National Symposium on Spices and Aromatic Crops – Strategies for Smart Production, Product Diversification and Utilization

Souvenir & Abstracts

NATIONAL SYMPOSIUM ON SPICES AND AROMATIC CROPS

2025

SYMSAC-XI

07-09 January 2025

Venue

ICAR - Indian Institute of Spices Research, Kozhikode, Kerala

Organized by

Indian Society for Spices (ISS), Kozhikode, Kerala

In collaboration with

National Symposium on Spices and Aromatic Crops – Strategies for Smart Production, Product Diversification and Utilization

07-09 January 2025

Organiser

Indian Society for Spices, Kozhikode, Kerala, India

Collaborators

Indian Council of Agricultural Research, New Delhi
ICAR-Indian Institute of Spices Research, Kozhikode, Kerala
ICAR-National Research Centre on Seed Spices, Ajmer, Rajasthan
Directorate of Arecanut & Spices Development, Kozhikode, Kerala
Spices Board, Kochi, Kerala

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Indian Society for Spices
ICAR-Indian Institute of Spices Research
Marikunnu P.O., Kozhikode, Kerala

2025

National Symposium on Spices and Aromatic Crops – Strategies for Smart Production, Product Diversification and Utilization

07-09 January 2025

Organized by

Indian Society for Spices, Kozhikode, Kerala, India

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MESSAGE

I am happy to know that the Indian Society for Spices, Khozikode is organizing the XI^th "National Symposium on Spices and Aromatic Crops (SYMSAC-XI) in collaboration with ICAR-Indian Institute of Spices Research, Kozhikode; ICAR-National Research Centre on Seed Spices, Ajmer; Directorate of Arecanut & Spices Development, Kozhikode; and Spices Board, Kochi during January 7-9, 2025 at Kozhikode, Kerala. The Symposium will focus on the theme "Strategies for Smart Production, Product Diversification and Utilization."

Spices and aromatic crops have long been celebrated as integral components of India's agricultural and cultural heritage. Their unparalleled significance extends beyond their culinary allure, serving as key contributors to traditional medicine, wellness industries and global trade. India, being a leading player in the production and export of spices, is uniquely poised to further harness the potential of these crops, not merely for economic gain but as a pathway to sustainable agriculture and improved farmer livelihoods.

The evolving challenges of climate change, resource limitations, and market dynamics demand innovative solutions. SYMSAC-XI provides a vital platform for the exchange of ideas, fostering collaboration among scientists, policymakers, industry leaders, and farmers. With a focus on themes such as climate-resilient varieties, advances in production systems, integrated soil and plant health management, and the development of nutraceuticals and novel products, this symposium is set to address pressing issues while unlocking new opportunities for growth and innovation.

I wish the National Symposium a grand success.

(Himanshu Pathak)

Dated the 1st, January, 2025
New Delhi

SPICES BOARD
(Ministry of Commerce & Industry, Govt. of India)
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पी. हेमलता, आई ए एस
P. HEMALATHA, IAS
सचिव / SECRETARY

MESSAGE

I take immense pleasure in congratulating the Indian Society for Spices (ISS) for conducting the Eleventh National Symposium on Spices and Aromatic Crops (SYMSAC-XI) in collaboration with ICAR and Spices Board. The symposium with its forward-looking theme "Strategies for Smart Production, Product Diversification and Utilization" has once again demonstrated ISS's pivotal role in shaping the future of the spice sector.

Indian spices contribute nearly 25% of volume and 40% of value of horticultural exports from the country. Spices export was pegged at the 4th place in terms of value in the total agricultural exports from India in 2023-24. At a time when we strive to reach an export target of 10 Bn USD in spices by 2030, this symposium offers the right platform, by uniting the diverse stakeholders, to have productive deliberations focussing on innovation, sustainability, and market expansion. Such initiatives are invaluable in reinforcing India's leadership in the global spice trade, ensuring prosperity of the farmers and resilience of the spice economy.

My heartfelt appreciation to the organizers for their vision and commitment. I hope that the outcome of this symposium will translate into tangible benefits to the sector.

(P. Hemalatha IAS)
Secretary
Dated:31.12.2024

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MESSAGE

The Indian Society for Spices, Kozhikode, Kerala, in collaboration with renowned institutions, such as the Indian Council of Agricultural Research, New Delhi; ICAR-Indian Institute of Spices Research, Kozhikode; ICAR-National Research Centre on Seed Spices, Ajmer; Directorate of Arecanut & Spices Development, Kozhikode; and Spices Board, Govt. of India, Kochi, is set to host the Eleventh National Symposium on Spices and Aromatic Crops (SYMSAC-XI). Scheduled during 7-9 January 2025 at the ICAR-Indian Institute of Spices Research, Kozhikode, Kerala, this prestigious event will centre on the theme **"Strategies for Smart Production, Product Diversification and Utilization."**

As of recent estimates, India produces over 6.00 million metric tonnes of spices annually from approximately 3.2 million hectares of land. About 15% of this production is exported, reflecting India's pivotal role in meeting the global demand. The compelling versatility of spices, used in diverse forms, such as whole, ground, roasted, and extracted, highlights their significance in enhancing flavour, aroma and nutritional value. Beyond the culinary realm, they are vital in nutraceutical, pharmaceutical, and cosmetic industries. However, modern challenges such as pesticide residues, heavy metal, post-harvest losses, and climate-induced stresses underscore the urgency of advancing research, fostering innovation, and promoting sustainable practices.

SYMSAC-XI offers an exceptional platform for addressing these challenges and exploring opportunities. Themes, such as climate-resilient varieties, integrated soil and plant health management, and the development of novel products will drive discussions that aim to transform the spice sector. The symposium's focus on food safety, value-chain enhancement, and organic cultivation standards reflects a commitment to aligning traditional wisdom with contemporary scientific advancements. The inclusion of interactive sessions for farmers and a dedicated Dialogue between Farmer Producer Organizations and the spice industry exemplifies the grassroots orientation of this event.

I extend my heartfelt congratulations to the Organizers for their commendable efforts in orchestrating this pivotal event.

My Best Wishes to all participants for insightful deliberations and impactful collaborations.

31/12/2024

(Sanjay Kumar Singh)

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TAMIL NADU AGRICULTURAL UNIVERSITY

Dr. V. GEETHALAKSHMI, Ph.D., FAAM.
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Coimbatore – 641 003
Tamil Nadu, India

MESSAGE

The ICAR-Indian Institute of Spices Research, Kozhikode, in collaboration with renowned institutions such as the Indian Society for Spices, Kozhikode, Kerala, Directorate of Arecanut & Spices Development, Kozhikode; and Spices Board, Kochi, is set to host the Eleventh National Symposium on Spices and Aromatic Crops (SYMSAC-XI) during its Golden Jubilee year. Scheduled during 7-9 January 2025, this prestigious event will centre on the theme, "Strategies for Smart Production, Product Diversification and Utilization."

In recent times, India exported 15% of its production for meeting the global spices demand, highlighting its significance in enhancing spices beyond the culinary realm. However, modern challenges such as climate-induced stresses and food safety issues stresses the need to advance the research areas fostering innovation and promoting sustainable practices.

At this juncture, this SYMSAC-XI with specific themes on climate-resilient varieties and technologies, precision agriculture in spices and soil and plant health management offers a unique platform for exchange of ideas and exploring opportunities. The interactive sessions for farmers, scientists and industries represents the mass reach out of this event.

I extend my heartfelt congratulations to the organizers for their commendable efforts in orchestrating this key event and best wishes to all participants for perceptive deliberations.

(V. Geethalakshmi)

Place : Coimbatore
Date : 30.12.2024

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MESSAGE

It is with great pride that I acknowledge the Indian Society for Spices, Kozhikode, Kerala, and its collaborating institutions for organizing the Eleventh National Symposium on Spices and Aromatic Crops (SYMSAC-XI). Scheduled during 7-9 January 2025 at the ICAR-Indian Institute of Spices Research, Kozhikode, addressing the theme, *"Strategies for Smart Production, Product Diversification, and Utilization."*

The enduring significance of spices and aromatic crops to India's agricultural landscape and global trade cannot be overstated. As the world's largest producer and exporter, India has a unique responsibility to ensure sustainable cultivation practices while enhancing value addition and market accessibility. SYMSAC-XI stands as a vital platform for uniting researchers, policymakers, farmers, and industry leaders to address the challenges and harness the opportunities in this vibrant sector.

By fostering dialogue on climate-resilient varieties, innovative production systems, and the expansion of value chains, this symposium promises to make meaningful contributions toward a resilient and progressive spice industry.

I extend my heartfelt congratulations to the organizers and participants and wish the event a great success in advancing the vision of a sustainable and prosperous future for spices and aromatic crops.

(Sudhakar Pandey)

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सत्यमेव जयते

Dr Homey Cheriyan
Director

31 December 2024

MESSAGE

I extend my heartfelt congratulations to the Indian Society for Spices (ISS) for the successful organization of the Eleventh National Symposium on Spices and Aromatic Crops (SYMSAC-XI) in collaboration with the DASD, Kozhikode. The meticulous planning and execution of this symposium, held under the theme *"Strategies for Smart Production, Product Diversification, and Utilization,"* reflect ISS's unwavering commitment to advancing the spice sector.

By bringing together diverse stakeholders—scientists, farmers, policymakers, and industry leaders—SYMSAC-XI has fostered a vibrant exchange of ideas and innovations crucial for addressing the challenges and opportunities in the spice industry. This collaborative effort underscores the ISS's pivotal role in driving research, development, and sustainable practices in the realm of spices and aromatic crops.

I applaud the organizers for their dedication and vision and wish ISS continued success in its endeavours to elevate India's spice sector on the global stage.

(Homey Cheriyan)

भाकृअनुप-भारतीय मसाला फसल अनुसंधान संस्थान
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Three times winner of Sardar Patel Outstanding ICAR Institution Award

डॉ. आर. दिनेश/ Dr. R. Dinesh
निदेशक / Director

MESSAGE

It is with immense pleasure that I extend my warm greetings on the occasion of the SYMSAC-XI National Symposium on Spices and Aromatic Crops. As the host institution, ICAR - Indian Institute of Spices Research (IISR) is celebrating its Golden Jubilee, we are proud to be part of this significant event, organized by the Indian Society for Spices (ISS) and our esteemed partner organizations.

This symposium serves as a vital platform for scientists, researchers, and industry stakeholders to come together, share knowledge, and discuss strategies to drive innovation and sustainability in the spice and aromatic crop sectors. The theme of this symposium is timely and crucial and addresses the various challenges faced by the spices and aromatic crops sector.

I whole heartedly welcome all participants to engage in this knowledge sharing, where diverse perspectives will foster deeper collaboration and breakthroughs that will propel our industry forward. Let us work together towards a more sustainable, resilient, and prosperous future for the global spice ecosystem.

Looking forward to your active participation and insightful contributions.

(R DINESH)

Spicing up the Nation's Progress

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Dr. Vinay Bhardwaj
डॉ.विनय भारद्वाज
Director
निदेशक

Date: 01/01/2025

MESSAGE

I am delighted to extend my heartfelt congratulations to the Indian Society for Spices (ISS) for organizing the Eleventh National Symposium on Spices and Aromatic Crops (SYMSAC-XI). The theme, *"Strategies for Smart Production, Product Diversification, and Utilization,"* is both timely and visionary, addressing critical areas of innovation, sustainability, and market expansion in the spice sector.

Spices and seed spices hold a pivotal place in India's agricultural and economic fabric. India is the world's largest producer, consumer, and exporter of spices, contributing over **75% of the global spice trade volume** and earning foreign exchange of approximately **₹30,000 crores annually**. This sector supports the livelihoods of millions of small and marginal farmers, providing economic security and employment.

SYMSAC-XI has created a robust platform for scientists, policymakers, farmers, and industry stakeholders to converge, share knowledge, and deliberate on the future of this vital sector. The symposium's focus on smart production technologies, value addition, and product diversification aligns with the need to address global challenges like climate change, sustainable resource use, and evolving consumer preferences.

The discussions and outcomes of this symposium are poised to significantly contribute to achieving India's spice export target of **$10 billion by 2030**. They will also enhance domestic productivity, ensure quality and safety standards, and position India as a global leader in the spice trade.

I commend the ISS and all collaborating institutions, including ICAR, ICAR-IISR, ICAR-NRCSS, the Directorate of Arecanut& Spices Development, and the Spices Board, for their tireless efforts in making this event a success. I am confident that this symposium will inspire innovative research, strengthen partnerships, and chart a course for the sustainable growth of the spice sector.

Wishing SYMSAC-XI and the ISS continued success in their noble mission of empowering the spice community and advancing this vibrant sector.

01/01/25
(Vinay Bhardwaj)

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Dr. Manish Das
Director & Project Coordinator (AICRP MAPB)

F. No. DIR/DMAPR/2024
16-December, 2024

MESSAGE

I extend my warm congratulations to the Indian Society for Spices (ISS) for organizing the Eleventh National Symposium on Spices and Aromatic Crops (SYMSAC-XI). The theme *"Strategies for Smart Production, Product Diversification, and Utilization"* is both timely and vital in addressing the evolving challenges and opportunities in the spices and aromatic crops sector.

Spices and aromatic plants hold immense potential not only in culinary and medicinal applications but also in fostering sustainable livelihoods and contributing to the green economy. SYMSAC-XI has provided an exceptional platform for collaboration and knowledge exchange among scientists, farmers, policymakers, and industry stakeholders, paving the way for innovation and growth in this dynamic sector.

I commend the organizers for their dedication and vision and look forward to the continued contributions of the ISS in advancing research and sustainable development in spices and aromatic crops.

(MANISH DAS)

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CONTENTS

WESTERN GHATS KOKUM FOUNDATION ENDOWMENT LECTURE

LEAD LECTURES

ABSTRACTS

Abstracts

Western Ghats Kokum Foundation Endowment Lecture

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Beyond flavour and taste - Spices in human wellness

P N Ravindran
Formerly of ICAR- Indian Institute of Spices Research, Kozhikode, Kerala

Spices are natural products of plant origin, used primarily for flavouring, seasoning or adding pungency and colour to foods and beverages. All spices are medicinal and are being used extensively in the traditional systems of medicine such as Ayurveda, Unani, and Sidha, as well as in the herbal drugs of both the West and the East. Spices are also widely used in Chinese and Japanese native medicines. Some spices (pepper, long pepper, ginger) are among indigenous medicines' most commonly used and inevitable ingredients. These three spices (black pepper, long pepper, ginger- all in dry forms) constitute the 'Trikatu', the three acids that cure the discorded humour- vata, pitta and kapha, and help maintain normal health. In his lexicon, Charaka Samhita, the founder of Ayurveda, lists 32 spices for the preparation of various formulations.

The spices become essential in health care due to diverse secondary metabolites synthesised by the plants. Secondary metabolites are small organic molecules originating during the metabolism of plants, such as photosynthesis (hence, they are termed secondary metabolites), and they characteristically have molecular masses of less than 3000 da. They are not directly involved in growth and development, but they are essential for the survival of plants in unfavourable environments and to overcome various stresses that the plants are constantly subjected to. Secondary metabolites contribute to the flower colour, fragrance, and flavour and attract pollinators. They are also involved in interacting plants with symbiotic microorganisms and tolerance against insect pests and diseases. They also contribute to frost tolerance, nutrient storage, protection from UV radiation and chemical signals, and adapting plants to adverse environmental, survival and growth conditions. Some of the secondary metabolites play significant roles in the prevention and protection of human health. Such health-promoting actions include antioxidants, cholesterol-lowering, antibacterial, insecticidal, antifungal, antitumoural, antimicrobial, antibiotic, anticancer, *etc.* Many secondary metabolites are being used as curative drugs.

Though most spices benefit human health, some are exceedingly useful both as curative medicines and nutraceutical agents. Such spices include black pepper, long pepper, garlic, turmeric, ginger, black cumin, rosemary, and wasabi. Apart from the curative properties, spices are, in fact, more significant as nutraceuticals. Many spices can contribute to human wellness by avoiding many ailments, including lifestyle diseases.

In the last few decades, several health-beneficial effects of spices (both curative and preventive) have been experimentally documented, which suggests that the use of spices extends beyond taste and flavour for which they have been used universally from ancient times. The emerging research from in vitro and animal studies has given excellent positive indications that spices can be used as nutraceuticals to prevent many human ailments. Spices' preventive (as well as curative) benefits include digestive-stimulant action, anti-atherogenic and cardioprotective potential, anti-lithogenic properties, antidiabetic influence, anti-inflammatory properties, and cancer-preventive potential. Many spices possess strong anti-oxidative effects, which are particularly important for preventing oxidative stress, thereby preventing the onset of degenerative diseases such as cardiovascular disease, neurodegenerative disease, inflammatory disease and cancer. Spices deserve to be the essential ingredients of our daily diet. Especially worth mentioning are the cancer-prevention properties of spices, and diverse mechanisms are proposed for such anticancer properties. Spices are taking on this new role as nutraceutical, beyond imparting taste, flavour and colour to our food.

Spices and their phytochemicals fight chronic diseases of humans by influencing the actions of a variety of cellular molecules such as interleukins, cytokines, chemokines, enzyme proteins, effectors, transcription factors, signalling pathways, and so on, and they, in turn, lead to the down-regulating or up-regulating the cellular functions. A summary of such events taking place in a cell facing a disease condition is discussed in this presentation.

Of the many phytochemicals of spices, a few are often considered superior in their health benefits, and they can be termed as 'master molecules of spices. This presentation looks at four such health-giving and health-promoting nutraceutical phytomolecules, namely, (1) piperine from black pepper and long pepper, (2) gingerol from ginger, (3) curcumin from turmeric and (4) garcinol of kokum (and other species of Garcinia). The above master molecules are briefly discussed in the light of the current knowledge of the mechanisms involved in their actions and their mode of protection offered to the biological systems, cells, animals, and humans.

Piperine is an aromatic alkamide, showing diverse biological activities such as antioxidant, anti-inflammatory, analgesic, antiplatelet aggregation, antihyperlipidemic, antihypertensive, cytoprotective, antitumor, antimicrobial, hepatoprotective and antidepressant activities. The structure of piperine resembles that of capsaicin, the pungent component in most chilli pepper species. Like capsaicin, piperine also serves as a natural agonist of the vanilloid receptor (TRPV1 channel), which is involved in the neurotransmission of thermal and nociceptive stimuli. The cellular targets of piperine include anti-apoptotic factors, cell-cycle proteins, inflammatory cytokines, enzymes, kinases, transcription factors, ion channel proteins, transporter genes, and others like microRNAs. Piperine is an inhibitor of cancerous tumours. It is a potent inhibitor of cancer stem cells" (CSC's) self-renewal - through its inhibitory influence on the signalling pathways controlling cell division and differentiation. Piperine blocks angiogenesis in breast carcinoma singcraft by inhibiting VEGF (vascular endothelial growth factor) expression. Piperine inhibits the development of breast stem cells, inhibiting mammosphere formation (directly involved in the initiation of breast cancer). Piperine reduces breast cancer cell proliferation- angiogenesis, and metastasis.

6-Gingerol from ginger has multiple effects on cellular machinery; it has suppressing or inhibitory action on many cellular conditions, leading to anti-allergic, analgesic, anti-emetic, anti-nausea, anticancer, etc. effects. It is antipyretic, cardiotonic, gastro-stimulant, digestive, and so on. In Ayurveda, it is one of the *maha oushadhis* (Great medicines). Gingerol impacts transcription factors, enzymes, inflammatory mediators, protein kinases, drug resistance proteins, adhesion molecules, growth factors receptors, cell-cycle regulatory proteins, cell-survival proteins, chemokines, and chemokine receptors. 6-gingerol / 6-shogaol targets several cellular molecules contributing to tumorigenesis, cell survival, cell proliferation, invasion, and angiogenesis.

Curcumin of turmeric is a multi-targeted molecule, impacting many target molecules in normal and cancer cells. It is a DNA-protectant, hepatoprotective, lipase promoter, NO-scavenger, P450 inhibitor, protease inhibitor, protein kinase-C-inhibitor, protein tyrosine kinase inhibitor, quinine reductase inducer, radioprotective, topoisomerase I&II-inhibitor *etc.* Curcumin has multiple effects on molecular targets in cancer cells. Cellular targets of curcumin include transcriptional factors, growth factor and growth factor receptors, protein kinases, adhesion molecules, enzymes, inflammatory cytokines, apoptosis-related proteins *etc.* Curcumin impacts many signalling pathways and several targets in cancer cells. Curcumin suffers from significant drawbacks, such as low solubility, poor absorption, and rapid disintegration in the human gut. As a result, biologically effective levels of curcumin will never reach in cells in the normal course of the spice use. The alternative is using highly solubility, stability, and bio-availability derivatives. Many such formulations are now available in the market. A notable one is the Cur-Alb, a fibrin–water wafer impregnated with curcumin-albumin complex developed at the Sree Chithira Thirunal Institute of Medical Sciences and Technology at Trivandrum, which is to be implanted surgically at the site for sustained release of curcumin for an extended period. All evidence strongly indicates that curcumin cannot be manipulated in any way to produce a viable, effective drug.

The lecture's last part is devoted to kokum and related Garcinia species, as well as the critical phyto-molecule **Garcinol.** Garcinol is a natural polyisoprenylated benzophenone derivative (prenylated chalcone (a benzophenone central core with two isoprene side chains). It has many biological properties such as antibacterial, antiseptic, diuretic, emetic, laxative, toxic, protisticide, sternutator (agent that causes sneezing), vermifuge, anti-carcinogenic, *etc.* It is reported to be effective in the management of colorectal cancer. In Colorectal cancer cases, garcinol increased apoptosis and cell growth inhibition, inhibition of angiogenesis and invasion, and inhibition of DNA repair. Garcinol is a histone acetyltransferase (HAT) inhibitor possessing antioxidant, anti-inflammatory, and neuroprotective properties. It can alter the neurochemical status in the brain and regulate memory and cognition. Increasing evidence of altered histone acetylation in the Parkinsonian brain strongly supports the use of the HAT inhibitor, garcinol, in the management of Parkinson's disease. Although this is a promising molecule in terms of its anticancer and anti-Parkinson disease properties, investigations in relevant pharmacological and clinical studies are essential to confirm the clinical effectiveness of the compound. Garcinol is also reported to be effective in preventing oxidative stress-related bone marrow mesenchymal stem cell (BMSC) damage and bone loss through the NRF2-antioxidant signalling, and hence potentially valuable for the treatment of oxidative stress-related bone loss such as osteoporosis. Future studies on synthesising therapeutically potent

Garcinol analogues and their evaluation for efficacy and safety will go a long way in managing difficult-to-treat diseases like cancer, Parkinsons and Alzheimer's.

The overall conclusion is that spices, in general piperine, gingerol, curcumin, garcinol, and many other active ingredients of spices, result in the suppression (down-regulation) of many groups of target molecules in the cells such as cell growth factors, carrier protein molecules, transcription factors, enzymes, cytokines, protein kinases, receptor proteins, and many others like glutathione, Beta-amyloid, survivins, and so on. Curcumin and garcinol are also useful in preventing microbial infections (including viral infections like Coronavirus).

The takeaway point is that some spices are good as nutraceuticals. They have multi-targeted effects on cell systems. When used as spices, the concentration of active ingredients may be too low to be effective. Nutraceuticals are not substitutes for medicine or food; they are only preventive and not for curing serious health problems. They help us have a sound body and mind and a healthier life. Use them judiciously.

Abstracts

Lead Lectures

LL-1

Seed spices in combating climate change in arid and semi-arid regions

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Seed spices are indispensable to sustaining agriculture and rural livelihoods in arid and semi-arid regions due to their adaptability, resilience, and economic value. These high-value crops, including cumin, coriander, fennel, fenugreek, and others, thrive in marginal soils with minimal inputs, making them ideal for challenging environments. India, as the largest global producer and exporter of seed spices, contributes over 70% of essential spices like cumin and coriander. With primary cultivation in Rajasthan, Gujarat, and Madhya Pradesh, the seed spice sector has expanded rapidly, fuelled by domestic and international demand. From 1980 to 2019–20, cultivation area grew from 4.96 lakh hectares to 20.52 lakh hectares, production increased from 2.48 lakh tons to 9.62 lakh tons, and productivity doubled to over 1,049 kg/ha by 2023–24. These crops now account for 43.61% of India’s total spice cultivation area and 18.46% of total spice production.

Resilience of Seed Spices to Climate Extremes

Seed spices like cumin, coriander, fennel, fenugreek, and nigella play a vital role in addressing the challenges posed by climate change in arid and semi-arid regions. These crops are naturally adapted to harsh climatic conditions, including high temperatures and water scarcity, making them ideal for regions like Rajasthan and Gujarat (Figure 1). Their ability to thrive in low-humidity environments and marginal soils provides a sustainable solution for agriculture in fragile ecosystems.

With their efficient water-use capabilities, seed spices are well-suited for cultivation in water-limited areas. Crops such as cumin and coriander utilize shallow root systems to maximize limited soil moisture, while fenugreek and fennel access deeper soil nutrients with their extensive root systems. Modern irrigation techniques like drip and sprinkler systems further enhance productivity by delivering water directly to the root zone, minimizing wastage. Rainwater harvesting and advanced irrigation methods can strengthen the climate resilience of seed spice farming, ensuring sustainable agriculture and improved farmer incomes in vulnerable regions.

Seed spices have the potential to enhance climate-resilient agriculture, with over 20 varieties developed focusing on traits like higher yield, resilience to abiotic and biotic stresses, and other essential attributes. Notably, Ajmer Coriander-1 has been introduced as a climate-resilient variety specifically designed to combat stem gall disease. The coriander variety NRCSS ACr-1 is considered superior in comparison to other varieties due to its higher yield and better tolerance to stem gall disease. This variety has been developed specifically for its resistance to the disease, which commonly affects coriander crop, ensuring more consistent and higher production. Its improved disease tolerance allows for reduced crop loss, making it a more reliable choice for farmers in regions where stem gall disease is prevalent.

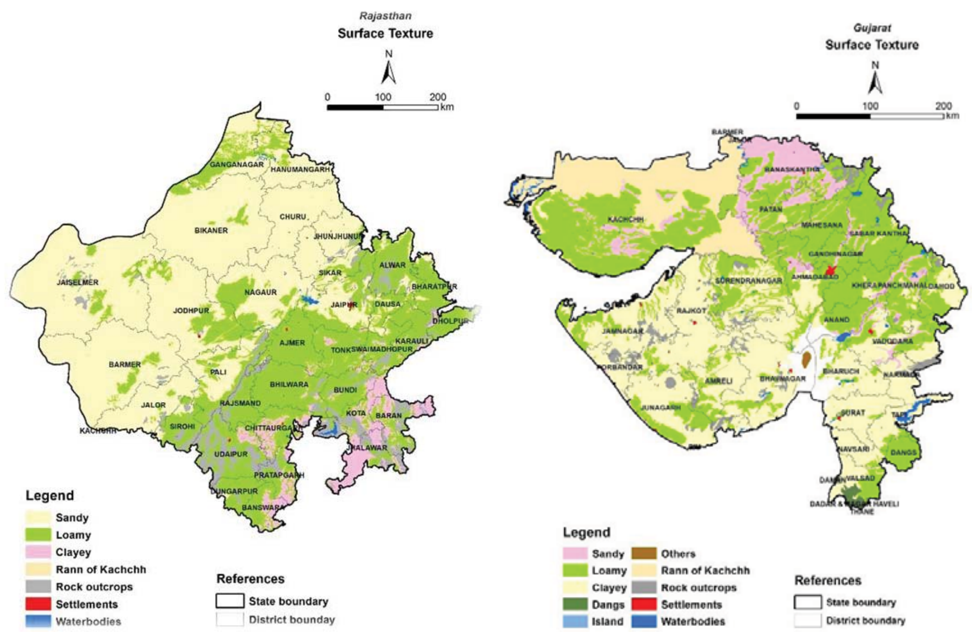

Figure 1: Soil texture of Rajasthan and Gujarat (source: ICAR-NBSS&LUP, Nagpur)

Livelihood Security and Economic Benefits

Seed spices provide a stable source of income for farmers in arid and semi-arid regions. Their high market value and export potential contribute significantly to rural livelihoods. Furthermore, the cultivation of seed spices supports agro-industry development, creating opportunities for value addition, employment, and economic diversification in these regions. In 2021, the global spice export market was valued at USD 13.79 billion, with India contributing USD 4 billion (1.76 million metric tons). This represents 40% of the global spice trade volume and 12% of its value (Spices Board, 2023). In 2020, India produced 11.04 million metric tons of spices from 4.48 million hectares, out of the total 15.82 million metric tons produced globally across 123 countries.

Redefining R&D in Crop Improvement of Seed Spices

Enhancing genetic diversity and breeding efficiency: Advancing seed spice crop improvement requires a blend of traditional and modern technologies. Approaches like sexual hybridization, marker-assisted selection (MAS), and genome editing (e.g., CRISPR/Cas9) are essential for developing superior traits such as yield, stress resilience, and essential oil quality. Mutagenesis and tissue culture techniques further enrich genetic variability, overcome hybridization barriers, and expedite the creation of true-breeding lines. Incorporating genomic selection (GS) and precision genome editing alongside speed breeding can significantly reduce breeding cycles from 10–12 years to 7–8 years, accelerating genetic advancement.

Accelerating breeding with speed breeding and area expansion: Speed breeding, using controlled environments or off-season cultivation in high-altitude regions like Leh, offers a game-changing opportunity to fast-track crop improvement. Simultaneously, expanding seed spice cultivation to non-traditional regions such as Odisha, Telangana, and the North-Eastern Hill (NEH) areas is a promising avenue due to favorable climates and high cost-to-benefit ratios. By integrating these innovative strategies, India can enhance seed spice productivity, resilience, and global competitiveness, ensuring sustainable growth in both domestic and export markets.

Conclusion

Seed spices are pivotal to achieving sustainable agriculture in arid and semi-arid regions, particularly in the face of escalating climate change challenges. Promoting their cultivation empowers policymakers, scientists, and farmers to enhance agricultural resilience and improve livelihoods. The integration of advanced genetic tools such as WGS, GWAS, CRISPR-Cas, and genomic selection offers immense potential for accelerating genetic improvements in seed spices. Strategic investments in developing and disseminating climate-resilient practices for these crops will lay the foundation for a more sustainable and secure agricultural future.

LL-2

Harnessing genetic and genomic approaches for superior spice varieties

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Spices are high value and low volume, export-oriented commodities, which yield aromatic and pungent principles commonly used for flavouring and seasoning of food and beverages. Spices also constitute a major portion of medicinal plant wealth of India and are widely used in indigenous medicines. India produced 11.8 million tons of spices from an area of 4.76 million hectares during 2023–2024 and accounts for 40% of global spice production (Spices Board, 2024). India plays a major role in spices export trade globally. In 2023-24, India exported 1.54 million tonnes of spice worth 4.46 billion USD.

Issues in spices breeding

Development of improved cultivars by spice crop breeders may require many breeding cycles and dozens of years because of perennial nature (black pepper, cardamom, and tree spices). Other major issues in spices breeding are polyploidy (turmeric), incompatibility, and sterility (ginger). Like other sectors of horticulture, the spices also face highly dynamic situations arising from such factors as decreasing labour availability, increasing environmental concerns, cost of energy, climate change and epidemics of new and invasive insects and diseases. The generally reactive nature of response to these factors translates to the release of new cultivars only after such pressures have accumulated significant impact on production.

In a typical plant biochemical pathway, a single precursor synthesizes multiple metabolites. So, the presence of a precursor does not assure the synthesis of any specific metabolite (Dixon et al. 2006). Several plant biochemical pathways crosstalk for effective regulation of cellular processes in an organism. A product of one pathway becomes the precursor or intermediate substrate for another pathway. Furthermore, a single enzyme affects several biochemical pathways. Therefore, a single point mutation could lead to significant changes in a metabolome (Newell-McGloughlin 2008). Alteration in one pathway could potentially change the flux in non-target metabolites (Davies 2007).

Quality-enhancing metabolites are often governed by quantitative trait loci, and epistatic interactions make a major contribution to these phenotypic variations (Fernie and Schauer, 2009). The diversity in quality- enhancing metabolites in plants not only comes from genes, but also from divergent, substrate- specific enzymes and sub-cellular, non-enzymatic activities (Hall *et al.* 2002).

Plant genetic resources of spices

Plant genetic resources are the building blocks upon which global food and nutrition security depend as well, they are key to any plant breeding programmes. Collection and conservation of genetic resources of spices assumes priority in view of the changing climatic and edaphic factors, depletion of forest areas, wide spread use of few cultivars *etc*. Presently, 16775 germplasm accessions of major spices are being maintained in the field gene banks of NARS in India (ICAR-IISR 2023, ICAR-NRCSS 2023, ICAR-AICRPS 2023).

Way forward

- High-throughput phenotyping platforms can enable rapid and non-destructive assessment of underground rhizomes, improving the evaluation of key traits such as yield, dry recovery, and curcuminoids content.
- Artificial intelligence-based sensor systems can streamline data recording, integrating real-time environmental monitoring with phenotypic data collection, which is particularly useful for managing environmental variability during trials.
- Large scale genotyping using advanced molecular markers (SNPs and SSRs) to assess genetic diversity and identify duplicates. This will also help to identify unique traits among spices varieties.
- Application of genotyping-by-sequencing of available germplasm to discover desirable donor and economic genes.
- Genome-wide association studies may also help in allele mining and gene discovery.

Crop improvement in spices

Pre-breeding refers to all activities designed to identify desirable characteristics and/or genes from unadopted materials that cannot be used directly in breeding populations and to transfer these traits to an intermediate set of materials that breeders can use further in producing new varieties for farmers. It is a necessary first step in the use of diversity arising from wild relatives and other unimproved materials. Conventional methods have been employed in evolving high yielding varieties of spices. The research efforts of NARS so far resulted in the release of 190 improved varieties of spices (ICAR-AICRPS 2024).

Controlled environment production systems are gaining attention for yield and quality enhancement in spices. These systems focus on growing high-value specialty crops due to the high initial investment, which is needed to meet the demands of the crop and be profitable as well. Breeding for controlled environments shifts the focus to a completely distinct set of plant traits, such as rapid growth, performance in low light environments and active manipulation of plant stature. Instead of breeding for phenotypic stability, genotypes need to be bred to maximize its genetic plasticity, allowing specific traits to be presented as a function of the quality of the ambient light spectrum. In this scenario plant varieties may be grown with optimal size, supporting a focus on consumer traits like colour, phytoconstituents and volatile compounds or accumulation of health-related compounds. Raghuveer et al. (2024) observed significant variation among 21 turmeric genotypes across three different production systems in terms of yield, dry recovery, oleoresin, essential oil, and curcuminoids. CIM Pitambar, Acc. 849, Acc. 214, and IISR Pragati demonstrated superior fresh rhizome yield per clump under vertical structures. IISR Pragati performed well in both under greenhouse and field condition.

Metabolomics-assisted breeding, in conjunction with genomics and proteomics, offer such tools for nutraceutical breeding. Techniques, such as, mass spectrometry, nuclear magnetic resonance spectroscopy, chromatography, etc., have been utilized to study the impact of time, stress, and environmental conditions and to analyse hundreds of metabolites simultaneously (Dixon et al. 2006). Instead of monitoring a single putative bioactive metabolite, hundreds of biosynthetically related metabolites and enzymes could be analysed by metabolic profiling, which in turn could be used to develop stable genotypes for nutraceutical cultivars.

Way forward

- Recombination breeding programs hold significant potential for some of the clonally propagated spice crops. Also, proper study into incompatibility mechanisms and production of inbred progenies may help in developing desirable recombinants and heterotic hybrids.
- Need to develop a model ideotype that embodies the most desirable characteristics for yield, quality, and resilience.
- The utilization of wild relatives can be enhanced through pre-breeding programs that overcome sterility barriers, incorporating valuable genetic diversity into elite lines.
- Advanced genotyping techniques, such as next-generation sequencing and SNP arrays, can accelerate the identification of genetic markers associated with desired traits, even in a complex polyploid genome. Genomics-assisted breeding, incorporating tools like genome-wide association studies (GWAS), can enhance genetic gains by targeting polygenic traits such as curcuminoids, disease resistance and abiotic stress tolerance.
- To combat diseases and pests, integrating resistance breeding with microbiome engineering and developing bio-pesticides can offer sustainable solutions.
- Aligning breeding objectives with suitability of genotypes for organic farming, adaptability to controlled environment production, and vertical farming, while fostering collaboration with the industry to ensure the rapid deployment and adoption of new varieties.
- Breeding for nutraceuticals needs metabolic screening and therefore, integration of metabolomics with traditional breeding is needed for releasing new cultivars with nutraceutical properties. Modified breeding programs could reveal the hidden biochemical variation for targeted crop improvement and better-quality products.

Biotechnological approaches

Various biotechnological approaches have great significance in conservation, utilization and increasing the production and productivity of spices. Protocols for micropropagation and commercial production of disease-free planting materials are available for many spices. Efficient plant regeneration protocols are also available for exploiting somaclonal variation especially in crops like ginger, turmeric and vanilla where the available natural variability is relatively low. Synseed and micro-rhizome technology is also available for many spices for propagation, conservation, movement, and exchange of germplasm. *In vitro* and cryo preservation technologies for conservation of spices germplasm are available for many spices.

The use of molecular markers in traditional plant breeding is increasing rapidly. Molecular markers are being used for genotyping, finger printing, molecular taxonomy, identification of duplicates, hybrids, estimation of genetic fidelity of micropropagated and *in vitro* conserved plants in many spices. The identification of new molecular markers for quality traits requires a thorough understanding of the biochemical basis of intricate pathways for metabolites. The integration of metabolomics with genomics will provide new molecular markers of quality traits for marker assisted selection in existing breeding programs. Transcription factors play a major role in secondary metabolite biosynthesis and offer new hope for nutraceutical breeding through their integration into marker assisted breeding (Newell-McGloughlin 2008).

Genome-wide association study *(GWAS)* has emerged as a powerful technique to dissect the molecular basis of complex traits in crop plants including non-model crops. The high quality 30438 SNPs filtered based on < 10% of missing data and > 5% of minor allele frequency obtained from ddRAD based genome sequencing of 51 turmeric genotypes were utilized for association analysis (Aswathi *et al.* 2023). The analysis has resulted in the identification of nine significant MTAs (marker-trait associations) for the three phenotypic traits. The number of significant MTAs per trait were as follows: curcumin content (1), rhizome length (5) and rhizome girth (3).

High performance *de novo* transcriptome assembly based on in-depth sequencing provides an opportunity for genome-wide gene expression analysis of disease resistant and secondary metabolites pathway genes, which is particularly useful to study spices. Transcriptomics and proteomics were applied to understand the plant response to major biotic (*Phytophthora*, *Piper yellow mottle virus* in black pepper, cardamom mosaic virus in cardamom, *Ralstonia* in ginger), abiotic (drought in black pepper, cardamom) stresses. George *et al.* (2021) identified the entire terpene synthase family responsible for the biosynthesis of the flavor-imparting volatiles in black pepper berries using a combinatorial approach, the berry hybrid transcriptome assembly of llumina and nanopore sequencing. Also, identified the transcripts related to biosynthetic pathways of several anti-cancer compounds like taxol, curcumin, and vinblastine in addition to anti-malarial compounds like artemisinin and acridone alkaloids, emphasizing turmeric's importance as a highly potent phytochemical (Annadurai *et al.* 2013). In ginger, five genes associated with gingerol biosynthesis were identified as being significantly differentially expressed in the rhizome at an early developmental stage (Jinag *et al.* 2018).

