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ICAR-INDIAN INSTITUTE OF SPICES RESEARCH KOZHIKODE

Spicing up the Nation's progress

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Sugandha Bhavan
P.B. No: 2277, Palarivattom P.O.
Ernakulam 682 025
Tel: + 91 484 2333610 - 616, Extn: 263
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ICAR - Indian Institute of Spices Research

A Journey Through History and Achievements

R. Dinesh, Praveena R., Lijo Thomas, V. Srinivasan

ICAR-Indian Institute of Spices Research, Kozhikode -673012, Kerala

Indian spices significantly influenced the course of India's political history. The spice trade between India and Mediterranean countries flourished even before the Christian era. The fame of Indian spices indirectly led to the discovery of America by Christopher Columbus. Later, in 1498, Vasco da Gama's arrival at Kozhikode marked the beginning of European colonisation in India, first by the Portuguese, and later by the French, Dutch, and the British.

Recognising the need for focused research and development in the spice sector, the Government of India constituted a Spices Enquiry Committee in 1951. Based on the committee's recommendations, the Government of India assigned the responsibility for spices research to the Indian Council of Agricultural Research (ICAR). This move marked a significant shift towards a well-organised and coordinated research framework, laying the foundation for future advancements in the Indian spice sector.

The improvement of spices cultivation in the country received a significant boost with the launch of the All India Coordinated Spices and Cashew Nut Improvement Project in 1971, headquartered at the Central Plantation Crops Research Institute (CPCRI), Kasaragod. The primary focus of the project was to enhance the productivity of major spices and cashew. During the Fifth Five-Year Plan, seed spices were also brought under the project's purview. Subsequently, the project was bifurcated, and the All India Coordinated Research Project (AICRP) on Spices was shifted to Calicut (now Kozhikode) following the establishment of the National Research Centre for Spices (NRCS) in 1986 and serves as the headquarter for 40 centres that are spread over 15 agro climatic zones of the country.

During the Fifth Five-Year Plan, the Indian Council of Agricultural Research (ICAR) recognised the need to initiate both basic and applied research on major spices, including black pepper, cardamom, ginger, turmeric, and various tree spices. To achieve this objective, a regional station of the Central Plantation Crops Research Institute (CPCRI) dedicated to spices research was established on November 10, 1975, in a rented building in Calicut. Subsequently, 14 hectares of land, previously assigned to the Employees' State Insurance (ESI) Corporation, became available at a nominal cost within the Calicut Corporation limits. With the support of Prof. M. S. Swaminathan, the then Director General of ICAR, necessary funds were sanctioned, and the headquarters for Spices Research was established at Chelavoor, Kozhikode.

Within a decade of its establishment, the station was upgraded to the National Research Centre for Spices (NRCS) during the Eighth Five-Year Plan (April 1986). The Cardamom Research Centre at Appangala, which had earlier been transferred from the Indian Institute of Horticultural Research (IIHR), Bengaluru to the Central Plantation Crops Research Institute (CPCRI), Kasaragod in 1974, was also merged with the National Research Centre for Spices (NRC for Spices) in April 1986. Based on the recommendations of the Quinquennial Review Team (QRT) and the Parliamentary Committee, the NRC for Spices was upgraded to the ICAR–Indian Institute of Spices Research (ICAR-IISR) in July 1995.

Technological Innovations in Spices

Improved spice varieties for enhanced yield, resilience, and quality

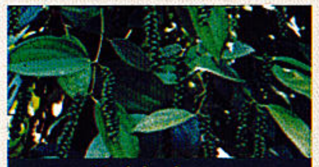
The commodity specific research institutes under ICAR like ICAR- IISR and ICAR National Research Centre on Seed Spices along with the All India Coordinated Research Project on Spices (AICRPS) act as an institutional umbrella for coordinating and directing the research agendas in the sector. Collectively, these institutions maintain the world's largest germplasm collection of spices and develop production and protection technologies for different agro climatic zones of the country.

The focus of varietal development in spice crops has evolved from solely enhancing yield to incorporating desirable trait deployment. This shift in approach emphasises not only higher productivity but also improved quality parameters and stress tolerance. The institute has developed and released 36 improved varieties and 189 varieties through AICRPS system across the major spice crops, noted for their high yield, quality, and resistance to pests and pathogens.

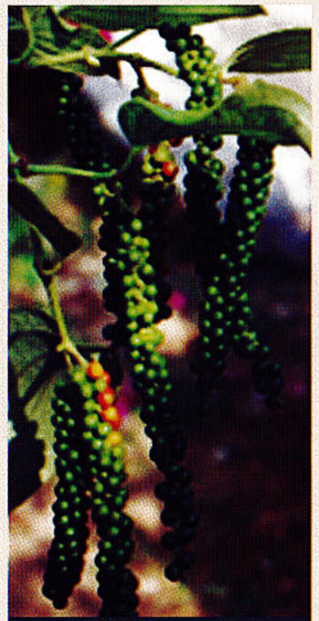
Over the years, the ICAR-IISR has become a key repository of one of the world's largest spice germplasm collections. The institute maintains an extensive collection, including 3511 accessions of black pepper, 625 of small cardamom, 668 of ginger, 1404 of turmeric, 77 of vanilla and 461 of tree spices. The institute has successfully developed thirty-six high yielding high quality varieties of spices like black pepper, small cardamom, ginger, mango ginger, turmeric, cinnamon, and nutmeg. These new varieties offer better resistance to diseases, require less water, and give more yield. Cardamom variety (IISR-Appangala-1) is preferred widely by the oil extraction industries, whereas IISR-Appangala-2 and IISR Vijetha are suitable for mosaic affected areas. Drought-tolerant cardamom varieties, IISR Manushree and IISR Kaveri, featuring bold capsules and stable yield capacity under moisture stress conditions, were recently released.

The focus on trait specific breeding in spices is expected to provide specialty spice varieties and will help in leveraging the heirloom germplasm stock. The latest ginger varieties, IISR Vajra and IISR Surasa,


Panchami


Subhakara


IISR Thevam


IISR Chandra


IISR Kaveri


IISR Surya

have high yield potential, desirable flavour, and high zingiberene content. In case of turmeric, the focus on improving the curcumin content of the varieties has yielded varieties like Suguna, Suvarna, Sudharsana, IISR-Pratibha, IISR Pragati, IISR Kedaram, and IISR Alleppey Supreme, which are suitable for growing throughout India. The recently released turmeric variety, IISR Surya, features light yellow rhizomes with a curcumin content of two to three per cent and a unique flavour and light yellow colour, making it highly suitable for the powdering industry.

Sustainable production technologies for spice crops

Key approaches include integrated nutrient and pest management (INM & IPM), organic farming, precision agriculture, and conservation practices such as mulching, crop rotation, and intercropping. The use of biofertilisers, biopesticides, and water-efficient irrigation systems like drip and sprinkler irrigation reduces chemical dependency and minimises environmental impact.

The institute has developed several Good Agricultural Practices in spice crops to promote sustainable agriculture and efficient use of resources. These technologies have resulted in substantial improvement in production and availability of food safe spice commodities. Organic production packages were developed for black pepper, ginger and turmeric and were demonstrated in farmers' fields with sustainable yields. Organic packages for spices were also developed for the Northeast region and demonstrated. These organic production packages offers several advantages, benefiting both farmers and consumers while ensuring environmental sustainability.

Innovations in plant and soil health management

The institute has always remained in the forefront of developing farmer friendly technologies for enhancing soil and plant health. The lime-based microbial formulations developed by ICAR-IISR seek

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to combine the benefits from amelioration of soil pH and prophylactic control of soil borne pathogens through a single product.

- **TRICHOLIME:** This formulation combines lime and *Trichoderma* in a single product. It neutralises soil acidity, enhances plant growth, and protects crops from soil-borne pathogens in a single application.
- **BACTOLIME:** A granular lime-based bacterial formulation integrating beneficial bacteria with lime. It improves low-pH soils while ensuring the simultaneous delivery of plant-beneficial microbes.
- **BACTOGYPSUM:** Designed for ameliorating high pH soils and also ensures simultaneous delivery of plant beneficial bacteria.
- **TRICHOGYPSUM:** A gypsum-based *Trichoderma* formulation that helps manage high-pH soils and supports microbial colonization for plant health.

Microbial encapsulation technology

Another groundbreaking technology developed by ICAR-IISR is the microbial encapsulation technology, which involves creating biocapsules for beneficial microorganisms used in agriculture. These capsules have a longer shelf life and ensure efficient delivery of microbes to crops. The biocapsules play a critical role in improving nutrient mobilisation in the soil, enhancing crop productivity, and providing natural disease control without the need for chemical pesticides. The technology has already been commercialised to eight Indian firms and got international attention, with a license issued to M/s Lysterra LLC, Moscow, Russia.

Decision Support System for fertiliser recommendation (Spice FeRT)

The Decision Support System software for generating soil test and crop response-based fertiliser (NPK) recommendation for different yield targets has been developed for crops like black pepper, ginger, turmeric, and cardamom.

Designer micronutrient formulations

The crop specific micronutrient technology has revolutionised spice farming by increasing crop yields by 10-25 per cent. This technology is particularly beneficial for crops like black pepper, cardamom, ginger, turmeric, and nutmeg. By using these micronutrient formulations, farmers can improve their soil fertility, and increase crop productivity. The technology has been licensed to several entrepreneurs across the country.

Micronutrient formulations of licensee available in the market

Innovations in crop protection technologies

The institute has developed several innovative technologies for mitigating abiotic stress factors in spice crops. The seed coating technology, which is a novel process of coating efficient strains of Plant Growth Promoting Rhizobacteria (PGPR) on seeds and seed priming *Trichoderma* formulation, assures improved and uniform germination. Some other technological innovations in this genre include

- A PGPR consortium for nutrient mobilisation, growth promotion and biocontrol in black pepper.
- Integrated technology for the management of bacterial wilt in ginger:- This involved soil solarisation followed by drenching the beds with calcium chloride (3%) at the time of planting and repeated drenching at 30, 45, 60 and 90 days after planting or treating the seed rhizomes with *Bacillus licheniformis* (the commercial product Bacillich 2%).

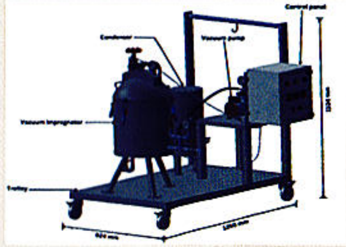
- IPM technology for the management of cardamom thrips: - An IPM package integrating the entomopathogenic fungus, *Lecanicillium psalliotae*, a reduced risk insecticide, spinosad and their combinations with the existing chemical and cultural methods.
- New entomopathogenic fungus against Shoot borer, *Congethes punctiferalis*:- An entomopathogenic fungus *Metarhizium pingshaense* was isolated and characterised. This fungus holds promise towards development of a potential mycoinsecticide.
- Liquid formulation of *Pochonia chlamydosporia*:- A liquid culture-based process was developed for large-scale production of *P. chlamydosporia* formulation
- Rhizome priming using *Trichoderma*:- A product for priming rhizomes and tubers using the biocontrol fungi, *Trichoderma spp.* was developed to shorten the germination time of rhizomes, to improve the vigour of buds, to prevent the growth of dry rot pathogens during storage and to provide protection from diseases during initial stages of the crop.
- A PGPR strain (*Bacillus safensis*) for plant growth promotion, soil nutrient solubilisation and disease suppression.
- Various diagnostic techniques have been developed for the detection and differentiation of plant pathogens. Protocols for Polymerase Chain Reaction (PCR), Recombinase Polymerase Amplification (RPA), and Loop-mediated Isothermal Amplification (LAMP) have been established to identify different *Phytophthora* species, while a multiplex PCR assay enables the simultaneous detection of *Phytophthora*, *Pythium*, and *Fusarium*.
- Molecular techniques have also been optimised for detecting viruses affecting black pepper and cardamom. In ginger, both single plex and duplex RPA assays have been designed for efficient pathogen identification. Additionally, an RPA-LFA (recombinase polymerase amplification-lateral flow assay) method has been developed and validated for the detection of piper yellow mottle virus (PYMoV) in black pepper.

Innovations in post-harvest technologies

Post-harvest value addition hold immense potentials in the spice ecosystem. Several technologies for processing and value addition in spices have been developed and successfully commercialised. Three spice-based formulations designed as adjuvants for milk and dairy products have been developed and commercialised through MILMA, Kerala's Co-operative Milk Marketing Federation.

A process for the development of ginger-lime juice powder has been successfully formulated, using advanced dehydration techniques to retain the natural flavour, aroma, and bioactive compounds of ginger and lime. The formulation ensures extended shelf life, making it suitable for commercial production and easy consumer use. In addition, a spice-flavoured ice cream has been developed using a combination of toned milk, cream, sugar, and skim milk powder, enriched with black pepper oleoresin. Furthermore, an innovative spice oleoresin-infused finger millet milk fortified ice cream has also been developed. This novel formulation offers a dairy-free alternative with functional health benefits, catering to health-conscious consumers.

A pilot-scale vacuum impregnation unit has been recently developed to produce novel food products incorporating spice extracts. This technology enables the efficient infusion of bioactive compounds from spices into various food matrices, enhancing their nutritional and functional properties.



Several advanced drying protocols combining various sources of energy have been developed for meeting specific drying requirements. These technologies enhance energy efficiency, reduces processing time, and ensures better retention of nutrients, colour, and aroma in dried products. The innovations in spice processing and value addition hold significant commercial potential and can be transferred to entrepreneurs and startups, offering opportunities for business growth in spice- based food processing sector.

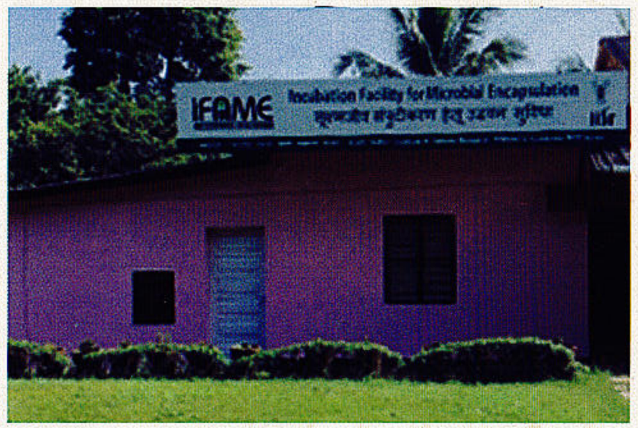
Agribusiness Incubator (ABI): Fostering Entrepreneurship

Recognising the importance of nurturing entrepreneurship in the spice sector, ICAR-IISR established the Agribusiness Incubator (ABI) in 2013 to support startups and aspiring entrepreneurs. As a one-stop incubation center, it helps in research and development, technology transfer, business planning, and marketing strategies.

Facilities at ABI

One of the key highlights of the Agribusiness Incubator (ABI) is the iFAME Incubation Facility for Microbial Encapsulation, designed to support startups specialising in biocapsule manufacturing. This advanced facility provides essential infrastructure and technical expertise for the development of microbial encapsulation products.

Another significant facility under ABI is the spice processing unit, established in 2014. This state-of-the-art facility is equipped with modern machinery for cleaning, grading, and processing spices into powders, essential oils, and curry masalas. Currently, more than seven startups are leveraging this processing unit to develop spice powders, curry masalas, and other value-added spice based products.



To further support the marketing and commercialisation of these products, ABI has launched Spiisry, an e-commerce platform that connects spice entrepreneurs directly with consumers.

The Kisan Seva Kendra – Bio Input Resource Centre at ICAR-IISR facilitates the sale of farm bio-inputs developed by ICAR institutes, aiming to support farmers across the country by providing easy access to ICAR technology-based inputs.

The Agribusiness Incubator (ABI) offers comprehensive support to entrepreneurs by providing state-of-the-art infrastructure, office space, laboratory facilities, pilot production units, and expert mentoring.

As India continues to consolidate its position as a global leader in the spice production, processing and trade, the role of ICAR-Indian Institute of Spices Research (ICAR-IISR) stands out as both foundational and forward-looking. From pioneering research in crop improvement and disease management to driving innovation in precision agriculture, biotechnology, and value addition, ICAR-IISR has consistently aligned its scientific endeavours with the evolving needs of the spice sector. Its holistic approach-integrating traditional knowledge with cutting-edge technology-has not only empowered farmers and entrepreneurs but has also strengthened India's spice value chain.

