वार्षिक प्रतिवेदन
Annual Report
2021

भाकृअनुप
ICAR

भाकृअनुप-भारतीय मसाला फसल अनुसंधान संस्थान, कोषिक्कोड
ICAR-Indian Institute of Spices Research, Kozhikode

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भाकृअनुप - भारतीय मसाला फसल अनुसंधान संस्थान
ICAR-Indian Institute of Spices Research
(Two times winner of Sardar Patel Outstanding ICAR Institution Award)
कोषिक्कोड, केरल, भारत
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PREFACE

I consider it a privilege to present the annual report of ICAR-Indian Institute of Spices Research, Kozhikode for the year 2021. Though we faced unique set of challenges and constraints, the institute could still deliver on its promises. In a sense, the institute has relished these challenges. Along with hard work and steadfast commitment, we have brought in an eclectic mix of innovation and creativity in our research and allied activities, which has helped in meeting the expectations of the stakeholders. The strong output performance of the spice sector in the country, even amidst the pandemic, is heartening to note. This indicates the resilience and robustness of spice production system. The research output from the public funded spice crops research has also played a significant role in fashioning this competence.

The institute explored a range of possibilities for maintaining the research momentum and its grass root connectivity across the nation. The outreach initiatives have become more robust and diverse in terms of inclusiveness and geographic coverage. More than 60 training programmes of various duration were conducted by the institute catering to the needs of diverse groups like primary producers, rural youth and women with a special focus on socially and geographically disadvantaged clientele.

A steadfast focus on maintaining, characterizing and enriching the germplasm resources continued and the strategic exploration programme has resulted in several new additions across spice crops. The new facility for ginger germplasm conservatory at the experimental farm was also completed during this year. The institute also received patents for its microbial encapsulation technology for storage and delivery of beneficial microorganisms, micronutrient formulation of black pepper and bacterial fermentation technology for production of white pepper. I am hopeful that the completion of whole genome sequencing of *Phytophthora capsici* (05-06) and *P. tropicalis* (98-93) will facilitate development of new strategies in disease management. Further, molecular and genome level information on several important pathogens including plant viruses has been generated, which will translate into more effective approaches for mitigating biotic stress in spice crops.

Our explicit commitment to ensure sustainability of spice production systems is reflected in all our research endeavours. The organic management packages for crops, biocontrol & IPM strategies, development of integrated farming system with spice crops as important component and the studies on carbon sequestration potential of spice production systems are a few of them with specific focus. Even during these difficult times, the institute has kept an unwavering focus on integrating cutting edge science with meticulous prioritization to address the most vexing problems faced in production and plant health management, processing and utilization of spices.

Driven by nutraceutical and pharmaceutical applications, the recent years have witnessed an increased demand for spice commodities and their value-added products across the globe. Concerns about food safety and quality are also on the rise. As a premier institute engaged in spice research, we remain committed to address the emerging challenges and crop production, soil and plant health management & crop utilization scenarios.

I am thankful for the trust, confidence and guidance received from Dr. T Mohapatra, Director General, ICAR in all the endeavours of the institute. I also thank Dr. A K Singh, Deputy Director General (Horticultural Science) and Dr. Vikramaditya Pandey, Assistant Director General (Hort I) for their persistent support and motivation. Special thanks to the editors for bringing out this report.

Kozhikode
18 January 2022

J. Rema
Director

OUR VISION

Enhancing the productivity of spices to meet the growing demand and to make India the global leader in spices export

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कार्यकारी सारांश

काली मिर्च

- प्रायोगिक प्रक्षेत्र, पेरुवण्णामुषि, केरल में, काली मिर्च जर्मप्लाज़म नर्सरी में तीन हज़ार चार सौ छियासठ अक्सेशनों का संरक्षण किया जाता है।
- कुल 31 संग्रह किए गए और संग्रह के एक सेट को क्षेत्रीय स्टेशन अप्पंगला में रोपण किया गया।
- सफेद काली मिर्च के उत्पादन से जुड़े लक्षणों के लिए अठारह काली मिर्च जीनोटाइप का चरित्रांकन किया था। अध्ययन से सूचित करता है कि 'अगली' और 'आईआईसआर-गिरिमुंडा' बीज के आकार, पेरिकार्प से बीज अनुपात और अन्य गुणवत्ता विशेषताओं के मामले में सफेद काली मिर्च उत्पादन के लिए उपयुक्त सर्वोत्तम जीनोटाइप है।
- एक 'किसान' के खेत (मिथुन, शानिवरशंते) से एक आशाजनक जीनोटाइप (स्थानीय प्रकार) की पहचान की गई। इस जीनोटाइप में मध्यम स्पाइक की लंबाई और उच्च सूखी उपज की प्राप्ति के साथ मोटे बेरी है।
- काली मिर्च की तीन प्रजातियों जैसे आईआईएसआर थेवम, आईआईएसआर गिरिमुंडा और आईआईएसआर शक्ति के लिए फर्टिगेशन शेड्यूल को मानकीकृत किया गया। 50% एनपीके 24 विभाजनों (3.1 कि. ग्रा./पौधा) की दर में फर्टिगेशन उपचार करने पर अधिकतम उपज अंकित की गई।
- 40 जीनोटाइप के एसन्शयल तेल के जी सी-एम एस विश्लेषण ने 62 बाष्पशील योगिकों की पहचान की, जो जीनोटाइप के बीच महत्वपूर्ण वेरियेशन्स को दिखाता है। के-अर्थात् मेटाबोएनलिस्ट 5.0 का उपयोग करके बाष्पशील योगिकों का क्लस्टरिंग करता है और एक डेन्ड्रोग्राम ने अपने वोलाटाइल प्रोफाइल के आधार पर जीनोटाइप के चार समूहों का उत्पादन किया।
- *फाइटोफ्थोरा कैप्सीसी* (05-06) औऱ पी. ट्रोपिकालिस (98-93) की संपूर्ण जीनोम अनुक्रमण को PacBio और Illumina प्लेटफार्म में किया गया था और पहचान किये जीन के लिए हाइब्रिड असेंब्ली और KEGG पाथवे विश्लेषण किया गया था।
- पाइपर येल्लो माटिल वाइरस (PYMoV) संक्रमित काली मिर्च से अलग किए गए कुल डीएनए की अगली पीढ़ी के अनुक्रमण का उपयोग करने वाले अध्ययनों ने 7178 बीपी और 892 बी पी की लंबाई वाले दो कोंटिग्स की पहचान की, जो टंग्रोवायरस और बैडनावायरस को समरूपता दिखाता है। इन कोंटिग्स को पाईपर डीएनए वाइरस 1 (पी डी वी-1) (जीन बैंक अक्सेशन संख्या JX406741) तथा पी डी वी-2 (जीन बैंक अक्सेशन संख्या JX406742) के रूप में नामित किया गया था।
- पीसीआर 1 और आरपीए के माध्यम से PYMoV, पी डी वी-2 का पता लगाने के लिए एक सरल विधि संक्रमित पौधे से कच्चे रस का उपयोग करके विकसित की गई थी। अध्ययन से पता चला है कि काली मिर्च में संक्रमित करने वाले वाइरस को पौधे के साधारण कच्चे रस का उपयोग करके 5 मिनट के अंतर पता लगाया जा सकता है।

- रूट मीलीबग (प्लानोकोकस स्पी.) के लिए कम जोखिम वाले कीटनाशकों की जांचः परीक्षण किए गए सात कम जोखिम वाले अणुओं में से, फ्लोनिकेमिड कम खुराक (0.3 ग्रा./ लि) और क्लोरपाइरिफॉस (2 मि. लि. / लि.) के बराबर प्रभावी था। अन्य कम जोखिम वाले कीटनाशक जैसे बुप्रोफेज़िन (3 मि. लि. / लि.) और डायफेंथियुरोन (1 ग्रा. / लि.) को भी बहुत प्रभावी और एक दूसरे के बराबर पाए गए।
- माईकोरहिज़ा के रोग प्रतिरोधक लक्षणों के साथ संभावित सह-संबंध का पता लगाने के लिए रक्षा संबंधी जैव रासायनिक मापदंडों जैसे टोटल फिनोल, ऑर्थोडिहाइड्रोक्सि (ओडी) फिनोल, लिग्निन और पेरोक्सिडेस का अध्ययन किया गया।
- काली मिर्च के संदर्भ जीनोम की तुलना मेंक्रोमसोम PN1 और PN13 में गैप्ड क्षेत्रों की पहचान की गई। लापता क्षेत्रों के अनुक्रम की पहचान करने के लिए इन हाउस स्क्रिप्ट्स का विकास किया गया था।
- फाइटोफ्थोरा और इसके होस्ट्स के बीच प्रकाशित प्रोटीन-प्रोटीन अंतःक्रियाओं का उपयोग अंतःक्रियात्मक पूर्वानुमान के लिए एक मॉडल विकसित करने के लिए किया गया था। पर्यवेक्षित शिक्षण एल्गोरिथम- समर्थन वेक्टर मशीन (एसवीएम) और सामूहिक विधियों के नए संयोजन को इन्टराक्शन का पूर्वानुमान करने के लिए लागू किया गया था।
- आमतौर पर काली मिर्च मानकों के रूप में उपयोग किए जाने वाले छायादार पेड़ों से कार्बन तुल्यता (सीई) की गणना एफएओ मानदंडों और मौजूदा मानक प्रक्रियाओं के आधार पर की गई थी। पेड़ों के बीच, ऐलेन्थस स्पी. प्रति वर्ष 2.98 कि.ग्रा. सी (प्रति वर्ष 10.94 कि.ग्रा. सीओ$_2$ अनुक्रम के बराबर) के साथ उच्चतम सी सीक्वेस्ट्रेशन क्षमता दिखाई गई, इसके बाद ग्लाइरिसिडिया स्पी. प्रति वर्ष 1.9 कि.ग्रा. सी (प्रति वर्ष 6.99 कि.ग्रा. सीओ$_2$ अनुक्रम) की क्षमता के साथ आता है।

इलायची

- आईसीएआर-आईआईएसआर, क्षेत्रीय स्टेशन, अपंगला में राष्ट्रीय सक्रिय जर्मप्लाज्म साइट (एनएजीएस) के तहत अप्पंगला स्टेशन से 423, पांपाडुम्पारा से 102, मुडिगेरे स्टेशन से 41 और सकलेशपुर से 56 अक्सेशनों के साथ कुल 622 इलायची अक्सशनों का अनुरक्षण किया जाता है।
- विभिन्न रूपात्मक लक्षणों के आधार पर 85 फील्ड जीन बैंक (एफजीबी) अक्सेशनों का चरित्रांकन किया गया।
- नौ संकरों वाले सीवीटी परीक्षण में, प्रति पौधे कैप्सूल की उच्चतम शुष्क उपज संकर PH-13 (841.67 ग्राम/पौधे) में दर्ज की गई थी, इसके बाद संकर बोल्ड × IC 547219 (361.33 ग्राम/पौधे) में दर्ज किया गया था।
- इलायची से पृथक एक *कोलेटोट्राइकमम ग्लियोस्पोरियोइड्स* ने dsRNA की उपस्थिति को दिखाया जो एक माइकोवायरस के जुड़ाव को दर्शाता है। यहभारत से *सी. ग्लियोस्पोरियोइड्स* को संक्रमित करने वाले माइकोवाइरस की पहली रिपोर्ट है।
- इलायची उगाने वाले दो प्रमुख राज्यों केरल और कर्नाटक में हाल ही में पृथक किए गए एंटोमोपैथोजेनिक कवक, *लीकेनिसिलियम प्साइलियोटे* (ट्रेश्यू) ज़ारे और डब्ल्यू. गम्स (एस्कोमाइकोटा: हाइपोक्रेलेस) की जैव नियंत्रण क्षमता का मूल्यांकन दो वर्षों के खेत परीक्षण के

द्वारा किया गया था। इसके परिणामों ने संकेत दिया कि कवक के दानों के मिट्टी में चार बार लगाने से नियंत्रण की तुलना में कैप्सूल क्षति को थ्रिप्स द्वारा 79% तक कम कर दिया।

- मिट्टी की स्थिरता सूचकांक को पोषक तत्व सूचकांक, सूक्ष्मजीव सूचकांक और फसल सूचकांक के साथ मापा गया और इलायची के लिए विभिन्न प्रबंधन प्रणालियों के तहत तुलना की गई। समग्र स्थिरता सूचकांक आईएनएम प्रणाली के तहत उच्चतम था, इसके बाद पारंपरिक और जैविक प्रणालियों का स्थान था।
- इलायची थ्रिप्स के प्रबंधन के लिए घटकों के रूप में मौजूदा रासायनिक और सांस्कृतिक (फाइटोसैनिटेशन) विधियों के साथ एंटोमोपैथोजेन (एल.प्सालियोटे), और एक कम जोखिम वाले कीटनाशक (स्पिनोसाद) और उनके संयोजनों को एकीकृत करने वाले एक आईपीएम पैकेज को खेत में परीक्षण किया गया। यह इलायची के इस प्रमुख कीट के खिलाफ जैविक नियंत्रण के साथ एक घटक के रूप में विकसित पहला आईपीएम शेड्यूल है।

अदरक

- फील्ड जीन बैंक में छह सौ अड़सठ अदरक अक्सेशनों का संरक्षण किया गया है। आईसीएआर-आईआईएसआर, प्रायोगिक प्रक्षेत्र में अदरक की एक नयी संरक्षिका स्थापित की गयी है।
- वर्ष 2020-2021 के दौरान उपज के लिए चेक, आईआईएसआर वरदा के साथ नौ अदरक प्रविष्टियों (आईसीएआर-आईआईएसआर से पांच आशाजनक म्यूटेंट, ओयूएटी से चार और आईजीकेवी से एक) का मूल्यांकन किया गया।
- अदरक ट्रान्स्क्रिप्टोम (PRJNA311170) से प्राप्त यूनीजीन्स को ओमिक्सबॉक्स के BLAST2GO मॉड्यूल का उपयोग करके पूर्व-संसाधित और कार्यात्मक रूप से एनोटेट किया गया था। 18222 स्वदेशी को GO डेटाबेस में मैप किया गया।
- बारह फ्लैंकिंग पॉलीमॉर्फिक ईएसटी-एसएसआर प्राइमरों को उत्तर-पूर्वी भारत का प्रतिनिधित्व करने वाले 48 अदरक जीनोटाइप का उपयोग करके मान्य किया गया था और पीसीआर एम्प्लीफिकेशन और एलील साइज़िंग द्वारा केशिका वैद्युतकणसंचलन द्वारा विभिन्न पर्यावरण-भौगोलिक अनुकूलन का उपयोग किया गया था। UPGMA क्लस्टर विश्लेषण से पता चला कि 12 मार्करों ने 48 जीनोटाइप को तीन मुख्य समूहों में विभाजित किया।
- अतिसंवेदनशील और प्रतिरोधी अदरक स्पीसीस में मार्कर जीन की अभिव्यक्ति पर तुलनात्मक अध्ययन करने पर अतिसंवेदनशील और प्रतिरोधी अदरक स्पीसीस के बीच सभी समय के अंतराल पर सांख्यिकीय रूप से भिन्न (पी <0.05) गुना परिवर्तन के साथ कई जीनों की पहचान की।
- लाल अदरक के दो जीनोटाइप, नामतःपूर्वोत्तर लाल अदरक और विदेशी लाल अदरक के लिए राइज़ोम कलियों को एक्सप्लान्ट्स के रूप में उपयोग करकेएक कुशल प्रत्यक्ष इन विट्रो पादप पुनर्जनन प्रोटोकॉल स्थापित किया गया है। आईएसएसआर और एसएसआर आणविक मार्करों का उपयोग करके पुनर्जीवित पौधों के बीच आनुवंशिक स्थिरता की पुष्टि की गई थी।
- पूरी तरह से जैविक और विभिन्न कार्बनिक स्रोतों के मिश्रण वाले उपचारों में, जैविक 100% ने मिट्टी में अधिकतम नाइट्रोजन, फास्फोरस, पोटेशियम, कैल्शियम, मैग्नीशियम और ज़िंक का दर्ज किया, जिसके लिए रोपण (डीएपी) के 120 दिनों के बाद नमूना लिया गया था।

- अदरक के प्रकंदों में तरल क्रोमैटोग्राफी उत्तरदायी कीटनाशकों के विश्लेषण के लिए एक विधि विकसित की गई है। एलसी द्वारा टेंडेम एमएस के साथ 29 कीटनाशकों के अवशेषों की निगरानी के लिए एक QuEChERS तकनीक-आधारित नमूना तैयार करने की विधि को अनुकूलित किया गया था।
- गैर-सौरीकृत खेत की परिस्थितियों में अदरक के सॉफ्ट रोट/विल्ट रोगों के प्रबंधन के लिए कैल्शियम क्लोराइड और बायोइनोकुलेंट्स की प्रभावकारिता का मूल्यांकन करने के लिए एक खेत परीक्षण किया गया था। उच्चतम पौधे जीवित रहने और सबसे कम रोग घटना (रोट / विल्ट) कैल्शियम क्लोराइड (21.5%) के साथ दर्ज की गई, इसके बाद बेसिलिक (पाउडर फॉर्मूलेशन) (23.7%) और मिथाइलोबैक्टीरियम कोमागेट (24%) थे।
- अदरक के जीवाणुक म्लानी रोगजनक में कोरम सेंसिंग के लिए जिम्मेदार जीन का पता लगाने के लिए, प्राइमरों को आर. स्यूडोसोलानेसीरम, जैसे SolI और phcB के जीन को लक्षित करने के लिए डिज़ाइन किया गया था।

हल्दी

- खेत जीन बैंक में एक हजार चार सौ चार कुरकुमा अक्सेशनोंका संरक्षण किया गया है।
- हल्दी की आठ किस्मों का एसन्शयल तेल, ओलियोरेसिन, कुरकुमिनोइड्स, वाष्पशील घटकों, समीपस्थ और सूक्ष्म पोषक तत्वों की संरचना और उनकी ऑक्सिडेंटरोधी और मधुमेह विरोधी क्षमता के लिए मूल्यांकनकिया गया था। कुरकुमिन, BDMC और DMC ने ऑक्सिडेंटरोधीऔर मधुमेह विरोधी क्षमता के साथ सकारात्मक संबंध दिखाया।
- भारत में चार जीआई हल्दी (इरोड हल्दी, कंधमाल हल्दी, वैगाँव हल्दी और सांगली हल्दी) के फाइटोकेमिकल घटक, न्यूट्रास्यूटिकल्स और जैव सक्रियता का चरित्रांकन किया गया। परिणामों ने प्रमुख गुणवत्ता मानकों जैसे एसनश्यल तेल (4.00-5.60%), ओलियोरेसिन (8.36-18.12%) और कुरकुमिनोइड्स (2.23-5.50%) में काफी अंतर प्रकट किया।
- हल्दी की 18 जारी किस्मों में परीक्षण किए गए 57 माइक्रोसेटेलाइट मार्करों में से 56 बहूरूपी थे। प्रति मार्कर प्रति जीनोटाइप एलील की औसत संख्या 1 से 3.44 तक थी, जिसमें अधिकांश मार्कर हल्दी की रिपोर्ट की गई ट्रिप्लोइड स्थिति के अनुसार दो एलील दिखाते हैं।
- टैफ्रिना मैक्युलान के कारण होने वाले पत्तों के धब्बे के खिलाफ प्रतिरोधी स्रोतों की पहचान करने के लिए प्राकृतिक एपिफाइटोटिक स्थितियों के तहत हल्दी के एक सौ बयानबे जीनोटाइप की जांच की गई।
- हल्दी की जैविक खेती के तहत खरपतवार प्रबंधन के लिए, रोपण के समय सूखे नारियल के पत्ते का प्रयोग, रोपण के 45 और 90 दिनों पर हाथ से निराई करने से अधिकतम उपज और शुद्ध लाभ (2 लाख / हेक्टेयर) दर्ज किया गया।
- मसाला फसलों के साथ एक एकीकृत जैविक खेती प्रणाली मॉडल स्थापित किया गया था। एक एकड़ से 2.1 लाख रुपये का लाभ प्राप्त हुआ।
- उन्नत जैव-उपलब्ध सक्रिय घटकों के साथ अघुलनशीलता की समस्या पर काबू पाकर हल्दी दूध तैयार करने के लिए एक नया मसाला मिश्रण तैयार किया गया था। मसाले के मिश्रण की प्रमुख सामग्री हल्दी, अदरक और दालचीनी हैं।

- ग्रीनहाउस परिस्थितियों में पौधों की वृद्धि को बढ़ावा देने और पी. घुलनशीलता के लिए *बी. सेफेंसिस* (आईआईएसआर टीबी 4) और बी. सेरेस (आईआईएसआर जीबी 7 (3)) का मूल्यांकन आईआईएसआर टीबी 4, आईआईएसआर जीबी 7(3) और 75% P के अकेले प्रयोग की तुलना में 75% अनुशंसित पी. के साथ उपज में उल्लेखनीय वृद्धि दर्शाती है।
- चेलवूर, कोषिक्कोड में हल्दी को संक्रमित करने वाले प्ररोह बेधक के खिलाफएक कीटनाशक नियंत्रण, क्लोरेंट्रानिलिप्रोल के साथ *एम. पिंगशाएंस* कवक का परीक्षण तीन अलग-अलग खुराकों में किया गया था। परिणामों ने संकेत दिया कि 1×107 कोनिडिया / एम.एल. की खुराक पर कवक का छिड़काव कीट के प्रबंधन में प्रभावी था।
- हल्दी के खेतों में निमेटोड क्षति, प्रेटिलेंचस स्पी. के प्रबंधन के लिए नव पंजीकृत नेमाटिसाइड्स, फ्लुओपाइरम और फ्लुएनसल्फोन का मूल्यांकन किया गया था। उपचारों में फ्लुओपाइरम (0.75 मि. ली./लीटर) का प्रयोग प्रकंद और मिट्टी दोनों में सूत्रकृमि की आबादी को कम करने में बेहतर था।