Spices being non-model crops have been schemed out of sequencing projects earlier, due to high running cost of Sanger sequencing. However, the advent of fast and cost-effective next generation sequencing (NGS) platforms in the recent past has enabled the unearthing of certain characteristic gene structures unique to these species. It has also aided in gaining insight into mechanisms underlying processes of gene expression and secondary metabolism.

All ortologous gene sequences involved in alkaloid and piperine biosynthesis in black pepper were captured from comparative genomics analyses, and corresponding gene functions were verified by searching the published literature and the NCBI and UniProt databases (Hu *et al.* 2019). Based on the results of ginger genome sequencing, transcriptome analysis, and metabolomic analysis, backbone biosynthetic pathway of gingerol analogues consisted of 12 enzymatic gene families, *PAL*, *C4H*, *4CL*, *CST*, *C3'H*, *C3OMT*, *CCOMT*, *CSE*, *PKS*, *AOR*, DHN and *DHT* were identified (Li *et al.* 2021).

Way forward

- Pangenome sequencing of turmeric offers a promising approach to understanding the genetic basis of important traits, including curcumin content, disease resistance, and environmental adaptability.
- By identifying structural variants through the comparison of multiple genomes, researchers can uncover the genetic diversity that contributes to these traits. This can lead to more efficient breeding programs, the development of improved cultivars, and better conservation of turmeric's genetic resources.
- Existing genomic information must be exploited for development of novel molecular markers and marker-trait association.
- A comprehensive whole genome sequencing aimed to high-quality, haplotype-resolved chromosome-level genome assembly of cultivated spices should be developed.
- Conducting T2T sequencing will provide a complete reference genome of turmeric. This will help researchers to explore the genetic makeup in its entirety, including regions that influence traits like curcumin content, disease resistance, and stress tolerance.
- The utilization of cisgenics could help overcome the limitations of conventional breeding and contribute to development of disease-resistant, high-yielding, and more nutritionally enriched varieties.

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LL-3

Water management strategies for *enhancing* crop production in the changing climate

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Introduction

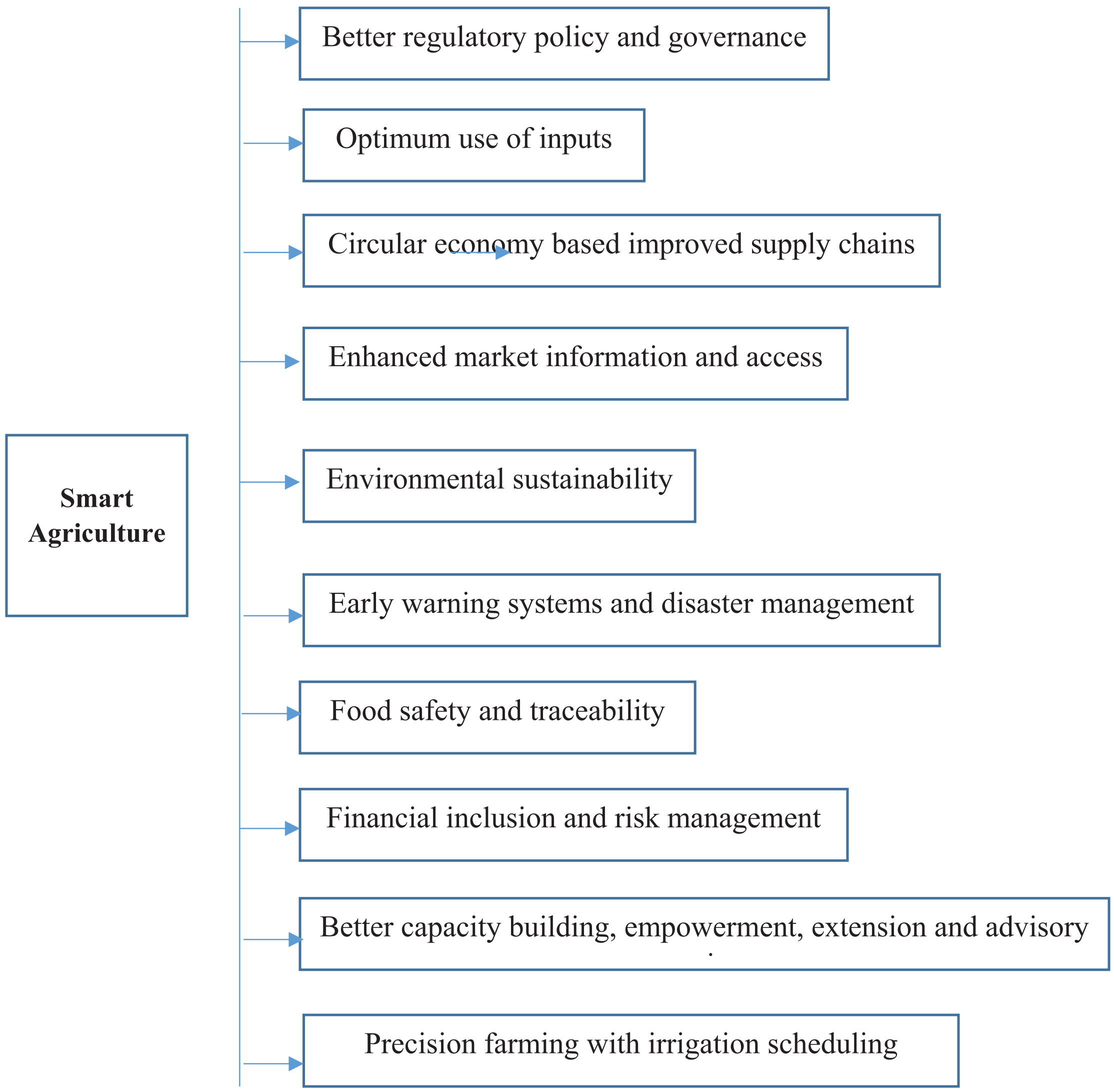
Agriculture in India is transforming in a faster rate. The strategy of grow more at any cost has been converted to sustainability in production. Climate change is generally emerging as a major threat to farm production and it induces forceful changes in rhythm of agricultural practices and thereby disturb the crop calendar. Water, being the most important input in farming either became scarce or excess necessitating drainage during critical crop seasons and subsequently leading to crop loss. Not only water, the function of most of the actors along the supply chain is related to the climate change. Apart from climate change, many factors such as the changes in land use pattern, availability of farm laborer, demography, migration, soil fertility, policies *etc.* affect the agricultural production and productivity. Increasing emission of green house gases (GHG) from agriculture and animal farming raise concerns. However, all these constraints can be managed in a better way using advanced technological solutions, tools and platforms.

Technology driven smart management of agriculture

When talking about modern farming technology, we have to acknowledge the role of information and communication tools and advanced IT platforms as a decision support system for farmers. Artificial intelligence, analytics, connected sensors, geo-spatial products and other emerging technologies could further increase yields, improve the efficiency of water and other inputs, and build sustainability and resilience across agriculture.

Modern information tools have largely revolutionized the way people, governments, and businesses function in the modern world. Close to 60% of the global population has access to the internet, and mobile phone is now the most widely-used channel for internet access worldwide. This transition has facilitated better communication and ensured the delivery of services and information to people who previously lacked access. If connectivity is implemented successfully in agriculture, the industry could have $500 billion in additional value to the global gross domestic product by 2030 (Goedde *et al.* 2020).

The infusion of new, advanced agriculture technologies has allowed the global agriculture sector to surge ahead and transform the way the producers cultivate, harvest, and distribute agricultural commodities. Smart agriculture with the use of advanced IT tools and platforms can be applied anywhere and at any time along the value chain (Figure. 1). It makes the process much simpler as well as faster and ensures better quality of the end product while assuring better price to the producers. The use of technology in Indian agriculture has particularly revolutionized smallholder agriculture and has helped to address several challenges associated with the traditional form of agriculture.



The agricultural scenario today requires the integration of sophisticated technologies such as temperature and moisture sensors, robots, GPS technology, and aerial images and geo-spatial data, hyper spectral sensing and many more. Such digital farming technologies help the rural farmers towards accessing effective production strategies, banking and financial services, and real time market information.

In many countries, ICT in agriculture provides farmers with vital information pertaining to sowing, crop protection, and improving soil fertility that enables them to improve agricultural productivity. Weather-related advisories and alerts help them prepare for sporadic events such as floods, drought, or even pest and disease outbreaks, thus preventing significant crop loss. The Water Resources Information System portal developed by State agencies provides dynamic details of weather, surface water, groundwater, reservoir operations, canal flow, soil moisture, water quality and all other relevant and required information on water in the respective States.

The use of ICT in modern agriculture technology has also significantly transformed agriculture and farming in developed countries at a different scale. Internet of Things (IoT), Cloud Computing, ML, Deep learning, Hierarchical systems and Big Data have all had a profound impact on the efficiency of current processes. Several farmers in US and Europe manage their farms remotely using sensing technologies, drones, and other devices that gather vital data on soil properties, air, crop health, and weather conditions.

FATIMA (FArming Tools for external nutrient Inputs and water MAnagement) is one of the joint research efforts which used the earth observation data in order to monitor and manage the agricultural resources in a more effective and efficient way. The project was funded by the European Commission under the Horizon 2020 programme of research and innovation. It is a multi-national project with 9 active participating countries. In the project, satellite data from Landsat-8 and Sentinel-2 sources were used to monitor pilot plots where various crops have been traditionally cultivated. In the process of 3 years in the project, each harvest provided new outputs about forecasting crop water requirements (CWR) and crop yield variability (Cordis 2023). OpenET platform avaliable in western states of USA provide easily accessible satellite-based estimates of evapotranspiration (ET) for improved water management across the western United States. Browsing the website openetdata.org, users can explore ET data at the field scale for millions of individual fields or at the original quarter-acre resolution of the satellite data (Melton *et al.* 2021).

All available spatial, temporal and physical data should be scouted, processed and analyzed in such a way that some user-friendly products and deliverable are developed and made available to the farmers. These products can be in the form of a DSS, expert system, Mobile App, Web based tool, url, GuI or anything. It should ultimately enable the farmers and agribusinesses to closely monitor the crop cultivation inputs and practices, optimize the use of agrochemicals and natural resources, and adapt quickly to changing environmental conditions.

IoT, in particular, has several applications in agriculture, from real-time monitoring of soil, plant, and animal health using in-situ sensors to tracking the origin of a product or agri-commodity and its environmental impact, as well as its storage environments along the supply chain. In near future sensors and machines will be developed, based on in-built AI and data analytics capacity, which is capable of self-optimizing and initiating activities on their own, without much human intervention. The self-managed precision farming systems with Agrobots can revolutionize the future farming.

India's water woes and opportunities

The total utilizable water resources in India including both surface and groundwater resources is 1123 BCM and country's average annual demand is about 840 BCM (Gupta and Deshpande 2004). However, the projections show an increase in demand to the tune of 1200 BCM by 2050 and this may lead to water crisis (CWC 2012). The demand-supply paradigm of water in India shows the trend of narrowing the gap between the supply and demand with shrinking supply with increasing demand. Though half of the agricultural area is rainfed and without access to irrigation, the sector uses close to 90% of the total water used in the country. Further, the groundwater table show small to very high decline in 36% of the blocks mainly due to water withdrawal exceeding water recharge (Chand 2022). In the irrigated agriculture sector conventional irrigation practices prevail. Overall efficiency of Canal Distribution Network in India is only about 35-50% (Madhok 2020) and there is ample scope for improve the water distribution and use efficiency so that the total water demand in the country can be brought down.

Marginal increase in supply is possible by means of rainwater harvesting, reuse and recycling of grey water etc., but it may not be in match with the rapid increase in water demand by different sectors, including agriculture, drinking/domestic, industrial, recreational/tourism, inland fisheries etc. Improving water use efficiency or enhancing agricultural water productivity is a critical response to growing water scarcity, including the need to leave enough water in rivers and lakes to sustain ecosystems and to meet the growing demands of cities and industries (Drechsel *et al.,* 2015). Agricultural water productivity is the ratio of the net benefits from crop, forestry, fishery, livestock and mixed agricultural systems to the amount of water used to produce those benefits (Molden and Oweis 2007). The agricultural water productivity can be improved by means of reducing losses while diverting, distributing and applying water to the crops. Adaption of modern tools and technologies for scheduling and optimizing water application is also important.

Managing land and water- Novel approaches

Land and water are among the most important of all natural resources, hence maintaining these resources are essential for sustainable development specially to sustain the agricultural productivity. Land and water are vital resources in urban, agricultural, and natural ecosystems.

The availability of water has become unpredictable with the disruption in weather pattern due to climate change. Proper understanding and modelling of climate variability are essential for efficient and sustainable utilization of water resources. Under rapidly changing environment, sustainable water management through targeted research on each sphere of soil: plant: water continuum is essential and to increase food production through enhancing water productivity, identifying adaptation needs and addressing the challenges and research directions in water management in humid tropics are of great importance.

The productivity of most of the crops is low in many parts of the country, when compared to the national average. Lack of irrigation and low fertile lateritic soils are some of the important factors contributing to this low productivity. These are coupled with the serious unresolved problems such as high labour charges and high cost of cultivation and due to this, the farming community is in a deplorable plight. The country faces the challenges of both increasing farm productivity and increasing sustainability and resilience to climate change. Effective government intervention based on modern tools and technologies, with people's participation is the need of the hour to save the grave crisis faced by farmers.

One of the major factors which affect the production and productivity of agricultural crops is crop water management. In view of increasing water demand and shrinking supply, the only way to ensure sustainable agricultural production is to enhance the water use efficiency.

The efficiency of conventional irrigation systems is less and hence there is a need for greater awareness among the farming community to adopt new practices including micro-irrigation systems. Institutional innovations coupled with novel practices and technologies in irrigation sector is the need of the hour. The water conveyance, distribution and application efficiencies in traditional systems of irrigation are also to be improved. Community management of water resources, participatory irrigation systems, recycling of grey water for irrigation, pollution management of water resources etc. are also vital for productivity enhancement of crops. New approaches and technologies like water budgeting of major crops in various agro-climatic-ecological zones, AI/ML/Sensor based irrigation scheduling, automated irrigation, conjunctive use of surface and groundwater, climate smart irrigation, and drought proofing models are to be linked to the irrigation planning and operations.

Community-based micro-irrigation systems can be introduced to agricultural areas that were earlier under rainfed agriculture and faced crop failures due to scanty rainfall. The introduction of micro-irrigation systems would help to bring down pressure on groundwater resources, enhance the yield and quality of the produce and reduce the farm energy and fuel consumption, leading to considerable reduction in green house gas emissions.

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LL-4

Prosperity through sustainable cultivation of medicinal and aromatic plants

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India has a lot of potential to become a global leader in the market for medicinal and aromatic plants (MAPs). Our country is a treasure trove of medicinal and aromatic plants, owing to its rich biodiversity, and a gold mine of medicinal knowledge. It is the second largest exporter of medicinal plants, next to China, in the world and a host to more than three hundred thousand herbal medicine preparations used in ancient healing systems such as Ayurveda, Unani and Homeopathy. In India, a major volume of medicinal herbs come from wild sources. Unsustainable harvesting practices of medicinal plants from the wild often result in rapid degradation of the natural biodiversity and poor regeneration capacity. This in turn affects the production and supply of medicinal plants from forest areas and the quality of the raw materials. An all-encompassing solution lies in cultivating these plants outside forest areas and as a part of existing farm lands. This would also enable farmers and farming communities to enhance their income and livelihood through crop diversification with the high-value medicinal plant species.

Quality management

The quality of herbal medicines depends on the quality of the raw material used in the preparation and has a direct impact on their safety, efficacy and market price. Presently, the most of the MAPs are being collected from the wild and do not meet the required quality standard often due to heterogeneous nature of raw drug. Authentication of raw drugs of MAPs for ensuring quality, fixation and monitoring the quality (active compound, nutritional value, pesticide residue and heavy metal contamination) of MAP produce, use of high technology oriented advanced hyphenated analytical techniques are providing promising leads. Establishment of safe waiting period/pre harvest interval (PHI) for the pesticides recommended for control of pests on MAPs as per Good Agricultural Practices (GAP), fixing of limits for the presence of contaminants in the market produce of MAPs, developing chemical fingerprinting for individual species to avoid adulteration and certification of MAP produce complying World Health Organization (WHO) GAP and good agricultural and collection practices (GACP) guidelines play role in ensuring the quality of raw drugs.

Marketing

Demand for medicinal and aromatic plants is increasing worldwide, and the bulk of the material trade is still from wild harvested sources on forest land and only a very small number of species are cultivated. The supply and demand of MAPs is narrow leading to fluctuation in the market price. Collectors, processors and traders are unable to find favourable markets due to price factors, quality and quantity considerations. Lack of current market and price information affect the income of the actual local collectors or cultivators who are dependent on the middlemen or village traders. There is need for demand and supply assessment of major MAP species and development of easily accessible market information system for their promotion.

Post-harvest management and mechanization

Post-harvest management and mechanization play important role in ensuring the quality of the raw drugs of MAPs. Optimization of harvesting time, drying, sorting, grading, packaging, transportation systems and storage facilities for MAP are essential to avoid deterioration and to enhance the shelf life of the MAP produce. Emphasis should be given to the development of post-harvest infrastructure for MAP crops. Value addition of different MAP enhances quality and efficacy of raw drugs intern bring premium market price. Systematic approach is needed in mechanization of different cultivation operations in MAPs help in reducing the cost of cultivation. Efforts should be made in byproduct development from processing waste and incorporation of MAPs as functional foods.

Knowledge management

Traditional knowledge (TK) is the knowledge that an indigenous community accumulates over generations of living. TK associated with MAP is considered as an important asset inherited through generations by the local communities. A part of this knowledge is recorded in local languages and a major portion is still not recorded and remains confined to local communities. Preserving and disseminating information on TK associated with MAP is needed for the posterity.

Constraints in the production and marketing of MAPs

Lack of technical knowledge and awareness for increasing oil recovery from the crop, low price in the market, and lack of storage and market facilities near the production area of the crop are important constraints. The mint crop is highly sensitive to lower and higher temperature. Lack of processing and value-added facilities are major constraints reported by 80 per cent of the mint growers. Lack of information, high cost of input, lack of supply of electricity, and a regulated market are the major problems faced by farmers. Lack of proper marketing information, pest and disease problems, higher cost of cultivation, and fluctuation in market price, low price are major challenges faced by producers during the crop production and marketing phase. Lack of a minimum support price, lack of a regulated and organized market are also constraints in smooth cultivation of MAPs. To understand the farming system and the success of the value chain of the plants, a thorough financial feasibility and technical study are required in this sector. The widespread price difference is found to be the most important marketing problem in most of the MAPs (*eg*. Vanilla, mentha, patchouli, chamomile, lemongrass, palmarosa, tulsi *etc*.) production. Most of the farmers feel that lack of a minimum support price, lack of subsidies, lack of good credit facilities and shortage of human labour during peak season are major challenges faced by them which inhibit the growth in this sector. Supply chain management, consultancy, processing, and trading are the major areas for entrepreneurship in the medicinal and aromatic plant sector which need to be boosted. Marketing, poor knowledge of the package of practice, and inadequate domestication are important issues for medicinal and aromatic plant cultivators which need to be looked into for sustainability in medicinal and aromatic plants cultivation.

Important recommendations for MAPs' sustainable cultivation

- Finger printing and geographical indicators of the medicinal and aromatic plants from the different agro-climatic zones of India is needed for the promotion of cluster-based farming.
- National database for demand and supply is required to be developed for critical assessment of demand-supply gap and supply chain.
- The real-time database/portal for demand of raw material (based on quantitative and qualitative specifications from pharmaceutical industries) can provide better market access to farmers.
- Supply/value chain for these crops need to be shortened so that the sustainable supply of good quality (in terms of the content of active ingredients) could be ascertained.
- Traceability (qualitative/quantitative) of the supplied material could be made available. Buyback of quality raw material directly from the cultivators/growers may be promoted by the industries.
- Holistic scientific approach must be followed for utilisation of the substitute plants particularly for those crops which are high in demand and low in supply.
- Scientific approach from field to the pharmacy needs to be adopted for taking medicinal and aromatic crops as well as Ayurveda to the next level.
- Medicinal and aromatic crops resilient to climate change need to be identified and developed.
- Research and development studies in the areas of post harvest management shelf life, storage and simple agro-techniques to be taken up through ICAR, CSIR, NBRI, DMAPR, CIMAP, ICFRE, RRLs, DBT, Horticulture and Forest Department.
- Corpus fund-based promotion of research activities and public private partnership (PPP) for research and development of herbal medicines should be undertaken.
- Knowledge sharing and industrial training of human resources is to be facilitated by the industries from this sector.
- Good agricultural practices need to be refined as per the industry demand.
- National policy for adoption of uniform methodologies, monitoring of residues/ microbial contamination, tagging of area, prevention of negative campaign and validation of Vriksha Ayurveda also need to be considered.
- General and specialised surveys of the international market for medicinal plants and products to be undertaken for identifying niche areas.
- Efforts to create mass awareness about the importance of medicinal plants among the people and publish distribution material for the purpose.

Conclusion

The importance of the MAP sector can be gauged from the fact that herbal medicines serve the healthcare needs of about 80 per cent of the world's population. Medicinal and Aromatic Plants continue to play important role in ensuring health and income security. Although, MAPs being used in health care since time immemorial, the systematic research has begun in the country in the last century. Several national as well as state level institutes are working on various aspects of MAPs. MAPs form the priority crops for central as well as state governments in India as a result, National Medicinal Plants Board and State Medicinal Plants Boards have been set up to usher various research needs of these crops. Quality research is being carried out in the country by several national institutes like ICAR-DMAPR, Anand; CSIR-CIMAP, Lucknow; CSIR-NBRI, Lucknow *etc.* on priority areas suggested above and it is expected to bring substantial progress in the coming years that facilitates sustainable development of MAP in the country. The systematic cultivation of economically important medicinal and aromatic plants has to be taken up in cluster basis.

LL-5

Integrated weed management using modern tools

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Weeds are plants that grow in areas where they are not desired, and they compete with crops and natural vegetation for nutrients, water, light, and space. The common characteristics of weeds are rapid growth, high reproductive capacity, and ability to thrive in a variety of environments. Weeds can significantly reduce agricultural productivity by interfering with crop growth and causing yield losses (Singh *et al.*, 2022). They can also affect biodiversity, disrupt ecosystems, and complicate land management practices. While some weeds may have beneficial uses in certain contexts, their presence in fields, gardens, and other cultivated areas often requires management through various control methods to prevent them from becoming invasive and causing damage to human activities and natural landscapes. The reliance on indiscriminate use of chemical herbicides for controlling weeds can be counter-effective due to the possible development of herbicide resistance (Norsworthy *et al.*, 2012). Integrated Weed Management (IWM) is a comprehensive approach that combines multiple strategies to control weed populations in agricultural systems, aiming to reduce their impact on crop yield and biodiversity (MacLaren *et al.*, 2020). Modern tools and technologies, such as precision agriculture, remote sensing, genetic engineering, and advanced herbicides, have significantly enhanced the effectiveness and efficiency of IWM (Ghatrehsamani *et al.*, 2023). These innovations allow for more precise targeting of weeds, minimizing chemical use and environmental impact while optimizing resource use. This approach not only focuses on physical, biological, and chemical control methods, but also emphasizes sustainable practices that ensure long-term productivity and ecosystem health. As weed resistance to traditional herbicides continues to grow, the integration of these modern tools into IWM is crucial for developing adaptive, eco-friendly, and economically viable weed management solutions.

Advancements in digital technologies for weed management

The targeted or spot control of weeds requires a thorough knowledge of weed identification and dynamics at each location, followed by target delivery of chemicals in the required dose. The outlook of traditional weed management has been changed by modern technologies such as drones, ground platforms, sensors, image analysis software, artificial intelligence (AI), machine learning (ML), data handling frameworks, and cloud computing (Paul *et al.*, 2024). These innovations provide farmers with sophisticated tools to monitor, analyze, and manage weeds more effectively, leading to higher yields, better resource management, and more sustainable farming practices.

Drones, sensors, and ground platforms

Drones, equipped with high-resolution cameras, sensors, and advanced multispectral sensors, can fly over fields and capture detailed imagery that can detect weed infestations early. These aerial images provide valuable information, allowing us to identify the extent and type of weed pressure in crop fields. Ground platforms, such as autonomous vehicles and robotic systems, are being used to perform more precise tasks. These platforms can track weed populations and even apply herbicides in a targeted manner, reducing chemical usage and ensuring that treatment is localized to areas with high weed concentrations. Combining drones and ground-based platforms enables real-time monitoring, allowing better decision-making and resource allocation.

Sensors installed in the soil or on drones can measure various parameters, including weed species, apart from data like soil temperature, moisture, *etc.* This data is crucial and helps farmers take management actions. For example, farmers can optimize irrigation schedules by monitoring soil moisture levels to discourage weed growth in areas with excess water. Additionally, these sensors can be integrated into an overall precision agriculture system, providing farmers with localized data that supports better management of both crops and weeds.

Image analysis software and algorithms

Image analysis has revolutionized weed control by enabling precise identification, mapping, and site-specific management. The use of advanced software and algorithms enhances the accuracy and efficiency of weed management strategies, minimizing the need for blanket herbicide applications and reducing environmental impact. There are different commercial software such as Pix4fields, AgroSense, and Taranis, as well as open-source resources such as QGIS, OpenCV, and DeepWeedsDataset.

Weed detection approaches

Sensor-based weed detection approaches: Sensor technologies provide automated, real-time weed detection.

a. Optical Sensors: It works by detecting the light reflectance differences between weeds and crops. The GreenSeeker sensor differentiates plants based on their normalized difference vegetation index (NDVI). The main advantage of such a system is that it works under various light conditions. However, the detection is limited to distinguishing plants with significant reflectance differences.

b. Thermal Sensor: It identifies the temperature variations caused by metabolic differences between crops and weeds. This technique can detect weeds during cooler periods and is effective only for distinct thermal contrasts.

c. LiDAR (Light Detection and Ranging): It measures plant height and density to distinguish weeds from crops. It is effective in differentiating weeds based on physical structure. However, it has limitations of high cost and complex data processing.

d. Multispectral and hyperspectral sensors: They work by capturing reflectance data across multiple wavelengths to differentiate vegetation types. It provides high accuracy in detecting weeds at different growth stages. However, advanced algorithms are necessary for analysis.

Image analysis-based weed detection approaches

This approach uses cameras combined with advanced algorithms to analyze images and identify weeds (Dobbs *et al.*, 2022).

a. RGB image analysis: It captures red, green, and blue color data to differentiate weeds based on visual features like color, shape, and texture. It is affordable and widely available. It is less effective in complex environments or low light.

b. Multispectral and hyperspectral imaging: It uses cameras that capture additional wavelengths (e.g., near-infrared) to detect spectral differences. It provides high precision in distinguishing crop and weed species. However, expensive equipment and computationally intensive processing are the limitations.

c. Machine learning-based detection: It uses algorithms like Support Vector Machines (SVM) or Random Forests to classify weeds based on features. This approach improves accuracy with training. It requires large datasets for training.

d. Deep learning-based detection: It works by employing neural networks (e.g., convolutional neural networks) to analyze images at the pixel level for weed classification. This technique has the advantage of being able to handle complex environments and detect multiple weed species. High computational requirements and dependency on labeled data are the main disadvantages. Sapkota *et al.* (2022) successfully used convolutional neural networks to detect weeds in cotton.

e. Real-time detection: Systems like YOLO (You Only Look Once) perform weed detection in real time for immediate action. It is suitable for integration with automated platforms. However, this requires powerful hardware for real-time processing.

Emerging hybrid approaches

Combining sensor data, image analysis, and AI is a promising approach to modern weed management.

Sensor-image fusion: Integrates data from optical, thermal, and spectral sensors with image analysis for enhanced accuracy.

Robotics integration: Uses autonomous robots equipped with cameras and sensors for real-time weed detection and removal.

IoT and cloud integration: Connects weed detection systems to cloud platforms for data storage and decision support.

AgIR: A national weed and crop image repository

The AgIR (Agricultural Image Repository; https://www.precisionsustainableag.org/agimagerepo) initiative represents a collaborative effort to establish a comprehensive and standardized image repository for weed and crop identification, enabling advanced research and technological innovation in agriculture. Its objective is to create a high-quality, publicly accessible repository of annotated weed and crop images. This initiative involves contributions from prominent institutions such as PSA (Precision Sustainable Agriculture), USDA-ARS (United States Department of Agriculture - Agricultural Research Service), NC State (North

Carolina State University), Texas A&M University-AgriLife Research, Aarhus University, and GROW (Get Rid of Weeds).

International Weed Recognition Consortium (IWRC)

The International Weed Recognition Consortium (IWRC; www.weedrecognition.org) is a global initiative aimed at fostering collaboration, innovation, and knowledge sharing in the domain of weed detection and management. The consortium brings together researchers, technologists, agronomists, and industry stakeholders to develop advanced tools and strategies for precise weed identification and control. The IWRC actively collaborates with key global institutions, and network is growing.

Conclusions

- **Global trends in weed issues**: The rising prevalence of weed-related problems across diverse agricultural systems highlights the need for innovative and advanced solutions.
- **Site-specific weed management**: Precision approaches tailored to specific field conditions have proven to be highly efficient in reducing resource wastage and improving sustainability.
- **Broadcast applications using drones**: While site-specific methods are preferred, drone-based broadcast applications can be advantageous in certain scenarios, such as large-scale or inaccessible areas.
- **AI/ML for detection**: The application of artificial intelligence (AI) and machine learning (ML) for weed detection is context-dependent, requiring customization based on specific needs and crop-weed dynamics.
- **Challenges remain**: Key obstacles include data collection standardization, technology adoption, and ensuring affordability for widespread use.
- **Need for further R&D**: Continued research and development are essential to overcome challenges, refine technologies, and enhance their efficacy for global weed management practices.

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LL-6

Field-scale evidence for agroecological approaches: Enhancing soil and plant health in Asia and Africa

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Introduction

Agricultural intensification has led to an overreliance on chemical inputs, particularly pesticides, resulting in increased production costs and significant adverse impacts on human health and the environment. While intensive agricultural systems prioritize short-term economic benefits, their environmental costs-such as greenhouse gas and ammonia emissions, soil degradation, eutrophication, pesticide dispersal, and freshwater depletion-are often overlooked. This highlights the urgent need to transition toward sustainable farming systems that are resource-efficient, environmentally sound, socially supportive, and economically viable (Ikerd 1989).

Although organic agriculture is widely recognized as a sustainable practice, the complexity and rigidity of certification processes often pose barriers for adoption, particularly for smallholder farmers (Leitner and Vogl 2020). Agroecological and regenerative agriculture approaches, which integrate ecological principles into agricultural systems, offer more accessible and context-specific alternatives for smallholder farmers, especially in developing countries.

Agroecological Approaches for Sustainable Vegetable Production

Agroecology emphasizes a holistic understanding of farming systems by focusing on the biological, physical, and chemical interactions that sustain productivity (Gliessman 1995). It seeks to redesign food systems through five levels of transformation, ranging from farm-level practices to broader food system changes (Gliessman 2014; 2016). Agroecological systems empower farmers to make informed, context-specific decisions, reduce dependence on external inputs, and enhance resilience to external shocks.

The World Vegetable Center (WorldVeg) has initiated agroecological pilots in Asia and Africa, generating evidence on their effectiveness. In Assam, India, WorldVeg partnered with local agricultural institutions to evaluate an improved black gram variety (IPU-0423) combined with good agronomic practices (GAP), including biofertilizers and integrated pest management (IPM). Results demonstrated a 130% yield increase when GAP was applied compared to the variety alone. Additionally, the residual nitrogen fixed by legumes significantly improved the yield of subsequent rice crops, reducing the need for nitrogen fertilizers (Aung & Prot 1990; Rahman *et al.* 2014). For example, rice grown after mung bean and cowpea yielded 37% more than rice grown after rice.

In China, a combination of a microbial restoration substrate (MRS) and an avirulent strain of *Ralstonia solanacearum* effectively controlled bacterial wilt in tomatoes, achieving an 86% reduction in disease incidence and a 464% yield increase, alongside improvements in soil health and pH (Zheng *et al.* 2019). Similarly, at WorldVeg, combining biocontrol agents (*Talaromyces* sp., *Trichoderma* sp., *Bacillus* sp., and *Variovorax* sp.) with resistant tomato cultivars significantly reduced bacterial wilt incidence (Maxwell *et al.* 2022). Tomato grafting using eggplant rootstocks resistant to bacterial wilt, when integrated with biocontrol agents, could offer a sustainable solution for managing both biotic and abiotic stresses (Msabila *et al.* 2024; Bihon *et al.* 2022; Kitundu *et al.* 2022; Ravishankar *et al.* 2021).

Strengthening biodiversity and pest management

Agroecological practices enhance biodiversity in production systems by reducing pesticide use and promoting natural enemy populations. For instance, in South Asia, the withdrawal of pesticides in eggplant cultivation allowed parasitoids such as *Trathala flavo-orbitalis* to proliferate, achieving parasitism rates of 39% in Sri Lanka and 55% in India (Alam *et al.* 2003). In Assam, IPM adoption in cabbage and cauliflower cultivation reduced pesticide use by 44–55%, increased yields by 24–38%, and improved benefit-cost ratios, enhancing both economic returns and product quality (Ravishankar *et al.* 2024).

In vegetable brassicas in Southeast Asia, the integration of biopesticides (Srinivasan, 2012; Srinivasan *et al.* 2017) and pheromones (Zhao *et al.* 2011) improved natural enemy performance against key pests. Agroecological practices also reduced pest infestations in collard production in Kenya, particularly during the dry season and in low-production zones (Wangungu & Srinivasan 2024).

Conclusion

Agroecological and regenerative agriculture practices offer multifaceted benefits, including improved crop productivity, enhanced biodiversity, reduced dependence on external inputs, and resilience to external shocks. These approaches not only strengthen local food systems but also contribute to long-term environmental and economic sustainability. However, scaling these practices among smallholder farmers requires an enabling policy and institutional environment at national and regional levels to facilitate widespread adoption.

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LL-7

Green technologies for soil & plant health management in spices

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Excessive use of chemical fertilizers and plant protection chemicals affects soil health and non-target organisms, result in pesticide residues in the produce and cause human and environmental hazards. Spices are high-value products obtained from diverse crops and are extensively used all over the world to add flavour and taste to human food besides being used in indigenous medicine. In India, the land of spices, spices are cultivated in an area of 4.43 m ha with a production of 11.14 m t during 2022-23. The export of spices/ spice products from the country has been 1.40 m t valued at Rs. 31,761 crores (3.95 billion US$) during 2022-23. The spices economy of the country has proved its vital role in the agricultural sector owing to its high value of output role contributing 43% of the total horticultural exports from India, indicating its importance in agricultural export basket, even during the COVID pandemic.

Healthy planting materials: Rapid multiplication techniques have been developed to meet the demand of planting materials. The continuous demand for quality planting material (QPM) created a novel idea of producing orthotrope on vertical columns filled with composts fortified with bio-control agent *Trichoderma asperillum/ PGPRs*. In ginger and turmeric, the major diseases are soft rot caused by *Pythium* sp. and bacterial wilt caused by *Ralstonia solanacearum* that are seed borne, infection by these pathogens can be reduced by at least 50.0% through the use of disease-free planting materials multiplied by single bud sprouts (about 5 g) method with bio priming of bio-control agent *Trichoderma asperillum/ PGPR,* eventually reducing the cost on seeds. Technique to produce high quality, disease free ginger microrhizomes through tissue culture and seed multiplication from microrhizomes using high tech production system in polyhouse were also standardized.

Crop management & organic farming: Plantation crops being perennial in nature contribute large quantities of waste by-products, which by composting and recycling will meet the nitrogen requirement of the crop and partly other nutrients. Application of dried coconut leaves as mulch in ginger beds after removing the petiole reduced weed growth and enhanced the yield by 10% compared to green leaf mulch application. The ICAR-IISR, Kozhikode, has developed package of practices for organic production of major spices like black pepper, ginger and turmeric. Talc and biocapsule based formulation (IISR Biomix) consisting of a consortium of PGPR [*Micrococcus luteus* (BRB 3)] + [*Enterobacter aerogenes* (BRB 13)] + [*Micrococcus* sp. (BRB 23)] have been developed for application in the nursery and main field for enhanced growth and yield. Application of composts and biofertilizers for nutrient supplement, *Bacillus amyloliquefaciens* (GRB 35) as seed treatment and drenching are helpful in sustaining the yield and keeping the rhizome rot disease incidence under check in ginger and turmeric. Organic management system showed highest population buildup of total bacteria, *Azospirillum* sp., *Pseudomonas* sp., Actinomycetes and *Trichoderma* sp. with less incidence of rhizome rot.

Spraying lime @1.5% or spraying Kaolin @2.0% protects the black pepper crop preventing leaf fall and defoliation due to sun scorching. The practice of pre-monsoon irrigation was found to enhance black pepper productivity. Irrigation of black pepper vines around the basin from March to May @ 50-80 L/ vine at an interval of 15 days can markedly enhance spike length, number of spikes, oleoresin content and berry yield. This technology promotes uniform spike initiation and reduces the spike shedding due to late monsoon and guarantees good crop.

SSNM for soil & plant health: ICAR-IISR has also developed site-specific integrated nutrient management for sustainable soil heath for spice-based cropping systems and demonstrated the same in major spice tracts for increasing productivity, assuring 15-20% increased production. With this soil test-based fertilizer recommendations can be made for obtaining targeted yield in major spice crops like black pepper, ginger, turmeric and cardamom. This helps in achieving balanced fertilization achieving maximum use efficiency for the applied fertilizer inputs. A decision support system 'Spice FeRT' helps the farmer to get the fertilizer recommendation for targeted yield levels in major spice crops based on the soil fertility levels. Fertigation helps in saving the fertilizer inputs by about 50 percent. Maximum yield was obtained in the black pepper (IISR Girimunda and Shakthi) when drip irrigation @ 8 liters of water daily from September-May and 50% RDF was applied as fertigation in 24 splits, doubling the use efficiency of the applied nutrients. 75% of recommended dose of fertilizers (RDF) supplied through fertigation produced significantly higher rhizome yield in ginger.

The majority of soils in the spice growing areas are encountering fertility issues due to acidity, nutrient imbalances and deficiencies of secondary and micronutrients that becomes yield limiting. Besides crop specific, soil pH-based nutrient mixtures for foliar application in black pepper, cardamom, ginger, and turmeric crops which guarantees 10 to 25% increase in yield and quality have been developed and patented. The micronutrient technologies have been licensed to 29 entrepreneurs for large scale production and commercialization. Site specific soil acidity corrections by amendments, fertilizer management based on soil test and supplementation of micronutrients through foliar spray significantly increased the soil available nutrients as compared to farmers practice in coconut + black pepper and coconut + nutmeg systems studied in different agro ecological units of Kerala. Very promising Zn solubilizing bacteria (ZSB) were isolated from the rhizosphere of turmeric and ginger and assessed for the type and quantity of organic acids secreted. Sustainable yield levels could be attained even in mild and moderately virus affected black pepper vines when adopted with integrated application of FYM, soil test based NPK, foliar micronutrient (IISR Black pepper special) @ 5g/L twice (June and September) and PGPRs twice (June & Sept) either fortified with FYM (and applied 10 kg vine^{-1}) or as drenching (2-3 L standard^{-1}) boosted the health of virus infected vines resulting in increased yield (30-50% higher) and sustainability.

