes. The later instars larvae hide inside the stem making it inaccessible for the insecticidal sprays to reach them.

Biology The moth is straw coloured with minute black spots. The adult moths usually feed on nectar and the female lay about 20-35 eggs singly or in groups of 2 to 3 on the leaf margins or along leaf veins or sometimes on the dry leaf sheaths. Larval emergence occurs within a period of 5-7 days. The fully grown caterpillar is 15-25 mm long and pale reddish brown in colour with numerous tubercles on the body. Matured larvae undergo pre-pupal stage for one or two days and after that they undergo pupation within a selfmade cocoon and the pupation lasts for about 10-21 days. The total life cycle will be completed within 41-68 days during summer while, during winter season their life cycle extends even up to 123 days. Peak population of the pest is observed from January-

February, May and September-October under the conditions that prevail in Kerala.

Geographic Distribution Cardamom shoot and capsule borer is a highly polyphagous pest that is dispersed widely around the world. It is distributed in most of the Asian countries like Brunei, China, Cambodia, Tibet, India, Indonesia, Java, Japan, Malaysia, Myanmar, Philippines, Sri Lanka, Taiwan, North Korea, South Korea, Thailand and Vietnam. The pest was also reported from Australia, Europe and Papua New Guinea.

Host Plants This pest has a wide host range and the host plants that are recorded include guava (*Psidium guajava* L.), mango (*Mangifera indica* L.), peach (Prunus persica Benth and Hook), pomegranate (*Prunus granatum* L.), jack (*Artocarpus integrifolia*), ginger (Zingiber officinale Rosc.), turmeric (Curcuma longa L.), avocado (*Persia gratissima* Gaertn.), mulberry (*Morus alba* L.), loquat (*Eriobotrya japonica* Lindl.), pear (*Pyrus communis* L.), sorghum (Sorghum bicolor (L.), cocoa (*Theobroma cacao* L.), castor (*Ricinus communis* L.), tamarind (*Tamarindus indica* L.), soap nut (*Sapindus emarginatus* Vahl.), *Caesalpinia bonducella*, *Annona cherimola*, *Curcuma aromatica*, *C. amada*, *Alpinia sp.*, *Amomum sp*. and *A.framomum melegueta*. Other hosts include *Amomum subulatum*, *A. microstephanum*, *Hedychium coronarium*, *H. flavescens* and *A. galanga.*

Natural Enemies of Shoot and Capsule Borer:

Numerous parasitoids have been reported against *D. punctiferalis* infesting in different crops. Important parasitoids seen parasitizing shoot and capsule borer in cardamom are *Agrypon sp.*, *Eriborus trochanteratus*(Morl.), *Friona sp.*, *Temecula sp*. and *Xanthopimpla australis* Kr. (Varadarasan, 1995). Common natural enemies of shoot borer infesting ginger are the parasitic nematode, *Hexamermis sp*., larval parasitoids, *Apanteles taragamae* and *Bracon sp*. under the conditions of Kerala. Diversity of parasitoids were seen associated with the shoot borer of turmeric and it includes *Phanerotoma hendecasiella* Cam., *Bracon brevicornis* (Wes.), *Myosoma sp., Apanteles sp., Xanthopimpla sp., X. australis Kr., Angitia trochanterata Thomson, Theromia inareolata, Dolichorus sp., Brachymeria euploeae* West. and *B. nosatoi* Habu. Important predator

associated with *D. punctiferalis* infesting cardamom was the reduviid predator, *Sycanus indigator Stal*. (Varadarasan, 2011). Other predators reported were *Euborellia stali Dohrn, Philodicus sp., Heligmoneura sp., Araneus sp., Micaris sp*. and *Thyene sp.*

Management:

Diafenthiuron 50 WP @ 300g a.i ha−1was found effective in managing both the cardamom shoot and capsule borer and thrips (Stanley et al., 2018). Botanical insecticide, Ponneem was also effective in suppressing shoot and capsule borer (Deepthy et al., 2015).

Integrated Pest Management for Shoot and Capsule Borers

- ✓ Since the mature caterpillars hide inside the stem, they are very much protected.
- ✓ The varieties having a stem girth of <3cm, such as PV-1, and stems of higher tensile strength (Kalarickal- White flower cardamom) are highly suitable for hotspot areas.
- ✓ Excess application of fertilizers would lead to more succulence and increased damage hence application of fertilizers should be done only with the recommended dosages.
- ✓ Cultivation of crops such as ginger and turmeric in the immediate vicinity of the plantation should be avoided. All the alternate host plants such as Amomum spp., castor, etc. should be destroyed.
- ✓ Trashing should be done twice in a year (September-October and January-February).
- ✓ Installation of bird perches in the plantation will attract insectivorous birds such as golden backed woodpecker and crowpheasant that help to reduce the insect population.
- ✓ Spraying of ICAR-NBAIR-*Bacillus thuringiensis* @ 5ml/L of water at First - instar larvae stage at an interval of 15 days.
- ✓ Spraying of ICAR-NBAIR-*Beauveria bassiana* @ 5g/L of water at 3rd& 4th instar larvae at an interval of 15 days.
- ✓ Releasing of *Apantele sp*. @20000 Larval parasites /ha at 2nd& 3rd instar larvae.

- ✓ Releasing of *Friona sp* @ 20000 Larval parasites /ha at 2nd& 3rd instar larvae.
- ✓ In case of severe infestation, application of insecticides such as Dimethoate 30EC (1.5 ml/l), Spinosad 45% SC (3.3 ml/10l), Quinalphos 25EC (2ml/l) should be done at 30 days intervals during February to May. During August-January, the insecticides recommended are Flubendiamide 39.35% SC (0.1ml/l and Chlorantraniliprole 18.5 SC (0.3 ml/l). Insecticide application should be avoided during peak monsoon showers. Rotation of chemicals should be followed each time.

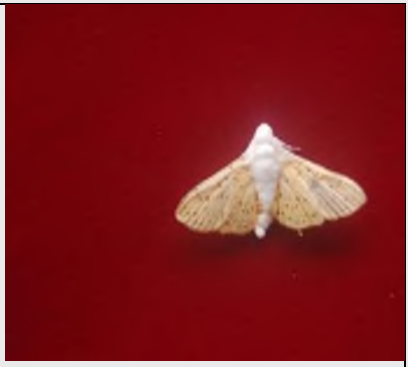
Bore hole symptoms on stem and pupa

Adult of borer

Dead heart symptoms on shoot

Bore hole symptoms on capsules

Apantelesp parasitoids on capsule borer



Beauveria *infected* adult

(ii) Thrips (*Sciothripscardamomi***):**

The first report of *S. cardamomi* infesting cardamom is from South India (Ayyar and Kylasam, 1935). Severe damage of thrips on cardamom pods was reported by them. Population of both nymphs and adults colonize and breed in unopened leaves, leaf sheath, spindles, flower bracts, perianths and flower tubes of cardamom.

Nature of Damage and Symptoms

Both the adult and the nymphs cause damage to panicles, flowers and capsules. Thrips lacerates the surface tissues with its mandibles and sucks the exuding plant sap and hide inside the leaf sheaths and floral bracts. Congregation of both the nymphs and the adults can be seen inside the unopened leaves, leaf sheath, spindles, flower bracts, perianths and flower tubes of cardamom and cause damage to panicles, flowers and capsules. The nymphs and adults feed by lacerating surface tissues with the help of their rasping and sucking type of mouth parts from different plant parts and suck the exuding sap resulting in scab formation on capsules. Pest infestation on panicles results in stunted growth, and infestation on flowers leads to premature shedding of flowers. When capsules are injured, a scabby growth is formed over the capsule surface due to plant allergic reactions and the scabbed capsules become undersized, malformed and shriveled, inferior in quality and fetch very low market values. The injured

tissues form a corky layer on the capsule surface, which appear as scabs. Such capsules appear malformed, shriveled and cankerous. This condition is known as "Cardamom itch" (Josephrajkumar et al., 2007).

When the infested capsules split open, under-developed and shriveled seeds can be seen inside. The symptom is known as 'Cardamom itch' also for the reason that scab or wart is developed on the surface of the capsule. Itched capsules are inferior in quality and have no export value. The number of seeds will be lesser when compared to the healthy capsules but the qualitative analysis revealed that the essential oil content is more in the itched capsules. In case of severe infestations capsule damage of 60 to 90% occurs resulting in a crop loss of 45-48% (Gopakumar and Chandrasekar, 2002; Dharmadasa et al., 2008).

Biology

Both sexual and parthenocarpic mode of reproduction is noticed in cardamom thrips. Tiny elongated grayish brown thrips measure about 1.25 to 1.55 mm length. The adult female lays on an average of 5-31 eggs and the oviposition period extend from 4 to 25 days. Adult female thrust their eggs inside the leaf sheaths or floral parts. Nymphal emergence is within 9-12 days and the actively moving first and second instars grow by feeding on the plant sap and they undergo pre-pupation and pupation. The entire life cycle will be completed within a period of 27-30 days. Most of the population hide and breed inside the unopened leaf sheaths, spindle leaf, flower bracts and flower tubes which afford protection to these insects. Maximum population of thrips is observed during the dry summer periods starting from December to April and a drastic population decline is observed during the monsoon season.

Geographic Distribution Cardamom thrips have been reported from South India, Kerala, Sri Lanka (Ayyar and Kylasam, 1935, Dharmadasa et al., 2008) and Gautemala. It is also reported from other Zingiberaeceous plants from Hawaii (Mau and Kessing, 2007).

Host Plants Panicum longipes, Hedychium flavescens, H. coronarium, Amomum cannaecarpum, A. involucratum, Remusatia vivipara, Colocasia antiquorum, Alpinia galanga, Curcuma pseudomontana, Zingiber sp., Costus

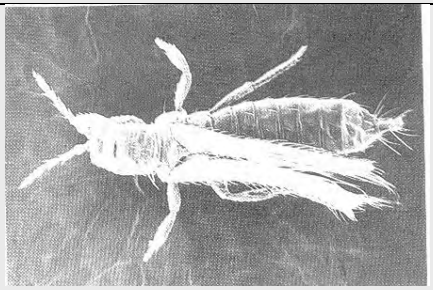
speciosus, Crinum sp. and Globa ophioglossa are noticed to be the alternate host plants for population buildup of the cardamom thrips.

Natural Enemies of Cardamom Thrips: Naturally occurring green lacewings check the population of thrips effectively. Chrysoperla eggs can be seen on capsules and other plant parts and are usually observed in plantations with less insecticidal usage. The reduviid bugs and entomopathogenic fungus, *Lecanicillium psalliotae* are effective in managing the cardamom thrips.

IPM Strategies for Cardamom Thrips

- ✓ Malabar types are relatively tolerant to thrips infestation.
- ✓ Just before the application of insecticides, during January-February, trashing, which is the practice of removal of dry drooping leaves and dry leaf sheaths, should be done. This will reduce the pest load and enhances the efficacy of the insecticides.
- ✓ All the collateral host plants such as Amomum, Alpinia, Curcuma, Colacasia present in the immediate vicinity of cardamom plantations should be destroyed.
- ✓ Spraying of insecticides should be undertaken once in 30 days, during February – May with quinalphos 25EC @ 2ml/litre, spinosad 45SC @ 3.3ml/litre, and imidacloprid 200 SL @ 0.5ml/litre. Four rounds of insecticide application at 30 days interval is recommended during August-January with quinalphos 25EC @2ml/litre or phosalone 35EC @2ml/litre, thiamethoxam 25 WG @ 0.3g/litre, and dimethoate 30EC @1.5ml/litre Application of insecticides is not advised during peak monsoon showers (June-July). No insecticide is given for two successive sprays.
- ✓ Among the bio-rationals evaluated, fish oil insecticidal soap (Na) 2.5% plus tobacco extract 2.5% reduces the damage caused by thrips, S. cardamom effectively.
- ✓ Only one-third of the plant from the base along with panicles need be sprayed for the management of thrips infestation.
- ✓ Innundative release of *Chrysoperla zastrowii Zillemi* eggs will reduce the infestation of thrips.

- ✓ Need based and judicious intervention with insecticides should be done.

	
Microscopic view of adult thrips	Thrips on under leaf sheath
	
Green cardamom capsule damaged by thrips	Corky encrustations on Pods
	
Lecanicillium applied green capsules	*Lecanicillium* applied dry capsules

(iii) Root grub

Root Grub, *Basilepta fulvicorne* (Jacoby)

Root grub is one of the most important subterranean pests of cardamom. Root grub infestation is severe in plantations having less shade. Grubs cause damage by feeding roots. Congregation of grubs which are cream colored and 'C' shaped can be seen at the root zone of cardamom clumps. Root grubs feed on roots and cause irregular patches on them. Continuous root feeding will obstruct the uptake of nutrients and as a result, yellowing of leaves is seen. During severe infestation, complete drying of leaves followed by gradual death of plant leading to yield reduction of 29-66%. Since the pest is subterranean in habitat, damage caused to roots remains unknown till the foliage show yellowing symptoms. Infestation by root grubs also facilitates the secondary infection of wound pathogen, clump rot pathogen and the incidence of clump rot is severe in root grub affected plantations Nature of Damage and Symptoms Grubs cause economic damage by feeding the roots and thereby reduce uptake of nutrients which will lead to yellowing of leaves. Grubs feed on rhizome too. Nutrient uptake is badly affected and in severe cases complete drying of leaves, wilting and death of plants occur. Population of grubs will be more in cardamom plantations with less shade. In shady area, root grub infestation is comparatively less. Adults feed on the leaves of jack, mango, guava, ficus, cocoa etc.

Biology and Bionomics

Adults are small metallic blue/green or greenish brown-coloured shiny beetles feeding on the leaves of shade trees planted in cardamom plantations. These polyphagous beetles usually emerge during March–April and August–October, with peak populations at April and September. Mating and copulation usually take place during day time and there is a pre-oviposition time of 4-6 days after which the adult females first secrete a transparent fluid on dry leaf sheaths or leaves and lay eggs in group. An adult female lays on an average of 124–393 eggs in batches of 12–63. The oviposition period extends from of 8 to 71 days. Freshly laid eggs are creamy yellow in colour and hatch after an incubation period of 13–19 days. Emerging grubs are creamy in colour which enter the soil, reach the root zone and feed on the cardamom roots (Nair, 1978; Gopakumar et

al., 1987; 1987a; 1988c; 1991). Peak population of grubs is observed during April–July and August– September until up to December–January. Grub duration will be completed within a period of 45 to 60 days and the full-grown 'C' shaped grubs are stout, undergo pupation in earthen shells and pupate for about 10-17 days. Under favourable conditions (28-30ºC), the pest will complete its life cycle within 65-102 days or otherwise it will extend up to 111 days.

Geographic Distribution Occurrence of root grub both on the nurseries and plantations of cardamom was first reported by Varadarasan et al. (1988) from Kerala, Tamil Nadu and Karnataka. In Karnataka, severe incidence of the pest was reported in the primary and secondary nurseries (Thyagaraj et al., 1991).

Alternate Host Plants Adults feed on the leaves of shade trees viz. jack (*Artocarpus heterophylla*), Indian almond (*Terminalia catapa*), mango (*Mangifera indica*), guava (*Psidium guajava*), ficus (*Ficus indica*, *F. bengalensis*), cocoa (*Theobroma cacao*), dadaps (*Erythrina lithosperma*), etc. planted in cardamom plantations.

Natural Enemies Natural Infections of entomopathogenic fungi viz. *Beauveria bassiana*, *Metarhizium anisopliae* were first reported by Varadarasan (1995). Natural infection of adult beetles with *B. bassiana* was reported by Varadasan et al. (2000). Grubs infected with Metarhizium turn green in colour and a white mycellial growth can be seen on grubs infected with *B. bassiana*. Grubs were also seen infected with the entomopathogenic nematode (EPN), *Heterorhabditis sp*. under field condition. Grubs turn brick red colour after being infected with EPN, *Heterorhabditis sp*.

Management

The mechanical collection of adult beetles using sweep net and the destruction of adult population during their peak period of emergence.

- ✓ Using light traps, mass trapping and destruction of adult beetles can be done.
- ✓ Cultivation of alternate host plants such as jack, mango, fig, dadaps, Indian badam, coca, guava etc. can be avoided in the vicinity of

cardamom plantation and these trees should not be selected as shade trees especially in the case of new plantations.