वैनिला

- विभिन्न वैनिला प्रजातियों का तुलनात्मक शारीरिक विश्लेषण किया गया। *वैनिला प्लैनिफोलिया* और *वी. एफिला* के बीच अंतर-विशिष्ट संकरण किया गया था।
- *वी. प्लैनिफोलिया* और *वी. ताहितेंसिस* (जड़ गलन रोग के प्रतिरोधी के रूप में रिपोर्ट की गई प्रजाति) के बीच पारस्परिक संकरण आयोजित किया गया और दोनों संकरणों में उच्च प्रतिशत फल सेट देखा गया।
- वैनिला की पत्तियों पर हल्के क्लोरोटिक धब्बे और धारियाँ पैदा करने वाले वाइरस को कोट प्रोटीन जीन अनुक्रम तुलना और फ़ाइलोजेनेटिक अध्ययनों के आधार पर सिंबिडियम मोज़ेक वाइरस (CymMV) के एक स्ट्रेन के रूप में पहचाना गया।

वृक्ष मसाले

- *सिनामोमम पेरोटेटी, सी. वाइटी, सी. सल्फ्यूरेटम* और दो अज्ञात प्रजातियों को केरल के इडुक्की जिले के इरविकुलम, पेटीमुडी, राजमाला, मन्नावन शोला और आनकुलम में आरक्षित वनों से एकत्र किया गया था।
- वर्ष के दौरान भारत के प्रमुख लौंग उगाने वाले इलाकों में सर्वेक्षण किए गए और लौंग की 15 किस्मों में अद्वितीय वेरिएंट और उच्च उपज वाले एक्सेशनों को एकत्र किए गए। इस संग्रह में बोल्ड फ्लावर बड्स (किंग लौंग) के साथ 6 लौंग, दो बौने प्रकार, एक अर्ध बौना प्रकार, एक छोटे फूल वाले प्रकार और पांच उच्च उपज वाले एक्सेशन शामिल थे।
- *जी. कोनिकार्पा, जी. पुष्पांगदानियाना, जी. तलबोटी*, पश्चिमी घाट में गार्सिनिया की तीन स्थानिक प्रजातियां और *जी. गम्मी-गट्टा* का मोटे फलवाले अक्सेशनों को इडुक्की जिले के आरक्षित वनों से एकत्र किया गया था।
- आंकड़ों के एकत्रित विश्लेषण से पता चला कि मई के दौरान कॉयर पिथ कम्पोस्ट (5 कि. ग्रा./पौधा) का प्रयोग, जून और सितंबर के दौरान मिट्टी में अनुशंसित पोषक तत्वों के साथ सूक्ष्म

पोषक तत्व (0.5%), और बेंज़ाइल एडेनिन (10 पीपीएम) का जून में और सितंबर में पत्तों पर छिड़काव करने से जायफल में प्रति पौधा अधिकतम कनोपी वृद्धि/पौधे, वंश उत्पादन और फल उपज दर्ज की गई।

- लौंग के एसनश्यल तेल के एक प्रमुख सुगंधित घटक यूजीनॉल का जायफल और मिर्च में एफ्लाटॉक्सिजेनिक *एस्परगिलस फ्लेवस* की वृद्धि और विकास को नियंत्रित करने में इसकी प्रभावकारिता के लिए परीक्षण किया गया था। डेटा से पता चला है कि बीजाणु अंकुरण और हाइपल वृद्धि और विकास के लिए यूजेनॉल की न्यूनतम निरोधात्मक एकाग्रता (MIC) क्रमशः 0.15 µl / ml और 0.4 µl / ml थी।

अखिल भारतीय समन्वित मसाला अनुसंधान परियोजना

- भाकृअनुप-अखिल भारतीय समन्वित मसालाअनुसंधान परियोजना (एआईसीआरपीएस) की XXXIIवीं वार्षिक समूह बैठक 22-24 सितंबर 2021 के दौरान भाकृअनुप-भारतीय मसाला फसल अनुसंधान संस्थान, कोषिक्कोड में वर्चुअल मोड में आयोजित की गई थी।
- वार्षिक कार्यशाला के दौरान विभिन्न एआईसीआरपीएस केंद्रों से मसाला उत्पादन प्रौद्योगिकियों पर दस पुस्तिकाएं/पैम्फलेट जारी किए गए।
- समूह बैठक के दौरान विभिन्न मसाला फसलों की छह नई किस्मों (मेथी- एचएम 273 और गुजरात मेथी-3, धनिया-छत्तीसगढ़ रायगढ़ धनिया 3, सौंफ- आरएफ 289, अजवाईन-लाम अजवायन 3 और हल्दी- छत्तीसगढ़ रायगढ़ हल्दी 3) को जारी करने की सिफारिश की गई थी।
- सुगंधित हल्दी (*कुरकुमा एरोमेटिका*) और काली हल्दी (*कुरकुमा कैसिया*), धनिया, जीरा, सौंफ और मेथी में विशिष्ट गुणयुक्त नए सीवीटी पर नए शोध परीक्षण और राइजोबैक्टीरिया को बढ़ावा देने वाले पौधों के विकास का मूल्यांकन, अदरक और हल्दी में फास्फोरस (पी) और ज़िंक घुलनशीलता क्षमता के लिए *बैसिलस सेफेंसिस* (Zn) शुरू की गई।

सामान्य

- संस्थान ने वर्ष के दौरान तीन पेटेंट प्राप्त किए जैसे, बायोकैप्सूल के माध्यम से पीजीपीआर/रोगाणुओं के भंडारण और वितरण की नई विधि, काली मिर्च के लिए सूक्ष्म पोषक तत्व संरचना और इसकी तैयारी के लिए एक प्रक्रिया और परिपक्व हरी मिर्च से उच्च गुणवत्ता वाली 'ऑफ-गंध मुक्त' सफेद मिर्च के उत्पादन के लिए जीवाणु किण्वन तकनीक आदि है।
- आईटीएमयू-बीपीडी इकाई ने ग्यारह प्रौद्योगिकियों का व्यावसायीकरण किया। प्रौद्योगिकी व्यावसायीकरण के माध्यम से राजस्व के रूप में 25.5 लाख रुपये की राशि अर्जित की गयी।
- दालचीनी में प्रौद्योगिकियों के हस्तांतरण और क्षमता निर्माण के माध्यम से हिमाचल प्रदेश में ग्रामीण विकास के लिए आईसीएआर-आईआईएसआर और सीएसआईआर-हिमालयी जैव संसाधन प्रौद्योगिकी संस्थान के बीच एक समझौता ज्ञापन निष्पादित किया गया।
- आईटीएमयू-बीपीडी इकाई ने स्टार्टअप उत्पादों की बिक्री और विपणन का समर्थन करने के लिए पेमेंट गेटवे के साथ एक ई-कॉमर्स प्लेटफॉर्म www.spiisry.com विकसित किया है।

- आईसीएआर-आईआईएसआर की मसाला प्रसंस्करण सुविधा का लाभ उठाकर मसाले आधारित खाद्य उत्पादों के विकास के लिए वर्ष 2021 के दौरान नौ स्टार्टअप/उद्यमियों को इनक्यूबेटी के रूप में नामांकित किया गया था।
- ओट्स के दूध में चीनी के अनुकूल ओट्स दूध में ओलियोरेसिन के रूप में मसालों को मिलाकर मसाला आधारित फ्लेवर्ड ओट्स मिल्क तैयार किया गया था। ओट्स के स्वाद वाले दूध को प्राप्त करने के लिए हल्दी (कुरकुमिन सामग्री 10%), अदरक (जिंजरोल सामग्री 14%) और दालचीनी पाउडर (60 मेश तक पाउडर) के मसाले ओलियोरेसिन का उपयोग किया गया था।
- गढ़वाले कुकीज़ में प्रत्येक मसाले का अनूठा स्वाद प्राप्त करने के लिए मसाले से भरपूर फिंगर मिलेट कुकीज को अलग-अलग मसालों को तीन अलग-अलग सांद्रता जैसे, इलायची (3, 4 और 5%), काली मिर्च (10, 12.5 और 15%), दालचीनी (3, 4 और 5%), जायफल (4, 5 और 6%), कड़ी पत्ता (5, 7 और 9%)), बर्ड्स आई चिल्ली (1, 2 और 3%), ताजा अदरक का पेस्ट (30, 35 और 40%) और मसाला मिश्रण (6, 8 और 10%) में मिलाकर तैयार किया गया था।
- मिट्टी के जीवाणु समुदाय संरचना और चयापचय कार्यों पर ZnO नैनोकणों (nZnO) के विभिन्न सांद्रता के प्रभावों की जांच एक तटस्थ मिट्टी में की गई। परिणामों ने संकेत दिया कि प्रोटोबैक्टीरिया, एसिडोबैक्टीरिया, प्लैक्टोमाइसेट्स, बैक्टीरियोएडेट्स, नाइट्रोस्पिरा और पेट्सिबैक्टीरिया के सापेक्ष बहुतायत (आरए) नियंत्रण की तुलना में ZnO उपचारों में अधिक थे।
- मिट्टी की स्थिरता सूचकांक को पोषक तत्व सूचकांक, सूक्ष्मजीव सूचकांक और फसल सूचकांक के साथ मापा गया और इलायची और हल्दी के लिए विभिन्न प्रबंधन प्रणालियों के तहत तुलना की गई।
- *एम. पिंगशाएंस* फंगस की तीन अलग-अलग खुराकों पर एक कीटनाशक नियंत्रण, क्लोरेंट्रानिलिप्रोल के साथ चेलवूर, कोषिक्कोड में 21 दिनों के अंतराल पर खेत की परिस्थितियों में छिड़काव करके हल्दी को संक्रमित करने वाले प्ररोह बेधक के खिलाफ परीक्षण किया गया था।
- काली मिर्च की उन्नत किस्मों की लगभग 1,00,000 जड़ लगाए कतरनें, 10,000 इलायची सकेर्स, , 4000 दालचीनी के बीजपौधे, जायफल के 2500 कलमों का उत्पादन करके किसानों को वितरित किया गया। अदरक की उन्नत किस्मों (200 बेड) और हल्दी (750 बेड) को बीज उत्पादन के लिए रोपण करके संरक्षण किया जाता है।
- अदरक का किसान सहभागी बीज उत्पादन (प्रजाति आई आई एस आर वरदा और आई आई एस आर महिमा) चार किसानोंके खेतों पर समझौता ज्ञापन पर हस्ताक्षर करके किया जा रहा है
- मट्टिलयम वाटरशेड, वेल्लामुंडा पंचायत, वायनाड जिला, केरल में काली मिर्च की लगभग 30,000 बेलों के साथ एक सन्निहित क्षेत्र की पहचान की गई है और उत्पादन प्रौद्योगिकियों का बड़े पैमाने पर प्रदर्शन किया गया है।
- केवीके ने इस अवधि के दौरान विभिन्न विषयों में 28 ऑन-कैंपस, 14 ऑफ-कैंपस और 18 ऑनलाइन मोड में क्षमता निर्माण प्रशिक्षण आयोजित किए, जिससे 2219 प्रतिभागियों को लाभ हुआ।
- भाकृअनुप-भारतीय मसाला अनुसंधान संस्थान, कोषिक्कोड द्वारा 48 प्रतिभागियों के लिए आर फॉर बायोलॉजिस्ट विषय पर 6-8 अक्तूबर, 2021 तक एक ऑनलाइन कार्यशाला का आयोजन किया गया।

- मसालों और बागान फसलों की उपज वृद्धि और निर्यात प्रतिस्पर्धात्मकता में प्रवृत्तियों के तुलनात्मक अध्ययन से पता चला कि अधिकांश फसलों में उपज लाभ वैश्विक औसत लाभ से अधिक था, इन फसल वस्तुओं में आरसीए द्वारा मापी गई सापेक्ष निर्यात प्रतिस्पर्धात्मकता सामान्य रूप से कम हो गई।
- दक्षिण भारत में लौंग उगाने वाले प्रमुख क्षेत्रों में प्राथमिक सर्वेक्षण किया गया। सह सर्वेक्षण तमिलनाडु में नागरकोइल और शेनकोट्टई और केरल में कोषिक्कोड, मलप्पुरम, अंबानाडु और पोनमुडी में लौंग के बागानों के बीच किया गया था।
- मसालों में आत्मनिर्भरता में महत्वपूर्ण अंतराल की पहचान करने हेतु आयात प्रोफ़ाइल विश्लेषण का उपयोग करने के लिए एक रूपरेखा को स्पष्ट किया गया था। आत्मनिर्भरता अंतराल की पहचान करने के लिए आत्मनिर्भरता के रणनीति विकास के ढांचे में पैरामीटर्स के संयोजन जैसे, फसल विविधता, घरेलू उत्पादन, आयात निर्भरता, आयात में सापेक्ष हिस्सेदारी, उत्पादन के सापेक्ष मूल्य, निर्यात से आयात का अनुपात, प्रासंगिक कृषि-पारिस्थितिकीय कारकों और वस्तुओं के निर्यात अभिविन्यास जैसे मानकों का एक समग्र उपयोग किया गया था। ।
- संस्थान ने विभिन्न हितधारक समूहों के लिए कुल 52 सामान्य प्रशिक्षण कार्यक्रम आयोजित किए। इसके अलावा अनुसूचित जाति और अनुसूचित जनजाति के लाभार्थियों के लिए 12 प्रशिक्षण कार्यक्रम आयोजित किए गए।
- वर्ष के दौरान कृषि प्रौद्योगिकी सूचना केंद्र से बिक्री से अर्जित कुल राजस्व 50 लाख थे। बिक्री के प्रमुख घटक सूक्ष्म पोषक तत्व (12 लाख रुपये), जैव कैप्सूल (18.4 लाख रुपये) और रोपण सामग्री (8.3 लाख रुपये) थे।
- दिनांक 20-21 मई, 2021 के दौरान अदरक और हल्दी में अच्छी कृषि पद्धतियों और प्रौद्योगिकी प्रगति पर दो दिवसीय प्रशिक्षक प्रशिक्षण कार्यक्रम आयोजित किया। प्रशिक्षण कार्यक्रम ने देश के सात राज्यों में फैले 75 स्थानों से विभिन्न एफपीओ से जुड़े 130 क्षेत्रीय अधिकारियों और प्रशिक्षकों को लाभान्वित किया।

राष्ट्रीय महत्व के कार्यक्रम

- संस्थान के सभी परिसरों में 75वां स्वतंत्रता दिवस मनाया गया
- आईसीएआर-आईआईएसआर मुख्यालय, कोषिक्कोड, क्षेत्रीय स्टेशन, अप्पंगला और प्रायोगिक प्रक्षेत्र, पेरूवण्णामुषि में 26 अक्तूबर 2021 से 1 नवंबर 2021 तक सतर्कता जागरूकता सप्ताह मनाया गया। इस अवसर पर संस्थान के समस्त स्टाफ एवं शोधार्थियों ने ई-प्रतिज्ञा ली। सार्वजनिक जीवन में अखंडता, पारदर्शिता और जवाबदेही को बढ़ावा देने के लिए और भ्रष्टाचार के हानिकारक प्रभावों और गंभीरता के बारे में जागरूकता लाने के लिए और इस वर्ष की थीम "स्वतंत्र भारत @ 75: आत्मनिर्भर भारत" पर आधारित आत्मनिर्भर भारत की आवश्यकता के लिए सत्यनिष्ठा से विभिन्न कार्यक्रम आयोजित किए गए थे। ।
- संस्थान के सभी परिसरों में स्वच्छता अभियान सक्रिय रूप से चलाया गया। 'अपशिष्ट से धन' पर ध्यान केंद्रित करते हुए कई विशेष कार्यक्रम आयोजित किए गए। परिसरों के भीतर और बाहर दोनों जगह नियमित स्वच्छता और सफाई अभियान आयोजित किए गए।

- भाकृअनुप-भारतीय मसाला फसल अनुसंधान संस्थान (आईआईएसआर) ने 27 फरवरी 2021 को कॉलेज के छात्रों द्वारा मॉडल और आविष्कारों के आभासी प्रदर्शन के साथ राष्ट्रीय विज्ञान दिवस मनाया। राष्ट्रीय विज्ञान दिवस पर "रिविजिटिंग रामन" पर एक मुख्य व्याख्यान भी कार्यक्रम के हिस्से के रूप में आयोजित किया गया था।

EXECUTIVE SUMMARY

BLACK PEPPER

- Three thousand four hundred and sixty six accessions are maintained at the black pepper Germplasm nursery at the experimental farm, Peruvannamuzhi, Kerala.
- A total of 31 collections were made and a set of collections was planted at Regional Station, Appangala.
- Eighteen black pepper genotypes were characterized for traits linked to white pepper production. The studies indicate that 'Agali' and 'IISR-Girimunda' are best genotypes suitable for white pepper production in terms of seed size, pericarp to seed ratio and other quality traits.
- A promising genotype (local type) was identified from a farmer's field (Mithun, Shanivarsanthe). The genotype has bold berries with medium spike length and high dry recovery.
- Fertigation schedules for three black pepper varieties IISR Thevam, IISR Girimunda and IISR Shakthi were standardized. Maximum yield was recorded in the fertigation treatment with 50% NPK in 24 splits (3.1 kg/plant)
- The GC-MS analysis of essential oil of 40 genotypes identified 62 volatile compounds which showed significant variations among the genotypes. K-means clustering of volatile compounds using Metaboanalyst 5.0 and a dendrogram produced four clusters of the genotypes based on their volatile profile.
- Whole genome sequencing of *Phytophthora capsici* (05-06) and *P. tropicalis* (98-93) was carried out in PacBio and Illumina platforms and Hybird assembly and KEGG pathway analysis were carried out for the identified genes.
- Studies using next-generation sequencing of total DNA isolated from *piper yellow mottle virus* (PYMoV) infected black pepper identified two contigs with length 7178 bp and 892 bp that showed homology to tungrovirus and badnaviruses. These contigs were named as Piper DNA virus 1 (PDV-1) (GenBank accession no JX406741) and PDV-2 (GenBank accession no JX406742).
- A simple method for detection of PYMoV, PDV-1 and PDV-2 through PCR and RPA was developed using crude sap from infected plant. The study revealed that viruses infecting black pepper can be detected within 5 minutes using simple crude extract of the plant.
- Screening of low-risk insecticides for root mealybug *(*Planococcus *sp.):* Among the seven low-risk molecules tested, flonicamid was very effective at lower dose (0.3g/l) and on par with chlorpyriphos (2ml/l). Other low risk insecticides like buprofezin (3ml/l) and diafenthiuron (1g/l) were also found effective and at par to each other.
- Defense related biochemical parameters *viz.*, total phenols, orthodihydroxy (OD) phenols, lignin and peroxidase were studied to find out the possible correlation with disease resistance traits of mycorrhizae.
- The gapped regions in chromosome PN1 and PN13 were identified comparing with the reference genome of black pepper. In house scripts were developed to identify the sequence of the missing regions.

- Published protein-protein interactions between Phytophthora and its hosts were utilized for developing a model for interaction prediction. Supervised learning algorithms-Support vector machine (SVM) and novel combination of ensemble methods were applied to predict interactions.
- The Carbon Equivalence **(**CE) from the shade trees commonly used as black pepper standards (*Glyricidia, Ailanthus, Garuga*) was worked out based on the FAO norms and existing standard procedures. Among the trees, *Ailanthus* spp. showed the highest C sequestration potential with 2.98 kg C per year (equivalent to 10.94 kg CO_2 sequestration per year) followed by *Glyricidia* spp. with a potential of 1.9 kg C per year (6.99 kg CO_2 sequestration per year).

CARDAMOM

- 622 cardamom accessions consisting of 423 accessions from Appangala station, 102 accessions from Pampadumpara, 41 accessions from Mudigere station and 56 accessions from Sakaleshapura are maintained under National Active Germplasm Site (NAGS) at ICAR-IISR, Regional Station, Appangala.
- Characterization of 85 field gene bank (FGB) accessions was carried out based on different morphological traits.
- In the CVT trial consisting of nine hybrids, highest dry yield of capsules per plant was recorded in hybrid PH-13 (841.67 g/plant) followed by hybrid Bold × IC 547219 (361.33 g/plant).
- A *Colletotrichum gloeosporioides* isolate from cardamom showed the presence of dsRNA indicating association of a mycovirus. This is the first report of a mycovirus infecting *C. gloeosporioides* from India.
- The biocontrol potential of a recently isolated entomopathogenic fungus, *Lecanicillium psalliotae* (Treschew) Zare & W. Gams (Ascomycota: Hypocreales) was evaluated under field conditions for two years in two major cardamom growing states, Kerala and Karnataka. The results indicated that four rounds of soil application of the fungus granules reduced capsule damage by thrips up to 79% compared to control.
- The sustainability index of the soil was measured with nutrient index, microbial index and crop index and were compared under different management systems for cardamom. The overall sustainability index was the highest under INM system followed by conventional and organic systems.
- An IPM package integrating the entomopathogen (*L. psalliotae*), and a reduced-risk insecticide (spinosad) and their combinations along with the existing chemical and cultural (phytosanitation) methods as components was field tested for cardamom thrips management. This is the first IPM schedule developed against this major pest of cardamom with biological control as a component.

GINGER

- Six hundred and sixty eight ginger accessions have been maintained in the field gene bank. A new conservatory of ginger is established at ICAR-IISR, Experimental farm.