Green technologies for biotic stress management: Spice crops are prone to attack by many pests and diseases for which several eco-friendly green technologies have been developed utilizing cultural methods, use of resistant varieties, natural products and bio-control agents. Soil solarization and fortifying the nursery mixture with *Trichoderma* sp. and *Pochonia chlamydosporia* in black pepper and cardamom gives protection from *Phytophthora* sp and *Pythium* sp. and the nematodes. PGPR consortiums have also been developed to promote rooting and growth of plants and controlling diseases in the nursery. Effective control of foot rot disease under field condition can be achieved by adopting cultural practices like shade regulation, phytosanitation, minimum tillage, adequate drainage and application of *T. harzianum* @ 50 g/vine mixed with 1 kg of neem cake. In cardamom, shade regulation, phytosanitation, adequate drainage and application of *Trichoderma* sp. @ 50 g/clump, multiplied in decomposed coffee compost and mixed with cow dung (2.5 kg/plant) gives good control of capsule rot caused and rhizome rot.

In ginger, *Bacillus amyloliquefaciens* (PGPR) as seed treatment and drenching are helpful in managing rhizome rot disease incidence in the field. IDM protocols involving $CaCl_2$ and *Bacillus lichiniformis* based formulation (Bacillich) for the control of bacterial wilt of ginger was standardized and demonstrated across India. Technologies like, *Pochonia chlamydosporia*, a biocontrol agent against nematodes, use of an entomopathogenic fungus, *Lecanicillium psalliotae*, for controlling the cardamom thrips *etc.* offers immense scope for reducing the pesticide use in spice based cropping systems. Spinosad (derived from the Actinomycetes, *Saccharopolyspora spinosa*) can substitute synthetic insecticides for thrips control in cardamom, when sprayed three times. Entomopathogens such as *Metarhizium anisopliae* and *Beauvaeria bassiana* are effective against root grubs in cardamom and white grubs in ginger.

Novel delivery of biocontrol agents: ICAR-IISR has made a significant breakthrough in encapsulation and patented the process for delivery of PGPR for growth promotion and disease control in spice crops. The encapsulation process is simple and can be used to deliver all kinds agriculturally important microorganisms such as N fixers, nutrient solubilizers and mobilizers, PGPR, *Trichoderma* sp. *etc*. Liquid formulation of *Trichoderma* sp. has been developed containing minimum population of 10^8 fungal spores per ml that can be stored up to one year without significant reduction in viable cells. Seed coating using PGPR is a novel approach of coating efficient strains of PGPR on seeds/ seed rhizomes. The coated seeds/ rhizomes can be stored at the room temperature. Constraints like low germination, slow initial growth and high susceptibility to diseases can be addressed through this technology and can be easily adopted in spices like ginger, turmeric, tuber crops and seed spices. The institute has also developed a granular lime/ gypsum-based *Trichoderma*/ PGPR formulation for simultaneous delivery of microbes during soil amelioration. This ensures soil acidity/ alkalinity neutralization and addition of beneficial microbes to the soil simultaneously to improve the soil bio activity. This formulation was found to be effective in neutralizing the sub soil acidity as well as the soil population of the delivered beneficial microbes in the lower soil depths of crops like black pepper, nutmeg, coconut and turmeric.

Diagnostics: Development of diagnostics for virus infecting spices by loop-mediated isothermal amplification (LAMP) and real-time LAMP and RPA-LFA (recombinase polymerase amplification-lateral flow assay) based assays have been developed and deployed for quick and sensitive detection of virus diseases of black pepper, cardamom and ginger. The technology can be used for certification of mother plants/planting materials of black pepper for freedom from viruses. The technology has potential to transcend crops in its scope of application. A strain specific and sensitive technique based on Real Time Loop Mediated Isothermal Amplification (Real Time- LAMP) developed for detecting race 4 strain of *Ralstonia solanacearum* causing bacterial wilt in ginger. The method can be used to index both soil, water as well as seed rhizomes. The technology can be easily adopted in field for pathogen-free site selection as well as selecting disease-free seed materials for planting.

There is great scope to improve the productivity of major spices by adopting technologies that will help to bridge the gap between potential yields realized in the research stations and in farmers' plots. Nurturing and improving sound techniques, technologies and innovations in the entire spices sector can help in surmounting the major challenges and constraints faced in the crop production sector and India could emerge as a major player by exploiting its own strength with the adoption of these green technologies.

LL-8

Spices to Spiceuticals: A science-based approach

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Nutraceuticals and food/supplements are becoming increasingly complex with phytonutrients to maintain healthy metabolism and cellular homeostasis; and hence to prevent/treat chronic diseases. Research in the past 3 decades have shown kitchen spices itself as Generally Recognized as Safe (GRAS)-source for phytonutrients characterised with wide range of health beneficial pharmacological effects and safety. But, by virtue of its chemical structure and physicochemical properties (insolubility, hydrophobicity, instability *etc.*), these nutrients pose several limitations for its therapeutic/functional applications. Most of the phytonutrients are poorly absorbed and exhibited poor bioavailability, and undergo rapid metabolism to inactive metabolites, and rapid elimination. Delivery of the bioactive forms at cellular level (beyond bioavailability) is the key for its therapeutic/functional efficacy. Hence, there exist a need for scientifically validated technologies for phytonutrients delivery - to deliver physiologically relevant dose of phytonutrients/servings at the cellular level, including organ tissues such as brain.

A number of attempts, including nanoparticle formulations, have been reporting globally. Despite the success in drug delivery, phytonutrients delivery poses several challenges and limitations, such as regulatory issues, lack of food-grade/clean label status, limitations in the use of solvents and synthetic process aids, limitations to use synthetic emulsifiers, polymers and chemicals, and above all the cost. Moreover, the emerging consumer trends to consume nutraceuticals in food formats, say as gummies, sachets, beverages, *etc.*, cause several other challenges due to their insolubility, incompatibility under process conditions, and taste/flavour issues. Here comes the significance of scientifically validated 'green' approaches for phytonutrients delivery - *to deliver physiologically relevant dose of phytonutrients/servings in a bioavailable manner with acceptable sensory attributes.*

A decade ago, we developed and patented a GREEN approach in phytonutrient delivery based on fenugreek-derived galactomannan soluble dietary fiber. The characterisation of this delivery technology as a 100% natural, food-grade, clean label, cost-effective 'natural self-emulsifying reversible hybrid-hydrogel' technology suitable for both pharma (tablets, capsules, soft gels) and food delivery formats (sachets, gummies, protein bars, chocolates *etc*) will be discussed in the presentation. The presentation would also discuss the way we transformed spices (turmeric, chilli, asafoetida, black cumin *etc*) as Spiceuticals® and their commercial success in USA and Europe as nutraceuticals.

LL-9

Pesticide residues in spices: National and global perspective

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The burgeoning demand for spices worldwide makes cultivation of spices a lucrative option for the Indian farmers to boost export of spices to different countries. India is presently the largest producer, consumer, and exporter of spices in the world. Since times immemorial, India is known as "World's spice bowl" or the "Land of spices" as no other country exhibits the diversity of spice crops similar to India. The International Organization for Standardization (ISO) has notified a list of 109 spices of which 75 are cultivated in India. Some of the majorly produced and exported spices in India include black pepper, cardamom, chilli, ginger, turmeric, coriander, cumin, fennel, fenugreek, and saffron. Of these spices, chilli, cumin, turmeric, ginger, and coriander make up about 76% of the total production. In 2022-23, a total of 11.83 million tons (MT) of spices were produced in India of which the major spices grown were chilli (23.5%), ginger (18.6%), turmeric (9.9%), coriander (8.2%) and cumin (4.9%). The export of spices from India has shown a constant increase during the last decade. During the fiscal year 2022-23, India exported 1.4 MT of spices valued at $3,952.68 million. Of these, chilli (36.8%), cumin (13.3%), turmeric (12.1%), coriander (3.9%), ginger (3.6%) were the five most exported spices from India.

Spice yield losses due to insect pests and diseases

Spice crops like chilli, cumin, black pepper, cardamom, ginger, turmeric, coriander, cumin, fennel, fenugreek etc. are attacked by various insect-pests and diseases causing severe yield losses and reduction in quality causing huge economic losses to the farmers. For instance, thrips alone can cause about 60.5-74.3% yield loss in chilli, while thrips and mites together can cause a yield loss of about 34% (Chauhan *et al.* 2021). The top shoot borer can cause 57-100% yield loss in black pepper while the anthracnose disease can damage the crop causing 28-34% yield loss going up to 100% in some cases (Talucder *et al.* 2020). The root grub can cause a yield loss of 10-70% in cardamom crops depending on the intensity of infestation (Pervez *et al.* 2016).

Pesticide residues in spices and food safety challenges

Considering the global culinary usage of spices and the wide expanse of its trade, food safety aspects related to presence of pesticide residues in spices have become crucial. At present, in India 339 pesticides are registered for use and about 109 pesticide label claims are approved for six commonly grown spices out of which more than 80 label claims are mainly for control of pests in chilli.

***Lack of approved pesticides and Maximum Residue Limit (MRLs) for spices*:** MRL is the legal standard for pesticide residues worldwide which is established by the regulatory bodies of the respective countries based on their Good Agricultural Practices (GAP) taking into account the toxicity of the pesticides. Globally, for setting MRLs, the residue data has to be generated in different agro-climates. Spices are classified as minor crops as they are grown on a small area and their dietary intake is low in comparison to other agricultural commodities. Most of the pesticides are registered against the major crops while the minor crops such as spices do not attract commercial interest of the manufacturers to seek registration of the pesticides. Owing to the higher costs involved in generation of bio-efficacy, toxicology, and residue data to support pesticide registration for spices, the industry is unwilling to pursue the data generation as they find it economically unviable. This results in limited number of approved pesticides on spices leaving farmers with insufficient pest management options and fewer pesticide MRLs that may impede trade.

***Detection of off-label pesticides in spice exports*:** Non-availability of products for minor uses negatively impacts international/national/regional economies and lead to a surge in the cases of off-label pesticide use. Detection of off-label pesticides may often be one of the reasons for rejection of spices by the country of export.

***Lack of awareness among farmers about safe use of pesticides*:** There is a lack of awareness among farmers regarding the safe and judicious use of pesticides. This may lead to the usage of pesticides which are not registered on spices but may be effective on the insect-pest and diseases affecting the spice crop. Since, there are no recommendations for the use of such pesticides which lack legal approval on the spice crop, the farmers lack guidance on the dosage of application and may resort to non-judicious and indiscriminate use of pesticides resulting in higher residues on the crop, adverse effect on the environment and the non-target organisms and/or phytotoxicity to the crops.

***Trade challenges*:** Variations in the MRLs of the same pesticide-crop combinations in the country of import and export, may impede trade. Many countries have the practice of setting either default MRLs or fixing stringent MRLs based on their capability of detecting the pesticide residues at the lowest level. In such cases, when residues of pesticides are detected, the spice exports are unable to meet the strict standards of the importing country leading to their rejection. Lacunas such as limited number of registered pesticides on spices, absence of domestic MRLs, and detection of off-label pesticides in spice exports aggravate the issues of non-tariff trade barriers leading to the rejection of the export consignments of spices from port of entry causing huge economic losses and thus hampering smooth export of spices from India.

Overcoming challenges of pesticide residues in spices

Crop grouping: The problem of limited number of MRLs on spices can be addressed to some extent by adopting concept of Codex principles of crop grouping for the extrapolation of maximum residue limits for pesticides to commodity groups. Crop grouping aims at uniting similar types of crops into a group or subgroup to facilitate use of pesticides in as many crops as scientifically possible. Crops are grouped based on their similarities in botanical classification, morphology, cultural practices, growing seasons, locations or growth habit, edible portion of the commodity, as well as potential for pesticide residues. Crop grouping enables extrapolation of data generated for a representative/major/target crop to other related crops of the same crop group eliminating the need for fresh data for each individual crop in the group. As per Codex crop grouping, the spices have been classified into nine subgroups namely, a) seeds; b) fruit or berry; c) bark; d) root or rhizome; e) buds; f) flower or stigma; g) aril; h) citrus peel; i) any other commodity. According to this principle, the residue levels on a representative commodity can be used to estimate the residue levels on related commodities present in the same group/sub-group for which trials have not been conducted through the method of residue extrapolation.

Shifting to crop grouping approach would therefore lessen the burden of obtaining label claim for each and every crop-pesticide combination as it allows researchers to apply residue data collected from one crop to other similar crops without the tedious process of data generation for every crop. Practicing crop grouping can thus be highly advantageous as it gives farmers a range of pesticides for pest management on a crop.

Harmonization with International MRLs: As per the International guidelines (FAO/WHO/Codex), the MRLs are fixed based on dietary risk assessment which assesses the safe consumption of the crop commodities by human beings. In cases of lack of MRLs in a country, national MRLs may be aligned with Codex MRLs to facilitate smooth trade between countries. In India MRLs of pesticides for spices and culinary herbs are fixed by Food Safety and Standards Authority of India (FSSAI) based on the field trial data received through Central Insecticide Board & Registration Committee (CIB&RC). As per the recent FSSAI notification dated April 8, 2024, in cases where the pesticide is registered with CIB&RC and MRLs are specified for food commodities other than spices and culinary herbs, then the MRLs specified under Codex shall be applicable. In case the MRLs are not specified by Codex, MRL of 0.1 mg/kg shall apply for spices and culinary herbs. In case the pesticide is not registered with CIB&RC, then also the MRL of 0.1 mg/kg will be applicable for spices and culinary herbs. This would ensure that export consignments from India are not rejected on account of non-tariff trade barriers.

Role of ICAR-AINP-PR for fixation of MRLs of spices at National and International Level

Internationally, Joint Food and Agriculture Organization (FAO)/ World Health Organization (WHO)/ Codex Alimentarius Commission (CAC) member countries establish science-based food standards to ensure food safety, quality and fairness of international trade.

India is signatory to CAC and keeping in view the challenges associated with consumer safety and export of spices from India, the ICAR- All India Network Project on Pesticide Residues (AINP-PR) has established linkages with the FAO/ WHO/ Joint Meetings on Pesticide Residues (JMPR) and Codex Committee on Pesticide Residues (CCPR) for fixation of Codex MRLs on spices. The pesticide residue monitoring data generated under the Department of Agriculture and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, sponsored central sector project "Monitoring of Pesticide Residue at National Level (MPRNL)", is being regularly submitted to FAO/WHO/JMPR for risk assessment and fixation of Codex MRL. During 2014 to 2024, Codex MRLs (CXLs) for 22 pesticide-spice combinations on five different spices (cardamom, coriander, fennel, cumin, pepper (black and white) has been fixed based on the monitoring data submitted by India. Most of these codex CXLs have also been adopted by many countries worldwide including EU.

India can play a pivotal role in generating pesticide residue data for the specialty crops like spices and herbs and setting the standards that facilitate the smooth export of spices from India. To achieve this goal, efforts have to be put in by all the stakeholders to adopt policies such as crop grouping to find a viable solution and overcome the challenges related with spices as a minor crop. Continued efforts under the ICAR-All India Network Project on Pesticide Residues has led to the fixation of FSSAI MRLs for spices at national level and Codex MRLs at international level which would ease trade barriers between countries and facilitate smooth export of spices from India thereby increasing the farmers' income and earning foreign exchange. However, more needs to be done at the domestic level such as expanding the label claim of pesticides on spices, encouraging industry partners to generate data as per regulatory requirements, and expediting the process of fixation of MRLs on spices as well as harmonizing them with international standards. These steps would facilitate fair trade practices and help India move towards economic prosperity and promote its role as one of the major producers and exporters of the spices in the world.

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LL-10

Role of spices ahead of food flavoring: Nutraceuticals with multiple health effects

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India is the largest producer, consumer, and exporter of spices and condiments with historic track record. India, with diverse agroclimatic regions, and with varied topography and biogeography, offers tropical, subtropical, and temperate conditions to cultivate almost all spice species. The history of spices is very long with their use in various ways during ancient times. Indian food is famous for its special taste, color and aroma in the world which explains the diversity of spices and condiments in their land. Since the beginning of human history, all of India's spices have been strongly associated with its culture, traditions, preservation, and healing system. During ancient times spices were largely used for medicinal purposes than use in food preparation. At that time, India had become the centre of the world's spice trade due to its top position in spice production. At present India contributes 70% to the global production of spices and ranks first in the world among major spice-producing countries. Spice and condiments not only enhance the sensory quality of food but also boost the immune system and give healthy nutrition which prevents the risk of chronic diseases.

The ancient study also reveals that an adequate amount of daily intake of spices balances the three doshas (Tridoshas) of the human body such as *Vata, Pitta* and *Kapha*. The imbalance of these doshas effect directly immune health and makes the body susceptible to disease. Spices have been a part of our culinary for a long time, but their value goes beyond just making food taste better. This talk goes into detail about the exciting field of using spices as key ingredients in the creation of nutraceuticals, which blend nutritional and pharmacological benefits. Also, this talk leads into the many different ways spices can be used to improve health and wellness. It does this by combining ancient knowledge with the latest scientific results. Discussion starts with a glance at how spices have been used as both flavor enhancers and medicine in different cultures. It then goes on to look at spices wide-ranging historical and cultural importance. After that, the work shifts to a thorough look at a number of spices that are thought to have possible health benefits. Turmeric and curcumin, which is the bioactive part of turmeric, have become very important in the fight against inflammation and chronic illnesses. Also, the topic gives insight into the antioxidant properties of spices like cinnamon, cloves, and oregano to see if they can help lower oxidative stress and the health problems they can cause.

Given the centrality of the digestive system to one's overall health, spices like ginger and peppermint are being studied for their potential to alleviate stomach aches. The relevance of using these natural medicines in contemporary diets is further emphasized as the study investigates the effect of spices has on blood sugar regulation, cardiovascular health, and weight management. Research on the potential of spices like turmeric to lower the risk of neurodegenerative illnesses has been extensive. This session offers important insights into the promising field of nutraceutical therapies that aim to improve brain health. Also, the discussion leads at the many ways spices can be used to treat pain, boost the immune system, and possibly help avoid cancer. Further, by nurturing and improving techniques, technologies and innovations in the entire spices sector, it is possible to overcome the challenges posed by competing countries in global spice trade and help in consolidating our position as a market leader in meeting the global demand for spices. In this direction, Department of Plantation Products Spices and Flavour Technology, CSIR-CFTRI conducts basic research on chemistry, and development of new technical know-how's, products, and spice processing machinery. Therefore, the purpose of this presentation is to provide a comprehensive review on the recent research/technologies on spice processing, including value addition and its nutraceutical applications.

LL-11

Spices production in India: Achievements, challenges and the path ahead

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Being the world's largest producer, consumer and exporter of spices, India plays a critical role in the world agricultural market. While the role of India has historically been dominant in this sphere, its continuity into the future will be determined by whether it would adequately meet the various challenges in production, post-production, and value addition. The challenge of climate change, changing patterns of global production, and volatilities in the global market are factors that additionally emerge as constraints. In this context, this brief presentation would examine the need for and the ways in which competitiveness can be enhanced in the spices sector in India, with some specific reference to the situation in Kerala. It would argue that the challenge of the future would be the integration of the needs of closing yield gaps along with developing climate resilience in the plant types. A reform of the agricultural research and extension sectors will be essential in this regard. A close relook at the organization of production in the spices sector will also be essential. New forms of organization, focused on the small and marginal farmers, allowing for economies of scale in production, ensuring aggregation, and viability of value addition must be the themes of serious discussion. At the same time, the economics of spices cultivation are not divorced from the overall challenges in the economics of agriculture in India. A policy ecosystem that focuses on the viability of farming across crops is equally important. This presentation will attempt to expand upon some of these themes, and put forward some ideas for broader discussion.

LL-12

Impact of socio economic and policy factors in spice industry

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Indian Spices have dominated global spice trade for centuries and are renowned for their exquisite taste and flavour. Their role in the economy, history and culture of India cannot be overemphasized. In the global spice landscape, India is the largest producer, consumer and exporter of spices. India's diverse geo climatic zones facilitate the cultivation of 75 out of 109 spices listed under ISO and India leads in the production and export of chilli, turmeric, coriander and a number of other important spices. Spices are high value products that contribute 8.2% of the total agri exports from India (53.1 billion US Dollars). The Indian spice industry has shown considerable growth over the past decade. Spice production has increased from 5.8 million Metric tons in 2013-14 to 10.48 million Metric tons in 2023-24. Export has also shown a similar trend and has doubled from 2.2 billion US Dollars to 4.4 billion US Dollars in the same time span.

The vision of the Indian spice industry is to become the premier processing hub of value-added spices and herbs in the industrial, food service, retail and health / wellness sectors of the global market. Apart from being the largest exporter, India also imports a high volume of spices for consumption in the domestic market as well as for re-export after value addition. Given the expected growth of population and the increasing usage of spices not only in the culinary but nutraceutical and pharma sectors, demand for spices is bound to expand substantially in the coming years. Production in India may not be sufficient to meet this requirement. Hence, it is important to ensure that the trade policies conducive to the smooth export and import of spices are implemented by the government. Judicious duty-free import of spices, Free Trade Agreements with more countries and a more liberal export and import policy will go a long way in smoothening spice trade and aid the industry in meeting its vision and objectives.

Spice production in India is dominated by small-scale farmers, who typically farm on less than two hectares of land and seasonally rotate spices with other crops. Spice cultivation offers them an additional source of income. However, small landholdings also mean that the effort required to implement traceability, sustainability and good agriculture practices at the farm level is that much more complex when compared to more organized sectors. Spice production is susceptible to environmental factors like climate vagaries, unseasonal rainfall leading to floods or droughts and invasive pests and disease attacks. Lack of awareness about sustainable agriculture practices and limited access to latest technology and modern cultivation methods reduce the productivity and effectiveness of cultivation. The ever-increasing domestic consumption of spices and low productivity reduces the availability of exportable surplus of spices with the desired intrinsic properties.

In such a scenario, government felt that FPOs would be a more effective vehicle to assist farmers to access modern methods of cultivation and thereby enhance productivity and improve their livelihood. It is estimated that there are more than 24000 FPOs registered with the Ministry of

Corporate Affairs. As per government policy, the target is to bring in another 10000 FPOs by 2024-25. Industry has also endeavoured to follow this policy and WSO has been working with over 50 FPOs covering 25000 farmers under National Sustainable Spice Program (NSSP). The activities under NSSP mostly focus on educating and imparting training to farmers and FPOs in soil health, water quality and nutrient management so that farmers are able to meet quality requirements and thereby gain market access.

It is crucial to increase the spice production and productivity using high yielding and disease resistant spice varieties. Use of recommended practices for efficient cultivation and modern technology for reduction of post-harvest losses is equally important. Introduction of schemes to promote sustainable and ethical sourcing and to ensure that the recommended practices are followed at the farm level will also help. India can also consider diversifying its spice exports by tapping into products like Seasonings which is estimated to expand at around 5 -7% and India's export shares is negligible. Spice processors and exporters too face many obstacles before the product reaches its final destination. The ever-changing regulatory landscape, Arbitrary imposition of stringent standards & food laws by importing countries and lack of harmonisation of quality standards in global trade are some of the non-tariff barriers to trade faced by the spice industry. Highly fluctuating prices, increase in the freight rates and tariffs and competition from other producing countries also cause disruptions in smooth trade.

Globally, there has been a shift in consumer preference towards companies providing Traceability and Transparency in their sourcing/ processing practices. Consumers are getting more aware and conscious about the quality and food safety aspects of the products they eat. Furthermore, Sustainable/ eco-friendly packaging solutions, sustainably sourced products and organic spices are becoming more popular. Interest in diverse cuisine, ethnic flavours and innovative mixes, blends & seasonings is on the rise. After the Covid pandemic, emphasis on spices with health and wellness benefits has also increased considerably. All these trends have influenced the direction of spice demand and supply and India must take cognizance of this if it wants to retain and further deepen its premier position in global spice trade.

The challenges faced by the spice industry also throw light on the urgent need to adopt sustainability and educate producers on sustainable agriculture practices. Sustainable practices will go a long way in helping farmers face the issues related to climate change, floods, drought and pest attacks and increase the productivity and income. Increase in consumer awareness of food safety issues, recognition of need for sustainable and ethically sourced spices and a demand for safe, clean label foods are also driving factors towards the production of sustainable spices. With the advent of mandatory sustainability requirements globally like the Corporate Sustainability Directive and Deforestation Regulation planned by the European Union, need to take initiatives to enable sustainable growth of this sector and help build a resilient supply chain is more important than ever.

India has the advantage of having a large pool of scientists and experts and modern processing systems and world class facilities set up by exporters. A joint effort by the industry, regulatory bodies and the government is guaranteed to assure the growth of spice production and exports and achieve the objectives of the industry.

LL-13

Indian spices- Strategies for production and development

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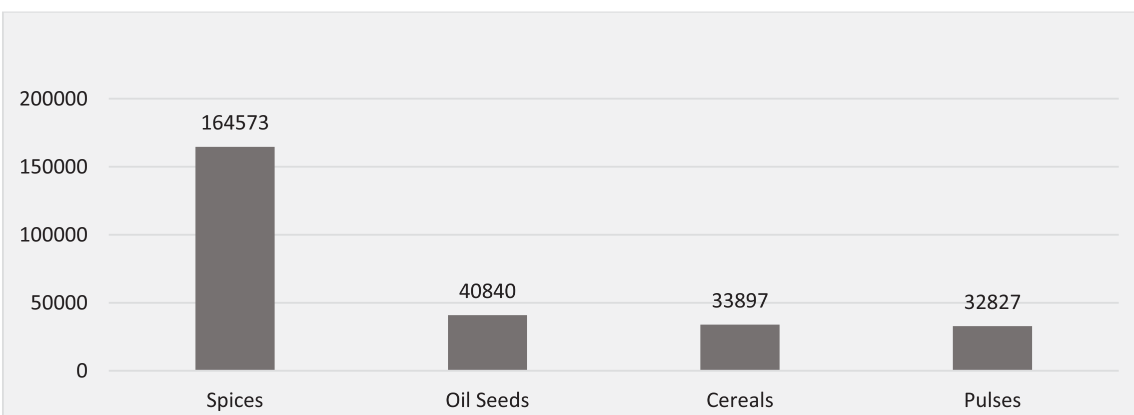
India, often referred to as the 'Land of Spices,' stands as a global leader in spice production, export and consumption with its rich heritage and diverse array of intrinsic quality spices. The country's vast geographical diversity, spanning various agroclimatic regions, supports the cultivation of approximately 63 different spices. Almost all the states produce one or the other spices. India is also the world's largest consumer of spices. The average monthly per capita consumption of spices has been estimated at 513.3 grams in rural areas and 565.7 grams in urban areas (NSSO, 2024). Additionally, significant quantities of spices are consumed by the restaurant and catering sectors as well as in food processing industries. Despite consuming over 80% of its domestic spice production, India remains the world's single largest supplier, offering spices in various forms viz. raw, ground, processed and as active ingredient isolates.

Spices are high-value, low-volume commercial crops with the potential to generate better income for farmers. Value of output per unit area from spices is significantly higher than that of field crops like cereals, pulses, oil seeds *etc.* On an average, spices yield an output of Rs 1,64,000/ha compared to cereals, pulses, oil seeds *etc.* which ranges from around Rs 33000 to 41000 per hectare (Fig.1). The self-sufficiency achieved in several agricultural crops like food grains and pulses will enable us to focus on value chain development in horticultural crops like spices, where the value of output per unit area is much higher. Spices accounts for about 5% of Gross Value of Output (GVO) and 9% of total export earnings from agriculture in the country. Being crops of higher returns, spices play an important role in providing the much-needed livelihood to millions of people directly or indirectly in the country.

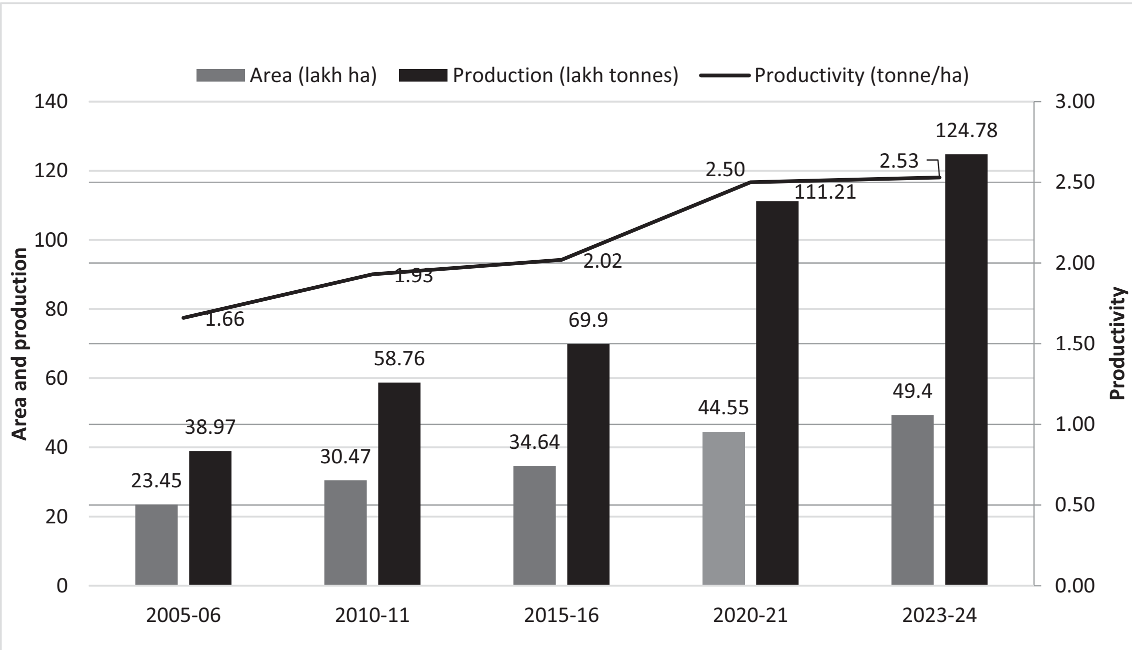


Data Source: NSO, 2024 & DA&FW, 2024

Fig. 1. Output (in *Rs*) of various crops

1. Spectacular Growth in Spices Sector

Spices sector in India is witnessing an unprecedented growth in the country at present as its production and export reach at their historical highs. Production of spices in the country increased from 38.97 lakh tonnes in 2005-06 to 124.78 lakh tonnes in 2023-24 with a growth rate of 6.7 % annually. Area has increased from 23.45 lakh ha to 49.40 lakh ha with a compound annual growth rate of 4.2% during the same period. Productivity of spices also increased substantially from 1.6 to 2.5 tonnes/ha in this period due to the spread of HYV of spices with good quality attributes.



Data Source: DASD, 2024

Fig. 2. Growth in spices area, production and productivity

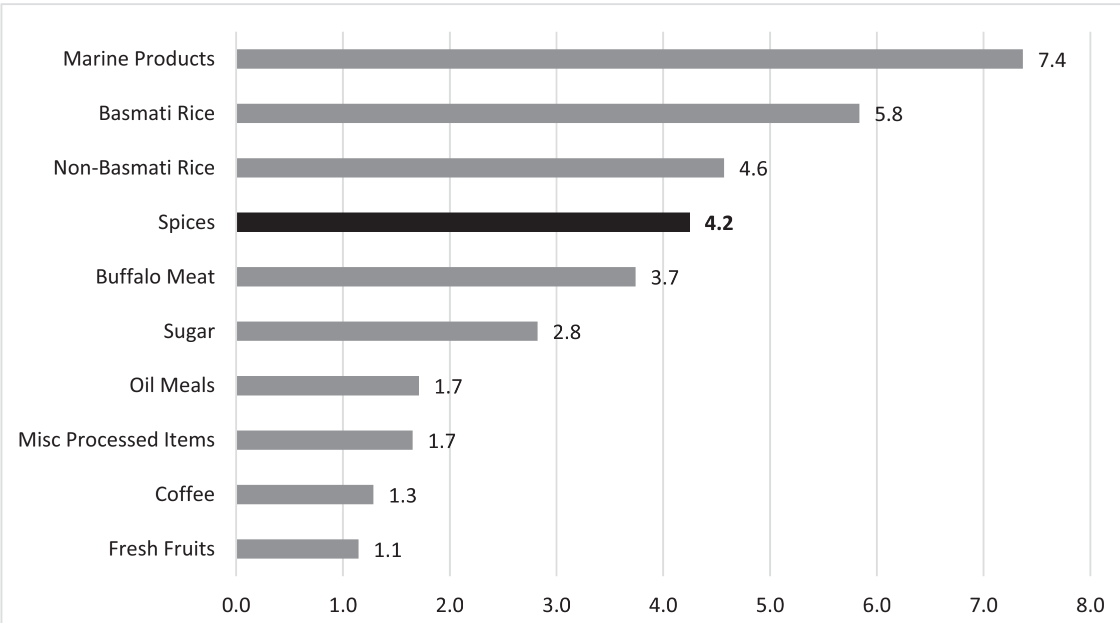
Mission for Integrated Development of Horticulture (MIDH), the flagship programme of Government of India, which is being implemented through state Governments and SAUs/ICAR institutes had tremendously contributed to this growth in spices sector. The programmes implemented by the DASD especially the "Production and distribution of quality planting material" has significantly contributed to the increase in productivity and production of spices in the country.

This surge in production has led to exportable surplus of good quality spices resulting in a tremendous growth in export earnings of spices, which increased from Rs 2628 crores to Rs 36959 crores (4.46 billion US $) during this period. Spices emerged as the top export earner among horticulture crops and 4th largest export earner among agriculture commodities, after marine products, basmati rice and non-basmati rice (Fig. 3) India dominates the world spice trade because of the intrinsic qualities (chemical constituent in flavour profiles) of Indian spices such as the bold black pepper with high piperine and bold berries, turmeric with high curcumin, chillies with varying capsaicin and good colour, superior quality cardamom, ginger with low fibre content, seed spices with high volatile oil *etc.*

Table 1. Export of spices from India

Year	Quantity (lakh tonnes)	Value in crore Rs	Value in Million US$
2005-06	3.50	2628	592.90
2010-11	5.26	6841	1502.85
2015-16	8.43	16238	2482.83
2020-21	17.59	30973	4178.80
2023-24	15.40	36959	4464.17

Source: Spices Board (2023-24)



Data Source: APEDA, 2024

Fig. 3. Export earnings (billion US $) from various agricultural products

2. Development Programmes Boosting the Spices Production

The Ministry of Agriculture & Farmers Welfare (MoA &FW), Government of India has the mandate for the production of agricultural crops including spices in the country. It fulfils its mandate through various agencies at national level and state level. As far as spices are concerned, the production is overseen by the Directorate of Arecanut and Spices Development (DASD), situated at Kozhikode (Kerala). These activities are funded through the flagship schemes of Govt of India implemented by the MoA&FW like Mission for Integrated Development of Horticulture (MIDH), Rashtriya Krishi Vikas Yojana (RKVY), Paramparagat Krishi Vikas Yojana (PKVY), Pradhan Mantri Krishi Sichai Yojana (PMKSY), Pradhan Mantri Fasal Bhima Yojana (PMFBY), Natural Resource Management (NRM), Soil Health Card, e-National Agriculture Market *etc.*

MIDH prgrammes are being implemented by Department of Agriculture & Farmers Welfare (DA&FW) under Ministry of Agriculture with the objectives of increasing production and productivity of horticulture corps including spices and augmenting farmers' income. The development activities in spices are undertaken through the State Horticulture Missions (SHM) set up under the Department of Horticulture /Agriculture of different states. Major development programmes under MIDH are given below.

1. Plantation infrastructure development: Establishing nurseries and tissue culture units to produce quality seed and planting material.
2. Area expansion: Creating new area under cultivation of various crops
3. Rejuvenation: Revitalizing old, unproductive and senile plantations.
4. Protected cultivation: Setting up poly-houses, greenhouses, shade net houses, and walk-in tunnels, along with micro irrigation facilities.
5. Promotion of organic farming: Encouraging organic practices, certification, and establishing vermi compost units.
6. Creation of water resources: Developing community tanks, on-farm ponds, and water harvesting systems.
7. Horticulture mechanization: Providing power tillers, tractors, and plant protection equipment.
8. Human resource development: Conducting awareness programs, farmer training, exposure visits, and study tours.
9. Post-harvest management (PHM) infrastructure: Setting up cold storage, pack houses, ripening chambers, reefer vehicles, processing units, and food processing facilities in North Eastern states.
10. Marketing infrastructure: Developing static and mobile vending carts, retail outlets, rural markets, wholesale markets, and direct market platforms.

Apart from the above programmes, the DASD directly implements certain development programmes for spices like production of quality planting materials, establishing seed storage and processing infrastructure, accreditation of nurseries, technology dissemination through frontline demonstration, innovative programme to address national issues in spices, national /state /district level seminars/workshops and farmers training programmes. These porgrammes are being implemented through various State Agricultural Universities and national level institutes across the country.

3. Rising Global Demand for Spices

The global demand for spices is expected to grow at a rate of 3.19%, slightly exceeding the population growth rate (ISSR, 2013). Similarly, according to the Spices Board of India "Vision 2047" document, global spices consumption is projected to reach 580 lakh tonnes by 2047, with an estimated export demand of 120 lakh tonnes. Out of this, India's domestic consumption has been estimated at 130 lakh tonnes. The Board has set a target of achieving exports of 27 lakh tonnes of spices and spice-based products worth 25 billion USD by 2047. This goal focuses on establishing a sustainable, safe, and chemical-free export supply chain, emphasizing innovative, value-added products marketed under the Brand India label.

The rising global demand for spices presents significant opportunities for the spice industry in the coming years. The Vision Document of the Spices Board highlights that achieving the projected global demand will require a total spices production of 650 lakh tonnes, with India's contribution targeted at 170 lakh tonnes. With the current growth rate of 6.7% in production, this target appears promising. Even with a modest annual growth rate of 2%, India's spices production is projected to reach 197 lakh tonnes by 2047.

Considering the current growth rate in spice production, achieving the targeted production and export levels seems feasible. However, the emphasis must be producing high quality spices that meet the certification standards of importing countries while fulfilling domestic demands. Therefore, our development programmes for spices should be strategically realigned to prioritize achieving the desired quality standards in spice production.

4. Realigning the Development Programmes to Meet Growing Demand

In order to meet the domestic consumption and to make sufficient exportable surplus to meet the global demand, our productivity level should be increased. The productivity level in India is believed to be low compared to other countries. A major effort is needed to bridge this gap in productivity. In India, even the gap between national average and the realizable yield is very wide. The yield gap in the major spices is given in Table 2.

Table 2. Potential for productivity increase in spices

Spice	National average (t/ha)	Potential yield (t/ha)
Black pepper	0.4	2.4
Ginger (fresh)	12.1	20.0
Dry chilli	3.0	7.5
Turmeric	3.5	10.7
Cardamom (small)	0.5	1.6
Nutmeg	0.7	3.0

Bridging this gap is sufficient to increase country's production many folds. There is a great scope to improve the productivity of major spices as the potential yield realized in the research station and at the progressive farmers' plots are very high and well above the national average.

4.1 *Production of nucleus planting materials of spices*

Ensuring the availability of healthy planting materials is crucial for enhancing spice productivity in the country. To meet this need, DASD implements nucleus planting material production programme using released high-yielding varieties. This includes building necessary facilities in research farms under State Agricultural Universities (SAU) and ICAR institutes. Financial assistance is provided for producing nucleus planting materials for spices such as black pepper, ginger, turmeric, chilli, tree spices and seed spices. These programmes are implemented through SAUs and ICAR institutes in major production centres and further multiplied by State Departments or farmers under MIDH programmes. This ensures sufficient availability of high-yielding spice varieties for farmers in subsequent years.