Nutraceutical Potential of Indian Spices: From Ancient Wisdom to Modern Medicine

R. Dinesh, Anees K.
ICAR-Indian Institute of Spices Research, Kozhikode 673012, Kerala

India, often called the "land of spices," has contributed immensely to the world's spice trade and medicinal knowledge for thousands of years. The subcontinent's diverse climatic conditions have fostered the growth of numerous aromatic plants whose seeds, fruits, roots, and bark have not only tantalized taste buds but also served as potent remedies in traditional healing systems. This rich heritage of spice-based medicine continues to influence modern nutraceutical research and development. Long before modern pharmaceuticals lined medicine cabinets, our ancestors understood the healing power of spices. These aromatic plant substances not only transformed bland foods into culinary masterpieces but served as nature's pharmacy, offering remedies for countless ailments. Today, science is catching up

to what grandma's medicine using spices is made of in the form of powerful bioactive compounds with remarkable health benefits.

Spices in Traditional Medical Systems

Ayurveda: The Science of Life and Longevity

The 5,000-year-old Ayurvedic medical system forms the cornerstone of traditional Indian healing practices. Ayurveda classifies spices according to their effects on the three doshas (*Vata, Pitta,* and *Kapha*) that govern physiological and psychological functions. Ancient texts like *Charaka Samhita* and *Sushruta Samhita* meticulously document the medicinal applications of numerous spices. In Ayurvedic pharmacology (*dravyaguna*), spices are categorised based on their *rasas* (tastes), *virya* (potency), *vipaka* (post-digestive effect), and *prabhava* (special effects). This sophisticated classification system guides practitioners in prescribing specific spices for individual constitutions and conditions:

- **Turmeric *(Haldi)*** is considered *tridoshic* (balancing for all three doshas) and is prescribed in formulations like *Haridra Khanda* for skin disorders and respiratory conditions.
- **Black Pepper *(Kali Mirch)*** is valued for its heating virya and capacity to enhance bioavailability of other herbs, making it an essential component in formulations like *Trikatu.*
- **Cardamom *(Elaichi)*** is used in Ayurvedic formulations like *Sitopaladi Churna* for respiratory conditions, leveraging its properties as a digestive stimulant that simultaneously clears excess *Kapha* from the respiratory tract.
- **Cinnamon *(Dalchini)*** features prominently in formulations for vata disorders, particularly in *Dashamula Kwatha* preparations for joint pain and neurological conditions.
- **Cumin *(Jeera)*** is classified as having *katu* (pungent) and *kashaya* (astringent) *rasa*, making it valuable in formulations like *Hingwashtak Churna* for treating digestive disorders.

Ayurvedic practitioners prepare spices in various forms including decoctions (*kashaya*), medicated ghee (*ghrita*), medicated oils (*taila*), and powders (*churna*). The timing of administration often corresponds with specific times of day when particular doshas are dominant, demonstrating the system's holistic approach to chronopharmacology.

Siddha Medicine: The Tamil Healing Tradition

The Siddha system, originated in Tamil Nadu, represents one of India's oldest medical traditions, attributed to the 'Siddhars' who were yogic adepts with profound knowledge of herbs and minerals. Spices play a crucial role in Siddha's 'food as medicine' philosophy.

In Siddha pharmacology, spices are classified according to *suvai* (taste), *thanmai* (nature), *pirivu* (post-digestive transformation), and *veeriyam* (potency). The system recognises 96 fundamental principles governing the body, with spices prescribed to balance the three humors (vatham, pitham, and kapham):

- **Dry Ginger *(Sukku)*** features prominently in formulations like *Sukku Chooranam* for digestive disorders and respiratory conditions. It's considered especially effective in balancing excess kapham.
- **Long Pepper *(Thippili)*** is a cornerstone of Siddha respiratory treatments, used in preparations like *Thippili Rasayanam* for chronic respiratory conditions and immunity enhancement.

- **Asafoetida *(Perungayam)*** is valued for its vatha-reducing properties and features in formulations treating neurological and gastrointestinal disorders, particularly in *Ingu Chooranam*.
- **Fenugreek *(Venthayam)*** is prescribed extensively for diabetes in formulations like *Venthaya Chooranam*, predating modern scientific validation of its hypoglycemic properties by centuries.

Uniquely, Siddha medicine places special emphasis on fermented preparations of spices called "parpam" and "chendooram," which enhance bioavailability and potency. The tradition also features "mezhugu" (medicated waxes) that incorporate spices for sustained release of active compounds.

Unani Medicine: The Greco-Arabic Connection

Unani medicine, introduced to India during the medieval period, synthesises Greek, Arabic, Persian, and Indian medical knowledge. It conceptualises health as a balance of the four humours (dam/blood, balgham/phlegm, safra/yellow bile, and sauda/black bile) and the four temperaments (mizaj): hot, cold, moist, and dry. Spices in Unani are classified by their temperament and degree of potency (from one to four). They are incorporated into formulations designed to restore humoral balance:

- **Black Cumin *(Kalonji)*** is considered a warming spice of the second degree and features prominently in formulations like *Majoon-e-Nankhwah* for digestive disorders and respiratory conditions.
- **Coriander *(Dhania)*** is classified as cold and dry in the first degree, making it valuable in formulations treating excess heat conditions, particularly in *Khameera Gaozaban* preparations.
- **Fennel *(Saunf)*** is prescribed in Unani as a diuretic and carminative in formulations like *Jawarish Mastagi*, taking advantage of its moderately warm temperament.
- **Clove *(Laung)*** is considered hot and dry in the third degree, making it powerful for treating conditions with excess cold and moisture, particularly in preparations like *Jawarish Jalinus*.

Unani's sophisticated compound formulations called "murakkabat" often feature precise combinations of spices. These include syrups (sharbat), electuaries (majoon), powders (safoof), and decoctions (joshanda), each with specific preparation methods that maximise the therapeutic potential of the spices. A distinctive feature of Unani spice preparations is the concept of "tadeel" or modification, where secondary ingredients are added to mitigate potential side effects of primary ingredients, creating balanced formulations suitable for long-term use.

Grandma's Kitchen: The First Pharmacy

In Indian households, the dividing line between kitchen and medicine cabinet has always been blurred. In kitchens across cultures, spices have served dual roles as flavour enhancers and healing agents. This indigenous knowledge, passed down through generations, represents one of humanity's oldest healthcare systems. In India, the principles of Ayurveda have incorporated turmeric, known as "haldi," for over 4,000 years. Grandmothers would prepare "golden milk" by simmering turmeric in milk with honey, often to treat colds, inflammation, and digestive issues. Similar wisdom exists in Chinese traditional medicine, where cinnamon has been prescribed for millennia to improve circulation and warm the body. Caribbean and Latin American communities have long relied on allspice berries for relieving indigestion and arthritis pain. African healing traditions incorporate cloves for toothaches, while Mediterranean grandmothers have used rosemary not only in cooking but as a remedy for improving memory and circulation.Grandmothers (or "dadis" and "nanis") have long been the primary healthcare providers, wielding spices with precision to address common ailments:

- **Haldi (Turmeric)** mixed with warm milk, known as "haldi doodh" or golden milk, has been administered for generations to heal wounds, reduce inflammation, and boost immunity, especially during cold and flu season.
- **Ajwain (Carom Seeds)** steeped in hot water or chewed raw has been the go-to remedy for indigestion, gas, and stomach pain. Grandmothers would often prepare a digestive mix called "pachak" combining ajwain with cumin and fennel.
- **Jeera (Cumin)** water, prepared by boiling cumin seeds, has been prescribed for digestive disorders and to boost lactation in new mothers.
- **Dalchini (Cinnamon)** combined with honey has traditionally been used to soothe sore throats and treat respiratory infections.
- **Saunf (Fennel Seeds)** offered after meals serves both as a mouth freshener and digestive aid, demonstrating the seamless integration of culinary and medicinal practices.
- **Laung (Clove)** has been placed directly on aching teeth to relieve pain, owing to its natural anesthetic properties.
- **Kali Mirch (Black Pepper)** mixed with honey has been a traditional remedy for coughs and congestion.

Modern Scientific Validation of Indian Spices

Modern scientific research has increasingly validated the traditional uses of Indian spices, illuminating the biochemical mechanisms behind their therapeutic effects:

Turmeric: The Golden Healer

Turmeric *(Curcuma longa)* contains curcumin, which has been the subject of over 15,000 scientific papers. Research has confirmed its anti-inflammatory properties, comparable in some studies to pharmaceutical drugs but without the side effects. Indian researchers at the Jawaharlal Nehru University and All India Institute of Medical Sciences have been at the forefront of exploring curcumin's potential in treating Alzheimer's disease, noting India's significantly lower prevalence rates compared to Western countries despite similar life expectancies. Current clinical trials are investigating turmeric-derived compounds for treating rheumatoid arthritis, inflammatory bowel disease, certain types of cancer and few metabolic syndrome

Black Pepper: More Than Just Spice

Piperine, the alkaloid responsible for black pepper's pungency, has been shown to enhance the bioavailability of numerous beneficial compounds, including curcumin. This scientific finding validates the traditional practice of combining black pepper with turmeric in remedies. Research from the Indian Institute of Science has demonstrated piperine's potential to inhibit fat cell formation, suggesting applications for weight management. Additionally, its antimicrobial properties confirm its traditional use as a food preservative.

Cardamom: The Queen of Spices

***Elaichi* (cardamom)** contains compounds that have demonstrated gastroprotective effects, validating its traditional use for digestive disorders. Studies from Manipal University have shown its potential in controlling blood pressure and improving antioxidant status. Recent research indicates cardamom's 1,8-cineole content might have applications in respiratory health, supporting its traditional use in treating bronchitis and asthma.

Ginger: The Universal Medicine

***Adrak* (ginger)** contains gingerols and shogaols that demonstrate remarkable antiemetic, anti-inflammatory, and analgesic properties. Research

from the Central Food Technological Research Institute in Mysore has validated its traditional use for nausea and arthritis pain. Emerging research suggests ginger may play a role in managing diabetic complications through multiple pathways, including inhibition of sorbitol accumulation and reduction of oxidative stress.

Cinnamon contains compounds that may help regulate blood sugar by mimicking insulin and increasing insulin sensitivity. This supports traditional uses for managing diabetes symptoms. Garlic's allicin has demonstrated antimicrobial properties against a wide range of pathogens, supporting its historical use in fighting infections. Additionally, studies show it may help lower cholesterol and blood pressure.

Convergence of Traditional Systems: Shared Wisdom on Spices

Despite their distinct theoretical frameworks, Ayurveda, Siddha, and Unani systems share remarkable consensus regarding the therapeutic applications of many spices. This cross-system validation strengthens the evidence base for their medicinal value:

Cross-System Validated Spices

- **Ginger** is recognised across all three systems for its digestive benefits and anti-inflammatory properties, though explained through different conceptual frameworks:
  - **In Ayurveda:** A warming spice that pacifies *Vata* and *Kapha*
  - **In Siddha:** A substance that balances *vatham* and *kapham* through its heating action
  - **In Unani:** A hot and dry substance that counters excess *balgham* (phlegm)
- Fenugreek is universally acknowledged for its benefits in diabetes management:
  - **Ayurveda** attributes this to its capacity to reduce *Kapha* and *medha dhatu* (fatty tissue)
  - **Siddha** identifies its action on the *yakkai* (liver) to regulate glucose metabolism
  - **Unani** recognises its moderating effect on the humour *safra* (yellow bile)

Complementary insights across different systems of medicines is also evident in the case of spices. The three systems sometimes offer complementary perspectives on the same spice, enhancing our understanding of its full therapeutic potential:

- **Black Cumin *(Kalonji)*** is primarily valued in Unani for respiratory and digestive disorders, while Ayurveda emphasises its Kapha-reducing and digestive properties. Modern research validates both perspectives, identifying thymoquinone as the compound responsible for these diverse actions.
- **Cinnamon** is primarily used in Ayurveda for *Vata* disorders affecting the nervous system, while Unani emphasises its warming effect on the digestive system. These complementary views align with current understanding of cinnamon's multiple mechanisms of action.

The convergence of traditional wisdom and scientific research has given rise to nutraceuticals – foods or food components that provide health benefits beyond basic nutrition. Spice-derived nutraceuticals represent one of the fastest-growing segments of this industry. Pharmaceutical companies are now isolating and standardising bioactive compounds from spices for therapeutic applications. For example, curcumin extract is being developed into treatments for inflammatory conditions and cancer prevention. Capsaicin from chilli peppers has found its way into pain-relieving creams. Meanwhile, food scientists are enhancing spice bioavailability through technologies like nano-encapsulation and finding ways to incorporate effective doses into everyday foods. This approach addresses one of the main challenges in spice-based therapy – delivering sufficient quantities of active compounds to achieve therapeutic effects.

Spice Synergies: The Masala Approach

Traditional Indian medicine rarely employs spices in isolation. Instead, carefully formulated combinations create synergistic effects that modern science is only beginning to understand:

Trikatu: The Three Pungents

This ancient formulation combines black pepper, long pepper, and ginger to enhance bioavailability and digestive power. Modern pharmacokinetic studies confirm that this combination significantly increases the absorption of beneficial compounds from other herbs and spices.

Garam Masala: More Than Flavour

This warming spice blend typically contains cinnamon, cardamom, cloves, cumin, coriander, and black pepper. Recent metabolomic studies have revealed that these spices together modulate multiple metabolic pathways simultaneously, potentially explaining their traditional use in preventative healthcare.

Panch Phoron: The Five-Spice Wonder

This Bengali five-spice mixture combines cumin, fennel, fenugreek, nigella, and mustard seeds. Research from Jadavpur University has demonstrated its collective antioxidant and antimicrobial properties exceed those of the individual spices.

From Kitchen Gardens to Clinical Trials

The journey of Indian spices from grandma's kitchen garden to pharmaceutical laboratories represents a fascinating convergence of traditional knowledge and cutting-edge science:

Fenugreek: Managing Diabetes

Methi (fenugreek) seeds, traditionally used to control blood sugar, have been validated through clinical trials at the National Institute of Nutrition in Hyderabad. The fiber and 4-hydroxyisoleucine in fenugreek improve insulin sensitivity and glucose metabolism. Current pharmaceutical development includes fenugreek-based formulations for diabetic management, with standardised extracts showing promising results in Phase II clinical trials.

Holy Basil: Adaptogenic Wonder

Tulsi (holy basil), revered as sacred in Indian households, contains eugenol, rosmarinic acid, and other compounds with adaptogenic properties. Research at the Central Drug Research Institute has validated its traditional use for stress management, showing it modulates cortisol levels and supports adrenal function. Commercialised tulsi extracts are now being incorporated into supplement formulations for stress management and immune support.

Asafoetida: The Gut Healer

Hing (asafoetida), with its distinctive sulfurous aroma, has been used traditionally for digestive disorders. Modern research confirms its antispasmodic and carminative properties, attributing these effects to its ferulic acid and coumarins content. Recent studies from the Indian Institute of Integrative Medicine have identified compounds in asafoetida with prebiotic potential, supporting gut microbiome health.

Challenges and Opportunities

Despite the immense potential of Indian spices in modern healthcare, several challenges and opportunities define the current landscape. The potency of bioactive compounds in spices varies significantly based on growing conditions, harvesting practices, and storage methods. The Indian Council of Agricultural Research is developing standardised cultivation practices and post-harvest technologies to ensure consistent bioactive profiles. Many spice-derived compounds, including curcumin, have poor bioavailability. Indian pharmaceutical companies are pioneering delivery technologies including:

- Phytosome complexes
- Nanoemulsions
- Solid lipid nanoparticles
- Black pepper-derived bioenhancers

Intellectual Property and Traditional Knowledge

India has established a Traditional Knowledge Digital Library to prevent biopiracy and inappropriate patenting of traditional spice-based remedies. This database documents over 300,000 formulations from classical texts, protecting the cultural heritage while facilitating legitimate research and development. The future of Indian spice nutraceuticals lies in respectfully integrating traditional wisdom with modern scientific methods:

Integrative Research Approaches

Research institutions like the Central Council for Research in Ayurvedic Sciences (CCRAS), Central Council for Research in Siddha (CCRS), and Central Council for Research in Unani Medicine (CCRUM) are conducting systematic studies validating traditional spice formulations through modern scientific methods. The AYUSH ministry's initiative to develop "Ayush 82" for diabetes management exemplifies this approach, combining traditional methi (fenugreek) and jamun (Indian blackberry) with other herbs in a formulation that has demonstrated efficacy in clinical trials.

Reverse Pharmacology Approach

Indian research institutions are pioneering "reverse pharmacology," which begins with documented traditional uses and works backward to isolate active compounds and understand mechanisms. This approach has proven more efficient than conventional drug discovery for spice-derived compounds.

