MAJOR PESTS AND DISEASES OF SPICES

Crops and their Management

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Preface

Spices have been integral to human civilization for centuries, enhancing flavors, preserving foods, and even serving as currency in ancient trade routes. As essential components of culinary traditions around the world, spices enrich our lives with their diverse tastes and aromas. However, the cultivation of spice crops is not without its challenges. Pests and diseases pose significant threats to spice crops, jeopardizing yields, quality, and livelihoods of farmers.

Recognizing the critical need to address these challenges, this book, titled "Major Pests and Diseases of Spice Crops and Their Management," delves into the intricate world of pest and disease management in spice agriculture. Through comprehensive research, analysis, and practical insights, this book aims to equip farmers, agronomists, researchers, and policymakers with valuable knowledge and strategies to combat the threats posed by pests and diseases in spice cultivation.

Acknowledgement

The creation of this book has been a collaborative endeavor, made possible by the contributions and support of numerous individuals and organizations. We extend our heartfelt gratitude to the researchers, academicians, and experts whose invaluable insights and expertise have enriched the content of this book. We also express our sincere appreciation to the farmers and growers whose dedication and resilience in the face of agricultural challenges inspire our work.

Furthermore, we would like to acknowledge the publishers, editors, and reviewers whose meticulous attention to detail and unwavering commitment have helped shape this manuscript into its final form. Their dedication to excellence has been instrumental in bringing this project to fruition.

Lastly, we extend our gratitude to our families, friends, and colleagues for their unwavering encouragement, understanding, and support throughout the writing process.

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Dr. Bhavna Verma has devoted her academic career to Agriculture particularly in Agriculture Entomology. She is presently working as a Senior Technical Officer (Entomology) in Directorate of Plant Protection Quarantine & Storage, PQS, Indore, MP. She did her B.Sc. (Ag) and M.Sc. (Ag) from college of agriculture Indore, RVSKVV University Gwalior. Thereafter, she did her Ph.D. from Dr. B. R. Ambedkar University of Social Sciences Dr Ambedkar Nagar Mhow, Indore, MP. She has a wide experience in research and she taught several courses of Entomology like Integrated pest management, Plant quarantine, Biological control, Bio agent, Crop pest, Taxonomy, Sericulture, Apiculture etc. She has received 5 awards from varous societies in the outstanding contribution of the relevant discipline, published 9 research papers, 2 books 14 articles, 4 pamphlets, 8 book chapters and 2 lead lectures. Dr. Bhavna has participated in many national and international conference and she has also organizing successfully 2 international conference as a Co-Organizing Secretary.

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Dr. Aftarika Azmi Ahmed was born on April 4th 1991 and working as an Assistant Professor in the Department of Entomology, Mahatma Gandhi University of Horticulture & Forestry, Sankra, Patan, Durg (C.G.). She did B. Sc. (Agri.) from RVSKVV Gwalior (M.P.), M. Sc. (Agri. Entomology) from JNKVV Jabalpur (M.P.) and Ph. D. from BRUSS Mhow (Indore- M.P.) with highest percent in the university. Dr. Aftarika also serves as Teaching Associate in AKS University, Satan (M.P.), Assistant Professor cum Junior Scientist in BAU Ranchi (Jharkhand) and Assistant Professor cum Junior Scientist in Institute of Livestock Management, Lucknow (U.P.). She awarded with National Fellowship (MANF) in 2017. Dr. Aftarika received numerous prestigious international and national awards, including Young Scientist Award, Young Professional Award, Best Paper Award and Best Paper Presentation Award.

Dr. Wajid Hasan, PhD PDF, is devoted to research and extension activities in Agriculture Entomology. Dr Hasan is a Subject Matter Specialist in Entomology at KVK Jehanabad, Bihar Agricultural University in Bihar. He was awarded Dr DS Kothari UGC-Post Doctoral Fellow (PDF) in 2010, offered by the University Grant Commission of India. He holds a doctorate in Agricultural Entomology from GB Pant University of Agri & Tech, Pantnagar, UK, India. He has good terms with farmers, and he serves them as an adviser for plant protection measures. Dr Hasan has received eleven awards from several societies for his outstanding contribution to the relevant discipline. He has 63 research papers, 35 books, 56 book chapters, 42 popular articles, 140 success stories, 3 Practical Manuals, 16 success stories and 48 delivered lectures in different seminars/symposia/conferences/workshops and seven radio talks. Dr Hasan stayed as the chief organizer for eleven international conferences with more than three thousand participants each and managed a team of about three hundred co-organizers each. He has also organized 551 training programs for farmers, rural youth and agricultural professionals with 20450 participants. In addition, he has conducted three skill development training programs of 200 hours each and 43 On-Farm Trials (OFT). Dr Hasan has a lifetime membership in 6 scientific societies. He is the Editor-in-Chief of the International Journal of Agricultural and Applied Sciences (IJAAS) and an Editorial board member for 5 scientific International Journals.

Sanjay Vaishampayan Joined J.N.K.V.V. Jabalpur in 1995 as Training Associate (Entomology) in Krishi Vigyan Kendra. Selected as Programme Coordinator K.V.K. in 2006. Recently posted as senior scientist (Entomology) at Directorate of Extension Services, J.N.K.V.V. Jabalpur. Obtained M.Sc. (Ag) degree in Entomology in 1989 from J.N.K.V.V. with gold medal and Ph.D. degree in Entomology in 1993 from Instt. of Agril. Sciences, Banaras Hindu University Varanasi (U.P.) with first position in the subject. Ph. D. thesis work was on migration behavior of three lepidopterous pest species (Heliothis armigera, Agrotis ipsilon and Plusia orichalcea) analyzing light trap catches. Earlier, during 1994-95, worked at I.A.R.I. regional station, Karnal. Published 40 research papers in reputed scientific journals and more than 140 technical bulletins. Research work on light trap continued and developed new designs of Solar powered light trap (SMV Traps) with UV-LED light source in collaboration with Aaditya Marketing Indore. These solar light traps are very effective for pest management and economical in farmers point of view.

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AN OVERVIEW OF PEST AND DISEASES IMPACTING LARGE CARDAMOM IN INDIA AND THEIR CONTROL STRATEGIES

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ABSTRACT

Large cardamom (Amomum subulatum Roxb), referred to as the 'Queen of Spices' and a member of the Zingiberaceae family, holds significant importance as a spice crop. However, it faces ongoing challenges from multiple diseases caused by both viruses and fungi. Large cardamom (Amomum subulatum Roxb) is susceptible to a total of 23 insect pests, 4 fungal diseases, and 2 viral infections. The leaf caterpillar (Artona chorista Jordon), the white grub (Holotrichia sp.), the stem borer (Glyphipterix spp.), and the shootfly (Merochlorops dimorphus Cherian), all are pests that pose significant threats to large cardamom. A prevalent disease associated with cardamom is 'Chirke' and 'Foorkey,' which is transmitted by aphids. Furthermore, fungal infections, particularly leaf blight, and viral diseases are major concerns, leading to substantial crop damage and economic losses. This chapter provides insights into the various pests and diseases that affect large cardamom and offers guidance on effective management practices

Keywords: Amontum subulaturn, Pests, large cardamom, diseases, Phomahedericola Boerema, integrated pest management system, strategies

INTRODUCTION

Large cardamom (*Amomum subulatumRoxburgh*) also known as the "Queen of spices," a member of the Zingiberaceae family, holds significant importance as a spice crop in North East India and is commonly referred to as a currency crop. This sciophyte, thrives in shaded conditions, typically flourishes under the canopy in diffused filtered light and is well-suited for the humid subtropical, semi-evergreen hills of the eastern sub-Himalayan region, particularly in forested areas. The cultivation of large cardamom (*Amomum subulatum Roxb*.) stands as a significant economic activity in the north-eastern states of India such as of Sikkim and the Darjeeling district of West Bengal. This cash crop holds a pivotal role in the economic landscape for these regions where large cardamom is cultivated, owing to its potential for export and foreign exchange earnings. Sikkim is the leading contributor, accounting for 85% of India's total large cardamom production. Additionally, this crop is cultivated in select areas of Uttarakhand and other north-eastern states such as Arunachal Pradesh, Manipur, Nagaland, Mizoram, and Assam (Mandy et al. 1999; Paudel *et al*. 2018; Vijayan, 2020). The cultivation of large cardamom serves as a vital source of income and livelihood for

these states of India specially Sikkim. The income generated from this crop surpasses that of other livelihood options in these states but unfortunately, over the past 15–16 years, large cardamom cultivation in the region has witnessed a significant decline, amounting to nearly 60% (Paudel *et al.* 2018; Vijayan, 2020**.** Experts attribute this decline to various factors, including climate change, changes in cultivation practices, insufficient pollination systems, and the incidence of pests and diseases, both viral and fungal (Srivastava and Verma, 1995;1989; Saju *et al.,* 2011; Gopi *et al.,* 2018). Open-field plantations of large cardamon is very popular in India but it also leading to prevalence of various foliar diseases. At times, the severity of these incidents results in extensive damage to the leaves caused by the pathogen, impacting the entire plantation and therefore increased susceptibility when cultivated in open-field conditions. This chapter provides insights into the various pests and diseases that affect large cardamom and offers guidance on effective management practices.

Some pests and diseases affecting large cardamom

1. Blight (*Colletotrichum gloeosporioides*)

Leaf blight caused by *Colletotrichum gloeosporioides* was found to devastate the large cardamom plantation and is the cause of concern for severe crop loss and decline in plant population in recent years. This blight is attributed to *Colletotrichum gloeosporioides* and its perfect state, *Glomerella cingulata*.Fast spread during continuous rain and consequent damage indicates its potential to devastate (Prasad *et al.* 1984; Thomas and Suseela *et al.* 1995; Gurung *et al.* 2020). In Sikkim, the disease was found to occur during late winter and peak rainy periods.Water-soaked lesions appear either at margins or tips or any other point on the leaves which rapidly enlarge, coalesce and cover major portion or the entire leaf lamina giving a blighted appearance The advancing lesions are blackish brown in color and margins give a yellow halo. In some cases, the entire lamina becomes yellowish and blighted. The affected area becomes necrotic and dry up. The large cardamom plantation has been severely impacted by Colletotrichum blight, raising concerns about significant crop loss and a decline in plant population in recent times (Vijayan, 2020; Sunil *et al.* 2021). This disease causes lesions on leaves and sheaths that exhibit black dots and a rough texture, identified as perithecia of the pathogen. The disease typically manifests with the onset of pre-monsoon showers in April-May and rapidly progresses during the rainy season. However, in certain areas, incidence begins during winter months (January-March).

The disease mostly affects the bearing tillers of the clump while the new tillers remain apparently healthy. However, later in the season, in some cases the young emerging leaves of the new tillers in the diseased clump show pale yellow discoloration in the inter-venal areas. Sometimes the emerging leaves are whitish in colour and droop without opening properly. Slight yellowing and narrowing of emerging leaves are also noticed and, in some cases, the pseudostem break open longitudinally in the middle and

the young leaves emerge through the opening. Examination of the rhizomes of such tillers showed brown lesion with air space in the middle and then the affected clumps and, consequently, the entire plantation appears desiccated. The disease primarily impacts the bearing tillers of the clump, with the new tillers initially appearing healthy. Furthermore, the spikes from the affected clump appear elongated when compared to those from the healthy clump, primarily due to the absence of fruit setting. Alternatively, in some instances, flowering and seed-setting occur, but the seeds fail to mature, remaining whitish or light brown instead of the natural black colour (Rao *et al.* 1993; Gurung *et al.* 2020; Vijayan *et al.* 2020).

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2. Aphid (*Aphis gossypii*)

Aphids pose a greater threat as vectors rather than as pests, being linked to the transmission of viral diseases (Foorkey and Chirke) in large cardamom. Both nymphs and adults of aphid feed on the tender shoots and leaves, resulting in yellowing, curling, and crinkling of the leaves in support plants such as Sesbania spp. The honeydew secreted by the aphids falls onto the betel vine leaves, fostering the growth of sooty mold, evident as black spots. An aphid colony comprises two forms of females: alate (winged) and apterous (wingless). These females can reproduce parthenogenetically and viviparously, giving birth to 10-20 nymphs daily. The nymphs mature into adults within a week (Rao *et al.* 1993; Vijayan *et al.* 2014; Vijayan 2020).

3. Phoma Leaf Spot Disease

The first evidence of leaf spot disease caused by *Phomahedericola Boerema*, noticed in 2007 that raised concerns within specific endemic areas, especially Arunachal Pradesh and Sikkim affecting large cardamom cultivation (Saju *et al.* 2011). The rapid propagation was gradually observed during persistent rainfall and the subsequent harm underscores its capacity for widespread devastation. In Sikkim, the occurrence of the disease was noted during late winter and the height of the rainy season. The disease manifests initially as a small circular water-soaked lesion on younger leaves. The centre of these spots takes on a greyish hue, surrounded by a water-soaked margin and develops a distinct yellow halo. Over time, the spots transition to yellow, brown, and occasionally black. Confluence of numerous spots can result in the formation of extensive patches on the leaf surface, resembling blighted areas. In severe cases, the entire plant may succumb to infection. This poses a significant challenge to the cultivation of large cardamom in the affected regions (Vijayan 2020; Saju *et al.* 2011).

4. White Fly (*Aleurocanthus nubilans* and *Dialeurodes pallida* (Aleurodidae: Hemiptera)

Both nymphs and adults extract sap from tender leaves, resulting in yellowing, chlorotic spots, and the development of sooty mold on the leaves. The adult is a tiny insect covered with a white waxy bloom (Vijyan 2020).

5. Leaf Streak

Leaf streak, induced by *Pestalotiopsis royenae* (Guba) Steyaert, has been identified as a novel affliction affecting large cardamom (*Amomum subulatum*). The condition is characterized by rectangular spots aligning parallel to the veins, as reported by Shrivastva *et al.* in 1995. Additionally, a survey conducted by Gopi *et al.* in 2018 in 2014-2016 in various large cardamom plantations in Sikkim revealed the presence of tea mosquito bugs on the infected segments of *A. subulatum*. These spots, originating from different instars, exhibited diverse sizes on the infected leaves. Initial symptoms manifest predominantly on the young and tender leaves of large cardamom. Upon collecting tea mosquito bugs from the infested leaves and subjecting them to controlled feeding conditions, similar leaf streak symptoms were reproduced in large cardamom, as well as in other non-host crops like maize and turmeric. The findings suggest that the leaf streak is a result of feeding injuries inflicted by tea mosquito bugs, thus ruling out *P. royenae* as the causative agent for the leaf streak disease symptoms. Furthermore, *Pestalotiopsis* sp. was isolated as an endophyte from large cardamom (Raychowdhury and Chatterjee 1964; Rao *et al.* 1993; Vijyan *et al.* 2020).

6. Chirke Disease

Large cardamom production faces the impact of viral disease known as chirke which disease, characterized by streak mosaic symptoms on leaves, has been documented since 1958 (Raychowdhury and Chatterjee 1964; Raychowdhury *et al.* 1985; Liou *et al.* 2003; Vijayanandraj *et al.* 2013). This viral disease leads to a gradual decline in plant growth, resulting in a significant yield loss typically observed in the third year of infection (Raychowdhury *et al.* 1985; Raychowdhury *et al.* 1961; Raychaudhuri *et al.* 1965). The virus responsible for chirke disease is identified as large cardamom chirke virus (LCCV), representing a new species under the genus *Macluravirus* within the family Potyviridae. LCCV, a (+)ssRNA virus, is transmitted by aphids, namely *Rhopalosiphum maidis, Brachycaudushelichrysi,* and *Myzus persicae*, in a non-persistent manner (Mandal *et al.* 2012). Disease is characterized by appearance of mosaic pattern on leaves. This symptom is particularly noticeable on newly emerged leaves, displaying distinct pale green to yellow longitudinal stripes running parallel (Paudel *et al.* 2018; Vijayan 2020). The flowering process is significantly reduced, resulting in a gradual decline in yield over successive years. The causative agent of this ailment is a virus transmitted both by insect vectors and mechanically through sap (Vijayanandraj *et al.* 2013; Sharma *et al.* 2019).

7. Foorkey Disease

First of all, documented by Vasudeva in 1956, foorkey disease inflicts significant harm in the Darjeeling district of West Bengal. The disease is characterized by the emergence of bushy, stunted shoots that, unfortunately, remain sterile.The virus responsible for foorkey, categorized within the genus Nanovirus and the family Nanoviridae (Mandal *et al.*, 2004), exhibits size measuring approximately 32 nm in diameter. Foorkey disease

spreads *via* vectors, namely the banana black aphid (*Pentalonia nigronervosa*), *Micromyzus kalimpongensis* (Raychaudhuri and Chatterjee, 1958; Basu and Ganguly, 1968), and *Mollitrichosiphum* sp. Utis (*Alnus nepalensis)* assumes significance as a shade tree in large cardamom plantations, with the aphid *Mollitrichosiphum* sp. commonly observed on utis twigs within the large cardamom ecosystem (Anon., 2014; Vijayan and Chhetri, 2014). Infected plants exhibit numerous stunted shoots that fail to produce flowers. The leaves undergo reduction in size, slight curling, and a pale green coloration, occasionally resembling a slightly broadened pan. The inflorescence is stunted, leading to the absence of flowers and fruits (Vijayan, 2020). Although diseased plants may persist for a few years, they remain sterile and unproductive. The virus is transmitted persistently, signifying its ability to endure inside the aphid for an extended period after acquiring it from infected plants. The virus also spreads through infected rhizomes (Aryal, 2018; Vijayan, 2020).

8. Stem Borer

Glyphepterix sp. (Lepidoptera: Glyphiperidae) is a pest specifically associated with large cardamom. Its young larvae bore into the shoots and consuming the central leaf core. This feeding behavior leads to dead heart symptoms, ultimately resulting in the death of the shoot (Bhowmick 1962; Azad Thakkur 1982; Rao et al. 1993; Vijayan 2020). Stem borer activity is observed throughout the year, with peak abundance occurring in December-January, March-April, May-June, and September-October. The larvae predominantly target the central part of the shoot, obstructing the passage of nutrients to the growing tip. Consequently, the central leaf dries up, manifesting the characteristic dead heart symptom. Infestation by this pest is also specified by the presence of entry holes sealed with excreta (Vijayan 2020).

9. Fusarium Rot

Fusarium rot, induced by *Fusarium oxysporum* (Schlech. ex. Fr), stands as one of the most prevalent and important fungal disease affecting large cardamom (Srivastva 1995; Thomas & Vijayan 2002). The impact of this disease can be severe at all stages of crop growth, especially under favorable weather conditions, predominantly during the summer season and in the context of changing climatic patterns. Dhanya *et al.* (2018) reported that mismanaged plantations could experience \up to a 50 percent yield loss due to Fusarium rot. The pathogen's capability to survive in both soil and crop residues presents significant challenges to manage. Diseases Seedling rot and Collar rot caused by this pathogen are very much destructive to productivity of large cardamom (Srivastva 1989). These diseases are particularly detrimental during the nursery and field stages. In the nursery phase, it is referred to as seedling rot, while at maturity, it manifests as collar rot, clump rot, or spike rot.

The characteristic symptoms involve sudden wilting of the plant or individual leaves. Initial signs include leaf paleness, followed by yellowing and decay of the collar,

gradually spreading towards the base. Typically, flowers remain unopened, and if some do open, they fail to bear fruit, ultimately leading to spike rot or wilting. Locally known as 'agulta,' this disease thrives in conditions of continuous rainfall during the flowering period, water stagnation, and in old plantations with degenerated clumps. The most significant damage to the nursery occurs in February and March, with the disease reaching its peak intensity in plantations from October to February.

10. Leaf Rust

Rust disease caused by *Phakopsora elettariae* (Racib.) Cummins, was reported by Srivastava & Verma (1987). It was mainly observed in May and June on the ventral surface of lower leaves in the form of numerous minute brown uredosori. In early stages of development, the uredosori were surrounded by chlorotic holes. In the advanced stage, the whole leaf was covered by uredosori causing premature drying of leaves (Rao *et al.* 1993).

11. Leaf Eating Caterpillar

The leaf eating caterpillar (*Artona chorista* Jordon) is one of the significant pests causing economic losses across the entire region. The pest occurs sporadically in epidemic form every year in all the cardamom growing area of NE region and Darjeeling District of West Bengal. Another leaf eating caterpillars *Clelea plumbiola* Hampson (Lepidoptera: Zygonidae), the moth was described by Hampson (1892) from Burma. Typically, the occurrence of the pest is observed from June to July and October to march in the field.The leaf caterpillar exhibits monophagous behavior and displays high host specificity (Pangtey & Azad Thakur 1986). The larvae of both species are gregarious in nature and feed on chlorophyll contents. Underneath the leaf, leaving transparent epidermis and veins (skeletonization).

The larvae of both species exhibit gregarious tendencies, consuming chlorophyll contents beneath the leaves and causing transparent epidermis and vein exposure (skeletonization). Mature larvae ultimately defoliate the plant, leaving only the midrib of the leaves intact. Indirectly, the pest-induced defoliation negatively impacts the plant's yield. There are two generations per year, with the first occurring from May to August and the second from September to April (Azad Thakur 1982).

12. Shoot Fly

The shoot fly, *Merochlorops dimorphus* Cherian (Chlororpidae: Diptera), has been identified as a significant pest affecting large cardamom by causing damage to young shoots. The extent of damage inflicted by the shoot fly ranges from low to moderate (Vijayan, 2020; Raj *et al.* 2021). This pest is present throughout the year in the large cardamom cultivation areas, with a higher incidence recorded in new plantations within the first three years. The characteristic symptoms include browning of the shoot tip, leading to the eventual drying up of the entire shoot. The larvae bore into the young shoot, consuming the core of the pseudostem from top to bottom. This feeding behavior

damages the central leaf, ultimately resulting in the death of the tiller (Yadav *et al.* 2021).

3. MANAGEMENT STRATEGIES

The large cardamom plant protection guidelines by the Spice Board (Ministry of Commerce & Industry, Government of India) in their 2020 policy on the usage of plant protection formulations in large cardamom plantations in India provide crucial strategies for safeguarding large cardamom plantations from pests and pathogens. Among these strategies, the Integrated Pest Management (IPM) system is highlighted. In this approach, a combination of suitable methods and techniques is employed in a compatible manner to keep pest incidence at levels below those causing economic losses to the crop. Developing an effective IPM strategy requires a comprehensive understanding of the bio-ecology of pests and pathogens, the economics of control measures, and awareness of the potential adverse effects of pesticides on non-target living organisms, the environment, and human health.

Several non-chemical strategies have been implemented to combat various pests affecting large cardamom, encompassing cultural, biological, physical, and mechanical methods. These strategies are recommended for integration with chemical control measures in the North Eastern States, excluding Sikkim, which is designated as an organic state where the use of chemical plant protection formulations is prohibited. These approaches not only prove effective in pest control but also offer a pathway for the judicial use of chemical pesticides, thereby reducing the adverse impact of chemicals on the environment. To implement a successful Integrated Pest Management (IPM) program, it requires knowledge on:

1. Identification of pest species and their prevalence
2. Understanding the life cycle and biology of the causal organism
3. Recognizing the site of attack
4. Identifying damage symptoms and signs of pest attack
5. Understanding the mode of migration/dispersal
6. Identifying alternate hosts

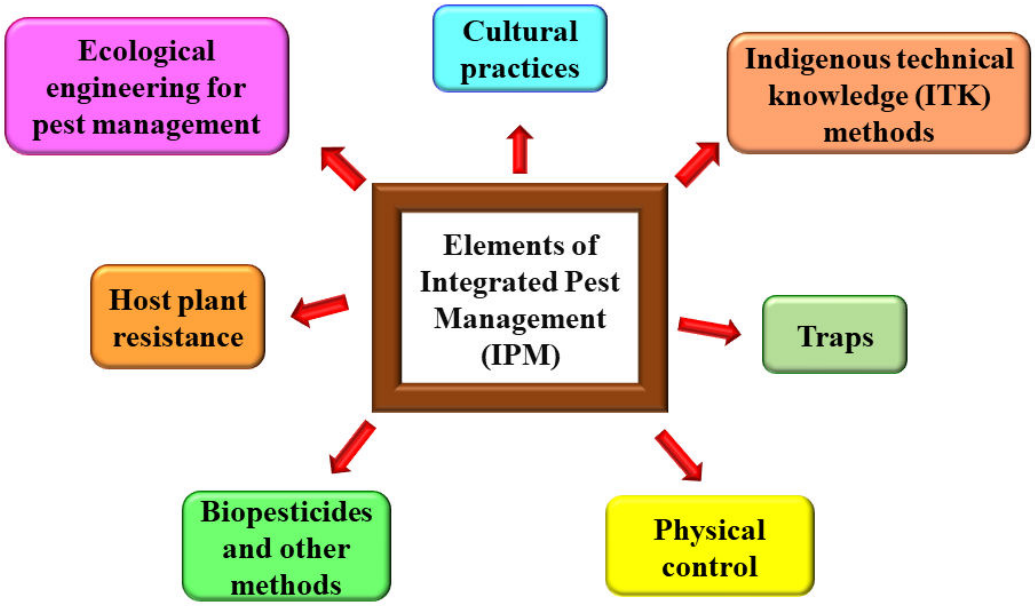

Fig.1. Elements of Integrated Pest Management (IPM)

Integrated pest management system (IPM), has been implemented in large cardamom plantations in the North East region since 1985, leading to a reduction in the reliance on harmful agrochemicals which means that IPM prioritizes the cultivation of a healthy crop while minimizing disturbances to agro-ecosystems and promoting natural pest control mechanisms. This system comprises multiple components (Fig.1) aimed at eliminating pests and protection the large cardamom crop from diseases. Table 1 illustrates various strategies for managing pests and diseases that impact large cardamom.