4.2 ***Establishment of seed processing and storage infrastructure***

Seeds produced at seed production centres require proper storage after processing for a reasonable period of time ranging from three months to one year, necessitating adequate storage facilities. For certain spices, infrastructure like drying platforms, machineries for threshing, cleaning, winnowing & grading, storage structures and packaging units are essential. DASD provides financial assistance to SAUs and ICAR institutes to establish these facilities. The programmes implemented has contributed significantly enhancing seed storage, processing, and infrastructure development across these institutions.

4.3 ***Accreditation of spice nurseries***

The planting material requirement of the spices growers is mainly met by nurseries established under State Department of Horticulture/Agriculture, SAUs, ICAR Institutes and nurseries in private sector at present. The major part of the demand is met by the unregulated private nurseries, which lacks modern infrastructure such as green house, mist chamber, efficient nursery tools and gadget, implements and machinery. Establishment of a network of Spice Nurseries to ensure the availability of good quality, disease-free, certified planting material of desired high yielding variety will have a tremendous impact on production, productivity and quality of the spices produced. Towards this direction, DASD has been authorized by the Union Ministry of Agriculture for accrediting spice nurseries. Under the accreditation programme, DASD grants graded recognition to nurseries based on their infrastructure, production system & quality parameters of planting material and management practices adopted. DASD had accredited 60 spice nurseries primarily located in the States of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Odisha. As per the MIDH norms, planting materials need to be procured only from accredited nurseries for all required for area expansion programme and other government programmes.

4.4 ***Hi-tech production system for quality disease free seed rhizomes of ginger & turmeric***

The major constraint in ginger planting material production is the prevalence of diseases such as soft rot (fungal and bacterial), Bellakettu, and pests like shoot borer and rhizome maggot. Soft rot, in particular, is widespread and discourages large-scale cultivation. Other challenges include the high seed rate, bulk handling & storage of seed rhizomes, diseases activity, and low viability. These issues can be mitigated by producing disease-free planting materials, reducing seed rate requirements and minimizing storage losses. These bottle necks can be confronted if totally disease-free planting materials can be produced, seed rate requirement is reduced and loss of ginger seeds during storage can be reduced. The micro-tuber production technology in ginger can ensure pathogen-free seeds. Hence, the DASD initiated the production of disease-free planting material using micro rhizome technology in ginger and turmeric.

High-yielding varieties (HYVs) of ginger and turmeric were developed using micro rhizome technology. Multiple shoot cultures were prepared from rhizome sprouts, and micro rhizomes were induced using a high-sucrose medium. High-tech intensive cultivation of micro rhizome in poly houses and production of single bud derived budlings from the harvested rhizomes was resorted to scale up the production of disease-free seed rhizomes in ginger. On an average, 169 micro rhizomes could be obtained from a single rhizome bud.

The DASD also promotes multiplication of HYV of ginger through the Pro-Tray Nursery Technique, where single sprout rhizomes are raised in pro-trays and transplanted to the field after 30-40 days. This method ensures healthy planting materials, reduces quantity of quantity of seed rhizome and lowers cost of production of seed material.

4.5 Accreditation and establishment of large cardamom nurseries in NE states

Due to high prices prevailed for large cardamom during last few years, the cultivation has spread to newer areas in North-Eastern states. The planting material from Sikkim was transported in large scale to nearby states, which lead to spread of fungal/ viral disease in the crop. Solution for this is to regulate the multiplication and exchange of planting material to prevent the spread of diseases. Therefore, DASD developed accreditation norms for large cardamom sucker nurseries. Large cardamom nurseries have been established in NE states like Sikkim and Arunachal Pradesh by DASD in association with State Horticulture Departments to generate source of disease-free nucleus planting material for establishment of nurseries in public and private sector.

4.6 Clean Plant Programme (CPP) under MIDH

It is an ambitious programme of Ministry of Agriculture and Farmers Welfare, Govt of India under MIDH. This programme will provide access to virus-free, high-quality planting materials to famers regardless of their landholding size or socio-economic status. Under this programme, nine advanced Clean Plant Centres (CPC) will be established across India, each focusing on specific horticulture crops. These centres will be equipped with modern diagnostic and therapeutic facilities, including tissue culture labs. The Ministry anticipates the following benefits from the implementation of CPP.

- By providing virus-free, superior planting material, the CPP aims to boost crop yields.
- Higher quality produce will lead to better market prices and income for farmers.
- Streamlined certification processes and infrastructure support will help nurseries in efficiently producing clean planting material.
- Improved facilities will foster growth and sustainability in the nursery sector.
- The initiative ensures that consumers receive fruits that are not only virus-free but also enhanced in taste, appearance, and nutritional value.
- With higher-quality, disease-free products, India will enhance its position as a leading global exporter, thereby expanding market opportunities and increasing its share in the international trade.

4.7 Dissemination of technologies through frontline demonstration (FLD)

The realization of the potential yield can be achieved through dissemination of the improved production technologies evolved at various Research Stations under SAUs and ICAR Institutes. The DASD establishes frontline demonstration plots to popularize the improved technologies like Organic production technology in spices, production technologies for seed spices, Micro irrigation (drip method) in spices *etc*. These demonstration plots serve to disseminate and convince farmers of the applicability of these technologies developed by the Research Institutes.

5. Export Oriented Production Programmes

To make available exportable surplus of quality spices, the DASD focusing on following programmes:

5.1 Pesticide free cumin production for export

Indiscriminate use of plant protection chemicals results in pesticide residues beyond tolerable limits (MRL) leading to rejection of many consignments of spices. Promotion of sustainable spices cultivation has been urged and Good Agricultural Practices (GAP) had been prepared for cumin from a common platform involving all the research institutes like ICAR-Indian Institute of Spices Research, AICRP on Spices, ICAR-National Research Centre on Seed Spices (NRCSS) and the exporters. To disseminate sustainable cultivation practices of cumin among the farming community, the DASD in collaboration with the ICAR-NRCSS had undertaken demonstration of technology of pesticide free cumin in clusters of 25 ha each in Rajasthan (Nagaur and Barmer) and Gujarat (Banaskantha district). Promising yield (6.7 quintal/ha) was obtained on par with the conventional cultivation practices and fetched premium price.

5.2 Rejuvenation of Cochin Ginger (CG) and Alleppey Finger Turmeric (AFT) for export promotion

Cochin Ginger (CG) and Alleppey Finger Turmeric (AFT) are the most demanded trade varieties of ginger and turmeric for export market from Kerala state fetching premium price due to desired intrinsic qualities. Due to the unorganized cultivation and procurement, both these types are not available in the pure form now. The trade estimate collected from All India Spices Exporters Forum (AISEF, 2020) shows that the export demand of Cochin Ginger is 20000 MT whereas availability is only 1000 MT and AFT has a demand for 50000 MT whereas its availability is only 2000 MT. Therefore, the DASD has taken up a project to rejuvenate these varieties with the following activities.

- Survey and collection of ginger & turmeric types cultivated and marketed in central Kerala.
- Characterization and quality analysis of the varieties
- Multiplication of purified types of AFT and CG in association with KAU / State Department farms
- Large scale cultivation of the purified AFT &CG in farmers' clusters/Self Help Groups (SHG) in central Kerala.

On Identifying pure CG and AFT with desired trade quality, this can be used for mass multiplication and distribution to farmers. This, being high in demand for export, will help in shifting conventional farmers to export oriented cultivation of these trade varieties and thus earn premium price.

5.3 Popularisation of chilli varieties tolerant to viral and fungal diseases

Indian chillies are sought for unique colour and varied pungency. Export rejections were reported recently because of high level of pesticide residues (due to high level of pest/disease incidence) and incidence of mycotoxin contamination in dry chilli. Therefore, the DASD has taken up demonstration on high yielding, leaf curl virus tolerant chilli hybrids (5 varieties – Arka Tejasvi, Arka Yashasvi, Arka Saanvi, Arka Tanvi and Arka Gagan) having good quality attributes (pungency & color), released from ICAR-Indian Institute of Horticulture Research in core chilli growing areas of the country following sustainable production practices.

5.4 Promotion of GI Varieties

5.4.1. Identification and genetic purification of Byadagi chilli cultivars

Byadagi chilli is a traditional variety of chilli, which has a high demand due to its natural colour and mild pungency, grown in Karnataka State and having GI (Geographical Indication) registration. Due to semi allogamous nature, the original trait has been eroded. To restore and maintain the genetic purity of traditional chilli varieties, the DASD, in association with University of Agricultural Sciences, Dharwad, has initiated a programme to identify and revive the traditional Byadagi chilli cultivars. On completion of this project, we may be able to identify the pure cultivar of Byadagi so that the genetic purity of the traditional variety can be maintained. The pure Byadagi seeds will be multiplied and distributed to farmers for cultivation and export.

5.4.2. Promotion of Mundu chilli for increasing the production to meet both domestic and export demand

India is home to a wide variety of chillies with distinct quality traits. In Tamil Nadu, major types include Sannam, Teja and Mundu (bullet) chillies. Mundu chilli is an unique variety having GI tag, is grown exclusively in Ramanathapuram district and is highly sought after for its unique flavor. However, its average yield of 808 kg/ha under traditional practices is below its potential. Tamil Nadu Agricultural University has developed organic production technology that can boost yields by 25-30%. To promote this, DASD has established FLDs to disseminate the improved technology, which could enhance farmers' income by securing premium market prices. Given the existing organic niche market abroad, forming a Mundu chilli hub is a viable opportunity.

5.5 Horticulture cluster development programme

The Ministry of Agriculture and Farmers Welfare has launched a new programme for Horticulture Cluster Development to enhance the global competitiveness of the Indian horticulture sector. The Cluster Development Programme (CDP) is designed to leverage the geographical specialisation of horticulture clusters and promote integrated and market-led development of preproduction, production, post-harvest, logistics, branding, and marketing activities. The main objectives of the programme are to:

- Address the concerns of value chain from pre-production, production, postharvest management and value addition to logistics, marketing and branding
- Reduce harvest and post-harvest losses by developing the infrastructure for post-harvest handling, value addition and market linkages.
- Facilitate the introduction of innovative technologies and practices
- Build the capacity of stakeholders and enhance farmers' income through cluster-specific interventions, including brand promotion.

The MoA&FW has identified 55 horticulture clusters, of which 12 have been selected for the pilot launch of the programme. Among spices, West Jaintia Hills, Meghalaya has been identified for cluster development in turmeric. Based on the learnings from the pilot project, the programme will be scaled up to cover all 55 clusters.

5.6 Formation and promotion of 10,000 new FPOs

This is an important programme of the MoA & FW to provide holistic and broad-based supportive ecosystem to form new 10,000 Farmer Producer Organisations (FPO) to facilitate development of vibrant and sustainable income-oriented farming and for overall socio-economic development and well-being of agrarian communities. Other objectives of formation of 10000 FPS are:

- To enhance productivity through efficient, cost-effective and sustainable resource use and realize higher returns through better liquidity and market linkages for their produce and become sustainable through collective action.
- To provide handholding and support to new FPOs up to 5 years from the year of creation in all aspects of management of FPO, inputs, production, processing and value addition, market linkages, credit linkages and use of technology etc.
- To provide effective capacity building to FPOs to develop agriculture entrepreneurship skills to become economically viable and self-sustaining beyond the period of support from government.

5.7 Agri Infrastructure Fund

The Agri Infrastructure Fund, another initiative by the MA&FW, provides a financing facility aimed at benefiting all stakeholders in the agricultural ecosystem. Its key objectives include:

- *Enhanced marketing infrastructure*: Enabling farmers to sell directly to a broader consumer base, increasing value realization and boosting their overall income.
- *Improved logistics infrastructure*: Reducing post-harvest losses and minimizing intermediaries, allowing farmers better market access and greater independence.
- *Modern packaging and cold storage*: Allowing farmers to store produce, choose optimal selling times, and secure better prices.
- *Community farming assets*: Supporting improved productivity and efficient input use, resulting in significant cost savings for farmers."

Spices covered in this scheme are red chilli, cumin, cove, coriander, cinnamon, garlic, ginger, turmeric, fenugreek, cardamom *etc.* Eligible activities are cleaning, drying, sorting, boiling, polishing, grinding, packaging, storage *etc*.

6. **Import Substitution Programmes**

Although India is the largest producer of spices, it imports a significant quantity of spices and spice products to meet the specific demands of the domestic market and processing industry. The country imported 3.83 lakh tonnes of spices valued at Rs 12016 crores (US$ 1.45 billion) in 2023-24. Important spices that are being imported are pepper, clove, asafoetida, Cassia/Cinnamon, large cardamom, star anise etc. Imports of spices like cassia, clove, large cardamom, black cumin, star anise etc. are for domestic consumption as the production of these crops is not sufficient to meet the internal demand.

To augment the production of these spices, the DASD implements the following programmes

6.1 Promotion of organic production of high curcumin turmeric varieties

India imports more than15000 tonnes of turmeric worth Rs 150 to 200 Crores annually. Major portion of this import is used for curcumin extraction as production of high curcumin turmeric is limited in the country. The industry demand for high curcumin turmeric is around 50000 MT (AISEF, 2020). In order to make high curcumin Turmeric available for export, the DASD set up frontline demonstration of turmeric varieties with high curcumin content in selected locations (Kandhamal in Odisha, Waigaon in Maharashtra, Chintappalli in Andhra Pradesh), where high curcumin levels were obtained. Curcumin rich varieties like Roma, Waigaon, Megha and IISR Pragathi are demonstrated in these areas following sustainable production practices.

6.2 High density cinnamon cultivation in the interspaces of coconut gardens

Due to inadequate production of cinnamon in the country, cassia is imported as a cheaper substitute for cinnamon. We have imported 37814 tonnes of cassia valued at Rs 789 crores and 2473 tonnes of cinnamon valued at Rs 74 crores. Therefore, to popularize cultivation of true cinnamon and thus to increase the cinnamon production in the country, the DASD is promoting cinnamon in the States of Andhra Pradesh, Maharashtra, Karnataka, Kerala, Tamil Nadu and Goa by establishing demonstration plots of high-density planting of cinnamon as intercrop in coconut gardens.

6.3 Promotion of Clove Cultivation

Cultivation of clove in the country is very limited and it is confined to southern states like Kerala, Tamil Nadu and Karnataka. It is cultivated in an area of 1976 ha with a production of 1542 tonnes. Clove is imported mainly to meet the domestic demand. In 2023-24, we imported 23689 tonnes of Clove valued at Rs 1352 crores. To promote cultivation of clove in the country, the DASD makes effort to make available good quality clove seedlings through SAUs in the state of Kerala, Karnataka, Tamil Nadu and Andaman & Nicobar Islands.

7. Sustainable Spices Production

The above programmes aim to streamline spice production in the country, enabling the production of high-quality spices at globally competitive prices. This will support to achieve the export targets of US$ 10 billion by 2030 and US$ 25 billion by 2047, while also ensuring the availability of healthy and affordable spices for domestic consumption.

Table 3. Item wise import of spices into the country

Item	2022-23			2023-24		
	Quantity (MT)	Value (Rs in lakhs)	Value (Million US$)	Quantity (MT)	Value (Rs in lakhs)	Value (Million US$)
Pepper	35905	134023.64	167.50	34028	135968.68	164.22
Clove	17986	83828.46	104.77	23689	135176.51	163.27
Asafoetida	1441	150361.66	187.92	1457	124061.27	149.84
Spices oils & oleoresins	4756	106439.6	133.03	5179	118193.26	142.75
Mint products	4474	48653.3	60.81	11554	115583.23	139.60
Other spices (1)	109070	123776.03	154.69	86330	91886.02	110.98
Cumin black / white	2013	4395.74	5.49	17760	79247.21	95.72
Cassia	38545	87120.47	108.88	37814	78942.9	95.35
Cardamom (large)	9403	48840.33	61.04	6531	51817.67	62.59
Star anise	6741	37140.93	46.42	9215	43909.05	53.03
Caraway/fennel	10927	19873.07	24.84	19590	35646.3	43.05
Mace	2169	27183.85	33.97	2291	28188.47	34.05
Ginger fresh / dry	32172	18154.24	22.69	32926	27605.65	33.34
Garlic	3014	2496.58	3.12	20066	27173.94	32.82
Curry powder/paste	7960	20371.97	25.46	9414	24681.06	29.81
Coriander	31383	20961.76	26.20	28828	15721.19	18.99
Turmeric	16769	19579.01	24.47	14638	15006.52	18.12
Cardamom (small)	567	5092.4	6.36	2553	14772.71	17.84
Chilli / paprika	2698	6859.68	8.57	6283	14332.11	17.31
Cinnamon	2192	7216.82	9.02	2473	7384.96	8.92
Herbal spices	8206	10959.93	13.70	6087	7043.15	8.51
Nutmeg	1234	6363.4	7.95	886	4420.37	5.34
Tamarind	1058	2056.71	2.57	1332	2714.35	3.28
Others seed spices (2)	1490	1712.2	2.14	2037	2091.11	2.53
Poppy seed	24728	64250.11	80.30	0	0	0.00
Total	**376900**	**1057712**	**1321.91**	**382960**	**1201568**	**1451.26**

Source: Spices Board India

Despite these efforts, achieving sustainable spice production remains a significant challenge. SAUs, ICAR institutes and various private organizations are actively promoting sustainable practices in spice production. Sustainability in agriculture is defined as a system that is ecologically sound, economically viable, socially just and humane. These principles can be applied across all aspects of the spice production system, including cultivation, marketing, processing, and consumption.

The Union Ministry of Agriculture has launched the prestigious "National Mission for Sustainable Agriculture" to enhance agricultural productivity, sustainability, profitability and climate resilience. The mission encompasses initiatives such as location-specific integrated farming systems, soil and moisture conservation, comprehensive soil health management, efficient water management practices and the adoption of rainfed technologies. Key interventions under this mission include Rainfed Area Development (RAD), On-Farm Water Management (OFWM), Soil Health Management (SHM) and Climate Change and Sustainable Agriculture: Monitoring, Modelling and Networking (CCSAMMN).

Spices and spice-based cropping systems inherently align with the concept of sustainable farming. These crops exhibit wide adaptability and offer alternative options for farmers to cultivate a variety of crops across diverse environments, soils and climatic conditions. Spices can thrive even in marginal and degraded soils, barren lands, homestead gardens or underutilized lands, making them a viable option for small and marginal farmers.

To remain competitive, farmers must focus on increasing productivity, reducing production costs and ensuring sustained profitability from a given unit of land. This can be achieved through crop diversification, incorporating various spice crops in the form of intercropping, mixed cropping, multi-storied cropping and high density multi-storied cropping system. Such diversified systems provide farmers with guaranteed income from at least one crop, thereby reducing risks. Additionally, multispecies cropping systems generate multiple sources of food, income and employment, elevating the socio-economic status of small and marginal farmers in major spice-producing regions.

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Abstracts

NATIONAL SYMPOSIUM ON SPICES AND AROMATIC CROPS
2025
SYMSAC-XI

Theme 1: *Strategies for climate-resilient varieties for sustainable production*

ORAL PRESENTATION

S1 OP1

Leveraging YREM and BLUP for genotype selection in black pepper breeding under temporal environmental variability

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Black pepper (*Piper nigrum* L.), a perennial spice crop of economic and medicinal importance, requires robust methods for genotype selection due to its multi-year yield variability. This study evaluated ten black pepper genotypes over three years to identify stable, high-yielding cultivars using novel quantitative criteria: Yield Relative Environment Maximum (YREM) and Best Linear Unbiased Prediction (BLUP). Significant yield variations were observed, with genotype-by-year interaction (GYI) contributing 27.81% to total variation. AMMI stability values identified stable genotypes, while GGE biplots provided insights into genotype-environment relationships, highlighting HP2173 as the best-yielding genotype and OPKM as the ideal genotype. YREM and BLUP proved superior stability parameters, effectively capturing relative performance across years and environments. HP2173, OPKM, and IISR Thevam were identified as top-performing genotypes, with three-year average YREM values above 0.66 and BLUP values exceeding 2.9 kg vine^{-1}. Conversely, genotypes with YREM below 0.41 and BLUP below 1.50 kg vine^{-1} were categorized as poor performers and recommended for rejection. The predictive power of single-year and two-year YREM and BLUP values was validated, demonstrating strong correlations with three-year results. This study underscores the utility of YREM and BLUP for evaluating perennial crop genotypes under temporal environmental variability. By integrating these metrics, breeders can accelerate the selection and release of superior genotypes, addressing limitations of traditional methods.

Keywords: AMMI, BLUP, GGE biplot, perennial crops, YREM

S1 OP2

IISR Surya-A unique flavoured turmeric for powdering industries

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Turmeric (*Curcuma longa* L.) a well-known spice, has many improved varieties with high yield and high curcumin. An initiative was taken to identify a turmeric genotype with a light-yellow colour, which meets export requirements and is also suitable for the powdering industry, where it can be blended with different light and dark-coloured cultivars with this objective, ICAR-Indian Institute of Spices Research, Kozhikode through its crop improvement programme has identified a high yielding selection with light yellow colour rhizomes. Subsequently, trial was taken up at seven AICRP on Spices centres (Coimbatore, Guntur, Kammarpally, Kanke, Kozhikode, Pasighat and Pottangi) with nine entries along with one national check (IISR Prathiba) and local check (Mydukur) with three replications under RBD for three years (2021-24). Among the nine entries, Acc. 849 (IISR Surya) was found to be stable based on AMMI biplot analysis and high yielding (average yield of 29 t ha^{-1}), with a potential yield of 41 t ha^{-1}. The Acc. 849 (IISR Surya) showed 10% increase over national check and 30% increase over local check. In addition to high yield, the variety has light yellow colour (23 A code in RHS colour chart) and rich in minor volatile compounds *viz.,* zingiberene (21.07%), ß-sesquiphellandrene (14.13%), 1,8-cineole (3.42%) and α humelene (6.30%). The curcuminoid profile revealed high DMC (0.55%) compared to CUR (0.17%) and BDMC (0.08%). The identified variety is distinct from the closely related variety IISR Prathiba morphologically as well as at molecular level.

Keywords: AMMI, α humelene, industry, zingiberene

S1 OP3

Unravelling the breeding potential of multi-parent derived populations in chilli (*Capsicum annuum* L.)

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Chilli is considered to be the indispensable of part of Indian diet. There is often a resource constraint to evaluate large number of F_1 hybrids or populations. As a consequence, breeders limit number of crosses or populations or reduce the population size to be evaluated. Identification of breeding potentiality of any population is the pre requisite in this context. Selection in multi-parent derived populations can fix more alleles governing complex traits. Thus, it is possible to accumulate greater number of desirable alleles in these populations than from bi-parental populations. In this context,

breeding potential of ten populations constructed using sixteen parental lines were field evaluated for economical traits *viz.,* average fruit length, average fruit weight, fruits per plant and green fruit yield per plant. Breeding potential of these ten populations was assessed for these four productivity traits in terms of means, standardized range, coefficient of variation and frequency of transgressive segregants recovered. Considering the statistical parameters across productivity traits, rank-sum method was employed to identify desirable populations. Population designated as D5 × D2, D4 × D2 and D6 × D2 with lower rank-sum were considered to possess higher breeding potential. These populations could be preferentially advanced to isolate inbred lines. Further, field assayable traits such as, plant height, fruits per plant, average fruit weight and average fruit length had significant positive correlation with green fruit yield which could be used as proxy traits for selection of high green fruit yielding genotypes.

Keywords: Breeding potential, transgressive segregants, rank-sum method, inbred lines

S1 OP4

Identification of stable sources and genetic determinants controlling resistance to chilli anthracnose through genome wide association mapping in *Capsicum* spp.

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Chilli, a cornerstone of the spice industry, is valued for its colour and pungency. However, climate change, marked by erratic and unpredictable rainfall, has intensified the prevalence of anthracnose, a major threat affecting the quality and colour of dried chillies. Developing anthracnose-resistant varieties is essential for climate-resilient and sustainable chilli production. In this context, 188 *Capsicum* genotypes from six species were phenotyped for their response to artificial inoculation with *Colletotrichum capsici* and genotyped using 112 SSR markers to identify genomic regions associated with anthracnose resistance. The study identified four 'immune' genotypes from *C. baccatum* (VI012528, VI012497, PBC 81, and PBC 80) and two resistant genotypes from *C. annuum* (BDL-3 and ADL-4) as promising donors for breeding anthracnose-resistant varieties. Genotypic analysis revealed three SSR markers *viz*., NG12, AVRDC PP100 and Hpms E013 putatively associated with lesion size across six GWAS models. Primer NG12 corresponded to the SRC2 protein-coding region, associated with biotic stress resistance. AVRDC PP100 targeted regions linked to jasmonic acid activation pathway, a key player in plant defense, while Hpms E013 mapped to regions involved in histone methylation, which is crucial for stress tolerance. Current research highlights the potential of marker-assisted selection to accelerate the development of climate-resilient chilli cultivars. By integrating resistant genotypes and genomic insights, the spice producers can buffer the impacts of climate variability, ensure sustainability and quality of its produce.

Keywords: Anthracnose, association mapping, SSR markers, histone methylation

S1 OP5

Identification of potential genes that influence quality and nutritional content in the leaves and seeds of coriander (*Coriandrum sativum* L.)

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Essential oil from coriander (*Coriandrum sativum* L.) has been widely studied for its biological activity, yet molecular research on essential oil-related genes in Indian coriander cultivars remains limited. At ICAR-NRC on Seed Spices, an experiment using RNA sequencing was conducted on seeds and leaves of the coriander cultivar AgCr-1 from Ajmer to identify genes influencing essential oil quality. The sequencing data showed a high number of matches with *Daucus carota* subsp., and functional annotation revealed numerous genes involved in the production of essential oils, vitamins, and medicinal compounds. AgCr-1 seeds and leaves exhibited 30,882 and 24,963 coding sequences (CDS), respectively, with 21,837 shared between both samples. Comparative analysis identified 337 upregulated and 1,081 downregulated genes in leaves versus seeds. Notably, AgCr-1 demonstrated higher expression of the geraniol 8-hydroxylase-like gene, particularly in leaves, compared to other coriander varieties. This gene is crucial for essential oil biosynthesis. These findings offer valuable insights for molecular breeding and biotechnological approaches to enhance essential oil composition in coriander crop.

Keywords: Coriander, essential oil, candidate genes, RNA seq

S1 OP6

Identifying superior tamarind clones (*Tamarindus indica* L.) based morphological and biochemical traits through Multi trait Genotype-Ideotype Distance Index (MGIDI)

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Tamarindus indica L. is a versatile, multipurpose, monotypic tree species commercially grown in different agro-eco system. It plays a significant role in improving the livelihood in domestic and industrial sectors. The present investigation aims the selection of high productive tamarind clones with superior pulping quality. Sixty tamarind clones were evaluated for morphological and biochemical traits using the Multi-trait Genotype–Ideotype Distance Index (MGIDI), a cutting-edge selection tool for identifying high-performing genotypes. Principal component analysis revealed that the first five components accounted for 81.01% (2019-2020) and 78.10%

(2020-2021) of the cumulative variance, highlighting the effectiveness of using component traits in genotype selection, especially for yield contributing traits. Factor analysis grouped the morphological and biochemical assessed traits into five key factors (FA1 to FA5), encompassing essential yield and quality traits, such as fruit weight, pulp weight, seed weight, total soluble solids, and protein content. MGIDI identified nine promising clones *viz.,* IFGTBTI-14, IFGTBTI-15, IFGTBST-7, IFGTBTI-2, IFGTBTI-1, IFGTBST-17, IFGTBRT-18, IFGTBST-2, and IFGTBTI-17 signifying their potential in multi-trait improvement for tamarind breeding programs. Strengths and weaknesses of these clones were analyzed based on their association with the five identified factors for targeted breeding strategies. This study underscores the importance of multi-trait selection methodologies like MGIDI for enhancing the efficiency of tamarind breeding programs and advancing the development of high-yield, multi-attribute genotypes.

Keywords: Tamarind, Multi-trait Genotype–Ideotype Distance Index, selection

S1 OP7

Red Gold: PKM 2 Red tamarind-A revolutionary high anthocyanin variety for sustainable agriculture and food industry

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Red tamarind (*Tamarindus indica* var. *rhodocarpa*), a rare variant found in southern India, offers high anthocyanin content in its unripe fruits (180–360 mg g^{-1}), surpassing other fruits like grapes, cherries, and jamun. Known for its antioxidant properties, red tamarind holds potential as a bio-colorant for food and cosmetic industries. Department of Spices and Plantation Crops, TNAU, Periyakulam, developed a high-yielding, anthocyanin-rich red tamarind variety, PKM 2, through systematic breeding. PKM 2, a clonal selection (Ti-31) from 32 germplasm accessions, was identified between 2010-2017 and evaluated from 2017–2023 for quality and yield in Tamil Nadu conditions. The variety exhibits superior traits, including high pulp content, low seed count, and exceptional nutritional value. Released during the 53rd State Varieties Release Committee meeting in 2023, PKM 2 features early bearing, red fleshy pods with an average yield of 21.78 t ha^{-1}, reaching up to 23.00 t ha^{-1} under favorable conditions. Its pulp contains high protein (12.87%), potassium (234.12 mg/100g), calcium (477.50 mg/100g), iron (10.90 mg/100g), and anthocyanin (248.00 mg/g), along with low tartaric acid (14.50%). Additionally, it boasts significant antioxidant (1614 µg g^{-1}) and phenolic content (10.00 mg/100g) and is resistant to powdery mildew. PKM 2 is ideal for producing ready-to-serve drinks, jams, jellies, chutneys, pulp powder, and fruit bars, offering immense value to farmers and food industries.

Keywords: Red tamarind, germplasm, anthocyanin, food industries

POSTER PRESENTATION

S1 PP8

Epigenetic perspectives on gene regulation in *Piper nigrum* (black pepper) during drought stress

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Drought stress significantly impact plant growth, leading to reduced crop yields and decreased species diversity in black pepper. This study explores the relationship between epigenetic modifications and gene regulatory networks *vis-a-vis* drought stress in black pepper. Whole-genome bisulfite sequencing (WGBS) was conducted in a putatively drought tolerant accession 4024 under control as well as drought stress condition to identify approximately 2,098 significant differentially methylated regions (DMRs). DMR-associated regions were annotated, identifying eight DMRs situated near stress-responsive genes like protein kinase, polymerase and transcription factors. To validate these findings, methylation-specific primers were designed. Additionally, transcriptome data were analyzed to investigate the potential regulatory roles of these DMRs in modulating associated genes. This study underscores the epigenetic influence of DMRs on stress-related gene regulation in black pepper during drought stress, offering critical insights for advancing future crop improvement strategies.

Keywords: Black pepper, drought, whole genome bisulfite sequencing, differentially methylated regions

S1 PP9

Genomic investigation of the heat shock transcription factor gene family leveraging the secrets of drought resistance in black pepper

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Black pepper (*Piper nigrum* L.), known as "king of spices," holds global significance due to its extensive use in diets, medicines, and preservation. The productivity of black pepper in traditionally cultivated areas has been declining primarily due to drought stress and being naturally sensitive to drought, and studies reveal that the crop in its reproductive stage requires upto 3,000 mm of water, making it highly susceptible to water deficits that often result in plant mortality. Various mechanisms have been proposed to address this challenge to protect plants from drought stress, including the induced systemic tolerance (IST) process. Within this context, the HSF gene family, encoding specific chaperones, plays crucial roles in multiple abiotic tolerance processes. In our study, we comprehensively analyzed the Hsf gene family in black pepper through whole-genome identification and characterization, which is otherwise poorly understood. A total of 41 *Hsf* genes were identified in the *P. nigrum* genome, and these genes were unevenly distributed on 19 chromosomes. Detailed annotation using the Heatster database for the different domains and motifs indicated 19 belong to HsfA class, 21 belong to HsfB class, and the remaining one got included in HsfC class. Afterward, the neighbor-joining method constructed a phylogenetic tree indicating a similar clustering pattern. The *Hsf* genes in the same group had similar gene and protein structures. This is the first insight into this gene family and the results provide some gene resources for future gene cloning and functional studies toward the improvement in stress tolerance of the crop.

Keywords: *Piper nigrum*, drought, heat shock factor, phylogeny

S1 PP10

Root morpho-anatomical features of black pepper and related species

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Piper species is a dicotyledonous vine crop possessing a taproot system. However, cultivated *Piper* species have adventitious feeder roots due to vegetative propagation. Apart from that, they also possess runner roots, climber roots, and prop roots. The root morpho-anatomical features of three *Piper* species *viz., P. chaba* Trel. & Yunck, *P. colubrinum* Link, and *P. nigrum* L. and thirteen black pepper varieties *viz.,* IISR Girimunda, Panchami, Sreekara, Vijay, IISR Shakthi, IISR Thevam, PLD 2, Subhakara, Pournami, IISR Malabar Excel, Panniyur 1, Panniyur-5 and OPKM were examined in this present study. The highest root weight per plant was recorded in *P. colubrinum* (10.20 ± 5.17 g) when compared to *P. chaba* (7.25 ± 0.81 g) and *P. nigrum* (4.39 ± 0.88 g). *P. colubrinum* also had the highest root length (44.90 ± 7.14 cm) and root spread (50.23 ± 9.82 cm). Among thirteen varieties, Panniyur-5 recorded the highest root weight (6.70g) which was at par with Vijay (6.00g). Longest root was observed in IISR Malabar Excel (33.10 cm) which was at par with Pournami (32.55 cm). The highest primary root length was observed in IISR Thevam (28.87 cm) which was at par with PLD 2 (23.5 cm) and Pournami (24.97 cm) and the highest number of secondary roots was observed in IISR Thevam (74.67). Pournami had the highest number of xylem vessels (95.33) which was at par with IISR Shakthi (92.33) and IISR Thevam (88.33). IISR Shakthi had the largest number of root hairs per cross section (71.33) which was at par with Vijay (57.66). Widest steel was observed in IISR Shakthi (58.73 µm).

Keywords: *Piper* species, varieties, roots, morphology, anatomy

S1 PP11

Unravelling the biochemical and anatomical responses of black pepper (*Piper nigrum* L.) to biotic and abiotic stresses

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India, once the world's largest producer and exporter of black pepper lost its top position mainly due to biotic and abiotic stresses. Foot rot, a highly contagious disease, poses serious threat to black pepper cultivation mainly under water logging conditions. Hence, an experiment was conducted at ICAR-Indian Institute of Spices Research, Kozhikode to explore biochemical changes and anatomical variations in black pepper varieties, Sreekara and IISR Thevam in response to water logging and *Phytophthora* infection. Five-month-old cuttings of both varieties were subjected to water logging condition in pots and challenge inoculated with *Phytophthora* (*P. capsici* and *P. tropicalis*). Plants maintained under field capacity served as control. On third day, flaccidity of youngest leaf was observed in all waterlogged plants. By seventh day, exhibited symptoms of wilting, and defoliation, with Sreekara expressing severe symptoms. Plants inoculated with *P. capsici* showed higher mortality rates. Water logged plants of both varieties as well as those inoculated with *P. tropicalis* survived with symptoms of defoliation and wilting (more conspicuous in Sreekara than IISR Thevam) for 30 days. Control plants didn't show defoliation and wilting. Under water logging conditions, activity of peroxidase, catalase and superoxide dismutase revealed an increase in response to oxidative stress, while a decreasing trend was observed in plants inoculated with *P. capsici*. Anatomical studies revealed structural alterations in waterlogged plants, including chlorophyll degradation, tissue necrosis and presence of aerenchyma. IISR Thevam showed better tolerance to stresses than Sreekara which could be attributed to presence of a greater number of lengthy roots.

Keywords: Black pepper, biotic and abiotic stresses, foot rot, water logging, *Phytophthora*

S1 PP12

Evaluation of cardamom genotypes for moisture stress tolerance through multi-location evaluation

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Six cardamom genotypes (IC 349537, IC 584058, GG×NKE-12, IC 584078, CL 668, HS 1, IC 584090) and one check (Appangala 1) were evaluated for drought tolerance across four locations (Appangala, Sakleshpur, Mudigere, and Myladumpara) over three years. Moisture stress was imposed during summer (February-March) by withholding irrigation, while the control block received sprinkler irrigation (25 mm) every 12 days. Soil moisture, growth, yield, and quality parameters were recorded. Pooled analysis revealed IC 349537 as the highest-yielding genotype under both irrigated and moisture-stress conditions, followed by the check APG 1. AMMI and GGE biplot analyses identified IC 349537 as the top performer in Sakleshpur and Myladumpara, while IC 584058 and IC 584090 excelled in Appangala and Mudigere, respectively. The "mean v/s stability" analysis confirmed IC 349537 as both high-yielding and stable. IC 349537 recorded the lowest Drought Susceptibility Index (DSI) of 0.89 and the highest Drought Tolerance Efficiency (DTE) of 70.71%, demonstrating strong drought tolerance. It produced an average yield of 550 kg dry capsules ha^{-1} under irrigated conditions and 360 kg dry capsules ha^{-1} under moisture stress, with 50% of capsules >8 mm in size. Essential oil content was 8.74% under irrigation and 8.84% under moisture stress. Considering its superior yield, stability, and quality under stress, IC 349537 was released as a drought-tolerant cardamom variety, IISR Manusree.

Keywords: Small cardamom, moisture stress, drought, AMMI, GGE biplot

S1 PP13

Genetic diversity analysis of F_1 hybrids through ISSR markers indicates the heterozygous nature of parents in small cardamom [*Elettaria cardamomum* (L.) Maton

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PV1, a released Malabar-type cardamom variety, is known for its tolerance to biotic and abiotic stresses but lacks the desired capsule boldness, limiting its acceptance among growers and traders. To address this, hybridization was conducted at the Cardamom Research Station, Kerala Agricultural University, Pampadumpara to incorporate the capsule boldness to PV1 through crossing with Clone 57, an accession known for its bold, round capsules. The resulting F_1 progenies were evaluated in the *ex-situ* field gene bank of the station, including molecular characterization. Genetic diversity studies were performed using ISSR markers due to their ability to detect DNA-level variation and discriminate among closely related genotypes. Molecular analysis revealed a significant level of genetic variability among the hybrids. The findings highlight the heterozygous nature of one or both parents, which were originally developed through clonal selection. The results validate the heterozygous genetic makeup of the parents utilized in the breeding program, strengthening the concept of maintaining genetic variability for crop improvement.

Keywords: Cardamom, genetic diversity, hybrids, ISSR

S1 PP14

Characterization and evaluation of cardamom (*Elettaria cardamomum* Maton) germplasm accessions for morphological, yield and quality traits

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Small cardamom (*Elettaria cardamomum* Maton), commonly known as the "Queen of Spices," is native to the evergreen rainforests of the Western Ghats and belongs to the Zingiberaceae family. The study was conducted to evaluate 60 promising cardamom genotypes for morphological, yield and quality traits at ICAR-Indian Institute of Spices Research, Regional Station, Appangala, Madikeri. Significant phenotypic and yield variations were observed among the accessions. The highest plant height (354.59 cm) was recorded in accession IC 547164, while the highest number of bearing tillers (38.83), panicles (40.39) and the maximum number of leaves per plant (279.00) were observed in IC 349391. Accession IC 547196 exhibited the highest capsules per plant (289.98), fresh yield (2094.80g) and dry yield (416.0g). Multivariate cluster analysis characterized the accessions into four distinct clusters, each demonstrating significant diversity. Cluster 4 comprised 23 accessions, cluster 3 included 15 genotypes, cluster 2 encompassed 12 and clusters 1 covered 10 accessions. Cluster 3 exhibited the highest levels of intra-cluster and inter-cluster variation, suggesting its potential as a valuable source of genetic diversity for breeding programmes. The volatile oil content of cured capsules ranged from 6.11% (IC 349508) to 9.96% (IC 349426) and oleoresin content varied between 2.30% (IC 547149) and 4.24% (IC 547204). The results highlight the extensive diversity within the small cardamom gene pool and provide critical insights for further research and conservation.