- Nine ginger entries (five promising mutants from ICAR-IISR, four from OUAT and one from IGKV) along with check, IISR Varada were evaluated for yield during 2020-2021.
- The unigenes obtained from ginger transcriptome (PRJNA311170) were pre-processed and functionally annotated using BLAST2GO module of OmicsBox. 18222 unigenes were mapped to GO database.
- Twelve flanking polymorphic EST-SSR primers were validated using 48 ginger genotypes representing North-Eastern India and different eco-geographical adaptations by PCR amplification and allele sizing through capillary electrophoresis. UPGMA cluster analysis revealed that the 12 markers divided the 48 genotypes into three main groups.
- Comparative study on expression of marker genes in susceptible and resistant ginger spp. Identified several genes with a statistically different ($p < 0.05$) fold change among susceptible and resistant ginger spp. at all-time intervals.
- An efficient direct in vitro plant regeneration protocol has been established for two genotypes of red ginger, namely, Northeast red ginger and exotic red ginger, by using the rhizome buds as explants. Genetic stability among the regenerated plantlets was confirmed using ISSR and SSR molecular markers.
- In treatments involving fully organic and mixture of different organic sources, organic 100% recorded maximum nitrogen, phosphorus, potassium, calcium, magnesium, and zinc in soils sampled 120 days after planting (DAP).
- A method for analysis of liquid choromatography amenable pesticides in ginger rhizomes has been developed. A QuEChERS technique–based sample preparation method was optimized to monitor the residues of 29 pesticides by LC with tandem MS.
- A field trial was conducted to evaluate the efficacy of calcium chloride and bioinoculants to manage soft rot/wilt diseases of ginger under non-solarized field conditions. The highest plant survival and lowest disease incidence (rot/wilt) were recorded with calcium chloride (21.5%) followed by Bacillich (powder formulation) (23.7%) and *Methylobacterium komagatae* (24%).
- To detect the genes responsible for quorum sensing in ginger bacterial wilt pathogen, primers were designed targeting the genes of *R. pseudosolanacearum*, viz., *SolI* and *phcB*

TURMERIC

- One thousand four hundred and four *Curcuma* accessions have been maintained in the field gene bank.
- Eight turmeric varieties were evaluated for essential oil, oleoresin, curcuminoids, volatile constituents, proximate and micronutrient composition and their antioxidant and antidiabetic potential. Curcumin, BDMC and DMC showed positive correlation with antioxidant and antidiabetic potential.
- The phytochemical constituents, nutraceuticals, and bioactivities of four GI turmeric (Erode Turmeric, Kandhamal Haldi, Waigaon Turmeric and Sangli Turmeric) in India were characterized. The results revealed considerable differences in major quality parameters viz., essential oil (4.00-5.60%), oleoresin (8.36-18.12%) and curcuminoids (2.23-5.50%).

- Out of the 57 microsatellite markers tested in 18 released varieties of turmeric, 56 were polymorphic. The average number of alleles per genotype per marker ranged from 1 to 3.44, with most markers showing two alleles in accordance with the reported triploid status of turmeric.
- One ninety two turmeric genotypes were screened under natural epiphytotic conditions to identify resistant sources against leaf blotch caused by *Taphrina maculans*.
- For weed management under organic cultivation of turmeric, application of dried coconut leaf at the time of planting, hand weeding at 45 and 90 DAP recorded maximum yield and net returns (2 lakhs/ha).
- An integrated organic farming system model with spice crops was established. A profit of Rs. 2.1 lakhs was obtained from one acre.
- A novel spice mix formulation for turmeric milk preparation was developed by overcoming the problem of insolubility with enhanced bio-available active ingredients. The key ingredients of the spice mix are turmeric, ginger and cinnamon.
- Evaluation of *B. safensis* (IISR TB4) and B. cereus (IISR GB7 (3)) for plant growth promotion and P solubilization under greenhouse conditions showed significant increase in yield with 75% recommended P compared to the individual application of IISR TB4, IISR GB7(3) and 75% P.
- *M. pingshaense* fungus was tested at three different doses along with an insecticide control, chlorantraniliprole at Chelavoor, Kozhikode against shoot borer infesting turmeric. Results indicated that spraying of the fungus at a dose of 1 × 107 conidia/ml was effective in managing the pest.
- Fluopyram and fluensulfone, newly registered nematicides, were evaluated in turmeric fields for management of lesion nematode, *Pratylenchus* spp. Among the treatments, application of fluopyram (@0.75 ml/l) was superior in reducing the nematode population both in rhizomes and soil.

VANILLA

- Comparative anatomical analysis of different vanilla species was carried out. Interspecific hybridization was made between *Vanilla planifolia* and *V. aphylla*.
- Reciprocal crosses were conducted between *V. planifolia* and *V. tahitensis* (species reported as resistant to root rot disease) and high percent of fruit set was observed in both the crosses.
- A virus causing mild chlorotic mottle and streaks on leaves of vanilla was identified as a strain of Cymbidium mosaic virus (CymMV) based on coat protein gene sequence comparison and phylogenetic studies.

TREE SPICES

- *Cinnamomum perrottetii*, *C. wightii*, *C. sulphuratum* and two unidentified species were collected from reserve forests at Iravikulam, Pettimudi, Rajamala, Mannavan Shola and Anakkulam in Idukki district of Kerala.
- Surveys were conducted in major clove growing tracts of India during the year and 15 accessions of clove comprising of unique variants and high yielding accessions were

collected. The collection included 6 clove accessions with bold flower buds (King clove), two dwarf types, one semi dwarf type, one small flowered type and five high yielding accessions.

- *G. conicarpa*, *G. pushpangadaniana*, *G. talbotii*, three endemic species of Garcinia in Western Ghats and a bold fruited accession of *G. gummi-gutta* were collected from the reserve forests in Idukki district.
- Pooled analysis of data revealed that application of coir pith compost (5 kg/plant) during May, soil application of recommended nutrients during June and September along with foliar spray of micronutrient mixture (0.5%), and benzyl adenine (10 ppm) during June and September recorded maximum canopy growth, scion production and fruit yield per plant in nutmeg.
- Eugenol, a major aromatic constituent of clove essential oil was tested for its efficacy in controlling growth and development of aflatoxigenic *Aspergillus flavus* in nutmeg and chilli. The data showed that the minimum inhibitory concentration (MIC) of eugenol for spore germination and hyphal growth and development was 0.15 µl/ml and 0.4 µl/ml respectively.

AICRPS

- The XXXII Annual Group Meeting of ICAR-All India Coordinated Research Project on Spices (AICRPS) was held during 22-24 September 2021 at ICAR-Indian Institute of Spices Research, Kozhikode in virtual mode.
- Ten booklets/pamphlets on spices production technologies from different AICRPS centres were released during the annual workshop.
- Six new varieties of different spice crops were recommended for release during the Group Meeting (Fenugreek- HM 273 and Gujrat Methi-3, Coriander-Chhattisgarh Raigarh Dhaniya 3, Fennel- RF 289, Ajwain- Lam Ajwain 3 and Turmeric- Chhattisgarh Raigarh Haldi 3).
- New research trial on aromatic turmeric (*Curcuma aromatica*) and black turmeric (*Curcuma caesia*), trait-specific new CVTs in coriander, cumin, fennel and fenugreek and evaluation of plant growth promoting rhizobacteria, *Bacillus safensis* for phosphorus (P) and zinc (Zn) solubilization potential in ginger and turmeric were initiated.

GENERAL

- The institute received three patents during the year viz. Novel method of storing and delivering PGPR/microbes through biocapsule, Micronutrient composition for black pepper and a process for its preparation and Bacterial fermentation technology for production of high quality ‘off-odour-free’ white pepper from matured green pepper.
- ITMU-BPD unit commercialized eleven technologies. An amount of Rs. 25.5 lakhs was earned as revenue through technology commercialization.
- An MoU was executed between ICAR-IISR and CSIR-Institute of Himalayan Bioresource Technology for Rural Development in Himachal Pradesh through transfer of technologies and capacity building in cinnamon.

- ITMU-BPD unit has developed an e-commerce platform www.spiisry.com with payment gateway for supporting sales and marketing of startups products.
- Nine startups/ entrepreneurs were enrolled as incubatees during the year 2021 for development of spice based food products by availing spice processing facility of ICAR-IISR.
- Spice based flavoured oats milk was prepared by addition of spices in the form of oleoresin to the oats milk optimised with sugar. The spice oleoresins of turmeric (curcumin content 10%), ginger (gingerol content 14%) and cinnamon powder (powdered to 60 mesh) were used to obtain the flavoured oats milk.
- Spice enriched finger millet cookies were prepared by adding different spices in three different concentrations ***viz.*** cardamom (3, 4 and 5%), black pepper (10, 12.5 and 15%), cinnamon (3, 4 and 5%), nutmeg (4, 5 and 6%), curry leaves (5, 7 and 9%), bird's eye chilli (1, 2 and 3%), fresh ginger paste (30, 35 and 40%) and spice blend (6, 8 and 10%) to get unique flavour of each spice in the fortified cookies.
- Effects of different concentrations of ZnO nanoparticles (nZnO) on soil bacterial community structure and metabolic functions were investigated in a near neutral soil. The results indicated that the relative abundance (RA) of Proteobacteria, Acidobacteria, Planctomycetes, Bacterioidetes, Nitrospirae and Patescibacteria were higher in ZnO treatments than control.
- The sustainability index of the soil was measured with nutrient index, microbial index and crop index and were compared under different management systems for cardamom and turmeric
- *M. pingshaense* fungus was tested at three different doses along with an insecticide control, chlorantraniliprole at Chelavoor, Kozhikode at a spray interval of 21 days under field conditions against shoot borer infesting turmeric.
- About 1,00,000 rooted cuttings of improved varieties of black pepper, 10,000 cardamom suckers, 4000 cinnamon seedlings, 2500 grafts of nutmeg were produced and distributed to farmers. Improved varieties of ginger (200 beds) and turmeric (750 beds) are planted and maintained for seed production.
- Farmers participatory seed production of ginger (var. IISR Varada and IISR Mahima) is being taken up by signing an MOU at four farmer's plots
- A contiguous area subsumed in Mattilayam watershed, Vellamunda panchayat, Wayanad district, Kerala with approximately 30,000 black pepper vines has been identified and the large-scale demonstration of production technologies.
- KVK conducted 28 on-campus, 14 off-campus and 18 online mode capacity building trainings during the period in different disciplines, benefitting 2219 participants.
- An Online workshop on R for Biologists was organized by ICAR- Indian Institute of Spices Research, Kozhikode from 6-8 October, 2021 for 48 participants.
- Comparative study of the trends in yield growth and export competitiveness of spices and plantation crops revealed that while the yield gains in absolute terms in most of the crops were above the global average gains, the relative export competitiveness as measured by RCA declined in general for these crop commodities.

- A primary survey was undertaken in major clove growing niche regions in South India. The survey was conducted in Nagerkoil and Shenkottai in Tamil Nadu and Kozhikode, Malappuram, Ambanadu and Ponmudi in Kerala among clove plantations.
- A framework for using the import profile analysis to identify critical gaps in self-sufficiency was elucidated in spices. The framework for strategy development for self-sufficiency used a composite of parameters like crop diversity, domestic output, import dependence, relative share in imports, relative value of output, ratio of imports to exports, relevant agro-ecological factors and export orientation of commodities to identify the self sufficiency gaps.
- The institute conducted a total of 52 general training programmes for various stakeholder groups. Apart from this 12 training programmes were conducted for SC and ST beneficiaries.
- The total sales revenue from Agricultural Technology Information Centre during the year was 50 lakhs. The major components of sale were micronutrients (Rs. 12 lakhs), bio-capsules (Rs. 18.4 lakhs) and planting material (Rs. 8.3 lakhs).
- A two-day trainers training programme on Good Agricultural Practices and technology advances in ginger and turmeric during 20-21 May, 2021. The training programme benefitted 130 field executives and trainers associated with various FPOs from 75 locations in the country spread across seven states in the country.

PROGRAMMES OF NATIONAL IMPORTANCE

- The 75th Independence Day was celebrated at all the campuses of the institute
- Vigilance Awareness Week was observed from 26 October 2021 to 1 November 2021 in ICAR-IISR Headquarters, Kozhikode, Regional Station, Appangala and Experimental Farm, Peruvannamuzhi. All staff and research scholars of the Institute took E-pledge on the occasion. Various programmes were organized to promote integrity, transparency and accountability in public life and also to bring awareness on the harmful effects and gravity of corruption and the need for having a self-reliant India based on this year's theme "Independent India @75: Self Reliance with Integrity.
- Swachhta campaign was actively undertaken across all the campuses of the Institute. Several special programmes with a focus on 'Wealth from waste" was conducted. Routine sanitization and cleaning drives, both within and outside the campuses were organized.
- ICAR-Indian Institute of Spices Research (IISR), observed National Science Day on 27 February 2021 with the virtual demonstration of models and inventions by college students. A keynote lecture on "Revisiting Raman" on National Science Day was also held as part of the event.

INTRODUCTION

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INTRODUCTION

History

The origins of organized research on spice crops in the country can be traced back to the setting up of Spices Enquiry committee in 1953. A strong institutional foundation for spices research was made with the establishment of a Regional Station of Central Plantation Crops Research Institute (CPCRI) at Kozhikode, Kerala, during 1975, by the Indian Council of Agricultural Research (ICAR). This Regional Station was merged with the Cardamom Research Centre of CPCRI at Appangala, Madikeri, Karnataka and upgraded as National Research Centre for Spices (NRCS) in 1986. The NRCS was further elevated to the present Indian Institute of Spices Research (IISR) during 1995.

Location

The laboratories and administrative offices of the institute are located at Chelavoor (50 m above MSL), 11 km from Kozhikode (Calicut), Kozhikode District, Kerala, on the Kozhikode - Kollegal road (NH 766), in an area of 14.3 ha. The research farm is located 51 km North East of Kozhikode at Peruvannamuzhi (60 m above MSL), on the Peruvannamuzhi-Poozhithode road in Kozhikode District, in an area of 94.08 ha. The Regional Station (920 m above MSL) is located at Appangala, Kodagu District, Karnataka, on the Madikeri-Bhagamandala road, 8 km from Madikeri, in an area of 17.4 ha.

Mandate

- Basic, applied and strategic research on genetic resource management, crop improvement, crop production and protection technologies for enhanced production of safe spices.
- Transfer of technology, capacity building and impact assessment of technologies.
- Coordinate research and validation of technologies under AICRP on Spices.

The spice crops on which research is being conducted at the institute include black pepper (*Piper nigrum* Linn.), small cardamom (*Elettaria cardamomum* Maton), ginger (*Zingiber officinale* Rosc.), turmeric (*Curcuma longa* Linn.), cinnamon (*Cinnamomum verum* J. Presl.), cassia (*Cinnamomum cassia* Nees ex Blume), clove (*Syzygium aromaticum* (L.) Merrill & Perry), nutmeg (*Myristica fragrans* Houtt.), allspice (*Pimenta dioica* (L.) Merrill & Perry), Garcinia (*Garcinia gummi-gutta* (L.) N. Robson and *G. indica* Choisy) and vanilla (*Vanilla planifolia* Jacks. ex Andrews).

Organization

The Director is the administrative head of the institute. The Institute Management Committee, Research Advisory Committee and Institute Research Council assist the Director in matters relating to management and research activities of the institute. Research on various aspects of the mandate crops is conducted in three divisions, namely, Division of Crop Improvement and Biotechnology, Division of Crop Production and Post Harvest Technology and Division of Crop Protection. Apart from this, the institute has a separate Social Sciences section. The other facilities available at the institute include Agricultural Technology Information Centre, Agricultural Knowledge Management Unit, Bioinformatics Centre. The

Krishi Vigyan Kendra for Kozhikode is also under the administrative control of the institute. The institute also functions as the headquarters for the All India Coordinated Research Project on Spices (AICRPS) with a network of 38 centers located across the country. The institute has also linkages with several universities, research institutes, and developmental agencies for collaborative research and developmental activities in spices.

Budget

The total budget of the institute was Rs.2195.19 lakhs during the year. The institute earned total revenue of Rs.114.21 lakhs through sale of planting materials, biocontrol agents, trainings, publications and consultancy services *etc*.

Staff

The institute has a sanctioned strength of 48 scientific, 35 technical, 31 administrative and 31 supporting staff, of which 37, 25, 10 and 6 of scientific, administrative, technical and supporting staff, respectively are in position. The KVK has a sanctioned strength of 1 scientific, 11 technical, 2 administrative and 2 supporting staff.

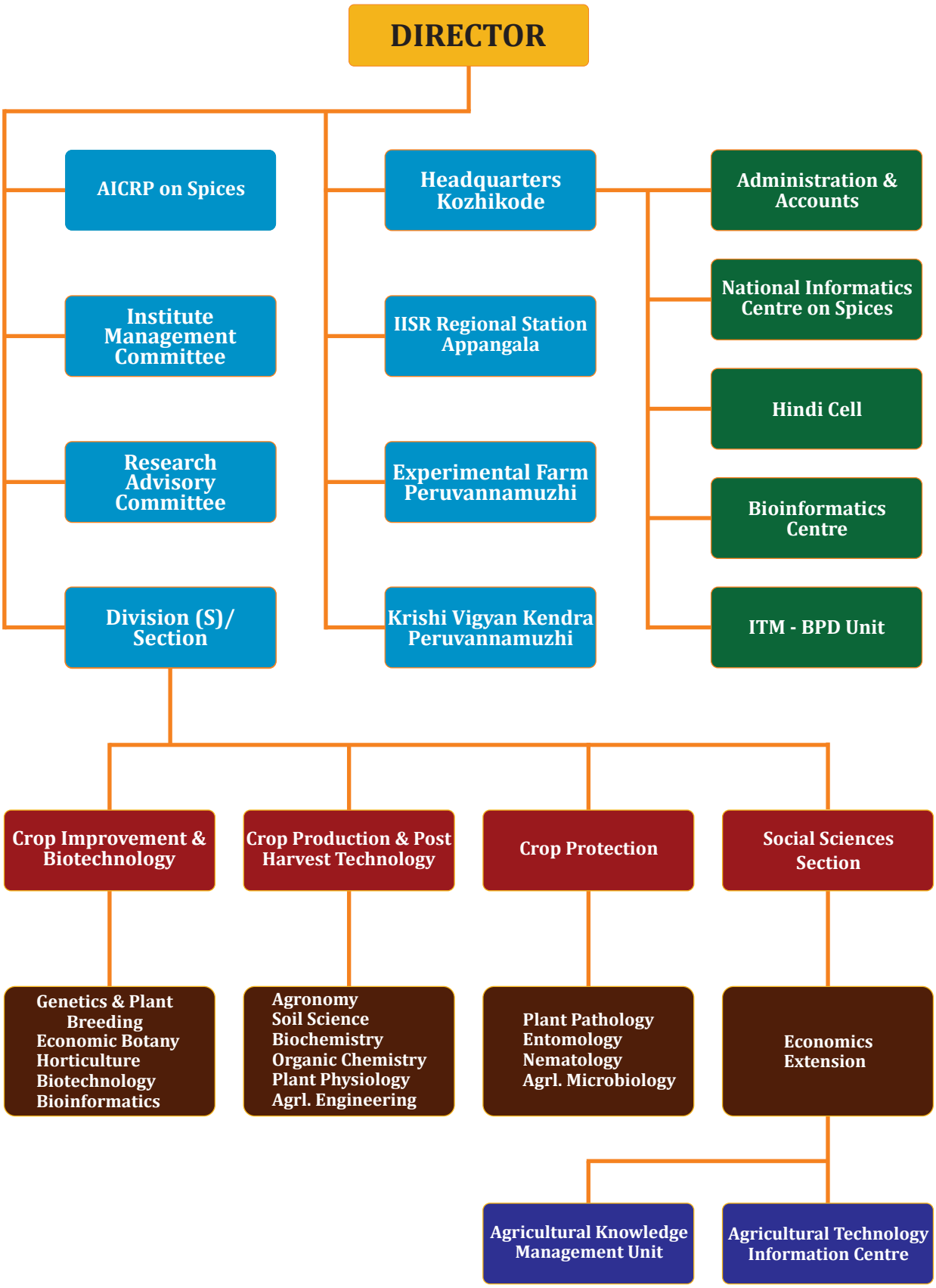
Staff position of the Institute as on 01 Januray 2022

Category	***Sanctioned***	***Position***			***Total***	***Vacant***
		Kozhikode	***Peruvannamuzhi***	***Appangala***		
Scientific	47+1	29	2	6	37	10+1
Technical	35	15	6	4	25	10
Administrative	31	9	-	1	10	21
Supporting	31	2	2	2	6	25
Total	145	55	10	13	78	67

Staff position of KVK, Peruvannamuzhi as on 01 January 2022

Category	***Sanctioned***	***Position***	***Total***	***Vacant***
Scientific	1	1	1	-
Technical	11	8	8	3
Administrative	2	1	1	1
Supporting	2	1	1	1
Total	16	11	11	5

ORGANIZATIONAL CHART



PAST ACHIEVEMENTS

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Black pepper

About 3467 germplasm accessions are presently being maintained at ICAR-IISR, Chelavoor; Experimental Farm, Peruvannamuzhi as well as in alternate sites (Appangala and Chettalli of Karnataka). So far, the Institute has released nine improved varieties such as Sreekara, Subhakara, Panchami, Pournami, PLD-2, IISR Thevam, IISR Girimunda, IISR Malabar Excel and IISR Shakthi. Three unique accessions, INGR 8099-*Piper thomsonii* (IC 398863) - for its character for sex change and INGR 8100 - *P. nigrum* (IC 563950) - a novel spike variant with proliferating spikes, and IC-0619910, known for its spike length were registered with NBPGR, New Delhi.

Microsatellites developed in the past for *Piper* species were successfully used to detect polymorphism in black pepper cultivars. Additionally, six polymorphic ISSR primers for fingerprinting varieties of black pepper were also identified. Assembly and functional annotation of sequences derived from the transcriptome of *P. colubrinum* and *P. nigrum* helped in the identification of many genes involved in defense and secondary metabolism. Seedlings of *P. colubrinum* on screening for *Phytophthora capsici* showed segregation of the resistance character. Putative transgenic black pepper plants with osmotin gene conferring resistance to drought and *P. capsici* have been developed. *In vitro* and *in vivo* propagation methods were standardized. Eighteen black pepper genotypes consisting of varieties/hybrids and land races/farmers selection characterized based on traits like spike length, number of mature berries/spikes, dry seed weight, fresh seed weight and berry weight showed high positive correlation with spike weight. Grouping of genotypes based on Scott-Knott test revealed Panniyur-1 and Nedumchola as contrasting genotypes for maximum number of traits.

The adoption of site-specific soil fertility management helped in increasing the productivity of black pepper besides enhancing soil quality. Soils from all Panchayats of Kerala state have been analyzed for their physico-chemical properties and nutrient advisory cards have been generated and distributed to farmers. Mathematical models for optimum climatic factors for high production of black pepper have been developed. Antitranspirants such as Kaolin 2.0%, Kaolin 2.0% + 0.5 % MOP, lime 1.5% and lime 1.5% + 0.5% MOP were tested for imparting drought tolerance in black pepper. Spraying lime 1.5% showed higher photosynthetic rate with lower leaf temperature.