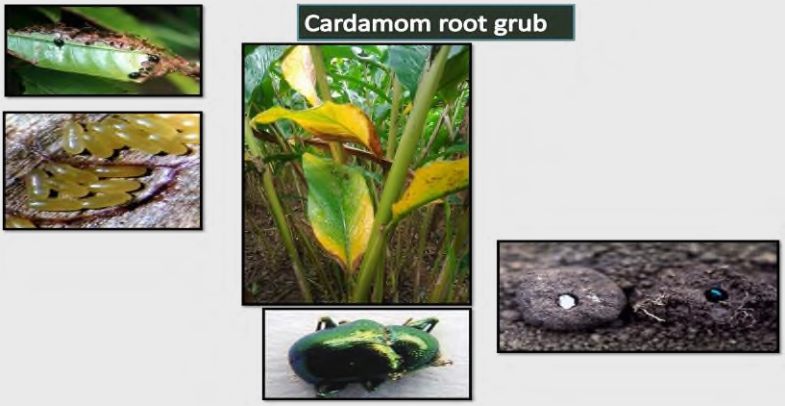
- ✓ Severe shade lopping should be avoided and 65-70% of shade should be maintained in endemic areas and the crop should be irrigated before attaining critical period.
- ✓ Raking the soil and removal of dried leaves before drenching insecticides should be done.
- ✓ Soil drenching of entomopathogenic fungi such as *Metarhizium anisopliae or B. bassiana* @ 10g/litre and 4-5 litres are needed for grown up plants.
- ✓ Soil application of entomopathogenic nematode, Heterorhabditis indica infected Galleria @ 4 cadavers per plant is very efficient in reducing the root grub incidence. The cadavers are dug in small pits very near to root zone at four directions.
- ✓ Soil drenching with chorpyriphos 20 EC @ 2ml/litre or imidacloprid 17.8 SL @0.75ml/litre @ 4-5 litres per plant is also effective in reducing the pest infestation.
- ✓ Combined application of imidacloprid and the EPN, *Hetrorhabditis indica* reduces the root grub population effectively.
- ✓ Necessary precautions should be done against clump rot fungus if both root grub and clump rot pathogens are associated in the same clump.
- ✓ Proper phosphatic nutrients (readily absorbable) are required for rejuvenation of cardamom roots under severe incidence of root grub infestation
- ✓ Soil application EPN power formulation @ 5gm per L of water in soil at the base of small cardamom plant (@5L of EPN Liquid per plant which mean two lakh to four lakh IJs of EPN) the IJs of EPN comes out from the cadaver in the soil, search for root grub and kill them. Field demonstrations of the formulation were carried out in Kerala and Around 13000 Ha small cardamom fields were applied with WP formulations of *H. indica* @ 4-5 kg/acre respectively. The technology could reduce the small cardamom root grub incidence by 62-78%. ICAR-KVK, IDUKKI has distributed, more than 11000 Kg of WP EPN formulation to the farmers for the management of root grubs in small cardamom.

Root Grubs

EPN infectedRoot Grubs

Demonstration field of EPN

EPN applied small cardamom plantation



(iv) Nematode:

Root Knot Nematodes, *Meloidogyne spp*.

Cardamom roots are seen infested with root knot nematodes and the problem is more prevalent in areas with less shade. Due to the infestation of root knot nematode, knots or galls can be seen on the roots and due to the obstruction in nutrient absorption, yellowing of leaves and stunted growth of plants happen. Narrowing of top whorls of leaves is commonly observed in the infested plants and the affected leaves turn leathery. Infested plants show excessive tillering near the root tips. Root hairs are absent in the affected roots. Root knot infestation also predisposes cardamom plants to *Rhizoctonia solani* infection leading to rhizome rot disease (Josephrajkumar et al., 2007). Incidence of lesion nematode, *Pratylenchus coffeae* and the burrowing nematode, *Radopholus similis* are noticed in mixed plantations (Ramana and Eapen, 1992).

Biology

Females of root-knot nematodes lay eggs on plant material or in soil. Temperature determines the eggs hatching without requiring stimulus from plant roots, whereas hatching sometimes encourages root diffusates. The root-knot nematode has four larval stages, J2s hatch as a vermiform second stage from the eggs. The first moult occurs inside the egg of nematodes. In the soil, freshly hatched juveniles have a short free-living stage and the host plant's rhizosphere. The juveniles enter the plant through the root tips and feed on the plant cells. The adjacent tissue of root stretches increases to a gall in which the developing juvenile is entrenched. After further feeding, the juvenile undergoes morphological changes and moult three times and finally developed into an adult. The life cycle of root-knot nematodes is 4 to 8 weeks, depending on temperatures, and an adult female may produce up to 2000 eggs.

Host range

Meloidogyne spp. have a pervasive host range, and cultivators with a root-knot nematode problem found it challenging to manage the nematode through crop rotation either due to this extensive host range [35]. Over 80 species of

Meloidogyne have been described worldwide. Three of them are incredibly polyphagous apomictic species namely, *M. incognita* (Kofoid and White) Chitwood, *M. javanica* (Treub) Chitwood, and *M. arenaria* (Neal) Chitwood (Karajeh, 2015). Species like *M. incognita*, *M. arenaria* race 1, and *M. javanica* can infect or survive on alternate hosts of the same fields. There is also a high degree of specialization of different variances in pathogenicity on the precise crop.

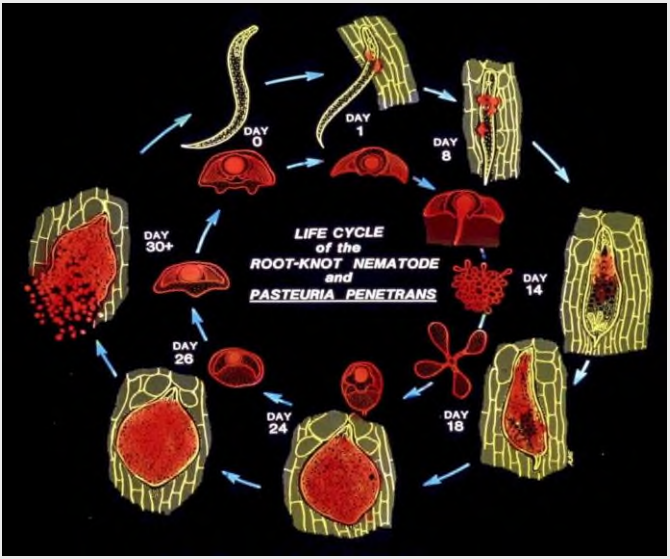
Symptomology

Root-knot nematodes are sedentary, polyphagous, and semiendo parasites. It parasitizes all higher plants and an inclusive range of products ranging up to two thousand plant species [38]. They pierce plants roam intercellularly, and developing galls on roots . In solitary cropping seasons, *Meloidogyne spp*. has many generations, and the plants are inhibited from water and nutrient uptake. They pass on a disease to various parts of plants such as taproots and tubers and lowering the economic and qualitative values of vegetable crops. Yellowing of plant leaves and stunting in growth are above-ground symptoms of root-knot nematodes. Wilting occurred due to xylem vessel blockage. The root

Management

- ✓ Shade trees such as dadaps and intercrops like banana should be avoided in cardamom plantation. Organic manures such as neem cake application @ 250-1000g twice a year reduces the nematode population drastically and increases the yield (Ali, 1985; Devasahayam et al., 2015).
- ✓ Mulching of cardamom roots with leaves of weed plants like wild sunflower, eupatorium, clerodendron etc. reduces the nematode population in soil (Mathew, 2007).
- ✓ Application of Trichoderma spp. and Paecilomyces lilacinus reduced the nematode population to a greater extent (Eapen and Venugopal, 1995).
- ✓ Improved growth and yield were observed in plants where soil application of Jeevamritha @ 10 litres/plant in combination with Azospirillum and *T. viride* (10g each) was done (Narayana et al., 2011).

- ✓ Rhizome dip treatment of cardamom clumps in 1% mixture of *Pseudomonas fluorescens* and azadirachtin solution for 10 minutes along with the application of cow dung + neem cake + marotti cake + AMF + *P. lilacinus* (90 kg: 5 kg: 2 kg: 2 kg: 1 kg) mixture @ 1 kg/pit before planting is effective in reducing the infestation (Mathew, 2007).
- ✓ Soil application of Arbuscular Mycorhizal Fungi (AMF), *Glomus fasciculatum* and *Gigaspora margarita* also effectively managed the pest in seedlings (Thomas et al., 1989).
- ✓ Soil application of P. liacinus also reduced the nematode infestation (Sheela, 2007).
- ✓ Soil application of *Paecilomyceslilacinus* strain ICAR-NBAII Plft5 (Pl55) @ 1 kg in 50 kg FYM in small cardamom and soil application of Jeevamrutha at 10 litre along with Azospirillum and ICAR-NBAIR-*Trichoderma. viride* (10g each) per plant in cardamom plantations.



Root Knot Nematode affected roots

Root Knot Nematode affected plants

Root Knot Nematode managed through ICAR-NBAIR bio-agents

V. Whitefly, *Kanakarajiella cardamom*

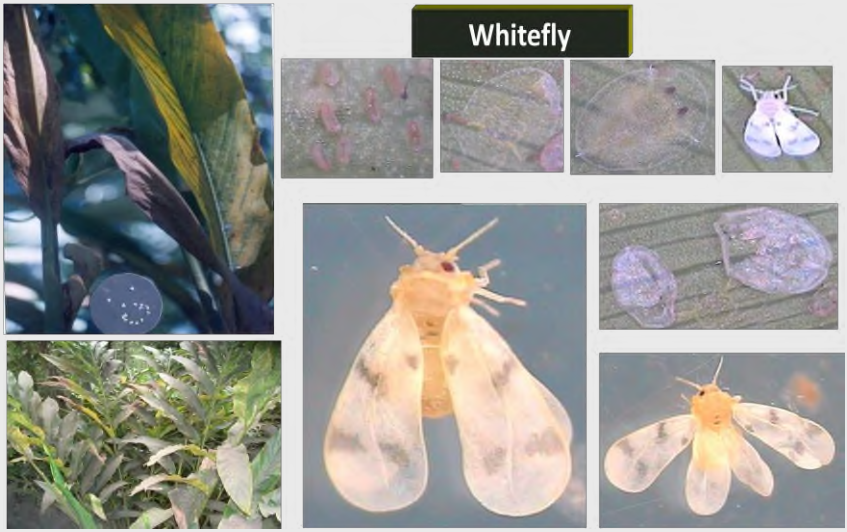
Due to the continuous use of synthetic pyrethroids and indiscriminate use of insecticides, many of the sucking pests which were minor earlier, attained major status. Reduced spraying intervals coupled with mixing of two or more insecticides, continuous spraying of the same insecticide throughout the year on the same piece of land also resulted in the outbreak of sucking pests. These practices had eliminated the natural enemies of the pest resulting in resurgence. Unusual sudden rise in temperature coupled with break in monsoon showers and

use of excessive nitrogenous fertilizers are also the reasons for the outbreak of pests like whitefly.

Nature of Damage and Symptoms

Both nymph and adults cause damage by sucking sap from the lower leaf surface. Continuous desapping results in discolouration of leaves, appearance of chlorotic patches on leaves, yellowing and in severe cases complete drying of leaves and wilting of the plant occurs. Adult are yellowish in colour and nymphs except the first instar crawlers are sessile. Nymphs secrete honeydew which is rich in nutrients and is sticky in appearance.

Honey dew exudation facilitates the growth of the blackcoloured fungus, *Capnodium sp*. (sooty mould) and because of that, black colouration can also be seen in case of severe infestation. Sooty mould formation adversely affects photosynthesis (Gopakumar et al., 1988a) Number of nymphs per square centimeter area will give an indication of the pest population and thereafter the insecticide application could be perfectly timed.



Biology and Seasonal Occurrence

The adult is a yellow-colored soft-bodied insect with two pairs of hyaline wings that are about 2 mm long. Eggs are frequently inserted into the leaf tissues by females. Adults reproduce through a combination of parthenogenetic and sexual means. Females deposit around 115 eggs, which are inserted into the stomata on the adaxial leaf surface through a short subterminal stalk (Gopakumar et al. (1988b) and Selvakumaran and Kumaresan) (1993). When eggs are first laid, they are pale yellow and darken to brown before hatching. Females are the only ones that develop from parthenogenetic eggs. The eggs are stalked, cylindrical and spiny. The first-instar crawlers have locomotory appendages and after locating the feeding site, crawlers shed them off and from second instar onwards and the nymphs are sessile. There are three nymphal stages and a pupal stage (Nair, 1978). Puparia adhere to the leaves after emergence of adults and appear as scaly patch on lower surface of the affected leaves. Life-cycle of the pest is completed within 43–60 days. The peak population of cardamom white fly was observed during February to March and declines thereafter. Whitefly incidence was positively correlated with the maximum temperature andsunshine hours whereas, negative relationship was observed with the relative humidity that is recorded in the morning hours (Sathyan et al., 2018).

Natural Enemies

Natural enemies such as predators like *Mallada bonninensis*, unidentified neuropteran, dipteran, coleopteran and mite and parasitoids such as *Encarsia septentrionalis* and *E. dialeurodes*, and a pathogen *Aschersonia placenta* (Muraleedharan, 1985; Selvakumaran and Kumaresan, 1993; Selvakumaran et al., 1996) are found effective. Josephrajkumar and Murugan (2001) reported the occurrence of an entomopathogenic fungus, *Verticillium sp*. on cardamom whitefly, *Kanakarajiella cardamomi* (David and Sundarraj, 1993).

Management

- ✓ Installation of yellow sticky traps coated with viscous castor oil in the cardamom plantations will reduce the infestation of whiteflies (Kumaresan et al., 1993).

- ✓ The traps can be placed between rows of cardamom plants or on the shade trees.
- ✓ Spraying neem oil emulsion 0.5% along with triton or sandovit 0.5% on the under surface of leaves reduces the pest incidence when the treatments are repeated at fortnightly intervals for 2-3 times.
- ✓ Use of entomopathogenic fungi such as *Aschersonia placenta*, *Verticillium sp.* is emerging as a potential alternative in whitefly management (Gopakumar and Kumaresan, 1991).
- ✓ Excessive nitrogen application leads to succulent leaves and thus increases the damage considerably. Judicious application of nitrogenous fertilizers should be ensured.
- ✓ Unnecessary and continuous use of synthetic insecticides should be avoided to reduce the pest buildup.
- ✓ In case of severe infestation, application of quinalphos 25EC @ 2ml/litre, spinosad 45SC @ 3.3ml/litre, and imidacloprid 200 SL @ 0.5ml/litreon the undersurface of the leaves is recommended. Spray fluid need not be applied on the panicles and the stem.

(vi). Root Mealybugs , *Pseudococcus sp., Xenococcus annandalei* (Silvestri)

Mealybugs infesting roots of crop plants are known as root mealybugs. Both nymphs and adults cause damage by sucking sap from the root and rootlets. Congregation of nymphs and adults are seen on the roots. Along with feeding, these mealybugs inject toxic saliva into the plant. Continuous desapping results in loss of vigor, yellowing, wilting, drying and complete death of plants. The root mealybug, Xenococcus annandalei, was first reported from Idukki district by Deepthy et al. (2017). Both nymphs and adults aggregate on the root zone and pierce the feeding roots of cardamom. Due to severe feeding injury, plants exhibit yellowing, wilting and defoliation of leaves. Cardamom plants infested by mealybug also facilitates clump rot pathogen. Ants are always seen in association with root mealybugs because of honey dew exudation. Honey dew is a rich source of nutrients, for which ants are attracted and in turn the ants provide protection to the root mealybugs. Root mealybugs are of subterranean in habitat and hence early diagnosis is very difficult, making the pest management cumbersome.

Management Continuous monitoring is needed for effective management of root mealybugs. Monitoring for the presence of ants should also be done because ants are always seen in association with root mealybugs and also help them for dispersal to other areas. Hence, ant management is also very important to reduce the pest incidence. Dispersal of ants with phoretic behaviour harboring mealybugs should be checked immediately. Soil drenching of affected plants with chlorpyriphos 0.05% @ 5-7 litres per plant is recommended. Drenching shall be repeated if the root mealybug persists. Care should be taken to ensure that the spray solution percolates down into the root zone while drenching (Josephrajkumar et al., 2007).

6. Lacewing Bug, *Stephanitis typicus* Dist.

This is the heteropteran bug with shiny transparent reticulate and lace like wings and is the only member of heteroptera producing honey dew. Both nymphs and adults suck sap from undersurface of cardamom leaves gregariously. Greyish yellow specks develop at the feeding site and in severe cases complete drying of leaves followed by retarded growth and finally the death of plant occurs. Yield is also reduced. Usually, it is a minor pest but occasionally become serious when the conditions are favourable. Honey dew exudation facilitates the sooty mould growth and results in black colouration of

the affected plant parts. Eggs are laid singly and are inserted into the lower surface of the leaves. About 30 eggs are laid by a single adult female and hatching occurs within a period of 12 days (Nair, 1978; Kumaresan, 1988). Emerging nymphs congregate on the adaxial surface of leaves and suck sap from there. Besides desapping, they also inject toxic saliva to the plant and result in necrotic spots on leaves. Besides cardamom, it also attacks banana, colocasia, coconut and turmeric.