Table 1.Management strategies for pests and diseases affecting large cardamom

S.no	Diseases/pests	Management strategies
1.	Blight	**Cultural Management:** 1. It is essential to cut and compost the infected leaves, tillers, mature bearing tillers after harvest. 2. For composting, leaves and remaining parts of spikes can be utilized. Compost pits should be prepared in convenient locations within each plantation before harvest. 3. Maintain a 50% shade and implement proper mulching during the summer months. **Biological Management:** 1. Treat the suckers with Pseudomonas at a ratio of 5 liters in 100 liters of water during planting. 2. Spray and drench Pseudomonas at a rate of 4 liters per

		plant (3 to 5 liters per 100 liters of water) in May and August-September. **Chemical Management:** Conduct three rounds of spray and drench with 0.3% Copper oxychloride (COC) (3g/liter of water).
2.	Aphid (Aphis gossypii)	1. Controlling the disease's further spread and reducing the aphid population is facilitated by the removal and destruction of diseased plants. 2. Cardamom plantations may experience significant losses on certain occasions due to minor pests such as the Hairy caterpillar (*Eupterote* sp.). Other minor pests include mealy bugs (*Planococcus* spp) and thrips (*Heliothrips haemorrhoidalis*).
3.	Phoma Leaf Spot Disease	**Cultural Control:** Severely infected and dead leaves should be cut and disposed of. **Chemical Control:** To manage the disease, spraying 0.3% Copper oxychloride (COC) two times is effective.
4.	White fly (Aleurodidae: Hemiptera)	1. Collect and dispose of leaves that are damaged, along with nymphs and puparia. 2. Implement yellow sticky traps at a rate of 12 traps per hectare. 3. Apply either 1.0 liter of methy demeton 25 EC, dimethoate 30 EC, or 500 grams of acephate 75 SP per 500-750 liters of water per hectare through spraying.
5.	Leaf streak	**Cultural Control:** 1. Remove severely infected and dead leaves by cutting and disposing of them. 2. During harvest, cut the infected leaves, tillers, mature, and bearing tillers, and compost them. **Chemical Control:** Apply one round of 0.2% Copper oxychloride spray (200 g/100 liters of water) at 15–25-day intervals, adjusting based on the severity of the disease**.**
6.	Chirke disease	1. Regularly inspect the plantation monthly, especially during the rainy season, and carefully identify any diseased plants. 2. Avoid collecting planting materials from infected gardens or apparently healthy plants from severely infected gardens. 3. Establish the nursery approximately 500 meters away from the main plantation to prevent aphid colonization.

		4. Keep clumps clean by removing old tillers with loosened leaf sheaths to discourage aphid colonization.
7.	Foorkey disease	1. Uproot infected plants, and saturate the surrounding area with systemic insecticides to inhibit the spread of aphids on both the primary host and secondary hosts like corn, banana, peach, and squash. 2. Apply regular sprays of metasystox every three weeks in the plantation to control aphid movement.
8.	Steam borer	Controlling this pest involves removing infested shoots along with the caterpillar. **Chemical Control:** Effectively manage the pest by spraying 3000 ppm neem oil (3.0 ml per liter of water) from July to October, at 21-day intervals.
9.	Fusarium rot	Root inoculation of *G. fasciculatum* combined with basal application, along with the spraying *of P. fluorescens*, as well as root inoculation of *G. fasciculatum* coupled with basal application of *T.asperellum*and *P. fluorescens* spray, were found to be efficacious in combating the disease**.**
10.	Leaf rust	Apply a solution of mancozeb (0.25%) or tebuconazole (0.05%) to the crop, and reapply at 10 to 15-day intervals.
11.	Leaf eating caterpillar	**Cultural Control:** 1. The larvae exhibit gregarious behaviour, preferring to feed beneath cardamom leaves. These clusters can be found at a certain distance and should be collected and eliminated in June-July and October-December. 2. Employing light traps is recommended to attract and capture adult moths. A strategically positioned light trap, such as Actinic BL light or the NCIPM, ICAR-designed light trap, should be deployed during the early evening for 3-4 hours along roads and vacant areas. **Chemical Control:** Quinalphos 25 EC at a concentration of 0.05% proves effective against this pest. It can be applied in non-organic areas for pest control.
12.	Shoot fly	1. Eliminate infested young shoots by cutting them at ground level and disposing of them. 2. The caterpillars can be manually removed from the plants, followed by their termination. 3. The application of neem seed kernel extract (5%) is also effective in mitigating the pest issue.

4. CONCLUSION

The economic significance of large cardamom (Amomum subulatum Roxb.) as a cash crop emphasizes the importance of expanding its cultivation in the North Eastern region to enhance crop productivity. The prevalent fungal, viral and other pathogenic diseases pose a significant threat to large cardamom, leading to substantial damage and subsequent crop losses of alarming proportions. This chapter provides an overview of the pests and diseases affecting large cardamom, along with recommended management practices.

Declarations

The author declared that the book chapter has not been published elsewhere

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MANAGING COMMON INSECT PESTS OF TAMARIND TREES: GAINING INSIGHTS INTO PESTS AND THEIR LIFE CYCLES FOR EFFECTIVE PEST CONTROL

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ABSTRACT

Tamarind (Tamarindus indica) is a remarkable tropical tree known for its delicious sweet and tangy fruit. It's not just a tasty treat but also plays a crucial role in agriculture, medicine, industry, and our efforts to combat climate change. This tree is tough, able to thrive in diverse environments, making it an essential ally in the fight against climate change. Tamarind serves various purposes, from providing food and medicine to supporting income generation and helping us adapt to changing climates. However, tamarind faces a challenge in the form of pesky insect pests that can harm its yield and quality. This chapter provides a list of common insect pests that affect tamarind trees, underscoring the importance of understanding these pests and their life cycles for effective pest control. To ensure tamarind trees stay healthy and productive, it's crucial to thoroughly examine and manage these insect pests. This way, tamarind can continue to contribute to different aspects of human life and environmental sustainability.

Keywords: insect pests, tamarind trees, food and medicine, climate change, environmental sustainability

Tamarind commonly known as Imli in Hindi, scientifically *Tamarindus indica* L. is a remarkable evergreen tropical tree celebrated for its delightful sweet and sour fruit. It thrives in diverse regions across the globe and belongs to the Leguminosae family, commonly known as Fabaceae. This tree plays a crucial role in social forestry and agroforesrty due to its robust root system, making it exceptionally resilient to droughts, typhoons, cyclones, and well-suited for marginal and wasteland areas (Joshi and David, 2018). This adaptability makes it a valuable resource in the fight against climate change. It is a versatile tree, with nearly every part boasting not only nutraceutical and medicinal properties but also industrial and economic significance. It serves a multitude of purposes, such as providing food, medicine, fodder for livestock, supporting apiculture (beekeeping), serving as a fuel source, supplying timber, tannin and dyestuff for various applications, contributing to paint and varnish production, offering shade and shelter, functioning as a live fence, and even enhancing aesthetics as an ornamental tree. In essence, tamarind addresses a wide range of needs, including food security, nutrition, income generation, and adaptation to changing climates. (Joshi and David, 2018)

However, like many tropical fruit trees, tamarind faces challenges from various herbivores. Insects are the primary culprits, as they feed on tamarind foliage, flowers, and fruit in the field, as well as on stored fruit, significantly impacting both yield and quality. In this chapter, we will delve into a comprehensive examination of the most common insect pests that afflict tamarind trees. Understanding these pests, their life cycles, and the damage they inflict is essential for effectively managing pest issues in tamarind plantations.

Tamarind can be susceptible to a variety of insect pests. Here is a list of some of the common insect pests that can affect tamarind trees:

1. **Tamarind Pod Borer**
2. **Tamarind Fruit Fly**
3. **Aphids**
4. **Mealy bugs**
5. **Whiteflies**
6. **Scale Insects**
7. **Leafhoppers**
8. **Tamarind Seed Bugs**
9. **Tamarind Leaf Beetle**
10. **Tamarind Webworm**
11. **Tamarind Butterfly**
12. **Tamarind Defoliator**
13. **Tamarind Stem Borer**
14. **Tamarind Moth**

These pests pose challenges for tamarind growers, and effective management strategies are essential to safeguard the health and productivity of tamarind trees (FAO 2009)

1. TAMARIND POD BORER (*HELICOVERPA ARMIGERA*)

Identification: The Tamarind Pod Borer, scientifically known as *Helicoverpa armigera*, is a well-known troublemaker for tamarind trees. This relentless insect has quite the appetite and doesn't limit itself to just tamarind; it can cause havoc on a wide range of crops. When the adult moths of this species lay their eggs, they choose tamarind pods as their nursery. As soon as these eggs hatch, the young larvae waste no time, burrowing their way into the pods and feasting on the tasty pulp and seeds inside.

Life Cycle: The life cycle of the Tamarind Pod Borer comprises four distinct stages: egg, larva, pupa, and adult. During the night, adult moths lay their tiny spherical eggs on various parts of the tamarind tree, with a particular preference for the vulnerable pods. These eggs typically have light green or yellow hues. Once the eggs hatch, small larvae emerge, displaying shades that range from pale yellow to green often marked with longitudinal stripes. As they continue to grow, their colour deepens, and they can reach sizes of 4-5 cm. After a few weeks, the larvae enter the pupation stage in the soil, and from this pupal stage, adult moths eventually emerge.

Damage: The larvae of the Tamarind Pod Borer are responsible for causing considerable harm to tamarind pods. They burrow into the pods, munching on the pulp and seeds within. This feeding frenzy leads to a decline in the quality and quantity of tamarind produced. Additionally, the openings made by these larvae become vulnerable spots for fungal infections, which further worsen the condition of the fruit (Bhagat and Jat, 2009).

Management: Effective management of Tamarind Pod Borers requires ongoing vigilance in your orchard. It's crucial to keep a close eye on your tamarind trees. When you spot pods that have been invaded by these pests, make sure to collect and dispose of them to decrease the pest population. Applying the right insecticides at the right time can also be a useful method for keeping the borers in check. Additionally, maintaining a clean orchard by removing fallen or infested pods goes a long way in disrupting the life cycle of these pests (Patil and Lokhande, 2015).

2. TAMARIND FRUIT FLY (*BACTROCERA SPP.*)

Identification: The Tamarind Fruit Fly, part of the *Bactrocera* genus, is another major insect pest that tamarind growers contend with. This troublesome pest doesn't limit itself to tamarind alone; it can also infest a range of other fruit crops. When adult fruit flies come into play, they lay their eggs inside the growing tamarind fruits. The resulting larvae that hatch out of these eggs then feast on the fruit pulp, causing extensive harm and rendering the fruit unsuitable for sale or consumption.

Life Cycle: The Tamarind Fruit Fly undergoes a life cycle comprising four key stages: egg, larva, pupa, and adult. These adult flies come in a variety of species, each with its own unique patterns and colours. They have a strong attraction to tamarind fruits that are ripe or in the process of ripening. When females are ready to reproduce, they carefully lay their eggs inside the fruit, typically just below the skin. The hatched larvae start their feast on the fruit pulp, leading to its decay. Pupation takes place right within the infested fruit, and, when the time is right, the adult flies emerge from this stage.

Damage: Infestations of the Tamarind Fruit Fly can spell significant financial losses for tamarind cultivators. The larvae's voracious appetite for fruit pulp leads to a decline in fruit quality and, consequently, market value. Affected fruits often turn mushy and

unappealing, rendering them unsuitable for both consumption and sale (Krishnamoorthy and Chakravarthy, 2003).

Management: Successfully handling Tamarind Fruit Fly issues calls for a range of strategies. Employing traps allows for the monitoring of adult fly populations, which can help in determining when to implement control measures. When needed, chemical treatments should be applied following recommended protocols and safety measures. Alternatively, organic methods, like using neem oil or protective fruit bagging, can be effective in safeguarding tamarind fruits from infestation (Kulkarni and Jyothi, 2014)

3. APHIDS

Identification: Aphids are tiny, delicate insects that can be found infesting tamarind trees. These pests primarily feed on the sap from the leaves and young shoots of the tree. Aphids typically come in shades of green or black and have bodies that resemble a pear shape. What makes them especially challenging is their rapid reproduction, which allows them to swiftly form colonies on tamarind plants (Latha, 2017).

Life Cycle: Aphids follow a straightforward life cycle, where females give birth to live offspring without the need for mating. These offspring are also female and carry on this cycle, resulting in the production of multiple generations. In certain situations, when environmental conditions turn unfavourable, some aphid species are capable of producing winged individuals, enabling them to move to new host plants.

Damage: Aphids, with their needle-like mouthparts, nourish themselves by puncturing tamarind leaves and shoots to sip the plant's sap. This feeding process can result in the distortion and curling of tamarind leaves. Moreover, aphids release a sweet substance known as honeydew, which can draw in sooty mould, causing additional harm to the tree.

Management: Nature's own defenders, like ladybugs and lacewings, have a crucial job when it comes to managing aphids. These helpful insects act as a natural check on aphid populations, keeping their numbers in balance. In cases where aphids become a real issue, insecticidal soaps or neem oil can be employed to keep them under control. Consistent monitoring of tamarind trees to detect aphid infestations is equally important to make sure that timely action can be taken (Hegde and Swamy, 2011).

4. MEALYBUGS

Identification: Mealybugs are yet another frequent nuisance that can invade tamarind trees. These pests tend to take up residence on the underside of leaves and have a distinctive appearance, as they cloak themselves in a waxy, cottony substance. This waxy shield makes them quite easy to spot, and mealybugs usually come in shades of pink or gray.

Life Cycle: Mealybugs follow a life cycle that's reminiscent of aphids. Females give birth to live offspring, and these descendants, too, carry on the cycle through asexual reproduction. Mealybugs have a rather unhurried development process, requiring several weeks from hatching to reach adulthood.

Damage: Mealybugs dine on the sap of tamarind plants, sapping the tree's strength and vitality. Their feeding habits can lead to symptoms like yellowing leaves, wilting, and stunted growth. What's more, the waxy substance they emit can draw in ants and sooty mould, making the situation even more troublesome.

Management: Managing mealybugs can be tackled using a variety of approaches. Trimming and safely disposing of affected branches and plant material can make a dent in the pest population. Insecticidal soaps or neem oil are effective options for controlling mealybugs (Karuppuchamy and Dhanapal, 2019). Consistently checking tamarind trees for any signs of mealybug trouble is essential to catch the problem early and take timely action (Yadav and Kumar, 2016).

5. WHITEFLIES

Identification: Whiteflies are petite, white insects that have a penchant for feasting on tamarind leaves. You'll usually discover them on the underside of the leaves, where they tend to congregate in significant numbers. If you happen to disturb them, these whiteflies will take flight in a flurry, creating a cloud of tiny white insects.

Life Cycle: Whiteflies go through a life cycle comprising four stages: eggs, nymphs, pupae, and adults. The adult whiteflies lay their eggs on the undersides of tamarind leaves. These eggs then hatch into nymphs, which go on to become pupae, eventually emerging as adult whiteflies. This entire life cycle can be quite speedy, taking just a few weeks, which enables their population to grow rapidly.

Damage: Whiteflies nourish themselves by sipping on the sap of tamarind leaves, a habit that can lead to the leaves turning yellow and curling. What's more, their feeding process results in the production of honeydew, a sweet substance that can draw in ants and create the conditions for sooty mould to thrive on the leaves.

Management: Successfully handling whitefly infestations requires employing a range of tactics. Yellow sticky traps serve as an excellent way to both keep an eye on their population and diminish the number of adult whiteflies. Using insecticidal soaps or neem oil can be an effective approach to controlling whiteflies. Consistent inspections of the undersides of tamarind leaves are crucial for early detection and prompt intervention in case of whitefly presence (Gupta and Upadhyay, 2018).

6. SCALE INSECTS

Identification: Scale insects are troublesome pests that stay firmly affixed to the stems, branches, and leaves of tamarind trees. They take the form of small, oval or circular

bumps, and their armour-like, waxy coatings give them the appearance of scales. Typically, scale insects come in shades of brown or grey (Selvaraj and Murugan, 2016).

Life Cycle: Scale insects have a reproductive process that involves laying eggs or directly giving birth to their offspring. They typically attach themselves to different parts of plants and stay put, using their needle-like mouthparts to feed on plant sap. The females are usually immobile, whereas the males can be more active as they search for females to mate with.

Damage: Scale insects sustain themselves by syphoning the sap from tamarind plants, gradually weakening the tree in the process. This weakening can result in stunted growth, a decrease in fruit production, and an overall deterioration in the tree's health. Additionally, the sticky honeydew produced by scale insects can draw in ants and create conditions favourable for the growth of sooty mould.

Management: Effectively managing scale insects requires a combination of strategies. Pruning and eliminating heavily infested branches can help reduce the population of these pests. The use of horticultural oils can be a useful method for suffocating scale insects. It's crucial to regularly inspect your tamarind trees and intervene early to prevent significant damage (Mahadev and Devi, 2017).

7. LEAFHOPPERS

Leafhoppers are among the insects that can affect tamarind trees. These small, nimble creatures feed on plant sap by piercing the leaves, stems, or other plant parts with their needle-like mouthparts. Leafhoppers can come in a variety of colours and patterns, not only green or brown.

When tamarind trees are infested with leafhoppers, it often results in symptoms like leaf discoloration, stippling, and wilting. Additionally, these insects are known for their role in transmitting plant diseases, which can add to the damage experienced by tamarind trees. To manage leafhoppers, it's essential to keep an eye on their presence, intervene early, and consider using insecticides when necessary (Anand and Nagaraja, 2018).

8. TAMARIND SEED BUGS

Tamarind Seed Bugs are a common pest that can trouble tamarind trees. These bugs usually take up residence within the seeds of tamarind pods, where they feed on the developing seeds. They tend to be small and brown, much like what you'd expect from typical seed bugs.

When Tamarind Seed Bugs infest tamarind pods, it can result in a decrease in the quality of the seeds, making them unsuitable for sale. Managing these pests may involve checking tamarind pods for their presence and implementing measures to control their population. This can include removing affected seeds or, when needed, using insecticides to address the issue (Kaushik and Singh, 2016).

9. TAMARIND LEAF BEETLE

The Tamarind Leaf Beetle is one more of the pests that tamarind trees need to contend with. These beetles have a strong preference for tamarind leaves, where they feed on the foliage. They are often easy to identify due to their unique appearance and colouring.

When Tamarind Leaf Beetles infest a tamarind tree, it can lead to a condition called defoliation, where the tree loses its leaves. This can result in reduced photosynthesis and an overall decline in the tree's health. To manage these beetles, it's important to keep a close watch on the tree's leaves to detect their presence and take steps to control their population, which may involve using insecticides or other appropriate methods of control.

10. TAMARIND WEBWORM

The Tamarind Webworm is a pest that can trouble tamarind trees. These small caterpillars construct protective webs on the leaves, using them as a shield while they munch on the foliage inside these webs. As a result, you often see noticeable areas on the tamarind tree covered in these distinctive webs (Kumar and Reddy, 2019).

When Tamarind Webworms infest the tree, they can cause harm to the leaves and take a toll on the tree's overall health. Dealing with these pests typically involves watching out for their web-covered areas on the tree and taking action to control their population. This could include physically removing the webs or, if necessary, using insecticides to manage the infestation (Umesha and Shivaraju, 2018).

11. TAMARIND BUTTERFLY

The Tamarind Butterfly is one of the insects you might encounter near tamarind trees. These butterflies often choose tamarind leaves as a place to lay their eggs, and when their caterpillars hatch, they feed on the leaves. These butterflies can be easily recognized by their unique markings and colours.

Although Tamarind Butterflies don't typically cause as much harm as some other pests, their presence can result in minor leaf loss and some cosmetic damage to the tamarind leaves. Managing them might involve keeping an eye out for their eggs and caterpillars and, when necessary, using suitable control methods or relying on natural predators to maintain their population at a manageable level.

12. TAMARIND DEFOLIATOR

The Tamarind Defoliator is a pest that can cause trouble for tamarind trees. These defoliators mainly go after the leaves of the tamarind tree, where they munch on the foliage. Their presence can result in a significant loss of leaves, which in turn impacts the overall health of the tree.

Infestations of Tamarind Defoliators can lead to a reduction in photosynthesis and, consequently, a weakening of the tree's vitality. To deal with these pests, it's crucial to regularly check for their presence and take action to manage them, which might involve using insecticides when it becomes necessary.

13. TAMARIND STEM BORER

The Tamarind Stem Borer is a pest that tamarind trees have to contend with. These borers have a preference for the stems and branches of the tamarind tree, where they dig in and dine on the inner tissue. Their presence often results in harm to the tree's structural strength.

Infestations of Tamarind Stem Borers can lead to weakened branches and stems, raising the risk of breakage and a general decline in the tree's overall health. Managing these pests may involve inspecting the tree for any signs of infestation and taking action to control their population. This could include trimming affected branches or using insecticides when necessary (Yadav and Kumar, 2017).

14. TAMARIND MOTH

The Tamarind Moth is a pest that can create problems for tamarind trees. These moths typically lay their eggs on tamarind pods, and once the larvae hatch, they start feeding on the seeds and pulp inside the pods. This feeding can lead to damage to the tamarind fruit.

When Tamarind Moths infest tamarind trees, it can result in a decrease in both the quality and quantity of tamarind fruit. Dealing with these moths often involves examining tamarind pods for their presence and taking measures to control their population. This might include removing infested pods or, if necessary, using insecticides to address the issue.

CONCLUSION

Insect pests are an ongoing challenge for tamarind cultivation, and they can pose serious risks to both fruit production and the overall well-being of tamarind trees. To tackle this issue effectively, tamarind growers need a solid grasp of these insect pests, their life cycles, and the harm they can inflict. Adopting integrated pest management (IPM) strategies, which encompass monitoring, cultural practices, biological control, and targeted pesticide use, is essential to mitigate these risks.

With vigilance and proactive measures to shield their tamarind crops from these insect pests, growers can ensure a plentiful harvest and the ongoing health of their tamarind trees.

Table: 1. Identified Pests of Tamarind

Sl. No.	Common Name	Scientific Name
1	Tamarind leafhopper	*Amrasca biguttula biguttula*, *Idioscopus clypealis*
2	Tamarind stem borer	*Indarbela tetraonis*
3	Tamarind root grubs	*Holotrichia spp*
4	Tamarind mealybug	*Maconellicoccus hirsutus*
5	Tamarind gall psyllid	*Trioza alacris*
6	Tamarind fruit fly	*Carpomya vesuviana*, *Bactrocera spp.*
7	Tamarind aphid	*Aphis gossypii*
8	Tamarind pod borer	*Hypothenemus obscurus*
9	Tamarind leaf skeletonizer	*Plutella xylostella*
10	Tamarind stem borer	*Indarbela tetraonis*
11	Tamarind fruit borer	*Helicoverpa armigera*
12	Tamarind scale insect	*Aonidiella orientalis*
13	Tamarind leaf webber	*Sylepta derogata*, *Diaphania indica*

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SPICE CROPS: PLANT NEMATODES AND THEIR MANAGEMENT

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ABSTRACT

Roundworms referred to as plant-parasitic nematodes are microscopic pests that can seriously harm spice crops, leading to lower yields and financial losses for the sector. Spice crops are infested by a number of significant nematode species, and managing them effectively is crucial to reducing their effects. Meloidogyne spp. (root-knot nematodes), Pratylenchus spp. (root lesion nematodes), and Radopholus spp. (burrowing nematodes) are a few of the main plant parasitic nematodes that affect important spice crops. These worms burrow into the roots of plants, feeding on them and interfering with their ability to absorb nutrients, which results in stunted growth and reduced yields of spices. To protect spice crops, nematode management techniques must be implemented effectively. In order to control nematode populations in a sustainable manner, integrated nematode management (INM) practices combine different techniques. Nematode populations can be decreased by rotating spice crops with non-host plants, which denies the nematodes their preferred hosts. To manage these pests, an integrated framework for nematode management combining chemical, biological, and cultural methods is required. By putting these tactics into practice, farmers can protect the economic sustainability of the spice industry by reducing nematode damage and ensuring the sustainable production of spice crops.

Keywords: Spice crops, Plant Parasitic Nematodes, Management

INTRODUCTION

Spices are an essential part of culinary traditions around the world, contributing tastes, scents, and variety to cuisines everywhere. These fragrant plant products have great historical and economic worth in addition to improving the flavor of our food. A variety of regions develop spice crops, which support local and global economies. However, plant parasitic nematodes continue to pose a threat to these precious commodities, which can significantly affect the profitability of the spice industry (Pervez, 2017a; Pervez and Prasanakumari, 2015; 2016a,b,c).

Spices like pepper, ginger, turmeric, cloves, and cinnamon are prized for their taste-enhancing qualities and are frequently honored for their therapeutic qualities. Many countries and civilizations have a strong heritage of utilizing spices to add unique and delicious flavors to regional foods. Furthermore, historical occurrences and worldwide geopolitics have been greatly impacted by the production and trading of these spices.

Spice crops have a significant economic impact. For millions of people, they are an essential source of income, especially in tropical and subtropical areas. The production and export of spices is a major industry in nations like Vietnam, Indonesia, India, and Sri Lanka, supporting both their total economic growth and agricultural development. Due to the growing interest in herbal medicines and traditional medicine, as well as the growing desire for unique and exotic flavors in the food and beverage business, this economic sector has been steadily rising.

However, a persistent enemy known as plant parasitic nematodes poses a threat to the very health of spice crops. Often undetectable to the naked eye, these microscopic roundworms take root in the soil and cling to the intricate root systems of spice plants. The economics of producing spices and the livelihoods of individuals working in this sector might be severely damaged by their presence. The subterranean environment has been altered by plant parasitic nematodes such as *Radopholus similis* (burrowing nematodes), *Pratylenchus penetrans* (root lesion nematodes), and *Meloidogyne incognita* and *M. javanica* (root-knot nematodes) (Pervez, 2017b; 2018). Their damage includes slowed development, decreased yields, and reduced uptake of water and nutrients due to their feeding on plant roots. This affects the production of spices in both quantity and quality. Plants that are infested may show signs of withering, yellowing, and poor development. Spices contaminated with nematodes may in extreme circumstances become unsafe for processing or human consumption.

Nematode infestations have significant negative effects on the economy. A decrease in product quality and lower spice yields have left farmers struggling with lower incomes. In addition, the expenses related to controlling nematode populations can be high and include costs for crop rotation, soil treatment, and resistant cultivar purchases. Nematicides are chemical agents that are used to control nematodes; however, their use can put additional financial strain on farmers and raise health and environmental concerns. Furthermore, nematode infestations can cause long-term soil degradation, which makes it difficult for spice crops to thrive in impacted areas and endangers the long-term viability of the spice industry.

The goal of this chapter is to present a thorough overview of nematode management techniques in different spice crops by synthesizing the knowledge.

MAJOR PLANT NEMATODE OF SPICE CROPS

Plant nematodes are a diverse group of microscopic roundworms that can be detrimental to spice crops, causing damage to plant roots and reducing yields. Here are different plant nematodes that can affect spice crops, along with information about each of them:

***Meloidogyne incognita* and *javanica* (Root-knot nematode)**: These nematodes are one of the most damaging pests in spice crops, forming galls on roots and leading to stunted growth, wilting, and yield reduction.