Targeted yield equations for predicting nutrient requirements for fixed yield targets in soils with varying fertility levels were standardized with minimum deviations in black pepper. Irrigating pepper vines once in a fortnight from March to May months at the rate of 50 L vine^{-1} enhanced yield substantially. Drip fertigation schedules for three black pepper varieties, IISR Thevam, Girimunda and Shakthi have been standardized. Quality analysis of black pepper genotypes indicated that the total alkaloid content (mg g^{-1}) ranged from 16.7 (Panniyur 4) to 35.7 (Subhakara). Oleoresin was negatively correlated with bulk density (r= –0.49) but positively correlated with essential oil content (r=0.44) and piperine content (r= 0.71). Organic production technology and GAP for black pepper have been developed and standardized. Cost effective method for production of disease-free rooted cuttings was developed. Novel soil pH based micronutrient mixture for enhancing growth, yield and quality of black pepper has been developed and licensed. Drip fertigation schedules for three

varieties, IISR Thevam, IISR Girimunda and IISR Shakthi were standardized for yield and quality. Package for enhancing sustainability of black pepper in coconut based cropping system through site specific nutrient management was also standardized.

Major pests, pathogens, viruses and their insect vectors and nematodes affecting pepper were characterized and documented. Morphological and molecular characterization of black pepper isolates of *Phytophthora* further revealed that isolates shared the characters of both *P. capsici* and *P. tropicalis*. A RNA virus, *Cucumber mosaic virus* (CMV) and a DNA virus, *Piper yellow mottle virus* (PYMoV) were found to be associated with stunted disease of black pepper. A method for simultaneous isolation of RNA and DNA from infected black pepper plants and multiplex PCR for simultaneous detection of CMV and PYMoV in a single reaction was standardized. SYBR green based real-time PCR was developed for detection of PYMoV and CMV in black pepper. Integrated strategies involving cultural methods, biocontrol agents, plant products and resistant varieties were developed for the management of pests and diseases including nematodes. A novel molecular assay based on recombinase polymerase amplification (RPA) was developed for the detection of *P. capsici* and *P. tropicalis* infecting black pepper.

Species-specific primers were developed for detection of *R. similis* in soil and plant samples. Black pepper accessions, HP-39 and Acc. 1090 were found to be resistant to nematodes besides being rich in caryophyllene. Basal application of *Trichoderma harzianum* and aerial spray with 1% Bordeaux mixture were found effective in controlling anthracnose disease.

Finger printing data was generated for biocontrol agents, *Trichoderma asperellum* (NAIMCC-SF-0049) and *Pochonia chlamydosporia* (NAIMCC-SF-0048) and these organisms were deposited in NAIMCC, NBAIM, Mau under safe deposit. Large scale multiplication of biocontrol agents such as *T. asperellum, P. chlamydosporia* and PGPR was also undertaken for distribution to farmers. A PGPR consortium (*Micrococcus luteus* + *Enterobacter aerogenes* + *Micrococcus* sp) for enhanced growth promotion and disease management in black pepper has been developed and licensed for large scale production. A novel method for targeted delivery of beneficial microorganisms by encapsulation (biocapsules) was developed and licensed to two companies for mass production.

An integrated pest management schedule for management of root mealy bug has been developed. Metalaxyl-MZ sensitivity of 81 *Phytophthora* isolates was tested and the EC_{50} and EC_{90} values ranged from 0.0002 to 14.4 ppm and 1.1 to 68.5 ppm, respectively. PCR based techniques were developed for identification of traded black pepper and to detect adulterants in commercial black pepper powder. The existence of fungicide sensitive or resistant isolates among the field populations of *Colletotrichum gloeosporioides* infecting black pepper tolerant to recommended doses of Bordeaux mixture and carbendazim were documented. Post-harvest technologies for drying, processing, storage and production of value-added products like white pepper were standardized.

Genetic diversity of *Phytophthora* isolates from black pepper was studied by SSR profiling and ITS sequencing with the universal primers ITS 6 and ITS 4. A native isolate of *P. capsici* (Is. No. 98-93) infecting black pepper was completely sequenced using next generation sequencing platform. A new database, *Phytophthora* Genome Database (http://220.227.138.212/genomedb/) based on *Phytophthora* whole genome sequencing and annotation was developed. PhytoWeb, a comprehensive portal on *Phytophthora* diseases of horticultural crops in India was developed. Phytolib, an electronic database of research

publications on phytophthora and database on *Radopholus* genus RADOBASE were developed and launched. A multiplex PCR assay has been developed for simultaneous detection of *Phytophthora*, *Pythium* and *Fusarium*.

Climate analogues sites were identified for cultivation of pepper in newer areas to reduce climate change effects on production. Impact studies on adoption of IISR varieties of black pepper in farmers' fields indicated that the mean yield for high yielding varieties was 1160 kg ha^{-1} with the adoption of scientific packages as compared to 620 kg ha^{-1} for traditional varieties. The estimated cost benefit ratio was 2.48. The level of adoption studies of recommended technologies indicated that the adoption level for aerial spraying of Bordeaux mixture for the control of fungal diseases was 57.14% and for application of biocontrol agents was 64.2%. The adoption level for application of soil fungicides, fertilisers and pesticides were very low at 21.14%, 7.7% and 7.6 % respectively. A video on "Augmenting Black Pepper Production – A Success Story" (Malayalam, English, and Hindi) was produced.

A facility for DNA fingerprinting and barcoding was established for undertaking fingerprinting services to facilitate varietal release from AICRPS centres. So far, 25 varieties of spices have been fingerprinted and their uniqueness was established for the new varieties in comparison with its closely related/resembling varieties.

Cardamom

Germplasm collections are being maintained at the National Active Germplasm Site at IISR Regional Station, Appangala, Karnataka and IC numbers have been obtained for all the available 622 accessions. Four germplasm accessions with unique characters have been registered with NBPGR, New Delhi. Improved varieties such as Appangala-1, IISR Vijetha, IISR Avinash and Appangala-2 (hybrid) have been developed, which has immensely contributed in increasing the productivity of cardamom.

Molecular profiles were developed for 100 accessions of small cardamom germplasm using 25 ISSR markers for studying the genetic diversity. Molecular profiling of Indian cardamom revealed the existence of two genetically distinct clusters such as "Kerala cluster" and "Karnataka cluster' among the germplasm collections. Characterization of export grade cardamoms from India, Sri Lanka and Guatemala based on physical, biochemical parameters and molecular techniques revealed the superiority of Indian produce. GC-MS study confirmed superiority of Indian cardamom over Guatemalan and Sri Lankan cardamom. High production technology has been standardized. Drip irrigation and sprinkler irrigation once in 12 days significantly improved yield attributing characters. Soil and water conservation measures have been standardized in cardamom based cropping system. Organic packages and GAP have been developed and standardized. Cardamom accessions APG 257, APG 414 and APG 434 were found to be promising for drought tolerance. Targeted yield equations for predicting nutrient requirements for fixed yield targets in soils with varying fertility levels were standardized with minimum deviations.

A small cardamom-mosaic virus interactive transcriptome database (SCMVTDb) was developed in collaboration with ICAR-IASRI. A protocol for SYBR green based real-time RT-PCR for detection of *Cardamom mosaic virus* (CdMV) and *Banana bract mosaic virus* (BBrMV) in cardamom was developed. Surveys conducted in Karnataka and Kerala, revealed the prevalence of *Banana bract mosaic virus* (BBrMV) infection. A reliable RT-PCR based method was also developed for detection of the virus in plants. Based on molecular studies,

the *cardamom vein clearing virus* (CdVCV) was found to be a new virus species in the genus, *Nucleorhabdovirus*. Two isothermal molecular assays *viz*., reverse transcriptase loop-mediated isothermal amplification (RT-LAMP) and reverse transcriptase recombinase amplification (RT-RPA) were developed to detect the CdVCV.

The survival of *C. gloeosporioides* infecting cardamom in infected plant part (leaves) was studied under laboratory, greenhouse and field conditions. A new bacterial wilt disease on small cardamom was noticed in Wayanad, Kerala. The causative organism was identified as *Ralstonia solanacearum* biovar 3 phylotype 1, which is 100% similar to the ginger strain of *R. solanacearum*. An entomopathogenic fungus, *Lecanicillium psalliotae* (IISR-EPF-02) was found to reduce damage by thrips, *Sciothrips cardamomi* significantly and also promotes plant growth. Field screening of 180 cardamom germplasm accessions for three years at Appangala resulted in identification of eight accessions resistant to cardamom thrips. Different morphological traits such as panicle type, persistence of bract and nature of adherence of leaf sheath were found to impart resistance against thrips. A novel soil pH based micronutrient mixture for enhancing growth, yield and quality of cardamom has been developed and non-exclusively licensed.

Ginger

Six hundred and sixty eight accessions are being maintained in field germplasm conservatory. Four varieties namely, IISR Varada, IISR Rejatha, IISR Mahima and IISR Vajra were released for their high yield and quality. A superior red ginger genotype with high essential oil (4.3%) along with high pungent principles, gingerol (1.92%) and shogaol (0.55%) has been identified. Acc. 195, a tetraploid having 2n=44, showed mean pollen fertility of 67.73% by glycero-carmine staining and 60.31% by *in vitro* germination and is suitable for future studies on induction of seed set. Three potential mutants have been identified through gamma ray irradiation which showed resistant reaction against bacterial wilt caused by *Ralstonia solanacearum*. A conservatory (Garden of Gingers) for Zingibers has been established at ICAR-IISR. Targeted yield equations for predicting nutrient requirements for fixed yield targets in soils with varying fertility levels were standardized with minimum deviations. The relationship between leaf P/Zn ratio and soil P/Zn ratio to rhizome yield has been established. The economic optimum in terms of profitable response for money invested was found to be Rs. 3.75 bed^{-1} for N, Rs. 1.30 bed^{-1} for P and Rs. 0.60 bed^{-1} of $3m^2$ for K. Novel soil pH based micronutrient mixtures for enhancing growth, yield and quality of ginger has been developed and licensed.

Post-harvest technologies for processing and technologies for preparation of value added products were standardized. Comparison of essential oil constituents of fresh and dry rhizomes indicated that fresh rhizomes contained higher level of monoterpenes namely, *Z*-citral and *E*-citral whereas the dry rhizomes were predominated by the sesquiterpene hydrocarbons *viz*., zingiberene, farnesene and sesquiphellandrene. Indian mango ginger, *Curcuma amada* was found to be free from bacterial wilt even under inoculated conditions. The species of *Pythium* causing rhizome rot of ginger in Kerala, Karnataka, Uttar Pradesh and Sikkim was identified as *P. myriotylum.*

Nine actinomycetes isolates from ginger soil were found to be antagonistic to *R. solanacearum.* Technique for ginger seed rhizomes treatment (for elimination of bacterial wilt pathogen) and integrated disease management strategy for soft rot and bacterial wilt diseases and shoot borer was developed. *Bacillus amyloliquefaciens* (GRB 35) and *B. safensis* (IISR TB4) were effective for disease control and plant growth promotion in ginger.

PGPR formulation to enhance nutrient mobilization and growth, yield and biocontrol was developed and commercialized. New technology for integrated management of wilt integrating physical (soil solarization), chemical (soil amelioration with calcium chloride - 3%) and biological (ginger apoplastic bacterium – *B. licheniformis*) methods was developed. The formulation of the bioagent was launched as 'Bacillich'. A protocol for priming rhizomes with *Trichoderma* spp. was developed to regulate the germination process, prevent the growth of dry rot pathogens during storage, to improve the vigour of buds and to provide uniform tillering of seed rhizomes.

Seed treatment and three rounds of foliar spraying with tebuconazole (0.1%) at 15 days' interval was found to be effective in managing foliar diseases of ginger. Alternatively, first spray with tebuconazole (0.1%) followed by carbendazim+mancozeb (0.2%) at 15 days' interval was also found to be equally effective. Two viruses associated with chlorotic fleck disease of ginger were identified as ginger chlorotic fleck associated tombusviridae virus (GCFaTV) and ginger chlorotic fleck associated ampelovirus (GCFaAV) and the complete genomes of GCFaTV and partial genome of GCFaAV were cloned, sequenced and analyzed. Two isothermal assays, RT-LAMP and RT-RPA assays were developed and validated for the quick detection of GCFaV-1 and GCFaV-2.

The life cycle of shoot borer (*Conogethes punctiferalis*) on six resistant and six susceptible accessions was studied. The infectivity of EPNs strains IISR-EPN 01 to 08 was tested against shoot borer larvae under *in vitro* conditions. One species of EPN belonged to *Oscheius gingeri* and was identified as new species on the basis of morphological and molecular characterization.

Field studies indicated that spinosad, flubendiamide and chlorantraniliprole were effective in the management of ginger shoot borer (*Conogethes punctiferalis*) even at the lowest dose (0.3 ml litre^{-1} of water) tested. The combination of chlorantraniliprole and spinosad was also equally effective in managing the insect. The improved varieties and technologies developed on cropping system, nutrient and water requirement, pest and disease management and post-harvest processing techniques were disseminated to farmers and other agencies through publications, training programmes and demonstrations. Large scale multiplication and distribution of elite planting material were also undertaken.

Turmeric

The germplasm with over 1404 accessions is being conserved in the field gene bank. These have been characterized for yield, quality, and resistance to pests, diseases and drought. Seven high curcumin and high yielding varieties, Suvarna, Sudarsana, Suguna, IISR Prabha, IISR Prathiba, IISR Alleppey Supreme and IISR Kedaram were released for commercial cultivation.

Molecular genetic fingerprints of 16 *Curcuma* species using RAPD and ISSR markers revealed high degree of polymorphism. A total of 140 microsatellites containing genomic DNA fragments were isolated adopting the selective hybridization method with di and trinucleotide biotinylated probes. Two synonymous *Curcuma* species *viz*., *C. zedoaria* and *C. Malabarica* showed identical SSR profiles for 40 microsatellite loci. Efficient protocol for plant regeneration through organogenesis and somatic embryogenesis was standardized. Variations in rhizome morphology were observed among calli-regenerated somaclones indicating somaclonal variation. Accessions with high curcumin and root knot nematode resistance were identified. About 40 seedling progenies with higher curcumin (> 3%) and dry

recovery (> 20%) were identified. Three different curcuminoids (curcumin, demethoxycurcumin and bisdemethoxycurcumin) could be separated from oleoresin by employing chromatographic techniques. Turmeric essential oil components have been characterized by GC-MS. A PCR based method was developed to detect adulteration of turmeric powder with wild *Curcuma* species. Through transcriptome analysis the genetic basis and regulation of curcumin biosynthesis in *Curcuma* sp. were unravelled and micro RNAs that showed differential expression with respect to curcumin in turmeric accessions with contrasting curcumin content have been identified.

Targeted yield equations for predicting nutrient requirements for fixed yield targets in soils with varying fertility levels were standardized with minimum deviations. The economic optimum in terms of profitable response for money invested per bed of size 3 × 1 m was found to be Rs. 0.65, 0.40, 0.85 for N, P and K respectively. Increase in curcumin content was recorded when sprayed with micronutrients like zinc and boron. The optimum spacing, nutrient and water requirement were standardized for different soils and an organic farming system was developed for turmeric.

Among the management systems, organic system (75.0%) recorded maximum yield (13.9 t ha^{-1}) which was on par (13.8 t ha^{-1}) with integrated system (75.0% + 25.0%). Maximum oil content (5.3%) was recorded by organic 100.0% and organic 75.0% management system. Among the 12 turmeric varieties evaluated under 100.0% organic management, significantly higher yield was recorded in IISR Pragati (22.1 t ha^{-1}) followed by Kanthi (19.2 t ha^{-1}). Higher oil content was noticed in varieties IISR Prathibha (6.0%) and IISR Alleppey Supreme (5.9%) and least oil content was noticed in Suvarna. Novel soil pH based micronutrient mixtures for enhancing growth, yield and quality of turmeric has been developed and licensed.

A novel spice mix formulation with turmeric, ginger and cinnamon was developed for turmeric milk preparation; one as ready to serve flavoured turmeric milk and the other one as turmeric milk instant mix powder. The technologies were commercialized to Kerala Co-operative Milk Marketing Federation Ltd (MILMA), Kozhikode.

Basic data on distribution, bioecology, population dynamics of shoot borer (*Conogethes punctiferalis*) and its natural enemies and crop loss due to shoot borer was generated. Lamda cyhalothrin 0.0125% was more promising in reducing the percentage of shoots infested by the shoot borer. New generation insecticides such as, chlorantraniliprole, flubendiamide and spinosad were also found effective in the management of shoot borer even at the lowest dose (0.3 mL $litre^{-1}$ of water) tested. The combination of chlorantraniliprole and spinosad was also equally effective in managing the insect. The improved varieties and technologies were disseminated to farmers and other agencies through publications and demonstrations. The adoption of released varieties like IISR Prathiba in Andhra Pradesh, Karnataka and Tamil Nadu were studied. A novel soil pH based micronutrient mixtures for enhancing growth, yield and quality of turmeric, ginger, black pepper and cardamom were developed. Video film on success story of a 'IISR Prathibha' grower was produced.

Tree spices

The germplasm of important tree spices like nutmeg, clove, cinnamon including cassia, garcinia and allspice are being conserved. IC numbers for cinnamon, clove, nutmeg and allspice accessions were obtained from NBPGR, New Delhi. Cassia C1 (IC 370415) has been registered as INGR 05029 with NBPGR, New Delhi for its high oleoresin content (10.5%)

besides a dwarf clove accession. The cassia elite line A1 (IC 370400) has been registered with NBPGR for high cinnamaldehyde content in bark oil (81.5%) and leaf oil (80.5%). Two high quality cinnamon varieties, IISR Navashree and IISR Nithyashree and a nutmeg variety, IISR Viswashree were released. Nutmeg accession, A11/25 was found to be promising for high yield. Nutmeg accession A9-71(IC-537220), as a source of high sabinene (45.0% sabinene in nutmeg oil and 41.9% sabinene in mace oil) was registered with NBPGR. Tissue culture protocols have been developed for nutmeg. Protocols for DNA isolation from nutmeg have been standardized. Performance of nutmeg on *M. malabarica* continued to be better than other rootstocks for productivity. Green chip budding with orthotropic buds was standardized in nutmeg on *Myristica fragrans* rootstock with 90-100% success.

GC-MS study revealed the presence of two chemotypes in *Cinnamomum verum*. GC-MS analysis showed that eugenol, myrcene, chavicol and limonene were the volatile constituents in leaves, berries and fruit stalk of *Pimenta racemosa*. Drying and processing methods for cinnamon, nutmeg and mace have been developed. A package was developed for enhancing sustainability of nutmeg in coconut based cropping system through site specific nutrient management. Antioxidant properties and food color value are being studied in tree spices. GC-MS analysis of the chemical constituents of essential oils in leaves of *Cinnamomum sulphuratum, C. glaucescens, C. glanduliferum, C. macrocarpum* and *C. perrottetti* revealed that the major chemical constituents in these oils were α-phellandrene, β-phellandrene, camphor, t-*caryophyllene* and *germacrene*-D respectively. Vegetative propagation techniques were standardized for nutmeg, cassia and cinnamon. Major pests and diseases on tree spices were documented. The improved varieties and technologies developed on propagation and post-harvest processing were disseminated to the farming community.

Vanilla

Vanilla germplasm are being maintained in the repository, which includes a flower colour variant collected from Andaman and Nicobar Islands. The Institute has 65 accessions of *Vanilla planifolia*, 7 *Vanilla* spp. from Andaman, one each of *Vanilla pilifera*, *Vanilla aphylla*, *Vanilla tahitensis* and *Vanilla wightiana*, two species from Wayanad, one species from Assam and three species from Little Andamans. Comparative anatomical analysis of different *Vanilla* species was carried out. Interspecific hybridization was made between *Vanilla planifolia* and *V. aphylla*. Reciprocal crosses were conducted between *V. planifolia* and *V. tahitensis* (species reported as resistant to root rot disease) and high percent of fruit set was observed in both the crosses. Fifty interspecific hybrids each of *V. planifolia x V. tahitensis, V. tahitensis x V. planifolia* and selfed progenies of *V. tahitensis* were established *ex vitro*. Chromosome number analysis of two interspecific hybrids between *V. planifolia* and *V. tahitensis* showed 2n=30 in one (PT-5) and 2n=32 in the other (PT-17).

Protocols for micro propagation through direct shoot multiplication as well as callus regeneration were standardized. Root rot and wilting were found to be the major problems in most of the plantations. Root rot incidence ranged from 5 to 100%. Mosaic and necrosis were also observed in all the plantations and the incidence ranged from 2 to 80%. *Cucumber mosaic virus* (CMV) of vanilla was characterized on the basis of biological and coat protein (CP) nucleotide sequence properties, which showed that CMV infecting vanilla belongs to subgroup IB. A virus causing mild chlorotic mottle and streaks on leaves of vanilla was identified as a strain of *Cymbidium mosaic virus* (CymMV) based on coat protein gene sequence comparison and phylogenetic studies. Another virus associated with necrosis and mosaic on vanilla was identified as a strain of *Bean common mosaic virus* (BCMV) based on coat protein gene sequence comparison and phylogenetic studies.

Paprika

The germplasm collected from various places of cultivation were characterized for various morphological, yield and quality characters such as oleoresin, pungency and colour value. Considerable variability was observed in total extractable colour and capsaicin content (pungency) of selected paprika accessions. The lines ICBD-10, Kt-pl-19 and EC-18 were found promising with high colour value and low pungency. PCR based technique was developed to detect adulterants in commercial chilli powder.

Awards

Besides numerous prestigious fellowships and awards to scientists, the Institute was bestowed twice with the Sardar Patel Outstanding ICAR Institution Award (1999 & 2009). Recently, the All India Coordinated Research Project on Spices (AICRPS) won the prestigious Chaudhary Devi Lal Outstanding Award for the best AICRPS in the year 2017-18. Other notable awards obtained by the Institute in the past include, Rajbhasha Shield Award 2013, 2014 & 2015, Best official Language Magazine Award 2015 for Masalon Ki Mehak, ICAR Swachhta Pakhwada Award Second Prize 2018, Fakhrudin Ali Ahammed Award for outstanding research in tribal farming systems 2019 etc**.** The Institute has been awarded three patents for the designer micro-nutrient formulations developed for ginger and turmeric.