Management Destruction and removal of alternate hosts such as banana, colacasia, turmeric etc. will reduce the pest buildup. It is also noted that pest incidence is lower in plantations with adequate shade. In case of severe pest incidence, foliar spraying with systemic insecticides viz., acephate (0.075%) or dimethoate (0.05%) is recommended (Josephrajkumar et al., 2007).

7. Coconut Scale Insect, *Aspidiotus destructor* (Sign.), Hard Scale, *Mytilaspis sp*.

Different types of scale insects are seen infesting cardamom. Usually, incidences of all types of scale insects are seen during the summer months. Coconut scale insects are creamy white circular insects seen in aggregation on

the lower surface of the leaves. The incidence is not observed on other plant parts including upper surface of leaf. Both nymph and adults ofcoconut scale, suck sap from the under surface of leaves resulting in chlorotic streaks on upper leaf surface (Josephrajkumar et al., 2007). The circular females, which cluster on the under surface of leaves, feed on the sap. As a result of continuous sap sucking, the leaves turn yellowish and in severe cases wither and dry up. In severe outbreaks, the insect multiplies with abundance, so that, it appears like a continuous yellow crust all over the underside of leaf and cause premature death of leaves by sucking the sap and obstructing the stomatal opening. Infested leaf turns yellow in colour, wither and die. Other scale insects like Aonidiella sp., Mytlaspis sp., Pulmvinaria sp. were also found feeding on cardamom leaves. The hard scale, Mytilaspis sp., infest on almost all the parts of the plant like the lower surface of the leaves, green berries and their stalks, and also on the pseudostem within the leaf sheath. Attack on berries results in shrivelling and drying of berries (Nair, 1978).

Management

- ✓ Pruning and destruction of severely affected leaves and plant parts of scale insects will reduce the pest incidence to a greater extent.

- ✓ Conservation of parasitoids and predators is very important. Predators such as *Chilocoris circumdatus, Sarajiscymnus dwipakalpa, Pseudoscymnus sp*. were found feeding on scale insects and the population of scale insects is seen reduced during monsoon period.
- ✓ Among the bio-rationals evaluated, neem formulations 0.5% and fish oil insecticidal soap (3.0%) when applied four times at fortnight intervals was found to be effective in the suppression of scale population.
- ✓ Sprayings of dimethoate 0.05% two times at fortnightly intervals were found effective in reducing the pest incidence (Josephrajkumar et al., 2007).

8. Red Spider Mite (*Tetranychus urticae* Koch)

Red coloured spider mites are also seen infesting cardamom leaves. Both nymph and adults cause damage by sucking plant sap especially from the lower leaf surface. Mites while feeding penetrates plant tissues by their needle like chelicerae and suck the exuding sap. Photosynthetic efficiency of the leaves is affected and eventually the leaves dry up and fall off. Nymph and adults have four pairs of legs while larvae have three pairs of legs. Population of spider mites can be seen on the lower leaf surface. Spider webbings can also be seen on under surface of leaves. Severe and sporadic infestation of red spider mites on cardamom leaves during summer months (February–May). Continuous feeding results in the formation of white/yellowish specks which later turn into white blotches on leaves. On severe infestation, complete drying of affected leaves can be seen. Life cycle of red spider mites is completed within 20 days (Gopakumar and Chandrasekar, 2000). Incidence of sheath mite, *Dolichotetranychus elettariae* was also reported in cardamom. Sheath mites belong to the family tenuipalpidae and are flat, elongate, pear shaped and red coloured. These mites are observed in large numbers on the inner side of the leaf sheath causing severe reddening due to feeding. In severe infestations, their presence is noted outside as rusty patches on the leaf sheath (Josephrajkumar et al., 2007).

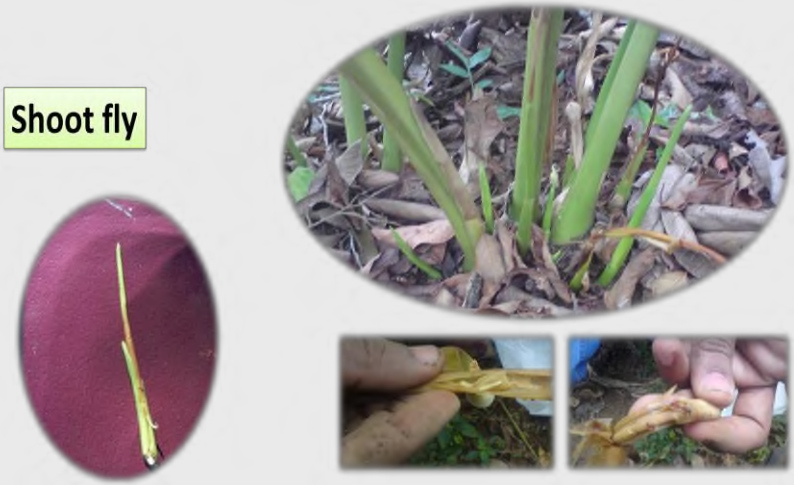
Management

- ✓ Adequate shade (50-60%) should be provided in the plantation.

- ✓ Predatory mites, Amblyseius sp. were found feeding on red spider mites of cardamom. In case of severe attack, chemicals like wettable sulphur 80 WP @ 2.5 g/litre or dimethoate 30EC @ 1.67 ml/litre or phosalone 35EC @ 1.5 ml/litre are effective against the pest (Selvan et al., 1996). Spiromesifen 22.9SC @ 8ml/10 litres is also found effective in reducing the mite infestation in cardamom.

9. Shoot fly, *Formosina flavipes (*Mall.)

Maggots cause damage by boring the central shoots of young plants, tillers and feed the internal tissues finally result in the decaying of the central spindle causing the dead heart symptom. This symptom is clearly visible from outside and the dead heart can be easily pulled out. Excessive application of nitrogenous fertilizers at the initial stages of crop growth and especially at tillering phase aggravates the incidence of shoot fly. Pest infestation is more during warm summer months infesting seedlings and young tillers under thin shade. Mature flies lay cigar shaped white eggs singly between the terminal leaf sheaths. The maggots bore into the inner whorl and cause dead hearts in young tillers. Pupation takes place within the stem at base of the plant (Nair, 1978; Josephrajkumar et al., 2007).



Management

- ✓ Excessive application of nitrogenous fertilizers should be avoided and proper shade (50-60%) should be maintained in the plantation to reduce the pest incidence. Severely infested tillers should be removed and destroyed.
- ✓ During severe incidence, dimethoate 30EC @ 1.5 ml/litre will reduce the pest infestation.

10. Aphid, *Pentalonia nigronervosa* (Coq.)

These aphids are the most important sucking pests in banana, occasionally attack cardamom, especially when there are banana plants in the vicinity of cardamom plantations. Not a major pest of concern, but acts as a vector for the katte virus. Proper management measures are to be taken immediately to control these vectors so that disease spread to other healthy plants can be avoided.

Management

Planting banana in the immediate vicinity of the plantation should be strictly avoided. If there are katte affected cardamom plants, they have to be destroyed from the field, as and when observed. Spraying dimethoate 30EC @ 1.5 ml/litre will reduce the incidence of pest.

(B) DISEASES OF SMALL CARDAMOM

FUNGAL DISEASES

Capsule rot and panicle rot, rhizome rot and Fusarium rot are the three major fungal diseases causing considerable yield reduction and crop loss in the main field.

Capsule Rot/Panicle Rot

As this disease affects the most economic part of the plant, panicle and capsule, its occurrence is critical in cardamom. The pathogen, as the name suggests, cause rotting in tender leaves, capsules and panicle. Heavy and continuous

rainfall (32-40 cm), high soil moisture (34.3- 37.6%), low temperature (20.4-21.3°C) and high relative humidity (83-91%) were the predisposing factors for the disease development (Nair and Menon, 1980). During the southwest monsoon, symptoms initiate on the young leaves as water-soaked lesions, progressing to drying and shredding along the veins. The emerging spindle leaf, if gets infected, will fail to unfold. Similar lesions also develop on capsules and progress as brown discoloration and rotting, resulting in capsule shedding within few days. Mature rotten capsules shrivel on drying with peeled off epidermis, exposing the fibrous tissues. The rotting spreads gradually to panicle, and as a result, they fail to develop and eventually dry up. Sometimes rotting symptoms occur simultaneously on capsules and leaves, otherwise first on leaves followed by capsules. The disease incidence is generally noticed in yielding plants. All the three cultivars of cardamom viz., Malabar, Mysore and Vazhukka were susceptible to the disease (Anandaraj and Bhai, 2011). In the plantations where irrigation is given throughout the year, the disease also appears in the post-monsoon period.

Causal Organism The association of *Phytophthora sp*. with the disease was reported for the first time by Menon et al. (1973). Nair (1979) isolated *P. nicotianae var. nicotinae* from the infected parts. Thomas and Bhai (1995) confirmed that the above species caused leaf rotting symptom during the post-monsoon period. The pathogen survives in the soil and plant debris as chlamydospore for up to 48 weeks (Nair, 1979). During monsoon, another sp., P. meadii, causes capsule rot and panicle rot. This species has not produced chlamydospores in moist field soils and culture media under in-vitro conditions (Thomas and Bhai, 2002).

Management:

- ✓ Since the disease is prevalent during the monsoon season, management strategies must be initiated during the pre-monsoon period. Correction of soil acidity by lime application is advocated before the onset of monsoon.
- ✓ During the pre-monsoon period, trashing and cleaning of the plant basin reduce the inoculum level both in the soil and plant parts.

- ✓ Shade regulation and phytosanitation were recommended by Peethambaran et al. (2008) as an effective management strategy. They also found a drastic reduction in the pathogen antagonist ratio when neem cake was incorporated into the soil ahead of the monsoon.
- ✓ The combined application of decomposed coffee compost and cow dung enriched with *Trichoderma harzianum* during May-June and August- September is an effective prophylactic management strategy against the disease (Devasahayam et al., 2015). Strains of *T. viride, T. harzianum and Laetisaria sp*. effective against the pathogen were identified from cardamom soils by Bhai et al. (1992). In addition to these, role of *Bacillus subtilis* in azhukal disease management was established by Thomas et al. (1991) and Bhai et al. (1993) under laboratory and field conditions, respectively. Ajay et al. (2015) found that the combined application of cashew shell extract and *T. harzianum* reduced the population of the pathogen in soil without inhibiting the bio-agent.
- ✓ Sivakumar et al. (2015) confirmed the role of defense related compounds like phenols and phenolic enzymes in disease suppression as a response to *B. subtilis* application. Dhanya et al. (2015) reported that application of 25 g each of *T. harzianum* (MTCC- 5179) and a consortium of *P. fluorescens* (IISR-6 and IISR-859) to the plant base was effective against capsule rot disease. Foliar application of 2% *P. fluorescens* at monthly interval for three times along with the single basal application of *Glomus fasciculatum* (50 g) and *T. viride* (100 g) per plant immediately after the onset of the monsoon is also effective against the disease (Dhanya et al. 2017). In hotspot areas, moderately tolerant Malabar types of cardamom (ICRI5 and ICRI6) could be recommended (Madhusoodanan, 2012).
- ✓ Prophylactic spray with 1% BM immediately after the onset of monsoon is very effective against the disease. The spray should be repeated at monthly interval for 1-3 times if the monsoon and heavy rainfall persisted (Thomas et al., 1991). Copper oxychloride (0.2%) as spray and drench was also recommended to manage the disease (Nair et al., 1982). A prophylactic spray with BM (1%) and drenching with copper oxychloride (0.2%) could be advocated during May-June and

August-September in fields where chemical control is followed (Ananandaraj and Bhai, 2011).

- ✓ Spraying and drenching with 0.3% potassium phosphonate 40% or metalaxyl 8% - mancozeb 64% WP (0.125%) were also found promising against the disease (Devasahayam et al., 2015). Three rounds of spraying with 1% BM or 0.3% fosetyl-Al 80 WP were recommended against cardamom's azhukal disease (Thomas et al., 1991). The above fungicides alternated with Ridomil MZ-72 were recommended by Anandaraj and Bhai (2011) to manage the disease. A lower dose of fosetyl- Al (0.1%) and a combination fungicide cymoxanil 8% + mancozeb 64% WP (0.2%) were proved effective against the disease (Dhanya et al., 2017).
- ✓ Soil application of peat formulation of ICAR-NBAIR-*Bacilus subtilis* strain Bs and prophylactic application of ICAR-NBAIR-*Pseudomonas fluorescens* (2% spray) along with basal application of *Glomus fasciculatum* (Arbuscular Mycorrhizal Fungi AMF) @ 50g and ICAR-NBAIR-Trichoderma. viride @ 100 g/plant at a monthly interval during the rainy season.The cost of application of ICAR-NBAIR-*Bacilus subtilis* is Rs.4400/ha as compared to regular chemical application where it costs Rs.18900/ha. Thus, it saves the cost of chemical application at the rate of Rs. 14,500 per ha and net returns gained per ha is Rs. 279000.

	
Leaf water soaked lesions and rotting	Capsules dull greenish brown and rot

Capsule Rot/Panicle Rot disease managed through ICAR-NBAIR bio-agents

(ii) Clump rot: It is otherwise called as rhizome rot occurs during monsoon period. This disease is widely distributed across cardamom growing regions in Kerala and Karnataka as well as heavy rain fall areas of Tamil Nadu such as the Anamalai hills. This disease is caused by combined infection of *Pythium vexans*, *Rhizoctonia solani* and *Fusarium sp*. Rotting symptoms develop at the collar region resulting in softening and bristling of the tissue. The tiller breaks at this point with a discolouration, and the infected tissue in the detached portion emits a foul smell. The developing tillers of the infected plants detach from their rhizome portion with a slight pull. Generally, root rotting and subsequent yellowing of plants are associated with the disease.

This disease predominated during the monsoon period and was reported for the first time by Park (1937). Rotting symptoms develop at the collar region resulting in softening and brittling of the tissue. The tiller breaks at this point with a discolouration, and the infected tissue in the detached portion emits a foul smell (Thomas and Bhai, 2002). The developing tillers of the infected plants detach from their rhizome portion with a slight pull. Generally, root rotting and subsequent yellowing of plants are associated with the disease.


Rotting at the collar region in softening and bristling of the tissue

Management

Shade regulation, phytosanitary measures and application of biocontrol agents recommended for capsule and panicle rot were effective against this disease also.

Aravind et al. (2015), identified the cardamom accession FGB 118 as a tolerant line to rhizome rot. IISR Avinash released from the Indian Institute of Spices Research, Kozhikode (Eapen and Bhai, 2012) and ICRI 2 released from the Indian Cardamom Research Institute, Myladumpara (Prasath et al., 2018) were advocated to be grown in the hotspot areas of the disease.

The endophytes AgR5A (Tulasnella sp.) isolated from Alpiniagalanga, Cb2 (Phoma sp.) isolated from the small cardamom variety Appangala 1 and AgR5d isolated from Alpiniagalanga were found to be effective against *R. solani, P. vexans and F. oxysporum* respectively (Peeran et al., 2018). Rhizome bacterization and soil application of a consortium of *P. fluorescens* (Pf5) and *B.subtilis (Bs45*) while planting cardamom suckers offered a better management strategy against the disease (Sivakumar et al., 2012).

BM 1% spray along with 0.25% COC drench as well as basal application with either 0.3% potassium phosphonate or 0.125% metalaxylmancozeb combination could be advocated in the plantations where chemical management is followed (Devasahayam et al., 2015).

Drenching soil with COC (0.2%) followed by basal application of cow dung enriched T. harzianum, P. fluorescens (4-8 kg), and Glomus fasciculatum (200 g/plant) suppressed the rot disease in cardamom (Dhanapal et al., 2012).

Soil application by a consortium of ICAR-NBAIR-*Pseudomonas fluorescens* (Pf5) and ICAR-NBAIR-*Bacilus subtilis* (Bs45) and soil application of ICAR-NBAIR-*Trichoderma harzianum* multiplied in a mixture of decomposed coffee compost and cow dung at 50g /clump during May–June and August–September. Ex-trainee of ICAR-KVK, Idukki Mr. Srinivasan from Santhanpara village in the Idukki district has been involved in the bio-control program since 2011. Approximately 5.25 hectares are cultivated by him for small cardamom. When it came to crop productivity, he previously employed more chemical herbicides and fertilizers.

Clump rot disease managed through ICAR-NBAIR bio-agents by farmer Mr. Srinivasan

(iii) Fusarium Rot:

F. oxysporum disease may become destructive at all growth stages of the crop under favourable weather conditions and can cause severe infection in this changing climate scenario. Dhanya et al. (2018) reported 50 per cent yield loss from poorly managed plants due to the disease. The pathogen survives in soil and crop residues for many years making the management of the pathogen very difficult.