Keywords: *Elettaria cardamomum*, evaluation, phenotypic, variability, essential oil, oleoresin

S1 PP15

Determination of the optimal condition for ethyl methane sulfonate-mediated mutagenesis in ginger (*Zingiber officinale* Roscoe)

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Ginger being obligatory asexual crop, mutation breeding is one of important crop improvement strategies. Different concentrations of ethyl methane sulfonate (EMS) were used to treat single buds of ginger variety IISR-Varada, to determine the optimal dose of EMS mediated mutagenesis. A total of 12 treatments were done including controls using different concentrations of EMS *viz.,* 0.5%, 0.75%, 1.0%, 1.25%, 1.5% at two incubation periods *viz.,* 2

h and 4 h. Highest germination percent and seedling survival percent was 96.23% & 84.97% respectively for 0.5% EMS dose at 2 h incubation period whereas the lowest was 3.70% for both at 1.5% EMS dose at 4 h incubation. Number of leaves, shoot length and root length of seedlings were recorded after 90 days of germination. Root less seedlings were observed in all treatments and the frequency was high in treatments with 4h incubation period. Most affected trait was shoot length with 77.17% of mean reduction followed by root length (72.15%). Low germination, low survival rate and abnormal seedling development indicated the inhibitory effect of EMS on growth and development and impact of effect was proportional to concentration of EMS and incubation time. Logistic regression (logit) model was used to obtain the regression coefficients β0, β1, and β2 using R software to calculate LD_{50} value. LD_{50} dose of EMS for 2 h incubation period was 1.01% while for 4 h incubation period was 0.41%. These results revealed that EMS can be used to increase genetic variability for key traits in ginger.

Keywords: Mutagenesis, EMS, LD_{50} value, regression

S1 PP16

Enhancing ginger (*Zingiber officinale* Rosc.) crop potential through morphological characterization and DUS descriptor assessment

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Ginger (*Zingiber officinale* Rosc.) is a widely utilized and economically important crop known for its significant medicinal and culinary uses. Investigating the diversity within ginger germplasm is essential for its effective application in breeding programs and conservation initiatives. This study was conducted at the Hybrid Rice Evaluation Centre in Gudalur, Nilgiris, using a collection of thirty-two ginger genotypes to examine variability and identify top-performing genotypes. Each genotype was evaluated for two qualitative and eight quantitative traits based on Distinctness, Uniformity, and Stability (DUS) criteria. Among the traits assessed, plant height, leaf count on the main stem, and dry recovery displayed no variation, indicating monomorphism across the genotypes. In contrast, traits such as growth habit, shoot diameter, leaf length, and leaf width showed two distinct forms, indicating dimorphism. Additionally, the number of tillers per clump, rhizome thickness, and rhizome shape displayed multiple variations, reflecting polymorphism within the population. Principal Component Analysis (PCA) performed on seven morphological traits revealed that seven principal components, each with eigenvalues greater than one, accounted for 98.28% of the total observed variability. Leaf length, rhizome thickness, and tiller count exhibited the greatest variation, whereas other traits showed lower variability. Based on the findings from PCA and cluster analysis, the genotypes Nadia, Manipur Local, Aswathy, Nagaland Local, Bhaise, ACC 578, Himachal Local, Rio De Janeiro, IISR Vajra, Humnabad Local, Hassan Local, Thalavadi Local and Chikkamagalore Local 2 emerged as the most diverse among the genotypes studied.

Keywords: Diversity, morphological variability, DUS descriptors, principal component analysis

S1 PP17

Genetic fidelity and *in vitro* studies using molecular markers in salt stress ginger (*Zingiber officinale* Rosc.)

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Ginger (*Zingiber officinale* Rosc.) is an important spice widely used in food, confectionery, and pharmaceutical industries for its aroma and flavour. This study focuses on the comparative regeneration of ginger rhizome explants of cv. Suprabha under varying hormone concentrations and NaCl-induced salt stress to identify salt-tolerant plants through *in vitro* and *in vivo* approaches. Callus induction was rapid in MS medium supplemented with IAA (0.5 mg L^{-1}) and NAA (1.0 mg L^{-1}). For shoot induction and regeneration, B_5 vitamins, 3% (w/v) sucrose, BAP (1.0 mg L^{-1}), and IAA (1.5 mg L^{-1}) displayed the highest regeneration potential after two weeks of subculture. Salt tolerance was evaluated by culturing callus under NaCl stress (0-300 mM). The most salt-tolerant callus at 200 mM NaCl regenerated effectively in MS medium fortified with NAA (1.0 mg/L) and BAP (1.5 mg L^{-1}). *In vivo* studies on ginger seedlings subjected to NaCl concentrations (0-400 mM) revealed significant salt tolerance up to 300 mM. Chlorophyll (a), chlorophyll (b), and total chlorophyll levels were estimated under control and salt stress conditions to assess physiological responses. Genetic fidelity of micropropagated plants was confirmed using ISSR molecular markers (UBC 841 and UBC 808), ensuring true-to-type regeneration.

Keywords: NaCl, NAA, BAP, genetic fidelity, ISSR, salt stress

S1 PP18

***In vitro* rooting and hardening in ginger using different rooting and hardening media**

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The present study was carried out with the aim to study on *in vitro* rooting and hardening in ginger of variety Mahima (local) using different rooting and hardening media in CRD

experimental design at Centre of Excellence in Plant Biotechnology and Department of Vegetable Science, Dr. PDKV, Akola during 2023-2024. The study was carried out in two parts with the objectives to standardize the media for *in vitro* rooting of regenerated shoots of ginger and to standardize hardening protocol for ginger. In the first part of study, the shootlets produced in *in-vitro* culture of ginger were transferred to rooting media where combination of half B_5 medium with 1 mg L^{-1} NAA and 1 mg L^{-1} IBA showed better response than other medium. Maximum number of roots (19.15), longest roots (9.79 cm) and highest shoot length (11.05 cm) were produced in this media composition. It also showed best results in number of shoots (1.02) and number of leaves per shoot (9.08) produced. The *ex-vitro* acclimatization of plantlets was best in peatmoss medium among the various hardening treatments tried which resulted in 100 percent survival rate, maximum of 16.78 cm plant height, 8.0 number of leaves and 2.0 number of tillers per plant at 60 days after transplanting to hardening media. Peatmoss showed better vigour of the plantlets also.

Keywords: *In vitro* propagation, rooting, hardening, *ex-vitro* acclimatization, ginger

S1 PP19

Sequence diversity analysis of ring finger family proteins in ginger

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Transcriptome wide analyses in many crops have identified the responsiveness of Ring Finger (RHF) genes in Arabidopsis, rice and many other crops during stress. The RING domain containing proteins are reported to have roles in many physiological functions like growth and developmental processes, hormone signalling pathways and defence response against abiotic and biotic factors. RHF is a variant of RING zinc finger protein with histidine at 5th coordination site. The E3 ligase activity of RING-containing proteins is catalyzed by the RING domains, which are protein-protein interaction domains. In this study we have analysed the diversity of RHF proteins in ginger and identified various domain combinations. Towards this, first a genome wide survey was performed using whole genome sequences of ginger and the evolutionary relationship among the ginger RHF family members was identified using phylogenetic analysis. Our analysis found that RHF family in ginger is a large family having more than 1000 sequences clustering into at least 6 clusters and many subclusters. Conserved motifs and domains in the protein sequences were identified using SMART, CDD databases. Domain predictions identified the diversity in the domain number as well as organization among the members of the family in ginger. The representative sequences from the 6 clusters identified in this study were found to have different domain combinations of which 15 were unique combinations. This study can contribute to development of climate resilient and high yielding varieties in ginger through new plant breeding techniques.

Keywords: Ginger, transcriptome, phylogeny, zinc finger, protein

S1 PP20

Studies on *in vitro* propagation in turmeric cv. PDKV Waigaon

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The present investigation was conducted at Centre of Excellence, Plant Biotechnology, Department of Agricultural Botany, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, (M.S.) during the academic year 2021-2022 and 2022-2023 with the aim *to standardize the protocol for in-vitro propagation of turmeric.* In this study, treatment combination of Bavistin 0.1% for 4 min + $HgCl_2$ 0.2% for 4 min of time showed highest survival percent of turmeric explants. When, rhizome buds were cultured on MS media with different combinations of BAP and NAA, the highest number of shoots and number of leaves per shoot was recorded by treatment MS media + 2mg L^{-1} BAP + 1 mg L^{-1} NAA, whereas, minimum number of days for shoot initiation and days for shoot proliferation after shoot initiation were also recorded by the same treatment combination. For *in-vitro* root induction, half strength of MS medium was used with different combinations of IBA and the highest number of roots per plant and the lowest days for root initiation were observed in treatment combination ½ MS media + 1mg L^{-1} IBA. In the hardening of *in-vitro* grown plantlets of turmeric, maximum survival percentage of plantlets, maximum plant height and number of leaves after one month of hardening was recorded in peatmoss.

Keywords: Turmeric, plant tissue culture, propagation, *in vitro*, hardening

S1 PP21

Leveraging DNA markers in identification of exotic ABLs as promising fertility restorers and field validation in chilli (*Capsicum annuum* L.)

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Most of the commercial hybrids are based on CMS system in chilli. Conventional phenotype-based identification of restorers for hybrid cultivar development is time consuming and resource demanding. Hence, DNA marker assisted identification of fertility restorers help save considerable amount of resources and time, which in turn enable increasing the pace and efficiency of breeding hybrid cultivars. In this study, Sequence Characterized Amplified

Region (SCAR) and Cleaved Amplified Polymorphic Sequence (CAPS) based five *Rf* gene linked markers were used to identify fertility restorers from among 18 advanced breeding lines (ABLs). To validate these markers 126 hybrids synthesized by using 18 ABLs with 7 CMS lines in line × tester mating design were evaluated for field assayable fertility traits such as anther structure, pollen release score, fruit set, seed set and fertility indicators such as pollen fertility and pollen viability. The ABLs involved in deriving F_1 hybrids with well-developed anthers, high frequency of viable pollen grains (>80%), germinable pollen grains (>80%) and successful selfed fruit and seed set were regarded as restorers. Results of laboratory and field assays suggested 14 out of 18 ABLs as complete restorers. The SCAR marker, CRF3S1S was highly efficient in differentiating restorers from maintainers and hence could reliably be used in rapidly detecting restorers from chilli germplasm.

Keywords: Restorer, *Rf* gene, pollen fertility, pollen viability

S1 PP22

Unveiling the potential of hybrids derived from exotic advanced breeding lines for fruit yield and its attributing traits in chilli (*Capsicum annuum* L.)

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Hybrids dominate chilli cultivation, with most derived from a single source of cytoplasmic male sterility. To diversify the genetic base, hybrids involving newly identified advanced breeding lines (ABLs) as effective restorers are crucial. To address this, 75 hybrids derived from 15 ABLs and 5 CMS lines along with 20 parents and 5 checks (Arka Meghana, Arka Kyathi, Arka Swetha, Arka Haritha and KBCH-1) were evaluated for seven quantitative traits *viz*., fruit length (cm), fruit width (cm), green fruits per plant, average green fruit weight (g), average red dry fruit weight (g), green fruit yield per plant (g) and red dry fruit yield per plant (g). Analysis of variance revealed significant differences among parents and crosses for all the seven productivity traits, justifying the material used in the study. Estimation of *per se* performance and general combining ability (GCA) effect suggested consideration of both for selecting parents for generating promising heterotic hybrids. The ABL's namely, AV 44, AV 43 and AV 54 were found good general combiners for most of the productivity traits. Large number of test hybrids registered significant positive heterosis over mid parent, better parent and checks, for fruit yield and its attributing traits. The crosses, CMS UAA × AV 44 and CMS UAA × AV 43 expressed high magnitude of significant positive heterosis over checks for both green fruit and red dry fruit yield per plant. Further, identified high yielding candidate test hybrids can be extensively evaluated in multilocation trials to check their yield superiority and wide adaptation.

Keywords: Test hybrids, advanced breeding lines, general combining ability, heterosis

S1 PP23

Reciprocal cross differences for breeding potential in chilli (*Capsicum annuum* L.)

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Assessing spectrum of variability among F_2 populations derived from straight and reciprocal crosses helps to explore cytoplasmic influence, if any, on trait expression. Besides cytoplasmic effects, differences between reciprocal cross derived progenies assist in identifying population with better breeding potential. Under this premise, reciprocal cross differences, if any, between two sets of reciprocal crosses [(ADL-4 × S-343), (S-343 × ADL-4), (BD × S-343) and (S-343 × BD)] were assessed based on trait mean, transgressive segregation index (TSI) and Usefulness criterion (Uc) at one and five *per cent* selection intensities for traits such as average fruit length (cm), average fruit width (cm), number of fruits plant^{-1}, average fruit weight (g) and green fruit yield plant^{-1} (g). F_2 populations derived from two sets of reciprocal crosses differed significantly. F_2 populations derived from S-343 × ADL-4 and S-343 × BD displayed higher mean, TSI and Uc for green fruit yield plant^{-1} than its reciprocal cross. Breeding potential of F_2 population derived from S-343 × ADL-4 irrespective of the direction of cross was better than that derived from other three crosses for green fruit yield plant^{-1}. It is worthwhile to forward the segregating individuals derived from S343 × ADL4 that exhibited high breeding potential to isolate superior stabilized recombinants in advance segregating generations for use in further breeding programs.

Keywords: Reciprocal cross, breeding potential, transgressive segregation index, usefulness

S1 PP24

Assessing genetic variability in *Capsicum annuum* using half diallel crosses

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Plant breeders face challenges in selecting genotypes with desirable traits due to genotype-environment (G × E) interactions, which affect consistent performance across environments. In the present investigation, 12 parents and their 66 hybrids of chilli were evaluated in the half diallel fashion for yield and quality characters. The analysis of variance revealed significant variations for all the parameters in parents and hybrids. The highest broad sense heritability estimates were observed for the biochemical parameters such as ASTA colour values, red and yellow carotenoids, ascorbic acid and oleoresin in the parents and hybrids. The highest values of genotypic and phenotypic coefficient of variation in parents and hybrids were observed in ascorbic acid mg/100g and the lowest values were observed in days to full maturity. The estimates of GCV were lower than the respective PCV, indicating the influence of environmental factors on the expression of the traits studied. Among the different traits studied, high heritability together with a high percentage of genetic advance was recorded for average fresh yield per plant followed by red carotenoids, ascorbic acid, yellow carotenoids, ASTA colours values and some other yield related traits suggesting that the additive gene action controlled these characters. The study aided in the selection of superior parents, cross combinations, and provided insight in to the suitable selection strategies with a focus on accumulating favourable alleles over generations.

Keywords: Chilli, GCV, PCV, heritability, genetic advance

S1 PP25

Variability and character association studies in coriander (*Coriandrum sativum* L.)

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One hundred genotypes of coriander *(Coriandrum sativum* L.*)* were evaluated in augmented block design to estimate variability and character association at ICAR-NRCSS, Ajmer during 2022-23. Analysis of variance revealed significant variability for most of the traits. Higher estimates of phenotypic coefficient of variance along with genotypic coefficient of variance, genetic advance and genetic advance as percentage of mean were observed for primary branches per plant, secondary branches per plant, umbellate per umbel, seed per umbellate and seed yield per plant. High heritability observed for primary branches per plant (73.29), secondary branches per plant (61.04), umbel per plant (73.84), umbellate per umbel (86.75), seed yield per plant (87.64). The association analysis at both genotypic and phenotypic level revealed that the seed yield plant was significantly and positively correlated with secondary branches per plant (0.56) and umbel per plant (0.67) and umbellate per umbel (0.32).

Keywords: Coriander, character association, genetic advance, heritability, variability

S1 PP26

Induced mutagenesis and determination of morpho-physiological traits for assessing water deficit tolerance in fennel

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An attempt was made to create genetic variability in fennel by using gamma rays mutagen. The fennel seeds irradiated with different doses (150, 175, 200, 225 and 250Gy) of gamma rays and M_1 generation was raised. In M_2 generation, mutant lines were selected based on dwarfness, earliness, multiple branching etc. The identified mutants were evaluated for dwarf and earliness with better yield and quality from M_3 to M_7 generation. When the selected mutant lines were showing the stable characters, they have evaluated for the moisture stress tolerance. The crop was prevented from receiving rain by shelter in and out and irrigation was given based on ETo approach and stress was imposed from flowering to seed setting. Targeting the photosynthetic efficiency by using photosystem II and using the infrared thermal imaging for canopy temperature depression, the tolerant genotypes identified. Under the moisture stress condition, highest yield was recorded in M-1 (24.5 q ha^{-1}) followed by M-25 (23.3 q ha^{-1}) & M-14 (22.3 q ha^{-1}). Minimum (21.5%) yield reduction was recorded in M-35 & M-26 and maximum (23.4%) was recorded in M-11. Results suggest that these genotypes can grow more successfully in arid and semi-arid regions during moisture deficit periods.

Keywords: Fennel, gamma rays, IR images, moisture stress, mutant lines

S1 PP27

Germplasm evaluation of fenugreek (*Trigonella foenum-graecum* L.) in the new alluvial zone of West Bengal

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An investigation was conducted during two consecutive *Rabi* seasons (2022–23 and 2023–24) at the Horticultural Research Station, Mondouri, BCKV, to identify suitable fenugreek germplasms for growth, yield, and quality parameters in the new alluvial zone of West Bengal. Sixteen accessions, collected from various locations in West Bengal and one check variety were evaluated in a RBD with 17 treatments and three replications. The tested location was characterized with well-drained, fertile, sandy loam soil with a pH of 6.7. Significant variations for various traits were observed among the accessions. Fenu. Col-10 recorded the maximum plant height (97.35 cm), Fenu. Col-16 had the highest number of branches per plant (8.21), and Fenu. Col-11 exhibited the maximum number of leaves per plant (37.22). The highest number of pods per plant (19.87) and pod weight (4.62 g) were recorded in Fenu. Col-2, while Fenu. Col-13 had the longest pods (13.95 cm). Maximum seed yield was obtained in Fenu. Col-16 (477.28 g), followed by Fenu. Col-2 (464.79 g) and Fenu. Col-14 (447.67 g), while Fenu. Col-5 recorded the lowest yield (367.07 g). Seven accessions outperformed the check variety (431.5 g). Based on the results, Fenu. Col-16 was identified as the most suitable accession for yield and growth under alluvial plains of West Bengal, followed by Fenu. Col-12 and Fenu. Col-14. Regarding quality, the highest essential oil content was recorded in Fenu. Col-13 (1.54%).

Keywords: Germplasm, fenugreek, alluvial zone, West Bengal

S1 PP28

Evaluation of mango ginger (*Curcuma amada* Roxb.) germplasm found in Manipur for yield, quality and medicinal properties

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Mango ginger (*Curcuma amada* Roxb.) germplasm from Manipur was evaluated during the *Kharif* season of 2023 at the Department of Horticulture, College of Agriculture, Central Agricultural University, Imphal. The experiment, conducted in a randomized block design with three replications, included 12 genotypes (CAUMGLC-1 to CAUMGLC-11) and a check variety (Amba). Results revealed that yield and yield attributing parameters such as fresh clump weight (398.50 g), number of mother rhizomes (5.93), primary rhizomes (20.53), secondary rhizomes (24.5), and yield per hectare (51.29 t) were highest in CAUMGLC-1. Additionally, primary rhizome length (8.22 cm), breadth (2.59 cm), and weight (133.93 g) were optimal in CAUMGLC-1. CAUMGLC-2 exhibited the highest essential oil content (1%), starch content (30.2%), curcumin (0.052%), oleoresin (5.1%), and aroma quality (7.8). CAUMGLC-4 recorded the highest total phenolic content (40.80 GAE mg^{-1}), while the check variety (Amba) showed the highest total flavonoid content (7.6 QE mg^{-1}). In medicinal properties, CAUMGLC-5 demonstrated the highest antioxidant activity (IC_{50} = 113.9 µg mg^{-1}), while CAUMGLC-4 showed superior anti-diabetic activity (IC_{50} = 75.69 µg mg^{-1}), comparable to CAUMGLC-5 (IC_{50} = 78.14 µg mg^{-1}). The findings suggest CAUMGLC-1 as the ideal genotype for high yield, CAUMGLC-2 for quality traits, and CAUMGLC-4 and CAUMGLC-5 for medicinal properties. These genotypes offer valuable potential for mango ginger improvement programs targeting specific traits.

Keywords: Mango ginger, yield, quality, medicinal properties

Abstracts

Theme 2: *Advances in production systems of spices and aromatic crops*

ORAL PRESENTATION

S2 OP29

Soil available nutrients variability on the slopes of the Indian cardamom hills (ICH)

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Soil nutrients are essential for sustained crop yields and soil health in agroecosystems, particularly in mountain regions like the Indian cardamom hills (ICH). These areas, with steep slopes and high rainfall, are prone to soil degradation, making regular monitoring of soil acidity and nutrient concentrations crucial. To assess the impact of slope on nutrient variability, surface soil samples (0-20 cm) were collected from three points along a 150-meter slope: the bottom (1 m), middle (75 m), and highest (150 m) points. The samples were analyzed according to standard protocols. A strong positive relationship was observed between Ca and Mg; pH and Ca; Zn and Na; pH and Mg; Mn and Na; Cu and Na; S and Na; S and Mn. Relationship between Zn and K; N and K; pH and Mn; Na and B; Cu and B; pH and S; Cu and K; B and Zn; pH and Zn; B and Fe was negative. Higher variability in the concentration was noticed for Na (19.2%) and Zn (15.6%) in PC1, while in PC2 the maximum percent of variability was contributed by Ca (33.7%) and Mg (31.4%). The results revealed a higher variability in available nutrient concentrations along the slope (between the top of slope and the bottom of the slope). The results emphasize slope site specific application of fertilizer and manure nutrients along the slopes for getting maximum agronomic and environmental benefits.

Keywords: Soil available nutrients, slope, Indian cardamom, soil acidity

S2 OP30

Delineating genotype × environment interaction in turmeric (*Curcuma longa* L.) genotypes for essential oil across three contrasting production systems using AMMI, GGE biplot models, and metabolomic profiles

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Our study investigated genotype-environment interactions (GEI) to identify both widely adapted and environment-specific turmeric (*Curcuma longa* L.) genotypes for essential oil (%) using AMMI and GGE biplot method on stability of different volatile compounds across three production systems *viz.,* vertical structures (L_1), greenhouse (L_2), and field conditions (L_3). Essential oil content varied significantly among 21 genotypes, with the highest content (9.60%) under greenhouse conditions. ANOVA of AMMI and GGE biplot models attributed most variation in essential oil to genotypes (68.90% and 72.11%), followed by GEI (23.90% and 25.01%). Waigon Turmeric recorded the highest essential oil (7.40-9.60%), while Megha Turmeric 1 and Uttar Rangini were the most stable genotypes. Mydukur Local recorded least essential oil (2.20-4.20%) across production systems. Among 14 major volatile compounds, *ar-turmerone* and curlone showed significant variability. *ar-turmerone* was highest in IISR Pragati and Erode Local in L_1 and L_2, and in NDH 8, Co 3, and Waigon Turmeric in L3. Curlone content was higher in Erode Local (L_1) and IISR Pragati (L_2), with increased levels in L_3 for several genotypes. Minor compounds like α-phellandrene, β-caryophyllene, and zingiberene also varied with production systems. PCA analysis revealed higher sesquiterpenes, including ar-turmerone, in L_1, while L_2 showed distinct volatile profiles with elevated minor constituents like eucalyptol. Environmental factors influenced essential oil composition across years, with compounds like β-caryophyllene and α-terpinolene showing correlations with production systems. This study enhances understanding of GEI in turmeric, aiding genotype selection and breeding to improve essential oil content across diverse cultivation methods.

Keywords: Vertical structures, greenhouse, genotype × environment interaction, essential oil, AMMI, GGE biplot, volatile compounds

S2 OP31

Evaluation of turmeric genotypes for growth, yield and phyto-chemicals

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An experiment was carried out during 2023-24 at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola to study the performance of different turmeric genotypes for growth, yield and phyto-chemical parameters and to find out the superior genotypes of turmeric. The experiment

consisted of seventeen genotypes of turmeric and one check, PDKV Waigaon 17, laid out in randomised block design with three replications. Observations on growth, yield, disease incidence and phytochemicals were recorded. The results showed that the genotypes PWTM-8, PWTM-11, AKTL-21, PWTM-19, AKTL-16, PWTM-9, and AKTL-19 had better growth traits, such as more tillers and larger rhizomes, including more mother and finger rhizome weight and longer primary finger rhizome. PWTM-14 was found resistance to the blotch and leaf spot infections. The study revealed significant variations in the number of rhizomes produced by each genotype. PWTM-8, PWTM-11, PWTM-19, AKTL-16, PWTM-9, and AKTL-19 produced notably higher numbers of rhizomes. Phyto-chemical analysis showed differences in concentrations across genotypes, with some exhibiting higher levels of beneficial compounds. These phytochemicals are known for their role in imparting disease resistance and tolerance properties to the plants. Curcumin and oleoresin were higher in PDKV Waigaon. The results revealed that the genotypes PWTM-19, PWTM-11, PWTM-8, PWTM-14, AKTL-8, AKTL-16, and AKTL-19 not only demonstrated excellent agronomic traits but also possessed high levels of valuable phyto-chemicals among all the 18 genotypes.

Keywords: Turmeric, phyto-chemical, genotypes, growth, yield, curcumin

S2 OP32

Protected cultivation technologies for seed spices under changing climate scenario

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Seed spices like cumin, coriander, fennel, fenugreek, and ajwain are vital high-value crops with significant economic importance, primarily cultivated in Rajasthan and Gujarat, which contribute over 80% of India's seed spice production. However, these crops face challenges from climatic variability, pests, and diseases. Protected cultivation technologies, such as shade nets, mulching, and temporary plastic barriers, offer innovative solutions to mitigate abiotic and biotic stresses, enhancing yield and quality. Techniques like off-season cultivation in shade nets, plastic mulching, and frost protection with plastic fences have demonstrated success in reducing crop losses and improving productivity. Walk-in tunnels and high tunnels provide additional protection from frost, pests, and climatic fluctuations while supporting efficient drying and promoting earlier flowering. Despite high initial costs and the need for technical expertise, low-cost, adaptable solutions like insect-proof nets and low-pressure drip irrigation can be highly beneficial for smallholder farmers. Challenges in adopting protected cultivation technologies are high initial capital investment, scarcity of skilled/trained labours and knowledge gaps regarding requirement of various crops under protected cultivation. The integration of protected cultivation with advanced practices like organic farming and genotype selection holds promise for resource-constrained regions. This approach ensures climate resilience, sustainable production, and enhances export potential, of seed spices in semi-arid and desert areas. Research is required to develop and refine protected cultivation models in

terms of crop behaviour, genotype response, production and protection systems, developing organic management practices and so on.

Keywords: Climate resilience, abiotic stress, biotic stress, yield enhancement, sustainable farming

S2 OP33

Impact of growing environment on growth and yield parameters of coriander under shade net and open field for year-round production

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A field experiment was conducted at the College Orchard, Department of Spices and Plantation Crops, Horticultural College and Research Institute, Coimbatore, to evaluate the performance of coriander (*Coriandrum sativum* L.) variety CO (CR) 4 for year-round foliage production under shade net and open field conditions. The experiment, set up in a randomized block design with three replications, investigated the effects of sowing months (September to May) and growing conditions on coriander production. Early germination (7.67 days) was noticed in the coriander raised under shade net compared to open field condition (11.33 days). Under open field condition, there was crop failure during summer months from March to May. Coriander sown during October showed vigorous growth both under shade net and open field condition recording maximum plant height (29.88cm and 26.59cm respectively), number of primary branches (4.50 and 5.50 respectively) and highest number of leaves (30.63 and 34.44 respectively). Leaf yield per plot in the crops sown during different months showed variations and highest average yield was recorded under shade net condition (4.71 kg/plot) when compared to open field condition (2.18 kg/plot). October sown crop recorded higher yield (5.69 kg/plot) under both the growing condition compared to sowing in other months. Cost economics of coriander cultivation revealed that net returns (Rs. 2,25,039/ha) and BC ratio (3.78) was high from the crop sown during October under shade net. Thus, remunerative coriander cultivation with year-round production is possible under shade net condition. Though, the initial cost of establishment is high, farmer can earn sustainable income through better quality of produce.

Keywords: Protected cultivation, coriander, leaf yield, economics

S2 OP34

Temperature influence on growth, yield and nutritional parameters of *Nigella sativa*

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Nigella, an important seed spice in India, is cultivated across diverse regions from Punjab to Tamil Nadu and Assam to Rajasthan. An investigation was conducted with five sowing dates to study the impact of temperature gradients on nigella from germination to maturity. Growth, chlorophyll content, nutrient uptake, and physiological parameters were recorded at 60, 90, 120 days after sowing (DAS), and maturity. Results showed that growth, yield, and nutrient uptake peaked with sowing by October 15 (T2) but declined thereafter. Biomass accumulation was adversely affected by rising temperatures and growing degree days. Yield decreased by 36.5% when temperatures exceeded 35°C, and late sowing reduced the crop duration by 18 days, further reducing the yield. Nutrient content varied with temperature and sowing time. Seed N decreased with delayed sowing, while Cu and Fe increased initially but declined in late sown crop. Other nutrients in straw increased with delayed sowing. Low temperatures (<20°C) negatively affected root P, K, and Na, while high temperatures impacted root N. Shoot N and P were sensitive to low temperatures, but K and Na were temperature-insensitive and increased with crop age. The temperature also showed effect on micronutrients. yield reduction in nigella was driven more by morphological impairments than biochemical factors. Both high and low temperatures are limiting factors under climate change, necessitating region-specific studies on optimal temperature requirements.

Keywords: Nigella, temperature, growth, yield, uptake

POSTER PRESENTATION

S2 PP35

Yield, quality and economics of fertigation in black pepper

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Black pepper (*Piper nigrum*), belonging to the Piperaceae family, is a highly valued spice cultivated mainly under rainfed conditions in humid tropical climates. Climate change-induced variations in rainfall distribution significantly affect its yield. Supplementing water and nutrients through fertigation could enhance black pepper production, yet research in this area is limited. An experiment was conducted at the ICAR-IISR Experimental Farm, Peruvannamuzhi, Kozhikode, from 2015 to 2022, to evaluate the yield, quality, and economics of black pepper under drip fertigation. The study involved three IISR varieties: IISR Thevam, IISR Girimunda, and IISR Shakthi, planted in 2015, with fertigation treatments initiated a year later. The experiment followed a randomized block design (RBD) with six treatments, including four fertigation levels and two controls, replicated thrice. Each plot comprised six plants spaced at 3×3 m on *Glyricidia* support. The treatments were applied from September to May. Economics was worked out based on yield and prevailing market price, and quality parameters were also recorded. Four years pooled data indicated that maximum fresh yield of 4.0 t/ha, net returns (3.09 lakhs/ha) in Girimunda and 1.45 t/ha yield and net returns (Rs 76,017/ha) in IISR Shakthi and maximum oil, piperine and oleoresin content were recorded in drip irrigation @ 8 litres of water daily along with 50% RDF applied as fertigation in 24 splits. For IISR Thevam, maximum yield (1.85 t/ha) and net returns (Rs. 87,915/ha) were achieved with 8 litres of drip irrigation and 100% RDF in three splits.

Keywords: Drip irrigation, net returns, IISR varieties, quality

S2 PP36

Impact of low cost polytunnel on sprouting and growth of black pepper rooted cuttings in tropical hilly zone

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Black pepper commercial plantations are established using rooted cuttings obtained from runner shoot. Serpentine layering is one of the propagation techniques in black pepper in which 50-60 cuttings can be produced from a single plant in a year. In higher elevations, the rate of multiplication is hampered due to late sprouting, lower sprouting percentage and less survival percentage under the prevailing cool weather. To overcome this problem, an experiment was conducted at ICAR-Indian Institute of Spices Research, Regional Station, Appangala. A low

cost polytunnel was made inside the polyhouse nursery with dimension of 200 cm length, 80-100 cm width and 60 cm height, and its top covered with white polythene sheet having thickness of 300 gauge. Then, single node plantlets with root and leaf separated from the serpentine layering were kept inside the low cost polytunnel for 21 days and it was compared with cuttings kept outside polytunnel. The experiment was conducted in different times of the year during 2023-24. Results showed significantly higher sprouting rates inside the polytunnel, ranging from 56.33% (June) to 89.00% (November), compared to 40.50% (August) to 76.33% (November) outside. Vegetative and root growth parameters, including shoot length, leaf count, root number, fresh and dry weight of shoots and roots, and survival percentage, were significantly better in polytunnel conditions. Hence, this method of using polytunnel in black pepper cutting production will be advantageous in the quality planting material production in the cooler climatic conditions.

Keywords: Black pepper, propagation, polytunnel, rooting, hilly zone

S2 PP37

Enhancing black pepper nursery growth with jeevamrutha: A sustainable approach for rooted cuttings

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The use of Jeevamrutha, a traditional organic formulation made from cow dung, cow urine, jaggery, soil and water, offers significant benefits in the establishment and growth of black pepper (*Piper nigrum*) nurseries. It is rich in beneficial microbes and essential nutrients, which plays a major role in enhancing soil fertility, improving microbial activity, and stimulating healthy root development in black pepper rooted cuttings. When applied to rooted cuttings in poly bags in serpentine method, it improves the soil structure, boosts nutrient availability, and promotes vigorous plant growth by enriching the rhizosphere with beneficial microorganisms that support nutrient uptake and disease resistance. The enhanced microbial activity also helps in the decomposition of organic matter, leading to better soil aeration and water retention. Moreover, Jeevamrutha strengthens seedling immunity, making them more resilient to common pests and diseases, thereby reducing the need for chemical inputs. By using Jeevamrutha in black pepper nurseries, farmers can ensure healthier seedlings, improved survival rates, and stronger plant establishment in the field, while promoting sustainable, eco-friendly farming practices. This approach aligns with organic farming principles and contributes to the long-term productivity and resilience of black pepper cultivation.

Keywords: Jeevamrutrha, black pepper, nursery, soil health

S2 PP38

Precipitation trends and cardamom yield over the montane cloud forest site in Kerala, India 1998-2023 CE

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This study investigates the precipitation trends, pattern and their impact on cardamom yield in the montane cloud forest site of Gavi, Kerala, India, over a 25-year period (1998-2023).The observed precipitation data of montane cloud forest site, "Gavi", were subjected for robust statistical analysis. To measure the ordinal association between the monthly climate data, the Kendall Tau coefficient was employed, and that revealed a mix of rising and falling trends across the years studied with a notable overall annual decrease in precipitation level. Sen's Slope test quantified the magnitude and direction of the precipitation trends. The p-values exposed the precipitation trends of March and June months which were statistically significant. The innovative trend analysis (ITA) has given higher values for the recent years signifying an increase in extreme rainfall events. Overall, the analysis uncovered a granular vision at a monthly and seasonal scales revealing a complex interplay of varying trends with potential implications for planning water resources for forestry and cardamom farming. In and around the montane cloud forest area there are many high yielding cardamom plantations with minimum yield variability over the study period which showed that the montane cloud forest precipitation trends continue to sustain cardamom yield than its counter part, less shaded and degraded rainforest cardamom hill reserves. The analysis showed sustained yield of cardamom to changing precipitation pattern in the montane cloud forest climate site which affirmed that cardamom is a climate resilient crop under the cloud and rainforest system.

Keywords: Precipitation trends, Kendall Tau coefficient, Sen's slope analysis, innovative trend analysis, autocorrelation coefficients

S2 PP39

Integrated management for enhancing productivity in ginger under vertical farming

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Ginger (*Zingiber officinale* Rosc.), a member of the Zingiberaceae family, has been valued since ancient times for its uses as a spice, medicinal plant, and vegetable. Recognized for its bioactive compounds, particularly gingerol, it is esteemed for its distinctive flavor, aroma, and pungency. Due to various factors contributing to the decline in ginger production, it became necessary to develop and implement more advanced technologies to improve cultivation and processing methods. In this regard, an experiment was conducted at ICAR-IISR, Kozhikode during 2021-2023 to compare growth and yield of ginger in vertical structure in polyhouse with that of conventional planting. The experiment consisted of 10 treatments with two nutrient application (100% NPK and targeted yield) and four different concentrations of the plant growth regulators (GA at 100 ppm, BAP at 100 ppm, cycocel at 100 ppm and paclobutrazol at 100 ppm) planted in vertical structure as well as conventional planting for comparison. The potting medium consisting of soil, sand, FYM, vermicompost, and coir pith compost in 0.5:1:1:0.25:1 ratio at 80% field capacity was used for the experiment. The design of the experiment was CRD with three replications. Results of pooled data over two years revealed maximum height of the plant (72.02 cm) and number of tillers (12.99) in T2 treatment (100%NPK + BAP 100 ppm) at 150 days after planting (DAP) in both vertical structures as well as conventional method. The maximum yield (493.62 g/polybag) was recorded in the T2 treatment (100% NPK + BAP 100 ppm) under conventional method of planting.

Keywords: Ginger, vertical structure, plant growth regulators, nutrients.

S2 PP40

Nutrient management regimes and their effects on soil biological processes and culturable microbial diversity in turmeric (*Curcuma longa* L.) rhizosphere

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Nutrient management practices have a profound impact on soil quality, soil biological processes and microbial diversity. The present work investigated the impact of management practices on soil biological processes and culturable microbial diversity in turmeric (*Curcuma longa* L.) rhizosphere. Soil samples were collected from the field experiment conducted in turmeric (Variety: IISR Pragati) in the year 2023-2024 involving organic nutrient management (ONM), chemical nutrient management (CNM) and integrated nutrient management (INM), at 120 days after planting (DAP) and before harvest. The soil samples were subjected to physio-chemical, biochemical/microbiological analysis. In general, soil pH was acidic. Enhanced levels of soil organic carbon (SOC), mineral N, Bray P and exchangeable K were registered by either ONM or INM when compared to CNM. Lower SOC level in the CNM treatment resulted in decreased soil microbial biomass carbon and decreased soil enzyme activities (acid and alkaline phosphatase, β-glucosidase, arylsulphatase, urease and dehydrogenase). Substrate induced respiration, soil microbial biomass phosphorous and nitrogen was found to be higher in ONM. Total culturable bacterial and fungal populations were significantly higher in ONM. Actinobacterial population did not show much variation among treatments. Diazotroph populations, denitrifiers, ammonium oxidizing bacteria, and nitrite oxidizers, were higher under ONM and INM, demonstrating the soil health and fertility benefits of organic and

integrated approaches. Root exudate profiling by GC-MS revealed that certain plant growth promoting and antimicrobial compounds were higher in the case of ONM and were very less or absent in the case of CNM. From the three different treatments, sixty morphologically different bacteria were isolated and further subjected to PGP activity assays and molecular characterization was conducted in thirteen potent isolates.