ANNUAL REPORT 2021

RESEARCH ACHIEVEMENTS - 2021

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BLACK PEPPER

Genetic resources

Three thousand four hundred and sixty six accessions are maintained at the black pepper Germplasm nursery at the experimental farm, Peruvannamuzhi, Kerala. A block of released varieties and local cultivars was established at the germplasm conservatory on non-living standards with drip irrigation facility. This includes nine released varieties and 19 promising lines (10 each) and farmers' varieties. A set of core collections was established at ICAR-IISR, Kozhikode as a backup. At present the field genebank at CHES, Chettalli has 827 cultivar accessions.

Two explorations were carried out at Agasthyamala reserve forest and Munnar forest of Kerala and some unique black pepper accessions were collected and established in nursery. A black pepper with good setting and bold berries collected from TATA coffee estate was established at Appangala. High elevation species like *Piper schmidtii*, *P. wightii*, *P. mullesua* and *P. pseudonigrum* were collected from the shola forests of Munnar and adjacent areas and endangered species *P. barberi* (both male and female) from Anakkulam forests. A total of 31 collections were made and a set of collections was planted at Regional Station, Appangala.

Characterization

Among the germplasm lines Acc. No. 1036 recorded highest fresh yield of 4.83 kg followed by Acc. No. 1037 (4.70 kg) and Acc No. 1321 (4.45 kg). Highest bulk density of 652.5 was recorded in Acc. No. 1197. Highest berry size of 7.9 mm was recorded in Vadakkan.

Identifying suitable genotypes for white pepper production

Eighteen black pepper genotypes were characterized for traits linked to white pepper production. Seed size of eighteen genotypes is represented in Fig. 1. Pericarp to seed (P/S) size ratio, one of the traits relevant for white pepper yield was studied for the first time and is depicted in Fig. 1. Among the genotypes under study, lowest P/S ratio was recorded in 'Agali pepper' (23.77%) followed by 'IISR Girimunda' (24.65%) and highest in 'IISR Malabar Excel' (47.94%) and 'Arakulamunda' (44.31%). Genotypes with low P/C ratio will have better white pepper recovery and can be regarded as white pepper suitable genotypes. Use of genotypes with high P/S ratio for white pepper is not advisable as turnover percentage decreases. In contrast, genotypes with low P/S ratio are highly recommended for white pepper processing as recovery will be better. The piperine content ranged from 3.90 to 7.17 % among the genotypes (Fig. 2). Maximum piperine content was recorded in 'Nedumchola 'and 'Jeerakamundi' followed by 'Arakulamunda' and 'IISR-Girimunda' while minimum in 'Narayakodi' and 'Mundi'genotypes. Since, mild pungency is preferred for white pepper, the genotypes with less piperine may be preferred. Oleoresin content in the seed ranged from 6.57 to 11.55 %. Phenolic content ranged from 0.47 to 1.62%. Our studies indicate that 'Agali' and 'IISR-Girimunda' are best genotypes suitable for white pepper production in terms of seed size, pericarp to seed ratio and other quality traits.

Correlation between seed size and biochemical parameters

Except reducing sugar and protein, no other traits showed significant association with seed size (Table 1). These results indicate the quality traits in white pepper don't depend on seed size rather are genotype dependant. Piperine showed positive correlation with oleoresin (r=0.541) and protein (r=0.539). Starch and phenol showed negative significant correlations indicating reduction in phenol content in berries as starch accumulates in seed during maturity. Hence, non-significant correlation between seed size and biochemical parameters suggests their independent genetic control and hence there is a better chance for identifying best genotype for white pepper production without compromising the quality.

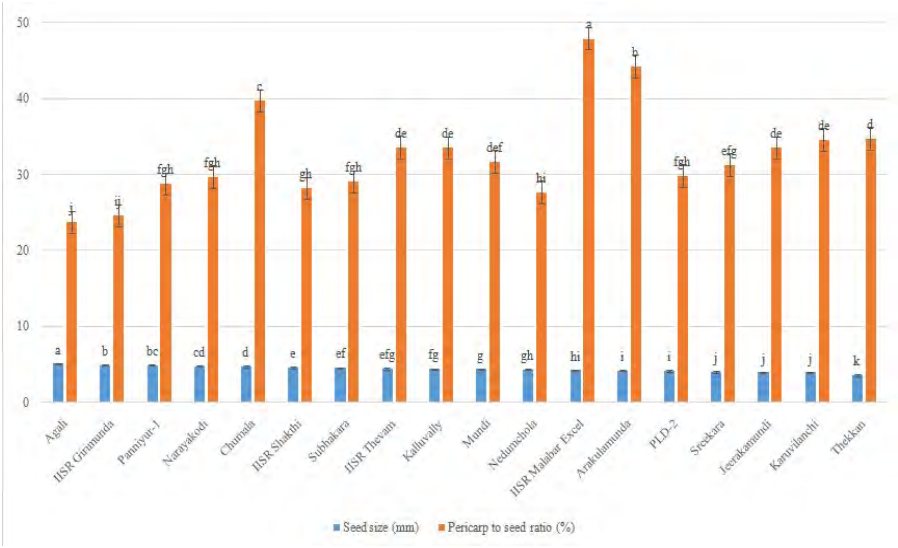


Fig. 1. Comparison of seed size (mm) and Pericarp to seed ratio (%) among 18 black pepper genotypes. Means followed by the same letter within each variety are not significantly different (Tukey's test, $p < 0.05$)

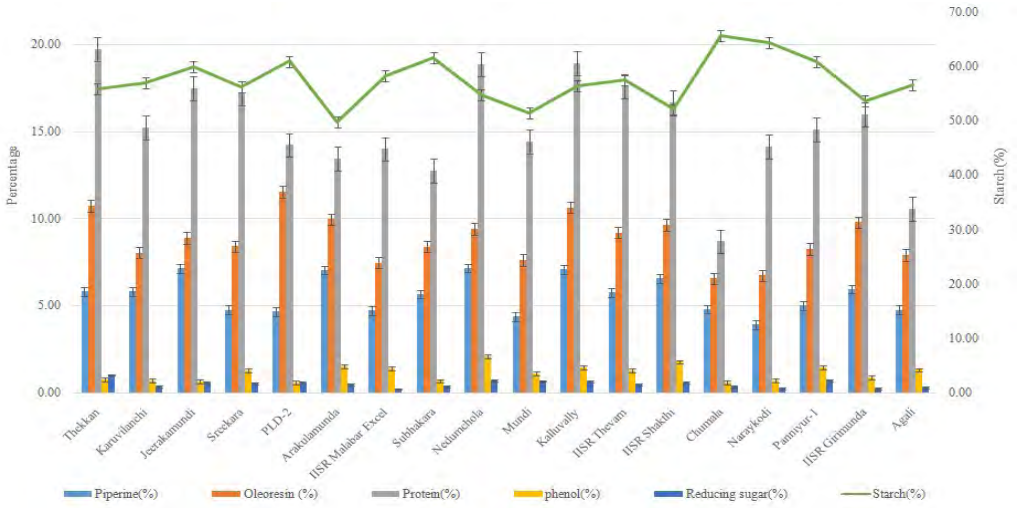


Fig. 2. Comparison of concentration of different biochemical compounds in seed of 18 black pepper genotypes

Table 1. Pearson correlations (R) among seed size and biochemical compounds in seeds of black pepper

Trait	Seed size	Piperine (%)	Oleoresin (%)	Protein (%)	Phenol (%)	Reducing sugar (%)	Starch (%)
Seed size	1						
Piperine (%)	NS	1					
Oleoresin (%)	NS	0.541*	1				
Protein (%)	-0.498*	0.539*	0.585*	1			
Phenol (%)	NS	NS	NS	NS	1		
Reducing sugar (%)	-0.500*	NS	0.535*	0.633**	NS	1	
Starch (%)	NS	NS	NS	NS	-0.579*	NS	1

* Significance at p < 0.01, ** significance at p < 0.05, NS: Non significant

Participatory plant breeding

A promising genotype (local type) was identified from a farmer's field (Mithun, Shanivarsanthe). The genotype has bold berries with medium spike length and high dry recovery.

Biotechnology

Piperine pathway genes

Gene specific primers and qRT-PCR parameters were optimised for amplification of six isoforms of the key piperine pathway gene *viz*., BAHD acyltransferase. The isoform candidate was identified by co-expression studies involving four berry stages (2MAP, 4MAP, 6MAP and 8MAP), leaf and stem. The isoform PNBAHDCh1A indicated in red colour correlated with piperine in all the tissues and developmental stages and may be the putative candidate isoform involved in piperine biosynthesis.

Crop Production

Fertigation

Fertigation schedules for three black pepper varieties IISR Thevam, IISR Girimunda and IISR Shakthi were standardized by supplying required quantities of fertilizer (as per treatment) along with irrigation water through dosing pumps in 24 and 40 splits respectively from September to May. Conventional irrigation @ 10 litres of water per day from September to May and irrigation @ 8 litres of water per day and the recommended dose of fertilizer in 3 equal splits, I in June, II in September and III in February served as control. Maximum yield was recorded in the fertigation treatment with 50% NPK in 24 splits (3.1 kg/plant) followed by the treatment drip irrigation @ 8 litres of water daily from September to May and 50% RDF in 40 splits (2.2 kg/plant).

Screening for moisture stress tolerance

To optimize the osmotic stress induced by different concentrations of PEG-6000 for moisture stress tolerance screening, an experiment was conducted with five different concentrations of PEG-6000 (5, 8, 10, 12, 15%) along with a control in black pepper cv. Panniyur-1, IISR-Thevam, IISR-Sreekara and IISR-Girimunda. The results showed that PEG-6000 concentration at 8% (Panniyur-1) and 10% (IISR-Thevam, IISR-Sreekara and IISR-Girimunda) reduced seedling survival almost by 50%. Seedling survival percentage further reduced above 10% PEG concentration. However, at 10% PEG, a significant increase in proline was recorded. Hence, 10% PEG-6000 appears to be an ideal concentration for screening of black pepper genotypes for moisture stress tolerance.

Quality analysis of black pepper germplasm

Quality analysis of around 100 black pepper genotypes from IISR germplasm was taken up for their essential oil, oleoresin, piperine and total phenolics contents. Among the genotypes, essential oil content ranged from 1.0 to 4.33 %, piperine content ranged from 2.58 to 6.59 % whereas oleoresin content ranged from 4.55 to 10.63%. Total phenolics content ranged from 2.34 to 11.01 mg GAE/g.

The GC-MS analysis of essential oil of 40 genotypes identified 62 volatile compounds which showed significant variations among the genotypes. The range of major volatile compounds detected in the genotypes are as follows: sabinene (0.27 % to 17.16 %), β-pinene (10 % to 17.16 %), limonene (7.2 % to 16.37 %), trans-β-caryophyllene (12.7 % to 50.69 %) and caryophyllene oxide (0.59 % to 3.1 %). There was no significant positive correlation between major volatile compounds and piperine. K-means clustering of volatile compounds using Metaboanalyst 5.0 and a dendrogram produced four clusters of the genotypes based on their volatile profile (Fig. 3 & Fig. 4).

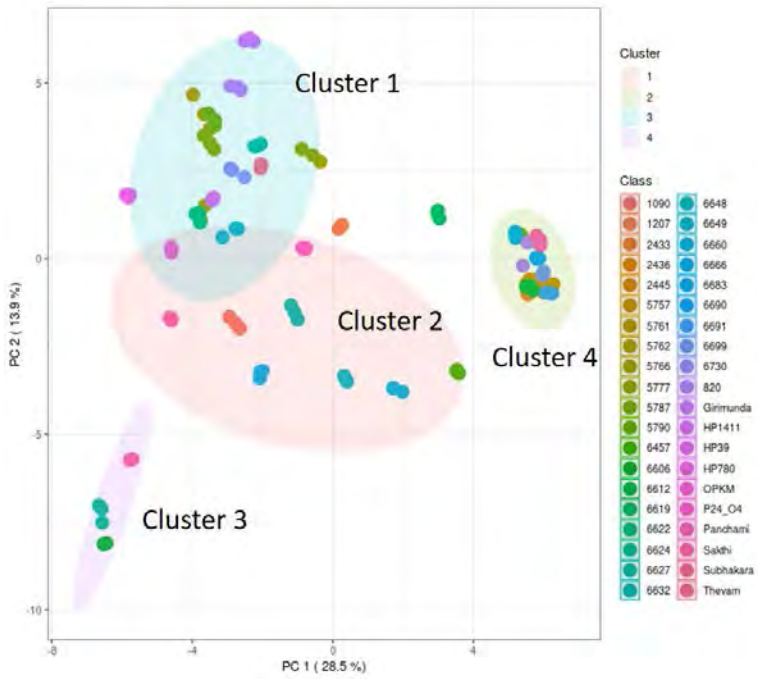


Fig. 3. Clustering of black pepper genotypes based on their volatile constituents

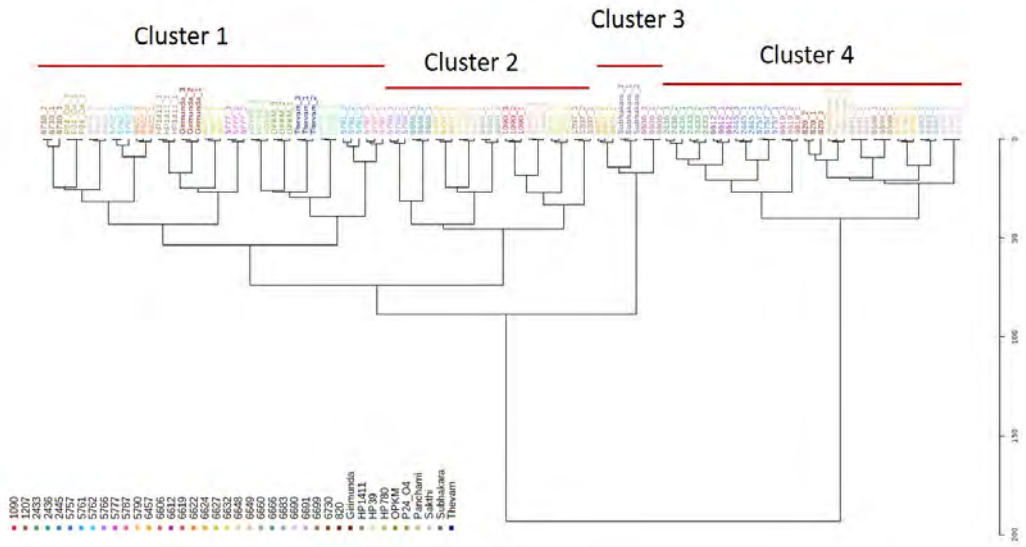


Fig. 4. Dendrogram drawn based on the volatile constituents of black pepper genotypes

Crop Protection

Foot rot disease

Genome sequencing of *Phytophthora capsici* and *P. tropicalis*

Whole genome sequencing of *Phytophthora capsici* (05-06) and *P. tropicalis* (98-93) was carried out in PacBio and Illumina platforms and Hybird assembly and KEGG pathway analysis were carried out for the identified genes. About 460 and 318 cytoplasmic effectors and 14 & 13 apoplastic effector genes were predicted in *P. capsici* and *P. tropicalis*, respectively, using offline tool Effector P3.0 beta.

Flow cytometry and confocal microscopy analyses of *Phytophthora* nuclei

The nuclei of *Phytophthora* isolate *viz*., 05-06 and ATCC 52239 (*P. palmivora*; as internal standard) were visualized and documented employing confocal microscopy. The DNA contents were also analysed using flow cytometry and found to be 82.9 Mb and 135 Mb in 05-06 and ATCC 52239, respectively (Fig.. 5).

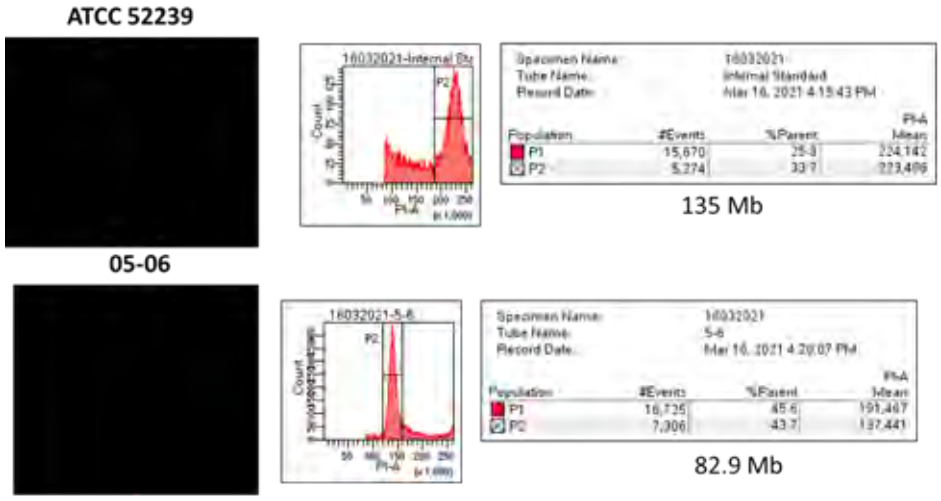


Fig. 5. Confocal microscopy and flow cytometry analyses in *Phytophthora*

Genetic diversity of *Phytophthora* isolates

Six isolates of *Phytophthora capsici* (05-06, 02-20, 06-12, 07-03, 18-12 and 20-05) and *P. tropicalis* (97-55, 98-93, 03-07, 06-17, 09-01 and 11-29) were selected for haplotype analysis. Four regions of the mitochondrial genome (Coxl, Cox2, Nadl and Nad5) and six nuclear genes (ß-tubulin, EE-l a, Enolase, HSP90, TigA and Ura3) were also amplified and subsequently sequenced which will be used for haplotype analysis.

In vitro evaluation of fungicides against *Phytophthora* isolates

The inhibitory effect of four fungicides *viz*., metalaxyl-mancozeb, propineb, metalaxyl and fluopicolide-propamocarb hydrochloride at five different concentrations on mycelial growth and sporangial production in *Phytophthora capsici* (05-06) and *P. tropicalis* (98-93) was studied under *in vitro* condition. Among the fungicides, propineb, metalaxyl-mancozeb and fluopicolide-propamocarb hydrochloride completely inhibited mycelial growth of *P. capsici* at recommended concentrations. However, the mycelial growth was 15.33 mm with metalaxyl at recommended concentration (Fig. 6). The sporangial production was found to be the minimum with metalaxyl-mancozeb and maximum in metalaxyl.

In the case of *P. tropicalis*, the fungicides, fluopicolide-propamocarb hydrochloride completely inhibited mycelial growth. Whereas, the mycelial growth was 19.66 mm, 25.33 mm and 99.8 mm with metalaxyl, propineb and metalaxyl-mancozeb, respectively. The sporangial production was found to be the minimum with propineb and maximum in metalaxyl-mancozeb. Among the fungicides, propineb and metalaxyl also induced aberrations in hyphal architecture both in *P. capsici* and *P. tropicalis* (Fig. 7).

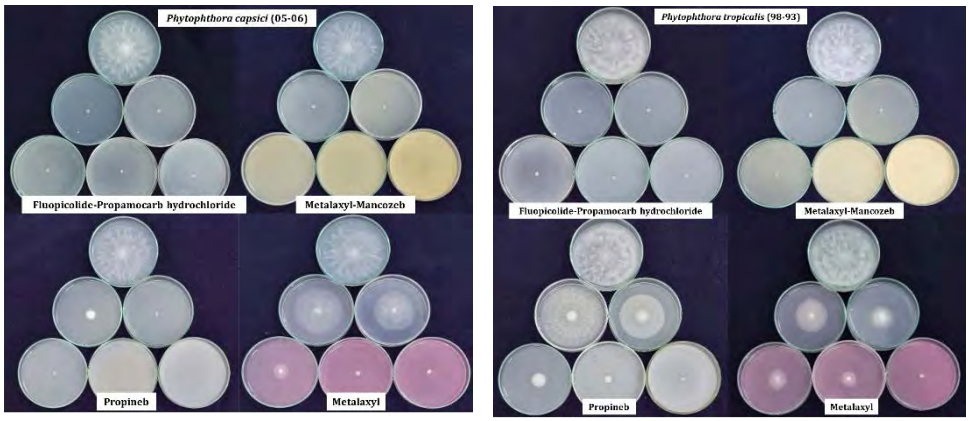


Fig. 6. *In vitro* evaluation of fungicides against *Phytophthora* isolates. (Left) *P. capsici (05-06);* (Right) *P. tropicalis (98-93)*

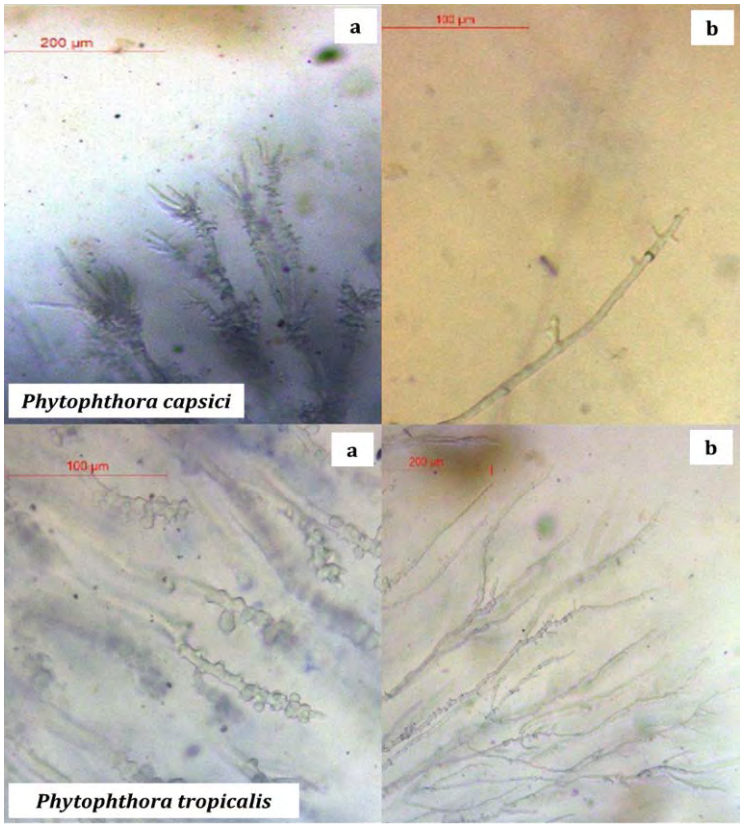


Fig. 7. Hyphal aberrations induced by propineb (a) and metalaxyl (b) in *P. capsici* and *P. tropicalis*

Plant viruses

Integration of endogenous pararetroviruses into black pepper genome

Studies using next-generation sequencing of total DNA isolated from *piper yellow mottle virus* (PYMoV) infected black pepper identified two contigs with length 7178 bp and 892 bp that showed homology to tungrovirus and badnaviruses. These contigs were named as Piper DNA virus 1 (PDV-1) (GenBank accession no. JX406741) and PDV-2 (GenBank accession no. JX406742). The HTS (high throughput sequencing) results were confirmed through polymerase chain reaction and Sanger sequencing. The sequenced region of both PDV-1 and PDV-2 contained partial genomes with motifs characteristic of pararetroviruses. BLAST analysis of PDV-1 and PDV-2 against the whole genome sequence of the black pepper showed integration of the PDV-1 at 22 loci in chromosome number 14, and PDV-2 at two loci in chromosome number 12 of black pepper. The integration was confirmed through amplification and sequencing of the junction regions. The present study suggests that both PDV-1 and PDV-2 occur as endogenous viruses in black pepper. Further studies are needed to determine whether they occur in episomal forms, their complete genome sequence and whether they can be activated under abiotic stress conditions.