AI and Machine Learning Applications

Artificial intelligence is being employed to analyse traditional texts from Ayurveda, Siddha, and Unani to identify potential spice combinations for specific health conditions. Researchers at the Indian Institute of Technology are using machine learning to predict synergistic effects among spice compounds.

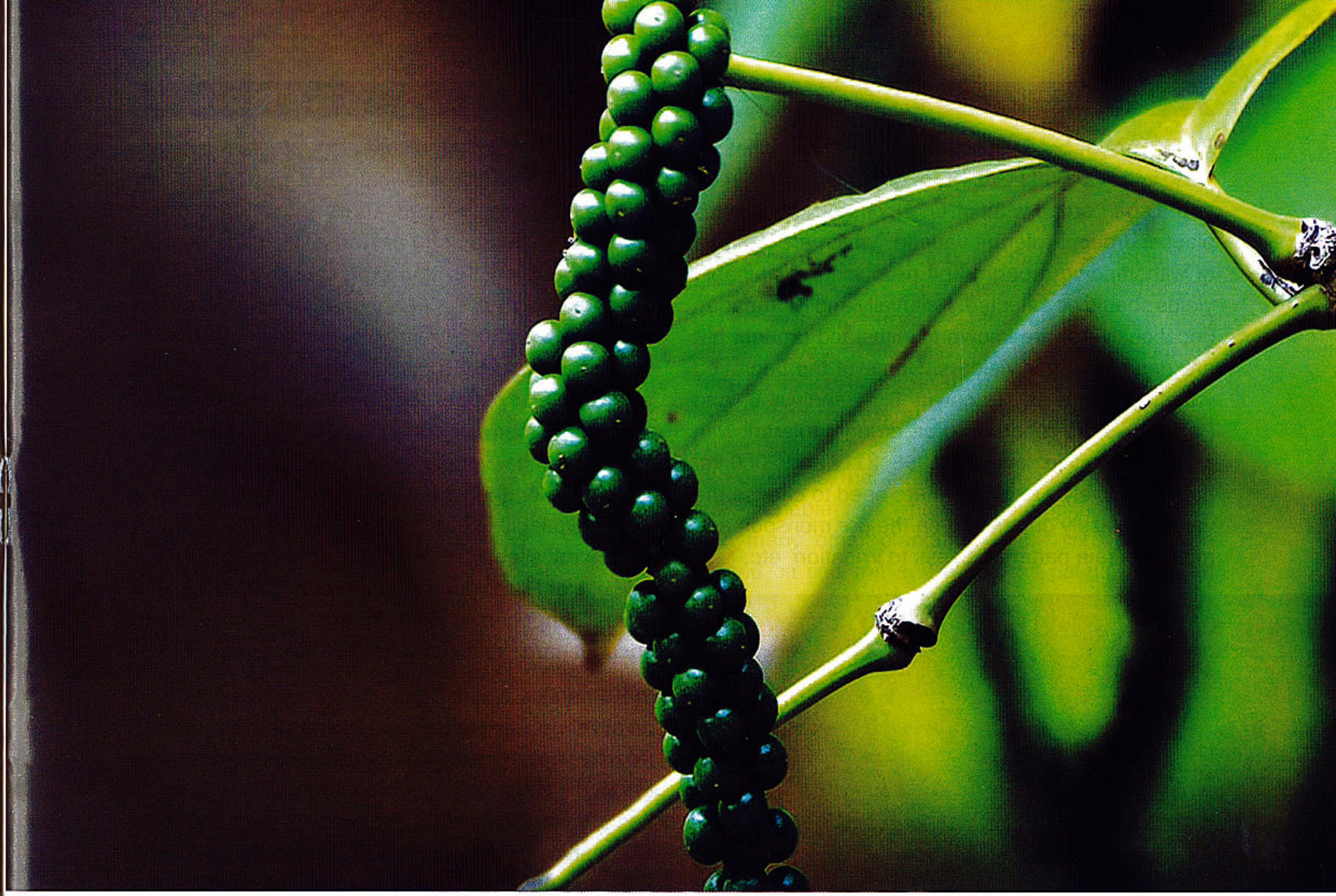
Community-Based Clinical Validation

Organisations like the Foundation for Revitalisation of Local Health Traditions are conducting community-based clinical documentation of traditional spice remedies, creating an evidence base that bridges the gap between anecdotal knowledge and conventional clinical trials.

As the world embraces integrative approaches to healthcare, Indian spice wisdom offers valuable lessons. Medical schools internationally are incorporating culinary medicine programmes inspired by traditional Indian spice usage. These programmes teach healthcare providers to prescribe food as medicine, with spices playing a central role in managing chronic conditions. The Indian approach of incorporating medicinal spices into daily cooking represents a sustainable model for preventative healthcare. This stands in contrast to the Western tendency to isolate compounds into supplements taken separately from food. Spice-derived compounds offer promising solutions for global health challenges including antimicrobial resistance, chronic inflammation, and metabolic disorders. International collaborations with Indian research institutions are accelerating the development of spice-based interventions for these conditions.

Honouring the Past, Enriching the Future

The nutraceutical potential of Indian spices represents one of humanity's most valuable medicinal treasures. By honouring the traditional knowledge preserved in Ayurveda, Siddha, and Unani systems while embracing scientific innovation, we unlock new possibilities for health and healing. When we add turmeric to our foods or sip on fennel tea, we are not merely following trends but participating in an ancient tradition of healing that has stood the test of time-and increasingly, the scrutiny of science. As research continues to unveil the molecular mechanisms behind these traditional remedies, we obtain not only new therapeutic agents but also a deeper appreciation for the wisdom embedded in Indian culinary and medicinal heritage. The humble spice rack, a fixture in every Indian kitchen, may well be the medicine cabinet of the future-fulfilling the ancient principle that food itself should be our medicine, and medicine our food.



Drought Mitigation Strategies in BLACK PEPPER

K.S. Krishnamurthy, S.J. Ankegowda, K. Kandiannan, C.K. Thankamani
ICAR-Indian Institute of Spices Research, Kozhikode 673012, Kerala

Black pepper belongs to the family Piperaceae. It is a crop of humid tropics. The Western Ghats region of India is the most suitable for black pepper cultivation. It can be cultivated between 12-40°C but the temperature range of 23-32°C is optimum for black pepper growth. It requires well-distributed rainfall of 2000-3000 mm for better productivity. It is susceptible to excessive heat and dryness. During 2022-23, black pepper was cultivated in an area of 2.78 lakh hectares in India with a production of 64000 metric tonnes. In India, Kerala, Karnataka, and Tamil Nadu are the important states cultivating black pepper and its cultivation is gradually spreading to north eastern states, Andaman and Nicobar Islands and East and West Godavari, Maharashtra, Odisha etc. In black pepper growing regions, More than 70 per cent of rainfall is received during June-October and plant suffers due to moisture stress from Jan-May due to scanty rainfall during north east monsoon and summer months. This results in wilting of vines, leading to low productivity. Flower primordia initiation, flowering, spike elongation, and berry development are the sensitive stages to moisture stress in black pepper. Hence, we need to be proactive and evolve strategies to withstand ill effects of drought and maintain sustainable production. The strategies include the following.

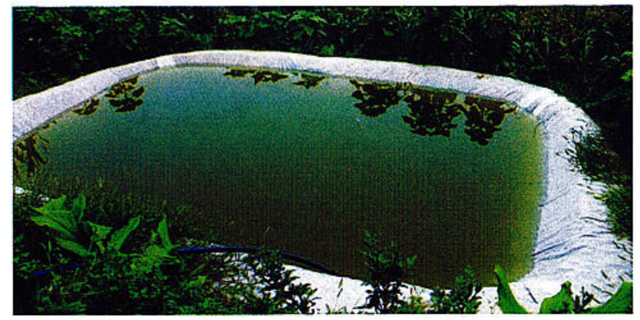
Selection of varieties: Selection of varieties is very important especially in drought-prone areas and also in areas without irrigation source. In such places, drought-tolerant varieties which are capable of withstanding drought and producing sustainable yields should be selected. Kalluvally and Kottanadan (local cultivars) are known to withstand drought but are generally poor yielders. Some of the improved varieties such as Panniyur 5, Panniyur 6, and Panniyur 8 are reported to be drought tolerant with a promising yield levels of 1098, 2117 and 2000 kg/ha respectively. Hence, farmers need to choose the varieties wisely depending on the pre monsoon and monsoon rain pattern, access to irrigation, etc.

Mulching: Mulching has several advantages apart from moisture conservation. It increases the infiltration of water, suppresses weed growth, regulates soil temperature, controls the microclimate, enhances microbial activity, decreases evaporation, and also improves soil fertility. Mulching can be carried out around the basins of black pepper vines at the withdrawal of north-east monsoon with organic materials, preferably green leaves 10 kg/vine, applied around 1 m radius. *Calapagonium mucunoides* and *Mimosa invisa* can also be grown as live mulch (cover crops), which provide soil cover, reduce evaporation, and prevent soil erosion. Care should be taken to prevent cover crops from twining on black pepper standards and black pepper and they can be cut at regular intervals and used as mulch. With all its advantages, mulching can enhance yield levels.

Irrigation: The root distribution of black pepper plants indicates that the main root goes deep, but fibrous roots are surface feeders and are distributed in 50-60 cm depth at 30 cm radius from the base of vines. Therefore, the plants are sensitive to moisture stress. Hence, basin irrigation of vines using hose at the rate of 80-100 litres per vine once a week during summer months is recommended to enhance yield of black pepper. Drip irrigation at the rate of seven litres per day during October-May especially for Karimunda variety enhances productivity and depending on the variety, canopy development and water availability, the quantity can be regulated or enhanced slightly. Providing drip irrigation at the rate of eight litres per plant daily during October-May saves 25 per cent water in bush pepper cultivated in coconut gardens compared to pot watering.

In Karnataka, where black pepper is mostly trained on silver oak, irrigating pepper vines during summer (March second fortnight to May second fortnight) at 12-15 days interval is recommended. This practice has shown the productivity enhancement by 90 to 100 per cent compared to unirrigated crop. Vines are irrigated at the basin through hose and 50 litres per vine is recommended for black pepper vines aged 15 years and above. This can be reduced to 40 litres per vine for 11-15 years age group and 30 litres for vines aged between 5 - 10 years. Also to prevent sun scorching and leaf fall, spraying of 1.5% lime or 2.0% kaolin is recommended which is very helpful. Providing overhead sprinklers for evaporative cooling or shade net also reduces the heat load on the plant and enhances productivity.

Rainwater harvesting: The Western Ghat region is the major black pepper growing area and this region receives heavy rainfall during south-west monsoon. Because of heavy rain, the soil gets saturated soon and most of the rainwater is not utilised and ultimately reaches to sea. Efficient conservation practices can help utilise this water during drought periods. Hence, the preservation of rainwater and the protection of underground water are need of the hour. In undulating areas, terraces and contour bunds should be constructed for conserving moisture as the terraces can hold moisture. Making of silt pits (50 x 50 x 50 cm) between the centre of two black pepper rows at a distance of 10 meters just



before the commencement of south-west monsoon can help to conserve soil moisture in black pepper plantation which contributes to productivity. Water harvesting and recycling during low soil moisture availability should be an integral part of rainfed cultivation.

Shade: Generally, black pepper rooted cuttings are planted during end of May, just at the onset of monsoon, followed by mulching. Protection of young vines from hot sun especially in open areas by providing shade using dry areca nut or coconut leaves or twigs of trees during summer is very essential, otherwise mortality of vines occurs. Shade should be removed with the onset of monsoon rains. After establishment, the side branches of standards should be pruned to enable the standard to grow erect. Shade regulation by pruning branches of standards during April and August-September is very essential to provide sufficient filtered light to the entire canopy and also to reduce the incidence of diseases.

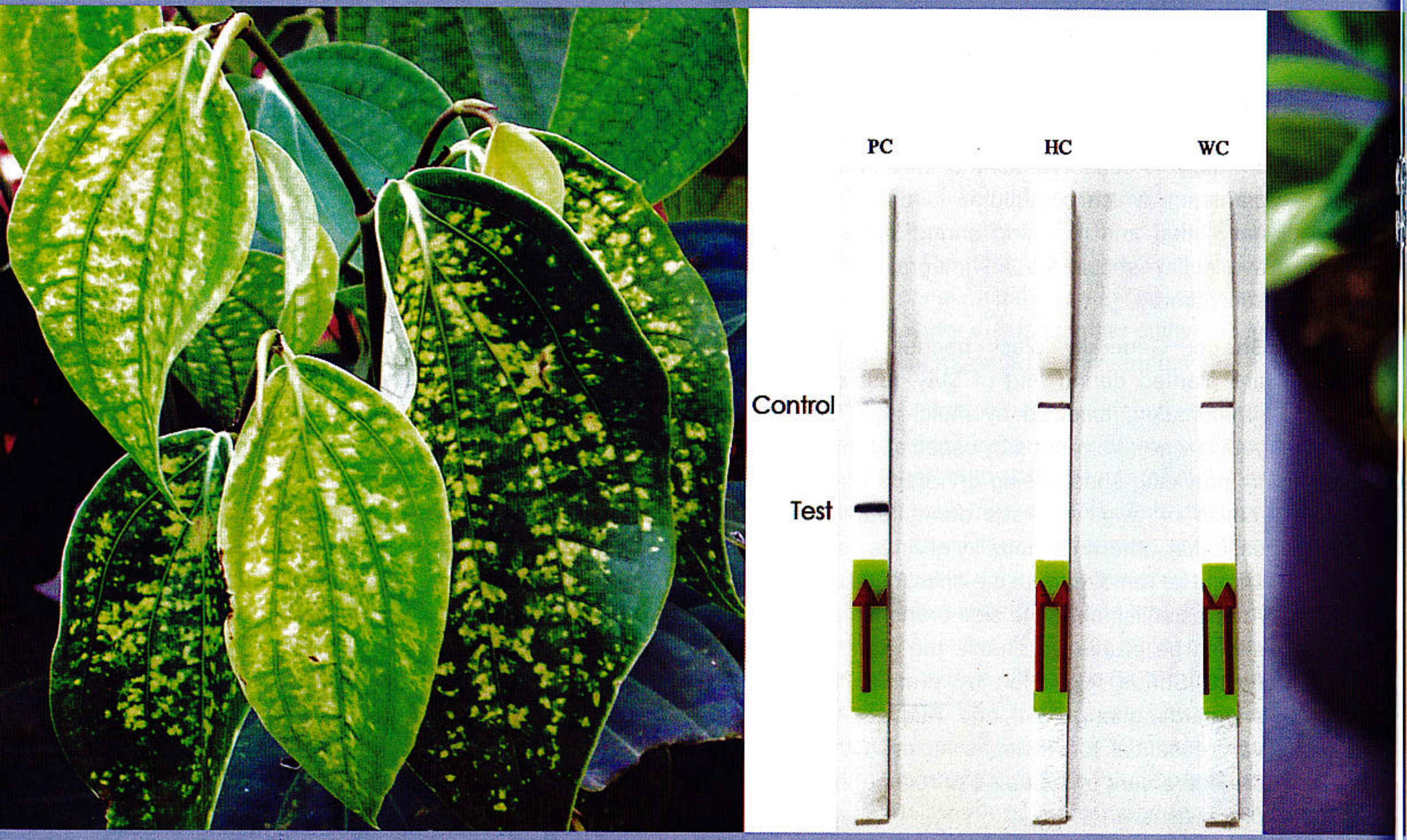
Pruning of excess canopy: Light availability plays a major role in black pepper productivity. 50-60 per cent of the filtered light is ideal for obtaining good flowering and yield. It is observed that top portion of the vine receives more than 50 per cent of the incident light, middle portion receives only 30-40 per cent, and base receives less than 30 per cent light. Hence, excess branches of the shade trees may be pruned to reduce transpiration from shade trees which minimises water loss and enhances light availability to black pepper vines. Highly shaded conditions leads to maximum female flowers and only three to nine per cent hermaphrodite flowers, but canopy exposed to light produces more than 80 per cent hermaphrodite flowers. The shift towards female phase leads to pollination failure and spike shedding during July, August, and September months. A high percentage of bisexual flowers is essential for good fruit set, which can be achieved through uniform distribution of light throughout the canopy.