Keywords: Microbial population, root exudates, soil enzyme activity

S2 PP41

Impact of nutrient regimes on yield and curcumin content of turmeric varieties- stability analysis

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Turmeric (*Curcuma longa* L.), the golden spice, native to South Asia, is renowned for its vibrant natural colour, distinctive flavour and is prized for its potential health benefits, that are attributed to its active compound, curcumin. This study evaluates the effects of different nutrient management regimes on the yield stability and curcumin content of turmeric varieties over nine years (2015-2022). The experiment was conducted at ICAR-IISR Experimental farm, Peruvannamuzhi with five nutrient regimes *viz.,* (i) fully organic nutrient management (ONM), which included farmyard manure (FYM), neem cake, ash, vermicompost, and rhizome biofertilizer treatments; (ii) 75% organic; (iii) integrated 1 (75% organic + 25% chemical) (iv) integrated 2 (50% organic + 50% chemical) and (v) 100% chemical management. The yield stability and curcumin content of various turmeric varieties under each nutrient regime were analyzed using AMMI and GGE biplots. The study found that nutrient regimes of 50:50 (integrated), 75% organic, and 100% organic resulted in higher and stable yields, with varieties such as Suvarna and IISR Pragati consistently achieved high dry yields and as per GGE biplot IISR Pragati can be preferred under organic management conditions. Suvarna and Sudharshana performed better under chemical or integrated environments. In terms of curcumin content, Sudharshana, IISR Prathibha and IISR Kedaram excelled under organic and integrated nutrient management, suggesting that organic inputs and biofertilizers promoted the secondary metabolite production. Both fully organic and integrated treatments delivered higher rhizome yields, comparable to 100% chemical treatments, while enhancing curcumin content. The study indicated that organic and integrated nutrient management are sustainable options for turmeric cultivation, highlighting the need to select suitable varieties for each nutrient regime.

Keywords: Organic, integrated, chemical, stability analysis, genotypes, turmeric.

S2 PP42

Enhancing turmeric's climate resilience: a review of breeding approaches for drought and salinity tolerance

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Turmeric (*Curcuma longa*) is a widely used spice and medicinal plant, but its growth is greatly impacted by environmental stressors such as drought and salinity, which can reduce yields and degrade quality. These challenges are particularly significant in arid and semi-arid regions. Breeding drought and salinity-tolerant varieties is crucial for enhancing turmeric's resilience and ensuring sustainable production. This review explores recent breeding strategies aimed at improving tolerance, including selective breeding, hybridization, mutation breeding, and marker-assisted selection, all aimed at strengthening turmeric's ability to withstand environmental stress. While these approaches show promise, the review highlights the need for a deeper understanding of the genetic mechanisms underlying tolerance and an overview of the current state of breeding approaches for improving drought and salinity tolerance in turmeric, highlighting both progress and challenges, such as maintaining genetic diversity and addressing potential trade-offs between tolerance and yield. By addressing these challenges, researchers can develop more effective strategies to enhance turmeric's resilience and productivity, ultimately benefiting farmers and consumers. The review concludes that developing drought and salinity-tolerant turmeric varieties is crucial for ensuring food security and adapting to climate change.

Keywords: Turmeric, drought tolerance, salinity tolerance, stress resilience

S2 PP43

Analysis of land suitability for turmeric under current and future climate scenarios of India using advanced geospatial techniques

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The objective of the study was to assess the current and future suitability for turmeric cultivation in India by analyzing climatic variables for future scenario using advanced geospatial techniques. The research utilized meteorological data from the Indian Meteorological Department for the period of 1986-2020 as historical data and projected future data from the Coupled Model Intercomparison Project Phase 6 (CMIP6). Four climatic scenarios of shared socioeconomic pathway (SSP) from the Intergovernmental Panel on Climate Change (IPCC) AR6 model of MIROC6 for the year 2050 (SSP 1-2.6, SSP 2-4.5, SSP 3-7.0, and SSP 5-8.5) were used. Results showed that suitable area for turmeric cultivation is declining in future scenario and this decline can be primarily attributed to fluctuations in temperature and an anticipated increase in rainfall in the year 2050. Notable changes in the spatial distribution of suitable areas over time were observed through the application of GIS techniques. The analysis indicated that some of the districts in Madhya Pradesh, Maharashtra and Chhattisgarh are changing from moderately suitable to highly suitable category by 2050. Similarly, some of the districts in Himachal Pradesh and Punjab are changing from highly suitable to moderately suitable category. The analysis also showed that suitability areas reduce

drastically by 2100 especially under SSP 3-7.0 and SSP 5-8.5. This reduction in area will have an impact on the productivity of the crop due to changes in temperature and rainfall patterns which calls for suitable adaptation and management strategies.

Keywords: Suitability, climate change, future scenario, SSP, temperature

S2 PP44

Assessment of leafy coriander (*Coriandrum sativum* L.) genotypes for yield and quality

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Coriander (*Coriandrum sativum* L.) is one of the oldest spice crops which belongs to Apiaceae family. Coriander plays a significant role in Indian cuisine, and is regularly eaten in one or other forms as a condiment. An experiment was conducted at Department of Spices and Plantation crops, Horticulture College and Research Institute, Coimbatore, during 2023-24 to evaluate the performance of leafy coriander (*Coriandrum sativum* L.) genotypes for yield and quality. Fifteen leafy genotypes were studied under a randomized block design with two replications. Observations were recorded on growth and yield parameters, including days to germination, plant height, number of branches per plant, number of leaves per plant, fresh leaf weight per plant, days to harvest, fresh plant weight, fresh shoot weight, root length, fresh root weight, dry plant weight, and herbage yield per plot (kg/6 cm^2).The results revealed that among the fifteen genotypes, CSL1 recorded the highest plant height (28.8 cm), number of branches per plant (9.95), number of leaves per plant (26.95), fresh leaf weight per plant (3.768 g), fresh plant weight (11.095 g), fresh shoot weight (10.042 g), root length (11.3 cm), fresh root weight (0.743 g), dry plant weight (0.883 g), and herbage yield (7.487 kg). CSL2 and CSL14 also recorded higher values compared to the other genotypes.

Keywords: Coriander, genotype, herbage, yield

S2 PP45

Performance of fennel genotypes for growth and seed yield under Hisar condition

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Fennel (*Foeniculum vulgare* Mill.) is a flowering plant in the carrot family, known for its hardy, perennial nature and feathery, yellow flowers. Widely cultivated for its edible, flavourful leaves and seeds, fennel is popular in both its native range and other regions. A trial was conducted at the Vegetable Research Farm, CCS Haryana Agricultural University, Hisar, during the Rabi seasons of 2021-22, 2022-23, and 2023-24, to evaluate and select the best-performing fennel genotypes for local conditions. A total of thirteen fennel entries/varieties, including HF 256,

HF 192, JF 18-13, JF 18-03, UF 231, UF 230, AF 87, AF 17, RF 67, RF 101 (Check), RF 205 (Check), NDF 59, and NDF 46, were evaluated under randomised block design for growth and yield parameters. Entries/varieties were sown in the first week of November at a spacing of 45x20 cm in each year. Significant differences were observed among the varieties for all the parameters studied. Over three years, the mean values ranged from 136.17 to 158.43 cm for plant height, 7.47 to 8.83 branches per plant, 31.87 to 41.07 umbels per plant, 19.93 to 24.90 seeds per umbellet, and 413.77 to 559.12 seeds per umbel. The highest seed yield (2111.40 kg/ha) was recorded in the variety HF 192, which was on par with HF 256 (2046.03 kg/ha) and AF 17 (1990.40 kg/ha).

Keywords: Fennel, varieties, entries, umbel, seed and seed yield

S2 PP46

Impact of sowing dates and varieties on growth, leaf yield, and quality of Kasuri methi (*Trigonella corniculata* L.)

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The study was carried out during the Rabi season of 2023-2024 at the Vegetable Research Centre, JNKVV, Jabalpur. A split plot design was employed to evaluate 12 treatments, combining four sowing dates (October 20, October 30, November 9, and November 19) and three varieties: AKFg-1, Pusa Kasuri, and Jawahar Sel Kasuri Methi-1 (JSKM-1). Early sowing on October 20 significantly enhanced growth and yield parameters. Treatment A1B3 (October 20 with JSKM-1) achieved the highest plant heights across growth stages, while A1B1 (October 20 with AKFg-1) recorded the most branches per plant at 30, 60, and 90 days after sowing (DAS), indicating that early sowing optimized the growth structure. Yield analysis also highlighted the benefits of early sowing. Treatment A1B3 (October 20 with JSKM-1) recorded the highest herbage and dry leaf yield per hectare, as well as the maximum number of clusters, pods, and overall seed yield. Treatment A1B1 (October 20 with AKFg-1) recorded the highest ascorbic acid and protein contents, while A1B3 excelled in moisture content, particularly at 35 DAS. The highest Benefit-Cost (B:C) ratio of 3.25 was observed in A1B3, followed by A1B1. The October 20 sowing date recorded the maximum harvest index, with the JSKM-1 variety showing the highest variety-specific harvest index. In conclusion, the study recommends October 20 as the optimal sowing date for maximizing yield, quality, and economic returns in Kasurimethi, with JSKM-1 emerging as the best-performing variety for the Kymore Plateau and Satpura Hills agro-climatic zones of Madhya Pradesh.

Keywords: Kasuri methi, date of sowing, morpho-physiological, yield, quality

S2 PP47

Evaluation of nigella (*Nigella sativa* L.) genotypes for yield attributes, yield and quality

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Nigella (*Nigella sativa* L.), or black cumin, is an important seed spice of the Ranunculaceae family, widely cultivated in India, Pakistan, Egypt, Turkey, and other countries. In India, it is grown in states like Rajasthan, Madhya Pradesh, and Bihar. The seeds, used as a spice, contain 0.5%-1.4% essential oil, with thymoquinone being the key active compound (18.4%-24% of volatile oil). Considering its importance, a trial was carried out at ICAR-NRCSS, Ajmer during 2021-22 and 2022–23 to select high yielding and adaptable genotypes of nigella for commercial production in India. Nine advanced nigella genotypes were evaluated with one standard check variety namely Ajmer Nigella-1 under randomised block design. All the recommended package of practices was followed to raise a healthy crop. The observations were recorded on plant height (cm), days to 75% maturity, primary branches per plant, capsules per plant, seeds per capsule, seed yield (kg/ha) and total oil (%). The highest seed yield was recorded in the genotype, AN-37 (1522.17 kg ha^{-1}) followed by AN-10(1478.67 kg ha^{-1}) and these genotypes had 27.30% and 25.16% yield advantage respectively over the check variety. Moreover, the two genotypes were better in total oil content among others. Therefore, the genotypes were selected as potential candidate genotypes for comparative varietal trial.

Keywords: *Nigella sativa*, black cumin, seed yield, total oil content

S2 PP48

Effect of integrated nutrient management on yield components and yield of curry leaf in alluvial plains of West Bengal

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Curry leaf (*Murraya koenigii*, L), a semi-evergreen perennial, grows in tropical and subtropical climate. An experiment was conducted during 2021-22 and 2022-23 at the MIDH field, Monduri, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, to study the effects of biofertilizers, organics, and graded levels of inorganic fertilizers on the yield components and yield of curry leaf. The experiment followed a randomized block design with three replications and ten treatments. The experiment involved three organic nutrient sources and three biofertilizers, with a total of ten treatment combinations. The treatments included T_1: Compost + NPK 100% + Biofertilizers, T_2: Compost + NPK 75% + Biofertilizers, T_3: Compost + NPK 50% + Biofertilizers, T_4: Vermicompost + NPK 100% + Biofertilizers, T_5: Vermicompost + NPK 75% + Biofertilizers, T_6: Vermicompost + NPK 50% + Biofertilizers, T_7: Mustard cake

+ NPK 100% + Biofertilizers, T_8: Mustard cake + NPK 75% + Biofertilizers, T_9: Mustard cake + NPK 50% + Biofertilizers, and T_{10}: NPK 100% (RDF 300:50:50 g NPK/plant/year). Yield parameters were recorded quarterly, *viz.,* January-March, April-June, July-September and October-December. The highest leaf count per rachis was in T_4 (23.08), at par with T_5 (22.64), while T_9 had the lowest (12.06). In July-September maximum fresh leaf weight and dry leaf weight were noted in T_4 (2.19 g and 0.94 g respectively). The fresh leaf yield per plant, per plot and projected yield per hectare recorded maximum in T_4 (2.51 kg/plant, 10.10 kg/plot and 4.20 t/ha respectively). The use of organic sources improved growth and yield by facilitating a slow release of nutrients, which enhanced nutrient absorption and promoted the production of growth-regulating substances.

Keywords: Biofertilizers, organic sources, vermicompost, fresh curry leaf yield

S2 PP49

Unlocking tamarind's potential: NAA and KNO_3-the dynamic duo for enhanced fruit set and quality

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Tamarind (*Tamarindus indica*; Fabaceae), native to tropical Africa, has been extensively cultivated in India, particularly in Tamil Nadu, the leading producer. It thrives in diverse environments and has a harvesting season from February to April, occasionally extending to May. Like mango, tamarind experiences alternate bearing, leading to low fruit set and variable yield. A study was conducted at the Horticulture College and Research Institute, Periyakulam, to evaluate the effects of plant growth regulators and foliar nutrients on fruit set, pod yield, and quality of tamarind. Various concentrations of plant growth regulators, including NAA (25 and 50 ppm) and GA_3 (20 and 40 ppm), along with nutrients like KNO_3 (0.25 and 0.5 percent), were applied to the tamarind variety PKM-1 during its vegetative and flowering stages. The results indicated that trees treated with these growth regulators and nutrients outperformed the untreated ones. The highest fruit set (82.30%), number of pods per tree (9,180), pulp weight (15.40 g), and pod yield (163 kg/tree) were recorded in trees treated with NAA at 25 ppm. In contrast, the longest pod length (13.00 cm) and highest seed weight (10.00 g) were observed in trees treated with KNO_3 at a concentration of 0.5 per cent. Additionally, the maximum seed count (10.00) was noted in trees treated with KNO_3 at 0.2 per cent. Biochemical analyses showed that the highest chlorophyll content (3.71 mg/g) was found in trees treated with KNO_3 at 0.2 percent, while the highest total soluble protein content (2.85 g per 100 g) was observed in trees treated with KNO_3 at 0.5 percent.

Keywords: Nutrient, growth regulators, foliar spray, pod yield

S2 PP50

Evaluation and characterization of lemongrass genotypes

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Lemongrass is an important aromatic plant that thrives well in Haryana, making it suitable for commercial cultivation. It is mainly cultivated for oil extraction which is utilized for making aromatic products. Now-a-days, it is also achieving popularity as a component of green tea/herbal tea round the world. Therefore, to evaluate lemongrass for high herbage yield and other traits, a field experiment was carried out using 60 genotypes in augmented block design at Research Farm, MAP Section, CCS HAU Hisar. The plot size was 3.0 × 0.6 m^2 with spacing 60 × 60 cm^2. The data on ten single plants were recorded during 2023-24 for various growth and yield parameters. Results of this trial revealed that, the plant height varied from 116.00 to 255.00cm, leaf length from 68.33 to 127.00cm, leaf width from 0.77 to 2.56cm, number of tillers/plant from 28.00 to 94.00 and fresh harbage yield from 0.49 to 1.30 kg/plant. The genotype HLG 39 was tallest in height with 255.00cm followed by HLG 35 (231.33 cm), HLG 51(215.33cm). The genotype HLG 31 was longest in leaf length with 127.00cm followed by HLG 53 (122.00 cm), HLG 44 (116.00 cm). The genotype HLG 59 was widest in leaf width with 2.55 cm followed by HLG 46 (2.29 cm), HLG 42 (2.20 cm). The maximum numbers of tillers/plant (97.00) were found in HLG 60, followed by HLG 17 (90.33), HLG 9 (80.00). The maximum herbage yield/plant (1.30 kg) was found in HLG 17, followed by HLG 51(1.22 kg), HLG 18 (1.13 kg), HLG 44 (1.11 kg), and HLG43 (1.08 kg). These genotypes will be further evaluated in multi-location trials for developing new variety for commercial cultivation.

Keywords: Lemongrass, aromatic plant, leaf length, genotypes, herbage yield

S2 PP51

Evaluating the impact of various seed priming agents on germination behaviour of bael (*Aegle marmelos* L.)

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The present study was carried out during 2023 at the research farm of the Department of Medicinal and Aromatic Crops, College of Horticulture, Anantharajupeta, Dr. YSR

Horticultural University, Andhra Pradesh to study the influence of hydropriming, GA_3, H_2O_2 and NAA at different concentrations on seed germination and growth of bael seedlings grown under shade net house. The experimental design followed a completely randomized design with 3 replications. The results showed that, there were significant differences among various seed priming treatments. Among the priming agents GA_3 at 200 ppm recorded as the best priming treatment with respect to the parameters, *viz.,* germination percentage (89.92%), shoot length (20.53), number of leaves per plant (2.11), root diameter (3.50 cm), root length (23.22 cm), fresh weight of plant (6.21 g), dry weight of plant (3.48 g), vigour index I (1845), vigour index II (2088) and vigour index III (313) than other seed priming treatments. The results showed that priming using GA_3 at 200 ppm can significantly improve the germination, establishment and growth of bael seedlings in nursery under shade net house conditions.

Keywords: Seed priming, GA_3, germination, root length, vigour index

Abstracts

Theme 2: *Advances in production systems of spices and aromatic crops*

ORAL PRESENTATION

S3 OP52

A rapid onsite detection of piper yellow mottle virus in black pepper using lateral flow immunoassay

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Piper yellow mottle virus (PYMoV) is a pararetrovirus associated with stunt disease of black pepper. Development of effective diagnostic assays are essential for the producing of virus-free plants for propagation. The present study reports the development of a simple, rapid and cost-effective lateral flow immunoassay (LFIA) for the onsite detection of PYMoV. In view of the presence of rare codons, a 303 bp codon optimized region of PYMoV coat protein having good antigenic potential was *in vitro* synthesized, cloned into *E coli* expression vector pET28a+, transformed into *E coli* BL21(DE3) and subjected to overexpression using IPTG. The overexpressed recombinant protein was purified through affinity chromatography and was used to generate polyclonal antisera in rabbits. The specificity of the antiserum was confirmed *via* ELISA and western blotting and purified IgG was subsequently used to develop LFIA. LFIA strips were assembled using various combinations of nitrocellulose membranes of different pore sizes printed with anti-PYMoV IgG (test line) and anti-rabbit IgG (control line), conjugate release matrix coated with gold nanoparticle-IgG conjugate, sample pad, and absorbent pad. Among different sample pads, conjugate release matrix and absorbent pads tested, best results were obtained with GFB-R4 (sample pad), PT-R5 (conjugate release matrix), and AP045 (absorbent pad). Similarly, among membranes of different pore sizes tested, 10 µM showed best results. An IgG concentration of 0.75 mg/ml was found optimum for printing test line and 1 mg/ml for control line. The final optimized LFIA when tested using a known PYMoV-infected and PYMoV-free black pepper plants showed positive reaction only with PYMoV-infected plant. The entire assay from sample preparation to visualization of results could be completed within 10 min. Sensitivity of the assay was similar to ELISA. The LFIA was validated using field samples of black pepper and other species of *Piper* such as *P. betle* and *P. longum*.

Keywords: *In vitro* expression, codon optimization, gold nanoparticle-IgG conjugate, western blotting

S3 OP53

Evaluation of various foliar nutrient application practices on growth, yield and quality attributes in cardamom (*Elettaria cardamomum* (L.) Maton)

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A field experiment was conducted at the Indian Cardamom Research Institute to evaluate the effect of foliar nutrient application on growth, yield and quality in cardamom (*Elettaria cardamomum* Maton). The aim of the study was to examine the impact of diverse foliar application practices commonly adopted by cardamom growers on growth, yield and quality traits as well as on key biochemical parameters in the leaves. A preliminary survey among cardamom farmers identified various foliar application practices employed in cardamom cultivation. The experiment was undertaken in randomized block design (RBD) with eight treatment groups *viz*., T_1, T_2, T_3 and T_4 consisting of biostimulant formulations widely used by growers; T_5 included complex fertilizer (NPK 19:19:19); T_6 (customized nutrient formulation), T_7 (IISR cardamom micronutrient spray) and T_8 (mono-potassium phosphate at different concentrations). The application of foliar treatments generally enhanced nutrient concentrations including nitrogen, phosphorus, potassium, calcium, magnesium, zinc, iron, manganese and copper. The treatments significantly impacted the metabolite levels such as total carbohydrates, chlorophyll and protein contents. The highest yield was achieved with the foliar application of water-soluble complex fertilizer (1%), with a benefit-cost ratio of 4.17.

Keywords: Foliar nutrient application, cardamom, biostimulants, micronutrients

S3 OP54

Combined application of cashew nut shell cake with bioconsortia for managing soil borne rot diseases of small cardamom (*Elettaria cardamomum*)

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Azhukal disease (capsule rot) of small cardamom caused by *Phytophthora meadii* is the major disease inflicting huge crop losses in the high ranges of Kerala. In our earlier studies, it was found that cashew nut shell cake, a waste product from cashew processing industry have antimicrobial properties was able to suppress the growth *in vitro* and soil population of *Phytophthora meadii*. In the present study, experiments were carried out to evaluate the efficacy of cashew nut shell cake and their combinations with bioagents in nursery and field conditions. In nursery experiments, where treatments were imposed after pathogen establishment, it was observed that direct application of either cashew nut shell cake or bioinoculants resulted in per cent disease protection ranging from 40-70% while, the combination treatments resulted in an improved protection ranging from 60-90%. In nursery

experiments, where treatments were imposed first followed by pathogen establishment, it was observed that direct application of cashew nut shell cake and *Bacillus subtilis* resulted in 87% protection followed by *Pseudomonas fluorescens* (80% protection) and *Trichoderma harzianum* (74% protection). However, in combination treatments, the cashew nut shell cake with *Trichoderma harzianum* resulted in 94% protection whereas with bacterial bioagents the protection was 100%. In field experiments, the application of cashew nut shell cake (0.5 kg/plant) along with 1% of individual bioinoculants were on par with copper oxychloride (0.2%). However, when cashew nut shell cake (0.5 kg/plant) was combined applied with a bioconsortium containing 1% each of *Pseudomonas fluorescens* + *Trichoderma harzianum* + *Bacillus subtilis*, the disease protection achieved was significantly superior to all other treatments. Also, the treatment resulted in lowering the disease potential index without affecting the general microflora.

Keywords: Cashew nut shell cake, rot diseases, soil inoculum, bioconsortium

S3 OP55

Development and evaluation of isotonic formulation (*Chaetomium globosum*) for the management of root and stem rot disease in vanilla

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Root and stem rot (RSR) is a serious global disease affecting vanilla, primarily caused by *Fusarium oxysporum*, though other *Fusarium* species are also involved. *F. oxysporum* is a diverse and widespread group of fungi, known for genomic recombination and horizontal gene transfer. *Chaetomium globosum*, a common plant endophytic fungus with strong biocontrol properties, was isolated from leaves, stems, and roots of *V. planifolia* and other wild species. Among the thirteen isolates, FVREP4 showed the highest inhibition of RSR at 74.66%. To develop an isotonic formulation, the water activity (aw) of *C. globosum* was measured at 0.85 using an Aqua Lab water activity meter Series 4TE. A 10-day-old culture of *C. globosum* was centrifuged and suspended in different chemical amendments namely 0.15 M trehalose, 0.21 M polyvinylpyrrolidone (PVP), 0.19 M glycine and 0.12 M glycerol to reduce the water activity to 0.85. Populations of *C. globosum* in these chemical amendments were monitored for 120 days. The population drastically reduced in PVP, glycine, and sterile water, whereas 0.12 M glycerol and 0.15 M trehalose-maintained populations of 4.0×10^8 and 1.7×10^8, respectively. Field studies were conducted to evaluate the efficacy of bioagents and fungicides in managing RSR. Chemical fungicide (copper oxychloride at 0.25%) drenching showed the maximum reduction in disease, followed by soil application of *C. globosum*.

Keywords: Vanilla, isotonic formulation, *Chaetomium globosum*, root and stem rot

S3 OP56

Strategies for management of seed wasp (*Systole albipennis* Walker) in fennel (*Foeniculum vulgare* Mill) crop

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In the present study, experiments were conducted for holistic management of seed wasps in fennel through agronomical manipulation, application of botanical and chemical insecticides. Intercropping of fennel with other crops showed that the percentage damage at harvest was minimal in fennel-dill combination at 2:1 ratio (4.4%) which was comparable with 3:1 fennel-dill ratio. The damage was minimal in the crop sown on 1st September (2.4%), whereas the maximum damage (6.0%) was recorded in the crop sown on 15th October. Application of botanical insecticides as soil amendments prior to sowing and foliar spray at 15 days interval from flower initiation showed that the minimum seed damage (2.87%) occurred in the treatment using karanj meal + karanj oil foliar spray followed by neem meal + neem oil foliar spray (3.7% damage). Soil incorporation of systemic granular insecticides at different sowing dates showed that, the minimum seed damage was with clothianidin @ 1.0 kg ai/ha applied 120 days after sowing (0.51%). Rhizospheric microbial population at harvest in treatments with botanicals indicated that the maximum fungal activity in soil application of castor meal + foliar application of castor oil. The highest bacterial population was observed in treatments using castor oil, followed by treatments with karanj oil. Soil application of cartap hydrochloride resulted in significant reduction in germination, while other insecticides showed no adverse impact on germination. Microbial population estimation in rhizospheric soil samples from different insecticidal treatments revealed no significant difference in the populations of fungi and bacteria compared to the control.

Keywords: Fennel, seed wasp, rhizospheric microbial population, agronomical manipulation

S3 OP57

From genomics to phosphorus clean-up: Metagenomics analysis of phosphorus toxic soils and their bioremediation

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Injudicious application of large amounts of straight/complex chemical phosphorus (P) fertilizers has led to massive accumulation of P in agricultural soils, leading to decreased soil fertility and reduced crop yields. An investigation was carried out to analyze the impact of varying P levels on bacterial communities and to identify the potential P accumulating bacteria which can be used for bioremediation of P toxic soils. Virgin soil samples were spiked with P at five levels (10, 50, 250, 500 and 1000 mg P kg^{-1}). The soil microbial endpoints were estimated on 60th day and selected samples (P0, P250 and P1000) were subjected to metagenomic analysis. The results suggested a stressed environment at 1000 mg P kg^{-1} as

indicated by decrease in soil microbial activities, increase in metabolic quotient, decrease in observed OTUs and alpha diversity parameters. Proteobacteria, Firmicutes and Actinobacteria were the major phyla that flourished at high P (1000 mg P kg^{-1}). Further, to identify efficient P accumulating bacteria, soil samples were collected from different arable soils in Kerala representing low, medium and high available P. Twenty-two P accumulators were selected from 366 bacterial isolates based on significant zone of clearance on PA medium, Toluidine blue-O dye medium and subjected to quantitative analysis. Twelve isolates were selected, of which seven exhibited polyphosphate accumulation. Among these, PAO-isolate 1 and isolate 2 showed the highest P accumulation and were identified as *Bacillus amyloliquefaciens* and *Acinetobacter* spp., respectively. Results of the study highlight *B. amyloliquefaciens* (member of Firmicutes) and *Acinetobacter* spp. (member of Proteobacteria) as the most promising candidates for bioremediation of P toxic soils.

Keywords: P toxicity, phosphate accumulating bacteria, soil health management, bioremediation

POSTER PRESENTATION

S3 PP58

Identification of resistance sources and histopathological insights into black pepper-*Phytophthora capsici* host-pathogen interaction

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Black pepper (*Piper nigrum*), is a globally significant crop with extensive culinary, economic, and pharmacological usage. However, its cultivation is severely threatened by the oomycete pathogen *Phytophthora capsici,* which is one among the etiological agent of foot rot disease. The present investigation aimed to standardize key parameters for growth of the pathogen and soil inoculation method for screening black pepper genotypes against *P. capsici* to identify resistant sources. In the present study, the effect of different temperature and pH levels on mycelial growth and sporangial production of *P. capsici* in different culture media (V_8 agar and carrot agar media) was analyzed. The *P. capsici* isolates showed optimal sporulation at 25ºC under continuous illumination on carrot agar medium at pH 6. Further, for screening the germplasm accessions, the inoculum was prepared adopting the standardized cultural conditions. Thirty black pepper germplasm accessions were screened against *P. capsici* adopting the soil inoculation method. Based on lesion development, among the thirty black pepper accessions, seven accessions showed resistance to root infection. Subsequent histopathological study revealed extensive colonization, disrupted cellular integrity, and limited structural defense in susceptible genotype compared to the resistant type. This study sought to identify resistant sources against *Phytophthora* infections in black pepper, thereby fostering sustainable cultivation practices.

Keywords: Black pepper, *Phytophthora*, resistance, histopathology

S3 PP59

Assessing the efficacy of abiotic stress tolerant *Trichoderma* strains in black pepper subjected to moisture stress

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Black pepper (*Piper nigrum* L.), an economically important spice crop, is highly susceptible to moisture deficit, which affects its physiological processes and reduces productivity. The present study was conducted to study the efficacy of abiotic stress-tolerant *Trichoderma* strains in mitigating moisture stress in black pepper (varieties: IISR Sreekara and Panniyur 1) under greenhouse conditions. Abiotic stress-tolerant *Trichoderma asperellum* (IISR NAIMCC0049) and *T. harzianum* (IISR APT2) strains were applied to black pepper plants subjected to

moisture stress. Initially, the plants were maintained under 100% field capacity (FC), inoculated with spore suspensions of *Trichoderma* isolates (1×10^8 spores ml^{-1}) and later moisture stress was induced 15 days after inoculation. *In vivo* evaluation on black pepper plants maintained under three different moisture levels (100%, 75% and 50% FC) showed that the plants inoculated with *Trichoderma* accumulated greater quantities of secondary metabolites *viz*., proline, phenols, MDA and soluble proteins at low moisture levels (50% FC and 75% FC). The plants inoculated with isolates of *T. asperellum* and *T. harzianum* exhibited markedly enhanced growth and root system development compared to uninoculated plants. Greenhouse experiments clearly demonstrated that the isolates of *Trichoderma* spp. have the potential to alleviate moisture deficit stress by enhancing the root and shoot growth and by triggering antioxidative defense mechanisms. Among the two isolates evaluated, the isolate IISR APT2 holds great promise in mitigating moisture stress in black pepper.

Keywords: *Trichoderma*, secondary metabolites, moisture stress, black pepper

S3 PP60

Studies on evaluation of pesticides against major pathogens of small cardamom (*Elettaria cardamomum* Maton.) and biocontrol agents under *in vitro* condition

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Small cardamom is an economically important spice grown in Kerala, Karnataka and Tamil Nadu. The rot diseases *viz*., capsule rot, rhizome rot and leaf blight are major diseases of cardamom. The fungicides namely, fosetyl-Al, Bordeaux mixture and copper oxychloride are recommended for the management of major rot diseases. The present study evaluated the fungicides as an alternative for the management of rot diseases. The fungicides *viz*., fosetyl-AL 80%WP (0.2%), hexaconazole 5%SC (1%), tebuconazole 25.9% w/w EC (1%), carbendazim 50% WP (0.2%), Fenamidone 10% + mancozeb 50%WG (0.2%), carbendazim 12% + mancozeb 63%WP (0.2%), copper oxychloride 50% WP (0.2%) and mancozeb 75% (0.2%) were tested against *Fusarium oxysporum, Phytophthora meadii, Colletotrichum gloeosporioides* and *Rhizoctonia solani* adopting poison food technique. The results showed that 100% growth inhibition was recorded with carbendazim, mancozeb, Fenamidone + mancozeb and carbendazim + mancozeb with the pathogens tested. The same concentrations of fungicides were tested against the biocontrol agents such as *Beauveria bassiana, Pochonia chlamydosporia, Paecilomyces lilacinus, Trichoderma harzianum, Verticillium lecanii* and *Metarhizium anisopliae*. All the fungicides inhibited the growth of all biocontrol agents at various level after 120 hours of inoculation. Further, the insecticides *viz*., diafenthiuron 50%WP (0.8%), lambda cyhalothrin 4.9%CS (0.04%), spinoteram (0.3%), spirotetramat (1%) were tested under *in vitro* condition against the pathogens and biocontrol agents mentioned above. All the insecticides inhibited the growth of all the pathogens and bioagents at various level. However, lambda cyhalothrin is highly inhibited all the biocontrol agents tested. The

study proved that the fungicides and insecticides inhibited both pathogens and biocontrol agents.

Keywords: Fungicides, biocontrol agent, *Beauvaria bassiana, Pochonia chlamydosporia, Fusarium oxysporum*

S3 PP61

Evaluation of spinetoram 12% SC on thrips and shoot, panicle and capsule borer in small cardamom

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Among the 60 species of insect pests reported in small cardamom, the thrips (*Sciothrips cardamomi*) and shoot, panicle and capsule borer (*Conogethes* sp.) are the major ones which occur throughout the year. In order to evaluate a safer insecticide molecule against the major insect pests, field experiments were conducted in different small cardamom zones located at Kerala, Karnataka and Tamil Nadu. A new insecticide formulation, spinetoram 12% SC (Delegate) was evaluated for two seasons to study the bio-efficacy on thrips and shoot borer, safety to the natural enemies, yield, phytotoxicity and residue on capsules, soil and leaves at different intervals after application. From the results it was concluded that, spinetoram 12% SC @ 54 GAH is the ideal dose for the effective management of thrips and shoot, panicle and capsule borers. Spinetoram 12% SC was comparatively less hazardous to the natural enemies and did not cause any phytotoxicity to small cardamom.

Keywords: Cardamom, spinetoram, thrips, shoot borer

S3 PP62

Bio-efficacy evaluation of bio-pesticides, botanicals and newer molecules for the combined management of shoot and capsule borers and thrips in small cardamom

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Shoot and capsule borer (*Conogethes punctiferalis*) and thrips (*Sciothrips cardamomi*) are the two major pests in small cardamom. A bio-efficacy evaluation of bio-pesticides, botanicals and newer molecules for the combined management both the pests were conducted during 2022-23. Among the treatments, two included bio-pesticides (T_1-*Bacillus thuringiensis* @ 5 g/l + *Beauveria bassiana* @ 20 g/l; T_2-*Bt* @ 5 g/l + *Verticillium lecanii* @ 20 g/l), four treatments included one bio-pesticide and one botanical (T_3-*Bt* @ 5 g/l + *Tithonia diversifolia* 5% leaf extract; T_4-*Bt* @ 1 ml/l + Aloe garlic extract 2%; T_5-*Bt* @ 1 ml/l + *Brugmansia suaveolens* 5%

leaf extract; T_6-*Bt* @ 1 ml/l + Horticultural mineral oil 10 ml/l), three chemical insecticides (T_7-spinetoram 11.7 SC @ 0.4 ml/l; T_8-chlorantraniliprole 8.8% + thiamethoxam 17.5% SL @ 0.5 ml/l; T_{10}-quinalphos 25 EC @ 2 ml/l) and control. Infestation of *C. punctiferalis* on tillers followed the order; $T_8<T_7<T_9<T_5<T_1<T_2<T_6<T_4<T_3<T_{10}$. The treatments T_7 and T_8 were on par and the treatments T_1, T_2, T_4, T_5 and T_6 were also at par. *S. cardamomi* infestation on capsules followed the order; $T_7<T_9<T_8<T_1<T_5<T_4<T_6<T_2<T_3<T_{10}$. The treatments T_7, T_8 and T_9 were at par and the treatments; T_1, T_2, T_3, T_4, T_5 and T_6 were also on par. Among the treatments, T_7, T_8 and T_9 in chemical pesticides and T_1 and T_5 in bio-pesticides/botanical combinations were found to be superior with low average infestation of both the pests.

Keywords: Small cardamom, *Conogethes punctiferalis, Sciothrips cardamomi,* pesticides

S3 PP63

Evaluating potting mixtures for large cardamom (*Amomum subulatum* Roxb.) seedlings in the Eastern Himalayan region of India

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Large cardamom (*Amomum subulatum* Roxb.) is a significant commercial crop traditionally cultivated in the Eastern Himalayan region of India, specifically in Sikkim and Kalimpong and Darjeeling districts of West Bengal. Typically, propagation of large cardamom is achieved through sucker multiplication. However, to minimize viral disease transmission and preserve genetic diversity, seed-derived seedlings are recommended. In the present study, nine potting mixtures were evaluated under 50% agro-shade net conditions. The mixtures comprised various combinations of forest soil, farmyard manure (FYM), vermicompost, *Trichoderma harzianum*, neem cake and arbuscular mycorrhizal fungi (AMF). Statistical analysis indicated that the treatment composed of forest soil, FYM and vermicompost in 1:1:1 proportion supplemented with 10 g AMF per seedling significantly promoted growth. This treatment demonstrated superior values for plant height (36.49 cm), number of tillers (4.22), leaf length and width (22.16 cm and 4.85 cm, respectively), and root parameters, including root length (37.60 cm) and total dry matter production (15.90%). Notably, the treatment which included forest soil, FYM and vermicompost in 1:1:1 proportion with 10 g neem cake per seedling, exhibited reduced incidence of pest infestation, particularly the shoot fly.

Keywords: Large cardamom, potting mixtures, arbuscular mycorrhizal fungi, growth parameters

S3 PP64

Bioassay of *Artona chorista* and characterization of soil microflora in large cardamom ecosystems of the Sikkim Himalayas

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Large cardamom (*Amomum subulatum*) is a key cash crop in the Sikkim Himalayas, but its cultivation is challenged by various insect pests of which, the leaf-eating caterpillar *Artona chorista* Jordon is recognized as a significant pest. In the present study, an aqueous mixture of wood ash was prepared by mixing ash with water at 1:4 (w/v) ratio, diluted tenfold and applied to final instar caterpillars of *A. chorista* under laboratory conditions adopting leaf and topical application methods. The bioassay revealed notable changes in the feeding behaviour and developmental stages of the treated caterpillars. Based on the findings, fine wood ash mixture at the same dilution rate was applied at a dose of 0.5 litre per clump to first year old plants (cultivar 'Sawney') in field trial at ICRI-RRS farm, Pagthang, Sikkim during 2023-24. The impact of the treatment on soil pH and soil microflora was also evaluated. The soil pH 15 days post-application showed a minor increase from 6.3 to 6.4. The serial dilution technique employed for microbial analysis resulted in the isolation of *Penicillium* spp., *Aspergillus* spp., *Mucor* spp., *Trichoderma* spp., along with Gram negative and Gram-positive bacteria. The treated plots exhibited reduced fungal and bacterial colony counts compared to control plots.

Keywords: Large cardamom, *Artona chorista,* wood ash, soil microflora

S3 PP65

A simple isothermal assay for the rapid and sensitive detection of cardamom bushy dwarf virus causing *foorkey* disease of large cardamom

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Foorkey disease caused by cardamom bushy dwarf virus (CBDV) (a DNA virus) is one of the two main viral diseases affecting the productivity of large cardamom. CBDV poses a major challenge primarily because the major spread of the virus takes place through infected suckers of large cardamom. Diagnosing viral infections based solely on symptoms is ineffective, as virus-infected plants may not always express visible symptoms. Hence, rapid, accurate, and sensitive detection of CBDV is important for the identification and propagation of virus-free plants. Laboratory-based assays like polymerase chain reaction (PCR) and real-time PCR are time-consuming and require sophisticated laboratory. In contrast, isothermal assay such as recombinase polymerase amplification (RPA) is rapid, does not require sophisticated equipment, and is amenable to onsite detection. In the present study, an RPA assay for the detection of CBDV in large cardamom was developed using twist amp reagents, crude extract isolated from infected plants, and primers designed to the replicase protein of CBDV. The concentration of magnesium acetate, time, and temperature for the optimum detection of CBDV were determined. The RPA assay was 1000 times more sensitive and required less time compared to the conventional PCR indicating its suitability for large-scale indexing of large cardamom plants.