The Fusarium sp. initially attacks the tiller producing pale discoloured lesions leading to dry rotting. The infected tillers are weakened at the point of attack resulting in partial breakage. These tillers bend down and hang from the point of infection (Josephrajkumar et al., 2007). Symptoms include burnt appearance of panicles and rotting of roots from the tip causing yellowing of the plant and thereby reduction in the yield (Murugan et al., 2016).

In the scenario of growing concerns over environment pollution and health hazards the need for an integrated approach in the disease management strategy is of high importance. The integrated disease management using various bio-control agents and bio inputs improved the vegetative growth and the yield of the plant in addition to disease management of Fusarium rot of cardamom (Dhanya et al., 2018). The farmers are also adopting integrated approaches by using combinations of bioagents and organic inputs for combating various diseases.This disease is also called as stem rot or stems lodging, normally appears during post - monsoon period. The disease was first reported in the cardamom plantations of Idukki district. This disease caused by a fungus "*Fusarium oxysporum*". The pathogen usually attacks middle portion of the tillers and produces a pale discoloured lesion leading to dry rotting. The infected tillers are weakened at the point of infection and leads to partial breakage of the tillers. The partially broken tillers bend down and hang from the point of infection. The infected tillers fall off and give lodged appearance if the infection occurs at lower part of the tillers.

	
Pseudo stem rot	Tillers bend down and hang

	
Panicle blight	Wilting symptoms

Causal Organism

Fusarium oxysporum Scheldt was identified as the causal organism of this disease (Thomas and Vijayan 2002).

Management

- ✓ Vijayan et al. (2012) reported good management of Fusarium infection with less pathogen- antagonist ratio in fields treated with bioagents like *T. harzianum and P. fluorescens*. In addition to these, the role of *T. viride and B. subtilis* against the disease was studied by Thomas and Vijayan (2002).
- ✓ Prophylactic application of two percent *P. fluorescens* in cowdung slurry as spray and drench or single basal application of *T. viride* (100g) and *G. fasciculatum* (50g) per plant along with two percent *P. fluorescens* spray at monthly intervals during summer months were effective in eradicating the disease (Dhanya et al., 2018).
- ✓ Covering exposed cardamom roots with soil during post-monsoon period, mulching and providing sufficient irrigation and shade in the plantation minimize the disease incidence in the field.
- ✓ Trashing and cleaning of plant base before the onset of monsoon is also recommended to manage the disease. *T. harzianum* or *P. fluorescens*,

mass multiplied on suitable carrier media may alternatively be applied to the plant basins @ 1-5 kg depending on the size of the clump during May-June and September-October (Vijayan et al., 2012). They also recommended basal application of copper oxychloride (0.2%) during August- September as a prophylactic measure against the pathogen. Vijayan et al. (2009) found that three rounds of aerial spray and basal application of carbendazim 50 WP (0.2 percent) or thiophanate methyl 70% WP (0.2 percent) were effective against the disease.

- ✓ The combination fungicide captan 70%+hexaconazole 5% WP @ 0.2 percent could be used as a curative method in already infected plantations. (Dhanya et al., 2018).
- ✓ Soil application of vermiculate based AMF inoculum (20 g) with 2 per cent P. fluorescens (1L/10 kg soil) per 10 kg soil at the time of planting along with 2 per cent P. fluorescens spray at 0.5 L per plant at monthly interval for three times; this treatment also resulted in good vegetative growth of cardamom plants therefore this can be used as an eco-friendly management strategy for the production of good quality cardamom.
- ✓ Prophylactic application of 2% ICAR-NBAIR-*Pseudomonas fluorescens* (Pf5) in cowdung slurry as spray and drench or single basal application of ICAR-NBAIR-*Trichoderma harzianum* (100g) and *Glomus*. *fasciculatum* (50g) per plant along with 2% ICAR-NBAIR-*Pseudomonas fluorescens* (Pf5) and ICAR-NBAIR-*Bacilus. subtilis* (Bs45) spray at monthly intervals during summer months. Ex-trainee of ICAR-KVK, Idukki Mr. Manikandan belonging to Senapathy village in Idukki district has four acres of land and is cultivating small cardamom. Fusarium disease was affected by the Disease Intensity (DI) level in his farm and he attempted to suppress the disease below DI level through numerous fungicides, but no avail. From 2016 until now, he has been connected to the KVK and adopted ICAR-NBAIR technology. As a result, he controlled the disease and saves his annual cost of cultivation of Rs. 150000. He now harvests good produce on his farm to the extent possible.

Fusarium rot disease managed through ICAR-NBAIR bio-agents by farmer Mr. Manikandan

FOLIAR DISEASES

1.**Chenthal**

Govindaraju et al., (1996) identified the causal agent of the disease as *Colletotrichum gloeosporioides*. According to Bhai et al. (1988) the pathogen resembles *C. gloeosporioides* causing anthracnose in cardamom capsules. The disease is prevalent in lower plantations with minimum shade.

Symptoms

Infection is generally seen during post monsoon period and becomes severe during the summer months. Symptoms initiate on the older and middle-aged leaves as water-soaked rectangular lesions, which later elongate to form parallelly arranged streaks of yellowish-brown to orange red in color. The central portion of the lesions appears necrotic. In advanced stages adjacent lesions coalesce to give a burnt appearance to the leaves. Generally, the infection is not seen on younger leaves (Thomas and Bhai, 2002).

Management

Shade regulation in plantations need to be carried out before the south west monsoon (Mathew, 2007). About 50% shade should be allowed in the plantation

to prevent the disease incidence. Endophytic fungi (AsuPe1) isolated from Amomum subulatum was found effective against the pathogen by Peeran et al. (2018). Cardamom accessions, CL- 736 and CL- 726 were identified as tolerant lines, whereas CL- 722, CL- 726 and Mudigere- 3 were reported to have moderate disease tolerance against cardamom leaf blight (Manju et al., 2014).Carbendazim 50 WP (0.2%) spray significantly managed the disease spread in the field (Murugan et al. 2016). Foliar spray with 0.1% hexaconazole and basal application of T. harzianum could also be advocated for the management of the disease (Devasahayam et al., 2015).

2.Leaf Blotch

Agnihothrudu (1968) reported this disease in cardamom for the first time. It is caused by Phaeodactylium venkatesanum. Symptoms usually appear during the post monsoon period especially in heavy shaded plantations. Continuous rainfall, high atmospheric humidity and thick shade are the predisposing factors of the disease.

Symptoms

Water-soaked lesions develop generally at the midrib region of middle and older leaves. They increase in size and become dark brown with a necrotic centre. Dark and pale brown zonation can be seen on the upper side of the blotched leaf, while powdery growth develops on the necrotic area especially on the underside of the leaf.

Management

Ali (1982) recommended COC (0.2%) and BM (1%) as effective fungicides against the pathogen.

3.Sooty Mold

This disease was reported for the first time by Nair (1979). The pathogen associated was identified as *Trichosporiopsis sp*. (Thomas and Bhai 2002). Cardamom plants growing under shade trees get covered by a sooty growth. The exudates of sucking pests harbor in the shade trees, promoting the growth of the

fungus. Since the leaf is completely covered by the pathogen,the plant's photosynthetic efficiency gets reduced which indirectly affects the crop yield.

Management

Foliar spray with 5% starch solution containing neem-based insecticide @ 3 ml/litre at 2-3 days interval for two weeks effectively manage the disease.

4.Cercospora Leafspot

The causal agent was identified as *Cercospora zingiberi Togashikatsaki* (Thomas and Bhai, 2002). Rectangular and parallelly arranged lesions with dark brown margin and white center develop along the leaf veins. They became greyish brown in color and dry off in the advanced stages.

Management

Malabar type cardamom is susceptible to the disease compared to Mysore type (Naidu, 1978).

5. Neopestalotiopsis Leaf Blight

Biju et al. (2018) reported the association of *Neopestalotiopsis clavispora* with leaf blight disease in cardamom. The production of brownish streaks with a yellow halo that eventually becomes brownish with wide coalition spreading towards the proximal and distal ends of leaves, leading to foliar blight, are the most common symptoms.

During the monsoon (June to September), the intensity of infection is relatively low, and it peaks during the post-monsoon period.Management In an in vitro investigation, carbendazim 50 WP, propiconazole, and a carbendazim-mancozeb combination fungicide totally reduced N. clavispora hyphal growth. The Bordeaux mixture, a commonly recommended fungicide for cardamom foliar infections, was shown to be less effective at the recommended amount (Biju et al., 2018). Fenamidoneand mancozeb were identified to be promising among the other molecules.

6.Leaf Rust

This disease is prevalent during post monsoon period and was reported for the first time by Thirumalacher (1943). The causal agent is Phakospora elettariae (Racib.) Symptoms Symptoms develop as yellowish rust like pustules that protrude out from the under surface of leaves. The corresponding upper surface of the leaves turned yellow and gradually dried off.

Management

Mancozeb 75% WP @ 0.2 percent is effective where chemical management is advocated (Thomas and Bhai, 2002). Darluca filum (Biv) Cast was identified as a hyperparasite of rust fungi. This mycoparasite produce dark brown to black pycnidia within the uredospores of rust fungi. The parasitized uredospores shrivelled and did not germinate (Naidu, 1978).

NEW FUNGAL PATHOGENS

1. Phoma sp.

A new fungal pathogen was isolated from cardamom plants grown in various parts of cardamom hill reserves of Idukki district, Kerala. Longitudinal sunken lesions of varying length (cm to inches) and colors (yellow to reddish-brown) were produced on the tillers by the fungus (Dhanya et al., 2021). The symptoms are mostly seen on the middle portion of the pseudostem, but sometimes they extend throughout the length of the tiller. In few plants, lesions develop at the base of the leaf petiole and later spread along the tiller. As the disease progresses, the center portion of the lesion turns cream in color with a reddish-brown margin. The infection gradually spreads to the inner sheaths, and the infected sheath slowly separates and sometimes split open longitudinally. In the advanced stages, the plant breaks at the point of infection. A few plants also showed infection in the panicle as rotting of raceme. The foliar infection associated with the disease initiates as brown spots of varying size on the leaf lamina. Later, the central portions of these lesions turn greyish brown. When spots coalesce, a considerable portion of the leaf lamina get blighted and dried up. Isolation of the pathogen was carried out from the infected plant parts

collected from various plantations following the standard protocol (Nelson et al., 1983). After 2-3 days, white to mouse black, floccose colonies with fuscus black colour on the reverse side was developed on the media. Hyphae were olivaceous to dark brown, thick, constricted near septa, branched, septate and upto 8.5 µm wide. Fruiting bodies or conidiomata were found globose to subglobose, oval and brown. Thick-walled brown chlamydospores were formed in chains. Conidia were seen as cylindrical, hyaline, smooth-walled, aseptate, up to 3.72-5.77 x 1.5-2.5 µm size. Based on the morphological, microscopical and molecular analysis, the pathogen was identified as Phoma sp. (NCBI Accession No. MN962956), Dhanya et al. (2021)

Management

Fungicides under triazole group like propiconazole 25 EC (0.1%) and hexaconazole 5 SC (0.1%) and the combination products viz., captan 70 + hexaconazole 5 WP (0.05%) and propiconazole 13.9+ difenoconazole 13.9 WP (0.1%) showed complete inhibition in the growth of Phoma sp.in an in vitro study. Minimum inhibition (less than 45%) was observed when the pathogen was grown in potassium phosphonate (0.3%) amended medium. The bioagent Trichoderma sp. showed more than 55 per cent inhibition of mycelial growth (Dhanya et al., 2021).

2.Sarocladium kiliense

Recently, cardamom plants in a few plantations of the CHR showed severe splitting and separation of the sheaths of pseudostem. One more fungus was isolated along with Phoma sp. from these infected plants. On the PDA media, pure white, puffy and floccose mycelial growth with cream colour on the reverse side was developed. Conidiophores were erect, simple, hyaline and smooth-walled. Phialides were produced laterally from superficial hyphae with clamp connections, and they were hyaline, solitary, slender and smooth-walled with a size of 26.75-37.95 x 2.0-3.95 µm. Globose gleosporic mass of conidia was present on the tip of the phialides. Conidia produced were cylindrical to bacilliform with a slight curve and had a size of 5 x 1.5 µm. Morphology and microscopical characters of the fungus showed affinity to Sarocladium bacillisporum. When molecular characterization of ITS- rDNA was carried out

using primers ITS 4 & ITS 5, the tested fungal strain showed 100 percent sequence similarity with Sarocladium sp. while the MycoBank database search showed 97.9 percent similarity with Sarocladium kiliense (NCBI Accession no. MN962925). When artificial inoculation was given with the pure culture of the pathogen on cardamom tillers, it produced dark brown discoloration on the outer sheath. However, its individual role in a serious disease outbreak is not established. But it was observed that the association of this fungus with Phoma sp. aggravates the splitting symptoms in tillers.

Management

While growing S. kiliense on fungicide amended media, growth inhibition of the fungus ranged from 58.52 to 100 per cent. Cent per cent inhibition of the fungal growth was noticed for systemic fungicides like carbendazim 50 WP (0.1%), propiconazole 25EC (0.1%), and hexaconazole 5 SC (0.1%), contact fungicides like mancozeb 75 WP (0.2%) as well as the combination products like captan 70+ hexaconazole 5 WP (0.05%) and propiconazole 13.9+ difenoconazole13.9 WP (0.1%). The least inhibition (58.52%) was recorded when the fungus was grown in Potassium phosphonate (0.3%) amended medium. Dual culture study with S. kiliense and Trichoderma sp. showed more than 79 per cent inhibition of the pathogen (Dhanya et al., 2021).

3.Marasmiellus sp.

Plantations of Kattappana, Nedumkandam, and Adimali blocks of Idukki district, Kerala, showed a new disease incidence on the tillers of cardamom. Symptoms developed as water-soaked lesions on the outer sheath of the pseudostem, and later enlarged into rotten areas with dark brown margin. The pathogen's presence was detected as white mycelial growth within the outer sheath. The fungal growth slowly progressed to the inner sheaths resulting in drying and death of the plant. It was observed that the infection aggravated during wet, humid conditions. On isolation, fluffy white colonies of the fungus were developed on the artificial media (PDA media), which later turned to a cream colour. It covered the Petri plate within 4-5 days after incubation. Microscopic studies revealed that the fungus was a non-sporulating type with branched hyaline hyphae. Therefore, the identity of the fungus was later

confirmed using sequencing of ITS region (partial) and was identified as Marasmiellus sp. with BLAST analysis (NCBI Accession no. MN962926).

Management In an in vitro study, cent per cent inhibition for mycelial growth of Marasmellius sp. was shown by contact fungicides like mancozeb 75 WP (0.3%) and copper oxychloride 50 WP (0.2%) as well as systemic fungicides such as propiconazole 25 EC (0.1%) and hexaconazole 5 SC (0.1%) and combination products viz., propiconazole 13.9+ difenoconazole 13.9 WP (0.1%) and captan 70+ hexaconazole 5 WP (0.05%). Least inhibition (39.26%) was observed when the pathogen was grown in Potassium phosphonate (0.3%) amended media. The results of the dual culture study of Marasmiellus sp. with Trichoderma sp. showed more than 55 per cent inhibition in the mycelial growth of the pathogen (Dhanya et al., 2021).

BACTERIAL DISEASES

Bacterial Wilt

This disease was reported for the first time by Kumar et al. (2012). The bacterial infection resulted in wilting of plants with rolling and upward curling of all leaves towards the midrib. Infected leaves finally turn yellow, and the whole plant dies. The collar region of the affected plant develops water-soaked lesions, which gradually turn into dark brown lesions.

Causal Organism The pathogen-associated with the disease was identified as *Ralstonia solanacearum* based on morphological characters and molecular characterization (Kumar et al., 2012).

Management Field sanitation is recommended as a management strategy against the disease.