Detection of Piper yellow mottle virus, Piper DNA virus 1 and Piper DNA virus 2 in crude sap

A simple method for detection of PYMoV, PDV-1 and PDV-2 through PCR and RPA was developed using crude sap from infected plant. Crude sap was extracted by grinding tissue in an alkali buffer and the extract was centrifuged at 5000 g for 30 s. The supernatant obtained was then diluted (1:10) using a buffer and was used as template for PCR. The results obtained

was comparable with the detection level obtained using CTAB isolated DNA. This study shows that viruses infecting black pepper can be detected in a short time (5 minutes) using simple crude extract of the plant.

Mycoviruses

Association of two novel viruses with *Fusarium concentricum* isolated from black pepper

A *Fusarium concentricum* isolate from black pepper showed the presence of dsRNA indicating association of mycoviruses. The dsRNA was purified and subjected to cDNA synthesis followed by cloning. Sequencing of one of the clones showed presence of 499 nucleotides potentially coding for 165 amino acids. The sequence analyses of this clone showed an identity ranging from 41 to 57% in the RNA-dependent RNA polymerase (RdRp) region of victoriviruses indicating that this virus isolate may represent a novel species in the genus, *Victorivirus*. Sequencing of the other clone showed the presence of 316 nucleotides potentially coding for 104 amino acids. The sequence analyses of this clone showed an identity ranging from 29 to 59% in the RNA-dependent RNA polymerase (RdRp) region of totiviruses indicating that this virus isolate may represent a novel species in the genus, *Totivirus*. The exact taxonomic identities of the virus isolates will be known only after obtaining complete sequence of the RdRp gene. This is the first report of mycoviruses infecting *F. concentricum*.

*Root mealybug (*Planococcus *sp.)*

Screening of low-risk insecticides

Seven low risk insecticides *viz*., buprofezin, chlorantraniliprole, spinosad, flubendiamide, spinetoram, diafenthiuron and flonicamid at three different doses along with chlorpyriphos as standard check were screened for their efficacy against root mealybug (*Planococcus* sp.) under laboratory conditions. The effective treatments were further tested in pot culture conditions. Among the low-risk molecules tested, flonicamid was very effective at lower dose (0.3g/l) and on par with chlorpyriphos (2ml/l). Other low risk insecticides like buprofezin (3ml/l) and diafenthiuron (1g/l) were also found effective and at par to each other (Table 2).

Table 2. Low-risk insecticide molecules screened against root mealybug *Planococcus* spp.

Name of the insecticide	Dosage	Mean no. of mealybugs		Per cent mortality over control
		7 DAT	14 DAT	
Buprofezin 25 SC	3 ml	14.80 ± 3.11 (3.829)^{c}	2.40 ± 1.48 (1.572)^{c}	69.96^{c}
Diafenthiuron 50 WP	1 g	15.60 ± 1.82 (3.944)^{c}	3.40 ± 2.07 (1.596)^{c}	68.20^{c}
Flonicamid 50 WG	0.3 g	7.40 ± 2.07 (2.699)^{d}	0.40 ± 0.55 (0.914)^{d}	86.22^{d}
Spinetoram 11.7 SC	1.5 ml	9.60 ± 1.82 (3.088)^{d}	0.80 ± 0.84 (1.089)^{cd}	81.63^{cd}
Spinosad 45 SC	0.5 ml	10.40 ± 3.78 (3.184)^{d}	1.40 ± 1.14 (1.322)^{cd}	79.15^{cd}
Neem oil 0.03%	3 ml	20.60 ± 1.52 (4.536)^{b}	10.60 ± 2.88 (3.309)^{b}	44.88^{b}

Chlorpyriphos 20 EC	2 ml	4.80 ± 2.39 (2.132)[e]	0.20 ± 0.45 (0.811)[d]	91.17[d]
Untreated check		28.60 ± 0.55 (5.348)[a]	28.00 ± 1.22 (5.393)[a]	-
CV		10.505	20.913	-
CD 0.01		0.654	0.725	-
CD 0.05		0.487	0.539	-

*Pollu beetle (*Lanka ramakrishnai*)*

Screening of new generation insecticides

Low risk insecticides such as chlorantraniliprole, flubendiamide and spinetoram at two doses (0.3ml/l and 0.5ml/l) along with quinalphos (2ml/l) as control were screened for their efficacy against pollu beetle (*Lanka ramakrishnai*) under field conditions at Chelavoor, Kozhikode for the second consecutive year. Among the insecticides tested, chlorantraniliprole was very effective in controlling the pest at all the doses tested.

Plant parasitic nematodes

Evaluation of nematicides against burrowing nematodes

The efficacy of two nematicides *viz*., fluopyram and fluensulfone along with carbosulfan against burrowing nematode in black pepper was assessed under nursery and field conditions. Among the treatments, fluopyram at all the concentrations tested reduced nematode population in soil as well as roots significantly. On the contrary, fluensulfone reduced nematodes only at the highest dosage (@ 1.5 g/plant) (Table 3). Carbosulfan @ 2ml/l also reduced soil and root populations by 61.9% and 43.8%, respectively, over initial populations. The highest plant mortality was recorded with fluensulfone (65% to 75%), followed by fluopyram (25%) and carbosulfan (20%).

Table 3. Evaluation of nematicides against burrowing nematodes in a black pepper nursery

Treatment	Dosage	Final nematode population				Plant mortality (%)
		In soil (per 100 cc)	Percent reduction over initial population	In roots (per 2 g)	Percent reduction over initial population	
Fluopyram (ml l^{-1})	1	1.0 (0.25)[d]	98.3	1.6 (0.20)[c]	93.3	0.0
	0.75	1.7 (0.36)[d]	97.3	2.0 (0.25)[c]	91.5	0.0
	0.5	27.3 (1.44)[c]	58.0	15.0 (1.17)[b]	36.4	25.0
Fluensulfone (g $plant^{-1}$)	1.5	56.7 (1.75)[b]	2.2	24.6 (1.39)[a]	-2.4	65.0
	1	91.0 (1.96)[ab]	-42.0	34.6 (1.53)[a]	-50.4	74.0
	0.5	94.6 (1.98)[ab]	-46.6	38.6 (1.58)[a]	-56.9	75.0
Carbosulfan (ml l^{-1})	2	24.6 (1.40)[c]	61.9	14.6 (1.16)[b]	43.8	20.0
Control	-	115 (2.06)[a]	-81.6	39.3 (1.59)[a]	-143.0	76.5

Figures in parenthesis are log transformed values. Numbers followed by the same alphabets are not statistically different.

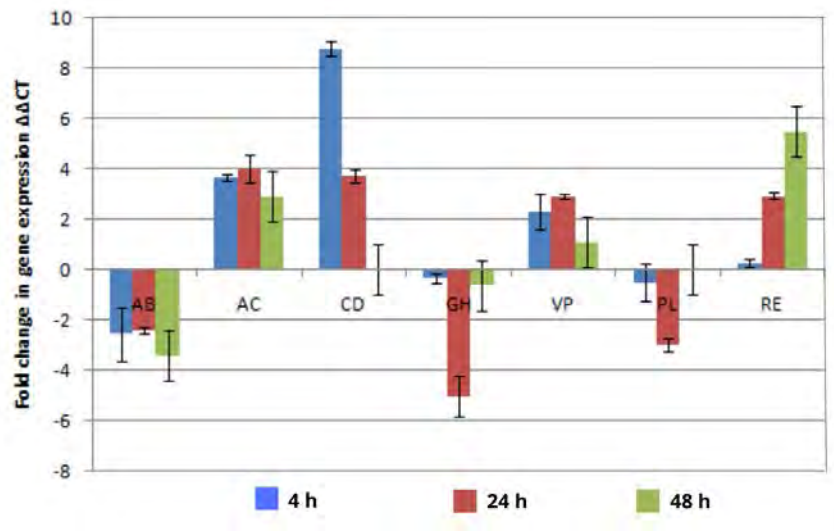
The efficiency of two nematicides namely fluopyram (0.75 ml l^{-1}) and fluensulfone (20 g $vine^{-1}$) along with carbosulfan (2 ml l^{-1}) against the burrowing nematode in black pepper was

evaluated under field conditions with single round (pre-monsoon and post monsoon alone) and two rounds (pre- and post-monsoon) of applications. Maximum reduction in nematode population was obtained with two rounds of fluopyram (0.75 ml l^{-1}) application followed by carbosulfan and fluensulfone.

Gene silencing studies in *Radopholus similis*

Seven genes (Rs-AB, Rs-Ac16, Rs-CDh, Rs-VpSA, Rs-GH, Rs-PL and Rs-ReCa2) that had important functional domains and conserved motifs, indicating their role in parasitism and survival, were amplified and cloned for this study. Possible silencing effects on these genes were investigated using long double-stranded RNAs (dsRNAs) as triggers. On soaking with dsRNA, many of the nematodes lost the typical body shape and displayed abnormal locomotory behaviour when compared to untreated nematodes. Fluorescence microscopy also indicated that the soaking solution diffused into the body of *R. similis* and did spread more evenly when observed after 24 h. After 44 h of incubation majority of the nematodes were dead and lost their typical body shape in all treatments. Changes in the expressions of the above seven genes 4, 24 and 48 hours after RNAi treatment, were not consistent in comparison to untreated nematodes. Although generally, RNAi treatment is expected to down-regulate target genes, expressions of just three out of the seven genes were significantly reduced (Fig. 8). Up to ~32-fold reduction was observed in Rs-GH gene expression after 24 h treatment whereas ~10-fold reduction after 48 h and ~15-fold reduction after 24 h were observed in Rs-AB and Rs-PL gene expressions, respectively. No expression was observed in case of Rs-CDh and Rs-PL after 48 h incubation.

The effect of silencing on the reproductive capabilities of *R. similis* was assessed by inoculating the treated nematodes on carrot disks. After culturing on carrot disks for 50 days, dsRNA-treated nematodes failed to multiply in almost all treatments except for glycoside hydrolase and reticulocalbin. This study suggests that responses of different genes to RNAi knockdown may have diverse results, therefore a comprehensive evaluation of target genes as targets for nematode control via RNAi is crucial.



AB - Abhydrolase domain-containing protein
AC - Immunodominant hypodermal antigen Ac16
CD - Carbonate dehydratase
GH - Glycoside hydrolase
VP - Vacuolar protein sorting-associated protein 45
PL - Pectate lyase
RE - Reticulocalbin-2

Fig. 8. Fold change in target gene expression of Radopholus similis 4 h, 24 h and 48 h after soaking with dsRNA of target genes

Evaluation of Trichoderma *spp. for abiotic stress mitigation in black pepper*

Moisture mitigation studies with different isolates of *Trichoderma viz., T. harzianum* (NAIMCC-SF-0049), *T. lixii* (IISR KA15), *T. asperellum* (IISR TN3), *T. harzianum* (IISR KL3), *T. erinaceum* (IISR APT1) and *T. atroviridae* (IISR APT2) in black pepper plants (Variety - IISR Sreekara) was carried out under *in vitro* conditions. The estimation of biochemical parameters *viz.*, proline, protein, phenol, lipid peroxidation, chlorophyll a and b and relative water content showed that the inoculation of *Trichoderma* decreased the stress induced due to moisture stress. The black pepper plants inoculated with the isolate *T. atroviridae* (APT2) showed the highest protein content while in uninoculated plants, there was a significant reduction in protein content (Fig. 9). Leaf proline content and lipid peroxidation increased in response to moisture stress but these parameters were maintained in plants inoculated with *Trichoderma* isolates *viz., T. asperellum* and *T. atroviridae.* Similarly, the higher relative water content of plants treated with these two isolates compared to other isolates under moisture stress indicated their ability to provide moisture stress tolerance. Among the tested isolates, *T. asperellum* and *T. atroviridae* have the potential to induce moisture stress tolerance by root and shoot growth promotion and also by triggering the protective mechanisms which prevent the oxidative damage.

Fig. 9. Black pepper plants inoculated with different isolates of *Trichoderma* under field capcity (Left) and under 50% field capacity (Right). Treatments (From left) - Control, NAIMCC 0049, KA 15, TN 3, KL 3, AP T1 and AP T2

Priming studies with arbuscular mycorrhiza

Defense related biochemical parameters *viz.*, total phenols, orthodihydroxy (OD) phenols, lignin and peroxidase were studied to find out the possible correlation with disease resistance traits of mycorrhizae. Black pepper (var: Sreekara) plants of 4-5 leaf stage were chosen for the pot experiment. The arbuscular mycorrhizal (AM) fungus, *Rhizophagus* sp. (MN710507) inoculum with 100 propagules per gram was prepared with vermiculite as the carrier. Five grams of inocula was mixed with the potting mixture as per the treatments. The sporulated discs of *P. capsici* were used for soil inoculation. AM inoculum and *P. capsici* were applied alone or in combination as per the treatments.

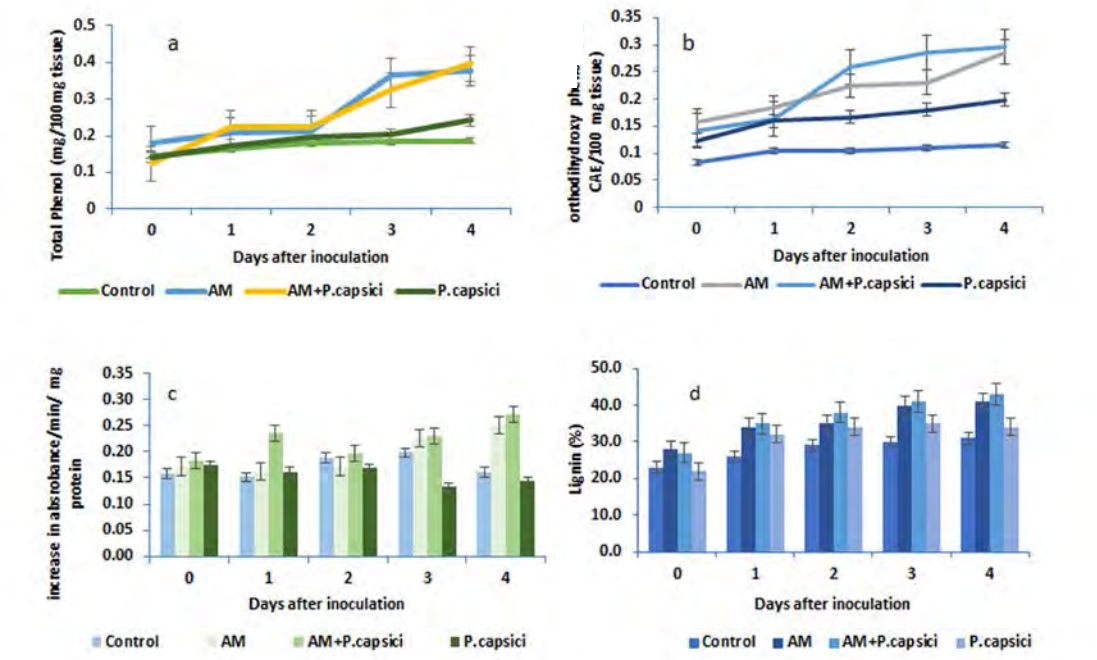


Fig. 10. Biochemical defense responses in black pepper to mycorrhizal colonization and *P. capsici* infection a) total phenol b) OD phenol content c) peroxidase activity and d) lignin content. Values are mean ± 1 SE (n=3).

Phenol content increased upon challenge inoculation with *P. capsici* and in AM alone inoculated samples. Significantly higher phenol content was noticed 4 days after inoculation in the *P. capsici* challenge inoculated treatment (0.39 mg/100 mg tissue) followed by AM alone inoculated treatments (0.37 mg/100 mg tissue) (Fig. 10a). A significant increase in the OD phenol content in roots was noticed in the *P. capsici* challenge inoculated samples (0.29 mg CAE/100 mg tissue). It plays an important role in increased resistance against *Phytophthora* and commencement of defense mechanisms like hypertensive reactions (Fig. 10b). In AM alone inoculated and *P. capsici* challenge inoculated plants, peroxidase activity remained at par on the 3rd day (0.22 increase in absorbance/min/ mg protein). During the fourth day, greater increase was noticed in AM with *P. capsici* inoculated plants (0.27 increase in absorbance/min/ mg protein) (Fig. 10c). In AM primed plants of both treatments, a significant increase in lignin content (%) was also noticed from the first day onwards as compared to uninoculated plants. The highest increase was around 43% in *P. capsici* challenge inoculated plants and 41% in AM alone inoculated plants on the fourth day (Fig. 10d).

CARDAMOM

Genetic resources

Around 622 cardamom accessions consisting of 423 accessions from Appangala station, 102 accessions from Pampadumpara, 41 accessions from Mudigere station and 56 accessions from Sakaleshapura are maintained under National Active Germplasm Site (NAGS) at ICAR-IISR, Regional Station, Appangala.

Three unique accessions MHC 1, MHC 2 and MCC 594 from Indian Cardamom Research Institute, Myladumpara were included in National Active Germplasm Site (NAGS) during 2021. Yield parameters of all the germplasm accessions were recorded and 24 accessions were shortlisted as high yielding. Characterization of 85 field gene bank (FGB) accessions was carried out based on different morphological traits.

Breeding

CVT on farmers varieties

Observations on morphological and yield parameters were recorded in CVT on farmers varieties of cardamom trial consisting of nine farmer's varieties of small cardamom *viz*., Arjun, Wonder Cardamom, Panikulangara, Thiruthali, Elarajan, Pachakai, Paupali, Njallani, PNS Gopinath supplied by National Innovation Foundation (NIF) and a local check variety Appangala-1. Observations *viz.*, plant height, number of tillers, number of bearing tillers, number of panicles and panicle length (cm) were recorded.

Highest dry yield per plant was recorded in cv. Panikulangara (340.67 g/plant) followed by Thiruthali (334.78 g/plant). Same varieties also recorded highest values for yield contributing traits *viz.*, number of bearing tillers, number of panicles and panicle length.

CVT on hybrids of small cardamom – 2018 Series VII

In the CVT trial consisting of nine hybrids *viz.*, Bold × IC 547219, (GG×Bold) ×Appangala 1 and (GG×NKE 19)×Bold from ICAR-IISR RS, Appangala; MHC-1 & MHC-2 from ICRI, Myladumpara; SHC-1 & SHC-2 from ICRI RS, Sakaleshapura and PH-13 & PH-14 from Pampadumpara with national check variety *Njallani* Green Gold, highest dry yield of capsules per plant was recorded in hybrid PH-13 (841.67 g/plant) followed by hybrid Bold × IC 547219 (361.33 g/plant). High essential oil content was recorded in Njallani Green Gold (9.08%) and a hybrid Bold × IC 547219 (8.80%).

CVT on drought tolerance

Six genotypes of cardamom (IC 349537, IC 584058, GG×NKE-12, IC 584078, CL 668, HS 1, IC 584090) with one check (Appangala 1) were evaluated for drought tolerance under AICRP (Spices). Mositure stress was imposed in summer from February to April in stress block by withholding irrigation. The control block was irrigated by sprinkler (25mm) once in 12-15 days interval. Soil moisture, gas exchange parameters, growth and yield data were recorded. Plant height, no of tillers/clump (yielding and non-yielding) , no. of green leaves/ tiller, total no. of panicles/ plant , length of panicle (cm), capsule yield (kg/ha) recorded variation between control and stress treatments. Dry capsule yield (kg/ha) showed significant variation between treatments and genotypes, ranging from 83.68 (IC 584090) to 313.54 (GGXNKE-12) in control and in stress, it ranged from 35.76 (IC 584090) to 151.04 (GGXNKE-12).

Accession IC 584058 recorded 70.28 per cent 8 mm bold capsules followed by HS 1which recorded 64.05% in control. In stress, accession HS 1 recorded 67.62 per cent 8 mm bold capsules followed by IC 584058 (67.05%). Essential oil content did not vary significantly between treatments and genotypes. It ranged from 8.35 (IC 584090) to 9.50% (IC 584078) in control with a mean 8.83% in control and in stress, it ranged from 8.69 (IC 349537) to 9.12 (IC 584090) with a mean of 9.01%.

Selection of open pollinated progenies for moisture stress tolerance

Open pollinated progeny seedlings of IC 584058 and IC 349537 were evaluated for moisture stress tolerance by using PEG. 2-3 leaf stage seedlings were raised in the Hoagland solution. After stabilizing the growth in Hoagland solution for one month, seedlings were subjected to moisture stress using PEG (15 %). After 30 days treatment in 15 % PEG, the seedlings which survived were subjected to 20 % PEG. Seedlings survived after subjecting them to 20 % PEG stress were transplanted to polythene bags filled with nursery mixture. IC 584058 (10 seedlings) and IC 349537 (7 seedlings) which put forth 4-5 leaves were transplanted in field and the remaining seedlings tolerant to moisture stress are being maintained in nursery.