***Pratylenchus penetrans* (Root lesion nematode):** This nematode feeds on plant root tissues, causing necrotic lesions and reducing nutrient and water uptake, especially in turmeric and ginger.

***Radopholus similis* (Burrowing nematode):** It can infest black pepper, ginger, and cardamom, causing necrotic lesions, and reducing nutrient and water uptake causing extensive root damage and plant weakness.

***Rotylenchulus reniformis* (Reniform nematode):** This nematode is known to infest the roots of spice crops, including turmeric, causing root swelling and reduced plant vigor.

***Hirschmanniella* spp. (Stunt nematodes):** These nematodes primarily affect turmeric, leading to stunted growth and leaf yellowing due to root damage.

***Tylenchulus semipenetrans* (Citrus nematode):** This nematode infests turmeric and ginger, leading to poor growth, wilting, and yield reduction.

***Hoplolaimus* spp. (Lance nematodes):** These nematodes affect black pepper, ginger, turmeric, cardamom, and other spice crops cultivation, leading to root damage and reduced plant vigor.

***Paratylenchus* spp. (Pin nematode):** Pin nematode is often found in soil associated with spice crops and can affect root health and nutrient uptake.

***Xiphinema americanum* (Dagger nematode):** Dagger nematode species are known to transmit certain plant viruses in black pepper and other spice crops.

***Longidorus* spp. (Needle nematodes):** Similar to dagger nematodes, they can transmit viruses to spice crops and disrupt plant health.

***Helicotylenchus* spp. (Spiral nematodes):** Spiral nematodes coil their bodies and can infest the roots of various spice crops, leading to damage to the root system and impacting their health and productivity.

***Trichodorus* spp. (Stubby root nematodes):** Stubby root nematode damages spice crop roots and may vector plant viruses.

Management

Management of nematodes is crucial for maintaining healthy and fruitful plants in spice crops. Hence strategies to manage plant parasitic nematodes infesting spice crops are discussed;

Crop Rotation

Break the nematode life cycle by rotating spice crops with non-host plants, or plants that nematodes do not feed on. This may aid in lowering soil nematode populations. An essential and long-term method for managing nematode populations in spice crops is crop rotation. This practice succeeds in numerous important goals. First of all, it deprives nematodes of a reliable source of food, which gradually lowers their

populations. Second, non-host crops have the ability to enrich the soil, enhancing its general structure and health. Crop rotation also reduces the possibility of nutrient depletion and soil fatigue, fostering a healthy and balanced agro-ecosystem.

Nematicide Application

Nematicides that are chemical can be used to manage nematode populations. However, since they might have a negative impact on the environment, their use should be carefully considered. Seek advice from an expert in agriculture regarding appropriate nematodes and how to apply them correctly. Although nematicide application is a powerful tool, it should be used carefully because of the possible effects it may have on the environment. To mitigate nematodes' harm to spice crops, chemical nematicides are made to specifically target and eliminate nematodes from the soil.

On non-target organisms as well as the ecosystem as a whole, these substances may, nevertheless, have negative consequences. By investigating the chemical management of *M. incognita* in ginger, George and Sabu (2016) added to our understanding of nematode management in particular crops. Their use puts wildlife and human health at risk by contaminating groundwater, harming beneficial soil organisms, and contaminating soil. It is essential to seek advice from agricultural specialists who can suggest appropriate products and offer knowledge on their safe application in order to use nematicides responsibly. Things like application timing, dosage, and appropriate safety precautions should be taken into account. In order to minimize the use of chemical nematodes and lessen their environmental impact, it is also important to investigate integrated pest management approaches that integrate multiple strategies. Sustainable production of spice crops requires a careful balance between environmental stewardship and nematode control.

Soil Solarization

This technique is placing sheets of clear plastic over the soil in the sweltering summer months. The soil temperature will rise as a result of the sun's heat being trapped beneath the plastic, killing nematodes and their eggs. This works best in areas with warm, sunny weather. Particularly in areas with hot, sunny climates, soil solarization is a natural and environmentally friendly technique for managing nematodes and enhancing soil health in agriculture. By using the sun's radiant energy, this method effectively lowers nematode populations by making their surroundings unfriendly. In the hottest part of summer, the clear plastic sheets are laid over the prepared soil. The temperature of the soil beneath the plastic can rise dramatically, to the point where nematodes and other small organisms are killed (Kranti *et al.,* 2019). This approach has additional advantages in addition to helping with nematode control. It creates a more hygienic and productive planting bed by sterilizing the soil and eliminating a variety of soil-borne diseases and weed seeds. Additionally, it improves the availability of nutrients and soil structure, which supports healthier plant growth. Although soil solarization works very

well in areas with lots of sunshine and heat, local climate factors can affect how well it works. It is an environmentally friendly, chemical-free method that can be a useful supplement to integrated pest management plans for the cultivation of spice crops.

Biological Control

Nematode population suppression through the use of beneficial organisms is known as biological control (Prasad et al., 2021). In order to contribute to environmentally friendly pest management techniques (Chattopadhyay et al., 2016; Pervez and Prasad 2018). Efficacy of biocontrol agents in the production of ginger, offering workable solutions for the control of nematodes in spice crops (Sharma and Singh, 2010). Sheela et al. (2018a, b) reported that employing *Trichoderma* sp. to manage *M. incognita* in ginger. Numerous biocontrol agents have been recognized for the purpose of managing nematodes. Prakash and Meena (2014) utilized *arbuscular mycorrhizal* fungi against root-knot nematodes infesting turmeric.

Archana *et al.* (2019) examined the effectiveness of particular fungicides in addressing root-knot nematodes, specifically *M. incognita* infesting turmeric. The usefulness of fungal biocontrol agents was highlighted into the effectiveness of the fungal antagonist *Trichoderma viride* against *M. incognita* in black pepper. The research done by Rani *et al.* (2019) demonstrated the potential of beneficial microorganisms in nematode management by examining the efficacy of *Pseudomonas fluorescens* in suppressing *M. incognita* and promoting ginger growth. Mitigating slow decline diseases of black pepper through the deployment of bacterial antagonists (Bhai *et al.,* 2017).

Nematodes can be decreased in number in the soil by fungi such as *Paecilomyces lilacinus* and the bacterium *Bacillus firmus*. Plant parasitic nematodes are captured and planted by nematophagous fungi such as *Arthrobotrys* and *Duddingtonia*, which offer a successful biocontrol method. In order to gain insight into the interactions between microbes and plants in pest management, Tiwari and Sharma (2015) examine the effects of mycorrhizal fungi on the growth and nematode resistance of cardamom plants. The difficulties the spice industry faces were highlighted by nematode parasites that are unique to spices (Mathur and Orlob, 2003). Biocontrol agents utilised to manage nematode and produced rooted back pepper cutting by serpentine method (Bhai *et al.,* 2018; Pervez and Eapen, 2021).

Using beneficial nematodes or other soil organisms to manage plant-parasitic nematode populations biologically is a sustainable and eco-friendly method of controlling nematode populations (Pervez and Rao, 2021). *Heterorhabditis* and *Steinernema* are examples of beneficial nematodes that suppress plant parasitic nematodes. The potential of biological control techniques was demonstrated by Jayanthi *et al.* (2007), who evaluated the effects of endophyte and entomopathogenic nematode *S. feltiae* on the suppression of *Pratylenchus brachyurus* in turmeric.

Organic Matter

It is a multifaceted strategy for managing nematodes. First, nematodes may find it more difficult to enter and harm plant roots due to the improved soil structure. Second, beneficial microorganisms that can naturally oppose plant-parasitic nematodes grow when organic matter is present. These microbes may even directly reduce nematode populations by engaging in resource competition.

Add organic materials to the soil, such as well-rotted manure or compost. Because healthy soil has a high content of organic matter, it improves soil structure and fosters beneficial microorganisms, which can reduce nematode damage. Using organic soil amendments to manage the root-knot nematode, *M. incognita*, in ginger provides insights into organic farming practices (Kumar and Srivastava, 2014). By strengthening the soil's structure and facilitating better root development, organic matter increases the soil's capacity to retain nutrients and moisture. Moreover, organic matter improves the general health of the soil, strengthening plants' defences against nematode damage. This strategy improves soil quality, which lessens the need for chemical solutions and promotes the production of spice crops sustainably, thus helping the environment and the field's long-term productivity.

Resistant Cultivars

Nematode damage in spice crops can be effectively and environmentally managed by selecting resistant cultivars. Certain plant varieties are useful tools in nematode management strategies because they have been specially bred to resist nematode infestations. These resistant cultivars often have mechanisms to prevent nematodes from reproducing or display characteristics that discourage nematodes from feeding on their roots. Growers can greatly lessen the effect of nematode damage on their spice crops by choosing and planting such varieties. This method reduces the need for chemical nematodes and other intensive management techniques while also assisting in the maintenance of healthier plants.

Nematode resistance can vary, so it's necessary to consider the local nematode species and their virulence into account when selecting resistant cultivars. Additionally, using resistant cultivars in conjunction with other nematode management strategies like crop rotation and soil enhancement can offer a comprehensive and long-term way to sustain spice crop productivity while protecting the environment.

Sanitation

In the cultivation of spice crops, sanitation procedures are important for nematode management. Farmers are able to mitigate the detrimental impacts of nematodes and drastically lower their population by diligently maintaining good field hygiene. This is how it operates:

Removal of infected plants: Since infected plants can act as nematode breeding grounds, it is important to identify and eliminate them. To stop the spread of nematodes, dispose of or destroy these plants. If these leftovers are left in the field, nematode eggs and juveniles may continue to infest the soil.

Weed Management: Nematodes may find other hosts among weeds. Nematode reservoirs in your fields can be avoided with the use of efficient weed management techniques, such as herbicidal management or weed removal.

Clean Equipment: Be sure to thoroughly clean and disinfect farm equipment, tools, and machinery in between uses in various fields. This stops nematodes from accidentally moving from one place to another.

Soil Disinfection: Under expert supervision, soil fumigation or sterilization may be taken into consideration if nematode infestations are particularly severe. In a novel approach to nematode control, George and Mathew (2015) examine the biofumigation potential of cruciferous crops in suppressing root-knot nematodes in black cardamom. Satyaprasad (2014) research offers insights into sustainable methods for the protection of spice crops, with a focus on the use of organic amendments to manage nematode pests in cardamom cultivation.

By using these sanitation techniques, you can disrupt the life cycle of nematodes and reduce their population. In the end, this will lead to higher yields and healthier spice crops. This approach also reduces the requirement for chemical treatments and aligns with sustainable and environmentally conscious agricultural practices.

Crop Health Management

Another proactive tactic to prevent nematode damage to spice crops is crop health management. Plants that are robust and well-fed are naturally more resistant to nematode infestations. An essential part of this strategy is balanced fertilization and proper irrigation. Sufficient irrigation guarantees that plants get the moisture they require without stressing them out or accumulating too much water, which can make nematode problems worse.

Moreover, plants that receive balanced fertilization are better able to resist nematode damage because they receive the vital nutrients required for strong growth. Plants in good health can direct resources toward defence systems, root regrowth, and general health. Although controlling nematodes is still essential, managing the health and nutrition of your spice crops is an additional tactic that will increase plant vigor and reduce nematode pressure. Verma and Tiwari (2019) study offers insights into natural pest management techniques by examining the efficacy of botanical extracts in suppressing root-knot nematodes in black pepper.

Mulching

Spread organic mulch around the base of your spice plants, like leaves or straw. Mulch can form a barrier that limits nematode access to plant roots and prevents them from moving. For spice crops, mulching is a useful and eco-friendly nematode management strategy. An physical barrier that prevents nematode movement can be created around the base of the plants by spreading organic mulch, such as leaves or straw. This barrier not only lessens direct plant root access but also aids in soil moisture conservation, temperature regulation, and weed suppression. Additionally, beneficial soil organisms that may be antagonistic to nematodes are encouraged by the mulch. By fostering a more robust soil ecosystem, this multimodal strategy strengthens spice crops' resistance to nematode damage. Mulching is a sustainable method that fits in with organic farming's tenets. It can be incorporated into a comprehensive nematode management plan, which lessens the need for more drastic measures.

Trap Crops

Some crops are more attractive to nematodes than others. You can plant trap crops like marigolds, which attract and then host nematodes. This can help reduce nematode pressure on your spice crops. Using trap crops, such as marigolds, strategically in your spice crop fields is a clever nematode management technique. Certain crops, like marigolds, are more appealing to nematodes and act as decoys, drawing the nematodes away from your valuable spice crops. Once the nematodes infest the trap crop, they become concentrated in that area, which makes it easier to manage and reduce their populations.

This approach reduces the pressure that nematodes put on your spice crops and lessens the need for chemical treatments or more drastic nematode control strategies. It's an all-natural and sustainable method to keep nematode populations under control while preserving the well-being and yield of your priceless spice crops. In order to provide insights into sustainable methods for producing spices, Nair and Joseph (2017) evaluate the effects of cover crops on nematode population dynamics and soil health in ginger cultivation.

Crop Timing

Avoid the periods of highest nematode activity, and modify the times harvest. It is common for nematodes to be most active in warm, damp soil. Crop timing is an estimated method of managing nematodes that makes use of their life cycle and activity patterns. Since nematodes usually prefer warm, moist soil, there are specific seasons or times of year when their activity is more noticeable. You can lessen the chance of nematode damage by modifying your planting and harvesting schedules to avoid these periods of peak nematode activity.

A simple way to reduce nematode infestation during the crucial early growth stages of spice crops is to plant them during colder, drier periods. Similarly, harvesting at times

when nematode activity is lower will help guarantee a more prosperous and less damaged crop. By managing nematode populations in a proactive and non-invasive manner, this technique maximizes the health and yield of spice crops while reducing the need for chemical treatments or other interventions. Crop activities must be coordinated with an understanding of local nematode behaviour if they are to be effective.

The particular nematode species, the local climate, and the soil conditions can all affect how successful nematode management techniques are. For specific advice on controlling nematodes in spice crops, it is imperative to speak with local agricultural extension services or specialists.

Soil Testing

For the purpose of monitoring nematode populations and determining their effect on crop health, routine soil testing is essential. The types of nematodes that are present and the population densities can be determined through soil tests. Equipped with this knowledge, farmers can modify their approaches to management in order to successfully deal with particular nematode problems. Because it provides vital information about the populations of nematodes in the soil, soil testing is an important tool in nematode management.

Identify Nematode Species: The accurate nematode species that are present in the soil can be ascertained through soil testing. Various nematodes might call for various approaches to management. Selecting the right control measures can be guided by knowledge of the species.

Population Density: The degree of infestation is indicated by the nematode population density, which is measured by soil testing. Farmers can decide whether nematode management is necessary by tracking population levels over time.

Making a Decision: Farmers have the option to adopt nematode management techniques or not based on the findings of a soil test. Nematode populations may not require management if they are below thresholds that could cause economic harm, which would minimize needless intervention.

Customized Plans: Nematode control plans can be tailored thanks to soil testing. For example, low populations may be controlled by cultural practices such as crop rotation, while high populations may require the use of nematicides, biocontrol agents, or resistant crop varieties.

Monitoring Efficacy: Soil testing enables farmers to keep an eye on the success of their selected nematode control tactics following the implementation of those measures. The management plan can be quickly adjusted if nematode populations continue to be high.

Farmers can reduce the need for needless chemical interventions, customize their strategies to specific nematode challenges, and make better-informed decisions by

utilizing soil testing as a proactive tool in nematode management. This method preserves soil quality and crop health while promoting economical and sustainable nematode control.

Organic Amendments

In light of these difficulties, it is clear that efficient nematode control is necessary to protect the profitability of spice crops and the livelihoods they support. The effectiveness of organic amendments against *M. incognita* in cardamom was determined by Prasad (2007), highlighting the significance of organic solutions for nematode control. An overview of nematode management in turmeric (Sindhu *et al.,* 2016), provides a thorough understanding of the difficulties encountered in this important spice crop. Chitwood (2002) reported that phytochemical-based nematode control strategies, with a focus on natural compounds derived from plants as a possible remedy. Premkumar *et al.* (2013) provided insights into the organic cultivation of ginger and nematode management through their focus on managing the burrowing nematode *R. similis* in ginger cultivation. Subramanian and Chinnadurai (2017) explore the possibility of using plant extracts to manage root-knot nematodes in turmeric. Nematicidal activity of *Strychnos nuxvomica* leaf and its constituents against the root-knot nematode, *M. incognita* and *R. simils* in black pepper (Leela *et al.,* 2012; Pervez *et al.,* 2012). Use of organic amendments to manage nematode communities and plant growth in turmeric (Varaprasad and Muniyappa, 2006).

Integrated Nematode Management

A comprehensive and environmentally friendly strategy called Integrated Nematode Management (INM) is used to manage nematode pests in agriculture. Microscopic roundworms called nematodes can seriously harm crops, resulting in lower yields and financial losses. In order to fight nematodes, INM combines a variety of tactics, which lessens the need for chemical remedies while boosting agricultural sustainability over the long run. Crop rotation, the use of nematode-resistant cultivars, soil solarization, organic soil amendments, predatory nematodes, beneficial microorganisms, and nematicides when needed are some of the techniques included in integrated pest management (INM). An integrated method for managing *M. incognita* in cardamom, supporting the crop's sustainable cultivation (Priyanka and Udayasuriyan, 2016).

Kaur and Chaudhary (2018) investigated integrated nematode management techniques for spice crops, providing insightful information on long-term pest management tactics. An integrated management strategy for *M. incognita* in black pepper was presented by Kokila *et al.* (2017), highlighting the significance of a multifaceted approach to nematode control. Farmers and the ecosystem both gain from this all encompassing strategy, which guarantees a more robust and effective agricultural system while protecting the environment and lowering the need for chemical interventions.

CONCLUSION

Conclusively, managing the major plant nematodes that infest spice crops is crucial to safeguarding the industry's financial sustainability, farmers' livelihoods, and a steady supply of these precious and fragrant products. Particularly vulnerable to nematode infestations are spice crops, such as black pepper, ginger, and turmeric, which can lead to severe financial losses and lower spice yields. Root-knot nematodes, root-lesion nematodes, and burrowing nematodes are the main nematode species that are a serious threat to spice crops. These nematodes attack the roots of the plants, causing a disruption in nutrient uptake, decreased growth, and a decrease in the production of spices. The nematodes cause qualitative as well as quantitative damage to spices, compromising their overall quality, flavour, and aroma.

Nematode control that is effective is essential to maintaining the financial stability of the spice sector. Practices known as Integrated Nematode Management (INM) provide a comprehensive strategy for controlling these pests in a sustainable manner. Nematode populations can be decreased and economic losses can be minimized by employing techniques like crop rotation, resistant cultivars, soil solarization, biocontrol with beneficial nematodes and microorganisms, and organic amendments. Nematicides can also be used carefully, although they should only be used in limited circumstances because of health and environmental risks. Monitoring and managing nematode populations in spice crop fields can be made easier by putting sanitation procedures and soil testing into practice.

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MAJOR PESTS AND DISEASES OF CUMIN AND THEIR MANAGEMENT

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ABSTRACT

Cumin (Cuminum cyminum L.) is an economically significant spice crop cultivated for its aromatic seeds, widely used in culinary and medicinal applications. However, the cultivation of cumin is frequently challenged by various diseases and pests that can adversely impact both yield and quality. Diseases affecting cumin include fungal, bacterial, and viral infections. Fusarium wilt, caused by Fusarium oxysporum, is a prominent fungal disease that leads to wilting, yellowing, and eventual death of the plant. Bacterial blight, attributed to Alternaria burnsii, A. cucumerina causes leaf spots and blighting, while viral diseases such as Cumin yellow vein virus result in yellowing and stunted growth. To mitigate these diseases, integrated disease management practices involving the use of resistant cultivars, proper crop rotation, and application of biopesticides have proven effective. Cumin cultivation is also susceptible to various pests, with aphids, thrips, and mites being among the most prevalent. Aphids, such as Aphis gossypii, feed on plant sap, causing stunted growth and transmitting viral diseases. Thrips and mites, including Thrips tabaci and Tetranychus urticae, respectively, lead to leaf discoloration and reduced photosynthetic activity. Integrated pest management (IPM) approaches, encompassing the use of predatory insects, insecticidal soaps, and cultural practices like maintaining proper plant spacing, are crucial in minimizing pest infestations.

INTRODUCTION

Cumin, also known as zeera or safaid zeera, holds a prominent position among the world's most popular spices, second only to black pepper. Native to Syria, Egypt, Turkistan, and the East Mediterranean, this spice is widely grown in Iran, India, Morocco, China, Southern Russia, Southern Europe, and Turkey. Belonging to the family Apiaceae, cumin is cherished for its delightful aroma, medicinal properties, and therapeutic benefits (Sowbhagya, 2013; Lal *et al*., 2014). Cumin is an annual herbaceous plant that typically reaches a height of 20-30cm and has a slender stem with a diameter of 3-5cm. All branches grow uniformly, giving the plant a well-balanced appearance. The stem itself is either gray or dark green in color. The leaves, 5-10cm long, are alternate and filamentous in shape. The flowers, which form in umbels, are small and come in shades of white or pink. Each flower consists of green sharp-pointed sepals and distinct unequal petals. With five stamens and a bicarpel ovary that produces schizocarp diackens fruit, cumin showcases elongated and fusiform diackene fruits that measure 5-6mm in length and 1.5-2mm in diameter. Numerous reports suggest that the

chromosomal set of Cuminum cyminum is 2n=14 in somatic cells and n=7 in gametic cells. When it comes to pollination, wind plays a crucial role in facilitating the pollination process (Baghizadeh *et al.,* 2013).

Spices: An Inseparable Part of Human Life

Spices have captivated human beings since ancient times, playing a significant role in various aspects of human life. India, known as the "Land of Spices," boasts the largest natural collection of these precious gems. Spices are not only essential for enhancing the flavors in our culinary preparations but also possess potential medicinal value. They find extensive use in pharmaceuticals, nutraceuticals, aromatherapy, preservatives, beverages, perfumes, dental preparations, cosmetics, as well as botanicals and pesticides, contributing significantly to the country's economy (Tiwari and Agarwal, 2004). India takes the lead as the largest producer, consumer, and exporter of spices. With spice production and export continually on the rise, India's dominance in the global spice market remains unchallenged. Currently, spices are cultivated on approximately 3.08 million hectares of land in India, yielding an annual production of about 5.4 million tonnes valued at around Rs 4500 crores. The country's spice exports amount to approximately 445,000 tonnes, with a total value of Rs. 4460 crores (Kumar, 2018).

Versatile and Nutrient-Rich Cumin in Indian Households

Cumin holds a special place in Indian households, with its seeds being an essential ingredient in various culinary preparations. Apart from adding a distinct flavor to dishes, cumin seeds are also known for their high content of iron and manganese. Additionally, cumin seeds offer numerous health benefits due to their antioxidant, stomachic, astringent, anticancer, stimulant, and carminative properties (Ravi *et al.,* 2013). It's worth noting that the flavor of cumin can vary depending on the variety and its place of origin.

Climatic and Soil Requirements for Cumin Cultivation

To ensure successful cultivation, cumin requires a moderate sub-tropical climate. It is not well-suited to regions with high humidity and heavy rainfall. Instead, cumin thrives in cool and dry climatic conditions, with temperatures ranging from 25-30°C. The crop is commonly grown in dry regions such as Gujarat and Rajasthan in India. Cumin is a tropical plant that flourishes during the Rabi season, which is characterized by low atmospheric humidity during the flowering and seed formation stages. The ideal soil for cumin cultivation is well-drained, sandy, or loamy soil, enriched with organic matter, and with a pH ranging from 6.0 to 8.3. Cumin predominantly grows in light-textured soils that are deficient in nitrogen and have low water retention capacity.

Pests and Diseases Affecting Cumin

Cumin is vulnerable to various pests and diseases that can negatively impact its yield. Common pests include aphids, mites, and whiteflies. As for diseases, cumin is

susceptible to wilt (caused by *Fusarium oxysporum f.sp. cumini*), blight (*Alternaria burnsii*), and powdery mildew (*Erysiphe polygoni*). These diseases, along with the lack of superior varieties and scientific crop production techniques, pose significant challenges for cumin growers, leading to decreased yields.

Fungal Diseases

- Wilt: Caused by *Fusarium oxysporum f.sp. Cumini*
- Blight: Caused by *Alternaria burnsii, A. cucumerina*
- Powdery Mildew: Caused by *Erysiphe polygoni*
- Damping Off: Caused by *Pythium aphanidermatum*

Nematode Disease

- Root-knot Disease: Caused by the Root-knot nematode *Meloidogyne* spp.

1. Wilt: A Devastating Disease for Cumin

Wilt, caused by *Fusarium oxysporum f.sp. cumini*, poses a severe threat to cumin crops. This disease manifests through wilting symptoms in both seedlings and mature plants. Upon cutting the stem longitudinally, brownish discoloration of vascular bundles becomes apparent. In the Rajasthan region of India, wilt of cumin has been reported, with *Fusarium oxysporum* identified as the causal organism.

Survival and Spread of Wilt Disease

Fusarium oxysporum f.sp. cumini is both soil and seed-borne, surviving as a saprophyte in infected plant debris in the form of mycelium and chlamydospores. The disease spreads through irrigation water, rain splashes, wind, and inter-cultural operations. Once a plant succumbs to wilt, the fungus invades and sporulates in all tissues, continuing to infect neighboring plants. The devastating effects of this disease significantly reduce cumin yield. Wilt usually infects crops during the last week of December when they are approximately one month old. Infected plants show patches, followed by drying of the affected plant. Early-sown crops tend to be more susceptible compared to late-grown ones.

Disease Management

Managing wilt proves challenging due to its soil-borne nature. No single factor or chemical treatment alone can effectively control this disease. Adopting a comprehensive management strategy is crucial, starting with the use of healthy seeds and implementing various practices such as summer plowing, crop rotation with beans, wheat, cluster beans, and mustard, and the application of fungicides or antagonistic fungi like Trichoderma. Additionally, soil solarization can help eliminate the soil-borne pathogen responsible for wilt.

2. Powdery mildew

Powdery mildew, caused by Erysiphe polygoni, is a significant and devastating disease that can result in the complete failure of crops. This destructive disease typically strikes the crop during the flowering stage, especially in cloudy weather between February and March. Initially, it affects the leaves, but it can quickly spread to succulent stems, branches, and even flowers, posing a serious threat to the crop's overall health (Sharma, *et al*., 2013). In severe cases, the development of seeds may be hindered, leading to further damage.