VIRAL DISEASES

1.**Mosaic/ Katte Disease of Cardamom**

Mosaic, commonly known as ‘katte’ in Karnataka and Marble in the Annamalais, is the most important disease in cardamom causing a devastating

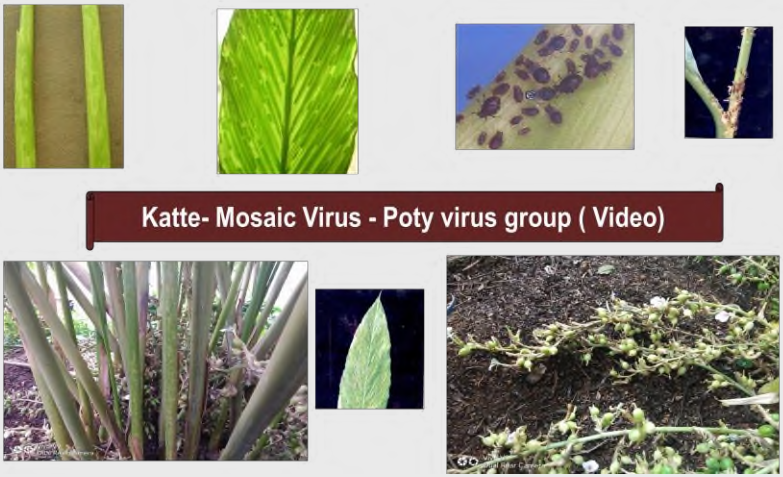
loss in yields and rapid decline of cardamom in Guatemala, India and Srilanka (Uppal et al. 1945). In India, katte is widely distributed in almost all cardamom growing tracts causing extensive damage and yield loss. The extent of damage varies extensively. Plants infected with katte for more than 3-5 years becomes commercially useless if the garden is not properly managed. Varma (1962) estimated a loss in yield due to katte as 10-68% in the first year, 26-92% in the second year and 82-98% in the third year of yielding, respectively.

Symptoms

Plants of all stages are found to be susceptible to virus infection. The disease initially appears on young leaves as general chlorosis of the entire blade. The leaves show slender, interrupted parallel streaks of pale green tissues running along the veins from the midrib to the margin. In the advanced stage of infection, the streaks of green tissue will be evenly distributed, showing a characteristic mosaic pattern. Diseased plants can be distinguished easily from a distance due to their pale appearance. Mosaic symptoms can also be seen on the leaf sheaths, and the infection causes the pseudostem to become stunted and the leaves to get smaller. The flowers do not exhibit any symptom. If the infection occurs in the seedling stage, it will not bear flowers and fruits. If mature plants are infected, the plants produce fewer and shorter pseudostem, and their bearing capacity gradually get declined. The rhizomes shrivel over time and the entire clump dies and will become useless.

Causal Organism The virus causing Katte has been identified as Cardamom mosaic virus (CdMV) belonging to the genus Maclura virus and Family– Potyviridae, based on the nucleotide sequence of the coat protein (CP) gene and 3' untranslated region (3' UTR), (Jacob & Usha 2001). Serologically the virus is related to Papaya ringspot virus, Zucchini yellow mosaic virus, Cowpea aphid-borne mosaic virus and Bean common mosaic virus. A comparative analysis of six symptomatologically distinct CdMV isolates representing different agro-ecological regions based on coat protein gene sequences showed that the coat protein sequences among isolates ranged from 74.8% to 99.3% 80.9% to 99.2% at nucleotide and amino acid levels.

Transmission The disease is not seed transmitted but can be transmitted through infected clones, and it adversely affects the germination of seeds. Uppal et al. (1945) first reported the transmission of katte disease by the banana aphid, Pentalonia nigronervosa. The disease symptom appears within 21-46 days after transmission of the virus to healthy plants by the vector. Aphids can transmit the disease at all stages of growth except very young seedling. The young plants in the nursery escape infection as alate insects are unable to colonize on them. Thirteen aphid species are reported to transmit the disease. Nymphal and adult stages can transmit the disease



2. Chlorotic Streak

Chlorotic streak disease is prevalent in the cardamom growing tracts of Kerala and Karnataka. Disease incidence of 0-15% was observed in a survey of cardamom plantations at 49 locations in Kerala, Karnataka and Tamil Nadu and the highest incidence of the disease was seen in Wayanad (Siljo et al. 2012).

Symptoms

Symptoms of chlorotic streak include continuous or discontinuous spindle-shaped yellow or light green intravenous streaks along the veins and midrib.

Since the characteristic symptom is intravenous chlorotic streaks, the disease is called ‘chlorotic streak’. The streaks later coalesce together and give yellow or light green colour to veins. Discontinuous spindle-shaped mottling is seen on the pseudostem and petioles. In the case of severe infection, the tillering is reduced. Plants of all stages are susceptible to virus infection, and the infection is systemic (Murugan et al., 2016).

Causal Organism The virus causing chlorotic streak belongs to the potyvirus genus and is closely related to the BBrMV banana isolate from India. Phylogenetic analysis also reveals that BBrMV-Cardamom isolate closely related to other BBrMV isolates (Bhai et al., 2018). The disease transmission is through infected planting materials. A simple, sensitive and rapid assay based on reverse transcription loop-mediated isothermal amplification (RT-LAMP) was reported to detect the BBrMV infecting cardamom (Siljo & Bhat 2014). One-step real-time RT-PCR based on SYBR Green was also reported for the detection of BBrMV (Siljo et al., 2014). The sensitivity of the assay was estimated to be 10 copies which were 1000 times higher than the conventional RT-PCR.

PHYTOPLASMA IN CARDAMOM

Phytoplasma association with small cardamom was first reported by Swarup et al., 2019. Symptoms of phytoplasma infection include excessive shoot proliferation with reduced panicle without capsules. Disease incidence of 20–30% was observed in Njallani variety of cardamom in Idukki district of Kerala. The phytoplasma was identified as 'Candidatus phytoplasma Australasia'-related strain. The detection of phytoplasma was done using PCR utilizing universal phytoplasma 16S ribosomal-specific primers pair, P1/P7 followed by R16F2n/R16R2. Sequence comparison analysis of the R16F2n/R16R2 region of 16SrRNA gene showed 100% sequence identity with the 'Candidatus Phytoplasma australasia'- related strain. The multilocus gene sequence comparison analysis further confirmed the association of 'Ca. P. australasia' with the ECSP (Elettaria cardamomum shoot proliferation) phytoplasma isolate.

INTEGRATED MANAGEMENT OF VIRAL DISEASES OF CARDAMOM

Production and Use of Virus Free Planting Material

The production and use of virus-free planting materials are required for integrated disease control of cardamom viral infections. It prevents disease from

spreading into disease-free areas. Even in endemic locations, largescale multiplication and planting of disease-free planting material is critical for controlling viral infections of cardamom. To combat the disease in nurseries and plantations, several strategies have been developed and recommended. Cardamom seedlings are routinely cultivated in the same nursery site near to the plantations that are most likely affected due to a variety of infrastructure restrictions. Because the nursery site is close to the concentrated viral source and 18-month-old seedlings are used for planting, there is prolonged virus infection exposure, and the virus infection occurs in the nursery stage. As a result, nurseries should be located in remote areas, and nucleus planting material should come from disease-free plantations (Venugopal, 1995). For Cardamom mosaic virus, an isolation distance of 200 m from virus sources is adequate. To avoid aphid infestation, set up a nursery about 500 metres away from the main crop. Every month, especially during the wet season, monitor the plantation and carefully identify unhealthy plants, uprooting and destroying them as needed. Before harvesting, the plantation must also be thoroughly investigated for the presence of sick plants. Because disease could be spread by the sap, the knife and other tools used for this purpose should not be used on healthy plants. Before harvesting or cleaning the healthy plants, soak the instruments in hot water for half an hour to kill the inoculum.

Early Detection For evolving a better management strategy, early detection of plant viruses, even at the asymptomatic incubation stage plays a significant role. Both serological and molecular detection methods were found effective in early diagnosis. Saigopal et al. (1992) reported early detection of the virus in the plant parts even before symptom expression with ELISA. ELISA was also used to detect the virus in viruliferous aphids. Virus indexing of the primary cultures after the in-vitro multiplication for the development of virus-free planting material was also performed using ELISA. Hence it can be used for rapid field diagnosis of mosaic infection and can be used extensively in virus control programmes (Gonsalves et al., 1986). Nucleic acid-based techniques such as RT-PCR, real-time RT-PCR and RT-LAMP can also be used to identify disease-free healthy mother genotypes for subsequent propagation (Biju et al., 2010; Siljo & Bhat, 2014; Siljo et al., 2014).

Avoidance of Volunteers Volunteers grown from the remains of sick plants could be as possible major sources of the viruses, facilitating disease spread in the plantations (Naidu and Venugopal, 1987). In the nurseries raised by volunteers, about 28% of infection was detected. So, for the production of virus-free planting materials, rouging and destruction of volunteers, as well as their entire removal in nurseries and hot spots, is required. Regular monitoring, tracing, and destruction of affected plants and collateral hosts such as Colocasia, Caladium, and Zingiberaceae family host plants, which may act as vector breeding sites, are also important in managing viral diseases cardamom.Movement of Planting Material

To prevent the introduction/reintroduction of viruses, increase awareness and prevent the transportation of diseased planting material.

Vector Management

Due to the nonpersistent or semi-persistent modes of virus transmission through vectors, chemical control techniques are deemed inefficient in managing viral diseases (Venugopal 2002). Spraying insecticides after trashing boosts the efficacy of the application and controls the vector to a greater extent.Use of Bio-Pesticides many plant extracts have been proven to be useful in lowering the aphid vector's breeding potential. Even at 0.1 percent concentrations, neem products greatly reduced the number of aphids on cardamom leaves, and at greater concentrations, they were lethal to aphids (Mathew et al., 1997). The settling percentage of aphids on leaves was lowered by aqueous extracts of *Acorus calamus* L. (dry rhizome), *Annona squamosa* L. (seeds), and *Lawsonia inermis* L. (leaves). Aphids are killed by the vapours of A. calamus, which are very poisonous. Turmeric essential oil (Curcuma longa L.) was also discovered to be aphid repellent (Saju et al., 1998). *Beauvaria bassiana*, an entomophagous fungus, has shown promise for reducing aphid populations (Mathew et al., 1998). It is the most effective bio-control agent, killing 96.6 and 75.4 percent of adults and nymphs, respectively. Due to the infection of *Verticillium intertextum*, the number of cardamom aphids is substantially reduced during the wet season (Deshpande et al. 1972). Mathew (2007) also reported the beneficial effect of *B. bassiana and L. lecanii* @ 2% on the control of vectors. Natural enemies such as *Peragum indica*, *Cocinella transversalis*, and Ischiodon

scutellaris were also observed to predate over the cardamom aphids (Gopakumar and Chandrasekar, 2002).

Resistant Cultivars

IISR Vijetha and IISR-Appangala-2 were suitable for mosaic affected areas of Karnataka, (Babu. 2018).

NATURAL FARMING: A WAY TO FORWARD SUSTAINABLE AGRICULTURE IN SPICES CROP

Introduction to Natural Farming:

Natural Farming is a chemical-free alias traditional Indian farming practice. It is considered as agro ecology based diversified farming system which integrates crops, trees and livestock with functional biodiversity that largely depends on use of on-farm biomass recycling with major stress on biomass mulching, on-farm production of cow dung urine based formulations for maintaining soil fertility as well as crop protection etc.Natural farming is a system where the laws of nature are applied to agricultural practices. This method works along with the natural biodiversity of each farmed area, encouraging the complexity of living organisms, both plants, and animals that shape each particular ecosystem to thrive along with food plants. Natural Farming builds on natural or ecological processes that exist in or around farms.

Need of natural farming:

In the green revolution era, the use of high yielding varieties, chemical fertilizers, synthetic insecticides were used extensively to increase the productivity of spices and plantation crops in Kerala. High yielding varieties were responsive to high inputs. Moreover, the argument behind using pesticides is that with the intensive agriculture, the problems of insect pests, and diseases are taking complex shape and posing serious challenges, which have to be dealt with by using synthetic pesticides. So, the use of pesticides during last few decades has emerged as one of the essential agro-inputs to increase crop yields. But scientific surveys and evidences indicate a number of hazards associated with the use of such chemicals. Further, injudicious use leads to resistance in

pests and pathogens, killing of various beneficial organisms like fishes, birds, wildlife, pollinators and microbes, poisoning to agricultural farm workers who are associated with application and spraying of chemicals on different crops, contamination of soil, air, surface and ground water, biomagnifications of toxicants in food chains, residues in food and feed stuff and much more. To overcome the noxious effects of chemical based farming, a more sustainable farming system is required which can reduce the dependence on external inputs and simultaneously take care of the ill effects of pesticides and enhance farm income. Natural farming as suggested by Shri Subhash Palekar is a viable and sustainable alternative. The idea is to let nature play a dominant role to the maximum extent possible. Natural farming has been accepted as a state policy in Himachal Pradesh and by 2022, the state government is contemplating to cover all 9.61 lakh families of farmers under natural farming. The pests on plants are managed by the farmers with natural products prepared easily by them from local resources at almost negligible or very less cost. Palekar has detailed the procedures of preparation and application of these man-made concoctions of natural pesticides. As per Palekar, these naturally prepared mixtures or astras will protect the crop from insect-pests and diseases and also simultaneously take care of toxic effects of pesticides.The two-way strategy recommended for crop protection by Palekar involves seed treatment for initial protection of the crop and sprays of natural inputs either preventive or curative.

Major Objectives of Natural Farming:

- ✓ Preservation of natural flora and fauna
- ✓ Restoration of Soil fertility through promotion of nutrient recycling
- ✓ Maintaining diversity of crop production
- ✓ Efficient utilization of natural resources (Soil, air, water)
- ✓ Promotion of local breeds of Livestock integration
- ✓ Use of on farm produced Natural inputs
- ✓ Reduce input cost of agricultural production
- ✓ Improve economy of farmers

Principles of Natural Farming:

- ✓ A healthy soil micro biome is critical for optimal soil health and plant health, and thereby animal health and human health.
- ✓ Soil may be covered with crops for maximum period of the year.
- ✓ The soil across a farm or larger field/collection of fields should have diverse crops, a minimum of 8 crops over the year. The greater the diversity, the better.
- ✓ Minimal disturbance of soils is critical, hence no till farming or shallow tillage is recommended.
- ✓ Animals should be incorporated into farming. Integrated farming systems are critical for promoting Natural farming.
- ✓ Healthy soil micro biome is the key to retaining and enhancing soil organic matter. Bio stimulants are necessary to promote the process of nutrient recycling in soil. There are different ways of making bio stimulants. In India, the most popular bio-stimulants are based on fermentation of animal dung and urine, and uncontaminated soil.
- ✓ Increasing the amount and diversity of organic residues returned to the soil is very important. These include crop residues, cow-dung, compost, etc.
- ✓ Pest management should be done through better agronomic practices (as enshrined in Integrated Pest management) and through botanical pesticides (only when necessary).
- ✓ Use of synthetic fertilizers and other biocides is harmful to this process of regeneration and is not allowed.

Natural Farming for Spices crop

Natural Farming is a chemical-free alias traditional Indian farming practice. It is considered as agro ecology based diversified farming system which integrates crops, trees and livestock with functional biodiversity that largely depends on use of on-farm biomass recycling with major stress on biomass mulching, on-farm production of cow dung urine based formulations for maintaining soil fertility as well as crop protection etc.

As in natural farming management use of synthetic chemicals are prohibited, the pest management is done by cultural or agronomic, mechanical, biological or by naturally accepted botanical extract. In natural farming mainly use Neem, cow

urine, fermented curd water, dashparni extract, neem-cow urine extract, mix leaves extract and chilli-garlic extract etc. can be used in the management of pests.

1.Beejamrita (Seed treatment):

Most of the diseases, insect-pest infestation and other disorders in plants are seed and soil-borne. So, it is important to treat seeds, seedlings or other planting material with beejamrita before sowing to prevent seed and soil-borne diseases and insect-pest infestation in plants.

Method of preparation:

1. Fill a plastic tub with 20 litres water and then slowly add the above mentioned ingredients.

2. Stir the solution for 2-3 minutes with a wooden stick in clockwise direction.

3. Cover the solution with jute bag and keep it overnight.

4. In the morning, stir the solution once again for 2-3 minutes in clockwise direction. Beejamrita is ready to use.

Method of treatment:

1. Treat the seed or planting material before sowing with 200ml beejamrita per kg seed. Spread the seeds of selected crop on a tarpaulin sheet and sprinkle the beejamrita on the seeds to make them properly wet.

2. In case of vegetative propagating crops, put tubers/rhizomes/sets/grafts of selected crop in a bamboo basket and dip the basket in a tub containing beejamrita for 15-20 seconds for treatment.

3. Dry the seeds in shade and use for sowing the next day.

Precautions:

1. Use the prepared beejamrita solution for treatment of planting material within 2 days. Discard the left over solution after 2 days.