Intercropping: Intercropping/mixed cropping is always a buffer as even if one crop fails, farmer can get some income from the other crop. Also, it is an effective way of utilising the available resources such as space, light, moisture, etc., to the maximum extent and obtaining optimum returns. Also, it protects the farmers from vagaries of weather, pest and diseases, market fluctuation, etc. Black pepper is amenable for intercropping/mixed cropping with many other plantation crops viz., it can be trained on coconut and areca nut palms, also can be grown along with coffee, cardamom, and tea. It can be intercropped with many crops such as pulses, vegetables, fodder crops, tuber crops for example elephant foot yam, greater yam, and spices like ginger and turmeric. The humid condition existing due to transpiration of crops creates better microclimate and helps to enhance photosynthesis and yield of black pepper. Dolomite at the rate of 500 g/vine can be incorporated to soil after the receipt of pre-monsoon rain. All the cultural operations should be carried out in time.

In conclusion, black pepper requires sufficient soil moisture for good flowering and spike setting. Drought is known to hamper flowering and fruit set, thus reducing the yield drastically. Hence, maintaining sufficient soil moisture during critical stages either through irrigation or rain or rainwater conservation, apart from selection of varieties, mulching, intercropping, etc., can boost black pepper production under drought condition.

Onsite Detection of Plant Viruses

A. I. Bhat
ICAR-Indian Institute of Spices Research, Kozhikode 673012, Kerala



Plant viral diseases are a major challenge in agriculture, causing substantial economic losses due to their impact on crop production and quality. The management of plant viruses is particularly difficult as they cannot be controlled by chemical treatments. Effective control strategies hinge on early detection and prevention of virus spread. Sensitive and reliable diagnostic tools are critical for identifying viral infections in plant materials, such as seeds, vegetative tissues, insect vectors, and alternative hosts. Early detection allows for the timely implementation of control measures, including the destruction of infected plants and the management of insect vectors.

Traditional diagnostic methods based on biological or physical properties of viruses often lack sensitivity and are time-intensive. In contrast, advanced methods targeting viral proteins and nucleic acids provide greater specificity, sensitivity, and speed. Molecular assays such as polymerase chain reaction (PCR) and enzyme-linked immunosorbent assays (ELISA) are highly effective but generally require laboratory infrastructure, sophisticated equipment, and trained personnel. This limits their accessibility, particularly in resource-limited settings or for field applications. Isothermal amplification methods, including loop-mediated isothermal amplification (LAMP) and recombinase polymerase amplification (RPA), overcome many of the limitations of traditional methods. These assays offer several advantages:

i They do not require thermal cycling, making them easier to perform

ii They can be used with minimal equipment, enabling on-site virus detection

iii Results can often be obtained in under an hour

iv these assays effectively detect viral nucleic acids, even at low concentrations. Additionally, isothermal assays can be paired with lateral flow devices, allowing for portable and user-friendly testing formats suitable for field use.

Onsite virus detection using Lateral Flow Immunoassay

Lateral flow immunoassay (LFIA), also known as "dipstick" test, is a widely-used field diagnostic tool for detecting viruses. Its simplicity, portability, and requirement for minimal technical expertise make it particularly valuable for onsite applications in agriculture.

Key components of LFIA

An LFIA device is typically composed of the following (Figure 1):

1. **Sample Pad:** The starting point where the sample (e.g., extracted plant sap) is applied.
2. **Conjugate Pad:** Contains antibodies specific to the virus, conjugated to coloured labels such as gold nanoparticles or latex beads.
3. **Membrane:** Immobilised with test and control lines for virus-specific capture and assay validation, respectively.
4. **Absorbent Pad:** Draws fluid through the device by capillary action.

How LFIA works?

1. **Sample Preparation:** The plant material is ground, and a small amount of sap is extracted.
2. **Sample Loading:** The sap is applied to the sample port, where it mixes with the conjugated antibodies in the conjugate pad.
3. **Complex Formation:** Virus particles, if present, bind to the conjugated antibodies, forming antigen-antibody complexes tagged with the visible labels.
4. **Lateral Flow:** The fluid containing the antigen-antibody complexes migrates along the membrane.

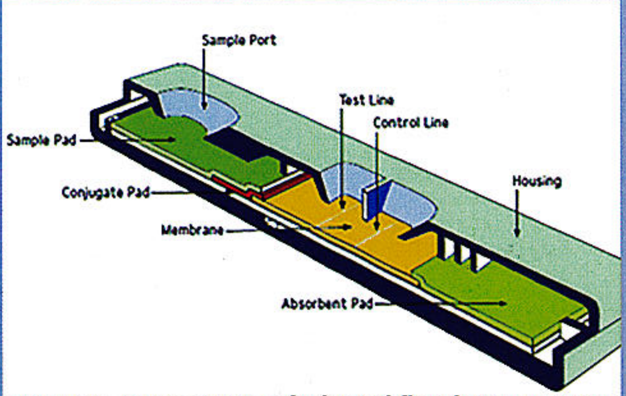


Figure 1: Components of a lateral flow immunoassay assay strips

5. **Test Line Binding:** At the test line, virus-specific capture antibodies immobilise the virus-antibody complexes. As labelled complexes accumulate, the line becomes visible.
6. **Control Line Binding:** Any unbound labelled antibodies bind to species-specific antibodies immobilised at the control line, confirming the test has run correctly.

Figure 2. Steps in the lateral flow immunoassay based detection of pathogens

Strengths of LFIA

- **Field Usability:** Requires no specialised equipment or skilled personnel.
- **Rapid Results:** Provides visual results within minutes.
- **Cost-effectiveness:** Low production costs and scalability for widespread use.

Limitations of LFIA

- **Sensitivity Issues:** LFIA is less effective for detecting viruses present at low concentrations, potentially leading to false negatives.
- **Limited Quantification:** Results are typically qualitative or semi-quantitative.
- **Specificity Concerns:** Requires carefully designed antibodies to avoid cross-reactivity with non-target viruses.

Advancements in LFIA

To address sensitivity issues, novel lateral flow assays incorporate nucleic acid amplification prior to detection (Figure 3):

- **Initial Amplification:** Viral nucleic acids are amplified using techniques like loop-mediated isothermal amplification (LAMP) or recombinase polymerase amplification (RPA). Labelled primers or probes are used during this step to enhance detectability.
- **End-point Detection:** The amplified products are then analysed using lateral flow devices, significantly increasing sensitivity.

This combination of molecular amplification and lateral flow detection bridges the gap between the simplicity of LFIA and the sensitivity of nucleic acid-based assays, enabling more reliable detection even at low viral titres.

LFA kits for the detection of viruses infecting spice crops

Both LFIA and LFA have been developed to detect large number of viruses infecting different crops. In the case of spices, LFA has been developed for the detection of piper yellow mottle virus and cucumber mosaic virus infecting black pepper and for the cardamom mosaic virus causing mosaic / katte disease in cardamom (Figure 4). All these assays use crude extract isolated from the test plant as template and the entire assay from template isolation to visualisation of results can be completed in less than an hour.

Conclusion

LFIA remains a powerful tool for rapid, onsite detection of plant viruses in high-titer samples. Integrating it with amplification technologies extends its utility to low-titer cases, making it a versatile choice for field diagnostics in agriculture. They combine simplicity, accessibility, and high diagnostic accuracy, making them particularly valuable for real-time, on-site disease management in agricultural settings. By enabling rapid and effective virus detection, these tools can significantly contribute to mitigating crop losses and improving global food security. With further innovation, LFIA-based methods can contribute significantly to the early detection and management of plant viral diseases.

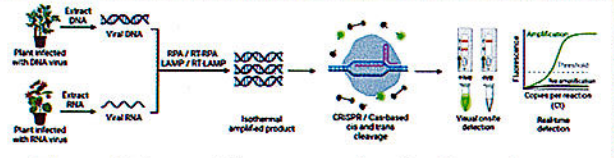


Figure 3. Lateral flow assay for the detection of viruses. Viral nucleic acids are initially amplified through LAMP or RPA using labelled primers. The amplified product is then analysed using lateral flow devices.

Future Directions

The future of onsite diagnostics is trending toward more integrated devices, capable of multiplex testing for multiple pathogens simultaneously. The use of AI and machine learning to interpret results is also on the rise, especially in smartphone-based diagnostics. Additionally, miniaturised molecular diagnostics and biosensors are being developed to improve sensitivity, reduce costs, and make these tools even more accessible to small-scale farmers. Overall, LFAs are a vital tool in integrated disease management, helping to keep crops healthy, ensure food security, and reduce economic losses by enabling timely, accurate on-site diagnostics.

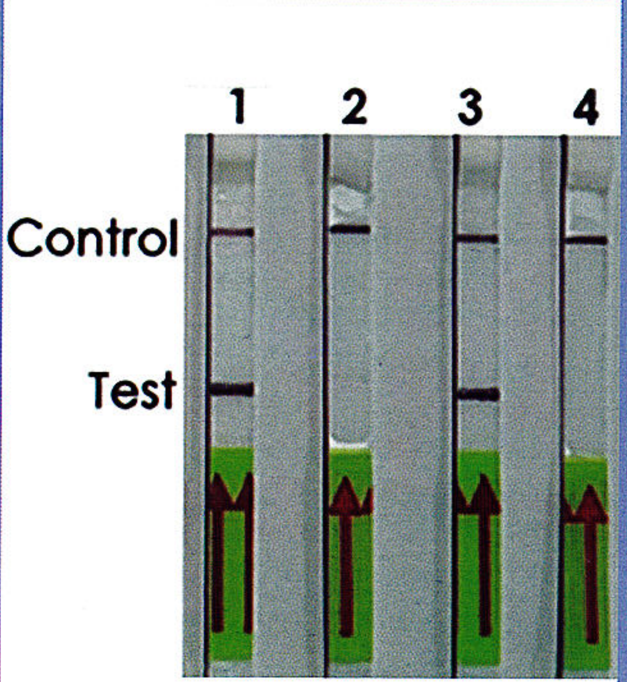


Figure 4. Detection of piper yellow mottle virus infecting black pepper using lateral flow assay. The coloured line at the control and test lines indicates that the sample is positive for the virus while the coloured line only at the control line indicates that the sample is negative for the virus

The Focus Shift from Lens to Leaves: Rashid's Journey to Peppering Success

Lijo Thomas, Sajesh V. K., Sreenath C. G.
ICAR-Indian Institute of Spices Research, Kozhikode 673 012, Kerala

Rashid, a photographer from Malappuram, has successfully ventured into running a pepper nursery making a career switch in his forties.

Twenty years ago, when Rashid Machingal from Alppattakulam, Kodoor, Malappuram, completed his photography studies and was considering opening his own studio, he did not have to think too hard to come up with a name. Inspired by the famous Japanese camera brand 'Konica', Rashid decided to name his studio 'Monica'. It did not take long for Rashid to become popularly known as Monica Rashid.

However, if you call Rashid today asking him to take a photograph or prepare an album, he would refuse and instead ask you if you need any pepper saplings. This Malappuram native has now shifted his profession from photography to running a successful pepper nursery, aptly named Monica Pepper Nursery.

Rashid knew it wasn't easy to leave behind a well-established business and start something new, especially in his forties. When asked why he made such a decision, he pointed to the ever-evolving trends in the photography industry. Rashid firmly believes that even photographers have a retirement age, which is why he voluntarily retired from the field.

Although Rashid was born into a farming family, he was not particularly involved in agriculture. He initially ventured into poultry farming and beekeeping, but soon realised these didn't meet his expectations for growth. His search for a new path eventually led him to the ICAR - Indian Institute of Spices Research (IISR), Kozhikode. With help from Senior Technician Mr O.G. Sivadas at the

Agricultural Technology Information Centre (ATIC) of the institute, Rashid narrowed down his focus to spice crops. After learning about cultivation and marketing, Rashid decided to specialise in pepper sapling production. He also learnt grafting and other production techniques from the institute, leading him to establish Monica Pepper Nursery, which now produces and markets around 75 varieties of pepper saplings.

Rashid began his pepper sapling production in a space of 100 square feet within the compound of his house, using vines from a small pepper garden nearby. Today, he has expanded his operations to two acres, with four sheds producing saplings simultaneously. His nursery offers a variety of pepper saplings, including the Panniyur varieties, IISR varieties like Thevam, Malabar Excel, Sreekara, and Panchami, as well as varieties such as Kumbukkal, Pepper Thekkan and Kairali. Rashid's goal is to provide all types of pepper saplings under one roof, and he says he has received excellent acceptance from farmers.

The main income for Monica Nursery comes from grafted bush pepper saplings, which are grafted onto colubrinum (Thippali) and sold at prices ranging from ₹100 to ₹200 depending on the variety. Popular varieties like Pepper Thekkan, Kumbukkal, and Kairali are sold for ₹200. Each colubrinum plant can be grafted with around 20 pepper vines at once, producing robust, high-yielding pepper plants. These saplings are also sometimes purchased as ornamental plants. In such cases, they are sold for premium prices. Most of the smaller pepper saplings at the nursery are also grafted onto colubrinum, and as a result, the nursery also cultivates colubrinum on a large scale. Rashid not only produces enough colubrinum saplings for his nursery but also sells them to other farmers for ₹50 each.

The nursery prepares pepper vines using the 'serpantine' method, and these vines are sold for ₹40 each. Grafted vines are in demand, especially for areas prone to waterlogging. Rashid has also made a collaboration with local timber merchants from his native, who supply pepper vines from trees they cut down in Malappuram and nearby districts. Rashid uses these vines to prepare low-cost saplings for customers.

In addition to producing healthy saplings, Rashid believes that a good marketing strategy is crucial. For this, he teamed up with his friend and videographer, Mohammed Ali. Their initial YouTube video together brought in many customers for the pepper vines, and today, customers from far-off places order saplings, which are safely delivered via parcel service. Rashid even designed a custom parcel box that can hold 10 saplings without damaging them during transit.

Beyond sapling production, Rashid also sets up pepper plantations for clients. He has already completed such plantations in Kannur and Kuttiyadi based on specific requests.

Rashid's family is also closely involved in his work. His wife Saifunneesa and children Rania Mirsha, Riyan Ahammed, Raya Bathool, and Rasmi Khadija all lend their support to his nursery business.

Fungal Disease Management in Ginger

Praveena R., C. N. Biju, M. Faisal Peeran
ICAR-Indian Institute of Spices Research, Kozhikode 673 012, Kerala

Soft Rot

Soft rot is the most destructive disease of ginger which results in total loss of affected clumps. This soil-borne disease is caused by *Pythium spp.* among which, *P. aphanidermatum* and *P. myriotylum* are widely distributed in the country. The pathogen multiplies as soil moisture builds up with the onset of southwest monsoon. The pathogen primarily survives within the infected rhizomes with the soil continuum and also in the crop debris. Warm humid weather condition is considered to be the major predisposing factor. High soil moisture, heavy precipitation, soil texture, prolonged water stagnation and low temperature around 25-30°C favours disease initiation and further development.

Younger sprouts are the most susceptible to the pathogen. The infection starts at the collar region of the pseudostem and progress upwards as well as downwards. The collar region of the affected pseudostem becomes water-soaked and the rotting spreads to the rhizome resulting in soft rot with characteristic foul smell. In the later stage, root infection is also noticed. Foliar symptoms appear as mild yellowing of the leaf margins of lower leaves which gradually spread to the leaf lamina. In early stages of the disease, the middle portion of the leaves remain green while the margins turn yellow. The yellowing spreads to all leaves of the plant from the lower region upwards and followed by drooping, withering and drying of pseudostems.