Survival and Spread

Powdery mildew can be transmitted through the soil and seeds. Primary spread occurs through these channels, while secondary spread is facilitated by the dispersal of conidia through wind and rain splashes.

Favorable Conditions for Disease Development

For conidial germination and disease progression, cool, highly humid weather (around 20-25°C) or cloudy conditions with a relative humidity (RH) exceeding 80% are conducive. These environmental factors create the ideal conditions for the disease to thrive.

Managing Powdery Mildew

Controlling powdery mildew in cumin crops can be challenging, making prevention the best remedy to inhibit the growth of the disease-causing mycelium. It's important to note that cumin crops are susceptible to a variety of pathogens that can negatively impact seed yield (Dange, 1995 and Sharma *et al*., 2010).

Chemical Control Options

Various chemical control methods have been tested against *E. polygoni*, with propiconazole (0.025%) proving to be the most effective fungicide compared to others. However, it is important to follow recommended guidelines for usage:

- Spray aureofungin 46.15%w/v. SP at a rate of 0.02% in 300 liters of water. Apply a second spray after a 30-day interval.

- Use difenoconazole 25% EC at a rate of 0.05% in 200 liters of water. Apply a second spray after a 15-day interval.
- Alternatively, sulphur-based fungicides can be used: sulphur 40% WP at a rate of 1.4 kg per acre in 400 liters of water, sulphur 80% WG at a rate of 0.75-1.0 kg per acre in 300-400 liters of water, or sulphur 85% DP at a rate of 6-8 kg per acre.
- Another option is dinocap 48% EC at a rate of 120 ml per acre in 300 liters of water.

These fungicides have shown promise in combating E. polygoni and can be considered as part of an integrated approach to disease management. By implementing preventative measures and utilizing effective chemical control options when necessary, farmers can effectively combat powdery mildew and protect their cumin crops from devastating losses.

3. Alternaria blight

In the realm of cumin crop diseases, alternaria blight maliciously holds the title of the second most damaging affliction, trailing closely behind wilt. This pesky disease primarily takes root during warm and humid weather, striking mercilessly at the flowering stage and compromising the maturation process of cumin seeds. The unfortunate outcome? Shriveled seeds that are easily carried away by the wind during winnowing. This disease poses a particular threat to early-sown crops, resulting in high intensities of infection and ultimately rendering the seeds unmarketable. Unfortunately, this spread of disease transpires at an alarming speed, leaving us with no choice but to rely on preventive measures to combat this blight effectively.

Survival and Spread

To truly comprehend Alternaria blight, we must confront its formidable survival and spread tactics. The fungus cunningly waits out the winter season as dormant mycelium, patiently nestled within diseased and decaying crop refuse. However, its ambitions don't end there. Alternaria blight may also find refuge in the cucurbit family of weeds, and

perhaps even within the soil itself. Remarkably, the fungus's conidia can withstand the test of time, enduring harsh and dry conditions for months on end. But how does this pathogen expand its reign? The answer lies within various modes of transportation: air currents, hitchhiking on clothing and tools, and even being carried by running water. Talk about resourcefulness! Once settled, the germinating spores skillfully penetrate susceptible tissues either directly or through existing wounds, spawning a fresh crop of conidia. These airborne invaders are then further disseminated by the likes of wind, rain, tools, or unwitting workers.

Favorable Conditions

Alternaria blight revels in wet weather where temperatures range from 20-32°C, accompanied by generous humidity levels and a cloudy ambiance. It is during these meteorological circumstances that the disease assumes its full, formidable form, leaving cumin crops vulnerable to its ravages.

Managing Alternaria Blight

Now that we've acquainted ourselves with the enemy, it's time to explore our options for disease management. Researchers have discovered that bio-agents exhibit significant efficacy in inhibiting the growth of A. burnsii's mycelium under controlled laboratory conditions. For instance, Ghosh et al. (2002) revealed intriguing findings, showcasing the inhibitory prowess of T. viride, T. hamatum, and A. awamori against A. alternata's growth. Furthermore, Monaco et al. (2004) reported commendable results, demonstrating that Trichoderma species displayed inhibitory effects on A. alternata's growth under similar laboratory settings.

Chemical Control

When it comes to combating Alternaria blight, chemical control tactics have proven valuable. These measures involve the strategic application of various compounds to thwart the disease's progress. Spraying aureofungin 46.15% w/v. SP at a rate of 0.02% in 300 liters of water, followed by a second spray 30 days later, has yielded promising results. Alternatively, one could opt for copper oxy chloride 50% WP at a rate of 1.0 kg per acre in 300-400 liters of water, or difenoconazole 25% EC at a rate of 0.05% in 200 liters of water, applying a second spray 15 days later. For those seeking alternative options, mancozeb 75% WP at a rate of 0.6-0.8 kg per acre in 200 liters of water or zineb 75% WP at the same rate in the same amount of water may prove to be effective choices. Additionally, the use of garlic clove and ginger rhizome extract has exhibited promising results in inhibiting the radial growth and spore germination of Alternaria.

4. Damping off

Damping off disease is soil borne. It occurs in two stages, i.e. the pre-emergence and the post-emergence phase. In the first stage, seeds get rotted and the seedlings are killed just before they reach the soil surface. A soft water-soaked lesion appears near the collar region after seedling emerges out of soil line. The disease is primarily spread by the

pathogen via soil, water and secondary spread of conidia via rain splash and wind. Low temperatures below 240C, high humidity, high soil moisture, high dose of nitrogenous fertilizers and cloudiness for few days are the favourable conditions for infection and development of disease. Crowded seedlings and dampness due to high rainfall ill-drained soil conditions increases the pathogenic damping-off.

Survival and spread

Disease is soil borne. Primary spread of pathogen is through soil, water and the secondary spread of conidia spread through rain splash and wind

Favourable conditions

High humidity, high soil moisture, high dose of nitrogenous fertilizers, cloudiness and low temperatures below 24° C for few days are ideal for infection and development of disease.Crowded seedlings, dampness due to high rainfall ill-drained soil conditions and excess of soil solutes hamper plant growth and increase the pathogenic damping-off .

Nursery affected with damping off

5. Root Knot Disease

Root knot disease in cumin is caused by nematodes specifically the Meloidogyne species. These microscopic, worm like organisms infest the roots forming characteristic knots or galls. The symptoms are galls on roots which hinder the plants ability to take up water and nutrients. Infected plants often show stunted growth and may exhibit signs of nutrient deficiency. The foliage turns yellow and overall plant vigor is compromised.

Survival and spread

The nematodes enter the plant through roots and induce the formation of feeding cells, leading to gall formation

Favourable conditions

Root knot nematodes thrive in warm, sandy soils. Overcrowded plantings and poor soil health can contribute to the severity of infestations.

Disease Management

Planting cumin varieties that are resistant or tolerant to nematodes can help mitigate the impact of disease. Rotation with the non-host crops will break the nematode life cycle. Solarization of and use of different nematicides with combination of various management strategies is often the most effective way to control root knot disease while minimizing environmental impact. Azadirachtin is the main active content of neem and is reported to be very effective in controlling insects and nematodes pests of the cumin.

Different Management Activities

- **Presowing**

Common cultural practices	Nutrients	Weeds
Timely sowing, field sanitation, rogueing, deep summer ploughing to control juveniles and adults of nematodes, and resting stages of insect pests. •Sow/plant sorghum/maize/bajra in 4 rows all around cumin crop as a guard/barrier crop. • Destroy the alternate host plants • Apply manures and fertilizers as per soil test recommendations • Follow crop rotation	Soil is brought to fine tilth by 2-3 ploughing with harrow or desi plough. Stubbles of previous crops should be collected and removed Clods should be broken and field should be leveled with the help of plank. Beds of 4 m x 3 m size with provision of irrigation channels should be prepared before sowing of seeds to facilitate proper irrigation and intercultural operations. • Incorporate 6-8 t FYM/acre in soil, 2-3 weeks before sowing.	• Soil solarization during summer at the time of field preparation, adopt stale seed bed technique to minimize weeds menace in the field. Soil borne pathogens, nematodes and resting stages of insect pests

- **Sowing**

Common cultural practices:	Nutrients	Weeds
Use resistant/ tolerant varieties.,Select healthy, certified, and weed seed	Apply 15 Kg nitrogen (N) and 15 Kg phosphorus (P) at the	Sowing/transplanting should be done in lines to facilitate hoeing and

free seeds	time of sowing as basal dose. Another, 15 Kg N should be applied as topdressing one month after germination of seeds.In zinc deficient areas, apply zinc sulphate @ 8 Kg/acre.	weeding operations during vegetative stage.Adopt recommended agronomic practices like timely sowing, proper spacing, irrigation etc. to obtain the healthy plant stand.

- **Vegetative stage**

Common cultural/ Mechanical/Biological practices

A. Collect and destroy crop debris, judicious use of fertilizers, irrigation at critical stages, avoid water logging and stress to the crop.

B. Collect and destroy disease infected and insect infested plant parts, collect and destroy eggs and early stage larvae. Handpick the older larvae and catterpillars during early stages of the crop and destroy them in kerosene mixed water.Use yellow sticky traps @ 4-5 trap/acre and light trap @ 1/acre and operate between 6 pm and 10 pm.Install pheromone traps @ 4-5/acre for monitoring adult moths activity. Erect bird perches @ 20/acre for encouraging predatory birds such as Kingcrow etc.

C. Conserve natural enemies through ecological engineering and augmentative release of natural enemies

- **Reproductive stage**

Nutrients	Incorporate crop residues in soil immediately after harvest.
Weeds	Remove left over weeds before shedding of the seeds to prevent further spread of weeds
Aphid,	Spray the pressurized water on the cropand apply fish oil rosin soap or NSKE (3%), neem oil (2%) or tobacco decoction (0.05%).
Thrips	Apply fish oil rosin soap or NSKE (3%), neem oil (2%) or tobacco decoction (0.05%).
Tobacco caterpillar	Ecological engineering by growing of ovipositional trap crops such as castor.
Cutworm	Deep ploughing of fields ,attracting cutworm larvae using rice bran , flood field prior to plantingon severely infested fields

- **Storage pests**

Cigarette beetle	Sticky traps baited with the female sex pheromone,store grains in gunny bags , use commercially available cigarette beetle

	traps with synthetic serricornin
Drugstore Beetle	Use commercially available traps and lures with the drugstore beetle sex pheromone, stegobinone (2,3-dihydro-2,3,5-trimethyl-6-(1-methyl-2oxobutyl) -4H-pyran-4-one), use sticky traps baited with the female sex pheromone,stegobinone, for monitoring adult beetles

CONCLUSION

Understanding the diverse array of diseases and pests affecting cumin is essential for the development and implementation of effective management strategies. Integrated approaches that combine resistant cultivars, cultural practices, and environmentally friendly control measures are pivotal for sustainable cumin cultivation. As the agriculture industry continues to evolve, ongoing research and collaboration are vital to address emerging challenges and ensure the resilience of cumin crops worldwide.

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IDENTIFICATION AND MANAGEMENT OF MAJOR PESTS OF SPICES

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ABSTRACT

India is conscientious as the land-living of flavors and one of the major spices producing and exporting country of the world. Cardamom possesses 25% of the world-wide trade in spices as, huge quantities of spices also restrained inside the country deliberating to eco-friendly determines then flavor of foods and other products. There is a appareled transfer demand for Indian spices by means of of high quality with the determined value of indispensable emollient, oleoresin and energetic integrities. Nearly one-sixth of all crops grown all-inclusive are vanished due to herbivorous insects and the plant diseases they communicate. Indeed, owing to environment variation coupled with rise in agriculture, there has been an architype move in invasion of insect pests mutually in stint and intergalactic. Likewise, over the period, Sustainable farming and food security at worldwide which arose as an alarming frequency. The planters traditionally use the pesticides as initial contour of defense and often alternative to undiscerning and non-judicious use of insect killer for management of insect pests. However, these insect pests to cause several complications, such as metabolomic profiles, eco-friendly effluence, pesticide scum in the harvested crops, progress of confrontation/retrieval of pests, emergence of novel pests, devastation of usual rivals and pollinators, in the culmination which would be improving the cost of production.

Keywords: Cardamom, Pest of spices, Disease management

INTRODUCTION

Indian spices are highly preferable in the world trade market for its flavour, texture and aroma. Spice crops are high value and low volume crops getting high income per unit area. These crops are both annuals and perennials in nature and its raw materials are the good source of raw material for ancillary industries (David and Ramamurthy. 2011; Muthukrishnan *et al*; 2005). India, hailed as the Land of Spices, boasts a rich diversity of aromatic and flavorful spices like Cardamom, Cinnamon, Black pepper, Turmeric and more. The cultivation and export of these spices contribute significantly to the nation's economy, with India being a major player in the global spice trade (Sivasubramanian *et al*; 2012; Regupathy and Ayyasamy, 2013). However, the menace posed by pests poses a substantial challenge to the sustained growth and productivity of the spice industry. Pest including insects, mites (Nair, 1995 & 1986), fungi and bacteria, present a grave threat to spice crops during cultivation, harvest, storage and transportation phases (Atwal and Dhaliwal. 2002). These intruders inflict damage by consuming, contaminating or degrading the quality of spices which leads to yield losses,

reduced market value and compromised export potential (Awasthi, 2007). Inadequate pest management practices exacerbate the vulnerability of spice crops to these destructive forces.

History of Spices

It is the history of human kind itself, with empires raising and falling based on the trade of exotic spices from distant lands, their intoxicating allure changing and shaping the very foundation of our society. Christopher Columbus set sail for the indies. He was searching for pepper. He never found the passage to the Indies he was hoping far, and he (never found the pepper he was searching for but the world was changed forever because of our passion for strange new flavours from faraway places. Spice trade developed throughout South Asia and Middle East at least 2000 BCE with cinnamon and black pepper and in East Asia with herbs and pepper. A spice is a seed, fruit, root, bark and plant substances primarily used for flavouring, colouring or preserving food materials (Dhaliwal and Ramesh Arora. 2004; Dhaliwal *et al*; 2006). According to India, it is blessed with varies climatic conditions and each of its state produces some spices. Apart from adding colour, flavour and taste consumption of spices provide infinite health benefits (Srivastava and Dhaliwal, 2011). Medical writings of Charaka and Sushruta referenced spices and herbs. Sushruta also used spices such as cinnamon, cardamom, ginger, turmeric and pepper for healing purposes (Manisegaran, and Soundararajan, 2010). Spices such as ginger, cardamom, turmeric and black pepper were included in ancient herbal medicines for different type of health benefits (Sonal Dubey 2017).

Scope and Importance

India is considered as the land of spices and one of the major spices producing and exporting country of the world. It contributes 20-25% of the world trade in spices besides, large quantities of spices also considered within the country for seasoning and flavouring of foods and other products (Rathore et al; 2013). Out of 109 spices in the world around 60 spice crops are grown in India (Verma *et al*; 2004; Vinod Kumar Paswan *et al*; 2021). India blessed with varied agro climatic conditions, tropical, subtropical and temperate spices can be grown and having good scope or cultivation of majority of the spices. There is a good export demand for Indian spices because of high quality with the maximum content of essential oil, oleoresin and active principles.

Pests of Cardamom

1. Thrips: *Sciothrips cardamomi*

Symptoms of damage

Panicles become stunted. Shedding of flowers and immature capsules thus reducing the total number of capsules formed. Infestation causes formation of corky encrustations on

pods resulting in their malformed and shriveled condition. Such pods lack their fine aroma and the seeds within are also poorly developed. The pest has been identified as

- **Eggs** kidney shaped lays singly in the tender part of the leaf sheath, racemes
- **Adult:** is minute, dark greyish brown with fringed wings.

Corky encrustations on pods

Adult

Management

The pest can be managed by regulating shade in thickly shaded areas and spraying of insecticides like quinalphos 0.025% or fenthion or phosalone 0.07% during March, April, May, August and September. Viz; for effective thrips management precautions like trashing before insecticide spray, avoiding spraying during heavy rain, using 250 to 500 ml spray fluid depending on canopy growth and proper coverage to panicles and one third portion, of plants from the base of plants are to be adhered strictly.

2. Shoot, panicle and capsule borer: *Dichocrocis (Conogethes) punctiferalis*

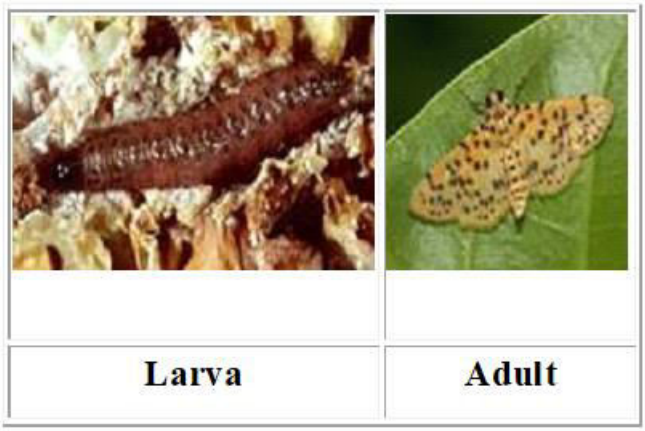
Symptoms of damage

Early stage of the larva bores the unopened leaf buds and feeds on the leaf tissue. They also bore the panicles leading to drying up of the portion from the affected spot. Immature capsules and feed on the young seeds inside rendering the capsules empty. Late stage larvae bore the pseudostem and feed the central core of the stem resulting in drying of the terminal leaf and thus produce characteristic 'dead heart' symptom. Oozing out of frass material at the point of tunnelling is the indication for the presence of larva inside the plant parts. The incidence of this pest is noticed throughout the year but they occur in enormous number in four periods, December-January, March-April, May-June and September-October and their abundance synchronizes with the panicle production, fruit formation and new tiller production.

Shoot damaged by capsule borer

Identification of pest

- **Egg**: is pink, oval, flat and lays singly or in group on the tender part of the plant
- **Larva:** is long, pale greenish with a pinkish was dorsally, head and pro-thoracic shield brown in colour and body covered with minute hairs arising on wards.
- **Pupa**: Pupation takes place in lose silken cocoon in larval tunnel.
- **Adult:** is a medium sized moth; the wings are pale yellowish with black spots on the wings.



Management

During day time adult moths rest on the lower surface of the cardamom. They may be collected with insect net and killed. The practice of removing the tillers showing 'dead heart' symptoms should be carried with due care. Tillers may be removed if the attack is fresh as indicated by extrusion of frass. The infestation by early stages of larva of this pest in emerging panicle, immature capsule and leaf bud can be controlled effectively with insecticide application. Once the late larvae bore and go deep inside the pseudostem, the chemical spray even in its higher dose becomes ineffective. Spraying fenthion 0.075% is effective in controlling this pest.

3. Capsule borers: *Jamides sp.*

Symptoms of damage

The caterpillars bore and feed on the inflorescence, flower buds, flowers and capsules. Affected capsules become empty with a big circular hole, turn yellowish - brown which decay and drop off in the rainy season.

Identification of pest

- **Eggs**: Spherical, greenish white lay on the panicled flower.
- **Larva:** Flat, trowel shaped covered with dense hairs covering all over the body.
- **Pupa:** Small and brownish in colour and pupates in the debris near the panicle.
- **Adult:** The wings of moth are bluish with metallic lusture on the upper surface and bordered with a white thin line and black shade

4. Beetle borer: *Onthophagus spp.*

Symptoms of damage

Larva makes the bore hole which is neat, circular tiny and at right angles to the pericarp mostly on the ventral side. When the attack is on young immature capsules, they put forth matured appearance, decay and drop off. Adults beetle bores the flowers and feed on tissues. Pest has been identified as Adult**:** small, dark brown, cylindrical beetle with short thick erect hairs covered all over body. The elytra are hard and shiny. Agriculture field

Management

By providing judicious shade regulation and spraying of contact insecticide viz., quinalphos @2ml or methyl parathion @2ml/lit.

5. Hairy caterpillars: *Eupterote cardamomi, E. canarica, E. fabia*

Symptoms of damage

These appear sporadically in enormous populations at intervals of several years and cause heavy damage to the foliage. Caterpillars are gregarious in habit and they congregate on the trunks of shade trees during day time and drop down on the cardamom plants during night time. They fed voraciously on leaves and defoliating the whole cardamom plants. Usually, the damage is observed during October-December. Pest was identified as:

E. cardamomi

- **Eggs:** Dome shaped and lay on undersurface of the leaves of shade trees. **Larva:** Robust, bluish black with pale brown head, white hairs and dorsal conical tuff of hairs. **Pupa:** Pupation takes place in soil. **Adult**: Large moth, pale yellow with wavy lines and a series of spots near the outer margin of wings.

E. canarica

- **Eggs**: Pale yellowish in colour and lays on the undersurface of the leaves of shade trees. **Larva**: Robust with red head and black 'V' shaped vertex border. **Pupa:** Pupation takes place in soil **Adult:** Large moth brownish yellow with two diagonal bunds and zig zag lines on wings.

E. fabia

- **Larva:** Robust, dark purplish brown with black head, grey tipped long hairs and red prologs. **Pupa:** Pupation takes place on dried leaves. A**dult:** Large bright yellow moth with prominent black wavy lines and patches on wings.

Management

Hairy caterpillar incidence can be checked by lopping off and burning branches of shade trees in which eggs are laid. Gradual elimination of shade trees favoured for egg laying will reduce the incidence. Caterpillars that congregate at the base of shade trees can be collected and killed. Moths can be attracted to light during night and by installing light traps, the moths can be collected and killed. Spray methyl parathion or monocrotophos or quinalphos 3ml/lit.

6. Shoot fly: *Formosina flavipes*

Symptoms of damage

The larvae feed on the growing shoot of the young cardamom suckers and symptoms of dead heart. The pest of ***Formosina flavipes*** **epitomize as Eggs:** cigar shaped and white colour and is laid in between leaf sheath and pseudostem on the whorl. **Adult:** Fly. **Management**: To remove the affected shoots at ground level and destroy them. Spray dimethoate or quinalphos (0.05% each).

7. White flies: *Dialeurodes cardamom*

Symptoms of damage

Nymphs and adults remain in colonies on lower leaf surface and suck the sap. Chlorotic patches appear on leaves, gradual yellowing and get dried. Sooty mould development occurs due to honeydew secretion. Pest has been detected as **Nymphs:** are pale greenish to greenish yellow in colour. **Adult:** with two pairs of white wings. **Management** represent as Spray methyl demeton or dimethoate (0.05% each) on the foliage.

8. Cardamom aphid: *Pentalonia nigronervosa* f.sp *caladii*

Symptoms of damage

Nymphs and adults suck up plant sap. Colonies of aphids are seen under concealed conditions inside leaf sheaths of the older pseudo stems. The aphids act as a vector of the mosaic or 'Katte' virus of cardamom.

Identification of pest show Wingless aphid is dark brown, pyriform. Winged aphids have wings having prominent black veins.

Management to represent the Removal of *Colocasia* and other hosts in the vicinity of cardamom plantation is recommended. Remove partly dried and decayed pseudostems which harbour the colonies of aphids to reduce aphid population. Foliar spraying with phosphamidon 1 ml or dimethoate 2 ml/lit at an interval of 2 weeks in November and April gives adequate control.

9. Root grubs: *Basilepta fulvicorne*, *Holotrichia serrata*

Among the three species *B. fulvicorne* is found to cause more damage in cardamom tracts. **Symptoms of damage**: The grubs feed on the roots in the form of irregular scraping. In advanced stages entire root system is found damaged resulting in drying and rotting depending on the season of attack. In the severely infested plants, leaves turn yellow and dry. **Identification of pest** - **Grubs:** Short, stout, 'C' shaped, pale white in colour. **Adult:** Beetles are shiny, metallic blue, bluish green, greenish brown or brown. **Management:** Collect the beetles using hand nets during peak period of emergence i.e., during April-May and kill them. Beetles can be seen resting on the leaves during day time. The time of insecticide application is to be synchronized with the emergence of adults and egg laying. Applying chlorpyriphos 0.075% or phorate 2-4 g a.i./plant in May and in September-October is effective in reducing the population of grubs. Light raking of soil before the insecticide application is essential for effective control of root grubs.

Pests of Pepper

Pollu beetle*: Longitarsus nigripennis*

Symptoms of damage

Stem and berry damage

Grub feeds on the growing tip, tender stem, leaf petiole, spikes and berry. Tunneling of tender stem causes drying up of the shoot. The portions of the spikes tunneled by grubs turn black and cause dropping of spikes due to the subsequent rotting. Grubs bore into the berries and feed on entire internal contents. Exit holes could be seen on dry berries. As a result of grub boring, the berries dry up and turn dark in colour. They are hollow and crumble when pressed. Such hollow berries are called 'Pollu' berries. **Leaf damage:** The adult beetles feed on all stages of the leaves. Most preferred one is tender leaves. Due to feeding irregular holes are seen. On mature leaves, the beetle scrapes the green matter leaving the layer of upper epidermis.

Identification of the pest - Eggs

- Female beetle scoops out shallow holes on growing bud, leaf, petiole, terminal buds, spikes and tender berries and lay eggs singly.
- Freshly laid eggs are yellow and turn brownish yellow.
- **Grubs:** Pale yellowish in colour.
- **Pupa**: Pupation takes place in the soil in an earthen cell
- **Adult:** Beetle is oblong with shiny black elytra and enlarged hind femur

Management

Regulation of shade in the plantation reduces the population of the pest in the field. Tilling the soil at the base of the vines at regular intervals and application of chlorpyriphos dust to the soil will kill the purpose. Spraying quinalphos (0.05% each) during June/July and September/October or quinalphos (0.05% each) during July and

Neemgold (0.6%) (neem-based insecticide) during August, September. The undersides of leaves (where adults are generally seen) and spikes are to be sprayed thoroughly.

2. Top shoot borer: *Laspeyresia hemidoxa*

Symptoms of damage

Larvae bore into tender terminal shoots and feed on internal tissues resulting in blackening and decaying of affected shoots. The pest infestation is higher during July to October when numerous succulent shoots are available in the vines.

Identification Of The Pest

Larva: The full-grown caterpillar is greyish green in colour. **Pupa:** Pupation takes place inside the shoots within the tunnel. **Adult** - It is a small moth. **Forewing:** The basal half of is black and distal half is red. **Hind wings:** Greyish in colour. **Management** - Spray quinalphos (0.05%) on tender terminal shoots; repeat spraying at monthly intervals (during July - October) to protect emerging new shoots.