Benefits of beejamrita:

1. Use of beejamrita increase germination capacity of seeds.

2. It leads to uniform growth of seedlings and faster development of roots

3. Plants remain free from seed and soil borne diseases, insect-pests and other disorders.

4. Plants show enhanced tolerance to adverse climatic conditions like low and high temperature, rainfall, hails etc.

5. Plants show increased resistance against insect-pests and diseases throughout their growth period.

2. Jeevamrutham:

Jeevamrutham is an organic fertilizer and a great replacement of chemical fertilizers. It is a very good source of biomass, natural carbon, nitrogen, phosphorous, calcium and other nutrients which are essential for plant growth and development. The microorganisms which are present in the soil are responsible for increasing the fertility of the soil and the productivity of the crops. In order to increase the microorganisms in the soil Jeevamrutham is used. Jeevamrutham enhances microbial activity in soil and helps in improvement of soil fertility

Introduction

Jeevamrutham is moderate green in colour with mild foul odour and with progression in storage period it attains darker in colour with strong foul odour. Jeevamrutham is made of two words – Jeeva and Amrutham .Both are derived from Sanskrit. The word “Jeeva” means a living being and “Amrutham” means the elixir (medicine) upto extending life. According to

agricultural view, Jeevamrutham is for crop life. It is the best culture to increase the count of microorganisms. Jeeamrut, is a microbial culture, mainly prepared from cow dung and cow urine generally used in organic farming to meet the nutritional requirement of crops. Jeevamrut can be used in many spice crops like. The freshly prepared Jeevamrutham was acidic in nature with a pH of 5.63. The EC (Electrical Conductivity) of Jeevamrutham was 0.23 dS m- and the calcium content (66.4 ppm) was recorded in fresh preparation.

Types of Jeevamrutham

- ✓ The liquid state of Jeevamrutham
- ✓ The semi-solid state of Jeevamrutham
- ✓ Dry Jeevamrutham (Ghana Jeevamrutham)

Method and application of liquid Jeevamrutham:

Requirements for liquid Jeevamrutham- Water, cowdung, cow urine, Jaggery, flour of any pulse and a handful of fertile from the same land.

Preparation: The dung and urine of cow, hybrid cow, were prepared by using 1kg dung, 1 litre urine, 200 g Jaggery,, 200g flour and 100 g soil from the same field mix them in a big tank properly and keep the tank in shade and cover it with jute bag and it should be breathable and leave it. The mixtures were kept for incubation under shade for 5 days and stirred vigorously for 10–15 minutes three times a day with a wooden stick. The average minimum and maximum temperatures during the study period were 13.4 and 31.1ºC, respectively. The final volumes of the mixtures were made to 20 litres with water in plastic containers.

Application --If Jeevamrutham is given by Irrigation like a drip, canal water, sprinkler utilize complete 200 liters. When you are considering the spray, you can dilute the mixture. First spray – One month after seed sowing or transplanting of seedling. Take 100-liter water to add 5 liters of filtered Jeevamurtham.

Second spray – 21 days after the first spray. Here 150 liters of water plus 10 liters of filtered Jeevamrutham.

Third spray – 21 days after the second spray, take the third spray. 200 liters of water plus 20 liters of filtered Jeevamrutham.

Fourth spray – When fruits are beginning to show up. 200 liters of water plus 6 liters sour buttermilk can be sprayed for one acre.

In summer, spray to be done in early morning or evening. In winter any time of the day can be sprayed. It can also be applied by hands whenever there is a water scarcity problem or no sprayer available, still we can use Jeevamrutham. The first month after seed sowing or transplanting seedlings add one cup (50ml) Jeevamrutham in between two main vegetable plants on the surface of the soil. Repeat this once or twice or even thrice a month. Repeat the same for every month for four months till the harvest is completed.

Method and preparation of semi-solid state Jeevamrutham

Requirements for semi solid Jeevamrutham- 100kg desi cow dung, 5 litre urine, 1kg jaggery, 1kg pulse, one handful of soil from the same land.

Preparation -Mix all of them with a small amount of water. Make the small balls out of the mixture. Keep these balls in full sunlight to dry them. Now, these dried balls can be kept near the mouth of a dripper or near the sprinkler. When the waterfalls on the semi-solid Jeevamrutham, the microbes get activated again.

Method and application of Dry Jeevamrutham (Ghana Jeevamrutham)

Spread 200kg of cow dung on ground uniformly in the form of layer and add 20 liters of liquid Jeevamrutham on it and mix it. Now, make a heap of treated cow dung and cover it using jute bag for 48 hours allow it for fermentation then spread on the floor, dry in the sunlight. After drying is completed, store it in jute bags in the room. Air should be flowing. You can store Ghana Jeevamrutham for 6 months.

Application --At the sowing period, use the 200kg Ghana Jeevamrutham per acre. For example, two hands of Ghana Jeevamrutham with each seed. Again during the flowering period of the crop, add 50kg of Ghana Jeevamrutham in between two crop lines on the soil per acre. Amazing yield will be produced.

Advantages

It helps the soil to activate their available nutrients, microorganisms to make them available for the crop sown in that particular area. It increases the count of earthworms in soil which is beneficial for soil fertility. Jeevamrutham is one of those organic fertilizer which have large number of nutrients like nitrogen, phosphorus, calcium, and other micronutrients. This will ensure higher yield by enhancing the availability of nutrients through faster decomposition of bulky organic manures by boosting the microbial activity in the soil. Many of these formulations are rich in beneficial micro flora and can act as efficient plant growth

Precaution

Do not use chemical fertilizers, pesticides or weedicides for 20 days before and after application of Jeevamrutha.

Conclusion

Jeevamrutham helps to maintain the soil health and fertility. It provides varieties of benefits to user like less cost, easily adoptable to poor farmers, increase the crop productivity, environmental safety, and successful crop production. Generally, only the fresh preparations of liquid organic formulations are used by the farmers as they do not have information about the shelf life of liquid organic formulations. We can store Jeevamrutham for many days or for weeks too. Stored material also has their own advantages like increase in nitrogen, micronutrients, EC, etc. To get good yield, healthy quality of crop, we must have to adopt this organic fertilizer application.

3.SASYAMRUTHA PREPARATION

Background

Sasyamrutha is one of the liquid fertilizers made by fermenting cow dung and cow urine along with different types of leaves in an appropriate proportion having medicinal value. Sasyamrutha plays some important specific roles in providing required nutritional benefits to the crops along with pest/disease resistant characters.

Ingredients:

- ✓ Indigenous cow dung – 30-40 kgs
- ✓ Indigenous cow urine 3-5 litres.
- ✓ Plants having latex (Milk hedge, Calatropis, Jatropa, Sweet scented oleander) - 3-5 kgs
- ✓ Plants having strong aroma (Parthenium, Lantana, Eupatorium, Cassia, Datura) – 3-5 kgs
- ✓ Oil cake (Groundnut, Pongamia, Neem) - 1-2 kgs.
- ✓ Jaggery – 1 kg
- ✓ Ash of Agnihotra – 500 gms
- ✓ Water - 200 litres
- ✓ A container with a capacity of more than 200 litres.

Procedure:

- ✓ Chop all the plant materials into finer pieces.
- ✓ Clean the drum well and fill it with the finely chopped plant materials.
- ✓ Add 200 litres of water and all other ingredients into this drum like indigenous cow dung, and cow urine, oil cake, Agnihotra ash, Jaggery in the mentioned quantities to the drum.
- ✓ Stir well and close the drum with a lid and allow it to ferment for one week.
- ✓ Daily stirring of the solution for aeration should be done.
- ✓ After a week the whole mixture must be filtered and sasyamrutha has to be collected in another drum. The filtered leaves and green

should be collected in a separate container and can be used in the fields along with water.

Usage: Filtered sasyamrutha liquid manure is given through irrigation water @ 200 litres per acre. Sasyamrutha also helps to control pests and diseases Sasyamrutha can be prepared once a month and can be used for the crops in the field at different stages of the crops like growing stage, flowering and grain filling stage.

4.AMRITH PANI

Background

Amrith Pani as the name suggests is as important as nectar in our life. It is a foliar spray that provides nitrogen to the growing plants through the leaves. This sprays also acts as insect repellant.

Ingredients:

- ✓ 1 litre cow urine of indigenous breed
- ✓ 1 kg cow dung of indigenous breed
- ✓ 250 gms jaggery
- ✓ 10 litres water
- ✓ 1 Drum or plastic bucket.

Procedure:

Clean the drum well and fill it with required quantity of water.

Mix indigenous cow dung with water to prepare cow dung solution. Add cow's urine and powdered jaggery.

Mix thoroughly the entire ingredients in a drum and keep it closed for one day for curing. 12-13 litres of mother solution is obtained by this method.

Usage: Dilute one litre of mother solution in 10 litres of water and use as a foliar spray OR 20-30 litres of Amrith pani is applied through irrigation for

one acre of land. Paddy, Ragi Vegetables, banana crops can be sprayed with this solution. Farmers are immensely benefited from this method.

AMUDHAM SOLUTION

This solution acts right away as a catalyst for growth. With very little work we can create this solution within twenty four hours.

Ingredients:

- ✓ 1 liter cattle urine
- ✓ 1 kg dung
- ✓ 250 grams jaggery
- ✓ 10 liters water

Preparation:

Mix the dung thoroughly in water. Add urine and mix well. Powder the jaggery, add to the above, and mix well. Make sure there are no lumps. Cover and set the mixture aside for 24 hours.

Usage: Add one liter of this solution to ten liters water (for a 10% solution) and spray. You must make sure to dilute the solution or else the leaves will get scorched. This solution helps give green manure to leaves directly. It also repels insects. Instead of using jaggery, you may use waste fruit in this manner: Tie one kilogram waste fruit into a nylon bag and immerse this in urine solution. Let it soak for five days. This helps the fruit ferment well. Add ten times water to this and spray or add 60-100 liters of this in irrigation water for one acre.

5.**CONCENTRATED AMUDHAM SOLUTION**

Ingredients:

- ✓ 5 liters cattle urine
- ✓ 1 kg dung
- ✓ 1 liter juice of any waste fruit.

Preparation:

Mix the dung thoroughly in urine and the juice and mix well. Set aside the mixture for five days.

Usage: Use 20-30 liters per acre of this solution.

Note: In this method, the use of jaggery, an external input, is avoided. This mixture can only be used for irrigation and not for spraying. Ordinary amudham solution used in irrigation requires 50-100 acres per acre. To reduce the quantity and work we developed this combination. It ensures excellent growth.

6.SANJIVAK

Ingredients:

- ✓ Cow urine- 100L
- ✓ Cow dung- 100-200kg
- ✓ Jaggery- 500g
- ✓ Water- 300L

Kept for 10 days (Fermentation)

Method of Application (Diluted 20 times before use)

• Along drip irrigation • Foliar spray • To enrich soil with microorganisms for quick residue decomposition.

Scientifically Validated by: University of Stellenbosch, South Africa

B. Natural products for insect-pest control (as sprays) under natural farming

1. Darekastra / Paudhastra:

This solution is used to control sucking insect-pests and young caterpillars attacking fruits and vegetables.

Method of preparation:

1. Cut the branches of dark tree along with leaves in small parts. Add 40 litres water, 2 litres cow urine, 400 g cow dung and 2 kg chopped branches in a barrel.

2. Stir the solution for 2-3 minutes in clockwise direction so that all the contents are mixed well. Keep stirring the solution intermittently for 2 days in clockwise direction for 2-3 minutes and then cover with jute bag.

3. After that, strain the solution through a cloth and store in a barrel/drum. This solution can be stored for up to 6 months.

Time of preparation:

Under normal environmental conditions in 2 days and during winters in a week

Precautions:

Store darekastra in a place away from direct sunlight and rainfall. Spray darekastra in evening.

Rate of application: spray 40 litres for spraying in 1 ha area.

2. Brahmastra:

This is a natural insecticide prepared from leaves which have specific alkaloids to repel pests. It controls all sucking pests and hidden caterpillars that are present in pods and fruits.

Inputs needed: 20 litre Cow Urine, 2 kg Neem leaves along with short stems or branches, 2 kg Karanj leaves, 2 kg Custard Apple leaves, 2 kg Datura leaves, 2 kg Castor leaves, 2 kg Mango leaves and 2 kg Lantana leaves.

Preparation of Brahmastra:

1. Take 20 litre of cow urine in a suitable vessel
2. Add into it paste of any five leaves as described above in the ingredients
3. Boil the above contents on slow flame,
4. Allow the above contents to cool for 48 hours in shade.
5. Stir the contents in clockwise direction twice a day for one minute
6. After 48 hours, filter the solution and store it in earthen pot for future use
7. Brahmastra can be stored for six months

Method of Application: Use 6 litre of Brahmastra diluted with 200 litre of water as foliar spray on the standing crop in one acre field.

3. Agneyastra: This solution is used against pests like fruit borers, root borers and leaf folders that are hidden inside fruits, roots and leaves of plants.

Method of preparation:

1. Take desi cow urine 10 litres, crushed leaves of dark 5 kg, tobacco powder

500 g, chilli powder 500 g and crushed garlic 500 g in a vessel.

2. Heat the solution on low flame till it starts boiling. Then remove the solution

from flame and let it cool for 48 hours.

3. Strain the solution through cotton cloth and store in a cool place. The solution can be used for up to 6 months.

Precautions:

1. Store the solution at a place that is away from direct sunlight and rainfall.

2. Spray the solution in evening.

Rate of application: 1 litre agneyastra in 40 litres water for spraying in 1 ha area.

4. Neemastra:

Neemastra is used to prevent or cure diseases, and kill insects or larvae that eat plant foliage and suck plant sap. This also helps in controlling the reproduction of harmful insects. Neemastra is very easy to prepare and is an effective pest repellent and bio-insecticide for Natural Farming.neemastra organic pesticide will help you to understand the preparation and uses of neemastra in the traditional way. Moreover, it is a traditional, indigenous, organic pesticide that you can prepare and use to control harmful pest. The basic material that is used for preparation is neem leaf (*Azadirachta indica*). Neem leaves have amazing pesticidal property. They also act as fungicide as well as have anti-bacterial properties. Moreover, neem also acts as a fertilizer. It helps in controlling wide range of pests. That's why if you are willing to start organic farming or gardening then you cannot avoid the importance of neem. Generally we spray neem oil mix to save our plants or crop. But, neemastra is an advanced version of neem oil mix.

Inputs needed:

200 litre water, 2 kg cow dung, 10 litre cow urine, 10 kg fine paste of neem leaves along with short branches.

Preparation of Neemastra:

1. Take 200 litre of water into a drum and add 10 litre of cow urine
2. Then add 2 kg of desi cow dung
3. Next, add 10 kg of crushed neem leaves along with its short stems or branches
4. Stir all the above contents in clockwise direction with a thick wooden stick
5. Cover the drum with a gunny bag
6. Prepare and keep Neemastra in shade to prevent sunlight and rainfall exposure.

7. Stir the above solution every morning and evening in clockwise direction for one minute.
8. After 48 hours, filter the solution and store it for use.

Method of Application:

Use the above prepared and filtered Neemastra without dilution with water. Neemastra so prepared may be stored for use up to 6 months.

Benefits of Neemastra

Because of the presence of neem extract, this organic pesticide is highly effective in controlling wide range of pests. However, this pesticide is mainly effective for sucker pests, rice weevil, caterpillars etc. It also improves the fertility of the soil. After preparing this solution you can also store them for 6 months.

5. Dashparni: This solution is used to control all types of insect-pests infesting crops, fruits and vegetables. It takes care of the difficult to control pests.

Method of preparation:

1. Put 4 litres of cow urine, 400 g cow dung, 100 g turmeric powder, 100 g ginger paste, 5 g asafoetida powder, 200 g tobacco powder in a barrel and cover with a jute bag.

2. Next morning, add 200 g green chilli powder, 100 g garlic paste and 400 g dark leaves. Mix the contents with a wooden stick for 2-3 minutes in clockwise direction.

3. Cover the solution with jute bag for upto 24 hours.

4. Next day, add lantana leaves, Dhatura leaves, papaya leaves, marigold leaves, guava leaves, bana leaves, basuti leaves, turmeric leaves and ginger leaves each at 400 g in the mixture and cover with jute bag.

5. Stir the mixture for 2-3 minutes every morning and evening for 30-40 days in

Clockwise direction.

6. Strain the solution through a cloth and store it. The mixture can be used for up to 6 months.

Precautions:

1. Store the solution in a place where sunlight and rain do not fall.

2. Spray the solution in evening.

3. While mixing this solution, cover nose with a cloth.

4. Keep children and cattle away from the place where dashparni is prepared and stored.

Time of preparation:

1. Under normal environmental conditions: 40 days

2. Hilly areas having severe cold: 50-60 days.

Rate of application: 1 litre dashparni in 40 litres of water for spraying in 1 ha area.

6. Neem paste:

It is prepared from the leaves and twigs of neem tree, *Azadirachta indica*. All parts of neem tree like seed kernels, flowers, leaves, twigs, bark possess insecticidal activity, seed kernel being most effective. Azadirachtin is the most potent limnoid isolated from neem tree which is effective against more than 550 insect species. It has properties of repellence, antifeedance, oviposition deterrence, and growth disruption against wide variety of insect-pests belonging to diverse orders. Besides insecticidal activity, neem also

displays strong nematicidal, fungicidal, bactericidal and molluscicidal activity.