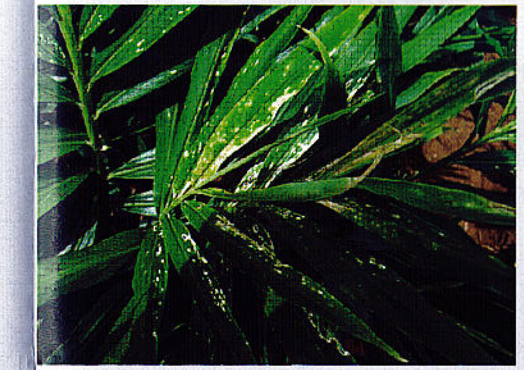
Management

- Cultural practices, such as selection of well drained soils for planting, are important, since stagnation of water predisposes the plant to infection.
- The soil may be solarised before planting by covering the moist soil with a transparent polythene film for 45-50 days.
- Seed rhizomes are to be selected from disease-free plots, since the disease is also rhizome-borne. Treatment of rhizomes with mancozeb (0.3%) or metalaxyl-mancozeb (0.125%) for 30 minutes before storage, and once again before planting and drenching at 30 and 60 days after planting reduces incidence of the disease.
- Priming of ginger seed rhizomes with Trichoprime at the rate of five per cent prior to storage enhances bud vigour, improves sprouting, and protects rhizomes from pathogens, ensures uniform tiller emergence and markedly enhanced yield compared to chemical treatments.
- *Trichoderma viride* or *T. harzianum* mass multiplied on suitable carrier media may be applied at the rate of 1 kg bed^{-1} helps in reducing incidence of the disease. If the soil is drenched with copper oxychloride or other fungicides, *Trichoderma* should be applied only after 15 days.
- Talc formulation of plant growth promoting bacteria *Bacillus amyloliquefaciens* (IISR Biopower G), can be used for ginger seed treatment at the rate of 10g L^{-1} and soil drenching (@ 2 kg ha^{-1}) at 30 and 60 days after planting.
- Bio-capsule formulation of *B. amyloliquefaciens* can also be used for plant growth promotion and rhizome rot suppression in ginger. Dissolve one bio-capsule in one litre of sterile water (water which has been boiled and then cooled to room temperature). Keep the solution for eight hours with intermittent stirring. This will activate and increase the population of beneficial bacteria in the solution. This stock solution is added to 200 litres of normal water and mixed well. On the day of planting, immerse the rhizomes in the bacterial solution for 30 minutes, followed by drying in shade before planting in beds. Once prepared, the solution can be used three times for soaking rhizomes. After this, the remaining solution can be used for drenching the beds.
- Solarisation of ginger rhizomes under polyethylene sheet (200 microns) at 47°C for 30 minutes, treating the solarised rhizomes with bioagents in combination *i.e. Trichoderma harzianum* and bacterial consortium for 30 minutes is recommended to manage the disease. Alternatively, treating the solarised rhizomes with mancozeb (0.25%) for 30 minutes before planting and application of fungicides two times after sowing of rhizomes were also found effective in reducing the rhizome rot disease.
- Incorporation of crop residues of mustard and cabbage in soil (biofumigation) and rhizome treatment with metalaxyl-mancozeb (1.25 g L^{-1} of water) for 15-20 minutes is recommended to reduce soil-borne diseases under field conditions.
- Once the disease is noticed in the field, remove the affected clumps and drenching the affected and surrounding beds with metalaxyl M 3.3%-chlorothalonil 33.1% SC at the rate of 0.2% [CIBRC approved], mancozeb at the rate of 0.3% or metalaxyl-mancozeb at the rate of 0.125% or copper oxychloride at the rate of 0.2% checks spread of the disease.

Phyllosticta leaf spot

Phyllosticta leaf spot caused by *Phyllosticta zingiberi* is reported in areas where ginger is grown commercially causing a significant reduction in the yield. The disease results in drastic reduction of photosynthetic area in the affected plants and under wet weather conditions resulting in yield loss to the tune of 13 to 66 per cent. The pathogen survives in contaminated rhizomes or in the field in the debris left after harvesting in the form of mycelia and conidia. The disease is favoured by warm and moist conditions and hence, severe in the warm monsoon season, especially when plants are closely planted, the soil is clayey, and the humidity is higher. The disease spreads through rain splashes during intermittent showers. Incidence of the disease is severe in ginger grown under exposed conditions.

The disease affects foliage, and the initial symptoms appear as spindle to oval or elongated spots on the leaves. Initially the spots are yellow to white in colour and later with white papery center with a brown



margin surrounded by a yellow halo. With time, the spots increase in size and merge and cover large areas of the leaf reducing photosynthetic area. As the disease advances, the affected leaves dry, and the crop will have a disheveled look.

Management

- The use of healthy pathogen-free rhizomes for planting is one of the important aspects for sustainable management.
- Cultivating ginger under partial shade reduces the intensity of Phyllosticta leaf spot and increases the number of tillers per clump.
- Treatment of seed rhizomes with carbendazim-mancozeb or carbendazim (0.25%) alone will substantially reduce the rhizome-borne inoculum.
- The disease can be controlled by spraying carbendazim (0.2%) or hexaconazole (0.1%) or propiconazole (0.1%), with the appearance of disease symptoms and then two times at 20 days interval. Care should be taken that the spray solution should reach lower surface of the leaves also.

Colletotrichum leaf spot

Leaf spot caused by *Colletotrichum gloeosporioides* and *C. capsici* initiates as ellipsoid or spindle-shaped brown spots with yellow halo on the leaf lamina which later spread inwards. Many spots coalesce and cause the leaves to turn brown and gradually lead to complete drying of leaves. The disease affects the foliage, leading to extensive damage of the effective photosynthetically active surface area and eventually a drastic reduction in the yield. The pathogen overwinters in the form of mycelia and spores in diseased plants or in the soil. Conidiospores are the main infecting source, disseminating the disease through rain. Continuous cultivation in the same area, higher humidity and non-judicious application of nitrogenous fertilisers favour the disease proliferation under field conditions.

Management

- Adopting strict phytosanitation by destroying the infected plants and crop rotation (avoiding solanaceous and zingiberaceous crops).
- Spray Bordeaux mixture (1%) or mancozeb (0.2%) or carbendazim (0.2%) with the appearance of symptoms and repeat sprays at fortnightly intervals are recommended to manage the disease.

Leaf blight

Leaf blight caused by *Exserohilum rostratum* is an emerging disease in major ginger growing areas. The disease initiates mostly on the lower and middle leaves of tillers in the form of water soaked, oval shaped reddish-brown spots bounded by yellow halo on the margin as well as distal end of the leaves. Subsequently, the spots coalesce resulting in severe blighting of entire leaves finally, giving the field a burnt appearance.

Management

- Rhizome treatment and spraying tebuconazole (0.1%) or alternating sprays with tebuconazole (0.1%) and carbendazim-mancozeb (0.1%) at fortnightly intervals were found to be effective in managing the disease.

Fusarium yellows

Fusarium oxysporum f.sp. *zingiberi* is reported as the causative agent of the disease. Different species of Fusarium viz., *F. solani*, *F. equiseti*, *F. graminearum* and *F. moniliforme* are also reported to be associated with the disease. The disease is both rhizome as well as soil-borne resulting in meagre establishment of the crop leading to severe economic loss. The pathogen survives in soil/

seed rhizomes and transmitted mainly through the infected rhizomes from one geographical region to another and through water within an infested field. Temperature range of 23-30°C, continuous prevalence of high humidity and free water are conducive for disease development under field conditions.

Foliar yellowing along the margins of lower leaves which gradually spreads through the entire leaf, leading to the death of older leaves initially followed by the younger leaves are the distinguishing symptoms of the disease. The infected plants exhibit untimely drooping followed by wilting as well as drying in random patches under field conditions. In comparison to soft rot and bacterial wilt diseases, the plants infected with *Fusarium* dries but do not topple. However, the tillers of the affected clump can be easily pulled off from the rhizome. The infected rhizomes turn soft and watery, with creamish-brownish discolouration. Root rot is also commonly associated with diseased plants. Under storage conditions, white cottony mycelial growth is also apparent on the rhizomes.

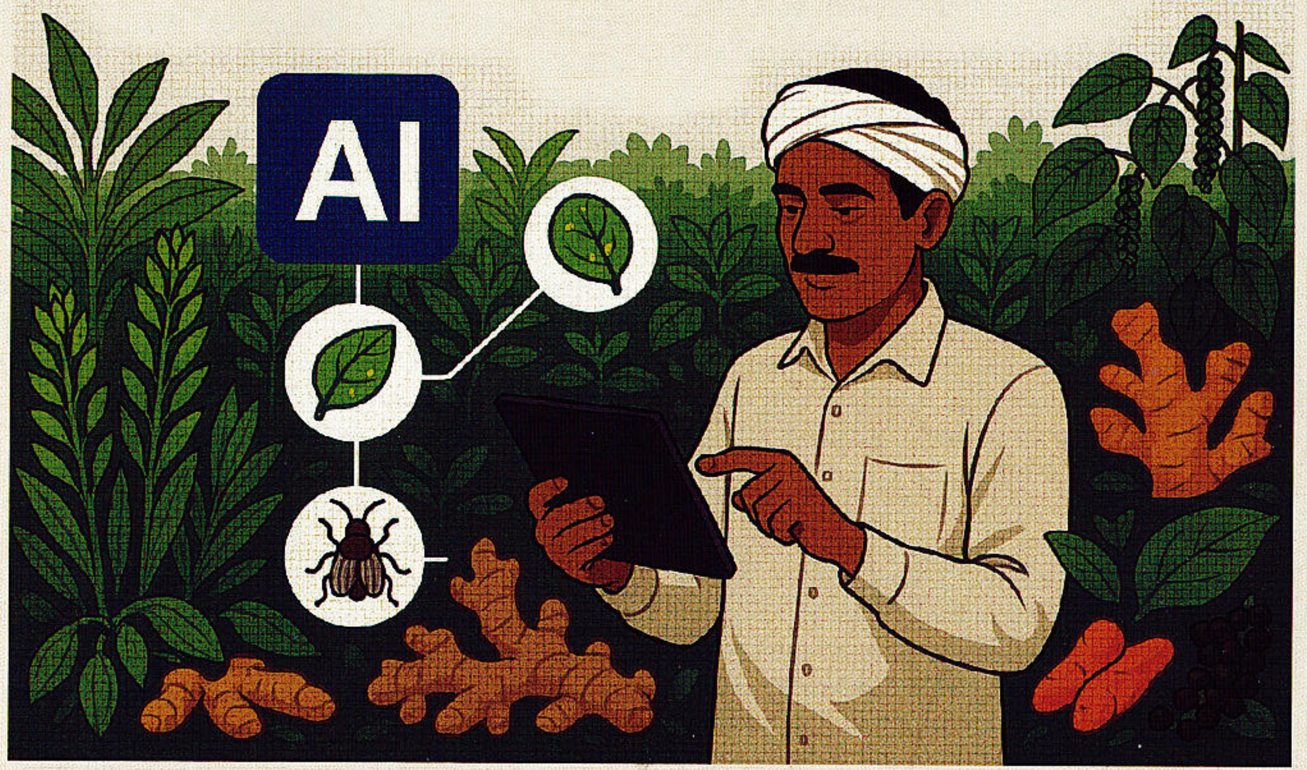
Management

- IISR Rejatha and Himachal are found to be tolerant to *Fusarium*.
- Use of healthy disease-free rhizomes as planting material significantly reduce the initial inoculum.
- Avoiding areas with nematode infestation (as it predisposes the crop to Fusarium yellows) and crop rotation for a period of two to five years (to reduce soil-borne inoculum) are found effective in managing the disease.
- Spraying and drenching fungicides viz., carbendazim (0.1%), copper oxychloride (0.2%), mancozeb (0.2%) and Bordeaux mixture (1%) with appearance of the symptoms are reported to manage the disease efficiently under field conditions.
- *Trichoderma viride* or *T. harzianum* mass multiplied on suitable carrier media may be applied at the rate of 1 kg bed^{-1} helps in reducing the incidence of the disease. If the soil is drenched with copper oxychloride or other fungicides, *Trichoderma* should be applied only after 15 days.

Artificial Intelligence for Pest and Disease Management in Spices

C. M. Senthil Kumar, M. Balaji Rajkumar, C. N. Biju, A. Ishwara Bhat

ICAR-Indian Institute of Spices Research, Kozhikode 673012, Kerala



(AI generated image using ChatGPT)

Spices have been at the heart of global trade, culture, and culinary traditions for centuries. They are an integral part of agriculture, contributing to the economy and playing a crucial role in enhancing the flavour and medicinal value of food. India, as a leading producer of spices like black pepper, cardamom, cinnamon, and turmeric, carries the legacy of being the "land of spices." However, spice cultivation faces significant challenges due to pests and diseases, leading to substantial losses for farmers. Traditional methods of pest and disease diagnosis often rely on extension experts and traditional knowledge for insect pest and disease diagnosis in spice crops, which poses limitations due to a lack of comprehensive knowledge about invading pests and diseases. The overlapping symptoms of damage among pests and diseases often lead to incorrect diagnoses, resulting in improper management solutions, economic losses for farmers, and potential environmental and health hazards. Conversely, early detection of insect pests and diseases allows for swift interventions with minimal chemical or organic inputs, effectively managing pests with reduced impact on the environment and food supply chains. This is where Artificial Intelligence (AI), a groundbreaking technology emerges as a revolutionary tool in modern agriculture, that is changing the game for farmers and agricultural experts offering smarter, more efficient, and eco-friendly solutions.

What is Artificial Intelligence?

In simple terms, AI refers to machines and software systems that can mimic human intelligence. It enables them to learn from data, identify patterns, and make decisions. In agriculture, AI tools can process vast amounts of data quickly and accurately, offering timely solutions to age-old problems.

The Role of AI in Pest and Disease Management

Artificial Intelligence is transforming agriculture by enabling early detection of diseases, precise pest control, and data-driven decision-making. By integrating AI with advanced technologies like image recognition, machine learning, and the Internet of Things (IoT), farmers can take proactive measures to protect their spice crops.

1. Early Detection and Diagnosis

One of the biggest advantages of AI is its ability to detect diseases and pest infestations at an early stage. AI-powered systems, equipped with image recognition and machine learning algorithms, can identify pests and diseases at an early stage by examining leaves, stems, and flowers for signs of infection. Farmers can capture images of affected leaves, fruits, or stems using smartphones, and AI algorithms can analyse these images to diagnose the problem. These algorithms compare the images with a vast database of diseased and healthy plants, identifying symptoms of fungal infections, bacterial diseases, or pest attacks. For instance, AI apps like Plantix or similar tools have proven effective in diagnosing plant damages caused by pests, diseases or nutrient deficiencies based on digital images of symptoms and able to suggest control measures. Early detection of pest and diseases reduces crop loss and allows farmers to take preventive measures.

2. Precision Pest Control

Traditional pest control methods involve blanket spraying of pesticides, which can lead to excessive chemical use, harming both the environment and beneficial insects. AI-based pest management systems, on the other hand, can predict pest outbreaks by analysing environmental factors such as temperature, humidity, and past pest occurrence patterns. AI enables precision agriculture, where farmers can apply targeted treatments rather than blanket approaches. These systems use predictive analytics to map pest-affected areas in spice plantations and guide farmers on the exact timing and location for pesticide application, optimal spraying schedules and the exact quantity of pesticides, reducing chemical use and ensuring effective control of pests without affecting the environment.

3. Automated Monitoring with IoT Devices

AI-powered IoT devices, such as smart sensors and cameras, are revolutionising spice farming by providing real-time monitoring of fields. These sensors can measure soil moisture, temperature, and plant health indicators. By continuously collecting data, AI algorithms can alert farmers to potential disease risks before they become widespread. This approach not only minimises yield losses but also helps in making informed decisions about irrigation and fertilisation. Further, AI systems can predict pest outbreaks and disease trends based on weather patterns, soil conditions, and historical data. For example, if a region is forecasted to have prolonged rainfall, which often leads to fungal diseases, AI alerts farmers to prepare in advance. AI based predictive tools can help farmers schedule planting and harvesting to avoid peak pest seasons. Nowadays, AI-driven pest traps are being developed, which use cameras and sensors to monitor insect activity. These traps with the AI algorithms can Identify harmful insect pests of crops and send real-time data to farmers' smartphones, helping them decide on countermeasures immediately. Through AI chatbots and virtual assistants, farmers can receive step-by-step guidance tailored to their crops. These services are also made available in regional languages, making them accessible to small-scale farmers.

Potential AI Applications in Spice Cultivation

Several spices, including black pepper, cardamom, ginger, and turmeric, are highly susceptible to pests and diseases. AI-based solutions are being developed to address these issues effectively.

1. Black Pepper

Black pepper plants are prone to diseases such as Phytophthora foot rot, viruses and pest infestations

like mealybugs, pollu beetle and thrips. AI-enabled smartphone apps will allow farmers to take pictures of infected plants, which are then analysed using deep learning models to diagnose diseases and recommend treatment measures.

2. Cardamom

Cardamom is affected by insect pests like thrips and shoot and capsule borers and diseases like leaf blight, rhizome rot, cardamom mosaic virus etc. AI-driven drone technology can be used to monitor large cardamom plantations and identify pest-infested areas. Based on AI analysis, targeted spraying of biopesticides can be carried out, minimising chemical use and improving yield quality.

3. Turmeric

Turmeric suffers from diseases such as rhizome rot and leaf blotch. AI-based health monitoring systems can detect early signs of fungal infections and suggest appropriate treatments. Predictive AI models can also forecast potential disease outbreaks based on weather conditions, helping farmers prepare in advance.

4. Ginger

Ginger crop faces challenges from insect pests like shoot borer, root-knot nematodes, as well as diseases such as soft rot, leaf spot, and bacterial wilt. These issues can lead to significant yield losses and affect the quality of the rhizomes.