Screening for drought tolerance

In order to optimize the osmotic stress induced by different concentrations of PEG-6000, a study was conducted with four different concentrations of PEG-6000 (5, 10, 15 and 20 per cent) along with a control in small cardamom cv. Appangala-1. PEG-6000 concentration above 15% reduced seedling survival almost by 50%. However, at 15% PEG-6000, a significant increase in proline, phenolic content and scavenging enzyme activity were noticed and a decrease in chlorophyll fluorescence was recorded. Hence, 15% PEG-6000 appears to be an ideal concentration for screening of small cardamom genotypes for moisture stress tolerance.

Development of an organic package

Nutrient management using different organic composts, pest and disease management using identified potential bioagents on cardamom showed that the growth parameters like plant height, number of total tillers and number of yielding tillers were significantly high in neem cake (NC)+vermicompost (VC) application, followed by farm yard manure (FYM) + NC applications. Among the organic nutrient sources, NC+VC combination application recorded 2.14 kg dry capsules per plot (of 12 plants) followed by FYM+NC+VC (1.46 kg/plot) and FYM+NC (1.23 kg/plot), with the least in VC alone (0.73 kg/plot). Integrated management yielded the highest fresh and dry capsule yield (3.33 kg dry/plot) which was on par with organic management (3.15 kg/plot) followed by chemical management (2.9 kg/plot) which recorded the lowest. Highest essential oil content (8.8%) was observed in NC+VC followed by FYM+NC+VC applications. Among the management systems, organic management recorded the highest oil content (6.46%) which was on par with integrated and chemical management systems (6.21%). With the application of spinosad and *Lecanicillium psalliotae* and spinosad with *Trichoderma* and *Pochonia*, no major incidence of shoot/ capsule borer (< 2.5 %) and thrips (<3.0 %) were observed in the treatments and management systems studied.

Effect of micronutrients on growth and yield of small cardamom

Experiment was laid out with two main treatments (T1- Recommended package of practice (Control), T2- Recommended package of practice (Micronutrients 4 sprays at March, April, May, June at 5 g l^{-1}), three sub treatments (varieties) V1-Appangala 1, V2-IISR Avinash, V3-Green Gold, at spacing of 2mx2m, with 12 plants per treatments. Treatments were imposed after establishment. Growth parameters like plant height, number of yielding tiller per clump, total number of tillers per clump, total number of panicles per clump, panicle length (cm), number of capsule per panicle, capsule yield (kg/ha) was recorded during cropping season. Plant height, number of yielding tillers, total number of tillers and panicle length were not significantly different between the treatments (Table 4). Total number of panicles per clump,

nubmer of capsules per panicle and capsule yield (kg ha^{-1}) varied significantly between the treatments. Spraying micronutrients in addition general package of practices increased yield by 5.5%.

Table 4. Influence of application of IISR cardamom special (micronutrient mix) on growth and yield of cardamom

Treatments and genotypes	Plant height (cm)		No. of yielding tillers/clump		Total no. of panicles per clump		Panicle length (cm)		No. of capsules per panicle		Yield (kg ha^{-1})	
Variety	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
Appangala 1	275	282.2	13.2	14.4	19.0	24.1	73.8	73.0	49.8	52.7	429.9	486.5
IISR Avinash	281.1	280.6	12.4	12.9	17.3	21.1	56.7	62.3	50.4	53.8	478.5	621.5
Green Gold	279.2	279.7	12.2	12.3	18.8	18.4	54.3	58.6	43.8	48.4	399.0	498.6
Mean	278.4	280.8	12.6	13.2	18.4	21.2	61.6	64.6	48.0	51.7	435.8	535.5
CD at 5%												
Treatment	NS		NS		2.12		NS		2.93		87.96	
Varieties	NS		NS		NS		4.92		3.59		NS	
Interaction	NS		NS		NS		NS		NS		NS	

T1- Recommended POP ; T2- RDF + micronutrients three sprays (5g litre^{-1})

Mycoviruses

Association of a novel mycovirus with plant pathogenic *Colletotrichum gloeosporioides* isolated from cardamom

A *Colletotrichum gloeosporioides* isolate from cardamom showed the presence of dsRNA indicating association of a mycovirus. The dsRNA was purified and subjected to cDNA synthesis followed by cloning. The cloned region contained 843 nucleotides potentially coding for 281 amino acids. The sequence analyses showed identities ranging from 10–18% and 22–29% in the RNA-dependent RNA-polymerase (RdRP) region with members of genera *Totivirus and Victorivirus* of the family *Totiviridae* suggesting that the present virus isolate is a novel member of the *Totiviridae*. Exact taxonomic identity of the virus isolate will be known only after obtaining complete sequence of the RdRp gene. This is the first report of a mycovirus infecting *C. gloeosporioides* from India.

*Thrips (*Sciothrips cardamomi*)*

Biological control of cardamom thrips with *Lecanicillium psalliotae*

The biocontrol potential of a recently isolated entomopathogenic fungus, *Lecanicillium psalliotae* (Treschew) Zare & W. Gams (Ascomycota: Hypocreales) was evaluated under field conditions for two years in two major cardamom growing states, Kerala and Karnataka. The results indicated that four rounds of soil application of the fungus granules reduced capsule damage by thrips up to 79% compared to control. Moreover, combined application of the fungus as spray and soil application was also effective in reducing the capsule damage by thrips, whereas spray application of the fungus was ineffective.

Compatibility of *L. psalliotae* with pesticides

The compatibility of *L. psalliotae* with commonly used insecticides and fungicides to manage insect pests and diseases in cardamom were evaluated under *in-vitro* conditions at their field recommended doses. Among the insecticides tested, only quinalphos significantly inhibited the fungal growth, and imidacloprid showed a negative effect only at 10 DAI; fipronil and

spinosad were compatible with the fungus. In case of fungicides, except copper oxychloride, all other fungicides tested were found to inhibit fungal growth under *in-vitro* conditions (Fig. 11 A, B).

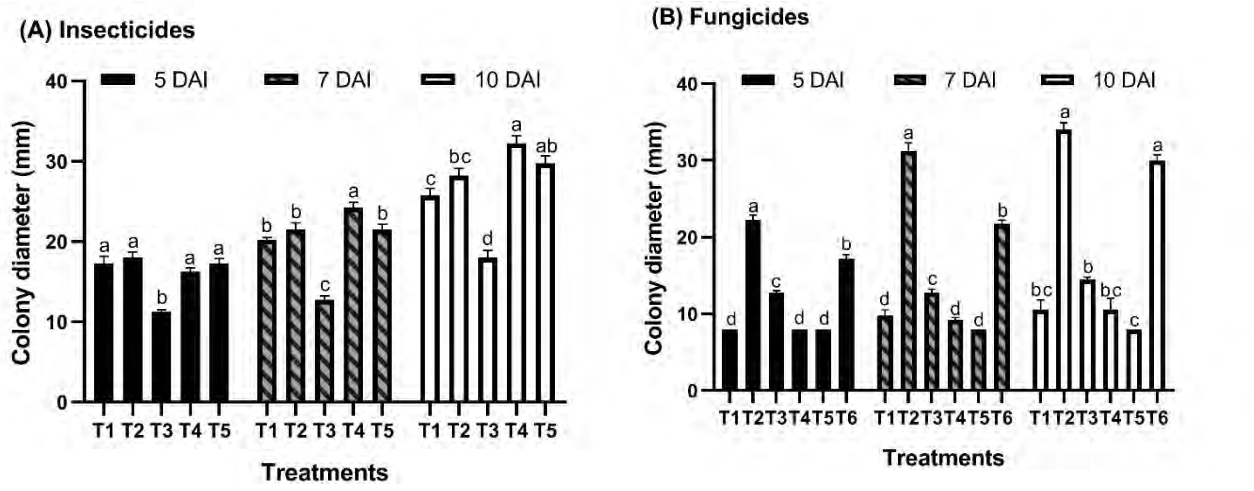


Fig. 11. Effect of (**A**) insecticides (T1=Imidacloprid 17.8% SL (0.5 ml/L); T2=Fipronil 5% SC (1.0 ml/L); T3=Quinalphos 25% EC (2.0 ml/L); T4=Spinosad 45% SC (0.3 ml/L); T5=Control) and (**B**) fungicides T1=Mancozeb 75% WP (2.0 g/L); T2=Copper oxychloride 50% WP (2.0 g/L); T3=Carbendazim 50% WP (1.0 g/L); T4=Metalaxyl 8% + mancozeb 64% WP (1.25 g/L); T5=Carbendazim 12% + mancozeb 63% WP (1.0 g/L); T6=Control) on the *in-vitro* growth (Mean±SE) of *Lecanicillium psalliotae* at 5, 7 & 10 days after inoculation (DAI). Error bars represent standard error (SE) of four replicates. Bars represented by the same letter are not significantly different by Tukey's HSD (α=0.05).

IPM technology for the management of cardamom thrips

An IPM package integrating the entomopathogen (*L. psalliotae*), and a reduced-risk insecticide (spinosad) and their combinations along with the existing chemical and cultural (phytosanitation) methods as components were field tested for cardamom thrips management. The trials indicated that initial sanitization of the crop with either quinalphos or spinosad followed by three rounds of soil application of the fungus or application of spinosad and *L. psalliotae* twice alternatively, reduced capsule damage by 70% to 90%. An increase in yield was also noticed in fungus soil application treatments. This is the first IPM schedule developed against this major pest of cardamom with biological control as a component.

LARGE CARDAMOM

Plant viruses

Development of isothermal diagnostic assays for the detection of chirke virus

Two isothermal molecular assays *viz.*, reverse transcriptase loop-mediated isothermal amplification (RT-LAMP) and reverse transcriptase recombinase amplification (RT-RPA) were developed to detect the large cardamom chirke virus (LCCV) infecting large cardamom. Assays were optimized for parameters like duration, temperature and concentration of magnesium sulfate, and betaine in the case of RT-LAMP and magnesium acetate and temperature in the case of RT-RPA. Detection limits of both assays were determined and

compared with conventional RT-PCR that showed RT-LAMP and RT-RPA assays were 10 - 100 times more sensitive than RT-PCR. Both assays were specific, rapid, and sensitive for detecting LCCV. Both these assays are economical and can be employed in large scale screening of large cardamom plants against LCCV for the selection of virus-free plants.

GINGER

Genetic resources

Six hundred and sixty eight ginger accessions have been maintained in the field gene bank. A new conservatory of ginger was established at ICAR-IISR, Experimental farm, Peruvannamuzhi, Kerala under the DBT funded project for conserving unique turmeric genotypes.

Fig. 12. New ginger conservatory at Peruvannamuzhi

Evaluation of mutants

Nine ginger entries (five promising mutants from ICAR-IISR, four from OUAT and one from IGKV) along with check, IISR Varada were evaluated for yield during 2020-2021. The maximum yield was recorded in R 1.25/4 followed by V1E4 1, which were on par.

Evaluation of mango ginger genotypes

Nine entries (two from ICAR-IISR, two from OUAT, three from NAU, one from Dholi and one from IGKV along with check, Amba were evaluated for yield during 2019-2020 and 2020-2021. In the second year of evaluation (pooled data), Acc. 347 (ICAR-IISR) recorded the maximum yield (52.29 t/ha), followed by NVMG 2 (44.38 t/ha).

Biotechnology

Functional annotation of unigenes in ginger transcriptome

The unigenes obtained from ginger transcriptome (PRJNA311170) were preprocessed and functionally annotated using BLAST2GO module of OmicsBox. 18222 unigenes were mapped to GO database. The sequence length of the annotated unigenes ranged from 301 to 14178 nucleotides. 10269 unigenes were mapped to known enzymes with EC numbers. 15965 unigenes had similarity measures >70%. The E-value distribution ranged from 0 to

9.85E-11. The annotated unigenes were grouped into three clusters *viz.* molecular function, biological process, and cellular component. The cluster biological process consisted of maximum number of GO terms (1951) whereas cellular component consisted of least (506). Molecular Function component included 1407 terms. Majority of the unigenes in biological process were distributed in sphingosine and ceramide biosynthetic pathways. In molecular function, it was chiefly distributed in ATP binding, mRNA binding and zinc ion binding. A high proportion of unigenes were in the cellular component of membrane proteins.

Molecular characterization

Twelve flanking polymorphic EST-SSR primers were validated using 48 ginger genotypes representing North-Eastern India and different eco-geographical adaptations by PCR amplification and allele sizing through capillary electrophoresis. UPGMA cluster analysis revealed that the 12 markers divided the 48 genotypes into three main groups. The dendrogram revealed that the North Eastern collections are highly diverse and fall in a different cluster along with other cultivated ginger varieties. Also, red ginger type (north-eastern collection) fell into a single cluster and did not cluster along with exotic red ginger indicating the diverse nature of North Eastern red ginger collection. The ginger variety, Athira, showed a distinct polymorphic band with ZoSSR25, visible from agarose gel and confirmed through capillary electrophoresis.

Expression of signalling pathway marker genes associated with bacterial wilt in susceptible and resistant ginger spp.

The expression of marker genes was compared among susceptible and resistant ginger spp. SA pathway marker genes, non-expressor of PR1 genes (NPR1) and TGACG sequence-specific binding protein (TGA6) and the ET pathway marker genes, AP2 domain class transcription factor (AP2) and 4-Coumarate: CoA ligase (4CL1), were expressed with a statistically different ($p < 0.05$) fold change among susceptible and resistant ginger spp. at all-time intervals. Expression of marker genes in resistant ginger showed higher expression in the first-hour post inoculation itself; however, marker genes of susceptible ginger had a slow pace in expression. Even though the marker genes of JA such as allene oxide cyclase (AOC) and lipoxygenase (LOX2) were activated in the initial hour post-inoculation in both ginger spp, the expression of these marker genes were significantly same ($p < 0.05$) among ginger varieties in almost all time intervals.

Ralstonia infected transcriptome of *Zingiber officinale*

The pathogenesis reaction leading to susceptibility of ginger to *Ralstonia* has not yet been revealed. Assembly of the raw reads was generated for healthy ginger and infected ginger using Trinity Software. The raw reads of healthy and infected ginger were 32.85 and 37.75 million respectively. The assembled transcriptome sizes of healthy and infected ginger were 0.23 million and 0.14 million respectively applying a contig size filter of 25bp. Approximately, 0.9 million contigs were found to be less in *Ralstonia* infected sample. Transcript abundance estimation using RSEM method followed by DE analysis using EdgeR revealed 476 genes to have significant differential expression. These genes are currently being analysed for identification of the associated pathogenesis related pathways.

Direct *in vitro* regeneration of red ginger

An efficient direct *in vitro* plant regeneration protocol has been established for two genotypes of red ginger, namely, north east red ginger and exotic red ginger, by using the rhizome buds as explants. The response of two genotypes were studied for shoot and root initiation and growth based on five different concentrations of 6-benzylaminopurine (1.0, 2.0, 3.0, 4.0, 5.0

mg l^{-1}) and a control using Murashige and Skoog (MS) medium. The results indicated that shoot multiplication was significantly high at 3.0 mg l^{-1} in north east red ginger (3.80) compared to exotic red ginger, the maximum shoot multiplication was at 5.0 mg l^{-1} (3.30). Maximum shoot length (4.40) was recorded at 3.0 mg l^{-1} in north east red ginger, whereas in exotic red it was recorded at 2.0 mg l^{-1}. Significantly highest number of roots were recorded at 5.0 mg l^{-1} in exotic red ginger (10.10) and north east red ginger (8.10) was observed in 3.0 mg l^{-1}. The root length was significantly high in exotic red ginger (6.98) and north east red ginger (4.99) at 2.0 mg l^{-1} and 3.0 mg l^{-1} concentration respectively. Genetic stability among the regenerated plantlets was confirmed using ISSR and SSR molecular markers.

Organic farming

In treatments involving fully organic and mixture of different organic sources, organic 100% recorded maximum nitrogen, phosphorus, potassium, calcium, magnesium, and zinc in soils sampled 120 days after planting (DAP). Regarding leaf nutrient status, organic 100 % recorded maximum potassium whereas phosphorus and calcium were higher in 50% organic + Beejamrit + Ghanjeevamrit + Jeevamrit. 50% organic + seed treatment with Beejamrit, application of Ghanjeevamrit + Jeevamrit recorded maximum uptake of nitrogen, phosphorus, and potassium (Fig. 13). Among the management systems, organic system (100%) (T1) recorded maximum yield (12.7 t/ha) followed by organic (50%) + seed treatment with Beejamrit + Ghanjeevamrit + Jeevamrit (T6).

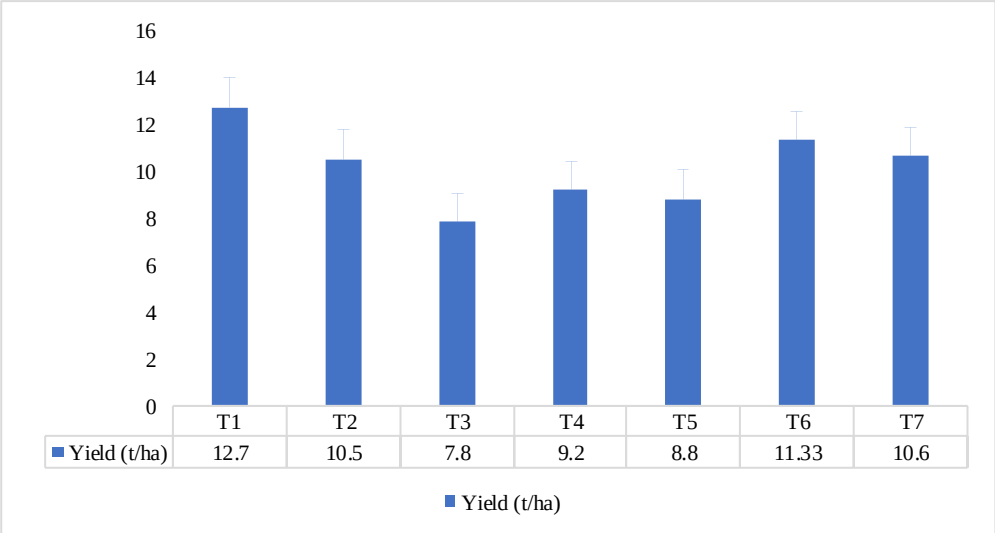


Fig. 13. Ginger yield as influenced by management system

Multi-residue method for targeted screening of pesticide residues in ginger by LCMS/MS

A method for analysis of liquid choromatography amenable pesticides in ginger rhizomes has been developed. A QuEChERS technique–based sample preparation method was optimized to monitor the residues of 29 pesticides by LC with tandem MS. The developed multi-residue method involved homogenising fresh ginger (2 g) with LCMS grade water (5 ml) followed by extraction with acetonitrile containing 1% acetic acid (5 ml) for ten minutes. To this, QuEChERS salt was added and vortexed, centrifuged at 5000 rpm for 5 minutes to collect 2ml of acetonitrile layer into a 15 ml centrifuge tube containing PSA (100 mg), MgSO4 (300 mg), C 18 (50 mg) and carbon black (50 mg) mixture. The mixture was vortexed and centrifuged at 5000 rpm for 5 minutes and the supernatant was filtered through

0.2 µ syringe filter into LCMS vials and analysed using LC-MS/MS in multiple reaction monitoring mode (MRM) via +/- mode electrospray ionization. The method was validated as per the SANTE/11945/2015 guidelines at 1, 5, 10, 15, 20, 50, and 100 ng/g spiking levels, and most of the analytes showed recoveries between 80 and 140% (with RSDs ≤10%). The LOQ of ≤5 ppb and LOD of < 2 ppb was achieved for all 29 target pesticides. The measurement uncertainties were evaluated at 50 ng/g and the global uncertainty values were below 20% for all the analytes.

Bacterial wilt disease

Field evaluation of calcium chloride and bioinoculants

A field trial was conducted to evaluate the efficacy of calcium chloride and bioinoculants to manage soft rot/wilt diseases of ginger under non-solarized field conditions with various treatments including calcium chloride (3%), Bacillich (powder formulation) (2%), Bacillich (capsule), cultures of *Bacillus licheniformis* and *Methylobacterium komagate*. The highest plant survival and lowest disease incidence (rot/wilt) were recorded with calcium chloride (21.5%) followed by Bacillich (powder formulation) (23.7%) and *Methylobacterium komagate* (24%).

Evaluation of fungicides and antibiotics (singly and combination) at three different concentrations against *Ralstonia pseudosolanacearum* under *in vitro* condition (inhibition zone assay) indicated that, the growth inhibition was maximum with the combination, copper oxychloride + tetracycline hydrochloride at all the concentrations (Fig. 14).

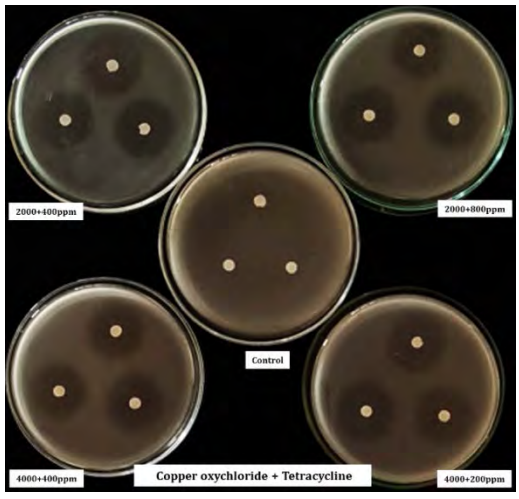


Fig. 14. Growth inhibition of *Ralstonia pseudosolanacearum* with copper oxychloride + tetracycline hydrochloride

Quorum sensing in *Ralstonia pseudosolanacearum*

In order to detect the genes responsible for quorum sensing in ginger bacterial wilt pathogen, primers were designed targeting the genes of *R. pseudosolanacearum*, *viz.*, *SolI* and *phcB* responsible for acyl homoserine lactones (acyl-HSL) and 3-hydroxypalmitic acid methyl ester (3-OH PAME) synthesis, respectively. The expected amplicons of 555 bp and 913 bp were generated with the primers *viz.*, ACYL-HSL2 and PHCB 2 r indicating the presence both *SolI* and *phc* genes responsible for synthesizing the quorum sensing molecules (Fig. 15).