3. Marginal gall thrips: *Liothrips karnyi*

Symptoms of damage

Downward and inward curling of leaves resulted in the formation of marginal leaf galls. Later the infested leaves become crinkled and malformed. In severe cases of attack, the whole plant may become stunted, affecting adversely the formation of spikes. To identify the pest which shown as **Eggs:** Laid within the marginal galls on the leaf surface singly. **Nymphs:** White and sluggish. **Adult:** Black thrips. **Management**: Spray dimethoate (0.05%) during emergence of new flushes in young vines in the field and cuttings in the nursery.

4. Scale Insects

Pepper mussel scale: *Lepidosaphes piperis*

Coconut scale: *Aspidiotus destructor*:

Symptoms of damage

Scales suck the sap from stems, leaves and petioles of pepper vine. They feed on plant sap and cause yellowing and wilting of infested portions. In severe cases of infestation, the affected portions of vines dry up.

Infested stem

Leaves dried

Identification of the pest has determined as **Pepper mussel scale:** Scale is small, dark, boat shaped. **Coconut scale:** Circular (about 1 mm in diameter) and yellowish brown.

Management: Systematic stripping of the affected plant parts reduces the pest incidence. Spray dimethoate (0.1%) repeat spraying after 21 days to control the infestation completely.

5. White tailed mealy bug: ***Ferrisia virgata***

Symptoms of damage: Mealy bug found in cluster on the terminal shoots, leaves, berries and suck the sap yellowing, withering and drying of plants or shedding of berries.

Identification of the pest

Female is apterous with long prominent waxy filaments at the posterior end. Body covered with waxy powder. **Management**: Removal of heavily infested plant parts and the destruction will minimize the inoculum. Spray dimethoate 2 ml (or) methyl parathion 1ml/lit.

Pests of Turmeric and Ginger

1. **Shoot borer:** ***Conogethes punctiferalis***

Symptoms of Damage

Yellowing and drying of leaves of infested pseudo stems. The presence of a bore-hole on the pseudo stem through which frass is extruded and the withered and yellow central shoot.

Damaged leaves and larva presence on the inside stem

Identification of pest

- **Egg**: It is in pink, oval, flat and lays singly or in group on the tender part of the plant. **Larva:** is long, pale greenish with a pinkish was dorsally, head and pro-thoracic shield brown in colour and body covered with minute hairs arising onwards. **Pupa**: Pupation takes place in lose silken cocoon in larval tunnel. **Adult:** is a medium sized moth, the wings are pale yellowish with black spots on the wings.

Larva **Adult**

Management

Spraying malathion 0.1% at 30 day intervals during July to October is effective in controlling the pest infestation. The spraying has to be initiated when the first symptom of pest attack is seen on the inner most leaves on the pseudo stem.

2. Rhizome scale: ***Aspidiella hartii***

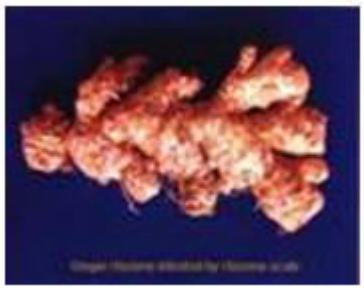
Symptoms of Damage

Field infestation

Plants look devitalized, pale and withered before drying completely. In such cases at the time of harvest minute yellowish crawlers can be seen moving in large numbers and this is the potential stage of dissemination.

Storage infestation

In Initial stage of infestation in, the white- coloured scales are seen scattered on rhizomes and later they congregate near the growing buds. When the infestation is severe the rhizome and buds shrivel and ultimately the entire rhizome dries.



Identification of pest

Adult - Female: scales are circular (about 1mm diameter) and light brown to gray and appear as encrustations on the rhizomes. **Male** is orange coloured with transparent wings, distinct head, thorax and abdomen.

Management

Discard and do not store severely infested rhizomes. Collect and destroy damaged leaves. Select healthy rhizomes free from scale infestation for seed materials. Treat seed material with quinalphos 0.075% (for 20-30 minutes) before storage and also before sowing in case the infestation persists. Apply well rotten sheep manure @ 10 t/ ha in two splits or poultry manure in 2 splits followed by drenching dimethoate 30 EC @ 2 ml or phosalone 35 EC @ 2ml /lit of water.

3. Leaf roller: *Udaspes folus*

Symptoms of Damage : Leaves become folded or rolled longitudinally and complete defoliation can be seen. **Identification of pest** : **Larva:** is smooth green with black

head; **Adult** : It is brownish black butterfly. **Forewing**: has a white spots; **Hind wing:** has a large white patch.

Management

A spray with carbaryl (0.1%) or dimethoate (0.05%) may be undertaken when the severe infestation.

4. Thrips: *Panchaetothrips indicus*

Symptoms of Damage: Thrips affected leaves become rolled up, turn pale and gradually dry-up: The identified pest were in adult is with fringed wings. **Management**: Spray insecticides like quinalphos 0.025% or fenthion or phosalone 0.07%.

CONCLUSION

The results obtained from this assessment revealing a systematic validation for the practice of spices and their spin-offs in defense of crop beneath the field and post-harvest measure the spices grains in storage conditions. Further, examine the isolation and apparatus of action of their active constituents might be hopeful approaches for the management of insect pests of crop plants. However, in vivo insecticidal efficacy of spices extracts and essential oils requires further investigation as well. Based on the results presented in this review paper, spices offer an opportunity for new compounds. These topographies indicate that plant protection chemicals from spice crops could be used in a variety of ways to control a large number of insect pests and diseases. In fact, the potential insecticidal activity of the spices extracts and essential oils need to be conduct and promote on a commercial scale. It can be concluded that essential oils, oleoresin and their phytoconstituents isolated from assorted spices might be useful and safe proxies for conservative artificial pesticides.

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MAJOR INSECT PESTS OF MUSTARD AND THEIR MANAGEMENT

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ABSTRACT

Cruciferous oilseeds, including yellow and brown sarson (Brassica campestris var: sarson), toria (B. campestris var. toria), raya (B. juncea), and taramira (Eruca sativa), constitute vital crops in India. However, these crops face substantial threats from various pests, with the mustard aphid, mustard sawfly, and painted bug emerging as particularly formidable adversaries. Among these, the mustard aphid stands out as the most significant pest affecting Brassica oilseeds across the entirety of India. This book chapter explores the challenges posed by insect pests to mustard crops, emphasizing the management strategies essential for safeguarding these crucial oilseed varieties.

Keywords: Mustard, Insect pests, Management.

INTRODUCTION

Oilseed crops play a pivotal role in the agricultural landscape of India, contributing significantly to the country's economy. *Brassica juncea* L., commonly known as mustard, holds the distinction of being one of the earliest domesticated oilseed crops within the Cruciferae family. Despite its importance, the yield of mustard faces challenges, with damage from various insect pests being a prominent factor. Understanding and studying these insect pests are crucial for the development of future transgenic plants in the cruciferous vegetable category (Shelton *et al.,* 2009). Rai (1976) identified 24 species of key insect pests affecting mustard and rapeseed crops in India, causing severe infestations at different stages of the crop. Building on this, Purwar *et al.* (2004) expanded the list to more than 43 insect pest species associated with rapeseed-mustard crops in India. Among these, the mustard aphid (Lipaphis erysimi), mustard sawfly (Athalialugens proxima), painted bug (Bagrada hilaris), and leaf miner (Phytomyza horticola) emerged as major pests of mustard of particular concern, the mustard aphid (L. erysimi) has been identified as the most significant insect pest, infesting the crop from seedling to maturity stages and causing substantial yield losses, reaching up to 96% (Singh and Sachan, 1994; Sharma and Kashyap, 1998; Singh and Sharma, 2002). This chapter delves into

the multifaceted challenges posed by insect pests to mustard crops and explores strategies for effective pest management and sustainable cultivation practices.

1. Mustard Aphid: *Lipaphis erysimi* (Aphididae:Hemiptera)

Distribution and status

Global Distribution of Mustard Aphid (Lipaphis erysimi)

The mustard aphid, scientifically known as *Lipaphis erysimi*, is a widely distributed pest with a global presence. It is a major concern for cruciferous crops, including mustard, rapeseed, and other Brassica species. The global distribution of the mustard aphid extends across various continents and regions where cruciferous crops are cultivated. It has been reported in countries across Asia, Africa, Europe, North America, and Oceania, indicating its adaptability to diverse climates.

Distribution in India

In India, the mustard aphid is a notorious pest that infests mustard (*Brassica juncea*) and other related crops. The distribution of the mustard aphid in India spans major mustard-growing states and regions. This pest is particularly prevalent in the northern and central parts of the country, where mustard cultivation is a significant agricultural activity. The infestation of mustard aphids in India can occur throughout the crop-growing season, causing damage to different growth stages, including seedlings, vegetative stage, and during the formation of seeds. The pest's presence has been documented in states such as Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, and others, where mustard cultivation is a key component of agriculture.

Impact on Mustard Cultivation

Mustard aphids feed on the sap of mustard plants, leading to stunted growth, yellowing of leaves, and, in severe infestations, a significant reduction in yield. The economic impact of mustard aphids on mustard crops in India underscores the need for effective pest management strategies to mitigate losses and ensure sustainable mustard cultivation Understanding the global and regional distribution of the mustard aphid is crucial for developing targeted pest control measures and implementing integrated pest management practices to protect mustard crops from this damaging pest. Distributed worldwide and is a serious pest.

Host Range

The mustard aphid (*Lipaphis erysimi*) primarily infests plants belonging to the family: *Brassicaceae.* The host range of mustard aphids encompasses several cultivated and wild plants within this botanical family. Here are some examples of plants that may serve as hosts for the mustard aphid:

1. Mustard Crops:

- *Brassica juncea* (Indian mustard)

- *Brassica napus* (rapeseed)

- *Brassica oleracea* (cabbage, broccoli, cauliflower)

2. Other Cruciferous Vegetables:

- *Brassica rapa* (turnip)

- *Raphanus sativus* (radish)

- *Eruca sativa* (arugula/rocket)

- Sinapis Alba (white mustard)

3. Wild *Brassicaceae*

- Various wild mustard species and cruciferous plants in natural ecosystems.

Bionomics

Aphids are small, soft-bodied, pearl-shaped insects that have a pair of cornicles (wax-secreting tubes) projecting out from the fifth or sixth abdominal segment. They are louse like, pale-greenish insects abundant from December to March. During summer, it is believed to migrate to the hills. The pest breeds parthenogenetically and the females give birth to 26-133 nymphs. They grow very fast and are full-fed in 7-10 days. About 45 generations are completed in a year. Cloudy and cold weather (20°C or below) is very favourable for the multiplication of this pest. The winged forms are produced in autumn and spring, and they spread from field to field and, from, locality to locality.

Damage Symptoms

Both the nymphs and adults suck cell-sap from leaves, stems, inflorescence or the developing pods. Vitality of plants is greatly reduced. The infested leaves acquire a curly appearance and at advanced stage plants may wither and die.The flowers fail to form pods and the developing pods do not produce healthy seeds. The yield of an infested crop is reduced to one-fourth or one-fifth. Plants remain stunted and sooty molds grow on the honey dew excreted by the insects. The infected filed looks sickly and blighted in appearance.

Management

- Sow the crop early wherever possible, preferably up to third week of October.
- Apply recommended dose of fertilizers.
- Use tolerant varieties like JM-1 and RK-9501.
- Destroy the affected parts along with aphid population in the initial stage.

- Set up yellow stick trap to monitor aphid population.
- Conserve the following natural enemies: Ladybird beetles viz., *Coccinella septempunctata, Menochilus sexmaculata, Hippodamia variegata and Cheilomones vicina* thatare most efficient predators of the mustard aphid. Adult beetles may feed on an average of 10-15 adults/day.
- A number of entomogenous fungi, *Cephalosporium* spp., *Entomophthora* and *Verticillium lecanii* infect aphids
- Several species of syrphid fly i.e., *Sphaerophoria spp., Eristallis spp., Metasyrphis spp., Xanthogramma spp* and *Syrphus spp*. are predating on aphids.
- The Braconid parasitoid *Diaretiella rapae,* a very active bio-control agent cause the mummification of aphids.
- The lacewing, *Chrysoperla carnea* predates on the mustard aphid colony.
- Predatory bird *Motacilla cospica* is actively feeding over aphids in February-March.
- Apply anyone of the following insecticides when the population of the pest reaches 50-60 aphids per 10 cm terminal portion (ETL) of the central shoot or when an average of 0.5-l.0 cm terminal portion of central shoot is covered by aphids or when plants infested by aphids reach 40-50 per cent.
- Chemical control involves the use of insecticides to manage and reduce aphid populations.
- Common insecticides used for aphid control include pyrethroids (e.g., lambda-cyhalothrin, deltamethrin) and neonicotinoids (e.g., imidacloprid).
- Apply insecticides at the appropriate stage of aphid development. Early application when aphids are in the nymphal stages is often more effective.
- Rotate between different classes of insecticides to reduce the risk of developing resistance in aphid populations.
- Integrate chemical control with other IPM practices, including cultural practices, biological control, and resistant crop varieties.
- Regularly monitor aphid populations to assess the effectiveness of the insecticide application and make informed decisions about further treatments.

2. Painted Bug: *Bagrada hilaris* (Pentatomidae: Hemiptera)

Distribution and status

This is widely distributed in Myanmar, Sri Lanka, India, Arabia and East Africa.

Host range: Crucifers, rice, sugarcane, indigo and coffee.

Bionomics

The full-grown black nymphs are about 4 mm long and 2.66 mm broad. Sub-ovate, black adult bugs are 3.71 mm long and 3.33 mm broad with a number of orange or brownish spots. It is active from March to December and during this period all the stages can be seen. It passes the winter months of January and February in the adult stage under heaps of dried oilseed plants lying in the fields. These bugs lay oval, pale-yellow eggs singly or in groups of 3-8 on leaves, stalks, pods and sometimes on the soil. Eggs may be laid during day or night. A female bug may lay 37-102 eggs in its life- span of 3-4 weeks. Egg period is 3-5 days during summer and 20 days during December. There are five nymphal instars with a duration of 22 -34 days. The entire life cycle is completed in 19-54 days and it passes through 9 generations in a year.

Damage Symptoms

Both nymphs and adults suck cell sap from the leaves and developing pods, which gradually wilt and dry up. The nymphs and adult bugs also excrete a sort of resinous material which spoils the pods.

Management

- Give first irrigation 3-4 weeks after sowing as it reduces the bug population significantly.
- Conserve egg parasitoid *Gryon sp*. (Scelionidae) and the adult parasitoid *Alophora sp*. (Tachinidae).
- Pest can also be controlled by oxy-demeton methyl (0.025%), permethrin (0.008%), fenvalerate (0.01%) or deltamethrin (0.0028%) or dimethoate (0.03%).

3. Mustard Sawfly: *Athalia lugens* (Tenthredinidae: Hymenoptera)

Distribution and status

This is widely distributed in Indonesia, Formosa, Myanmar and the Indian Sub-continent.

Host range

Mustard, toria (*Brassica campestris*), rapeseed, cabbage, cauliflower, knol- khol, turnip, radish, etc.

Bionomics

Dark green larvae have 8 pairs of abdominal proleg's. There are five black stripes on the back, and the body has a wrinkled appearance. A full-grown larva measures 16-18 mm in length. The adults are small orange yellow insects with black markings on the body and have smoky wings with black veins. The

mustard sawfly breeds from October to March and undergoes pupal diapause during summer. The adults emerge from these cocoons early in October. They live for 2-8 days and lay 30-35 eggs singly, in slits made with saw like ovipositors along the underside of the leaf margins. Egg period is 4-8 days and the larvae feed exposed in groups of 3-6 on the leaves during morning and evening. They remain hidden during the day time and, when disturbed, fall to the ground and feign death. There are 7 instars with a larval period of 16-35 days. Pupation is in water proof oval cocoons in soil and the pupal period is 11-31 clays. Lifecycle is completed in 31-34 days. It completes 2-3 generations from October to March.

Damage symptoms

The grubs alone are destructive. They bite holes into leaves preferring the young growth and skeletonize the leaves completely. Sometimes, even the epidermis of the shoot is eaten up. Although the seedlings succumb; the older plants, when attacked, do not bear seed.

Management

- Give first irrigation 3-4 weeks after sowing as it reduces the bug population significantly. Spray quinalphos 25 EC in 500-600 L of water per ha once in October and again in March-April.
- Conserve larval parasitoid *Perilissus cingulator,* Morby (Ichneumonidae) and the bacterium, *Serratia marcescens,* Bizio (Enterobacteriaceae).

4. Green Peach Aphid: *Myzus persicae* (Aphididae: Hemiptera)

Distribution and status: Throughout India

Host range

Mustard, peaches, beans, potato, tobacco, turnip, radish, etc

Bionomics

The aphids are minute (2.0-2.5 nun long), delicate, pear- shaped, yellowish-green winged or wingless insects. It remains active from December to March with peak activity during February. The nymph undergoes 4-5 instars taking 4-7 days for apterous and 5-8 days for alate forms. Apterous adults produce 5-92 young ones per female while the alate forms produce 8-49 nymphs. Longevity of adult is 15-27 days for alate and 10-25 days for apterous forms.

Damage symptoms

Both nymphs and adults damage plants by actively sucking their sap. After the appearance of inflorescence, the aphid congregates on terminal buds and feeds there. As a result, there is flower shedding, poor-pod formation and shriveling of

grains. The insect also transmits virus diseases. The honeydew attracts sooty mould.

Management

- Sow the crop in first week of October.
- Spray 500 ml of dimethoate 30 EC or 625 ml of oxydemeton methyl 25 EC in 750 L of water/ha when aphids start congregating on top flower buds. Only one spray is needed.

5. Pea Leaf-miner: *Chromatomyia horticola* (Agromyzidae: Diptera)

Distribution and status: Northern India

Host range

Cruciferous plants, antirrhinum, nasturtinum, pea, linseed *(Linum usitatissimum* L.) and potato *(Solanum tuberosum* L.).

Bionomics

The adults are two-winged flies having greyish black mesonotum and yellowish frons. It is active from December to April or May and is believed to pass the rest of the year in soil, in the pupal stage. The adults emerge at the beginning of December and after mating, start laying eggs singly, in leaf tissues. The eggs hatch in 2-3 days and the larvae feed between the lower and upper epidermis by making zig-zag tunnels. Maggot after 5 days pupates within the galleries. The adults emerge in 6 days and lifecycle is completed in 13-14 days. The pest passes through several broods from December to April-May.

Damage symptoms

The large number of tunnels made by the maggots interferes with photosynthesis and proper growth of the plants, making them look unattractive. If the attacked leaves are held against bright light, the minute slender larvae can be seen feeding within the tunnels.

Management

- Spray 1.0 L of dimethoate 30 EC in 750 L of water per ha and repeat spray at 15 days interval. A waiting period of 20 days should be observed for picking of pods.

6. Bihar Hairy Caterpillar: *Spilosoma obliqua* (Arctiidae: Lepidoptera)

Distribution and status

Sporadic pest widely distributed in the Orient. It is very serious in Bihar, Madhya Pradesh, Uttar Pradesh and Punjab.

Host range

Sesamum, mash (*Phaseolus mungo*), mung (*P. aureus*), linseed, mustard, sunflower and some vegetables.

Bionomics

The moth measures about 50 mm across the wing spread. Adults have crimson coloured body with black dots. Wings pinkish with numerous black spots. Larva is orange coloured with broad transverse bands with tuft of yellow hair that are dark at both end.Pest breeds from March to April and again from July to November. Adult female lays 400-1000 light green, spherical eggs in clusters on the underside of the leaves. Egg period 8-13 days. Larval instars 7 and period 30-56 days. Pupation takes place in plant debris or soil and pupal period 7-15 days. Adult lives for 7 days. Early instars are gregarious and later instars disperse in search of food.

Damage symptoms

The caterpillars eat leaves and soft portions of stems and branches. In severe infestation, the plants may be completely denuded of leaves.

Management

- Emamectin benzoate + Thiamethoxam 3.0%+12.0% WG, Emamectin benzoate 5% SG, Cartap hydrochloride 50% SP, Chlorfluazuron 5.4% EC .
- When they are full-grown, it is difficult to kill them and very high doses of the pesticides are needed. The chemical control measures are same as in case of red hairy caterpillar.

7. Cabbage butterfly: *Pieris brassicae* (Pieridae: Lepidoptera)

Distribution and status: Throughout India

Host range

Cabbage, cauliflower, knol-khol and it may also attack turnip, radish, sarson, toria (*Brassica campestris*) and other cruciferous plants

Bionomics

Full-grown pale yellow larva becomes greenish and measures 40-50 mm in length. In adults, the wings are pale white, with a black patch on the apical angle of each forewing and a black spot on the costal margin of each hind wing. The females have two conspicuous black circular dots on the dorsal side of each forewing. Males are smaller than the females and have black spots on the underside of each forewing In the Indo-Gangetic plains, this pest appears on cruciferous vegetables from October to April. From May to September, the pest is not found in the plains but breeding takes place in the mountains. The butterflies are very active in the field and lay, on an average, 164 yellowish

conical eggs in clusters of 50-90 on the upper or the lower side of a leaf. Egg period is 3-17 days. The caterpillars feed gregariously during the early instars and disperse as they approach maturity. They pass through five stages and are full-fed in 15-40 days. The larvae pupate at some distance from the food plants, often in barns or on trees. The pupal stage lasts 7-28 days. The butterflies live for 3-12 days and the pest breeds four times during October-April.

Damage Symptoms

The caterpillars alone feed on leaves, young shoots and green pods. When young, they feed gregariously but the grown-up caterpillars migrate from one field to another. The first instar caterpillars just scrape the leaf surface, whereas the subsequent instars eat up leaves from the margins inwards, leaving intact the main veins. Often, entire plants are eaten up.

Management

- When in the gregarious stage, the caterpillars can be easily controlled by picking and destroying the infested leaves.
- The grown-up caterpillars should be controlled with 500 ml of dichlorvos 76 SC in 600-900 L of water per ha.
- Conserve larval parasitoid Apanteles glomeratus (Braconidae) in the natural populations.

8. Diamond backmoth: *Plutella xylostella* (Plutellidae: Lepidoptera)

Distribution and status: World - wide

Host range

Serious past of Cabbage and cauliflower, but also feeds on other crucifers and solanaceous plants.

Damage symptoms

First instar larvae mine epidermal surface of leaves producing typical white patches.Larvae, second instar onwards feed externally making holes on the leaves and soil them withexcreta. Heavy infestations leave little more than the leaf veins.

ETL: 20 larvae/l0 plants

Bionomics

Yellowish, pinhead sized eggs are laid singly or in batches of 2-40 on the underside ofleaves. A female may lay 18-356 eggs in her life time. Egg period 2 -9 days. Larva: 8-12 mmlong, pale yellowish green in color, pointed at both the ends with fine erect black hairsscattered over the body. Larval period 8-16 days. Pupa is a barrel shaped silken cocoonwhich is open at both the ends and is attaché d to the leaf surface. Pupal period 4-5 days. Adults are small, greyish

brown having pale whitish narrow wings with inner margins yellow.Three pale whitish triangular markings on hind margins of each forewing are prominent. Atrest, a dorsal median patch of three diamond shaped yellowish white spots clearly visible byjoining both forewings. Hind wings have a fringe of long hairs. Adult moth may live for about20 days. Total life cycle is completed in 15-18 days. There are several generations in a year.

Management

- Grow mustard as trap crop. Raise 2 rows of mustard for every 25 rows of cabbage.
- Sow first mustard crop 15 days prior to cabbage planting or plant 20 days old mustardseedling at the time of cabbage planting. Plant 35 days old cabbage seedlings.
- Install pheromone trap to monitor DBM adults @ 5 /ha and 25/ha for mass trapping.
- Apply *Bacillus thuringiensis* formulation @1 g/L or NSKE 4% spray. Alternate Bt. Serotypes *kurstaki* (B.t.k.) and *aizawal (*B.t.a.).
- Reduce insects colonising on mustard to prevent defoliation of the entire plant byapplying dichlorovas 350 at 10 or 15 days interval starting from 15 days after sowing.
- Conserve larval parasitoids viz., *Cotesia plutellae* in plains and *Diadegma semiclausum*in hills. Release 40,000 adults / ac, five times @ 8,000 adults/release commencingfrom 20 days after planting. Also encourage other parasitoids like *Apanteles sicarius*, *Tetrastychus sokolowski* (larval) *Diadrumus collaris* (larval pupal) and *Brachymeriaexcarinata* (pupal parasitoids).
- Depending upon the pest intensity, spray any of the following insecticide with 500 -
- 1000 L water/ha primordial or head initiation stage. Mix teepol or sandovit 0.5 ml/Lt ofwater whenever sprays are made

o Azadirachtin 0.03% 2.5-5.0 L

o Chlorantraniprole 18.5 SC 50 ml

o Indoxacarb 14.5 SC 200-265 mlor 15.8 SC ml 265

o Chlorfenapyr 10 SC 750-1000 ml

o Diafenthiuron 50 WP 600 g

o Emamectin benzoate 5 SG 150-200 g

- Fipronil 5 SC 800-1000 ml
- Spinosad 2.5 SC 600-700 ml
- Flufenoxuron 10 DC 400
- Quinalphos 25 EC 1000 ml

- **Note:** Primordial formation takes place between 17 and 25 days after planting, depending on variety.

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DISEASE AND PEST MANAGEMENT OF BLACK PEPPER

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ABSTRACT

India is well known as the land of spices and out of 109 spices listed by the International Organisation for Standardisation (ISO), about 75 different types of spices are grown in India due to varied agro climatic conditions of the country. Black pepper also known as the Black Gold trace back its origin in the Western Ghats of India and is one of the most important export-oriented crop among the spice crops. India tops the list in production, consumption and export of pepper in the world. Different types of pest and diseases has been reported in Black pepper which ultimately decreases the yield and quality of the product hindering in production and export. Various symptoms, causal organisms and control measures of major disease and pest are outlined and discussed in this chapter.