Keywords: Crude extract, diagnosis, recombinase polymerase amplification, sensitivity

S3 PP66

Arbuscular mycorrhizal colonization enhances the plant growth and modulates the biochemical, molecular defense responses against *Pythium myriotylum* and *Meloidogyne incognita* in ginger (*Zingiber officinale* Rosc.)

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The present study investigated effects of arbuscular mycorrhizal fungi (AMF) inoculation on nutrient uptake, growth and defense mechanisms against pathogens like *Pythium myriotylum* and *Meloidogyne incognita* in ginger (*Zingiber officinale* Rosc.). The presence of *Rhizophagus irregularis* (AMF) notably increased plant height (48 cm), number of tillers (18), uptake of macro and micro nutrients compared with uninoculated control plants. The AMF-preinoculated plants demonstrated 50% reduction in disease incidence when challenged with *P. myriotylum* and completely inhibited the penetration of *M. incognita*. Additionally, protray experiment was conducted to study the possible correlation between the disease and nematode resistance traits of AMF using biochemical and molecular methods. In this study, enhanced activity of antioxidant enzymes, such as peroxidase, catalase, and β-1,3-glucanase was observed in AMF-primed plants under pathogen inoculation, particularly with combined infections of *P. myriotylum* and *M. incognita*, indicating improved systemic resistance. At the gene expression level, AMF priming altered the expression of key defense-related genes. The salicylic acid-related *NPR1* gene showed a consistent increase up to 3 days after infection (DAI) in AMF-primed plants, while *TGA*, *AP2*, and *4CL* genes displayed dynamic expression patterns depending on the presence of pathogens. Genes involved in jasmonic acid signalling, such as *LOX2* and *AOC*, also showed enhanced upregulation in AMF-primed plants. These results suggest that AMF colonization promotes nutrient uptake, growth and systemic defense, conferring improved resistance to pathogen infection in ginger.

Keywords: Induced systemic resistance, nutrient uptake, *Pythium myriotylum, Meloidogyne incognita*

S3 PP67

Performance of different genotypes of ginger (*Zingiber officinale*) for yield and resistance to rhizome rot and bacterial wilt

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The experiment was conducted to assess the performance of 37 ginger genotypes for high rhizome yield and resistance to soft rot and bacterial wilt diseases in Chhattisgarh plain zone agro-climatic condition during 2022-23 at research farm of AICRP on Spices, College of Agriculture and Research Station, Raigarh. The variability in ginger for rhizome yield and yield attributing traits were studied. It was observed that the occurrence of soft rot disease in ginger under natural conditions was minimum (5-10%) in Indira Ginger-1 while highest (60-65%) recorded in IG-31. While for bacterial wilt, moderate resistance was recorded in all the genotypes as well as the check varieties *viz*., Suprabha and Suruchi. The performance of ginger genotypes for fresh rhizome yield revealed that highest rhizome yield recorded by IG-1 (28.4 tonnes/ha) followed by IG-4 (26.1 tonnes/ha) followed by IG-3 and IG-28 with 22.4 tonnes/ha fresh rhizome yield. The per cent disease occurrence of soft rot showed negative correlation with fresh rhizome yield as well as other yield attributing traits. The quality parameters of ginger showed that IG-1 has 1.67% essential oil, 4 to 10% oleoresin content and 20% dry recovery.

Keywords: *Zingiber*, *Pythium*, bacterial wilt, fresh rhizome yield

S3 PP68

Antagonistic bacterial endophytes from gingers and their metabolite driven interactions for anti-*Pythium* activity

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Soft rot, caused by *Pythium* species is a highly destructive disease in ginger. Although fungicides can control soft rot effectively, their extensive use raises environmental and health risks. In the present study, the potential of bacterial endophytes from wild ginger relatives and their bioactive compounds were evaluated for their ability to suppress the pathogens *in vitro*. Fifty endophytic bacteria were isolated from wild ginger relatives and screened for their antagonistic activity against *Pythium myriotylum* and *P. deliense* using dual culture assays. Of these, 30 isolates inhibited *P. myriotylum* by more than 50%, while 27 achieved the same level of inhibition against *P. deliense*. The most promising isolates, showing the highest inhibition,

were identified through 16S rRNA gene sequencing. Among them, culture filtrates from *Pseudacidovorax intermedius* (NCC15), *Rhizobium* sp. (NCC17), *Pseudomonas* sp. (NCZ1), *Bacillus amyloliquefaciens* (CC11) and *Bacillus pumilus* (KG6) were selected for further investigation and their minimum inhibitory concentrations (MIC) were determined. Morphological changes in the hyphae and sporangia of *Pythium* spp. treated with the selected bacterial filtrates were examined using scanning electron microscopy (SEM). The extracts caused notable structural damage to the hyphae and sporangia, with *P. myriotylum* showing more pronounced abnormalities compared to *P. deliense*. Metabolic profiling of crude methanolic extracts from these bacteria revealed the presence of several antifungal compounds. Among them, four key metabolites *viz*., pyrrolo [1,2-a] pyrazine-1,4-dione, hexahydro-3-(phenylmethyl), N-(3-imidazol-1-yl-propyl)-N'-(4-isopropyl-phenyl)-oxalamide, [1,2,4] oxadiazole, 5-benzyl-3-(thiophen-2-yl) and cyclo-(S-2-mercaptopropionyl-S-phenylalanyl-S-prolyl) were selected and docked with major *Pythium* proteins, which yielded high docking scores, suggesting that these compounds possess anti-*Pythium* activity.

Keywords: Endophytic bacteria, soft rot, *Pythium* spp., secondary metabolites

S3 PP69

Improved methods for artificial inoculation of bacterial wilt pathogen, *Ralstonia pseudosolanacearum* in ginger

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Developing reliable and reproducible artificial inoculation methods is imperative to prove infective nature of a pathogen which also forms fundamental phase in unravelling host-pathogen interaction. In the present study, artificial inoculation methods for different growth stages of ginger *viz*., tissue culture (TC) hardened and rhizome-grown plants with *Ralstonia pseudosolanacearum* were modified and standardized. A leaf-to-whole plant assay was developed to revive the preserved cultures and assessing the virulence. From t*he isolates preserved and new isolates, the* inoculum (10^8 cfu/ml) was prepared adopting standard protocols. To identify the most virulent isolate, the leaf-to-whole plant assay was used and the Mananthavady (Wayanad, Kerala) isolate was found to be highly virulent. For rhizome-grown ginger plants (45 days old), 100 µL inoculum was injected at the lower-most leaf sheath through pin pricks besides drenching the base with 50 mL inoculum. The inoculation point was covered with coir pith and watered regularly. Water soaking at collar region developed 14-20 days after inoculation (DAI) followed by leaf rolling, yellowing and wilting (20-26 DAI). For TC-hardened plants (4-5 leaf stage), 50 mL inoculum was poured at the base and similar results were obtained 32-36 DAI. *The pathogen* was reisolated from the infected plants and colony PCR confirmed the results which paved the way in standardizing the inoculation protocols for *R. pseudosolanacearum* in rhizome-grown and TC ginger plants.

Keywords: ginger, bacterial wilt, *Ralstonia pseudosolanacearum*, artificial inoculation

S3 PP70

Development of artificial inoculation techniques for *Pythium myriotylum* infecting ginger

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Ginger is a valued crop, with its rhizome used both as a spice and for medicinal purposes. Among the various diseases affecting ginger, soft rot is regarded as the most destructive and major limitation for cultivation with an estimated economic loss ranging from 4 to 100%. Several species of *Pythium* are associated with the disease of which, *P. myriotylum* is the most widely distributed. Standardizing artificial inoculation methods is important to establish pathogenicity, understanding resistance mechanisms and host-pathogen interactions. The present study was focused on standardizing artificial inoculation protocols for ginger (variety: IISR Varada) *viz*., rhizome grown, *in vitro* regenerated and hardened tissue culture (TC) plants. The rhizome grown ginger and hardened TC plants were inoculated at the collar region with *P. myriotylum* multiplied in sand-maize medium and the inoculated plants were maintained at 26±2ºC. Water soaking at collar region was observed in TC plants 2-3 days after inoculation (DAI), followed by foliar yellowing and mortality 5 DAI. Similar symptoms were also observed in rhizome-grown plants; however, symptom progression and subsequent mortality were delayed appearing 7-10 DAI. The pathogen inoculum multiplied in sand-maize medium standardized for artificial inoculation of TC and rhizome-grown plants were 1.0 and 2.0 g, respectively. For *in vitro* regenerated plants, inoculation with sporangial suspension (1.25×10^3 sporangia/ml) and sporulating mycelial disc (1 unit) at the collar region were standardized as optimal inoculum. The present study developed reliable and reproducible artificial inoculation techniques using *P. myriotylum* which can be further utilized for proving pathogenicity and evaluation of germplasm for identification of resistance sources.

Keywords: *Pythium* soft rot, artificial inoculation, ginger

S3 PP71

Screening of bacterial isolates for nematicidal activity against the root-knot nematode (*Meloidogyne incognita*) infesting ginger (*Zingiber officinale*)

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Root-knot nematodes (RKN), *Meloidogyne* spp., are widespread plant-parasitic nematodes that cause about 5% of global crop losses. Although chemical nematicides have been traditionally used to control RKN, their environmental toxicity and adverse effects have led to a decline in their use. Biological control, utilizing antagonistic bacteria and fungi, offers a more sustainable alternative. This study focused on isolating and evaluating bacterial strains for their nematicidal activity against *Meloidogyne incognita*. From the five bacterial isolates studied, three isolates

viz., NAG-1, NAG-4 and NAG-5 were found to exhibit significant nematicidal activity (~95% mortality) at different concentrations of cell-free filtrates. Morphological characterization and staining techniques revealed that these three isolates were rod-shaped, Gram-positive bacteria. Further molecular characterization identified these isolates as *Bacillus megaterium* (NAG-1), *Bacillus aryabhattai* (NAG-4), and *Bacillus cereus* (NAG-5). Among the isolates, *Bacillus aryabhattai* (NAG-4) was found to be particularly effective in inhibiting nematode host penetration. These findings highlight the potential of these microbial isolates in the effective biocontrol of root-knot nematodes, offering an alternative to chemical nematicides. This knowledge can be further applied in developing effective biocontrol strategies for managing RKN infestations and reducing the environmental and toxicological risks associated with chemical treatments.

Keywords: *Meloidogyne incognita*, biological control, *Bacillus aryabhattai*, ginger

S3 PP72

Nano urea for increasing the N use efficiency and productivity of ginger and turmeric

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Nano urea, a nanotechnology-based N formulation (with 4% N) was tested to study its efficacy as foliar spray, to reduce application of conventional urea and effect on productivity in ginger and turmeric. The leaf nutrients status (at 120 DAP) with higher N content in nano urea foliar sprays + soil application of 50% N was on par with 100% N soil application. In ginger, the fresh rhizome yield was significantly higher in 50% N as soil application + nano urea @ 0.4% foliar application. In turmeric, foliar nano urea treatments at 0.2% level + 50% N as soil application, recorded 13% higher dry rhizome yield than 100% N through soil alone. Significantly higher rhizome uptake of the major nutrients (N, P and K) was recorded in treatments with 50% soil N application + nano urea application, followed by 100% N. The net returns over the cost of applied N (both as soil and nano foliar) was high in ginger amounting to Rs. 1.44 lakhs per ha in 0.4% nano urea + 50% soil N application. In turmeric returns from 2.0% nano urea + 50% soil N application was equivalent to that of 100% N soil application. The agronomic efficiency (AE) and recovery efficiency (RE) were found to be higher in nano urea treatments with reduced soil N application, indicating that N use efficiency can be increased with foliar supplementation of nano urea and soil application could be effectively cut down by 50%.

Keywords: Nano urea, leaf nutrients status, ginger, turmeric

S3 PP73

Biocontrol potential of *Pochonia chlamydosporia* against root lesion nematodes in turmeric (*Curcuma longa*)

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Root lesion nematode (*Pratylenchus* spp.) are significant pests affecting turmeric, leading to substantial yield losses and reduced crop quality. *Pochonia chlamydosporia*, a nematophagous fungus and root endophyte, demonstrates biocontrol potential through the formation of specialized structures like appressoria and secretion of proteolytic enzymes to parasitize plant-parasitic nematode (PPN) eggs. The present study evaluated bioefficacy of *P. chlamydosporia* against the root lesion nematode in turmeric using *in vitro* assays. Fungal culture cell-free filtrates, derived from liquid broth cultures at two different concentrations; 50% and 100% along with sterile water control were applied to nematode populations at various developmental stages. The filtrates exhibited significant nematicidal activity, with higher concentrations resulting in increased nematode mortality and a marked inhibition of egg hatching. Microscopic observations confirmed extensive egg parasitism, with optimal conditions leading to over 80% reduction in egg viability. These results highlight the potential of *P. chlamydosporia* as an eco-friendly and sustainable alternative to chemical nematicides.

Keywords: *In vitro* assay, bioefficacy, culture cell-free filtrate, egg parasitism

S3 PP74

Yield, quality and economics of cultivation of turmeric (*Curcuma longa* L.) in response to chitosan application

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An experiment was conducted with two varieties namely Sobha and Sona to assess the effect of foliar application of chitosan on yield, biochemical characters and benefit cost ratio. The treatments included, F_1: Chitosan 1 gl^{-1} (monthly), F_2: Chitosan 2 gl^{-1} (monthly), F_3: Chitosan 3 gl^{-1} (bimonthly), F_4: Chitosan 4 gl^{-1} (bimonthly), F_5: Chitosan 4 gl^{-1} (trimonthly), F_6: Chitosan 5 gl^{-1} (trimonthly), C_p: Primed control and C: Unprimed control. A significantly higher fresh rhizome yield per plot of 4.82 kgm^{-2} was recorded in F_2 and F_4 in varieties Sobha and Sona, respectively. The dry rhizome yield per plot in all the chitosan treated plants was found to be comparable in both the varieties. Carbohydrate content was significantly higher in F_2 in Sobha (84.93%) and Sona (96.41%). The volatile oil content was significantly higher in F_4 in Sobha (4.92%) and Sona (5.50%). Significantly higher oleoresin content was recorded in F_2 in Sobha (15.76%) and Sona (16.04%). Thus, F_2 and F_4 were identified as the best treatments based on

both yield and quality. Among them, the benefit cost ratio was higher in F_4 in both the varieties, which can be selected as the best chitosan treatment for improving yield and secondary metabolite in turmeric.

Keywords: Chitosan, secondary metabolite, turmeric, yield

S3 PP75

GC-MS analysis and anti-fungal activity of cinnamon genotypes

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Cinnamon has been used since the ancient period due to its medicinal values. Cinnamaldehyde and eugenol are the major constituents of cinnamon bark. Cinnamaldehyde has been shown to inhibit the growth of different Gram-positive and Gram-negative bacteria as well as fungi. In the present study simple, rapid, accurate, precise, and sensitive Gas Chromatography-Mass Spectrometry method was developed for estimation of cinnamaldehyde in cinnamon bark in five genotypes (PPI (C)-1 to PPI- (C)-5). GC-MS report revealed the presence of phenyl propynal (cinnamaldehyde) in the tested genotypes. The genotype PPI-1 had the highest cinnamaldehyde content (54.5%) followed by PPI(C)-4 (51.9 %). Hence, the methanol extract of PPI(C)-1, PPI(C)-4, PPI(C)-3, PPI(C)-2 & PPI(C)-5 were subjected to anti-fungal assay. Methanolic extract showed anti-fungal activity against foliar pathogens such as *Alternaria alternata, Fusarium* sp., *Sclerotium rolfsii etc.* The results of this assay showed that the methanolic extract of cinnamon has anti-fungal property and complete inhibition of fungal growth was observed above 200 ppm concentration. The inhibition of fungal growth increased from low concentration (50 ppm) to high concentration (>200 ppm) of the methanolic extract.

Keywords: Cinnamaldehyde, GC-MS analysis, chromatographic detection, anti-fungal activity

S3 PP76

Enhancing climate resilience in coriander: Screening for *Fusarium* wilt resistant genotypes for sustainable cultivation

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Coriander (*Coriandrum sativum*) is an important spice crop widely cultivated across major regions of India. Like other commercial crops, coriander is susceptible to infection by various soil-borne pathogens, with wilt caused by *Fusarium oxysporum* being the most devastating. Climate change, through rising temperatures, unpredictable precipitation patterns and extreme

weather events, create conditions that allow *Fusarium* species to thrive, leading to increased fungal proliferation and virulence. A total of fifty-four genotypes were subjected to both natural and artificial screening at Dr. YSRHU, Horticultural Research Station, Lam, Guntur, during December 2022. The disease symptoms started 20 days after sowing, with early symptoms including yellowing of leaves from the base, followed by drooping. Among the fifty-four genotypes, four showed high resistance, exhibiting less than 10% disease incidence. The findings of the present study highlight four genotypes with high resistance to wilt, marking a significant step toward developing climate-resilient coriander varieties. Breeding programmes focused on these resistant genotypes will support sustainable coriander production by fostering resilience against biotic stress and ensuring crop stability despite extreme weather events.

Keywords: Coriander, *Fusarium*, screening, climate-resilient

S3 PP77

Screening of coriander accessions for resistance to stem gall disease caused by *Protomyces macrosporus*

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Protomyces macrosporus causing stem gall is one of the most prevalent and destructive disease of coriander, particularly severe during flowering and fruit formation stages leading to significant yield losses. An experiment was conducted over three consecutive cropping seasons (2020-21 to 2022-23) in which, 19 Coordinated Varietal Trial (CVT) entries of coriander along with two check varieties (Acr-1 and Acr-2) were screened for stem gall disease resistance. The three years pooled data revealed that none of the accessions were completely free from the disease. However, three accessions namely, Acr-1, Acr-2, and ND Cor 102 were identified as resistant, with disease incidence ranging from 0.92 to 4.81%. Six accessions *viz*., DH 208, DH 312, ND Cor 110, RD 437, RCr 728 and AC 6 were moderately resistant with an incidence ranging from 5.15 to 18.17% while six accessions namely UD 818, UD 808, RKD 1, RD 383, Hisar Anand and AC 7 were moderately susceptible (disease incidence 23.05-47.09%) and four accessions (RK D 2, LCS-12-7, LCS 12-5 and RCC-12-7) were susceptible (disease incidence 52.77-57.29%) to the disease. More or less similar trends were observed for seed gall incidence.

Keywords: Coriander, stem gall, *Protomyces macrosporus*, resistance

S3 PP78

Insect-pests infesting fenugreek (*Trigonella foenum-graecum* L.) under semi-arid conditions and their management

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Fenugreek is an important and major seed spice in the country. Fenugreek is affected by several diseases and insect pests. Among the insect pests, aphids (*Aphis craccivora*, *Acyrthosiphon pisum*), thrips (*Thrips tabaci*, Scirtothrips *dorsalis*) and whitefly (*Bemisia tabaci*) are the common sucking pests. The others pests like jassids (*Empoasca* sp.), leaf miner (*Liriomyza trifolii*), stem fly (*Ophiomyia* sp.), weevil (*Hyperapostica*), pod borer (*Maruca testulalis*, *Heliothis armigera*), cutworm (*Agrotis ipsilon*) *etc.,* cause damage to fenugreek during different growth stages. The integrated strategy i.e. seed treatment with imidacloprid 600 FS @ 3 ml/kg seed followed by foliar application of ker plant extract 10 ml/l, lamda-cyhalothrin 5 SC @ 0.7 ml/l and *Veticillium lecanii* (4 g) + *Hirsutella thompsoni* (4 g) can effectively manage the sucking pests. Similarly, the IPM module with ker plant extract @ 10 ml/l, nimbecidine 0.03 EC 3 ml/l, indoxacarb 14.5% SC and emamechtin benzoate 5 SG @ 10 g a.i./ha was found effective for management of borers and weevil under field conditions.

Keywords: Fenugreek, *Veticillium lecanii*, *Hirsutella thompsoni*, ker plant extract

S3 PP79

Wilt and root rot management in cumin

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Cumin suffers from wilt (*Fusarium oxysporum* f. sp. *cumini*), blight (*Alternaria burnsii*) and powdery mildew (*Erysiphe polygoni*). A field experiment was undertaken during *Rabi* 2017-2021 to develop a strategy for wilt and root-rot management through soil application of bio-pesticides and soil drenching with fungicides. The seeds were treated with carboxin + thiram @ 2 g/kg seed in all the treatments except the untreated control. Among the different treatments, application of *Trichoderma viride* @ 2.5 kg/ha and *Pseudomonas fluorescens* 10^8cfu @ 2.5 kg/ha with 1-ton FYM/ha or *Trichoderma harzianum* @ 2.5 kg/ha and *Pseudomonas fluorescens* 10^8cfu @ 2.5 kg/ha with 1 ton FYM/ha at the time of sowing were effective for economical management of wilt and root rot in cumin.

Keywords: Cumin, wilt and root rot, *Fusarium oxysporum* f. sp. *cumini*, *Trichoderma viride*

S3 PP80

Studies on the detection and quantification of siderophores by potential biocontrol agents

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The present study evaluated *Pseudomonas fluorescens, Bacillus subtilis* and *Trichoderma harzianum* for siderophore production by qualitative and quantitative means. Chrome Azurol S (CAS) assay was used to visually detect siderophore production. All the bioagents showed positive response in the production of siderophore on CAS agar medium. Positive indication of siderophore production was observed on different media (Malt Extract Agar, Nutrient Agar and Skim Milk Agar) supplemented with CAS reagent. Nutrient agar supplemented with CAS reagent showed more characteristic and clearer yellow to orange discolouration around the colony compared to other media. In the quantitative assay, *Pseudomonas fluorescens* produced high quantity of siderophores (86%) in malt extract broth (MEB) followed by *Trichoderma harzianum* (63%) and *Bacillus subtilis* (60%) compared to nutrient broth (NB) and skim milk broth (SMB). The study demonstrated production of siderophores by the tested organisms widely used in biocontrol of diseases in spices. In addition, malt extract broth can be used for the production and purification of siderophores for various *in vitro* and *in vivo* studies.

Keywords: *Bacillus*, *Pseudomonas*, siderophores, *Trichoderma*

Abstracts

Theme 4: *Nutraceuticals, novel products and processes*

ORAL PRESENTATION

S4 OP81

Evaluation of AI-driven colour sorting and grading for enhanced cardamom quality

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Indian cardamom is recognized globally for its superior quality, with premium varieties often referred to as 'Fancy Green,' characterized by vibrant parrot green capsules. These capsules are highly sought after due to their exceptional extrinsic quality and are sorted using AI-assisted colour sorting technology. The present study aimed to assess the intrinsic physical and chemical qualities of different grades of AI-assisted colour-sorted premium-grade fancy green cardamom capsules. The study included nine treatments, among them four were AI-assisted colour-sorted grades, control samples, and a bulk sample. Physical and chemical parameters evaluated included bulk density, seed-to-husk ratio, seed count per capsule, and the weight of ten capsules, moisture content, essential oil content, total ash, acid-insoluble ash, crude fibre, chlorophyll, oleoresin, and mineral content. Findings revealed maximum bulk density of 370.7%. The highest seed count per capsule was 21, indicating that AI-assisted sorting enhances quality. Oleoresin content ranged from 6.1% to 7.8%, while essential oil content varied from 4.9% to 7.3%. AI colour-sorted samples exhibited lower total ash levels, and chlorophyll content differed significantly among treatments. Iron content ranging from 0.018% to 0.057%, with variations in phosphorus, potassium (0.080% to 0.267%), magnesium, and calcium levels (0.011% to 0.142%). Overall, the study demonstrates that AI-assisted sorting significantly improves the quality attributes of cardamom, increasing its market appeal and reinforcing India's competitive edge in the global spice market.

Keywords: Quality, AI-assisted sorting, colour grading, spice, market potential

S4 OP82

Effect of cold plasma on extraction of bioactive compounds from cardamom husk

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The objective of the present study was to evaluate the impact of cold plasma (CP) pre-treatment on the yield of bioactive compounds extracted from cardamom husk. The cardamom husk was initially treated with low-pressure dielectric barrier discharge plasma at 1 kV and 2 kV for 5 minutes and 15 minutes, respectively, followed by oil extraction using a Soxhlet apparatus at 50°C for 2 hours. The extracted oil was analyzed using gas chromatography-mass spectrometry (GC-MS). The alterations in the functional and chemical characteristics of the essential oil caused by the cold plasma treatment were also analyzed. The surface etching caused on the cardamom husk led to an increase in bioactive compounds in extracted cardamom oil. The husk sample treated at 2 kV for 15 minutes had D-limonene content of 14.82% while it was not detected in untreated sample. There was significant increase in Coronarin E after CP pre-treatment (untreated: 12.17%, 1 kV 5 minutes: 17.92%, 1 kV 15 minutes: 21.44%, 2 kV 5 minutes: 22.81% and 2 kV 15 minutes: 26.59%). Similarly, the percentage of (E)-Labda-8(17), 12-diene-15,16-dial in oil extracted from CP treatment at 1 kV was higher (20.70%). However, there was significant decrease in α-terpinyl acetate in CP treatment. In FTIR, the peak positions of untreated and CP treated samples remain largely unchanged, though noticeable variations in intensity were observed. Furthermore, CP pre-treatment showed an influence on the stability of oil, resulting in a rise in the peroxide value, while the acid value remained unchanged. In conclusion, cold plasma pre-treatment appears to be a promising method for improving both the yield and quality of bioactive compounds from cardamom husk.

Keywords: Cold plasma, cardamom husk, Soxhlet extraction, bioactive compounds

S4 OP83

NMR spectroscopy for quality analysis and profiling of curcuminoids in turmeric

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Turmeric, a widely used spice and medicinal herb, contains curcuminoids, primary bioactive compounds responsible for its health benefits. Accurate and reliable analysis of these compounds is essential for quality control and standardization of turmeric products. Total quantification and profiling of curcuminoids are commonly done using UV spectroscopy and HPLC, respectively. Nowadays, NMR is a relatively developed area for studying food quality because of its various notable elements. However, its benefits have never been investigated in turmeric quality analysis. This study explores the possibility of 1H-NMR-based method for measuring curcuminoids and their profiling. The methodology involved preparation of turmeric extracts followed by 1H NMR analysis, which provides detailed spectral data for curcumin, demethoxycurcumin, and bisdemethoxycurcumin. The method was cross-validated with HPLC and UV analysis, demonstrating its reliability and accuracy. Further, the use of selective homodecoupling enhances resolution, allowing for precise identification and quantification of these compounds. Application of the proposed method was demonstrated in turmeric samples from various Indian states. Therefore, NMR spectroscopy can be employed to monitor the stability of curcuminoids during storage and processing, providing valuable insights for the optimization of production methods.

Keywords: Turmeric, curcuminoids, NMR spectroscopy, quality analysis, quantification

S4 OP84

Development and evaluation of turmeric oleoresin impregnated biodegradable films

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Biodegradable packaging has been evolved as a sustainable solution to mitigate plastic waste concerns. This study aimed to develop starch based biodegradable film by impregnating turmeric oleoresin for extending the shelf-life of coriander leaves. The objective was to study the effect of different concentrations of starch (0.75%, 1%, and 1.25%) and oleoresin (0.25%, 0.5%, and 0.75%) on the physio-chemical properties of the packaging film. Polyethylene glycol and sorbitol were used as plasticizers, with the former enhancing flexibility and reducing brittleness by reducing intermolecular forces between polymer chains, and latter, improving film elasticity and moisture retention, thereby enhancing the overall performance of the biodegradable packaging material. Turmeric oleoresin was incorporated for its antimicrobial properties. The characteristics of the prepared films, including weight, thickness, moisture content, swelling index, solubility, water vapour permeability, colour value, free fatty acid value, peroxide value, heat sealability, and total plate count were analysed. Moisture content, swelling degree, solubility and water vapour permeability of the films varied from 5-11%, 19-24%, 58-63% and 5.24-7.86 g $mm.m^{-2}d^{-1}k.Pa^{-1}$, respectively. The prepared films exhibited excellent properties suitable for packaging food items.

Keywords: Turmeric, oleoresin, biodegradable, food packaging, permeability

S4 OP85

Coriander (*Coriandrum sativum* L.) response to bio-stimulants: Growth comparisons and GC-MS profiling of essential oil from phytocil enhanced plants

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This research examined the consequences of deploying three bio-stimulants *viz*., Phytocil, humic acid and seaweed extract on growth, yield and quality of coriander (*Coriandrum sativum* L.). The study followed a randomized block design, featuring eight treatments and three replications. The results revealed that bio-stimulant application improved the plant performance, particularly phytocil alone (T_3) or combined with humic acid (T_4) have profound influence on plant growth. Plant height, branching, and leaf area index were the growth factors that demonstrated notable enhancements compared to the control. Seed yield increased by 10-25% with biostimulant use, with T_3 and T_4 showing the best results than control. Quality parameters, including chlorophyll content, ascorbic acid levels, protein content, and essential oil yield, also improved, especially in T_4 and T_3 treatments. GC-MS analysis of essential oil

from Phytocil-treated plants identified 50 compounds, with dihydrocarveol and isopulegol acetate as the principal components, indicating no adverse effects on oil composition. The study concluded that phytocil, either alone or combined with humic acid, was the most effective treatment for various growth, yield, and quality parameters. Its consistent performance and cost-effectiveness make it a promising option for farmers seeking to enhance profitability in coriander cultivation.

Keywords: Coriander, biostimulants, phytocil, humic acid, seaweed, volatile profiling

S4 OP86

Optimization of process parameter for the development of microencapsulated spray dried sambar oleoresin and evaluation of its quality

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Sambar oleoresin was developed using oleoresins of different spices such as coriander, chilli, black pepper, turmeric, fenugreek, asafoetida, curry leaves, and cumin. The resulting oleoresin blend was subjected to microencapsulation *via*. spray drying, with optimization performed using Response Surface Methodology (RSM). A three-factor, three-level Box-Behnken design (BBD) was employed to optimize the spray drying conditions. Encapsulation efficiency and yield were the responses considered, while inlet air temperature, oleoresin concentration and wall material ratio were the factors evaluated. The study concluded that the optimal conditions for producing sambar oleoresin powder were achieved at the inlet air temperature of 150°C, maltodextrin-gum and arabic ratio of 1.2:1 and oleoresin concentration of 13.54%. Under these conditions, the encapsulation yield was 89.25% and the encapsulation efficiency was 76.64%. The powder exhibited a moisture content of 6.9±1.49%, with tapped and bulk densities of 0.54±0.04 and 0.26±0.007 g cm^{-3}, respectively. Flowability and cohesiveness were recorded as 100.0±1.1 and 2.0±0.05 respectively. The retention of major active compounds in the encapsulated powder were found to be 85% for curcumin, 84% for capsaicin and 80% for linalool. Sambar prepared using microencapsulated sambar oleoresin was well accepted by the panel members when compared to the sambar prepared using traditional sambar powder.

Keywords: Spice oleoresin, active compounds, powder properties, response surface methodology, microencapsulation

POSTER PRESENTATION

S4 PP87

Cardamom essential oil as flavouring agent in cashew nut testa phenolics incorporated milk pudding: flavour characterization, evaluation of physicochemical and functional properties

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Cashew nut testa is an underutilized cashew by-product and is rich in polyphenols. Milk pudding containing phenolic extract of cashew nut testa (CNT) and cardamom oil was formulated. Cardamom oil was used as a flavouring agent. The characteristics of the pudding were compared with the control (without CNT). Both the samples and control were stored for 7 days at 4ºC. HPLC analysis identified (+)-catechin, (-)-epicatechin and catechin gallate as the major phenolic compounds of CNT and these compounds were also detected in the milk pudding. E-nose, E-tongue and GC-MS analyses were used for the flavour characterization. The major volatile compounds in cardamom oil identified by GC-MS were 1,8-cineole, α-terpinyl acetate, linalool, and β-phellandrene. There was no significant change in the pH and fat content of the fresh and stored samples. Flavour compounds were characterized and the sensory analysis showed that the sensory quality of the sample did not differ significantly between the test samples and the control, and the sensory quality of the sample remained acceptable after storage at 4ºC for 7 days. Milk pudding exhibited a dose-dependent increase in its DPPH radical scavenging activity. Incorporation of CNT extract into milk pudding is a novel approach for highlighting and improving the functional qualities of the pudding with acceptable sensory quality and it can be an important value addition to this agricultural by-product, with nutritional and economic benefits.

Keywords: Cardamom oil, cashew nut testa, polyphenols, value addition, by-product

S4 PP88

Optimization of process parameters for microencapsulation of cardamom oleoresin and physico-chemical evaluation of the capsules

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Oleoresins are the viscous concentrates obtained from spices and herbs that contain wholesome flavour and aroma of the respective plant parts. Cardamom oleoresin is obtained by solvent extraction of the seeds of *Elettaria cardamomum.* The product has the characteristic aroma of cardamom and is a free-flowing liquid that is greenish to dark brown in colour. This study aims

to optimize the process parameters for microencapsulation of cardamom oleoresin and physico-chemical evaluation of the capsules. Response Surface Methodology (RSM) was used for simultaneous optimization of multiple responses. A 17 run Box-Behnken design with 3 factors such as inlet air temperature (150, 160 and 170°C), maltodextrin level (20, 25 and 30%) and oleoresin concentration (5, 10 and 15%) were the factors and the responses analyzed were encapsulation yield and water solubility. The parameters optimized for microencapsulated cardamom oleoresin powder were inlet air temperature of 150°C, maltodextrin concentration of 30% and the oleoresin concentration of 7.81%. The optimized values of encapsulation yield and water solubility were 86.48 and 87.32%, respectively. The functional parameters of optimized sample like flowability, cohesiveness, wettability, hygroscopicity, water absorption index and water solubility index were 56.96±2.88, 2.33±0.15, 135.6±3.93s, 6.02±0.02%, 0.09±0.01, and 92.31±0.43%, respectively. Concentration of active ingredient (1,8 cineole) and oleoresin were 805 ppm and 20.92 ± 0.04 %, respectively. The study prospects the scope for incorporating cardamom oleoresin capsules as a novel ingredient in tertiary processed spice products.

Keywords: Cardamom, oleoresin, microencapsulation, response surface methodology, process optimization

S4 PP89

Performance evaluation of microwave vacuum dehydrator and study on quality characteristics of dried cardamom capsules

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The objective of the present study was to evaluate the performance of a Microwave Vacuum Dehydrator (MVD) in drying fresh cardamom capsules and assess drying time, and energy use, and examine the quality (colour) and nutritional content of the dried product. Cardamom capsules were evenly spread in a single layer across 20 trays (30 cm diameter, 3 cm height) of MVD with 5 air-cooled magnetrons, each having a penetration depth of 30 cm and pulsed mode drying was applied with 30 s ON and 60 s OFF time. The drying status was periodically monitored until 7-10% d.b was attained. Post-drying, the capsules were analyzed for colour retention using the LAB colour test. Nutritional content was studied through proximate analysis including moisture, ash, crude fat, crude protein, and fibre content. Important components such as sodium, calcium, and vitamin C were also assessed. Energy consumption and drying time were recorded to determine the efficiency of MVD. The MVD achieved a final moisture content of 7.63 % in 8 hr 45 min (2hr 55 min ON,5 hr 50 min OFF), preserving a dried texture and colour (ΔE = 5.78). Total power consumption was 28.14 kW, costing approximately Rs. 355. The initial 6.5 kg was reduced to 1.58 kg post-drying. Nutritional analysis showed retention of essential nutrients: fat (13.2%), ash (7.9%), fibre (4.3%), protein (7.7%),

carbohydrates (66.4%), vitamin C (7.4 mg/100 g), sodium (1069 mg kg^{-1}), and calcium (264 mg kg^{-1}), demonstrating MVD's efficacy in preserving cardamom capsules nutrition. Hence, it is inferred that MVD performance for drying cardamom capsules in single layers is better and suggested for other commodities such as garlic, ginger, banana, and green leafy vegetables.

Keywords: Microwave vacuum dehydrator, moisture, efficiency, nutrition

S4 PP90

Unlocking the potential of turmeric: *Clpks11* gene manipulation for curcumin enhancement

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Turmeric (*Curcuma longa* L.), a rhizomatous perennial spice from the Zingiberaceae family, is well-known for its medicinal properties, primarily attributed to the presence of curcumin in its rhizomes. Curcumin has a wide range of therapeutic benefits, prompting efforts to enhance its production through genetic manipulation, especially through overexpression of genes involved in biosynthesis. In this study, we focused on *Clpks11*, a polyketide synthase (*PKS*) gene that plays a key role in curcumin synthesis. The *Clpks11* gene, approximately 1.6 kb in length, was successfully amplified from IISR Prathibha, a variety with high curcumin content and cloned into the pTZ57R/T vector. The recombinant constructs were transformed into *Escherichia coli* DH5α cells. Plasmids isolated from the positive colonies were digested with appropriate restriction enzymes and subcloned into a binary vector. This construct can be introduced into turmeric plants via *Agrobacterium* mediated gene transfer for elevated expression of *Clpks11*, and enhanced curcumin production. Ultimately, this genetic modification has the potential to revolutionize turmeric cultivation, offering higher yields of curcumin and thus enhancing the therapeutic value of this ancient spice.

Keywords: Overexpression, polyketide synthase, binary vector

S4 PP91

***In silico* studies to discover the pharmacological properties of mango ginger (*Curcuma amada*)**

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Mango ginger (*Curcuma amada*) is widely recognized as a rich source of bioactive compounds. GC-MS analysis of essential oil extracted from mango ginger identified 39 distinct compounds. To explore its therapeutic potential, molecular docking study targeting anti-inflammatory, anti-diabetic, and anti-viral proteins was conducted. Prior to docking, the compounds were evaluated using Swiss ADME to assess drug-likeness and pharmacokinetic properties. The docking results revealed that sesquirosefuran (-7.1 kcal/mol), myristicin (-6.2 kcal/mol), and copalic acid (-6.2 kcal/mol) demonstrated strong binding affinities against Human COX-2 (Prostaglandin G/H Synthase 2, PDB ID: 5IKQ), Fructose-1,6-bisphosphatase (PDB ID: 2JJK), and NS3 Helicase (PDB ID: 5JRZ), respectively. These compounds showed superior interactions compared to FDA-approved drugs, indicating their potential anti-inflammatory, anti-diabetic and anti-viral activities. These findings highlighted *Curcuma amada* as a promising natural source of therapeutic compounds, though further experimental studies are required to confirm these results and assess their clinical applications.

Keywords: Mango ginger, natural therapeutics, bioactive compounds, anti-inflammatory, anti-diabetic, anti-viral

S4 PP92

Process optimization of anthocyanin extraction from *Curcuma rubescens* and its chemical characterization using LCMS-MS

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Anthocyanins are natural pigments responsible for red, blue, and purple colours in many plant parts, known for their antioxidant properties and health benefits. They are commonly found in grapes, berries, and red cabbage and are widely used as natural colorants. *Curcuma* species, typically known for yellow coloured curcumin, contains other pigments too. *C. rubescens* contains anthocyanins in its leaf sheath, exhibiting a dark red colour at neutral pH. In the present work, anatomical studies of leaf sheath revealed a high pigment cell index of 15.6, indicating significant potential for pigment extraction. Moreover, in this study, an extraction process was optimized and extracted anthocyanins was characterized through the LCMS-MS analysis. Malvidin was observed as the major anthocyanin in the extract. To optimize anthocyanin extraction from leaf sheath powder of C. *rubescens*, various solvents were tested at different sample-to-solvent ratios using an incubator shaker. 1% acidified distilled water at 1:30 ratio showed the highest extraction, with a total anthocyanin concentration of 1123.44 mgL^{-1}, compared to lowest extraction in ethanol (303.1 mg L^{-1}). Among the method of extraction, probe sonication was found more effective than shaking, maceration and water bath sonication. Further optimization for finding optimum sonication time, sonication interval duration, temperature and sonication power output was carried out to obtain the optimum conditions for maximum extraction of anthocyanin. Crystallization conditions of anthocyanin

was optimized using KCl and NaCl at different pH ranges. The study successfully identified the pigment compound and developed an extraction protocol with 90% anthocyanin recovery.