Managing these problems has traditionally relied on manual monitoring, chemical treatments, and advice from agricultural experts. However, these methods often come with limitations like delayed detection, overuse of pesticides, and high costs. This is where AI steps in as a game-changer.

Benefits of AI-Driven Pest and Disease Management

1. **Increased Efficiency** – AI reduces the need for manual inspections, saving time and labour costs for farmers.
2. **Eco-Friendly Solutions** – AI optimises pesticide use, leading to a decrease in chemical contamination of soil and water.
3. **Higher Yields** – By detecting diseases early and providing targeted pest control, AI helps increase crop productivity.
4. **Cost Savings** – Farmers can save money on pesticides, fertilisers, and labour by using AI-driven precision agriculture techniques.
5. **Better Decision-Making** – AI provides farmers with real-time insights, allowing them to make informed choices about crop protection strategies.

Challenges and the Way Forward

Despite its potential, AI adoption in general by the farming community faces challenges such as high implementation costs, lack of digital literacy among farmers, and limited access to advanced technology in rural areas. Not all the farmers have smartphones with internet connectivity. Further AI systems require high-quality, region-specific, crop-specific data to function effectively. To overcome these challenges, governments, research institutions, and private companies must collaborate to make AI tools affordable, accessible, and farmer-friendly. Initiatives like training programs, subsidies for AI-based equipment, and the development of localized AI solutions can accelerate adoption.

In the future, AI is expected to become more accessible, enabling even small-scale farmers to benefit from its capabilities. AI-powered mobile applications, government-supported AI initiatives, and farmer training programs can accelerate the adoption of this technology, ensuring sustainable spice farming.

Conclusion

Artificial Intelligence is a powerful tool that can revolutionise how we grow, protect, and sustain spice crops by offering smart, data-driven solutions. From early disease detection to precision pest control, AI will empower farmers to protect their crops efficiently and sustainably. By embracing AI technology, spice farmers can enhance productivity, reduce environmental impact, and secure a better livelihood. As the technology matures and becomes more accessible, the day is not far when AI will be as integral to spice farming as the spices themselves are to our cuisine.

Spice-Flavoured Jaggery Cubes

Jayashree E., Meera Mohan, Alfiya P.V., Anees K., Rajeev P., Sarathambal C.
ICAR-Indian Institute of Spices Research,
Kozhikode 673012, Kerala

Jaggery, a non-centrifugal sugar (NCS) produced by concentrating sugarcane juice, offers significant health benefits, making it a valuable dietary alternative to refined white sugar. It contains the natural sources of minerals and vitamins inherently present in sugarcane juice and is one of the world's most wholesome and healthy sugars while refined sugars (sugar) contain sucrose (99.7%) only. Refined sugar undergoes huge nutritive losses due to multiple chemical processes whereas jaggery is prepared naturally and is relatively unrefined sugar, which retains more natural nutrients and other bioactive components required for human health. The complex structure of jaggery, with longer sucrose chains than refined sugar, slows digestion, leading to a gradual, sustained energy release and making it a healthier sweetening choice.

Beyond providing energy, jaggery offers a range of health benefits, including preventing rheumatic diseases and bile disorders, combating weakness, promoting muscle, nerve, and blood vessel relaxation, regulating blood pressure, and increasing haemoglobin levels to prevent anaemia. The ability of jaggery to prevent smoke-induced lung lesions in smoking populations suggests that it could be used as a safe food for employees in dusty and smoky environments and has been found useful in the treatment of throat and lung infections.

According to the Ayurvedic system, sugarcane jaggery is believed to cure most of the ailments affecting the human body. It is also quoted that jaggery is comparatively more beneficial in medicinal therapies and is considered a digestive stimulant that aids in the improvement of digestion and appetite.

The nutraceutical properties of jaggery can be improved by blending it with medicinally important spices which would not only enhance the nutritional quality of jaggery but also offer value-added products with exciting flavours for tabletop use of sweeteners.

Global jaggery production reaches approximately 13 million tonnes annually, with India accounting for over 70 per cent of this output. However, the jaggery industry frequently experiences financial losses. Developing and commercialising value-added jaggery products are essential to sustain future profitability in the jaggery trade.

Jaggery is among the major agro-processing industries in India. Nearly 20-30 per cent of the total sugarcane produced in the country is used for the manufacture of about 7 million tonnes of jaggery, which is known as the most nutritious agent among all sweeteners. The jaggery manufacturing sector employs about 2.5 million people. It is, therefore, imperative to expand the sector, as it provides higher food value and boosts the rural economic system.

Jaggery is one of the most common ingredients used in several traditional Indian cuisines as a sweetener, flavouring agent, and colour enhancer. With the elevating levels of urbanization and improving consumer living standards, there is a significant demand for processed and premium-quality jaggery.

The introduction of numerous stringent norms by the Food Safety and Standards Authority of India (FSSAI) and maintaining product safety during processing and packaging influences the jaggery market. Moreover, the growing consumer inclination towards clean-label and organic product variants with no added colours, synthetic flavours, preservatives, etc., is also propelling the market for jaggery in India.

The wide product availability across both brick-and-mortar and e-commerce platforms is further catalysing jaggery sales. With the outbreak of the COVID-19 pandemic, there has been a considerable shift from open and loose jaggery towards packaged variants to mitigate the risk of infection, which is anticipated to drive the Indian market in the coming years.

Consumers are increasingly hesitant to use jaggery as a natural sugar substitute due to several factors like the inconvenient one-kilogram block size, unhygienic handling and packaging, and concerns about adulteration. Additionally, jaggery cubes tend to be brittle, resulting in powdering during transportation and distribution. Traditionally, jaggery-based value-added products flavoured with spices are prepared using powdered spices. However, the use of powdered spices causes challenges like uneven distribution of flavours and only 40 to 60 per cent of the spice flavour is released into the ready-to-use beverage when powdered spices are added directly into the product. Therefore, there is a potential need for innovative and effective technologies to produce hygienic and consumer-friendly jaggery products in today's health-sensitized environment.

A significant challenge in jaggery storage is its hygroscopic nature due to the presence of invert sugars and mineral salts. The non-sucrose constituents present in jaggery such as glucose, fructose, protein, etc. tend to increase the moisture content during storage. These components readily absorb moisture from the environment, particularly during humid monsoon seasons, leading to spoilage. The shelf life and quality of jaggery is affected by the storage temperature and humidity. In most cases, jaggery is spoiled due to higher humidity present in the atmosphere particularly, during monsoon season. Consequently, it is estimated that over 10 per cent of India's annual jaggery production, valued at 400 million rupees, is lost each year due to deterioration. To mitigate these losses, comprehensive research is essential to investigate jaggery's storage behaviour in various packaging materials and develop effective storage methods that enhance the quality of jaggery and allied products.

ICAR- Indian Institute of Spice Research, Kozhikode has developed a technology to produce spice-flavoured jaggery-based products which are instantly soluble in water, convenient in size and available in consumer-friendly form. The product has improved active ingredient content with a longer shelf life and is devoid of any chemical preservatives. The technology provides a scope for the development of jaggery products with customised spice flavours. The developed technology also offers a uniform distribution of flavours throughout the product with 100 per cent utilisation of the spice flavour components and its release when added to the ready-to-use beverage. The moisture content of the developed jaggery-based product is very low and thus increases the shelf life of the product to eight months when packaged using suitable packaging material. The product's sensory attributes remained stable and acceptable to consumers throughout the storage period.

ICAR-Indian Institute of Spices Research, Kozhikode has filed a patent for the invention, 'A jaggery-based product and a process for preparing the same,' Application No. 202411070878, dated; 19-09-2024. The inventors of the technology are Dr. E. Jayashree, Ms. Meera Mohan, Dr. Alfiya P.V, Dr. Anees K, Dr. P. Rajeev, and Dr. C. Sarathambal.

The developed product was transferred as a licenced technology to M/s. Xignature Foods, Thrissur, Kerala. Shri P. Prasad, Honourable Minister, Department of Agriculture and Farmers Welfare, Kerala, handed over the Technology Licence Agreement for the commercial production of the product on 21 March 2025. During his address, the Minister highlighted the potential of this innovative technology and its projected value in the international market.

The spice-flavoured jaggery-based product developed by ICAR-Indian Institute of Spice Research, Kozhikode enables the hygienic production of a high-quality jaggery product, utilising quality raw materials and adhering to strict standard operating procedures (SOPs). The developed technology significantly enhances jaggery value addition, empowers new entrepreneurs, ensures fair prices for farmers, and provides a healthy alternative to refined sugar.

Spice-flavoured jaggery cubes

Handing over of the Technology Licence Agreement to M/s. Xignature Foods, Thrissur, Kerala by the Hon'ble Minister, Department of Agriculture and Farmers Welfare, Kerala

Packaged spice-flavoured jaggery cubes

Cinnamon Bark Extraction

Alfiya P. V., Jayashree E., Anees K., Muhammed Nissar V.A., Lijo Thomas
ICAR-Indian Institute of Spices Research, Kozhikode 673012, Kerala

Cinnamon bark of commerce is the dried bark of *Cinnamomum verum* (syn. *C. zeylanicum*). It is indigenous in Sri Lanka, which still produces the largest quantity and best quality mainly in the form of quills. However, cinnamon bark extraction is a highly labour-intensive and time-consuming unit operation. It involves harvesting, scraping, rubbing, peeling and drying.

Harvesting

Cinnamon trees can attain a height of 10-15 m but they are coppiced periodically. Harvest maturity of cinnamon bark is at an age of 24 months, stem girth of 3-6 cm and plant height of 2 m. Prior to harvest, peelability test is performed to assess the maturity of stem for peeling (Fig. 1). The skilled labourer intended for cinnamon peeling makes a test cut in the mature stem and lifts the bark to test the peelable nature of each stem. The stem is selected for harvesting once the bark is smoothly lifted and rejected when there is any difficulty in detaching the bark. The harvested stems are bundled up and transported to peeling sheds; where the stems are cleaned, brushed, and washed to remove extraneous material and to keep the stem afresh for peeling.

Fig. 1 Peelability test of cinnamon bark

Fig. 3 Scraping using *ko ketta*

Scraping

The initial operation carried out on cinnamon stems upon reaching the peeling sheds is the removal of knots using sharp edged knives. This is followed by scraping. Scraping is the removal of epidermal tissue layer from the stem using a traditional hand tool called *ko ketta*. The curvature of the *ko ketta* is designed in such a way to match the diameter of the stem (Fig. 2). As there is wide variation in the diameter of the stem within the plantations, peelers generally stock use *ko ketta* with different curvatures. Scraping of cinnamon stem using *ko ketta* is shown in Fig. 3.

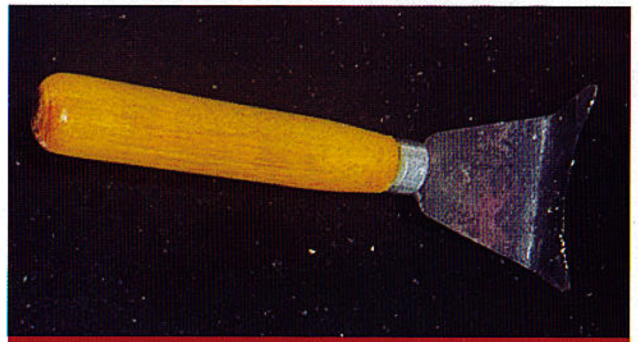


Fig. 2 Ko ketta

Rubbing

Rubbing is done to loosen the bark for easy detachment from the core of the stem. Prior to rubbing, a longitudinal slit is made from one end to the other end of the selected portion (Fig. 4). Rubbing is the most laborious operation in quill making and is conventionally performed using a brass rod of 15 mm diameter and 203 mm length, weighing about one kilogram. (Fig. 5). The approximate force required in rubbing is 9 – 30 N at 40 - 60 strokes. During the process, the bark sap oozes indicating proper rubbing (Fig. 6).

Fig. 4 Making of longitudinal slit prior to rubbing

Fig. 5 Brass rod

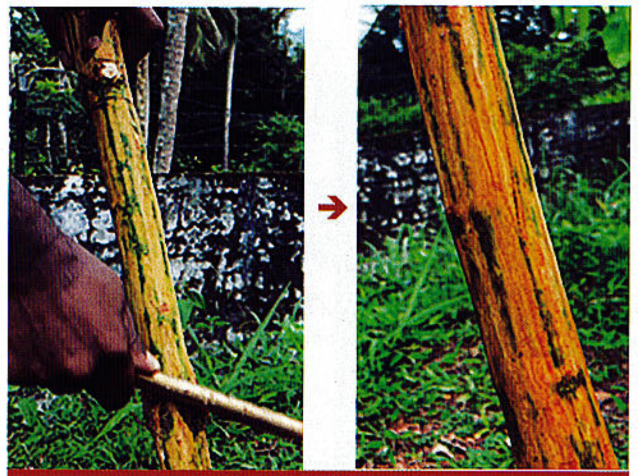


Fig. 6 Rubbing of cinnamon stem using brass rod

Peeling

Peeling or detachment of bark from the stem is a highly skilled and time-consuming operation in processing of cinnamon. Immediately after the rubbing process, the stem is examined to decide the maximum length of bark portions that can be peeled off to make the outer cover of the quills. Two cuts are made around the stem with maximum length of 30 cm between the cuts using a pointed cinnamon peeling knife (Fig. 7). Subsequently a special knife with a pointed curved beak tip is inserted between the bark and the hardwood while detaching the bark (Fig. 8). The unpeeled bark left on the bends/knots can be separately removed and can be used to fill the interior of the quills.

Fig. 7 Cinnamon peeling knife

Fig. 8 Peeling of cinnamon bark using peeling knife

Drying

The long and intact bark obtained during peeling are used to make the outer cover of the quills. The scraped peels of the inner bark are joined together by overlaps, the inner core of which is filled with smaller pieces of the peel. These are then filled with the bark curls, which are small strips of peel, that are obtained during the peeling process. Moisture content of dried cinnamon bark should be brought down to the range of 10-12 per cent. Drying imparts hardness to cinnamon bark and reduces breakage during transportation. Cinnamon quills are usually dried under shade (Temperature: 25 – 27 °C, Relative humidity: 60–65 per cent). High temperature drying of cinnamon adversely affects its colour and bioactive components. Drying periods extends from 12 – 48 hours, depending on the ambient weather conditions. An illustration of cinnamon stem to quill with the tools and peeled bark is shown in Fig. 9.

The dried bark of cinnamon is placed one inside the other to form cigar like rolls called quills (Fig. 10 -12). The pieces/brokens of bark that are unsuitable to make a single quill are filled inside the main quills. Several by-products such as quillings, featherings, and chips are obtained in cinnamon quill making process. Unit operations in cinnamon peeling are illustrated in Fig. 13.

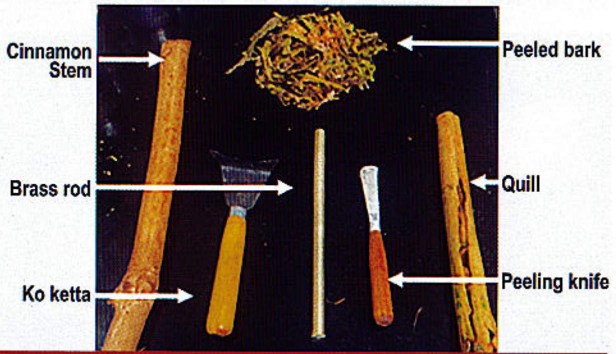


Fig. 9 Cinnamon stem to quill with tools and peeled bark

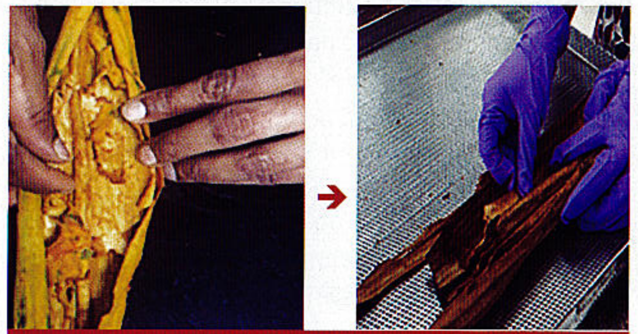


Fig. 10 Quill making process

Fig. 11 Cinnamon quills before drying

Fig. 12 Cinnamon quills after drying

Fig. 13 Cinnamon quill making process

Quillings

Quillings are made from all grades of cinnamon as brokens or splits. Though they have same aroma and taste as that of the quills, they are marketed as medium quality cinnamon. The proportion of featherings and chips in quills should not exceed three per cent of the total mass. Separation of quillings is done during the preparation of quills and they are dried separately under shade drying conditions.