Method of preparation

Take 50 litres water, 20 litres cow urine, 20 kg cow dung, 10 kg paste of neem leaves, twigs and 10 kg twigs of custard apple and place in a drum. Mix all the ingredients well and keep covered for 48 hours while stirring intermittently. The paste is ready to be used in 2 days period. Use within 7 days of preparation.

Time of application: Apply once in each quarter of the year.

7. Dasakavya

Method of preparation:

Ten types of ingredients are included in it. It contains cow dung, cow urine, cow milk, curd and ghee. If it is mixed and applied to the plants, its growth will be high. Dasakavya is recommended for plants in tropical regions. They are Neem (*Azadirecta indica*), castor (*Galotropis*), Kollinji (*Debrosia purpurea*), Nochi (*Vitex negundo*), Umatai (*Dattura mittal*), Marigold (*Jatropha curcus*), Adathoda (*Adathoda vesica*) and Saffron (*Bongemia pinnata*) used as an anti-inflammatory agent. To prepare plant extract, soak leaves separately in cow urine in 1:1 ratio (1kg chopped leaves – 1 liter of cow water) for 10 days. Add 1 liter of strained plant extracts to every 5 liters of panchakavya solution. Keep this solution for 25 days and shake well. At that time mix panchakavya and plant extract well.

Method of use:

Filter the Dasakavya solution otherwise the tip of the syringe will clog. 3% is recommended as a foliar spray.Soaking the roots of seeds or seedlings in 3% Dasakavya solution for 20 minutes before transplanting can increase seed growth and root formation. All vegetables and garden crops should be sprayed once a week while they are growing.

Benefits

Increases plant growth, yield and crop quality. Helps control aphids, aphids, spiders and other sucking insects. Helps to control diseases like leaf spot, leaf blight and gray blight.

8. Dashparni Ark-For Fungus and Bacterial Disease:

The greenness of leaves, the health of plants, the majority of diseases and pests can be managed by the Dashparni Ark. Along with this there is a reduction in the cost of improving the quality of the fruit and the cost of plant protection measures. Plants are protected against fungal and bacterial diseases like: – powdery mildew, Rust, Smut, Downy mildew etc. This mixture can be made easily by the farmers at home.

Materials for Dashparni Ark:

1. Gilloy, Ghanari, Dhatura, Neem, Kaner, Sitafal, Mahananda, Arand, Papaya leaves 2 kg

2. Cow dung 5 kg

3. Cow urine 5 litres

4. Water 100 litres

Preparation method:

Phase 1:

Take leaves of the above plants 2 kg each in a tank and crush the leaves well. Mix 5 litres of cow urine in crushed leaves and then add 100 litres of water and 5 kg cow dung to this mixture.

Phase 2:

Cover the above material with a jute sack or poly net for 21 days for the storage of fermentation and leave the tank.

Phase 3:

Filter the ingredients done after 21 days and use it.

Preparation time:

21 days

Storage:

6 months

Use:

1. Use this mixed mixture with 5 ml / litres of water for better results.

2. Sprinkle on plants at intervals of 10 days.

9.Sour Butter Milk (Khatti Lassi):

Sour Butter Milk are prepared with cow milk and curd is found to be very effective in controlling the fungus.

Method of Preparation:

- Take 3 litre milk and prepare curd from it
- Remove the creamy layer and leave for 3 to 5 days till the formation of a grey layer of fungus
- Churn it well, mix it with water and spray on infected crops after filtering

10. Southeaster:

Southeaster is prepared with Desi cow milk is found to be very effective in controlling the fungus.

Input needed:

1. Dried ginger powder: 200 g

2. Milk: 5 litre

3. Water: 200 litre

Method of Preparation and Application:

Boil the 200 g dried ginger powder in 2 litre of water till it remains 1 litre. separately boil milk and let it cool down. Mix both of these in 200 litre water. It is sufficient to spray in 1 acre to check leaf spots/ blights and other diseases in crops.

11. ORGANIC EARTHEN POT ARKH

Ingredients

Earthen pot - 1 unit

Indigenous Cow Urine - 5 litres Neem leaves - 1 kg Pongamia Leaves - 1 kg Calotropis Leaves - 1 kg Jaggery - 50 g

Method of Preparation 1. Collect the fresh leaves of Neem, Pongamia and calotropis and crush them 2. Mix the Cow urine, cow dung and jaggery properly in the earthen pot. 3. Add the crushed leaves to the earthen pot and stir well. 4. Cover the mouth of the earthen pot with a clean cloth 5. Store it in a shade place for 7-10 days. 6. Collect the extract and further add 5 litre of cow urine and again collect the extract every 10 days.

Method of application For use dilute 20 ml of extract per litre of water and spray the crop• or drench the soil in a rose cane for control of disease pests

Source: S K Parija Method, Bhubaneswa.

12. SANJEEVANI :

Ingredients Neem leaves Extract - 250 ml Desi Cow Urine - 2.5 Litre Earthen Pot - 1 Unit Method of Preparation 1. Collect the fresh leaves of

Neem, extract juice out of it. 2. Take an earthen pot and pour the cow urine. 3. Pour the neem juice extract and stir well. The medicine is ready in 1 day. Method of application Dilute 50 ml for every litre of water and spray in crop.•

Source:S K Parija Method, Bhubaneswar.

13.KHAJARA KHATA

Made up from residual dung and urine in which we have to add termite soil or ash after getting decomposed it act as bio-fertiliser.

Source:S K Parija Method, Bhubaneswar

14. AMRIT JAL

Method of Preparation:

Cow dung - 1 kg Cow urine - 1lt Jaggery - 50 g These are mixed in earthen pot, then cover with a cloth and tied. Allow 3days to decompose, then, it will act as a biofertilizer.

Use: Dose 200ml in 20 lt water.

Source: S K Parija Method, Bhubaneswar.

15. BILB RASYAN

Method of Preparation: Half kg dry Bilb powder or 5kg fresh Bilb dissolve in 20 liter water and then add 1kg jaggery. After one month, add this prepared solution to roots.

Benefits: This will increase potassium in the soil

Source:Tara Chand Balji Method, Madhya Pradesh.

16. GAAJAR GHAAS SVARAS

Method of Preparation Add 2kg Gaajar Ghaas Svaras in 20 lt water then add 20 gm powdered fitkari(Alum). After 15 days, filter and spray in 1acre land.

Benefits: This will increase Nitrogen in the soil

Source:Tara Chand Balji Method, Madhya Pradesh.

17. PHUSP RASAYAN

Method of Preparation: Add 2kg flowers in 2 litre cow urine and add 2lt water. After 7days, spray in 1acre land. Benefits: This will increase Boron in the soil

Tara Chand Balji Method, Madhya Pradesh.

18. AMRIT DHARA

Method of Preparation: Add 15 gm peppermint, 15 gm ajawaine, 15 gm kapur and mix well. Spray in 1 acre land.

Benefits: This will protect crops from sucking pests.

Tara Chand Balji Method, Madhya Pradesh

19. FUNGAL DISEASE CONTROL

• A mixture of ash (2-3 kg) and 1 liter of castor oil is spread on a seed bed of a size of about 100 m 2. The application is repeated 2-3 times at intervals of 7-10 days. This provides protection against soil borne diseases in tobacco nurseries. • A mixture of 2 kg of turmeric powder and 8 kg wood ash is used as dust over leaves for treatment against powdery mildew. • Ginger powder at 20 gm/lit of water and sprayed thrice at interval of 15 days can also effectively check the incidence of powdery mildew and other fungal diseases. • Handful of slaked lime applied at the base of tomato plant can combat damping off disease.

• Cattle and goat urine have fungicidal properties. Two cups of cattle urine with 5ml peppermint oil and 10 lit of water can be used to control fungal diseases on grapes.


Farm based low cost Mass
production technology for
Beauvaria bassiana


ARCHAE TECHNOLOGY


(EM)

ORGANIC FARMING: A WAY TO FORWARD SUSTAINABLE AGRICULTURE IN SPICES CROP

Fish Amino Acid (FAA)

What is Fish Amino Acid (FAA)

The Fish Amino Acid (FAA) is a liquid made from fish. FAA is of great value to both plants and microorganisms in their growth, because it contains and abundant amount of nutrients and various types of amino acids. Blue, back color fishes will get good FAA.

Fish Amino Acid is a liquid made from fish that contains abundant amount of nutrients and various types of amino acids. It is absorbed directly by the

crops and it also stimulates the activity of microorganisms. The effects of FAA are more observable when mixed with a pinch of urea.

Materials/ ingredients needed:

- ✓ Fish trash (head, bone, intestine, etc.)
- ✓ Jagerry / Brown sugar
- ✓ IMO-3
- ✓ Mosquito net
- ✓ Rubber band / thread
- ✓ Clay pot / plastic jar (PE container) or glass jar

HOW TO MAKE FAA

- ✓ Cut fish into pieces and put in a clay pot or plastic jar (Blue black colored fish are good because they contain high amounts of amino acid).
- ✓ Add Jaggery of an equal amount (1:1 weight ratio). Fill the jar up to 2/3 of its volume.
- ✓ Cover the opening of jar with a mosquito net. The meat will ferment in 7 to 10 days. In the presence of fat on the surface of the solution, put 2 to 3 tea spoons of IMO-3 to dissolve the fat.
- ✓ Extract the solution and use the liquid to crops.

Uses of FAA

- ✓ FAA is rich with nitrogen. It is good fertilizer for applying both to soil and foliage since it enhances the growth of crops during their vegetative growth period when used with other Natural Farming Materials
- ✓ For leafy vegetable, it is possible to use FAA continuously to increase yield and improve taste and fragrance.
- ✓ When making IMO or mixed compost apply the FAA after diluting it with water 1:1000 ratio. Then the FAA will help activate the micro organisms.
- ✓ Mackerel FAA is very effective in getting rid of mites and the green house whitefly (Trialeurodes vaporariorum). Dilute FAA with water and spray it on both sides of the leaf.

- ✓ Put the bones left over from creating FAA into the brown rice vinegar (BRV), which has a volume 10 times larger than the bones. The bones will decompose and produce good quality water-soluble calcium phosphate.

Note: It is not recommendable to use FAA during the period of reproductive growth, because it may induce over growth.

How to preserve FAA:

- ✓ The optimum temperature ranges between 23-250C
- ✓ No direct sunlight. A cool place is recommended.

ORIENTAL HERBAL NUTRIENT (OHN)

The oriental Herbal Nutrient (OHN)is a very important input in Natural Farming. It is made from herbs which are full of energy and function to increase plant robustness, to sterilize and keep plants warm. OHN revitalizes crops and activates their growth. It is made from popular oriental herbs such as Angelica, Acutiloba, Licorice and Cinnamon that are fermented, not boiled, to maintain the vigorous growth of crops. GARLIC / GINGER / CINNAMON The above ingredients may be classified as being in a raw state (Garlic / Ginger) in a dry state (Cinamon bark) can be used in their raw state.

Preparation of OHN with CINNAMON

Materials / ingredients needed:

- ✓ Cinnamon
- ✓ Rice wine/Bear
- ✓ Jars / Bottle
- ✓ Porous paper
- ✓ Rubber band

HOW TO MAKE

- ✓ Take cinnamon bark 250 gms / Bear 750 ml,

- ✓ Put the cinnamon bark in a jar and fill up with bear so that the bark is completely soaked.
- ✓ Fill the jar with 2/3 of the jar
- ✓ Add jaggary to the jar equivalent to the weight of the ingredients.
- ✓ Cover the jar using porous paper and tie with rubber band. Leave for 3 to 5 days for fermentation.
- ✓ Stir everyday with stick in the morning for two weeks.
- ✓ After fermentation, pour distilled liquor into the remaining 1/3 space of the 3 jar. (For long storage)
- ✓ If we use with in 45 days no need to add liquor, water will do.

HOW TO MAKE OHN WITH GARLIC / GINGER

Garlic : When using the whole bulb of garlic (1 kg), select freshly harvested garlic (Do not wash with water). Crush everything including the skins and the roots, which contain moisture. Crush 1kg of the garlic (Do not crush too finely)

Ginger : Collect ginger (Do not wash with water). Crush after shaking the soil off (Do not crush too finely).

1. Put 1kg of crushed garlic or ginger in the seperate jar.

2. Add the same amount of Jagerry 1kg (1:1 ratio) and cover it with porous paper. The amount of mixture should occupy 2/3 of the space of the jar. It is very important to fill only 2/3 of the jar in order for good fermentation. Leave it for 4-6 days.

3. The jar must cover it with tight lid / vinyl film. stir the mixture gently clockwise every day morning for a week. Leave it for 4-6 days. Filter the content and keep the extraction in another jar for long-term storage.

5. The extracting process is difficult add water to extract juce this can be used with in 45 days.

6. To preserve longer period add liquor to extract the juce easily.

HOW TO DILUTE OHN

The dilution ration of OHN to water is 1:1000. The ratio can be changed depending on the weather or the condition of the plant. The three kinds of OHNs (ginger, garlic and cinnamon) are mixed just before using in the following ratio: 1:1:1:1000. HOW TO USE OHN OHN is used for making IMO - 3, IMO - 4, the soil treatment solution, and the seed treatment solution. OHN is also good for all of the growth periods of crops, Nutritional growth period, Change-over period and Reproductive growth period. OHN is always used in Natural Farming.

WHEN AND HOW TO USE

OHN Throughout the Nutritive Cycle. OHN is considered a very important input in Natural Farming and can be used throughout the early, vegetative, changeover and fruiting or reproductive stages at the basic dilution ratio of 1: 500 to 1000 times in water.

WHEN CROPS ARE WEAKENED

To reinvigorate weakened crops, a mixture of OHN (1:1000) with FPJ (1:500) and BRV (1:500) can be applied. For plants with soft rot or anthracnose, WCA (1:1000) is added to the mixture

VERMIWASH

Background

Vermiwash is one of the liquefied fertilizers obtained from the earthworms. Vermiwash spray plays a dual role; it acts as a fertilizer as well as a pesticide. Increase in both quality and quantity of produce in fruit and vegetable crop is observed by spraying this vermiwash.

Ingredients:

- ✓ Plastic Drum
- ✓ Earthworms

- ✓ Small pebbles or brick pieces
- ✓ Sand particles
- ✓ Cow dung
- ✓ Fertile soil
- ✓ Waste grass

Procedure:

- ✓ Take a plastic drum with 250 kg. capacity and make a small hole at the bottom of the container.
- ✓ Fill the container at the bottom with small stones/pebbles to a height of 1 ½ inches. Add water to test if the water flows out through the hole.
- ✓ Above the stones, fill the container with sand (1 inch) and waste materials like manure, fertile soil, vegetable peels (30-40 cms.) as the food for earthworms. Add one kg of fresh cowdung into the drum and release 200-300 earthworms in the drum.
- ✓ Take a five litre capacity bucket and make a small hole at the bottom.
- ✓ Fill the bucket with water and place it on the drum so that water drips into the drum. Fill this bucket with water as it turns empty.
- ✓ Collect the vermiwash in a bottle that trickles slowly from the bottom of the drum.

Uses: Mix one litre of vermiwash with five litre of water and use it for crops. It can be sprayed directly to the crop or applied along with irrigation. The vegetable plants become very healthy and strong. Controls deflowering and increases the yield of a crop. Vermiwash mixed with cow's urine and water in the ratio of 1:1:6 is sprayed to crops for effective control of caterpillars and aphids in vegetable crops.

Coconut-buttermilk solution

This easy-to-make solution enhances plant growth, including flowering, repels insects, and increases resistance to fungal diseases. This solution has the same growth enhancing potential as that of cytozime/biozyme .

Ingredients:

5 liters buttermilk
1 liter tender coconut

1-2 coconuts
500ml – 1 liter juice from waste fruit
(or 500 gms - 1 kg waste fruit, if extracting juice is not easy).

Preparation:
Break the coconuts and collect the coconut water in a vessel. Add buttermilk to this and mix well. Grate the coconuts, add to the mixture, and let it soak. Or, mix grated coconut and fruit (if not in juice form), put the mixture in a nylon mesh, tie it, and immerse it in the buttermilk solution. The solution will ferment well in seven days. The contents of the nylon bag could be reused a few times in subsequent solutions by adding a small quantity of grated coconut every time.

Usage: Mix ten liters water with 300-500ml solution and spray. This can also be used in irrigation at the rate of 5-10 liters per acre.

A*rappu*-buttermilk solution

Ingredients:

- ✓ 5 liters buttermilk
- ✓ 1 liter tender coconut
- ✓ 1-2 kg *arappu* leaves (or,250-500 gms leaf powder)
- ✓ 500 gms waste fruit or 1 liter juice from waste fruit.