Keywords: Black pepper, black gold, spices, disease, pest

INTRODUCTION

Black pepper scientifically known as *Piper nigrum* is one of the oldest known spice crops cultivated before the birth of Christ. It is also known as the "King of spices" (Srinivasan 2007), crops or Black Gold. Black pepper (Piper nigrum), is the most traded important spices crop in the world (Ravindran 2000b; Hema 2007). Presently, it is largely cultivated in India, Brazil, Indonesia, Malaysia, Vietnam and China (Philip et al. 1992; Talucder 2019). It is cultivated sporadically in Bangladesh, specially in the Sylhet region. According to AIS (2016), the area under organized cultivation of spices crops is 374 thousand hectares, which shared only 3% of cultivable land, where the cultivable land under black pepper is about only 5 ha in Sylhet, Habigonj and Bogura district which produces only 6 Metric tons. However, the area and production status of black pepper are not available in the BBS (2017). Haque et al. (2017). India holds major share in production, consumption and export in the world. In India, Kerela holds first place in production of black pepper followed by other southern states like Karnataka, Tamil Nadu and to small extent in Maharashtra, Andaman & Nicobar Island and North eastern states. Beside commercial propagation, the crop is also grown in homesteads and as multi-tier crop in Coconut and Arecanut plantations. The economic part of the crop is dried matured fruits known as berries which is extensively used as a spice and for medicinal purposes. Two forms of pepper can be obtained from the vine i.e., black pepper and white pepper. Black pepper is prepared by drying the berries harvested from the fully mature and near ripe berries while for preparing white pepper the berries fully mature and ripened berries are dried after removing the outer skin. The crop is attacked

by several pest and disease which is a major constraint in production decreasing the yield and quality. Different types of disease and pest affecting black pepper at different stages and their management practices has been discussed in this chapter.

DISEASES OF BLACK PEPPER

1. Foot Rot Or Quick Wilt

It is one of the major and destructive disease caused by the soil fungus *Phytophthora capsici* affecting pepper production mostly during the monsoon season. This fungus affects all parts of the plant like leaves, spikes, stems and roots. It is prevalent in almost all pepper growing regions of India. Around 5-20% loss of vines is reported due to this disease (Manohara *et al*. 2004) which sometimes even rise upto 95% loss in individual gardens (Anandaraj *et al*. 1989).

Mode of spread

The fungus *Phytophthora capsici* belongs to the Class of Oomycetes which is found to survive in a wide range of environmental conditions. The pathogen feeds on infected plant debris in the soil throughout the year, which acts as the main source of inoculum. Termites, slugs, rain splash, root contact, contaminated items, soil, and water are the main means of disease spread. Various factors such as high relative humidity (81-99%), high rainfall (15.8-23.0 mm/day) and shorter duration of sunshine hours (3.5 hr/day) and temperature range of 23-29^{0}C increases the chance of disease severity (Ramachandran *et al.* 1988). The disease incidence occurrence is mostly observed during the onset of monsoon season (May-June) on the tender shoots which spreads on the ground surface. During the rains, large number of spores are produced on the rotting shoots infecting nearby leaves and stem. With persistent rain splashing the pathogen progressively moves from lower to upper portion of vine. Root and collar infections persist as long as the soil moisture content remains favourable even after the monsoon season.

Symptoms

Black, water-soaked lesions appear on the leaves during the rainy season which has characteristic fimbriate which advances and enlarge causing defoliation. Damage to the main stem at the ground-level can cause the entire vine to wilt, shedding leaves and spikes with or without black spots and the branches to break at nodes causing the vine to collapse within a month. When the damage is confined to the feeder roots, expression of symptoms is delayed until the rain ceases and eventually the vine starts showing declining symptoms. The propagating material (runner shoot) if collected from the infected plantation increases the severity of disease more. In some cases, the pathogen travels actively with the runner shoots in the form of incipient infection on the roots or through the adhering soil particles.

Management

1. The propagating material (runner shoots) should be collected from healthy plants and the adhering soil particles should be removed followed by washing and treating with fungicide (Bordeaux mixture @ 1%).
2. All the infected and diseased plant should be rogued out from the field.
3. Provision of good drainage facility should be provided and water stagnation should be avoided.
4. Foliar spray of 1% Bordeaux mixture should be applied to control the disease.

2. Slow Decline Or Slow Wilt

With the depletion of soil moisture October onwards the foliage of the pepper plant shows foliar yellowing. The infected vines show symptoms of root degeneration due to infestation by parasitic nematodes. Defoliation, foliar yellowing and die back includes the aerial symptom of this disease. The vines recover with the approach of south west monsoon during May-June arising new foliage. With the cessation of monsoon the symptoms reappear in the diseased vine which eventually lose their vigour and productivity showing loss of feeder roots. The infected plant shows necrosis in the root system and presence of root galls due to infestation by plant parasitic nematodes like *Radopholus similis* and *Meloidogyne incognita* which leads to rotting of feeder roots. The damage to feeder roots is caused by these nematodes and *P.capsici* either independently or together in combination. Therefore, it is advisable to adopt a combination of fungicide and nematicide application for the management of the disease.

Mode of spread

The fungus causing the disease is found to survive in disease plant debris. Egg masses present in the infected soil and plant debris and other host plants including Solanaceous, Leguminaceous and Malvaceous act as potential sources of inoculum. Apart from this, rainy season also favours the development of this disease.

Management

1. Cutting raised for propagation should be nematode free.
2. Cuttings of the resistant variety Pournami may be planted.
3. Severely affected vines which are beyond recovery should be removed.
4. Application of neem cake @ 2kg/ vine twice during May-June and August-September.
5. Application of biocontrol agent during pre monsoon shower (May-June) and August-September with *Pochonia chlamydosporia* @ 50g/vine (10^8 CFU/g formulation).
6. Carbofuran 3G @100g/vine or phorate 10G @ 30g/vine should be applied in case of heavy nematode infestation during May-June and August-September.

3. Pollu Disease (Anthracnose)

It is a fungal disease caused by *Colletotrichum gloeosporioides* which appears towards the end of monsoon affecting affects young leaves, spikes and berries. During the early stages brown sunken patches can be seen in the affected berries which advances in the later stage and show discolouration and characteristic cross splitting and cracks reducing the quality of the produce besides damaging the berry. It can be distinguished from the pollu (hollow berry) caused by the beetle by the presence of characteristic cracks on the infected berries. The fungus also causes irregular toangular brownish lesions with a chlorotic halo on the leaves. In severe form defoliation and spike shedding occurs.

Mode of spread

1. Sowing infected seeds is the primary source of infection and secondary by wind.
2. High humidity and rainaccounts for the development of disease.

Management

1. The disease can be managed by prophylactic spraying of Bordeaux mixture (1%) or carbendazim + mancozeb (0.1%).

4. Spike Shedding

Spike shedding is one of the emerging diseases especially in varieties like Panniyur-1 at higher elevations like Coorg and Idukki. The condition aggravates when the pre-monsoon showers are delayed resulting inflowering and spiking occurring during June-July which leads the spikesto produce female flowers instead of bisexual flowers. Lack of pollination also causes heavy spike shedding.

Management

1. Use virus free healthy planting material.
2. Regular inspection and removal of infected plants; the removed plants may be burnt or buried deep in soil.
3. Insects such as aphids and mealy bugs on the plant or standards should be controlled with insecticide spray.
4. Irrigation of vines from second fortnight of March coupled with prophylactic spraying with Bordeaux mixture one per cent or carbendazim 0.2 per cent reduces the intensity of spike shedding.

5. Stunt Disease

This is a viral disease in which the vines show symptoms of shortening of internodes at varying degrees. In India, this disease is mostly observed in the parts of Kannur, Kasargod, Kozhikode, Wayanad and Idukki Districts of Kerala and Kodagu, Hassan and Uthara Kannada districts of Karnataka. The foliage becomes narrow, small and appears leathery, puckered and crinkled with varying degrees of deformation. Chlorotic spots

and streaks are also observed often on the leaves occasionally. This disease severely affects the yield of the vine. Two viruses namely Cucumber mosaic virus and a Badna virus are associated with the disease.

Mode of spread

1. Use of infected stem cuttings is the major source of disease spread.
2. Insects like aphids and mealy bugs also can as a source of transmission for the disease.

Management

1. Virus free healthy planting material should be used.
2. Regular and timely inspection should be done to remove infected plants which should be buried deep under soil or burnt out.
3. For controlling aphids and mealy bugs which act as a potential source of disease transmission, insecticide spray like dimethoate or monocrotophos @ 0.05 per cent should be used.

6. Phyllody Disease

This disease is mostly prevalent in the state of Kerela and mostly noticed in parts of Waynad and Kozhikode districts. It is caused by phytoplasma and the infected vines shows symptoms of malformation of spikes at varying levels due to which the floral buds transform into narrow leaf like structure showing phyllody symptoms. The leaves become chlorotic and small at advanced stages resulting in shortening of internodes. The affected fruiting branches show characteristic witches broom appearance. Severely infected vines become unproductive within 2-3 years.

Mode of spread

Beside vegetative propagation, the disease is also spread by leaf hoppers.

Management

The infected vines should be destroyed to prevent further spread of the disease.

INSECTS AND PESTS OF BLACK PEPPER

1. Pollu Beetle

Pollu beetle (*Lanka ramakrishnai*) is the major and most destructive pest of pepper mostly prevalent in plains and altitude ranging below 300m. The word pollu in Malayalam denotes the hollow nature of the infected berries. The adult beetle measures around 2.5 mm X 1.5 mm with yellowish brown colour head and thorax and black forewings (elytra). Mature and fully grown grubs are about 5 mm in length with creamy white colour. It feeds and cause damage on the tender leaves and spikes and lays eggs on it. The grubs damage and feed on internal tissues causing the infected spikes to decay and tur black. The infected berries crumble when pressed and turn black.The infestation

is more severe in the shaded plantation area. The pest population rapidly increases during the months of September-October.

Management

1. Spraying quinalphos (0.05%) twice during the month of June-July and September-October and neem-based insecticide like Neemgold (0.6%) during August, September and October is found to be effective.
2. The underside of leaves should be thoroughly inspected at regular intervals (where adults are generally seen) and spikes are to be sprayed thoroughly.

2. Top Shoot Borer

The top shoot borer (*Cydia hemidoxa*) is a serious pest mostly witnessed in all pepper growing areas in the younger plantations. The adult is a tiny moth with a grey hind wings and crimson yellow forewings. Fully grown larvae measure around 12-15 mm in length with greyish green colour. The pest infestation is at peak when numerous succulent shoots appear on the vine during July- October affecting the growth of the vine. The larvae bore into tender terminal shoots and feed on internal tissues which ultimately results in decaying and blackening and of affected shoots.

Management

Quinalphos (0.05 per cent) spray on tender terminal shoots at monthly intervals (during July-October) to protect emerging new shoots.

3. Leaf Gall Thrips

Leaf gall thrips (*Liothrips karnyi*) is serious pest preavalentat higher altitudes mostly infecting the young vines. The adults measure about 2.5 mm-3.0 mm in length and black in colour while the larvae and pupae are creamy white in colour. The thrips actively feeds on the leaves causing the leaf margins curl downwards and inwards which results in the formation of marginal leaf galls. The infected leaves later become malformed and crinkled. The younger vines and cuttings are severely affected in case of heavy infestation.

Management

Spray dimethoate (0.05%) for cuttings in the nursery and also during emergence of new flushes in young vines in the field.

4. Scale Insects

Mussel scale (*Lepidosaphes piperis*) and coconut scale (*Aspidiotus destructor*) are the two major scale insects causing serious damage to black pepper vines at higher altitudes and to older cuttings in nurseries in the plains. Females are about 1 mm in length and dark brown in colour in mussel scales while it is yellowish brown and 1 mm in diameter in case of coconut scales. Scale insects are mostly inactive and remain fixed to plant parts like stems, leaves and berries. They usually feed on the plant sap causing wilting

and yellowing of the infected plant parts. The infestation is very high during the summer and post monsoon.

Management

1. Severely infested branches should be destroyed.
2. Dimethoate (0.1 per cent) spray on affected vinesat 21 days interval to control the infestation completely.
3. Spraying Neem oil 0.3% or Neem gold 0.3 % or fish oil rosin 3 %in nurseries is effective in controlling the pest infestation.

Integrated Pest and Disease Management Approach

Following management practices should be followed for management of major pest and disease of black pepper.

1. Collection of planting material from healthy and disease-free plant

Since black pepper is propagated by vegetative means, collection of planting material from healthy and disease-free plant and area is a prerequisite. In viral disease pathogen is systemic and carried actively in the propagating material. Likewise, in fungal disease as seen in case of Phytophthora, the pathogen is carried passively either through adhering soil particles or in the form of latent infection on the roots of runner shoots. Also, selection of variety resistant/tolerant to major pests and disease should be done accordingly.

2. Cultural Practices

As seen in the case of foot rot disease the fungus *Phytophthora capsici* spreads through water splashes of the soil. Therefore, in this regard minimum tillage is an alternative approach to prevent the rapid spread of inoculum. It is advised to keep the grass cover around the basin and in the interspaces to prevent the rapid spread of inoculum. Disturbance in the basin area of the vine results in root damage and would further aggravate the disease. Besides, proper spacing and optimum nutrient management especially organic manures and biofertilizers should be provided based on the soil test results. Water stagnation around the basin should be regularly checked to prevent the chances of infection.

3. Organic Amendments

4. Soil amendments with sustainable resources like farm yard manure, vermicompost, biopesticide, biofertilizer, neem cake, etc. reduce pathogen build up and favours the growth of antagonistic microorganisms.

5. Regular Monitoring Of Vineyard

The vineyard should be monitored regularly at weekly basis to check for disease and pest infestation. Direct action should be taken when needed (e.g., removal of infested plants, collection of egglarvae etc).

6. Biological Control

It was found that combined application of bio-products containing a combination of rhizosphere bacteria and endophytic bacteria increased health and yield of black pepper in Vietnam and post application less Phytopthora and Fusarium was detected in soil and on root (Nguyen *et al*., 2020). Besides, several species of VAM are reported to enhance growth of black pepper and in addition it also reduced the incidence of root rot caused by *P. capsici*, *R.similis* and *M. incognita*.Management of *Phytophthora capsici* infection in Black Pepper using New Generation Fungicides and Biopesticidewas checked and it was observed that spraying and drenching with Fenamidone 10WDG + Mancozeb 50WDG @ 0.2% was found to be the most effective with 12.4% disease intensity (Rini and Remya., 2020).

7. Chemical Control

Disease like Phytophthora foot rot, slow decline and anthracnose mostly occur during rainy season which leads to leaching out and loss of chemical from the surface. Therefore, to overcome this problem systemic fungicideslike Metalaxyl and Fosetyl AI should be used. Foliar spray with 1%Bordeaux mixture during the monsoon period prevents aerial infection. To minimize the build· up of soil inoculum, copper oxychloride (0.2%) @ 5-8 L/vine is recommended.

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DISEASES OF TURMERIC (*CURCUMA LONGA* L.) AND THEIR INTEGRATED DISEASE MANAGEMENT

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ABSTRACT
Turmeric (Curcuma longa L.) is severely affected by soil borne as well as foliar diseases. Rhizome rot takes a heavy toll in majority of turmeric growing areas. Among foliar diseases, leaf blotch and leaf spot are important. Several minor diseases have also been reported on the crop. Future studies on crop loss assessment due to these diseases. Their epidemiology under different cropping systems and the role of biocontrol agents and organic amendments in disease suppression need a thorough investigation to develop appropriate integrated disease management strategies. The present status of turmeric diseases and future strategies for their management are outlined in this chapter.

Keywords: Curcuma longa, diseases, Integrated disease management, turmeric

INTRODUCTION
Turmeric *(Curcuma longa* L.) "the Golden Spice" is widely cultivated in different countries such as India, China, Myanmar, Nigeria, Bangladesh, Pakistan, Sri Lanka, Taiwan, Burma, Indonesia, etc., (CABI,2002). India is the largest producer, consumer and exporter of Turmeric in the world. Indian Turmeric is considered to be the best quality due to its high curcumin content and thus it is increasingly used in medicinal and cosmetic applications. It is an important commercial spice crop grown in India and known as "Indian saffron".India is the largest manufacturer, consumer and exporter of curcumin, contributing more than 80 percent of the global production India occupies first position in an area of 2,46,000 ha with a production of 9,39,000 t and productivity 3817 kg/ha (Anonymous, 2020).Turmeric The crop is grown predominantly in Andhra Pradesh, Orissa, Tamil Nadu, Assam, Maharashtra and West Bengal. Turmeric, native to South East Asia, is a herb with underground rhizomes which constitute the turmeric of commerial value. Several diseases, mostly fungal, have been recorded on turmeric. Bacterial and viral diseases are of minor importance. The most important of them are rhizome rot, leaf spot and leaf blotch diseases (Rao, *et al*., 1993). The details of diseases recorded on turmeric, their management and future lines of work are outlined in this paper.

The common disease in turmeric (IISR (2001)

Disease	Casualagent	Stage infected
Rhizome and root rot	*Pythiiumaphanidermatum* *P. graminicolum*	All stages of crop
Leaf blotch or Taphrina leaf spot	*Taphrinamaculans*	2-3 months after planting
Colletotrichum leaf spot	*Colletotrichumcapsici*	2-4 months after planting
Dry rot	*Rhizoctoniabatalicola*	Rhizome maturing stage
Brown rot (nematode – fungal complex)	*Partylenchus* sp. & *Fusarium* sp.	All stages of crop
Leaf spot	*Cerocosporacurcumae*	All stages of crop
Leaf blight	*Rhizoctonia solani*	All stages of crop

Turmeric is mainly infected by three rhizome disease viz., rhizome and root rot, dry rot and brown rot and four foliar diseases viz., leaf blotch, Colletotrichum leaf spot, Cercospora leaf blight.

Rhizome and root rot and foliar disease of turmeric are very important because they affect the yield of rhizomes considerably.

1. Rhizome and root rot

Pythiumaphanidermatum, *P. graminicolum, P. myriotylum*, Association of *Pythium* sp. and *Fursarium* sp. This is an important disease prevalent in all turmeric growing area.

- Both *C. deomstica* and *C. aromatic* are affected by rhizome and root rot disease
- The disease was first reported from South India viz., Krishna district of Andhra Pradesh, Tiruchirappalli and Coimbatore of Tamil Nadu. The disease appears in patches in the field. In case of severe attack, yield is reduced considerably.
- Losses due to these of 50 percent and above have been reported in some parts of Telengana areas of Andhra Pradesh (Rao and Rao, 1988) and farmers resort to distress harvest to salvage the remaining crop once the disease starts appearing.

Symptoms

- The infected plants show yellowing of leaves starting from lower leaves which gradually spread to the upper regions of the plant.
- The margins of the yellowing leaves turn necrotic and start drying from the margins inwards resulting in partial or complete blighting of leaves.
- Collar region of pseudostem becomes soft and water soaked and plinths collapse.

- The affected pseudostems break away with a pull and the affected tillers topple off.
- The affected plants show varying degrees of rot.
- The infection spreads from roots to rhizome causing soft rot (affected rhizome becoming soft to touch).
- Infection is also noticed from tips of rhizomes show varying degrees of brown shades in contrast to the bright orange yellow colour of healthy turmeric.
- In advanced stages, the rotten rhizomes emit foul smell.

Epidemiology

- Turmeric is grown as pure and also as an intercrop along with maize, redgram and chilies.
- The disease is soil borne and seed borne, and occurs at random and spreads contiguously to adjacent clumps.
- Irrigation water from diseased fields also helps in the spread of the disease.
- In artificial inoculation studies, *P. graminicolum* could induce root rot in a week and death of two months old plants within 18 days.
- The fungus has been found to grow over wide range of pH (3.0 to 9.0) and the best growth is obtained between pH 7.0 and 8.0.Oospores production maximum between pH 6.0 and 9.0.
- The fungus was also found to be pathogenic seedlings of sorghum, maize, barley, oats, arrow root and cotton and could not infect ginger.
- Where it is intercropped with maize, the symptom expression would be sudden immediately after the maize harvest.

Dispersal: Seed, Soil and Water.

Role of associated organisms

- Association of maggots of *M. coeruleifrons* with disease affected rhizomes was noticed to varying degrees.
- Root knot infestation (*M. incognita*) in turmeric was noticed where rhizome and rootrot disease incidence is severe.

Integrated disease management

- Selection of healthy seed from disease free gardens.
- In endemic areas, rotation of crops using non-host crops.
- Removal and burning of the infected clumps from the field.

- The survival of the fungus was affected by application of urea (5 kg/ha) to the infested soil.
- Urea did have depressive effect on the fungal growth.
- Water-logging situation should be avoided. Light soil may be preferred and drainage facility to be ensured.
- Deep plough in summer. Planting is to be done in ridge and furrow method.
- Elite turmeric cultivars, PCT-18 (Suvarna), PCT-13 (Suguna), and PCT-14 (Sudarsana) are found to be field tolerant to rhizome and root rot.
- Turmeric Cv. Shillong, a traditional cultivar from Assam, was reported to be resistant to *Pythium myriotylum* (Rathaiah, 1982a, 1982b).

Chemical Control

- Seed treatment with metalaxyl (Ridomil) MZ or mancozeb 3g /l of water and soaking seed rhizome for 40 minutes and shade drying before sowing in the main fields.
- The combination of *Trichoderma harzianum*culture (i.e multiplication of 1 kg *Trichoderma* in 90 Kgs FYM and 10 Kg neem cake) andmetalaxyl (Ridomil) 1 g per litre of water is effective against rhizome rot caused by *F. solani* (Reddy *et al*., 2003).
- Immediately after the disease appearance, drench soil at the base of the affected plant and plants around with metalazyl (Ridomil) MZ 1g or captan 2g or copper oxychloride 3 g per litre of water.

2. Colectotrichum leaf spot

Casual organism: *Colletotrichumcapsici*Syn: *Vermiculariacurcume*, *V. capsici*, *C. curcumae*

- The disease is more destructive and prevalent in majority of turmeric growing areas of Tamil Nadu viz., Coimbatore, Vellore, Thiruvannamalai, Salem and Trichy districts.
- This was first recorded in Coimbatore district of east while Madras State in 1917.

Cross losses

- When the infection is severe resulting in drying up of the whole foliage, losses would exceed 50 percent.
- Reduction in the dry rhizome weight by 62.7percent was also reported due to foliar infection.

Symptoms

- Infection is confined usually to leaf blades and occasionally extends to leaf sheath also.
- Leaf spots elliptic to oblong of various sizes enlarge into 4-5 cm and 3 cm wide occupying the major portion of leaves.
- The mature spot appears grayish white at centre with a brown margin surrounded by a yellowish halo, which is responsible for the production of toxin.
- Endotoxin produced has been found to play a definite role is symptom expression. The whitish centre with dark acervuli often becomes papery and gets torn off.
- Sometimes spots are found on leaf sheaths.
- The rhizomes are also affected and black stroma appear on the scales covering the rhizomes.
- In severe infections, leaves dry up and defoliate.

Epidemiology

- The disease spreads by air borne conidia. The pathogen persists through infected rhizomes and other plant left in the soil.
- The disease generally appears in August -September when the crop is about 4-5 months old.
- Infection is evident when the humid condition prevails continuously
- The disease starts in the younger leaves and spreads to the other leaves.
- The younger leaves were more susceptible than older leaves, which was attributed to loss of carbohydrates and phenol and more of total nitrogen in younger leaves compared to older leaves.
- The time of planting influenced the onset and severity of the disease. The crop sown between 12th June and 17th July under Coimbatore condition showed severe disease incidence.
- Late planting during July-August also recorded severe disease incidence
- Weather factors in relation disease incidence showed a positive correlation of total rainfall to disease incidence at 90 days crop growth phase.
- At 120 days, there was positive correlation between relative humidity and disease incidence.

- The fungus could infect, *Artistolochiabracteata*, seedlings of *Gossypiumherbaceum*, chick pea, pigeon pea, cluster beans, jowar, ginger, papaya, brinjal fruit, chillies and *Whitianasominifera*.
- The disease spread is mainly during wet weather.
- C. *curcumae* was found to survive in the field and laboratory for about 9 and 12 months respectively, which could be potential source of primary inoculums.

Dispersal: Seed, air, rain and crop residue.

Integrated Disease Management

- Potash application reduced the disease incidence. Higher dose of potash at 70 and 120 kg/ha reduced the disease, the disease incidence was 21.8 and 18.6 percent, respectively compared to 46.3 per cent in control.
- Incidence is less if the rhizomes are planted in May- June.
- Select seed material from disease free areas.
- Crop rotations should be followed whenever possible.
- The infected and dried leaves should be collected and burnt in order to reduce the inoculum source in the field.
- The cvs. Nallakatla, Sugandham, Duvvur, and Gandikota are tolerant to leaf spots (Reddy *et al*., 1963).
- Turmeric plants under the shade of trees were found free of the disease (Subha Rao, 1985).

Chemical Control

- Spraying the crop with Bordeaux mixture (5 kg/ha) during August and mancozeb (1 kg/ha) and 0.5 ml ofsoap water /litre of waterat monthly intervals during September-December checked the disease.
- Edifenphos 1 ml with 0.5 ml ofsoap water/litre of water of spray at 15 days intervals starting from 15th June to 15th September reduced the disease caused by *C.curcumae* effectively.
- Spraying twice at initiation and 15 days later with carbendazim (500 g/ha) or copper oxycloride (1250 g/ha) and soap water 0.5 ml/litre of water is controlled the leaf spot.
- Treat seed material with mancozeb 3g/litre of water or carbendazim 1 g/litre of water for 30 minutes and shade dry before sowing.
- Spraying copper oxychloride (Blitox or Blue copper) at 3 g and soap water 0.5 ml for one litreof water was found effective against leaf spot.

3. Leaf blotch (Taphrina leaf spot)

Casual organism- *Taphrinamaculans*

- The disease is widely distributed in Southern States and the genetic plains in Uttar Pradesh and Bihar.
- This disease was first reported from Gujarat, Saharanpur (UP) and Rangpur (Bangladesh) in 1911.

Crop Losses

- The foliar destruction, it causes, would reduce the yields considerably especially when the disease starts in its early stages of crop growth.

Symptoms

- The individual spots are small 1-2 mm in width and are mostly rectangular in shape.
- The disease is characterized by the appearance of several spots on both the sides of leaves, being generally numerous on the upper surface. They are arranged in rows along the veins.
- The spots coalesce freely and form irregular lesions. They first appear as paleyellow discolorations and then become dirty yellow in colour.
- The adjacent individual leaf spots of 1-2 mm diameter colease forming reddish brownblotches leading to varying degrees of leaf blight.

Epidemiology

- The pathogen infects most of the leaves leaving 2-3 leaves at the top.
- The disease incidence is influenced by soil borne inoculums and prevailing weather condition.
- The dried leaves having spots and lying in the field may function as chief source of primary inculum.
- Moist cloudy weather with temperature of 25-30^{0}C during August-September was found conducive for the disease initiation.
- The primary infection occurs on the lower leaves during October- November when the temperature of 21-23^{o}C and relative humidity of 80 percent prevail.
- Young leaves, two weeks after unfurling remain susceptible for about a month and susceptibility gradually decreases with age.
- They remain susceptible considerably for a longer period irrespective of their age provided environmental conditions and inoculums are at optimum level.