Featherings

Featherings refers to light feather-like shavings of the inner bark formed during the quill making process. Scrapings from the bark and small stalk of the cinnamon are also included as featherings. These are also graded as medium quality cinnamon.

Chips

Chips are the scrapings obtained from the greenish, thick and mature pieces of bark and are not directly peeled out of the stem. Hence, they are considered to be of inferior quality as compared with quillings and featherings. Chips are graded into Grade 1 (containing small featherings and small amount of bark material) and Grade 2 (containing inner and outer bark and wood pieces).

Grades of cinnamon quills

Cinnamon quills, the major product from cinnamon, are commercially classified into nine grades based on the number of quills in one kilogram of the market product. The grades of cinnamon are presented in the Table 1.

Table 1. Grades of cinnamon quills

Standard index	Grade	Maximum diameter of quills (mm)	No. of quills per kg
I	Alba	6	45
II	C5 Sp	8	33
III	C5	12	27
IV	C4	16	22
V	M5	16	22
VI	M4	19	18
VII	H1	23	11
VIII	H2	25	9
X1	H3	38	7

The manual peeling of cinnamon requires a delicate balance of traditional skill and technical understanding to achieve optimal results. Through careful examination of the various techniques and tools employed in hand peeling, it becomes evident that the success of the operation depends heavily on factors such as bark moisture content, tool maintenance, and operator expertise. The recommended use of specialised curved knives, combined with proper bark conditioning at 85-90 per cent relative humidity, has been shown to significantly reduce breakage and improve quality outcomes.

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Arbuscular mycorrhizal Fungi Fortification: An Eco-friendly Strategy for Healthy Cardamom Seedling Production

C. Sarathambal[1], M. Faisal Peeran[1], V. Srinivasan[1], R. Praveena[1], B. Manimaran[1], H. J. Akshitha[2]
[1]ICAR-Indian Institute of Spices Research, Kozhikode 673 012, Kerala
[2]ICAR-IISR Regional Station, Appangala, Kodagu 571 201, Karnataka

Cardamom (*Elettaria cardamomum* (L.) Maton), known as the Queen of Spices, is a valuable spice native to the Indian Western Ghats and grown in countries like Guatemala, Sri Lanka, and Tanzania also. In India, it is cultivated at elevations of 900–1400 m in Kerala, Karnataka, and Tamil Nadu, with the Indian Cardamom Hills being a major growing area. Besides its culinary use, cardamom is employed in traditional medicine for digestive and kidney disorders. However, cardamom production faces challenges such as disease and poor planting material survival, necessitating improved propagation methods.

The use of *arbuscular mycorrhizal* (AM) fungi as a bioinoculant in potting mixtures is emerging as a sustainable solution to enhance seedling health, increase production, and reduce reliance on chemical fertilisers. Furthermore, the use of AM fungus as a bioinoculant is being promoted as a method of increasing production while reducing the demand for chemical fertilisers.

Arbuscular mycorrhizal (AM) fungi play a crucial role in horticultural ecosystems by forming a mutually beneficial relationship with a majority of plants. Spice crops such as turmeric, ginger, black pepper and cardamom colonise *endomycorrhisae* fungus in their roots. This symbiotic association is characterised by the exchange of resources: the fungi receive sugars from the plant, and in turn, their hyphae, which are thread-like structures, function as extensions of the plant's root system. This extension enhances the plant's access to essential, immobile nutrients like phosphorus, zinc, and copper. Due to this interdependence, the fungi are termed obligate symbionts. The symbiosis involves a flow of carbon compounds (such as sugars and lipids) from the plant to the fungus, while inorganic nutrients and water move from the fungus to the plant. Consequently, the relationship establishes a critical linkage between the plant and the soil, benefiting both the organisms. While the root hairs of plant typically extend only 1-2 mm into the soil, the hyphae of mycorrhiza explore a significantly larger soil volume, reaching up to 15 cm away from the plant's roots. The association between mycorrhizae and crop plants not only often boosts plant growth and yield but also, even in the absence of observable growth enhancement, plays a major role in phosphorus uptake.

AM fungi offer several benefits when used in nurseries:

Incorporating AM fungi into nursery practices can be a sustainable and effective way to optimise plant growth and health, ultimately leading to more successful plant establishment under field conditions.

- AM fungi increase the surface area of plant roots, improving the absorption of essential nutrients, particularly phosphorus and micronutrients.
- Presence of AM fungi helps enhance soil structure and moisture retention, leading to better drought resistance in plants.
- Enhanced nutrient and water uptake from AM fungi can lead to improved overall plant growth and vigour.
- AM fungi can help plants better tolerate environmental stresses, including salinity, heavy metals, and extreme temperatures.
- AM fungi can provide a protective effect against certain soil-borne pathogens, reducing the incidence of root diseases.
- With improved nutrient uptake efficiency, plants may require lower amounts of chemical fertilisers, leading to cost savings and reduced environmental impact.
- Incorporating AM fungi supports sustainable nursery practices by reducing dependence on chemical inputs and promoting biodiversity.
- AM fungi can improve the establishment rates of seedlings in the field by enhancing root development and nutrient availability.
- AM fungi can help reduce transplant shock in nursery plants, leading to higher survival rates when moved to permanent locations.

Effect of AM fungi on cardamom

Root development and nutrient uptake: AM fungi significantly enhance the rooting of cardamom plants. This symbiotic relationship not only promotes deeper root growth but also increases overall root biomass. As a result, the plants are better equipped to absorb essential nutrients from the soil, leading to improved growth and vitality.

Enhanced disease resistance: The association between AM fungi and cardamom improves the plant's ability to defend itself against diseases. This is achieved through the upregulation of defence-related enzymes. These enzymes play a crucial role in the plant's immune response, helping to protect against pathogens and reduce the incidence of diseases.

Soil microbial activity: AM inoculation positively impacts the microbial activity within the rhizosphere

of cardamom. It increases soil ensyme activity, which is vital for nutrient cycling and soil health. Additionally, the presence of AM fungi fosters a diverse community of beneficial microbes, contributing to a more robust and resilient soil ecosystem.

Considerations for applying *arbuscular mycorrhisae* in nursery conditions

- Ensure adequate soil moisture to support mycorrhizal establishment. A well-drained and sterile soil mix promotes effective colonisation.
- Avoid using contaminated or low-quality inoculum, as it may introduce pathogens or ineffective mycorrhisal species.
- Do not apply mycorrhisae in soils with high salinity, as this can negatively impact their effectiveness.
- Refrain from using fungicides immediately after applying mycorrhisae, as they can hinder the establishment of mycorrhisal fungi. If necessary, re-inoculation may be required to restore AM fungi.
- Avoid excessive fertilisation, as it may reduce plants' dependence on mycorrhisal associations.
- Ensure the soil pH is within the optimal range for the successful establishment of mycorrhisal fungi.

Conclusion

Inoculating potting mixtures with *arbuscular mycorrhisal* fungi enhances both root and shoot growth in cardamom, while also increasing fungal colonisation. This approach integrates soil health management, mycorrhisal symbiosis, and efficient seedling multiplication. By consistently creating favourable conditions, we can establish a healthy and self-sustaining population of AM fungi on the farm. This practice not only reduces nutrient loss and maintains soil fertility but also contributes to efforts in mitigating climate change.

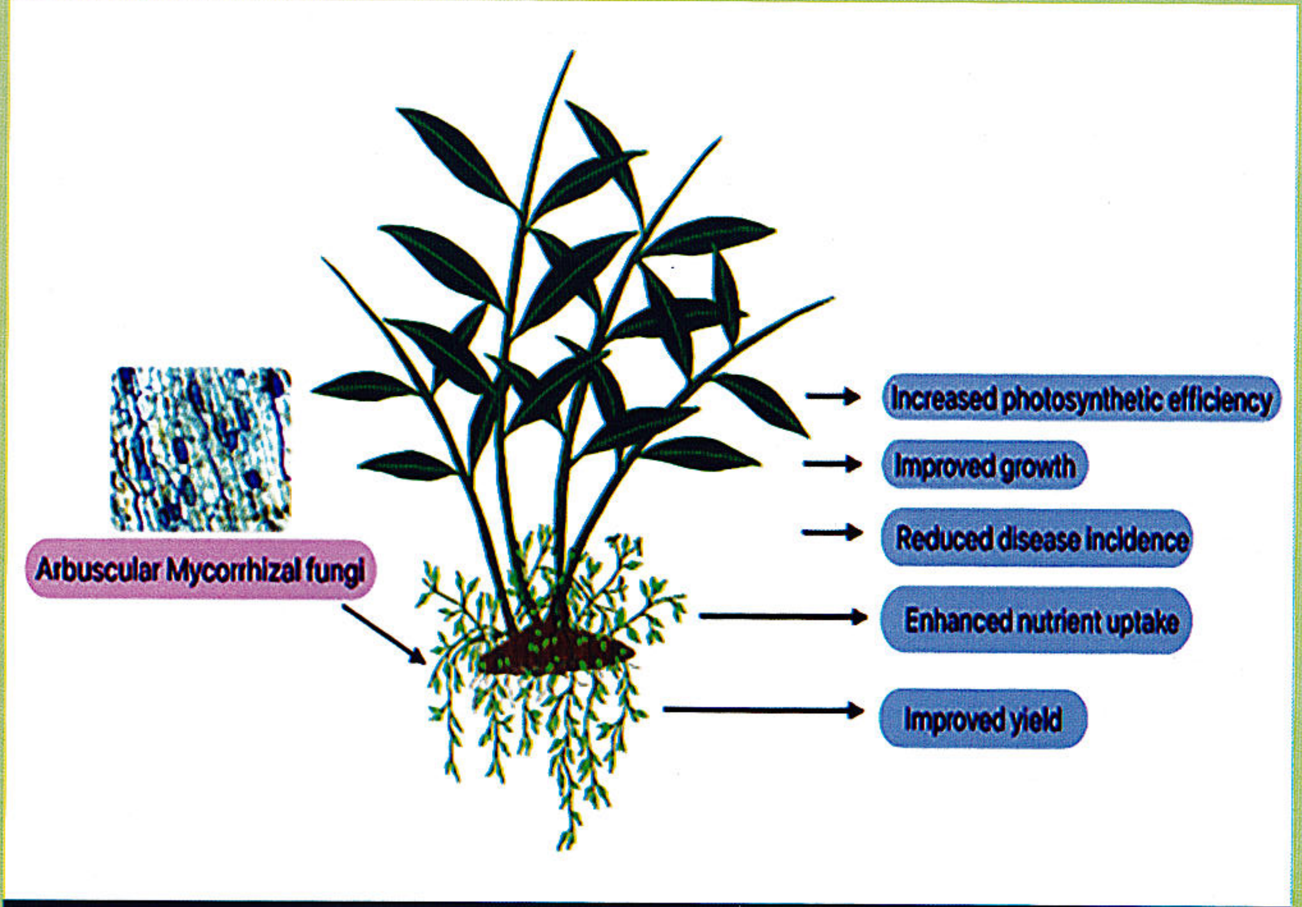
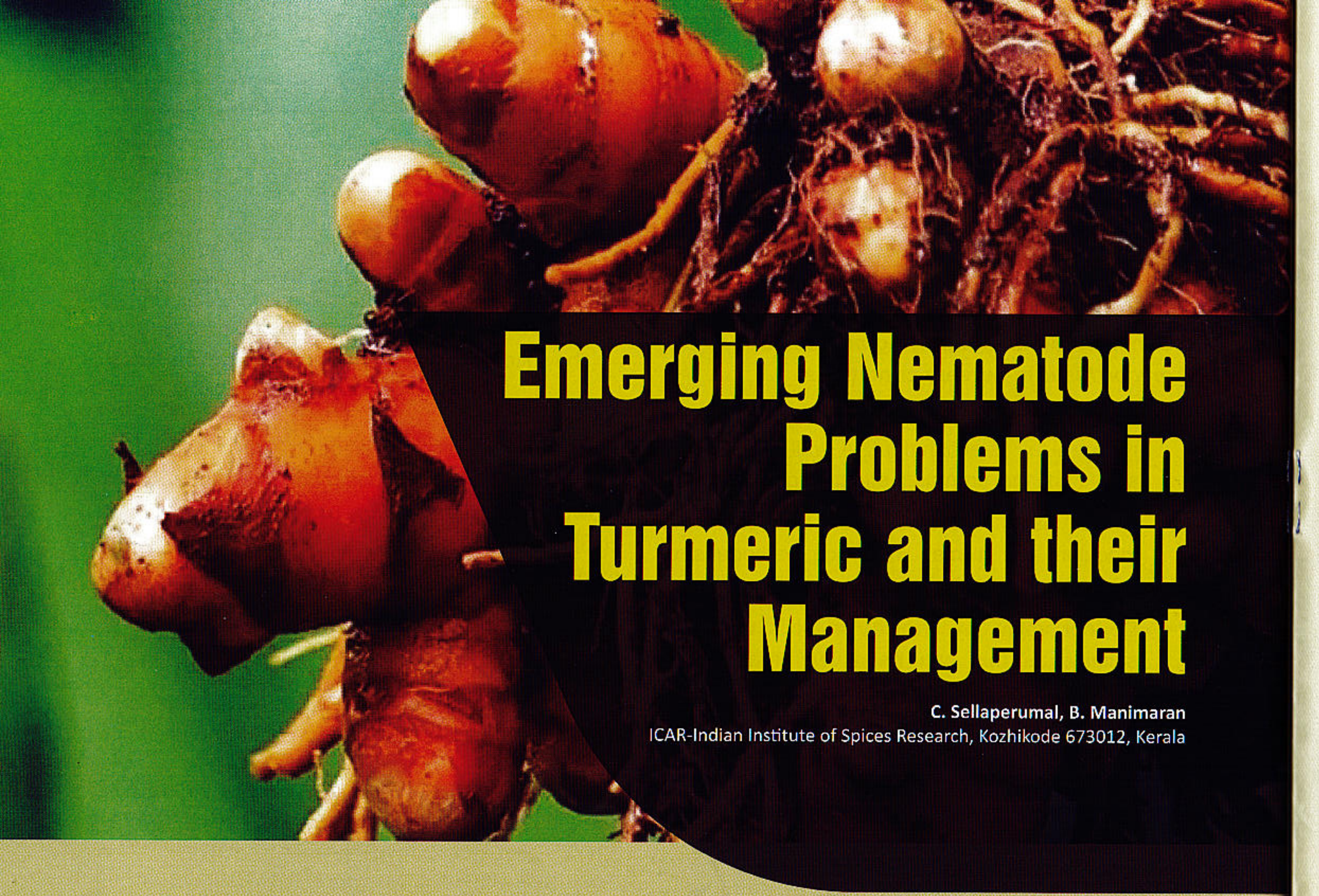


Fig.1. Effect of *Arbuscular mycorrhizal* inoculation on growth promotion and defense responses in cardamom



Emerging Nematode Problems in Turmeric and their Management

C. Sellaperumal, B. Manimaran
ICAR-Indian Institute of Spices Research, Kozhikode 673012, Kerala

Turmeric (*Curcuma longa L.*), a vital spice crop in India, is widely cultivated for its medicinal, culinary, and industrial applications. However, its production is increasingly threatened by plant-parasitic nematodes (PPNs), which cause significant yield losses by affecting root health and nutrient uptake. Among these, *Meloidogyne spp.* (root-knot nematodes), *Pratylenchus spp.* (lesion nematodes), and *Radopholus similis* (burrowing nematodes) are the most destructive, leading to stunted growth, poor rhizome development, and secondary infections. Despite being an overlooked problem in turmeric cultivation, recent surveys and research indicate a growing prevalence of PPNs across major turmeric-growing regions in India. The infestation of PPNs often remains unnoticed until severe damage occurs, making early detection and management crucial. The root lesion nematode is becoming a significant issue in the intensive turmeric cultivation areas of India, particularly in Andhra Pradesh, Telangana, West Bengal, Tamil Nadu, Kerala, Maharashtra, and Assam. It infects the economic part 'rhizome' and affects turmeric cultivation both qualitatively and quantitatively. Moreover, this nematode issue is often overlooked because its above-ground symptoms can be confused with those of nutrient deficiencies and water stress. This article discusses the emerging threat of PPNs, especially the lesion nematode (*Pratylenchus spp.*) in turmeric cultivation, their economic significance, and potential management strategies to safeguard turmeric production in India.