Preparation:

Mix the buttermilk and tender coconut. Crush the leaves well. If using waste fruit, add it to the crushed leaves and put this mixture in a nylon mesh and tie it. Immerse the mesh in buttermilk - tender coconut solution. Let it ferment for seven days. By using the nylon mesh we eliminate the need for filtering the solution while spraying. If you use *arappu* leaf powder, use fruit juice instead of waste fruit. Mix all four ingredients and let it ferment for seven days. Wherever *arappu* is not availabile, you may use soap nut seed powder instead. In that case, we call it the soap nut buttermilk solution.

Many plant parts when they ferment release a sticky, gum-like liquid. Hibiscus leaves, *kattukkodi* (cocculus hirsutus) leaves, *pasalai kIrai*

(greens), *AvArai*, tender betel leaves, and the thick peel (outer skin) of jackfruit are examples. You may add this liquid to the buttermilk and let it ferment.

Usage: Mix ten liters water with one liter solution and spray. This helps plant growth, repels insects, and adds resistance to fungal diseases. This solution has the same potential as that of gibberlic* acid.

Archae bacterial solution (Plant Growth Promoting Rhizobacteria - PGPR)

It is of no use to plants if we simply dump dung and other wastes next to the plant. We have to process them properly before plants can make use of these. Microorganisms exist precisely to carry out this task. Archae bacteria are the best such microorganisms. These thrive in anerobic conditions and are considered to be the earliest microorganisms that came into being in the course of the evolution of life on earth. We will reap good harvests if we make use of these microorganisms in the proper fashion. Mr. G. Balakrishnan has devised a simple way of preparing this solution.

Ingredients:

- ✓ 20 kg dung
- ✓ 200 liters water
- ✓ 3 kg *jiggery*
- ✓ 100 gms *kadukkAi* powder
- ✓ 10 gms *adhimadhuram*.

Preparation:

Mix dung, *jaggery*, and water well in a container. Add *kadukkAi* powder to it and mix well. Boil the *adhimadhuram* powder in 250 ml water and letit cool. Add the cooled *adhimadhuram* solution to the kadukkAi solution. Fill therest of the container with water so that no air is left inside and close it tight.Methane will form inside the container. Let the air out of it once in a while byslightly unscrewing the cap for a moment. The solution will be ready in ten days.It will be light brown in color.This solution enhances plant

growth. The archaebacteria are directly absorbed byplants; other microorganisms also ingest it. We can use this solution to grow blue greenalgae. Mr. G. Balakrishnan has recorded 15-20% increase in the leaf area.Such an increase in leaf area leads to a corresponding increase in photosynthesis (harvesting of solar energy as per Mr. Dhabolkar) and enhances yield.

Usage: 200-300 liters of this solution is sufficient for an acre. You can also mix one liter of the solution with ten liters water to spray.

ARCHAE TECHNOLOGY

Ingredients:

- ✓ Cow dung -50 kg
- ✓ Ferrous sulphate -100gms
- ✓ Jaggery -3 kg
- ✓ Castor oil -250 ml
- ✓ Yeast -100 gms

Preparation:

Take 50 kgs. of cowdung, mix it in 75 litres of water and pour it in a barrel or a large jar.

Take 100 gms of ferrous sulphate mix it in 2 litres of water and dissolves completely, pour it in the barrel.

Then take about 20 litres of water separately in a plastic container, put 3 kgs of sugar or jaggery, 250 gms castor oil and 100 gms yeast. Keep this separately for 3 hours, during which time the yeast which you have added will start working. Every 15 minutes you have to stir the mixture well since the castor oil won't naturally mix with the water. The activity of the yeast makes the oil soluble in water.

After 3 hours, you pour this mixture into the barrel. If the barrel is not full, add water to it till it is completely full and becomes anaerobic.

The archae works in anaerobic conditions and digests the cowdung slurry inside and new nutrients are formed. Seven days later, you remove it and boil it in a container. During boiling, all the microbes, both beneficial and non-beneficial, die and you will get a sterile solution.

After cooling, divide it into five equal parts and put it in separate containers.

In each one, you use pseudomonas, Trichoderma, Bacillus subtilus, Paecilomyces , 200 grams each and put it separately in each container and keep it for 24 hours.

In 24 hours, the contents will build up ten times. So if you use 200 grams, after 24 hours you will get 2 kg. You need to use only one fifth, so this activity can be shared by farmers, thereby reducing the cost. If you use it for 3 years, then it is not necessary to use it afterwards because the soil gets everything on its own and as long as you regularly give biomass to the soil it is enough, the rest will take care of itself.

Effective Microorganisms (EM)

Dr. L. Narayana Reddy introduced Effective Microorganisms (EM) to us. (EM technology was invented by Prof. Teruo Higa of Japan. In India EM is marketed by Maple Orgtech (I) Limited.) Dr. Reddy cautioned that uncontrolled production of microorganisms by farmers may lead to the proliferation of harmful organisms because farmers lack the laboratory equipment to check quality. So Dr. Reddy recommends that farmers buy EM from authentic laboratories. However, Mr. G. Balakrishnan has perfected a method for preparing a similar solution which he calls Efficient Microorganism solution.

(i) Activated EM

Ingredients:

- ✓ 20 liters potable water free from chlorine
- ✓ 1 kg jaggery,
- ✓ 1 liter ***EM*** stock solution.

Preparation:

Mix all the ingredients in a plastic drum and fill twenty, one-liter plastic jars with this mixture. Tighten the bottle caps. Keep for 7-10 days for multiplication of the various microorganisms. Methane gas forms in each bottle. On the first or second day unscrew the cap to release the gas and close it tightly again. Repeat this as often as necessary. Each unopened bottle's contents should be used in 3-4 months.

Usage:

Mix 1-2 liters of the ET solution in 100 liters water for spraying. This promotes growth and controls pests. It may also be used in composting at the rate of 500ml to 1 liter per 100 liters water to increase the rate of breakdown of crop residues. ET may be used in irrigation at the rate of 3-6 liters per acre.

(ii) EM-Treated Cow Urine (TTCU)

Ingredients:

- ✓ 5 liters cow urine,
- ✓ 250 gms jaggery,
- ✓ 250 ml EM solution, and
- ✓ 250 ml water.

Preparation:

Mix all the ingredients and allow to ferment for 7-10 days.

Usage:

Use within 30 days. For spraying: Mix 1-2 ml in one liter water.

For irrigation use 20-30 liters per acre. This controls pests and diseases.

(iii) Effective Microrganisms-5 (EM5)

It contains five items, so it is named EM5.

Ingredients:

- ✓ 100 ml organic vinegar
- ✓ 100 ml EM
- ✓ 100 gms jaggery,
- ✓ 100 ml brandy
- ✓ 600 ml water, for a total of one liter.

Preparation:

Mix all the ingredients and allow fermenting for 7-10 days.

Usage:

Use within 30 days. Spray: 1-2 ml per liter of water, along with any of the growth promoters. In case of severe infection use 5ml per liter of water.

Benefits:

Controls fungal, bacterial, and powdery mildew diseases.

To **prepare organic vinegar**, use one of the following: Add 500 gms jaggery to 1 liter tender coconut and store in a container for a minimum of 15 days. Grind 8 numbers rotten bananas, 200 gms jaggery, and a small quantity of water to a semisolid form. Mix this with the jaggery mixture. Add water to make it two liters and keep to ferment. Use after a minimum of 15 days. Vinegar may be kept for a long time. With each passing day the quality improves due to fermentation. The older it is, the more effective it will be in EM5 preparation.

ANALYTICAL TECHNIQUES FOR SOIL TESTING

Soil testing is an essential component of soil resource management. Each sample collected must be a true representative of the area being sampled. Utility of the results obtained from the laboratory analysis depends on the sampling precision. Hence, collection of large number of samples is

advisable so that sample of desired size can be obtained by sub-sampling. In general, sampling is done at the rate of one sample for every two hectare area. However, at-least one sample should be collected for a maximum area of five hectares. For soil survey work, samples are collected from a soil profile representative to the soil of the surrounding area.

Materials required

1. Spade or auger (screw or tube or post hole type)
2. Khurpi
3. Core sampler
4. Sampling bags
5. Plastic tray or bucket

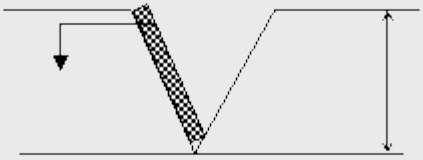
Points to be considered

1. Collect the soil sample during fallow period.
2. In the standing crop, collect samples between rows.
3. Sampling at several locations in a *zig-zag* pattern ensures homogeneity.
4. Fields, which are similar in appearance, production and past-management practices, can be grouped into a single sampling unit.
5. Collect separate samples from fields that differ in colour, slope, drainage, past management practices like liming, gypsum application, fertilization, cropping system *etc*.
6. Avoid sampling in dead furrows, wet spots, areas near main bund, trees, manure heaps and irrigation channels.
7. For shallow rooted crops, collect samples up to 15 cm depth. For deep rooted crops, collect samples up to 30 cm depth. For tree crops, collect profile samples.
8. Always collect the soil sample in presence of the farm owner who knows the farm better

Procedure

1. Divide the field into different homogenous units based on the visual observation and farmer's experience.
2. Remove the surface litter at the sampling spot.
3. Drive the auger to a plough depth of 15 cm and draw the soil sample.
4. Collect at least 10 to 15 samples from each sampling unit and place in a bucket or tray.

5. If auger is not available, make a ‘V’ shaped cut to a depth of 15 cm in the sampling spot using spade.
6. Remove thick slices of soil from top to bottom of exposed face of the ‘V’ shaped cut and place in a clean container.



1 inch / 2.5 cm 6 inches (15 cm)

1. Mix the samples thoroughly and remove foreign materials like roots, stones, pebbles and gravels.
2. Reduce the bulk to about half to one kilogram by quartering or compartmentalization.
3. Quartering is done by dividing the thoroughly mixed sample into four equal parts. The two opposite quarters are discarded and the remaining two quarters are remixed and the process repeated until the desired sample size is obtained.
4. Compartmentalization is done by uniformly spreading the soil over a clean hard surface and dividing into smaller compartments by drawing lines along and across the length and breadth. From each compartment a pinch of soil is collected. This process is repeated till the desired quantity of sample is obtained.
5. Collect the sample in a clean cloth or polythene bag.
6. Label the bag with information like name of the farmer, location of the farm, survey number, previous crop grown, present crop, crop to be grown in the next season, date of collection, name of the sampler *etc*.

Collection of soil samples from a profile

1. After the profile has been exposed, clean one face of the pit carefully with a spade and note the succession and depth of each horizon.
2. Prick the surface with a knife or edge of the spade to show up structure, colour and compactness.

3. Collect samples starting from the bottom most horizon first by holding a large basin at the bottom limit of the horizon while the soil above is loosened by a khurpi.
4. Mix the sample and transfer to a polythene or cloth bag and label it.

Processing and storage

1. Assign the sample number and enter it in the laboratory soil sample register.
2. Dry the sample collected from the field in shade by spreading on a clean sheet of paper after breaking the large lumps, if present.
3. Spread the soil on a paper or polythene sheet on a hard surface and powder the sample by breaking the clods to its ultimate soil particle using a wooden mallet.
4. Sieve the soil material through 2 mm sieve.
5. Repeat powdering and sieving until only materials of >2 mm (no soil or clod) are left on the sieve.
6. Collect the material passing through the sieve and store in a clean glass or plastic container or polythene bag with proper labeling for laboratory analysis.
7. For the determination of organic matter it is desirable to grind a representative sub sample and sieve it through 0.2 mm sieve.
8. If the samples are meant for the analysis of micronutrients at-most care is needed in handling the sample to avoid contamination of iron, zinc and copper. Brass sieves should be avoided and it is better to use stainless steel or polythene materials for collection, processing and storage of samples.
9. Air-drying of soils must be avoided if the samples are to be analyzed for NO3-N and NH4-N as well as for bacterial count.
10. Field moisture content must be estimated in un-dried sample or to be preserved in a sealed polythene bag immediately after collection.
11. Estimate the moisture content of sample before every analysis to express the results on dry weight basis.

Guidelines for sampling depth

S.No.	Crop	Soil sampling depth	
		Inches	cm
1	Grasses and grasslands	2	5
2	Rice, finger millet, groundnut,	6	15

	pearl millet, small millets *etc*.(shallow rooted crops)		
3	Cotton, sugarcane, banana, tapioca, vegetables *etc*. (deep rooted crops)	9	22
4	Perennial crops, plantations and orchard crops	Three soil samples at 12, 24 and 36 inches	Three soil samples at 30, 60 and 90 cm

Selecting sampling spot

Remove the surface litter at the sampling spot

Make a 'V' shaped cut to a depth of 15 cm in the sampling spot

'V' shaped cut

Drive the auger to a plough depth of 15 cm and draw the soil sample

Collect soils using khupri

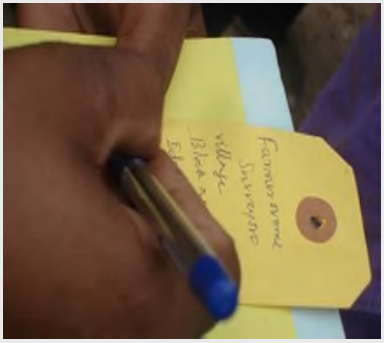
Mix the samples thoroughly

Remove foreign materials like roots, stones, pebbles and gravels

Quartering is done by dividing the thoroughly mixed sample into four equal parts

Two opposite quarters are discarded and the remaining is mixed

Collect the sample in a clean cloth or polythene bag



Label with required information

Source: https://agritech.tnau.ac.in/agriculture/agri_soil_sampling.html

BORDEAUX MIXTURE

Bordeaux mixture (1%)

Dissolve 1 kg of powdered copper sulphate crystals in 50 litres of water. In another 50 litres of water, prepare milk of lime with 1 kg of quick lime. Pour the copper sulphate solution into the milk of lime slowly stirring the mixture all the while. Test the mixture before use for the presence of free copper, which is harmful to the plants, by dipping a polished knife in it. If the blade shows a reddish colour due to the deposits of copper, add more lime till the blade is not stained on dipping. Always use wooden, earthen or copper vessels for the preparation of Bordeaux mixture. Use the fungicide in the same day of preparation

In order to confer sticking qualities to Bordeaux mixture, rosin washing soda mixture, may be added. The addition of the sticker is particularly recommended for spraying conducted during rainy season. For preparing the mixture, 10 litres of water out of 100 litres required for preparing Bordeaux mixture may be kept apart. Boil 10 litres of water , preferably in an earthen pot and add 500 g of good quality washing soda (sodium carbonate). Boil again until the solution becomes slightly dark in colour. Add one kg of powdered rosin (arpoos) in the boiling washing soda

solution. Reduce the flame for avoiding frothing, foaming and spilling over. Boil the solution for 5-10 minutes till the black bubbles appear. Cool the solution until the temperature reaches below 45 degree Celsius. The cooled mixture (10 litres) is then added slowly to the prepared Bordeaux mixture (90 litres) under vigorous stirring.

CONCLUSIONS:

Agrochemicals have contributed significantly in improving agricultural productivity but, at the same time, the threat posed to the environment by their indiscriminate use should not be underestimated. IPM originated as a reaction to the overuse of insecticides and is now the dominant paradigm that guides development of insect pest management technologies all over the world. Since its adoption as cardinal principle of plant protection in India, many programmes have been designed and implemented encompassing a variety of crops. But, it is imperative to restrict and minimize the use of chemical pesticides in IPM programmes. In light of this, bio-intensive integrated pest management is considered as the desirable path to sustainability in agriculture. Unfortunately, the pesticide industry has a myopic view regarding the economic gains and does not give due consideration to the environmental and health impacts of chemical pesticides. There is also a need to strengthen research in strategic areas like genetically improved bio-agents, bio-pesticides and pestresistant transgenics. Molecular approaches can go a long way in overcoming the major limitations of conventional pest control. The advancements in the field of biointensive IPM will shape it into an environmentally benign alternative to the chemical control for sustainable insect pest management. Climate change, biotic and abiotic stress, the emergence of new pests and diseases and lack of proper management strategies, especially for viral diseases, are all hindrances to successful cardamom cultivation. To implement effective management strategies to maintain and increase crop production, accurate pest and disease diagnosis are important. Therefore, continuous research is needed to maintain the cardamom yield and quality by mitigating the above factors. Moreover, IPM in future will emphasize on biological and ecological knowledge for efficient management of pests visà-vis intensification of consumer awareness programmes regarding the

environmental and health impacts of synthetic pesticides and their regulation. Thus, bio-intensive management needs to be emphasized as an effective means of pest regulation with the priority of human and environmental safety issues to achieve sustainability of agricultural production.

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