- The secondary infection is by ascorpores discharged from successively maturing asci which grown into *octosproumicrocolnies* and infect fresh leaves without any dormancy.
- The primary infection are less harmful than the secondary infection inciting profuse spotting covering a large foliage.
- The disease perpetuated from one season to other through viable ascogenous cells borne on the infected leaf debris in the field after harvest as well as through desiccated ascospores and blastospores ejected from mature asci during the crop season and over summaring in the soil and leaf trash.

T. maculans has been reported to infect. *C. amada*, *C. angustifolia, Zingiber cassumunuar*, *Z. zerumbeta* and *Hedychium* sp.

Dispersal: Seed, air, rain and crop residue.

Integrated Disease Management

- Select seed material from disease free areas.
- Panja *et al*., (2001) showed that PTS 62, Roma, BSR1, and Kasturi were highly resistant to leaf blotch disease.
- Singh *et al*., (2003) reported that turmeric cv. Azad Haldi-1 developed through clonal selection was resistant
- Treat the seed material with mancozeb 3g/litre of water or carbendazim 1 g/litre of water for 30 minutes and shade dry before sowing.
- Filed sanitation should be practiced.
- Crop rotation becomes important to reduce the inoculum build up.
- Aureofungin, antifungal antibiotic at 2.5 g/ml and soap water 0.5 ml for one litre of water was highly inhibitory to the growth of *T. maculans*.
- To reduce the spread of the disease, spray at 20 days interval with any one of the following chemicals.i.e Bordeaux mixture 5000 g/ha or copper oxychloride (50 WP) 12540 g/ha or zineb (75 WP) 500 g/ha or mancozeb (75 WP) 1000 g/ha. or carbendazim 50 WP 500 g/ha.

4. Storage Rots

Rhizoctonia and *Sclerotium* are also associated with storage rots of turmeric (Kumar and Roy, 1990). Fungi associated with turmeric rhizomes were *Aspergillus flavus, A.niger, A. tamari, Cladosporium cladosporioides, Drechslerarostrata, Fusarium moniliforme, F.nivale, F.oxysporum*, *Macrophominaphaseolina, Pythium aphanidermatum, Rhizoctonia bataticola, R.solani*and *Sclerotium (Corticium) rolfsii.*

Integrated Disease Management-

- Seed treatment with metalaxyl (2g/lit) checked the rot of seed rhizomes and ensured better germination.
- *A. flavus* was effectively controlled with pre- inoculation and post-inoculation treatments of Bavistin (carbendazim) and benomyl at 10 ppm (Sharma and Roy, 1984).

5. Brown Rot

- It is a complex disease caused by the nematode, *Partylenchus* sp. associated with a fungus, *Fusarium* sp.
- This was first reported from Kerala in *C. aromatic* and was noticed in freshly harvested rhizomes indicating its natural occurrence during the crop season.

Symptoms

- The disease affected plants were stunted with poor root development.
- The infected rhizomes appear dull coloured, later become deep grey to dark brown, less turgid, light and wrinkled exhibiting dry rot symptoms.
- The necrotic lesions in the rhizome start from margins and progress inwards involving a major portion of rhizome.
- Infection is initiated in the fields during harvest and later leads to spoilage in storage.
- The fungus is able to penetrate and establish infection through intact host tissues.

Integrated Disease Management

- Separation of rotted and dried rhizomes
- Spreading sand to thickness of half a foot on place of storing rhizomes
- Storing mother and finger rhizomes separately

6. Nematode Management

Root knot nematode *Meloidogyne incognita*

- The earliest record of nematode infestation on turmeric was that of root gall nematode by Ayyar (1926) in South India.

Symptoms

- Affected plants show stunted growth, yellowing, marginal and tip drying of leaves, reduced tillering and galling and rotting on roots.
- High densities of *M. incognita* cause yellowing and severe stunting and withering in large patches.
- Plants die prematurely leaving a poor crop stand at harvest.

- Infested rhizomes tend to lose their bright yellow colour.

Crop loss

- An initial inoculum level of 1,00,000 nematodes/plant caused 76.6 percent reduction in rhizome weight under pot conditions.
- Avoidable yield loss under field conditions was 45.3 percent.

Integrated Disease Management

- Use of resistant turmeric varieties like Kodur, Cheyapasupu, Armoor, Duggirala, Guntur 1, Guntur 9, Rajampet, Sugandham and Appalapadu.
- Soil application of carbofuran 3G (35 kg/ha) two times at 3rd and 5th months after planting followed by irrigation.
- Carbofuran 3G (35 kg/ha) effectively controlled the root knot nematodes and increased the yield by 68 percent.

Burrowing nematode, *Radopholussimilis*

Symptoms

- The infested plants show a tendency to ageing and dry faster than healthy plants.
- Infested rhizomes are of yolk yellow colour compared with the golden yellow colour of healthy rhizomes and have shallow water soaked brownish areas on the surface.
- Roots show rotting and most of the decayed roots are devoid of cortex and stelar portion.
- The scale leaves of rhizomes harbor *R.similis.*

Crop loss

- An initial inoculum level of 10 nematodes/plant can cause a reduction of 35 percent of rhizome weight after four months and 46 percent at the end of the season.
- With 1,00,000 nematodes, the extent of reduction in rhizome weight is 65 and 76 per cent after 4 and 8 months respectively.

Management

- Application of carbofuran 3 G (35 kg/ha) controls the nematode infestation.
- Lesion nematode, *Pratylenchuscoffeae*

Symptoms

- It causes discolouration and rotting of rhizomes of *C. aromatica.*
- In advanced stages of infection, the rhizomes become deep red to dark brown in colour, less turgid, and wrinkled with dry rot symptoms.

- The fingers are more severely affected than the mother rhizomes, internally the affected rhizomes show dark brown necrotic lesions.

Integrated Nematode Management

- Among the many species of plant parasitic nematodes reported on turmeric, *Meloidogyne spp., Radopholussimilis* and *Pratylenchus coffeae*are of economic importance.
- Survey of turmeric fields in Coimbatore and Erode districts revealed the presence of following plant parasitic nematodes associated with the crop are *Medoidogyne incognita*, *Longidorus elongatus*, *Xiphinema elongatum*, *Hoplolaimus seinharstii*, *Helicotylenchus multicinctus*, *Tylenchorhynchus martini*, *Pratylenchus delaltrei*, *Radopholus similis* and *Rotylenchulus renifornis*
- Under Vellore conditions, CO-1 turmeric grown after banana or solanaceous vegetables was affected severely by nematodes. So, planting turmeric after banana or solanaceous vegetables should be avoided.

Future Strategies

The epidemiology of these diseases under different cropping systems and the role of biocontrol agents and organic amendments in suppression of diseases needs thorough investigations. Integrated disease management strategies involving healthy seed material, crop rotation, need based chemical application, use of disease tolerant varieties coupled with biocontrol agents needs to be evolved.

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INSECT PESTS AND DISEASES OF CINNAMON (*CINNAMOMUM VERUM PRESI.)* AND THEIR MANAGEMENT

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ABSTRACT

Cinnamon (Cinnamomum verum Presi.) is important spice in the world which is cultivate in tropical and subtropical region of the world. It is widely used as beneficial spices and pharmacological agents from the inner bark of plants. The study is fully based on the use of secondary sources of data; related journals, government institutes, and related reports. Medically, this plant is very important but its production is humper due to insect pests and diseases are main barriers for the production of cinnamon fruit. The objective of this study was to document the insect pests and diseases of cinnamon and their management in agroforestry system compared to different cinnamon growing countries. Since many research works were done on these issues but all are not available to the policy makers, extension workers and public in a systematic manner to date. The major insects are jumping plant louse (Trioza cinnamomic), mite (Eriophyesboisi), common mime (Chilasaclytia Lankeswara, Moore), blue bottle (Graphium sarpedon Teredon), leaf and shoot Webber (Orthagavitialis), hairy caterpillar (Euproctis fraternal Moore), wood boring moth or hairy tussock moth (Dasychiramendosa), fruit borer (Alcides morio Heller), leaf miner (Acrocercops spp.), and sorolophasemiculta (Olethreutessemiculta) and major diseases are leaf spot and die back (Colletotrichum gloeosporioides), seedling blight (Diplodia sp.), grey leaf spots/blight (Pestalotia cinnamomic), black sooty mould (Stenella spp.), algal leaf spots (Cephaleuros virescens), stripe canker (Phytophthora cinnamomi), pink disease (Corticium salmonicolor B. and Br.), brown root rot (Phellinus lamaensis Murr.), and leaf spot/blight (Colletotrichum gloesporioides). The paper eventually would help to increase the productivity of C. verum through the management of its insect pests and diseases.

Keywords: Cinnamomum verum, insect pests, diseases, management, importance

INTRODUCTION

Cinnamomum verum, a plant belonging to Lauraceae family and genus Cinnamomum, is the hardiest tree among the spices (Mian et al., 2018). Since antiquity, it has been used as beneficial spices (Gruenwald et al. 2010) and pharmacological agents which are obtained from the inner bark of plants. It has been in use for many years with multiple culinary usages to enhance the flavor of food. Predominantly, they are cultivated for

their dried inner bark of the small evergreen tree (Ravindran, 2004). The major hubs of cinnamon cultivation in south Asia are India and Sri Lanka. Besides, it is cultivated commercially in the tropical regions like Brazil, Java, Madagascar, Vietnam, the West Indies and Zanzebar. Cinnamon can grow well in humid regions with typical temperature 27 0C and annual precipitation of 1500-2500 mm. It is popular with local name as 'Darchini'. Nearly 2000-2500 species and 32 genera fall under genus Cinnamomum trees of tropics and subtropics (Tiwari and Agarwal, 2004). These species are shrubs and small to medium-sized plants (Jantan et al. 1995; Braun, 2006) of rainforests thriving well at various altitudes from highland slopes to lowland forests. The most common species are Cinnamomum zeylanicum, C. loureirii, C. burmanni and C. aromaticum. The bark of C. aromaticum and C. zeylanicum has high commercial use in Asia and Europe as well. Some species are used in chocolate manufacturing industries, in many desserts' recipes, spicy candies, tea, hot cocoa and liqueurs worldwide. In the Middle East, it is usually used in savory dishes of chicken and lamb. 4000 years ago, Chinese literature has cited the traditional usage of cinnamon in manufacturing of naturopathic medicine (Qin et al., 2010), ayurvedic medicine for treatment of diabetes during ancient times (Modak et al., 2007). It was reported to be used as stomachic and carminative for gastrointestinal complaints as well as other ailments (Teuscher, 2003). Plants health and soil quality are the determining components for ecological production of the cinnamon that keep the agroforestry system working well. Only healthy soil can help upgrade the crop yield. Soil microorganisms (MOs), invertebrates, and other biotic agents play continuous role in maintaining soil fertility level as they respond differently to external agents and help undergoes biochemical reactions (McIntyre, 2000). According to Chang et al. (2013), the flavor of cinnamon is because of 0.5 to 1% perfumed in essential oil. It has antioxidant attributes that may reduce the risk of heart diseases or stroke and has strong antidiabetic effects and lower sugar level (Anonymous, 2015). It has economic importance as well. Global trade indices show that C. burmannii (Indonesian cassia) has substituted the more luxurious true or Ceylon cinnamon (C. verum) in recent days in Europe, the United States, and Canada (UN comtrade, 2011; BfR, 2006; Sproll et al., 2008; Raters and Matissek, 2008; Lungarini 2008). C. burmannii accounted for more than 90% of the "cinnamon" trade in the U.S. during the last five years in previous decade (UN comtrade, 2011). In view of extensive export and import prospects, cinnamon has high economic and trade value in an international market. Nonetheless, several constraints hold up the remarkable breakthrough in production of cinnamon throughout the world. The most important restraint that has hindered the breakthrough in cinnamon production globally is failure to effective control of pests, insects, and diseases associated with the plants. Cinnamon, although a hardy plant, is susceptible to infect by variety of pests and diseases during its various stages of development (Rajapakse and Kumara, 2007). Lower yield is related with aging of crop, improper

crop maintenance, severe pests and diseases incidence, climate changes, etc. Pests and diseases were found to cause severe damage to cinnamon in different regions. These pests and diseases are accountable for notable reduction in the production of cinnamon bark, the economic product and also for declining the quality of other products like leaf oil, bark oil and root bark oil even though, they are not economically significant. Keeping these points in view, this paper solely aims to review the information on the existing pests and diseases of cinnamon production, their impacts and role in yield decline, and the possible management strategies in agroforestry ecosystem.

Insect pests of cinnamon (*Cinnamomum verum*)

Ayyar (1940) first reported that nymphs and adults of Homopteran pest *Pauropsylla depressa* (Triozidae) produced galls on leaves and shoots of cinnamon plants in India. Mani (1973) found out 5 species of insects and mites forming leaf galls and another unrecognized insect species causing inflorescence galls. Rajapakse and Kulasekera (1982) have studied about the pest associated with cinnamon in Sri Lanka. Devashayam and Koya (1997) reported that important insects and pests of cinnamon include cinnamon butterfly (Chilasaclytia Lankeswara), Moore and leaf miner (*Conopomor phacivica*) in India. Major pests infesting cinnamon in South East Countries and their possible control techniques have been summarized in this study. Different researchers have studied on different insect pests of cinnamon. Table 1 shows the involvement of scientists in study of several diseases.

a. Jumping plant louse (*Trioza cinnamomic*)

A jumping plant louse (Homoptera: Triozidae) is mainly associated with the leaf galls of cinnamon. Hollis and Martin (1997) noted that 48 species of psylloids are allied with lauraceous swarm plants and 72% of significant of these insects. According to Rajapakse and Kulasekera (1982), *T. cinnamomi* is the most important insect pest of cinnamon in Sri Lanka. Mani (1973) also reported an indefinite psyllid also causes creation of galls in cinnamon in India.

Management

Jumping louse is serious pest in the cinnamon field. Mainly leaves infested by this insect and related to the leaves gall. Removal and burning the infested leaves and shoot. Perfect mass trapping of these pests could probably reduce the damage to a cinnamon crop. Some agrochemicals also can decrease the incidence of pests to some extent.

b. Mite (Eriophyesboisi)

A mite (Acarina: Eriophyiidae) is important pest in Sri Lanka and some other countries in Southeast Asia (Rajapakse and Kumara 2007). This pest has been considered to be form morphological galls in cinnamon leaves (Mani, 1973). in Sri Lanka, Perera et al. (1985) reported the mite, is an important pest producing leaf galls and the number of new galls found on young leaves were greater than on mature leaves. The nymphs and adult mites suck sap from young leaves that turn yellow and drop. The infested plant

obtained the mean oil content (18-43) % of leaves with galls. The lower surface of leaf is enclosed by a thin layer of cells which disagreements to permit the emergence of the adult. The leaf galls caused by psyllids are epiphyllous, conical, unilocular, hard yellowish green. Galls develop on both sides of the leaf blade (Mani, 1973). Rajapakse and Ratnasekera (1997) reported that in a spatial distribution study, the *T. cinnamoni* preferred young, growing incompletely expanded leaves than mature and over mature leaves and there was a positive significant correlation be-tween gall counts and the proportion of young leaves. This study was determined the nutrient composition of various leaves (Rajapakse and Ratnasekera, 1997), it was found no significant relationship of crude protein to abundance of galls. Another study has stated the relationship between young leaves and crude protein (Warren and Moran, 1978) in cinnamon plant.

Management

Application of Dicofol 18.5EC @ 2 L/ha or Ethion 46.5 EC @ 1.26 L/ha is effect to control of mite in the plant. Precautions should be taken during the application to avoid under or over dose than recommended by plant experts.

c. Common mime (*Chilasaclytia Lankeswara,* Moore)

The common mime (Lepidoptera: Papillionidae) is a swallowtail butterfly. This butterfly species first reported in Sri Lanka (van der Poorten, 2004). It flies very slowly however, during menace it flies fast. Predominantly, may become serious insect pests in young plantations and abundant from December to June. Bell (1912) reported that the fly is seen in large numbers in monsoon months and spends the dry months. Eggs are heavily parasitized by the egg parasitoid Telenomusremus.

Management

Hand picking the larvae and pupae from the field with the help of light trap. Application of quinalphos 0.05% on tender and partly mature leaves in severe infestations can minimize the pest.

d. Blue bottle (GraphiumsarpedonTeredon)

The blue bottles (Lepidoptera: Papililionidae) are noted throughout year in cinnamon cultivating areas. The common blue bottle and Tailed Jay, G. agememnon are the fastest nectar feeders of the butterflies in Sri Lanka (van der Poorten, 2004). The larvae of this bottle were reported to feed on Cinnamon tender leaves and stem (Bell, 1912).

Management

Remove and destruction of infested leaves. Hand picking of larvae of blue bottle is method to minimize this pest. Pesticides like Ethion, cumbush, and bavistin are commonly applied to control this pest.

e. Leaf and shoot Webber (Orthagavitialis)

The leaf and shoot Webber (Lepidoptera: Pyralidae) are very active and web the leaves and the terminal shoots. The webbed cluster of leaves harbors several larvae. Singh, et al., 1978[30] reported that the major pest mainly infested by the shoot and leaf webber in India.

Management

The damaged leaf and shoot webs with larvae should be collected and destroyed. Pheromone traps have been used to monitor pest populations in the cinnamon. Spraying Carbaryl (0.1%), or Quinalphos (0.05%) or Endosulphan (0.05%) and repeated either thrice at 10-12 days interval.

f. Hairy caterpillar (*Euproctis fraternal* Moore)

Hairy cater pillar (Lepidoptera: Lymantriidae) larvae feed voraciously on leaves. Initially the larvae scrape the green matter in skeletonization. Later the larvae move in to the other parts of the plant and defoliate (Rajapakse and Kumara, 2007).

Management

Hand picking of egg masses, early instar larvae and killing them by burning/keratinized water. Light traps are also effective method to destroy the moths. Application of Diazinon 60EC @ 2ml/L of water or Cymbush 10EC @ 1ml/L of water are effectively control the moth.

g. Wood boring moth or hairy tussock moth (Dasychiramendosa)

The Clearwing moth (Lepidoptera: Sesiidae) of these larvae was first reported in Sri Lanka Dharmadasa and Jayasinghe (2000). The symptoms were the dying branches, rough bark and insect excreta in infested plant with wood boring insect. These larvae feed on phloem of live trees and tend to mine horizontally. Repeated feeding weakens the branches or kill branches and that may break and fall during rainy weather.

Management

Hand picking of egg masses, early instar larvae and killing them by burning/keratinized water. Light traps may be used to destroy the moths. Sex pheromone use to control male moth. Destruction of alternate host and plant debris of cinnamon. Application of Diazinon 60EC @ 2ml/L of water.

h. Fruit borer (Alcides morio Heller)

The cinnamon fruit borer (Coleoptera: Curculionidae) feed the inner contents of the seed and tunnels into the cinnamon seeds. The damage is of considerable economic importance since cinnamon is propagated through seeds. Mature grub has a brownish head with a whitish body and attains the length of 8-10 mm. The pupation takes place inside the seed and lasts for 7-9 days. The resultant weevil cuts a circular hole on the seed coat. They are dirty black in color and not active. The females are larger than the males. The longevity of the beetle is 5-7 days (Biotech and Limited 2011).

Management:

Removal and destruction of all infested shoots, all fallen dry leaves and other debris from the field. Releasing Trichograma (egg parasitoid) @ 1gm (about 25,000 egg) at first weekend and Bracon (larval parasitoid) @ bunker (800-1200 larvae) at next weekend are found most effective. Application of Spinosad @ 0.4 ml/l of water is effectively controlling this borer.

i. Leaf miner (*Acrocercops spp*.)

The adult is a tiny silvery moth (Lepidoptera: Gracillaridae). The larvae enter the leaf tissue by mining. They feed on the tissues between the upper and lower epidermis of tender leaves resulting in linear mines that end in blister like patches. The infested leaves become crinkle and the mined areas dry up leading to formation of large holes on the leaves. The mined leaves turn pale and curl up and the development of young leaves is retarded. Infestation by leaf miners Conopomorphacivica (Anandaraj et al., 2001) and Phyllocnistischry sophthalma Meyer has been reported in India (Butani, 1983). Devashayam and Koya (1993) reported that *C. civica* has infested 20.2% of the seedlings of cinnamon in Kerala, India.

Management

Neem cake soaked in water and the decantation when sprayed also controls the pest. Application of dimethoate 0.03% or methyl demeton 0.025% or imidacloprid 0.01% is effect to control the pest.

j. Sorolophasemiculta (*Olethreu tessemiculta*)

The larva of this tortricid moth (Lepidoptera: Tortricidae) rolls the young leaves together. This study also reported the presence of the tortricid Sorolopha archimedias (syn. Eudemiop sisarchimedias) in cinnamon in South Andaman in India (Bhumannavar, 1991).

Management

Ploughing and cultivation of the soil before sowing reduce the pest burden and there is a modern trend to restrict the use of pesticides as far as possible. It can be achieved by regulating the crop, just using insecticides when necessary, and by cultivating varieties and crops which are resistant to Sorolophasemiculta. The infested leaves and shoot should be removed and burned to minimize this pest from the field. Light trap is the best way to manage adult caterpillar from cinnamon field.

Diseases of cinnamon (*Cinnamomum verum*)

Serious diseases reported from cinnamon are less compared to insects and mite damages and also are less economic importance. There has been no significant work done on diseases of cinnamon specially in Sri Lanka although this crop has been under cultivation for centuries. Cinnamon is considered as one of the hardy plants among other spice crops and therefore, chances are comparatively less for severe pathogenic

infections. Some of the diseases which have taken considerable attention in South East Asian countries have been described. The major diseases are leaf spot and die back, seedling blight, grey leaf spots/blight, black sooty mould, algal leaf spots, stem and root diseases, rough bark disease, stripe canker, pink disease, brown root rot and so on **(Table 1).**

a. Leaf spot and die back (*Colletotrichum gloeosporioides*)

Leaf spot and die back disease is caused by *Colletotrichum gloeosporioides*. Small deep brown specks appear on the leaf lamina, which later coalesce to form irregular patches. In some cases, the affected portions are shed leaving shot holes on the leaves. Later the entire lamina is affected and the infection spreads to the stem causing die back. Pruning the affected branches and spraying Bordeaux mixture 1% are recommended to control the disease. Karunakaran and Nair (1980) leaf spot and die back disease of *Cinnamomum zeylanicum* caused by *Colletotrichum gloeosporioides*.

Management

Sowing healthy and disease-free seeds. Destroy residues and remove infected leaves. Crop rotation should be followed and avoid excess irrigation. Spraying Bordeaux mixture @ 5% or Ridomi/ Dithane M-45 @ 0.2% for 3-4 times at 8-10 days interval has been found effective in reducing the spread to some extent.

b. Seedling blight (*Diplodia spp.*)

Seedling blight caused by Diplodia sp. occurs on seedlings in the nursery. The fungus causes light brown patches which girdle the stem resulting in mortality.

Management

Healthy and resistant variety seed use to minimize the seedling blight. Seed treated within Thirum and Vitavax 0.25% at 2.5-3.0 g/kg seed is effective against seedling blight. The disease can be controlled by spraying Bordeaux mixture 1%.

c. Grey leaf spots/blight (*Pestalotia cinnamomi*)

Grey blight is caused by *Pestalotia palmarum* and is characterized by small brown spots which later turn grey with a brown border. *P. cinnamomi* causing grey blight is also considered as one of the commonest dis-ease of cinnamon (Anonymous, 1996). In India, the disease was reported to be caused by P. palmarum on C. verum causing foliar damage up to 90% (Karunakaran et al., 1993). *Pestalotia furierea* causing similar leaf spot symp-toms were reported from Dominican Republic and also from Pakistan (Ciferri, 1926; Ciferri and Fragoso, 1927). This disease can cause severe damage and defoliation.

Management

Removal of infested plant parts from the field. Spraying Dithane M-45 @0.2% or Bavistin @0.25% at 15 days interval for 2 times. Spraying 1% Bordeaux mixture during May and September in field.

d. Black sooty mould (*Stenella spp.*)

The disease is not considered as economically important among cinnamon cultivators and therefore, seldom warrant control measures. *Stenella spp*. has been stated as the causal agents of the disease. Blackish growth on the leaf due to sooty mould fungus is the typical symptom of the disease. The fungal growth is narrowed only to the surface and no penetration into the leaf tissues has been observed.

Management

Removal and destruction of infested leaves and use of balance fertilizer dose in the field. Eco-oil and eco-neem are used to check a wide range of sap-sucking insects and black sooty mould. Spray with two times to kill the pests. Ensure proper coverage to all the plants so that no pest is missed.

e. Algal leaf spots (*Cephaleuros virescens*)

Another disease which considered as economically less important, is the algal leaf spot disease caused by *Cephaleuros virescens*. This disease is not currently present very seriously in Sri Lanka and other southeast Asian countries although reported in the past. Orange or brownish colored spots with velvet appearance are seen on the leaf surface. Leaf spots are rather small in size and enlargement of the spots are also not common or very slow. Three other minor leaf diseases caused by *Aecidium cinnamomi, Leptosphaeria spp*. and *Gloeosporium spp*. have been reported but, the extent of damage was not described (Weiss, 2002). *Caeoma keralensis* causing hypertrophy and witches' broom on young shoots was de-scribed by Hosagoudar (1984) and red leaf spots caused by *Colletotrichum capsici* was recorded in India Prakasam (1991).

Management

There are no control measures recommended for this disease. Removal and destruction of infested leaves and use of balance fertilizer dose in the field. Often, leaf spot caused by *Cephaleuros virescens* is not threatening enough to the cinnamon yield and thus usually does not need more management. If the plant is highly susceptible, a form of IPM can be used to check the spread and severity of the disease. This includes proper sanitation and pruning of diseased plant parts. The lower branches and debris should be removed since they are usually infected. Reducing humidity or increasing air flow can help mitigating the algae effectively. Use of a tolerant variety of plant, and if required, intercropping, can lessen the rate of infection. Copper fungicides may help but needed to be used every 2 weeks if the surrounding remains wet.

f. Rough bark disease

One of the important diseases in Sri Lanka that has drawn grower's attention at present is the rough bark disease. The causal agent is still unidentified. The disease is found in many cinnamon growing areas in Matara district of Sri Lanka and could leads to severe damages to young and mature plants. Kumara (1999a) also reported scab like appearance in cinnamon similar to this, affecting quilling efficiency considerably

however, causal organism of the disease was not reported. Sandy soil, slopy lands, long weeding intervals and low dose of fertilizer applications correlate with increasing disease condition (Kumara, 1999a).