Pratylenchus spp., an emerging threat to turmeric cultivation:

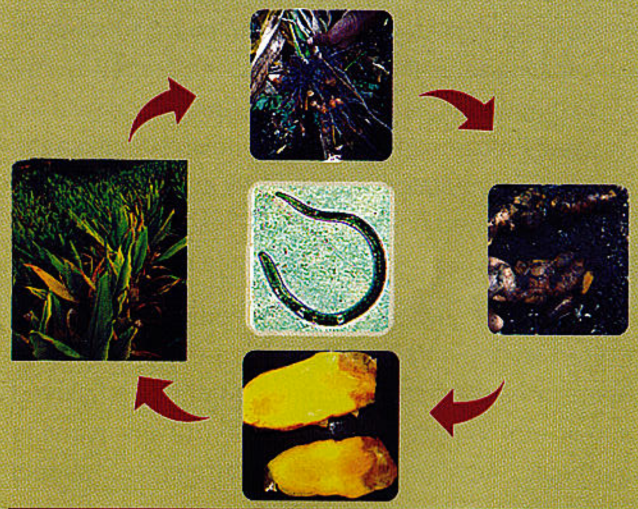
Root lesion nematode (*Pratylenchus spp.*) is a vermiform, migratory endoparasitic nematode that feed on parenchyma and cortical tissues, causing necrosis and resulting in brownish lesions on the

affected areas. It is a polyphagous nematode with over 400 known host plants and is a significant agricultural pest. It ranks as the third most economically important genus of PPNs, following root-knot and cyst nematodes, due to the substantial economic losses it inflicts on agriculture and horticulture. The number of identified species within this genus is continuously increasing, now totaling around 100. *Pratylenchus spp.*, are adaptable to various climatic conditions and can undergo anhydrobiosis during hot and dry seasons, surviving for up to seven to eight months until favourable conditions return.

They are responsible for significant yield losses in different crops worldwide, the wheat crop experiencing declines of up to 85 per cent in Australia, 70 per cent in Israel, and 37per cent in Mexico. In Norway, potato yields have been reduced by 58 per cent, while *Musa spp.* in Ghana face a 60 per cent loss. In India, rice yields have dropped by 25 per cent, and soybean losses in Brazil reach 21 per cent. North Carolina (USA) sees a 31 per cent reduction in yields, and yam losses range from 20 to 50 per cent. From these reports we can imagine the potential threat posed by *Pratylenchus spp.*, to the turmeric cultivation in India

Symptoms caused by *Pratylenchus spp.*

It produces classic symptoms of brownish root lesions or necrosis on rhizomes and roots, leading to 'rhizome rot' in conjunction with other soil-borne pathogens. In the initial stage, fresh rhizomes display dark brown spots on their surfaces. As they mature, they become low, dry, and have a wrinkled



Damage symtom in turmeric caused by *Pratylenchus spp.*

Different levels of infection by *Pratylenchus spp.*

appearance, lacking turgidity and weight. When an infected rhizome is broken open at the affected area, a light to dark brown discolouration can be seen, extending 3-5 mm from the surface to the centre. The nematode affects all parts of the underground portion of the plant, including the roots, fingers, and mother rhizomes, though the latter is typically less affected. When attempting to remove a turmeric clump from the soil, it can be easily pulled out due to the damage done to the anchoring roots. Above ground, symptoms include a patchy appearance, stunted growth, weakness, early maturity, and subsequently, yellowing and drying of the leaf tips and margins (Fig. 1 & 2).

Transmission

This nematode is seed-borne and can survive in the rhizomes, often going unnoticed, allowing for easy spread through planting material from one location to another. If a field is infected, it's important not to select planting material that appears healthy.

Disease complexes

Occasionally, higher yield losses can occur due to the synergistic interactions between nematodes and other pathogenic microbes in the soil. For instance, various species of *Pratylenchus* have been noted to associate with fungi; specifically, *P. thornei* has been found in conjunction with *Verticillium dahliae* in potatoes in Israel. Additionally, *Pratylenchus coffeae* has been reported alongside *Pythium aphanidermatum* in turmeric in India. These pathogens not only infect *Curcuma longa* but also affect related species, leading to the 'brown rot' disease in other cultivated turmeric species like *C. aromatica*, which is caused by *Fusarium spp.*, and the lesion nematode, *Pratylenchus spp.*

Management

Managing this nematode is crucial for turmeric cultivation. The following strategies are recommended to safeguard the turmeric crop from the potential threats posed by Pratylenchus spp.

1. **Seed Material Selection:** Choose only healthy seed materials and avoid purchasing seeds that appear healthy but originate from infected fields.
2. **Crop Residue Management:** Collect and dispose of infected crop residues, as nematodes can survive in the soil and infected planting material can be a primary source of inoculum. Infected tissues remaining in the field act as reservoirs for nematodes.
3. **Field Selection:** Cultivate in areas that are free from infection. If the field is infected, rotate it with non-host crops, and avoid monocropping. Implement deep summer plowing (two times at a depth of 15 to 30 cm) to expose nematode eggs and larvae to sunlight. Soil solarisation technique can be employed in infected fields, particularly if good sunlight is available during the summer months for duration of six weeks.
4. **Crop Rotation:** Crop rotation is a widely used strategy to prevent the accumulation of pathogens from infected fields. However, controlling nematodes that have a broad host range can be challenging, so the choice of crops should depend on the specific species of nematode involved.
5. **Organic Amendments:** Incorporating organic materials can help lower nematode populations by enhancing plant tolerance, improving nutrient levels, fostering beneficial microbial activity, and releasing toxic compounds.
6. **Hot Water Treatment:** This method has proven effective in managing nematode spread through planting materials in crops like banana, citrus, and strawberry. It is essential to use the correct temperature and duration; otherwise, the planting material may fail to germinate. In case of turmeric, rhizome treatment @ 52°C for 10 minutes can kill the nematode inside the tissue.
7. **Biological Control Agents:** Utilising biological agents such as bacteria, fungi, and actinomycetes, as well as *arbuscular mycorrhizal fungi* (AMF), when amended with well-decomposed farmyard manure (FYM), neem cake, or vermicompost, has shown promise in suppressing nematodes.
8. **Host Plant Resistance/Tolerance:** This is an effective and eco-friendly management strategy to reduce root lesion nematode populations. However, while a plant may be resistant to one nematode species, it may still be susceptible to others.
9. **Chemical Management:** Currently, there are no registered nematicides for spice crops in India; however, application of *Carbofuran at the rate of 1kg a.i/ha at 3rd and 5th month of sowing can effectively control nematodes. Some compounds, such as Fluopyram, Fluensulfone, and Fluozaindolizine, have shown effectiveness against nematodes (Note - * it can be applied in non banned area).

The ultimate challenge lies in developing a management strategy, which is complicated by the limited technologies available and the presence of nematodes within the rhizomes. Methods employed should not impact the germination of the planting material. Additionally, these strategies should incorporate pathogen control measures as part of a comprehensive approach.

Calendar of Operations
for Important Spices - August 2025

Timely planning and execution of farm operations, aligned with the agro-climatic conditions of the region, are crucial for successful farming, enhanced productivity, and long-term sustainability. A well-structured calendar of operations serves as a valuable tool for farmers and field personnel. To support this effort, a broad outline of key spice crop operations recommended for the month of August 2025 is provided below:

SMALL CARDAMOM

- Ensure adequate drainage in the seedling nursery and thin out overcrowded seedlings in nursery beds, removing and discarding any diseased plants.
- In the main field, complete trashing and weeding of interspaces, and plant shade tree saplings in open patches.
- Depending on prevailing weather conditions, continue replanting and rejuvenation activities.
- Where feasible, apply a fertiliser drench using five litres of solution prepared by mixing 1 kg MOP, 600 g DAP, and 400 g urea in 100 litres of water.

- For Integrated Pest Management, spray Diafenthiuron at a concentration of 80 g per 100 litres of water, timed to coincide with shoot borer moth emergence.
- To manage capsule rot and rhizome rot, drench with a 0.2% solution of copper oxychloride or Fosetyl-Al (200 g per 100 litres), and apply a 1% Bordeaux mixture as a spot treatment after removing affected rhizomes, panicles, and capsules.
- Continue harvesting operations and collect firewood for curing purposes, ensuring minimal disturbance to the surrounding ecosystem.

LARGE CARDAMOM

- Properly mulch nursery beds with dried forest leaves to prevent soil erosion and suppress weed growth.
- Remove and destroy suckers infested with pests or diseases, and erect overhead pandals in sucker nurseries established during June and July.
- Complete replanting and gap filling operations if they have not been carried out already.
- Uproot and bury plants infected with Chirkey and Foorkey at regular intervals to prevent disease spread.
- After removing blight-affected plants, spray and drench the area with a solution of *Pseudomonas fluorescens* at 3–5 litres per 100 litres of water.
- Additionally, spray and drench the soil with copper oxychloride 50% WP at the rate of 1 kg in 300–400 litres of water.
- Conduct regular field inspections to monitor for caterpillar, shoot borer, or shoot fly infestations, and hand-pick and destroy any detected pests.
- As the crop begins to mature in low-altitude areas, ensure completion of weeding and trashing before harvest.

- Farmers who do not have curing facilities (bhatties) should construct improved bhatties using the modified flue pipe technique.
- After harvesting, collect and destroy old shoots, mother plants, and dry leaves to maintain field hygiene and reduce pest incidence.

GINGER

- Carry out weeding, earthing up of beds, and mulching as required to maintain field hygiene and conserve soil moisture.
- Apply appropriate organic manures, followed by earthing up and mulching to improve soil health and support plant growth.
- The second foliar spray of ginger micronutrient mixture at 5 g per litre of water can be applied one week after the second dose of fertiliser.
- In organic ginger beds, apply one kilogram of neem cake mixed with *Trichoderma* to suppress soil-borne pathogens.
- For rhizome rot management, drench the beds with 0.2% copper oxychloride or 0.125% metalaxyl-mancozeb solution after uprooting the affected plants.

- Ensure adequate drainage in the field to prevent water stagnation, which can aggravate disease incidence.
- To control shoot borer, spray a 0.05 per cent solution of Dimethoate (167 ml per 100 litres of water) and remove and destroy infested clumps.
- If soft rot disease is observed, dig out the affected plants and drench the beds with a 1 per cent Bordeaux mixture to limit disease spread.

BLACK PEPPER

- Continue with new planting and replanting activities as required. Ensure that water does not stagnate around the base of the plants to prevent root diseases.
- Take care to avoid injuring the root system during cultural operations, and perform slash weeding as necessary.
- Prune the branches of shade trees to regulate light intensity, and tie and properly train the growing vines to the supporting standards.
- In the last week of August, apply half the recommended dose of fertilisers - Urea (55 g), Rock Phosphate (140 g), and Muriate of Potash (125 g) per vine.
- In organic farming systems, apply *Azospirillum* at 50 g per vine along with 2 kg of vermicompost or well-decomposed cow dung; if potassium deficiency persists, add Sulphate of Potash at 150 g per vine.
- Spray black pepper micronutrient mixture at a rate of 5 g per litre of water to support balanced nutrition.
- For managing foot-rot disease, spray a 1% Bordeaux mixture, and in severe cases, drench

the plant base with a 0.2% copper oxychloride solution (200 g per 100 litres of water), using 2–5 litres per vine, in addition to the Bordeaux spray.
- Apply the second round of biocontrol agents such as *Trichoderma* and *Pochonia chlamydosporia* in combination with organic manures to enhance disease suppression and soil health.

TURMERIC

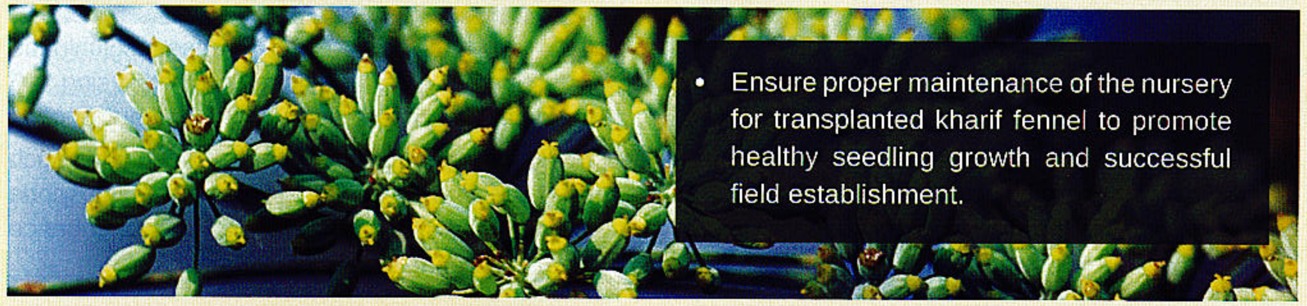
- Apply additional organic manures enriched with *Trichoderma* to enhance soil health and disease resistance.
- Carry out weeding, earthing up of beds, and mulching as needed to support healthy crop growth and moisture conservation.
- One week after the second dose of fertiliser application, apply a foliar spray of turmeric micronutrient mixture at the rate of 5 g per litre of water.
- Ensure proper drainage in the field to prevent water stagnation, which can lead to root and rhizome diseases.

- To manage shoot borer infestation, spray a 0.05% solution of Dimethoate (167 ml per 100 litres of water) and promptly remove and destroy any infested clumps.
- If rhizome rot is observed, drench the plant base with a 0.2% copper oxychloride (COC) solution, prepared by mixing 200 g in 100 litres of water, to control disease spread effectively.

CHILLI

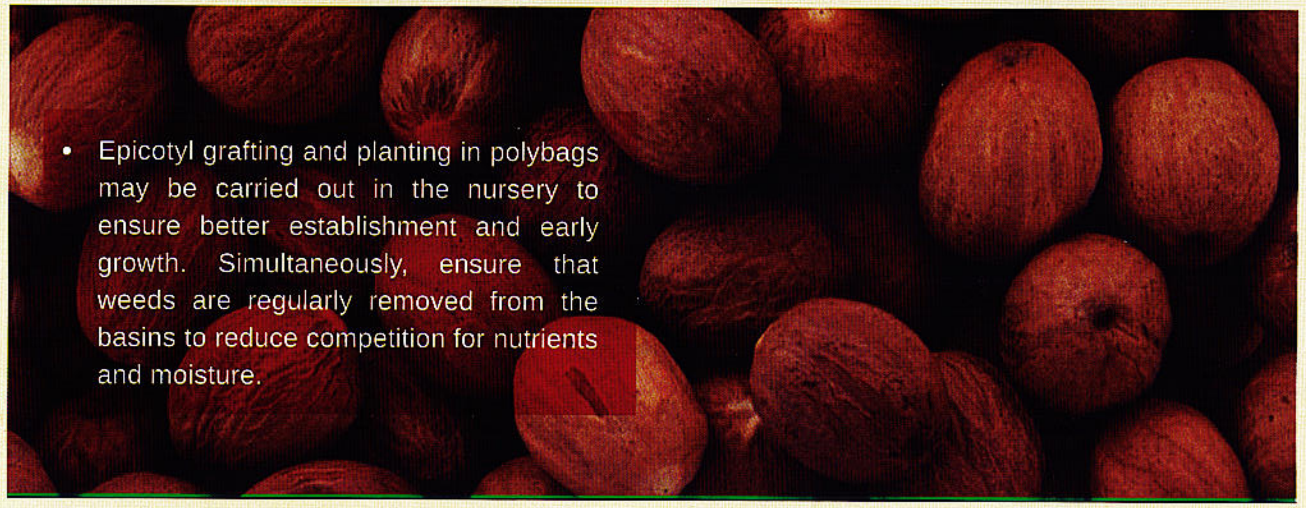
- Incorporate green manure into the fields to enhance soil fertility and structure.
- Transplant the seedlings to the main field at the appropriate stage for optimal establishment.
- In organic turmeric beds, apply one kilogram of neem cake mixed with *Trichoderma* to suppress soil-borne pathogens and improve soil health.
- Irrigate the field adequately if soil moisture is found to be insufficient.
- At the time of transplanting, apply 50% of the recommended fertiliser dose (NPK 100:50:50 kg/ha) to support initial crop growth.
- Supplement with bio-fertilisers to enhance nutrient availability and promote microbial activity in the soil.
- If rhizome rot disease is observed, uproot the infested clumps and drench the beds with 0.2% copper oxychloride (COC) or metalaxyl-mancozeb solution to contain the infection.

FENNEL (KHARIF)



- Ensure proper maintenance of the nursery for transplanted kharif fennel to promote healthy seedling growth and successful field establishment.

NUTMEG



- Epicotyl grafting and planting in polybags may be carried out in the nursery to ensure better establishment and early growth. Simultaneously, ensure that weeds are regularly removed from the basins to reduce competition for nutrients and moisture.