Keywords: *Crcuma rubescens,* anthocyanin, process optimization

S4 PP93

Convectional sun drying, hot-air and vacuum drying of mace: An evaluation on drying kinetics and quality

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This research aimed to investigate the effect of different drying methods (sun, vacuum and hot-air drying) on drying characteristic, physical properties and biochemical attributes of mace. The comparative drying experiments were carried out at drying temperature of 45°C, 50°C, 55°C and 60°C for both vacuum and air drying. Sun drying was accomplished by exposing mace spread over trays under direct solar radiation. Maximum and minimum drying air temperature recorded were 34.3°C and 23.7°C during sunshine hours. Final moisture content of mace dried under sun, vacuum and hot-air drying was recorded to be 12.6%, 9.5% and 9.8%, respectively. Drying temperature was optimized at 55°C for vacuum and hot-air drying due to higher drying rates and physico-chemical parameters of dried mace. Drying time was minimum for vacuum dried sample (5 h) followed by air dried (7 h) and sun-dried mace (12 h). Drying of mace followed falling rate period. The essential oil content of sun dried, vacuum dried and hot-air dried mace were 13.6%, 15.2% and 14.53%, respectively. Oleoresin content recorded maximum value for sun dried mace (21.3%) followed by vacuum dried (19.55%) and hot-air dried (18.44%). Vacuum drying retained 30.45% more lycopene when compared to hot-air drying. Lycopene content of sun-dried mace showed a very low value of 3.73 μg/mL. Overall, vacuum drying is a promising drying method for obtaining high quality dried mace when compared to hot air and sun drying.

Keywords: Mace, vacuum drying, hot air drying, sun drying, drying kinetics

S4 PP94

Volatile profiling of leaf oils from *Cinnamomum* sp. with distinct aroma reveals a biosimilar substitute for lemon grass oil for commercial exploitation

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The volatile profile of aromatic crop is specific to species, plant part used and the condition in which the plant is grown. *Cinnamomum* sp., is known for its characteristic aroma due to the presence of volatile compounds such as cinnmaldehyde, eugenol *etc.* In this study, 11 accessions of *Cinnamomum verum* and five other related species *viz., C. tamala*, *C. citriodorum, C. riperium, C. macrocarpum* and *C. impressinervium* maintained at germplasm conservatory of ICAR-IISR, Kozhikode were analyzed for leaf oil diversity. The leaf oil of *C. verum* was mainly composed of eugenol while the major constituent of bark oil was cinnamaldehyde in all the accessions studied with varying relative abundance. The leaf oil of *C. citriodorum* had 66.65% citrenellol. *C. riperium* leaf oil exhibited a unique volatile profile with eugenol (28.65%), geraniol (16.18%), alpha-cadinol (6.78%), alpha-terpinol (5%) and murolol (4.91%) as the major constituents. *C. macrocarpum* leaf oil was mainly composed of caryophyllene (24.98%) and bycyclogermacrene (13.65%). *C. tamala* leaf oil exhibited the relative abundance of alpha-terpenol (23.7%), O-cymene (11.60%), eucalyptol (11.29%), spathudinol (8.03%) and globulol (6.32%). Interestingly, leaf oil from *C. impressinervium* with characteristic lemon grass oil aroma exhibited a more closer volatile profile to that of lemon grass oil with geranyl acetate (15.42%), geranial (17.06%) and neral (10.49%) as major constituents. The study revealed that the leaf of *C. impressinervium* can be exploited for the extraction of similar aroma applications to lemon grass oil.

Keywords: *Cinnamomum* sp., leaf oil diversity, volatile compounds, chemotypes, essential oils

S4 PP95

A novel LC-MS/MS method for the quantitative analysis of HCA and HCA lactone and its diversity study in *Garcinia* species

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The most important secondary metabolite found in the genus *Garcinia* is (-)-Hydroxycitric acid (HCA), along with its lactone derivative, (-)-HCA lactone. These compounds have been extensively studied for their role in obesity prevention. Therefore, developing a novel and sensitive bioanalytical method for detecting HCA and HCA lactone is in high demand. In this study, a new LC-MS/MS protocol has been developed to quantify HCA and HCA lactone in *Garcinia* species. The different parts of the fruit (pericarp, pulp, and seed) and leaves at various developmental stages (mature and immature) from five species, *viz., G. gummi-gutta* (L.) Robs., *G. indica* (Thouars) Choisy., *G. kydia* Roxb., *G. xanthochymus* Hook. f. and *G. celebica* L. were used. The analysis was performed using a Shimadzu LC-MS/MS 8045 coupled with triple quadrupole mass spectrometer. LC conditions: column: Purospher STAR RP-18 endcapped (250 mm x 4.6 mm, 5µm) mobile phase: 0.1% formic acid in water and acetonitrile in a binary gradient programme at a flow rate of 0.6 mL/min. Injection volume: 10 µL. M/S conditions: ESI: negative ion mode, precursor ions: 206.70 m/z (HCA), 188.90 m/z (HCA lactone); product ions: 188.90 m/z &127.00 m/z (HCA), 126.95 m/z & 83.05 m/z (HCA lactone). All species except *G. xanthochymus* and *G. celebica* had significant levels of HCA and HCA lactone in their fruits and leaves. The content of HCA varied from 0.0009% (*G. celebica* immature seeds) to 6.12% (*G. indica* mature leaves). HCA lactone content varied from

0.0006% (*G. celebica* immature seeds) to 5.57% (*G. gummi-gutta* immature leaves). The protocol developed was able to detect, for the first time, HCA in *G. xanthochymus* and *G. celebica* indicating the sensitivity and robustness of the methodology.

Keywords: *Garcinia*, HCA, HCA lactone, LCMS/MS

S4 PP96

Determination of optimum harvesting stages in fennel (*Foeniculum vulgare* Mill.) for chewing

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In this study, umbels were harvested at six different stages of maturation to determine maturity indices of fennel for chewing. Seeds harvested at 35 and 40 days after anthesis had the highest overall sensory acceptability score (8.53 and 8.40) for chewing (raw seeds). Sensory analysis of fennel seeds harvested at various stages revealed that those harvested 35-40 days after anthesis (DAA) possess high quality from the consumer's perspective due to their superior appearance, flavour, texture, and taste. While delayed harvesting led to increased yield and higher concentrations of bioactive compounds like phenols and antioxidants, but negatively influenced sensory attributes. Seed colour characteristics, including lightness, hue, and chroma, varied significantly across harvest stages, with optimal values observed at 35-40 DAA. Additionally, moisture content and total soluble solids decreased with maturity, while crude fibre content increased, potentially affecting consumer acceptability. Although higher yields and bioactive compounds were recorded at later harvest stages, the overall sensory appeal and balanced nutritional composition of seeds harvested at 35-40 DAA make them the optimal choice for chewing. These findings emphasize the importance of optimum stage harvest of fennel seeds to meet specific market demands and optimize sensory quality and nutritional value.

Keywords: *Foeniculum vulgare*, chewing, sensory, phenols, antioxidants

S4 PP97

Metabolite and biochemical characterization of nigella genotypes

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Nigella (*Nigella sativa* L.) is a popular spice cum medicinal plant in Asia & the Middle East. The seed and its oil are used as a spice and as a source of medicine for several therapeutics. It is known for its rich source of metabolites and phenolic compounds, including thymoquinone

(TQ). The study aimed to investigate the bioactive components of nigella oil via different analytical techniques. A total of 39 established genotypes were screened for total oil, TQ content and different biochemical parameters. Results showed that Ajmer Nigella 8 has highest TQ (536.30 µg/100mg) followed by Ajmer Nigella 13 (258.00 µg/100mg), Ajmer Nigella 13 has the highest TPC (4.83 mg GAE g^{-1}seed), flavonoid content (34.92 mg QE 100 g^{-1} seed) and antioxidant activity (91.77 %). FTIR spectra revealed the presence of a number of peaks that correspond to C-H, -CH2, -CH3, C=O, C-O, and C=C functional groups indicating the existence of the key biomolecules thymoquinone, longifolene, P-cymene and thymol. The genetic divergence analysis grouped 38 genotypes into eight distinct clusters. The study highlights substantial variation in thymoquinone content across nigella genotypes, which may serve as a basis for exploring the crop's nutraceutical potential and further scope for novel product development.

Keywords: Bioactive, FTIR, biochemical, nutraceutical, antioxidant, thymoquinone

S4 PP98

Physicochemical and antioxidant characterization of blended spice flavoured jaggery cubes during storage

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Jaggery is a non-centrifugal sugar produced from sugarcane juice by the process of concentration. The blending of jaggery with spices would enhance its flavour and functional properties. In the present study, blended spice flavoured jaggery cubes were prepared by heating liquid jaggery with different concentrations of the emulsified blended spice oleoresins (ginger, black pepper and cumin). The optimized blended spice flavoured jaggery cubes were packaged in laminated and craft paper pouches and stored for 9 months under ambient conditions. The result of the storage studies indicated that the physico-chemical properties like moisture content, bulk density and water solubility increased with increase in storage period, while content of sucrose, vitamin C, water absorption index, hardness, antioxidant activity, total phenolic and total flavonoid content were decreased during storage period. The shelf-life studies revealed that the blended spice flavoured jaggery cubes packaged in laminated pouches showed greater stability and retention of physico-chemical parameters when compared with samples packaged in craft paper pouches. Initial values of important parameters like moisture content (4.56 %), water solubility (93.2%), hardness (285.36 N), sucrose content (79.04%), antioxidant activity (IC_{50} value-1.3 mg/mL) and total phenolic content (791.55 mg/100g) changed to 7.13 %, 94.2 %, 215.11 N, 69.20 %, IC_{50} value 1.47 mg mL^{-1} and 745.27 mg/100g, respectively during storage. The study indicated that the blended spice-flavoured jaggery cubes packaged in laminated pouches retained most of the important physico-chemical and antioxidant parameters and could be stored safely for up to 8 months under ambient conditions.

Keywords: Antioxidant property, jaggery, physico-chemical qualities, spice oleoresins, storage

S4 PP99

Enriching banana stem juice: A functional beverage boosted with spices and herbs for enhanced health and flavour

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This study optimized and assessed the quality, nutritional value and sensory acceptability of banana central core juice blended with selected spices and herbs. Using five banana varieties (Saba, Bangrier, Karpuravalli, Ney Poovan, and Poovan) and four spices and herbs (5% coriander leaf juice, 3% cumin seed extract, 2% cinnamon bark extract, and 2% mint leaf juice), we examined the physicochemical and sensory attributes of these blends. Spices and herbs were found to significantly enhance the nutritional profile and sensory appeal of the juice. Cinnamon bark extract in 'Saba' juice, recorded the highest total soluble solids (10.42 ºBrix), providing a natural sweetness that makes the beverage more enjoyable. The 'Ney Poovan' juice, when blended with cinnamon and mint, achieved lowest acidity (0.12%), making it a milder option suitable for broader consumer preferences. In terms of phenolic content, which contributes to antioxidant properties, 'Bangrier' juice blended with mint recorded highest level (0.44%), followed by cinnamon and coriander, indicating enhanced health benefits. Sensory analysis revealed that Bangrier juice with cumin blend had highest overall acceptability (7.80), followed by blends with cinnamon (7.66). The study highlighted the potent influence of spices and herbs on flavour and texture, with blends of Bangrier, Ney Poovan, and Karpuravalli combined with cinnamon and mint achieving optimal consumer satisfaction. These blends not only enhance flavour but also bring medicinal and functional properties, making banana central core juice an economical and health-promoting beverage option with strong commercial potential.

Keywords: Banana stem juice, functional beverage, spices, herbs, sensory evaluation

S4 PP100

Nutraceuticals and spices: A fusion of traditional and modern science

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Nutraceuticals represent a rapidly evolving sector within the food and health industries, bridging the gap between nutrition and pharmaceuticals. The development of innovative nutraceutical products has been made possible by recent advancements in extraction and formulation technology. Lower yields and bioavailability of active chemicals are frequently

the outcome of traditional extraction techniques. However, the effectiveness and efficiency of nutrient extraction from natural sources are being improved by developments like supercritical fluid extraction, microwave-assisted extraction, and ultrasound-assisted extraction. These methods enable the preservation of sensitive compounds and the enhancement of their bioactivity, leading to more potent nutraceutical formulations. In addition to extraction technologies, the use of biotechnological approaches has revolutionized the development of nutraceuticals. For instance, biofortification of crops to increase their levels of vitamins and minerals can lead to more effective nutraceutical products. Traditional forms of nutraceuticals, such as tablets and capsules, often face challenges related to stability and bioavailability. Recent advances in nanotechnology have led to the creation of nanoencapsulation systems that protect sensitive bioactive compounds from degradation and improve their absorption in the body. These systems can also facilitate targeted delivery, ensuring that nutrients are released at the site of action, thereby maximizing their therapeutic effects. In conclusion, the field of nutraceuticals is witnessing significant advancements driven by novel products and innovative processes. The future of nutraceuticals is not only about providing nutritional benefits but also about integrating science and technology to meet the evolving needs of consumers in a health-conscious world.

Keywords: Nutraceuticals, spices, nano technology**,** nutritional benefits

Abstracts

Theme 5: *Food safety, value chain, and business innovations*

ORAL PRESENTATION

S5 OP101

Seed storability behaviour of coriander varieties under different packaging materials and conditions

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Seed storability is crucial for coriander, an important seed spice with culinary and medicinal significance. The study investigated seed viability and insect resistance across three coriander varieties (ACr-1, ACr-2, and AgCR-1) under different packaging materials and storage conditions over two years. Results demonstrated significant variations in seed germination and preservation. Under ambient conditions, ACr-1 experienced a dramatic decline from 88% to 0% germination across all packaging materials. Controlled storage at -20°C and 4°C maintained seed viability between 42-80%. ACr-2 showed similar patterns, with germination falling to 4-64% in ambient conditions, while aluminium foil provided minimal protection and plastic bags offered maximum preservation. Packaging and temperature critically influenced seed quality. Aluminium foil storage at room temperature caused complete germination loss in AgCR-1, whereas other materials retained 30-70% viability. Controlled conditions stabilized AgCR-1 germination at 60-70%, highlighting varietal differences in storage response. Insect damage varied significantly across storage conditions. Room temperature storage in cloth, jute, and HDPE bags showed highest infestation rates, while plastic and aluminium foil bags under controlled conditions demonstrated lowest damage. Variety-specific susceptibility was evident, with ACr-1 experiencing 27-86% insect damage, ACr-2 at 12-65%, and AgCR-1 at 6.2-32%. The research underscores the importance of selecting optimal packaging and controlled storage conditions to enhance coriander seed storability, minimize quality loss, and mitigate insect-related damage.

Keywords: Coriander, seed storage, insect damage, germination, seed viability

POSTER PRESENTATION

S5 PP102

Effect of chemical analysis on packaging and storage behaviour of champaca (*Michelia champaca* L.)

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Michelia champaca, commonly known as the champaca tree, is a beautiful flowering tree native to the Indian subcontinent and Southeast Asia. The present experiment on pre-treatment and shelf life improvement in champaca flower was conducted at the Department of Post Harvest Management of fruit, vegetable and flower crops, Post Graduate Institute Post Harvest Technology and Management, Killa-Roha during the year 2022-23.The study employed a Factorial Completely Randomized Block Design, investigating six chemical pre-treatment combinations including Sodium Benzoate (100 and 150 ppm), Boric Acid (1 and 2 percent), and Ascorbic Acid (100 and 150 ppm). Flowers were packed in LDPE bags, polypropylene bags, and stand-up pouches, then stored in a refrigerator at 7°C. Research focused on tracking chemical and physical parameter changes during flower senescence. Carotenoid and total phenol contents demonstrated a consistent decreasing trend over the 7-day storage period. Carotenoid content declined from 274.08 to158.96 mg/100g, while total phenol content reduced from 19.68 to 13.95 mg/g when packed in LDPE bags. The treatment using 2% boric acid demonstrated superior preservation, maintaining the highest carotenoid (227.29 mg/100g) and total phenol content (18.61 mg/g) throughout the storage period. This treatment emerged as the most effective method for extending champaca flower shelf life. Conclusively, champaca flowers treated with 2% boric acid and packed in LDPE bags can be successfully stored for up to 7 days at low temperature (7±1°C), maintaining optimal quality and overall acceptability.

Keywords: *Michelia*, boric acid, phenol, carotenoid, refrigeration

Abstracts

Theme 6: *Socio-economics, trade and policy studies*

ORAL PRESENTATION

S6 OP103

Willingness of primary traders to participate in high value markets of black pepper in Kerala: An empirical analysis

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Integrating primary traders into modern agricultural high-value markets (HVMs) for black pepper in Kerala offers a sustainable approach to value chain development. The study, conducted across eight Agro Ecological Units (AEUs) with the highest black pepper cultivation, surveyed 120 primary traders. The analysis revealed that 63.33% of traders were willing to participate in HVMs, while 36.67% remained hesitant. The variables such as digital literacy, the number of transactions involving the commodity (green/black/white pepper), and the extent of value chain linkages (intra-state, inter-state, and international) demonstrated significance. Traders identified several significant constraints to HVM participation like high market volatility and risk exposure, delayed payments, low production, inadequate government financial support, insufficient quality testing centres, lack of proper processing facility, absence of commodity-specific trader associations and limited market information access. The policymakers and value chain stakeholders should consider establishing trading contracts with both primary traders and smallholder farmers as this duo can jointly contribute to expand HVMs in Kerala by incorporating their tacit knowledge to formal value chains and contribute to Indian pepper trade.

Keywords: High value markets, willingness, transactional attributes, logistic regression

S6 OP104

Challenges faced for production of residue free small cardamom (*Elettaria cardamomum* (L.) Maton.) and the development of road map for sustainable integrated pest management (IPM) strategies

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Small cardamom plantations in the Cardamom Hill Reserve (CHR) of Western Ghats ecosystem, Idukki, Kerala, represent one of the most expensive global farming practices, characterized by indiscriminate chemical input applications from planting to harvesting. The

continuous monoculture of small cardamom involves intensive chemical farming, resulting in capsules containing high levels of insecticide residues. The average consumption of harmful chemical pesticides in CHR is estimated at more than 21.5 kg active ingredient per hectare, with application frequencies 3-4 times higher than recommendations by the Indian Cardamom Research Institute (ICRI). Farmers predominantly rely on irrational pesticide applications, often guided by non-technical consultants and pesticide dealers, typically implementing 14-18 rounds of insecticides and fungicides with complex mixtures annually. Recent climatic changes have triggered severe secondary pest outbreaks, particularly cardamom scales, ranging from 45.7% to 58.5% between March to June in 2023 and 2024. ICRI has successfully developed bio-intensive management technologies, notably using native entomopathogenic nematode strains like *Heterorhabditis indica* for cardamom root grub control. Addressing current pesticide challenges requires developing eco-friendly, cost-effective bio-intensive Integrated Pest Management (IPM) technologies and Good Agricultural Practices (GAP). These approaches aim to increase export-quality, residue-free capsules while simultaneously preserving biodiversity in the CHR ecosystem, presenting a sustainable solution for small cardamom farmers in Idukki, Kerala

Keywords: Small cardamom, residue, GAP, IPM, CHR

S6 OP105

Adoption of improved varieties by ginger growers in Karnataka: A narrative analysis

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This study examines the adoption patterns of improved ginger varieties (IISR Varada and IISR Mahima) developed by the ICAR-Indian Institute of Spices Research (IISR) among ginger farmers in Karnataka. Through a comprehensive survey conducted across Chamarajanagar, Shivamogga, Hassan and Haveri districts, the research investigates the key factors influencing farmers' varietal preferences and adoption decisions. The study reveals that higher dry recovery, superior transportation durability, better storage capability during price fluctuations, and enhanced pest and disease resistance are primary determinants driving the adoption of improved varieties. However, these varieties face adoption challenges in the vegetable ginger market segment due to comparatively lower yields than the ruling variety Rio De Janeiro. The research identifies significant gaps in variety awareness and seed material availability among farmers. Findings suggest that strengthened collaboration with public extension agencies is crucial for wider dissemination and adoption of these improved varieties. Also, it is important to recognise and strengthen the crucial role of entrepreneurs and private sector initiatives for the development of the seed system of improved varieties This study provides valuable insights for agricultural extension strategies and future breeding programs aimed at enhancing ginger cultivation in Karnataka.

Keywords: Ginger varieties, adoption analysis, agricultural extension, Karnataka, IISR

POSTER PRESENTATION

S6 PP106

A quantitative assessment on knowledge and adoption level of spice species among the indigenous farming communities in Idukki district, Kerala

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The present study was conducted to compile and document knowledge and adoption of spices among indigenous farming communities for their diverse uses in Idukki, Kerala. For this purpose, comprehensive ethnobotanical surveys were conducted using a semi-structured interview schedule and focus group discussion. A total of 90 indigenous healers, 452 indigenous farmers of different gender, ages, were purposively selected. The majority of the informants (60.40 %) were >45-year-old. The collected spice species were quantitatively analyzed using various statistical indices i.e., 1) use value 2) botanical family use value 3) relative frequency citation 4) fidelity level 5) informant consensus factor value 6) relative importance 7) cultural importance index 8) plant part value. In total, there were 63 spice species identified that were used for seasoning, colouring, and flavouring of food items. Some of the spice species (eg. *Curcuma longa* L.) were mostly used as ethno medicines and vegetables (eg. *Coriandrum sativum* L.).Some other spices (eg. *Tamarindus indica* L.) has been used to preserve food items and recipes. *Elettaria cardamomum* (L.)Maton, *Piper nigrum* L., *Zingiber officinale* Roscoe, *Murraya koenigii* (L.), *C. sprengel, Syzygium aromaticum* (L.) Merr. Perry were identified as the most preferred species with highest statistical indices. Majority of the indigenous farming communities (85%) belonging to Idukki district have been regularly using these spice species. Most of the indigenous farmers had a medium to a high knowledge (83.5%) and adoption levels (77.88%).

Keywords: Spices, indigenous communities, knowledge, adoption

S6 PP107

Yield gap and remedial measures in seed spice in India

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Seed spices occupy nearby 6% of horticultural acreage, contributes meager 0.6% to national horticulture production in the country due to comparatively low productivity and existing wide yield gap (YG). YG in cumin, coriander, fennel, fenugreek and ajwain was estimated in Rajasthan, Gujarat and Madhya Pradesh during 2006-07 to 2020-21, to locate and develop YG bridging strategies. Yield gap over state and top yielding district was measured, taking average yield during study period as potential yield. In coriander 17% yield gap in Rajasthan and

Gujarat and 12% in Madhya Pradesh exists. In cumin a YG of 23% in Rajasthan and 17% in Gujarat was measured. More than this, higher YG in fennel and ajwain was found, need to bridge with promotion of newer technologies to the farmers with special emphasis on HYVs. Numerous biotic and abiotic constraints such as changing climate, poor soil, limited availability of pest and disease resistant varieties, low mechanization, and post-harvest management loses adversely affects yields. To address above yield-limiting constraints, research and development in seed spices and policy options for effective solutions are required. Climate resilient, pest and disease resistant HYVs, soil health management, specialized machinery, capacity building of farmers, and policies on support price and expanded insurance coverage are required to create a sustainable and profitable future for seed spice farmers and stakeholders. Continuous improvements in seed spice production and post-harvest management practices adhering to domestic and global quality standards are essential for maintaining and enhancing global dominance of India in world spices economy.

Keywords: Seed spices, yield gap, remedial measures, policy option

S6 PP108

Contributing role of women in spices, medicinal and aromatic plants

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Women play a critical role in spices, medicinal and aromatic plants (MAP) ecosystems, possessing unique medicinal knowledge and sensory expertise. They are primary users who assess product quality through colour, smell, and shape. These botanical resources represent a crucial income source for women and tribal communities, potentially improving their standard of living. Women's involvement in spice and MAP production spans a comprehensive range of activities. As housewives, home gardeners, and herbalists, they serve as seed custodians and plant breeders. Their knowledge encompasses local species identification and intricate home remedy formulations. Throughout the production cycle, women engage in seed preparation, nursery management, and cultivation processes. They are integral to processing responsibilities, including harvesting, cleaning, and grading. Post-harvest operations like essential oil extraction, packaging, labelling, and storage further demonstrate their expertise. Their participation varies across regions and crops, influenced by agro-climatic and socio-cultural factors. From traditional ethnic food preparations to rural market sales, women's expertise in spices and MAPs is deeply rooted in cultural practices, highlighting their essential contribution to botanical resource management and economic sustainability.

Keywords: Spices, medicinal and aromatic plants, women, medicinal value and health

S6 PP109

Bush pepper and millets popularization activities of KVK at Kozhikode

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Spices and millets represent two critical health and nutritional components essential for dietary enhancement. Bush pepper and millets offer unique opportunities for agricultural diversification and income generation, particularly in Kozhikode district. Krishi Vigyan Kendra (KVK), Kozhikode has been instrumental in promoting these crops through comprehensive cultivation and value addition strategies. In millet cultivation, 80% of local growers focus on ragi and sorghum in micro plots. Bush pepper production has enabled farmers to maintain plants in pots and grow bags, creating nursery opportunities. KVK's interventions have successfully created more than 50 nursery entrepreneurs in Kozhikode who supply plants even to farmers in other states. Progressive farmers have developed unique propagation and maintenance methods, enhancing both income and recognition. The SWOT analysis of millet cultivation reveals significant strengths including government support, small-scale processing industries, and farmers' traditional cultivation experiences. Weaknesses include unavailability of quality seeds, limited land data, and intensive rainfall. Opportunities emerge from public acceptance of millet products and farmers' willingness to cultivate traditional crops. Processing initiatives by entities like Pragathi Foods and individual farmers have further supported millet promotion. Despite challenges like seed mixture and potential crop damage, both bush pepper and millets demonstrate substantial potential for socio-economic improvement in Kozhikode, offering sustainable agricultural alternatives.

Keywords: Bush pepper, millets, SWOT analysis, innovation, Kozhikode

S6 PP110

The quiet cultivators: Exploring the realities of non-commercial ginger cultivation in India

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Ginger is a primary spice crop in India, with a production of 2.43 million metric tonnes in 2023. While ginger farming has transformed into a commercial enterprise through modern practices, improved varieties and techniques, this study examines challenges faced by non-commercial ginger farmers in selected 'stressed districts' across India. A comprehensive survey of 128 ginger farmers across 10 states revealed significant constraints in small-scale cultivation. The most critical challenge is limited land area, with farmers averaging only 0.78 acres per holding-substantially smaller than commercial farms. This restricted land access severely impacts potential productivity. Farmers also struggle with crop vulnerability to pests and diseases,

compounded by limited agricultural knowledge and reliance on unimproved seed varieties. Natural resource scarcity further complicates cultivation, with merely 5.46% of the land under irrigation and the majority dependent on rainfed water sources. Varying soil and climatic conditions across regions, coupled with inadequate land preparation and plant protection methods, exacerbate the challenges. Particularly concerning is that only 18.75% of farmers practice comprehensive plant protection strategies. These findings highlight the urgent need for targeted interventions to address the multifaceted issues confronting marginal ginger farmers. The research underscores the importance of developing strategies that can improve productivity, enhance sustainability, and increase profitability for small-scale ginger cultivators in these stressed districts, ultimately supporting rural agricultural communities.

Keywords: Ginger cultivation, small scale farmers, non-commercial

S6 PP111

Turning the tide: Marketing practices and challenges for ginger and turmeric in India's Untapped Production Hubs

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Although the market for ginger and turmeric in India appears robust, the reality differs significantly across regions. This study investigates the marketing challenges faced by cultivators in India's 'stressed districts' through a comprehensive survey of 326 farmers across 12 districts spanning 10 states. The districts were strategically selected using multiple indicators including poverty levels, disaster vulnerability, natural resource indices, integrated livelihood rankings, and deprivation scores. Key challenges identified were insufficient transportation facilities, reliance on intermediaries, and the low prices offered for their crops. Farmers predominantly sell to local traders within an average distance of 9.5 km for ginger and 9.6 km for turmeric, with prices fluctuating between Rs. 17 to Rs. 52 per kg for ginger and Rs. 32 to Rs. 75 per kg for turmeric, depending on the region and product form. A persistent challenge across these districts is the dominance of middlemen who exploit farmers' limited market access. These intermediaries purchase produce at lower prices and sell at higher rates, significantly reducing farmers' potential profits. By leveraging farmers' restricted connections to regulated markets and private companies, middlemen create a systemic barrier to agricultural sustainability. The research underscores the critical need for targeted interventions to improve market access, transportation infrastructure, and direct marketing opportunities, ultimately enhancing the profitability and resilience of ginger and turmeric cultivation in these underserved agricultural communities.

Keywords: Marketing challenges, stressed districts, transportation, ginger and turmeric

S6 PP112

Turmeric industry in India: Status and way forward

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India dominates global turmeric production, accounting for over 80% of world output. The turmeric industry faces significant challenges including global warming-induced climate uncertainties, leading to drought and flood risks during critical growth periods. Additional limitations encompass pest and disease emergence, processing complexities, value addition difficulties, adulteration and market fluctuations. The unavailability of quality planting materials of improved varieties further constrains crop development. Organic turmeric cultivation is gaining momentum, though it presents unique challenges in pest management and market penetration. To address these issues, the Government of India established the National Turmeric Board in 2023, focusing on research, market development, and value addition. Similarly, Maharashtra established the Hon. Balasaheb Thakare Turmeric Research and Training Centre in 2022 to advance turmeric research and disseminate improved technologies. Export opportunities have expanded through port facilities and promotional schemes by the Spices Board of India. Considering India's diverse climatic conditions and turmeric's requirements, significant potential exists for area expansion, presenting a promising pathway to double farmers' income and strengthen the nation's agricultural landscape.

Keywords: Turmeric, climate, production, market

S6 PP113

Land suitability analysis is a prerequisite to achieve optimum utilization of the available land resources for sustainable agricultural production

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Land suitability analysis is a prerequisite to achieve optimum utilization of the available land resources for sustainable agricultural production. Land suitability for agricultural cropping in Sanguem Taluka of Goa state for crop using a multi-criteria decision-making (MCDM) approach integrated with Geographic Information Systems (GIS). Given the region's unique climatic, topographical, and socio-economic conditions, the study aims to identify optimal locations for various crops to enhance agricultural productivity and sustainability. Key criteria such as soil type, land slope, rainfall, temperature, and proximity to water sources were analyzed through GIS mapping and spatial analysis techniques. The MCDM framework facilitated the prioritization of these criteria, enabling a comprehensive evaluation of land parcels. Results indicate significant variability in suitability across the region, highlighting

areas with high potential for specific crops. The objective of this study has been to provide an up–to date GIS-based agricultural land suitability evaluation (ALSE) for determining suitable agricultural land for crops in Goa. This approach not only aids in informed decision-making for farmers and policymakers but also promotes sustainable land use practices in Sanguem Taluka of Goa aligning agricultural development with environmental conservation. This study could be useful in assessing the potential agricultural yields and potential environmental degradation in the study area, it could also help to estimate the potential conversion of agricultural land to non–agricultural uses.

Keywords: Land suitability analysis, GIS, MCDM, agricultural land use, sustainable agriculture

S6 PP114

Sustainable agriculture practices and new technologies in cumin and fennel

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India is the largest producer, consumer and exporter of seed spices in the world. The major seed spices are coriander, cumin, fennel and fenugreek whereas, ajwain and dill are the minor seed spices. During 2022-23, the area and production of cumin in the country was 9,02,010 ha. and 6,27,031 MT, respectively, while, the area and production of fennel was 82,142 ha. and 1,37,408 MT respectively. India exported cumin and fennel worth Rs. 5,79,723.43 lakhs and 66,961 lakhs during 2023-24. The spice industry is embracing sustainable and regenerative agriculture not just for environmental stability but for boosting market demand and credibility too. However, it is possible only by adopting the practices to fit regional climates, incorporating Good Agricultural Practices (GAP) and integrating indigenous methods with modern technologies. Sustainable Agriculture is farming in a sustainable way meeting societies' present food and textile needs. Some of the best production practices for cumin and fennel growers aiming to reduce inputs, use of biological pest, disease & weed management, cycles nutrients for fertility & health, farm viable income and other factors are discussed.

Keywords: sustainable, GAP, modern technology, export

S6 PP115

Advantages and challenges of entrepreneur led extension system: An analysis in the context of spices sector

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Agricultural extension has been tasked with developing and sustaining entrepreneurship across agricultural value chains, yet the role of entrepreneurs in extension and advisory services (EAS) requires further examination to maximize potential benefits for farmers. Entrepreneurship in Extension and Advisory Services involves creating innovative business models that expand service delivery and capitalize on agri-food value chain opportunities. Unlike traditional

extension approaches, entrepreneurial models differ in innovation, technology adoption, motivation, funding, and operational flexibility. Initial results of survey conducted among extension professional reveal a balanced perspective on entrepreneur-led extension. Positive aspects include enhanced farmer outreach beyond traditional methods, potential for integrated financial services, and ability to leverage supportive policies for smallholder farmers. Simultaneously, significant challenges were identified, including risks of profit motives compromising service sustainability, potential neglect of economically disadvantaged regions, and possibility of critical service disruption due to start-up failures. Case studies in the spices value chain underscored critical insights such as the need for initial support for small-scale entrepreneurs, importance of establishing institutional-collective partnerships, and potential for entrepreneurs to transform agricultural extension services. The research emphasizes the necessity of strategic policy interventions to effectively integrate entrepreneurial approaches. Policymakers must carefully design extension strategies that balance entrepreneurial innovation with comprehensive agricultural support, ensuring sustainable and inclusive service delivery across diverse agricultural contexts. Continued research and thoughtful policy formulation will be crucial in harnessing the transformative potential of entrepreneurship in agricultural extension services.

Keywords: Entrepreneurship, extension, spices

S6 PP116

Target extension models for promoting technology adoption in spice farming in hill ecosystems

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Cultivation of spices like black pepper, small cardamom, ginger and a variety of tree spices are inextricably linked with hill agriculture and communities across many regions the country. ICAR - Indian Institute of Spices Research had implemented targeted TOT programmes aiming at appropriate technology adoption by farming community and productivity improvement of the crops. The various target area covered are NEH states of Meghalaya, Mizoram and Tripura, Attapady hills of Kerala and tribal farming communities in the buffer zones of Parambikulam and Periyar Tiger reserves in Kerala. The programmes (2022-2025) in NEH states were devised and designed to strengthen the seed supply chain of improved varieties of ginger. The programme in Attapady dry hills of Palakkad district Kerala was designed to strengthen the resource base of tribal cooperative farms managed by the Attapady Farming Cooperative Society an ambitious tribal rehabilitation programme of the Kerala state government. Front line demonstration and introduction of tested small cardamom varieties in the organic certified farms, establishment of mother gardens of improved varieties of tree spices like nutmeg, cinnamon and clove, supply of designer bio input technologies developed by IISR and capacity building for member farmers were the major activities (2016-2024). The programmes carried out in forest buffer zones aimed at strengthening agro forestry systems through tree crop diversification and bio intensification, bio-intensive management of spice crops and

introduction of improved varieties of black pepper, nutmeg and clove. The three extension models derived from the experiences of these interventions are Extension through tribal cooperatives, Extension through private seed entrepreneur and KVK partnerships and Extension model for sustainable agro forestry systems. All these can be classified as derivative extension models form the base models of partnership extension and convergence extension. These models need to be further tested and refined through replications.

Keywords: Spices, front line demonstration, extension, agro-forestry

S6 PP117

Rediscovering Cochin Ginger and Alleppey Finger Turmeric: Quality spices for export

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Purposive sampling was conducted for identification of Cochin Ginger (CG) and Alleppey Finger Turmeric (AFT) in the niche areas of Central Kerala region. Cochin Ginger (*Zingiber officinale* Rosc.) a traded dry ginger genotype known for its unique quality features such as high zingiberene, low fibre, unique flavour, light greenish yellow to lemon yellow core colour. Sixty collections of local ginger from the niche areas of Central Kerala were biochemically characterized for two seasons. On basis of the pooled data of GC-MS analysis of volatile oil, five collections *viz.,* CG 31, CG 47, CG 46, CG 53, and CG 52 were identified with unique Cochin Ginger properties such as α-zingiberine (28 to 32 %), β-bisabolene (6.7 to 8.15 %), β- and [6]-sesquiphellandrene (11.81 to 16.53 %), volatile oil (1.8-3 %), citronellol (0.22 to 1.0 %), crude fibre (6 to 12 %) and driage of 17 to 24 %. Alleppey Finger Turmeric (AFT) is one of the elite turmeric traded types from Kerala and exported to the USA, Middle East and Europe. AFT rhizomes are characterized by their slender finger shaped appearance with earthy aroma embedded with superior delicate top notes of lemon and mint. As a natural colouring agent with brilliant orange colour of 6000 ASTA, Alleppey Finger Turmeric is highly preferred in USA. In the current study, out of 58 turmeric samples collected and analyzed, three collections *viz.,* AFT 31, AFT 39 and AFT 19 were identified with unique AFT properties on basis of high curcumin levels ranging from 6 to 11.5% and comparatively lower volatile oil and meeting the export specifications.

Keywords: Alleppey finger turmeric, Cochin ginger, curcumin, export, α-zingiberine

S6 PP118

Towards greener agriculture: Research on organic cardamom cultivation in Kerala

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Most of the small cardamom (*Elettaria cardamomum* Maton) production in India is concentrated in the Cardamom Hill Reserve located in Idukki district in which variety Njallani Green gold has the major role. Due to monocropping, this variety is susceptible to various biotic stresses as the crop is managed by uncontrolled use of pesticides leading to pest resurgence which resulted in multiple pesticide residues in soil and cured cardamom samples, leading to economic loss to the farmers. Thus, as an eco-friendly approach, an investigation was conducted on the influence of application of bio inputs on growth, yield and quality of cardamom var. Njallani Green gold. The treatments included various bio-inputs combination of *Trichoderma* enriched FYM, jeevamrutha, panchagavya, fish amino acid, vermicompost, PGPR mix-1 with KAU Package of practices etc.. Among the treatments, the bio input combination of neem cake equivalents to N in FYM (5kg) + bone meal (100gm) + jeevamrutha @ 20 L plant^{-1} + PGPR mix I (50gm) recorded the maximum fresh capsule weight (963 g plant^{-1}) and dry weight (177 g plant^{-1}). The second-best bio input combination was FYM @ 5 kg plant^{-1} + monthly application of jeevamrutha @ 20 L plant-1+ *Azospirillum* (10 g plant^{-1}) + phosphorus solubilising bacteria (10 g plant^{-1}) + *Trichoderma* (10 g plant^{-1}) recording fresh capsule weight of 852 g plant^{-1} and dry capsule yield of 164 g plant^{-1} on par with the treatment organic PoP (KAU) + soil applications of jeevamrutha (20 L plant^{-1}). The absolute control treatment consisting of no bio-input application recorded lower yields as compared to majority of the treatments. Quality improvement in organically raised cardamom was evident on basis of bolder capsules as compared to absolute control. The produce is safer as it was devoid of any pesticide residue, however the crop needs to be evaluated for larger period.

Keywords: Cardamom, capsule yield, jeevamrutha, pesticide residue, organic

Author Index

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