Black/brown spots appear on the bark of stems and later become large patches. These spots are enclosed by a dark brown/ black border. Affected area of the bark appeared irregular nature giving scab like appearance. These scabby areas lengthy over the bark with crop maturity reducing yield quality. Interveinal chlorosis of leaves of young shoots is common in affected plants. Affected young shoots die in later stages giving heavy yield losses.

Management

Remove and destruction of affected seedlings/leaves/shoots help to reduce the disease incidence. The recommended dose of pesticides can be used as per the suggestions of the plant experts. Pruning should be practiced. Application of 1-2% Bordeaux mixture to reduce the disease incidence.

g. Stripe canker (Phytophthora cinnamomi)

Phytophthora cinnamomi causing stripe canker attacks shoots and young stems of cinnamon. Rands (1922) first stated *Phytophthora cinnamomi* initiating severe losses to forest trees and avocado, as causal agent of stripe canker of *C. verum.* The fungus also affects *C. campora, C. culitlawan* and *C. sintok* (Ciferri and Fragoso, 1927; Rands, 1922). The fungus *P. cinnamomi* from pineapple was also reported pathogenic on cinnamon, but with reduced virulence (Anandaraj and Devasabayam, 2004). Stripe canker is found on the trunks and branches, particularly of young trees of *C. verum* and *C. burmannii* in Indonesia (Mehrlich, 1934). Vertical stripes are seen on the stems with amber colour exudates at the advancing margins and hardens later. Vertical stripes of dead bark are most numerous near ground level. The disease is prevalent on ill-drained soils and causes up to 42% bark damage. Fungus produces chlamydospores and characterized by nonpapilate sporangia which can be obtained by incubating a nonsterile percolate of field soil (Mehrlich, 1934).

Management

Well drainage is important to minimize the disease incidence at a lower level. Phytosanitation such as removal and destruction of affected parts and wound dressing with tar have also been recommended as manage this disease.

h. Pink disease (*Corticium salmonicolor* B. and Br.)

Pink disease caused by *Corticium salmonicolor* B. & Br. (syn. *C. javanicum*) has been stated on cinnamon and considered as an important disease in Sri Lanka, India and Indonesia (Weiss, 2002). Formation of pale pinkish white covered areas on stems or branches is the visible symptoms at the beginning. Later contagion spreads destroying bark and finally leading to the death of the smaller shoots. Pathogen also reported to

attack mango, jackfruit, custard apple and other fruit trees often grown in the vicinity of cinnamon plantations (Weiss, 2002).

Management

Burning of affected pruning and other plant parts need to be practiced to reduce the disease incidence. The suggested fungicides for management of this disease are not available in the market. BIO-C is an economical and ecologically sound fungicide for control of pink disease. The application interval is once a week quarterly. The dose of each application is nearly 50 cc / plant depending on the extent of the infection of pink disease.

i. Brown root rot (*Phellinus lamaensis* Murr.)

This disease is caused by *Phellinus lamaensis* (Murr.) Heim, damages cinnamon plants. Chang (1992) reported brown root disease caused by fungus P. noxius on C. camphora. Wilting and death of the aerial portions can be observed in these plants. The fungus was found to affect adjacent shade and ornamental trees such as Dilonix regia, Annona sp. and Prunus sp. (Da Graca et al., 1980).

Management

The host plant should be removed from the field and also from near about field area. There is no effective fungicide recommended for control use. Plants may be treated with fungicides, if infection is not severe. Fungicides will suppress but not cure brown root rot.

j. Stem and root diseases

A stem disease caused by *Exobasidium cinnamomi* has been recorded in Sri Lanka (Weiss, 2002). This disease can also spread into leaves producing small yellowish concave spots whose underside bears grayish white spore bodies. *Diplidia spp.* causing stem blight on young twigs in the nursery, produce small light brown covers on stems.

Management

Control is hard because once symptoms are noticed; infection to the stem or roots is often severe. For cinnamon, use a soil drench of a recommended dose of fungicide. A fungicide could also be incorporated with soil before planting as recommended by the manufacturer.

k. Leaf spot/blight (*Colletotrichum gloesporioides*)

The leaf spots/blight caused by a fungus *Colletotrichum gloeosporioides* is found in almost all cinnamon growing areas in Sri Lanka mainly affecting the foliage (Anandaraj and Devasabayam, 2004; Kumara, 1999b). It appears in all growth stages of the plant and the entire foliage can be affected in severe infections. Kumara (1999b) reported 18% foliar damage due to this disease in Matara, Sri Lanka however, with no significant correlation detected between cinnamon yield and the disease severity. Considerably, higher disease incidence was observed in lands with high shades, high planting

densities, poor weeding, and improper pruning (Kumara, 1999 a and b). The symptoms in young seedlings include, small brown specks on leaf laminae which, later coalesce to form irregular patches. Small, brownish, leaf spots on older leaves can be seen, especially in shaded areas. These small specks coalesce to form large necrotic blotches giving scorching appearance. Spots later become papery with dark brown margins. In other cases, the central portion is shed, forming shot hole appearance. Lesions may extend from tip of the leaf or from the margins. At severe infections, lesions may be larger than the half of the leaf. In some seedlings, the infection spreads to the stem causing a dieback (Karunakaran and Nair 1980). In India, reddish elongated spots were observed arising from the margin and resulting in defoliation (Prakasam, 1991). This also caused shot hole symptoms in later stages. However, the fungus caused this disease has been identified as *Phytophthora capsici* (Prakasam, 1991). Fu and Chang (1999) also reported brown to black spots on C. verum leaves in Thaiwan. These spots later coalesced and the infected leaves were shed. The pathogen was identified as *C. gloeosporioides* (*Syn. Glomerellacingulata*). Partial drying of the seedlings is another symptom due to this pathogen as reported in India Bhat, et al. (1988). In this study, those seedlings yielded *C. gloeosporioides* and symptoms were reproduced 7 days after inoculation of healthy seedlings.

Management

Avoid overcrowding of plants, prune trees to improve light penetration and enable air circulation throughout the canopy, frequent irrigation is necessary to keep the plant moist, and destroy the fallen infected leaves. Reducing shades specially during nursery stages may reduce the disease severity. Application of Chlorothalonil 75% WP, Carbendazim 50% WP, Mancozeb 80% WP at 7-10 days intervals.

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INTEGRATED PEST AND DISEASE MANAGEMENT OF AN SPICES CROP RAPESEED AND MUSTARD IN INDIA

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ABSTRACT

The Brassicaceae family, which contains the genus Brassica, is home to several vital plants, such as quality food and industrial oils, common vegetables, and weeds. The mustard crop is more vulnerable to a wide variety of insect pests from sowing till harvest than other oil seed crops. The invasion by insect pests are one of the important factors responsible for low yield. The aggressive onslaught of several pests and diseases not only lowers crop quality but also adversely impacts many oil-producing brassica crops' oil content. To protect the crop from the effect of harmful diseases and insects, integrated pest management, is a widely used approach to supporting sustainable pest management of mustard crop. The need for environmentally sustainable agricultural practices is recognized worldwide given the widespread ecological imbalances, which are caused by highly intensive agricultural systems. To address the adverse impacts of chemical pesticides in the ecosystem Integrated pest management has evolved to manage the pest population below the economic threshold level (ETL). This article will help the reader to know, how to control the major and minor insect pests of rapeseed and mustard crop in a sustainable way by use of parasitoids, predators, and by use of biorationals pesticides.

Keywords: Mustard, Integrated, Insect Pests, Diseases and Management

INTRODUCTION

Mustard (*Brassica* spp.) is the major *Rabi* oilseed crops, grown over an area of 6.34 million hectare with a production of 7.82 million tones and productivity of 1234 kg/ha in 2012-13 in India and production of edible oils was about 7.05 Mt (Jha, 2017). In India, although mustard is cultivated in 13 states, production in Rajasthan, Uttar Pradesh, Haryana and West-Bengal with their respective share of 45,13,11 and 8 per cent accounts for 77 per cent of the total production of mustard in the country (Kaur, 2017). This crop accounts for nearly one-third of the oil produced in India, Mustard yields were lower in India compared to other mustard producing countries such as Germany (3811 kg/ha), France (3240 kg/ha), China (1834 kg/ha) and Canada (1769

kg/ha) as well as the world average (1849 kg/ha) (Kaur, 2020). Mustard yields, which were low (about 647 kg/ha on the average) during the early 1980s, witnessed a steady increase during the last three decades and reached a level of 1121 kg/ha in the recent decade in India. Among the major oilseed producing states, Haryana has the highest yield (1533 kg/ha) followed by Rajasthan (1170 kg/ha) and Uttar Pradesh (1121 kg/ha) while West Bengal (911 kg/ha) has the lowest yield. It is interesting to note that all states witnessed a positive growth in mustard yield during the last three decades but rate of growth was the highest during the decade of 1980's, which decelerated during 1990's but again picked up during the last decade (Sharma, 2014) More than 43 species of insect pests have been reported to infest rapeseed-mustard crop in India, of which sawfly (*Athalia lugens proxima*), aphid (*Lipaphis erysimi*), painted bug (*Bagrada hilaris*) and leaf miner (*Phytomyza horticola*) are the important ones (Singh *et al*. 2000). Among all the insect pests, the mustard aphid, *Lipaphis erysimi* (Kaltenbach) (Homoptera: Aphididae) has gained the status of key pest of rapeseed-mustard in India. It feeds by sucking sap from its host and damage to the crop ranging from 9 to 96% in different agroclimatic conditions of India (Singh and Sharma, 2002; Bakhetia,1984; Chorbandiand Bakhetia, 1987; Singh and sachan, 1994; Singhand Sachan, 1995; Parmar *et al*., 2007). The loss may go upto 100% in certain mustard growing. regions (Singh and Sachan, 1999). Large colonies of the aphid could cause the plant to become deformed due to curling and shriveling of leaves (Metcalf, 1962). Under severe infestation, both sides of leaves are attacked (Yadav *et al*., 1988).On mustard, *Lipaphis erysimi* prefers to feed on flowers as well as foliage of mustard (Singh *et al*., 1965).

Integrated Pest Management Strategy for Rapeseed and Mustard

Field monitoring and scouting

Surveillance of pest occurrence in the field should commence soon after crop establishment after transplanting and at weekly intervals thereafter. In each of the fields, s at each spot for recording counts of insects as per procedure finalized for individual insects. Pheromones and other semiochemicals offer a lot of potential when it comes to insect pest control.

For aphids and painted bugs

Count and record the number of both nymphs and adults on five randomly selected leaves per plant.

For leaf miners

Only the number of live mines on five leaves randomly selected per plant should be counted and recorded.

For defoliator/ borers

Count the number of young and grown larvae on each plant and record.

Threshold Level Determination

The foundation of integrated pest management as presented by Flint and van den Bosch (1981) is based on sampling, economic thresholds, and natural mortality in agroecosystems. The economic threshold level of pests of mustard crop varies from pest to pest, and on the bases of species on which they feed, e.g., ETL for mustard aphid in the mustard field is 22 aphids per 10 cm length of the twig on the top portion of the central shoot or infestation of 30 percent plants (Bhanu *et al.,* 2019).

1. Host/Varietal resistance or tolerance

Absolute resistance or very high degree of resistance to *Alternaria* blight (AB) is not availablein existing cultivars of desirable maturity type. Among different species, *Brassica juncea* and *B. rapa* are more susceptible than *B. carinata* and *B. napus*. Germplasm lines found tolerant to AB in *B. juncea* are: PHR-2 PAB9511, PAB 9534, EC 399301, EC399299. EC399313, and JMM 915. Early dwarf high yielding mustard strain "DIVYA" possesses the growth and developmental traits associated with high degree of tolerance to AB (Kolte *etal.,* 2000). Sources of resistance to *A. brassicae* have been spotted in wild crucifers suchas *Brassica (= Synapis) alba B. desnottesii*, *Camelina sativa. Capsella bursa pestoris. Coincya pseuderucastrum. Diplotaxis berthautii, D. catholica D. cretacea, D. erucoides, Erucastrum gallicum and E. canariense (Bhaskar et al., 2002; Sharma et al., 2002) B campestris ssp. rapifera* is also reported to be resistant to *A. brassicae*. Resistance or tolerance to *Alternaria* is found to be associated with factors like: (a) resistance to deposition or settling of spores, i. e. failure of spore (conidia) retention due to epicuticular wax; (b) resistance to germination of spore and penetration i.e. reduction in rate of conidial germination and germ tube formation due to high phenolic compounds viz, polyphenol oxidase, peroxidase and catalase activities in leaves; and (c) partial or infection rate reducing (race- nonspecific) characteristics of tolerant genotypes. There has been indications that components of partial resistance like small lesion size, low intensity of sporulation, high incubation period, and longer latent period all being significantly correlated with each other leading to lower infection rate and low AUDPC (Saharan and Kadian, 1983; Kumar and Kolte, 2001). Mechanisms of resistance/tolerance, when studied genetically, have been reported to be governed by additive genes or ploygenes with resistance being controlled by genes of partial dominance. From the above, it could be seen that breeding for resistance to *Alternaria* would involve exploitation of horizontal resistance by pyramiding of minor genes which would involve study of heritability of components of resistance, introgression of genes from material found resistant, reciprocal recurrent selection or diallel selective mating. Resistance to white rust (WR, *Albugo candida*) is known to be of race-specific nature governed by major genes (1 -3 genes). WR-resistant varieties, viz. Bio-902, and JMMWR 914-1-2 have been released. Resistance to WR has been transferred from *B. napus cv* EC 151964

to *B. juncea* cv RLM 198 and a progeny line NRG – 49 has been recovered which is superior to RLM 198 at the Punjab Agricultural University, Ludhiana. Some exotic *B. juncea* genotypes viz EC 399301 and EC 399299 are resistant to WRand varie+tal/genotypic specificity to infection by the same race of *Albugo candida* is also reported in *B. juncea* indicating the scope for development of more and new differential hosts within *B. juncea*, the main crop species in India. It is interesting to note that some genotypes of *B. juncea* viz EC 399301 and 399299 are susceptible at cotyledonary stage but resistant at true leaf stage indicating involvement of two separate genes for reaction to *A. candida* (Mishra *et al., 2009*). *B. napus, B carinata and B. maurorum* show resistance to a predominant isolate of *A. candida* from main mustard-growing region (from north). But *A. candida* isolate from Karnataka is virulent on *B. carinata* and most *B. juncea* varieties (Kolte – Personal observation). Thus *A. candida* Karnataka isolate appears to be highly virulent and distinct race and potentially much more dangerous from what are prevalent in main mustard- growing regions in the north of the county. The WR infection in mustard in India is mostly associated with downy mildew infection caused by *Hyaloperonospora parasitica*. It has been observed that *A. candida* can predispose downy mildew-resistant plant/variety to infection by *H. parasitica* and complicate the procedure for breeding for resistance to downy mildew. Breeding for resistance to *Sclerotinia* stem not (SRR) appears to be less successful because of wide host range of the pathogen and lack of tissue specificity to infection. However, morphological and developmental traits of mustard plants among available genotypes can be exploited in breeding for early apetalous varieties with stiff stem. Apetalous line (RC 199 of *B. juncea*) is less susceptible to aphid attack (Singh *et al,* 1991)and *Sclerotinia* in comparison to normal petalled lines. Infection is avoided due to depriving of ascospore germination in the absence of petals falling on susceptible sites. Resistance to mustard aphid is also not available among the germplasm/ varieties released. However, the most tolerant strains in *B. juncea* are: T 6342, RLM 198, RH 7846, Bio – 902, PCR – 7 (Rajat) and DLM 29. No definite pattern of appearance of biotypes in aphid species is known. (Bakhetia *et al.,* 2002)

2. Agronomic manipulations in disease/pest management: cultural control

Clean culture and weeding create conditions unfavorable for insect pest development and eliminate the alternate host of some pests of the mustard crop. They have been proven useful in controlling the dormant stages of pests either by burying them deep in the soil or exposing them to inclement weather conditions. Here are some cultural control practices which are being employed for the sustainable management of the mustard crop: Early sowing to avoid damage due to mustard aphid, use of tolerant varieties, and use of less amount of nitrogenous fertilizers, are some of the cultural practices for mustard aphid. While, Deep ploughing the soil to destroy eggs of painted bug. Irrigation of crop in 4^{th} week after sowing to reduce pest attack and quick threshing of the harvested crop, are

used for painted bug management. Among the cultural control measures early sowing is most important to prevent the loss from most of the pests like mustard aphid, painted bug and mustard sawfly. In Indian literature on the usefulness of cultural and agronomic practices such as timely sowing, sanitation, ploughing, crop rotation, intercropping, spacing and nutrient management in minimizing the losses due to diseases and pests in mustard. Early October sowing (Kolte, 1985) balanced NPK application –N_{100} P_{40} K_{40} (Sharma and Kolte, 1994) and sanitation are the important top priority practices in management of most major diseases and aphid infestation. The increase in infection rate of AB, WR and SSR diseases and infestation rate of aphid attack is directly proportional to delay in planting of the crop in most mustard-growing areas in the country. The same is true with respect to powdery mildew infection and severity in non-traditional areas in the central and southern states of India. Use of early maturing varieties allowing the diseases escape mechanism (Kolte e*t al.,* 2000), and spray application of micronutrients like boron and zinc (Table 1) are also very useful practices in the control of AB and aphid infestation. Club root disease is important in the State of West Bengal. It can be controlled at Soil pH 7.2 by adding 3t ha^{-1} of lime in the infested soil. Mechanical removal of aphid-infested twigs at 20% plant infestation (9 aphids/central shoot) offers great promise. This practice has been demonstrated to be useful in insecticide-free management of the crop in the Haryana state of India. Economic threshold of the aphid *L. erysimi* under different ecological situations in India is shown in Table 2.

Table 1: Effect of some chemical nutrient salts on severity of Alternaria blight and yield of Mustard cv. Varuna (Kumar, 2003)

Treatment	Conc (%)	AUDPG	Yield Kg/ha
$CasO_4$	0.50	32.25	1560
	1.50	35.33	1596
K_2SO_4	0.50	45.30	1339
	1.50	42.40	1443
$ZnSO_4$	0.25	45.30	1330
	0.75	46.75	1510
$Na_2B_4O_7$	0.25	46.60	1427
	0.75	45.10	1642
Check		77.95	1355
CD at 5%			213.10

Table 2: Economic threshold of *L. erysimi* under different agro-ecological situationsin India (Bakhetia *et al.,* 2002)

State	Mustard Variety	Economic threshold
Harayana	RL-1359	9 aphids/central shoot or 20%plant infestation.
Uttar Pradesh	Varuna	9-13aphids/15 cm top terminal
Punjab	RLM-198	50-60aphids/10 cm shoot or 40-50% plant infestation of 05-1 cm of aphid colony on central shoot.
Himachal Pradesh	Brown Sarson (Local)	4 mm shoot infestation

3. Mechanical and Physical control for insect pests of mustard

Removal or destruction of infested parts of plants and collection and destruction of insects of bigger size, generally by using manual labour. Installation of some mechanical devices in the field to monitor and control of insect pests is done to control a particular pest. Here are some mechanical practices which are done to manage the pest population below ETL: Destroying of the affected part along with aphid population in the initial stage and installation of yellow sticky traps are done to control aphid population. Jerking of leaves and stem is done to dislodge the bugs from the plant and further kill them by use of kerosene oil is done to control painted bugs. While, collection and destruction of Collection and destruction of larvae in the morning and evening is done for mustard sawfly, Bihar hairy caterpillar, and diamondback moth. Installation of pheromone traps @4 per hectare is done to control diamondback moth.

Biological control

Bio-agents are more environmentally friendly, beneficial to plant health, and non-hazardous to humans (Kumar and Kumar, 2016). It is not only a significant tool for sustainable agriculture,but it is also environmentally benign and human-safe. Natural enemies (parasitoids, predators, fungus, bacteria, nematodes, viruses, etc.) are introduced and proliferated artificially in this technique rather than relying on nature to control pests. Biocontrol is a time-consuming procedure that requires time to accomplish the desired pest control. Despite a good potential of biological control agents for disease and pest management, their usages in mustard are limited. Antagonists *Trichoderma harzianum, T. viride* (G R isolate), *Streptomyces rochei*, and *Bacillus subtilis* strain (UK-9) are very effective against *Alternaria brassicae*, A *brassicicola* and *Plasmodiophora brassicae.* Predators such as *Coccinella septempunctata* (10 grubs/m^2) are known to be efficient biocontrol

agents against mustard aphid infestation (Meena *et al.,* 2004). Evidence of inducing host resistance in the susceptible host variety in reported in *Brassica–A. brassicae* system. Resistance in susceptible mustard against aggressive *A. brassicae* isolate A can be induced using prior inoculation of plants with non-aggressive *A. brassicae* isolate D. (Vishwanath *et al*., 1999). Systemic induction of resistance in susceptible plants of mustard can be obtained by prior inoculation of plant with incompatible isolate of *Albugo candida* (Singh *et al.*, 1999). Considerable number of botanicals and plant-based products are reported to be useful in the management of AB and mustard aphid (Patni *et al.*, 2005). Among these garlic (*Allium sativum*) bulb extract (1% w/v) and leaf extract (1.5 – 2%) of*Azadirachta indica* (*neem*) and *Eucalyptus* species offer great promise (Meena *et al.,* 2004). Water-based neem seed kernel extract (NSKE) @ 10% is found to be very useful in the management of mustard aphid (Bakhetia *et al.*, 2002).

- **Some of the biocontrol tactics for major pests of rapeseed and mustard crop are discussed hereunder.**

Aphids (Liphapis erysimi):

- Ladybird beetles viz., *Coccinella septempunctata, Menochilus sexmaculata, Hippodamia variegata* and *Cheilomones vicina* are the most efficient predators of the mustard aphid. Adult beetle may feed an average of 10 to 15 adults/ day.
- Several species of syrphid /hoverfly *ie., Sphaerophoria sp., Eristallis sp., Metasyrphis spp., Xanthogramma spp. and Syrphus spp.*
- The braconid parasitoid, *Diaeretiella rapae.*
- The lacewing, Chrysoperla *zastrowi sillemi.*
- Predatory bird *Motacilla cospica*. Severalof entomopathogenic fungi, *Cephalosporium spp., Entomophthora* and *Verticillium lecanii* infect aphids.

Mustard sawfly (Athalia lugens proxima)

- Conserve Perilissus cingulator (parasitoids of the larvae), and the bacterium Serratia marcescens which infect the larvae of sawfly.
- Use of bitter gourd seed oil emulsion as an anti- feedant.

For painted bug (*Bagrada cruciferarum)*

- Conserve bio-control agents such as Alophora spp. (tachinidfl y) parasitizing eggs of painted bugs.

Bihar hairy caterpillar (*Diacrisia oblique)*

- Conserve the natural biocontrol population of spiders, long-horned grasshoppers, praying mantid, robber fly, ants, green lacewing, damsel flies/dragonfly, flower bugs, shield bugs, ladybird beetles, ground beetle,

predatory cricket, earwig, braconids, trichogrammatids, green muscardine fungus.

Diamondback moth (Plutella xylostella):

- Conserve *Cotesia plutellae*, as it is an important parasitoid for the diamondback moth.
- *Diadegma insulare* is the most important parasitoid of the diamondback moth.

4. Use of botanical insecticides

They can be as simple as pureed plant leaves, extracts of plant parts, or chemicals purified from plants. Pyrethrum, neem formulations, and rotenone are examples of botanicals. Some botanicals are broad-spectrum pesticides. Others, like ryania, are very specific. Botanicals are generally less harmful to the environment than synthetic pesticides because they degrade quickly, but they can be just as deadly to beneficial as synthetic pesticides. However, they are less hazardous to transport and, in some cases, can be formulated on-farm. The manufacture of botanicals generally results in fewer toxic by-products Neem products such as cake, oil, neem seed kernel extract (NSKE), neem seed powder extract (NSPE), pulverized NSPE, and soaps are being used extensively to manage crop pests of rapeseed and mustard. Neem extract along with other biorational insecticides proved better results than used alone (Singh *et. al.*, 1988).

5. Chemical Control

Pre-emergence and post-emergence seedling blight and damping-off diseases caused by *Rhizoctonia solani, Sclerotium rolfsii* and/or *Fusarium* species can be controlled by seed treatment with effective fungicides. Usually a mixture of thiram + carbendarim (2:1) or thiram + carboxin (2:1) @ 0.2% is recommended. In case of downy mildew infection at the seedling stage, the disease is brought under control by treating the seeds with Apron 35 SD (metalaxyl) @ 6 g/kg seed. Sowing time x pesticide (fungicide and insecticide) interaction also becomes an important consideration in disease and insect pest management in later stages of crop growth. If mustard crop is sown late and fertilized excessively with nitrogen, the crop tends to get affected more severely by pests and diseases but can be protected from major diseases and aphid (the key pest) by spraying the cop at flowering-to-early pod formation stage with a mixture of Ridomil MZ 72 WP (a mixture of metalaxyl (8 %) and mancozeb (64%) (Biswas *et al.,* 2007; Kolte, 1985). In case powdery mildew becomes severe in central Indian states, Karathane or carbendazim @ 0.05 – 0.1% is reported to be useful. The above discussion suggests that the disease and pest management in mustard can be best achieved by adopting an integrated approach i.e. use of early maturing and disease / pest tolerant variety, and early October sowing and need-based strategy of insecticide/fungicide use. The compatibility of bio-control agents with resistant/tolerant

cultivars, companion crops, cultivation practices followed and botanicals and safer pesticides is to be worked out for sustainability of the disease and pest management practices.

CONCLUSION

In conclusion, the extensive use of pesticides results in long-term in efficiency and fiscal waste. In reality, many pesticides successfully suppress pest populations as planned. They are a poor long-term option due to their harmful consequences on both human health and the environment. Additionally, the majority of pesticides, both natural and synthetic, are prone to losing their potency as insects develop resistance. Integrative pest management is therefore the only option that will work in the future. The financial gains and decreased social costs of these systems present a logical answer to the pest control problem. On the other hand, plants are rich sources of natural substances and have great potential to be formulated as botanical pesticides that can be utilized in the development of environmentally safe alternative methods for insect control in the place of synthetic insecticides (Kumar and Patel 2017).

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