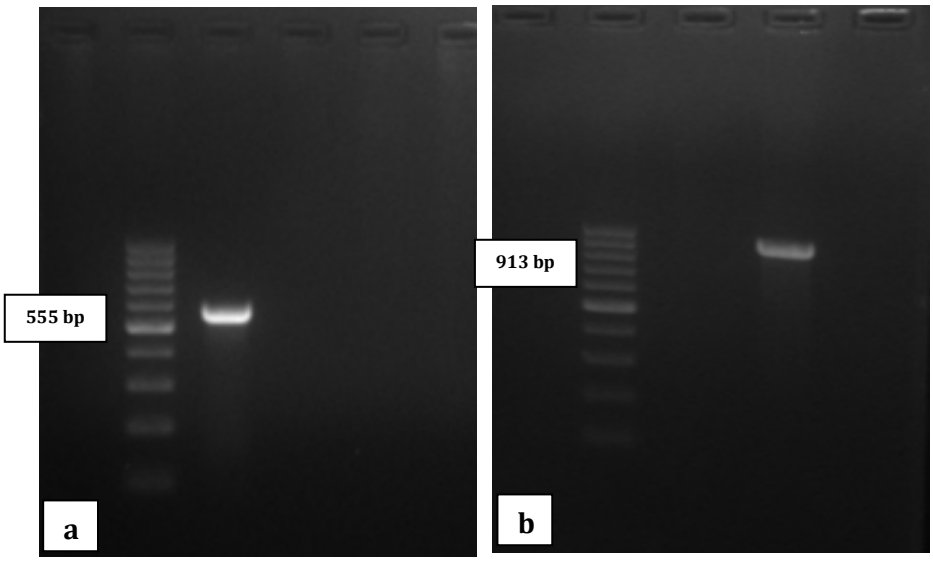


Fig. 15. Amplification of *SolI* and *phc* gene regions in *Ralstonia pseudosolanacearum*

TURMERIC

Genetic resources

One thousand four hundred and four *Curcuma* accessions have been maintained in the field gene bank.

Characterization

Phytochemicals, neutraceuticals and bioactivity profiling of turmeric varieties

Eight turmeric varieties were evaluated for essential oil, oleoresin, curcuminoids, volatile constituents, proximate and micronutrient composition and their antioxidant and antidiabetic potential. Suguna, Sudharshana and IISR Alleppey Supreme recorded high oleoresin (13%) and curcumin (4.5-4.75%); essential oil was high in Suvarna and IISR Kedaram (5.6%). Micronutrient composition, protein, carbohydrate, energy, DPPH scavenging activity and α-glucosidase inhibitory activity was comparable in these varieties. Ar- turmerone, ar-dihydroturmerone and curlone contributed 55-60% of the essential oil. Notable difference was observed in Suvarna with low turmerones and comparatively higher level of zingiberene and β- sesquiphellendenre. Curcumin, BDMC and DMC showed positive correlation with antioxidant and antidiabetic potential.

Quality characterization of GI (Geographical Indication) turmeric

The phytochemical constituents, nutraceuticals, and bioactivities of four GI turmeric (Erode Turmeric, Kandhamal Haldi, Waigaon Turmeric and Sangli Turmeric) in India were characterized. The results revealed considerable differences in major quality parameters *viz*., essential oil (4.00-5.60%), oleoresin (8.36-18.12%) and curcuminoids (2.23-5.50%). Among the GIs, Waigaon Turmeric was superior in quality and for rhizome traits. The Erode Turmeric contained significantly high protein (4.64%) and several minerals (K, Ca, Fe and Mg). The IC_{50} values of DPPH scavenging assay (160.72 µg/ml – 194.25 µg/ml) and α-glucosidase inhibitory assay (126.50 µg/ml - 146.57 µg/ml) ensured the potent antioxidant

and anti-diabetic activity of GI turmeric. The GC-MS fingerprints of essential oil unveils six major compounds ar-turmerone, β-sesquiphellandrene, α-zingiberene, α-curcumene, α-turmerone and curlone.

Molecular characterization

Out of the 57 microsatellite markers tested in 18 released varieties of turmeric, 56 were polymorphic. The average number of alleles per genotype per marker ranged from 1 to 3.44, with most markers showing two alleles in accordance with the reported triploid status of turmeric. The marker with the highest average number of alleles per genotype was CuMiSat 08 and UBC 889 with 3.44 allele; while with the lowest average number of alleles per genotype were UBC 896, CuMisat-01, CuMisat-25, CuMisat-31, CuMisat-33, CuMisat-36, Clest-04, Clest-06, Clest-08, Clest-09, Clest-11, Clest-13 and Clest-17 each with 1 allele. The Polymorphic Information Content (PIC), calculated to estimate the discriminatory power of each locus, ranged from 0 for CuMiSat 36 to 0.5 for CuMisat-33, with a mean PIC of 0.38. The markers utilized here are very informative and can be recommended for molecular studies in turmeric.

Maintenance of seedling progenies, hybrids and inbreds

First generation seedlings (212), mother genotypes (22), second generation seedlings (431), third generation seedlings (30), first generation inbreds (840), second generation inbreds (6), third generation inbreds (402) and fourth generation inbreds (149) and four inter-varietal hybrids were maintained. One hundred and seventeen F_2 progenies (36 H1 and 81 H2), and nine open-pollinated progenies of high curcumin line SLP 389/1 were also maintained. Additionally, inter-cross hybrids (29), back cross hybrids (7), OP progenies of two inter-varietal hybrids (30) and 60 somaclones were also maintained.

Second generation OP seedlings of SLP 389/1

Replicated trial involving five second generation OP progenies of SLP 389/1 namely SLP 389/1-OP-1, SLP 389/1-OP-4, SLP 389/1-OP-5, SLP 389/1-OP-6 and SLP 389/1-OP-7 were laid out in three replications at Chelavoor and Experimental Farm, Peruvannamuzhi. At Chelavoor SLP 389/1-OP-4 produced highest yield of 12.97 kg/3m^{2}bed followed by SLP 389/1-OP-6 with 10.26 kg/3m^{2}bed. At Experimental Farm, Peruvannamuzhi, SLP 389/1-OP-1 produced highest yield of 8.8 kg/3m^{2}bed followed by SLP 389/1-OP-4 with 8.2 kg/3m^{2}bed. All the seedlings except SLP 389/1-OP-7 showed dry recovery above 20% at both the locations (Table 5).

Table 5. Yield (kg/bed) data from the trial at Chelavoor and Peruvannamuzhi

Identity	Chelavoor		Peruvannamuzhi	
	Mean Yield (Kg/bed)	Dry recovery (%)	Mean Yield (Kg/bed)	Dry recovery (%)
SLP 389/1-OP-1	9.84	22.60	8.80	20.40
SLP 389/1-OP-4	12.97	20.50	8.20	22.00
SLP 389/1-OP-5	2.50	23.70	3.50	23.90
SLP 389/1-OP-6	10.26	26.50	6.17	21.50
SLP 389/1-OP-7	9.20	19.50	2.23	22.80

Screening turmeric genotypes against leaf blotch (*Taphrina maculans)*

One ninety two turmeric genotypes were screened under natural epiphytotic conditions during August to November 2021 to identify resistant sources against leaf blotch caused by *Taphrina maculans* using 0-6 scale. The per cent disease index (PDI) was computed and the genotypes were categorized into different groups based on reaction towards the disease among which, 119 genotypes were grouped under resistant category and 4 as well as 6 genotypes under moderately susceptible and susceptible categories, respectively. Sixty three genotypes were grouped under highly susceptible category and no genotypes were found to be moderately resistant towards the disease (Table 6). In moderately susceptible genotypes, the apparent infection rate (r) was maximum (0.0305) during October-November while it was maximum during September-October in susceptible (0.0531) and highly susceptible (0.1127) genotypes. The area under disease progress curve (AUDPC) registered the maximum with highly susceptible (723.35) followed by susceptible (432.5) and moderately susceptible (190.825) genotypes.

Table 6. Categorization of turmeric genotypes based on reaction towards leaf bloth

Category	Entries/Accessions
Resistant	**Released varieties:** Suguna, Sudarshana, IISR Pragati, IISR Prabha, IISR Pratibha, Alleppey Supreme, Uttar Ragini, CO 2, Pant Peetab, Suranjana, Suroma, Sugandham, NDH 98 **Local cultivars:** Cuddapah Local, Salem Local, Alleppey (Palakkad), Waigon Turmeric, Amballur, Rajapuri, Kandiala Haldi, Santra **Breeding lines:** RRN 2, RRN 1, RRN 3, RRN 4, SL 3, SL 5, SL 9, SL 8, SL 6, SL 4, SL 2, SL 14, Mydukur 8/16, MK 1, MK 3, MK 4, MK 7,69/5/22/I_1, 69/5/22/I_2, 69/5/22/I_3, 69/5/22/I_4, 69/5/22/I_5, 69/5/22/I_6, 69/5/22/I_7, 69/5/22/I_8, 69/5/22/I_9, 69/5/22/I_{10}, 69/5/22/I_{11}, 69/5/22/I_{12}, 69/5/22, BSR White, SLP 389/1 **Germplasm accessions:** Acc. 1545, Acc. 379, Acc. 849, Acc. 14, Acc. 214, Acc. 636, Acc. 582, Acc. 610, Acc. 620, Acc. 624, Acc. 619, Acc. 629, Acc. 621, Acc. 637, Acc. 707, Acc. 761, Acc. 830, Acc. 612, Acc. 580, Acc. 570, Acc. 617, Acc. 661, Acc. 596, Acc. 618, Acc. 567, Acc. 672, Acc. 599, Acc. 269, Acc. 286, Acc. 297, Acc. 300, Acc. 313, Acc. 376, Acc. 415, Acc. 449, Acc. 902, Acc. 235, Acc. 200, Acc. 161, Acc. 138, Acc. 84, Acc. 79, Acc. 19, Acc. 8, Acc. 2, Acc. 140, Acc. 119, Acc. 83, Acc. 63, Acc. 55, Acc. 53, Acc. 52, Acc. 50, Acc. 41, Acc. 29, Acc. 3, Acc. 332, Acc. 236, Acc. 221, Acc. 208, Acc. 15, Acc. 61, CL 272, PTS 50
Moderately resistant	Nil
Moderately susceptible	**Released varieties:** Chhattisgarh Haldi 2, NDH 8 **Germplasm accessions:** Acc. 23, IT 26
Susceptible	**Released varieties:**

Highly susceptible	Varna **Local cultivars:** Uganda Turmeric, Koirana, Dehati Haldi **Germplasm accessions:** Acc. 224, Acc. 80 **Released varieties:** Pitmaber, Rajendra Sonali, CO 3 (CL 34), BSR 1, BSR 2, Megha Turmeric, Roma, Kedaram, Suvarna, PH 1, Sona, Shobha, Kanthi, Rashmi **Local cultivars:** Mydukur Local, Mydukur White, Erode Turmeric, IHT Assam, Hasgova, Surkha, Futi Halood **Promising selections:** SL 1, SL 7, SL 10, SL 11, SL 13, SL 12, MK 6, MK 5, MK 2 **Germplasm accessions:** Acc. 258, Acc. 564, Acc. 577, Acc. 590, Acc. 560, Acc. 614, RH 9/90, Acc. 780, Acc. 821, Acc. 887, Acc. 1504, CO 1, Acc. 184, Acc. 171, Acc. 146, Acc. 142, Acc. 130, Acc. 1, Acc. 66, Acc. 58, Acc. 56, Acc. 45, Acc. 39, Acc. 24, NTC 192, NTC 193, CL 21, NVST 84, NVST 56, PTS 47, CL 223, PTS 6,

0.0 to 10 = Resistant (R), 10.1 to 20 = Moderately Resistant (MR), 20.1 to 40 = Moderately Susceptible (MS), 40.1 to 60 = Susceptible (S), > 60 = Highly Susceptible (HS)

Biotechnology

A novel candidate gene, O-methyltransferase from rhizomes of *Curcuma longa* was isolated and characterized by comparative transcriptome approach. Thirty-four O-methyltransferase unigenes were identified from the transcriptome. The full-length sequence of O-methyltransferase was identified from *Curcuma longa* using inverse PCR technique from genomic DNA.

Another novel gene, 1R MYB was identified, cloned and characterized through a comparative transcriptome analysis. The novel MYB was designated as *ClMYB1R1*, which encoded a putative *MYB*-related TF of 693 bp Open Reading Frame (ORF) carrying 230 amino acids encoding a protein of 25KDa with pI 9.51. The protein was predicted to consist of a single helix-turn-helix *MYB*-like motif and other residues, which are highly conserved among other *MYB*-related TFs. UV-C light was found to upregulate the expression of *ClMYB1R1*, while under salt and nutrient stresses, expression was down regulated and rhizomes exhibited maximum expression. The expression of *ClMYB1R1* correlated well with that of the candidate pathway gene *ClPKS11* in all the cases, indicating its putative role in regulation of curcumin biosynthesis.

qRT-PCR based screening strategy of turmeric lines for curcumin

A simple screening strategy based on expression levels of key genes *viz.*, *ClPKS11*, *ClPAL2*, *ClOMT2* and *ClOMT3* was standardised. Ct values below 22, indicate high curcumin lines, while Ct values above 25 indicates low curcumin lines. The method was validated using blind samples from a breeding population and the results showed a 100% match with conventional method. The method is non-destructive, requires very low quantities of plant tissue and can be completed within a day at 4th month of planting. The curcumin-based biomarkers may be used singly or together for more accuracy. The technique developed

could be employed as a useful tool in different scientific fields for characterizing and estimating the curcumin status in plants during development.

Identification and characterisation of a novel ZIP transporter gene

A novel ZIP transporter gene of 1268 bp gene encoding 366 amino acids (ORF-1101 bp) was cloned and sequenced from *Curcuma longa*. *In silico* analysis and deduced protein structure designated *ClZIP1* to Zn/Fe-regulated transporter (ZRT/IRT)-related protein (ZIP) family with 70.0% identity to Zn transporters from *Musa acuminata*. A 685 bp promoter sequence was identified with transcription start site located at 546 bp and TATA box with maximum score (6.258) at 513 bp. About 33 cis regulatory elements were predicted using Plant CARE database from both strands of *ClZIP 1*, which involves MYC and MYB binding sites and other response elements such as TCT-motiff, TGACG-motiff, G box, ABRE etc. A single 10-bp imperfect palindromic ZDRE motif sequence ATGTCGAACT was identified in the upstream region at 517 bp. ClZIP1 possessed eight Transmembrane (TM) domains with a variable region between TM-3 and TM-4 and conserved histidine-rich ZIP signature motif. *ClZIP1* expression evaluated in plantlets *in vitro* in the presence of ZnO (10-100 ppm), with/without ZSB indicated that it was higher in basal portion than leaf. High expression was observed in absence of ZSB and *vice versa* with maximum down regulation at 100 ppm (88%). This is the first report on ZIP gene from turmeric and suggests that *B. safensis* increases bioavailability of Zn in turmeric (Fig. 16).

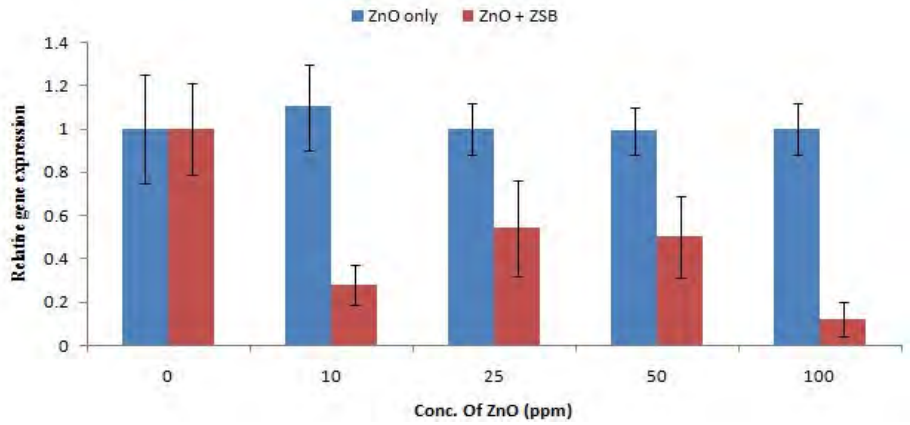


Fig. 16. Relative gene expression of ClZIP1 in basal tissue of turmeric at different concentration of Zn in the presence and absence of ZSB (Zn solubilizing bacteria, *B. safensis*) Vertical bars represent standard errors

Organic farming

Twelve turmeric varieties (IISR Prathibha, IISR Alleppey Supreme, Varna, Sobha, Sona, Kanthi, Suvarna, Suguna, Sudarsana, IISR Kedaram, IISR Prabha, IISR Pragati) were grown under 100% organic management system; 75% organic and 25% integrated nutrient management, 50% organic and 50% integrated nutrient management and 100% inorganic management respectively. Organic 100% recorded maximum organic carbon, nitrogen, phosphorus calcium, magnesium and iron in soil samples collected 120 days after planting turmeric**.** Acid phosphatase, alkaline phosphatase, dehydrogenase activities were higher in organic management. However, inorganic system recorded maximum yield (33.1 t/ha). Among the varieties, IISR Pragati recorded the highest yield (41.4 t/ha). Under organic management, Suguna and Sudarshana had maximum yield (37 t/ha) followed by Suvarna and IISR Pragati (Fig. 17).

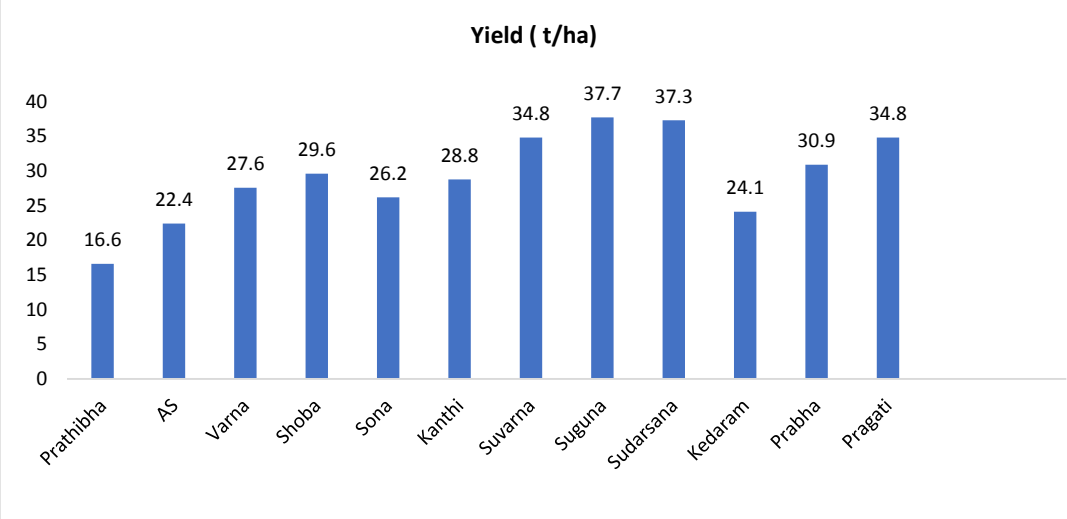


Fig. 17. Yield of turmeric genotypes under organic management

Evaluation of weed management practices under organic production system in turmeric

Application of dried coconut leaf at the time of planting, hand weeding at 45 and 90 DAP recorded maximum yield, net returns (2 lakhs/ha) and reduced cost of cultivation (2.23 lakh/ha).

Development of integrated organic farming system model with turmeric

A plot with spices, fodder, and vegetable combinations was established at Chelavoor farm. Crops such as black pepper, turmeric, fodder grasses (Congo signal grass, CO-3, CO-4), tapioca, banana, cowpea and coconut were planted and established (Fig. 18). Two cows and their calves were maintained. Turmeric 1200 kg, banana 625 kg, tapioca 900 kg, vegetable cowpea 240 kg and coconut 1210 kg were harvested from the plot. Fodder grass was fed to the cows that are maintained at the IISR farm. A profit of Rs.2.1 lakhs was obtained from one acre. Employment generated was 295 man days/year.

Fig. 18. Different components of spices based integrated farming system model

Development of spice based dairy products of nutraceutical importance

ICAR-Indian Institute of Spices Research, Kozhikode has developed a novel spice mix formulation for turmeric milk preparation by overcoming the problem of insolubility with enhanced bio-available active ingredients. The key ingredients of the spice mix are turmeric, ginger and cinnamon. The water soluble extracts of these constituent spices were used in a powder form to make an instant soluble spice mix. ICAR-IISR has developed three different technologies for turmeric milk preparation: (i) a ready to serve sterilized flavoured turmeric milk, (ii) a turmeric milk mix instant powder and (iii) a ready to serve spiced butter milk. The technology is successful in making an instant fully soluble spice mix powder for turmeric milk and butter milk preparation. Water insolubility, the inherent problem associated with turmeric was successfully overcome by using only soluble form of turmeric. The curcumin found in the soluble fraction of turmeric powder is largely bio-available. The spice mix is amenable for fortification with any flavour of choice depending upon the consumer preference. The liquid equivalent form of the developed spice mix powder has also been optimized for commercial production of turmeric milk. The spice mix blend, with its rich flavour and antioxidant properties, makes it nutritious, delicious and a perfect health drink.

Antioxidant and antidiabetic activity of Curcuma caesia

Petroleum ether and methanol extracts of *Curcuma caesia* were evaluated for antioxidant and antidiabetic potential. Antioxidant potential was determined by DPPH radical scavenging property and ferric reducing property and antidiabetic potential by α-glucosidase activity. Methanol extract showed higher activity in both the cases. In order to characterise the active compounds, petroleum ether extract was subjected to column chromatography and the major compounds identified were 1,8-cineole, camphor, isobornyl acetate, curzerenone and β-elemene.

Evaluation of Bacillus safensis *for P and Zn solubilization and disease antagonism*

Evaluation of *B. safensis* (IISR TB4) and *B. cereus* (IISR GB7 (3)) for plant growth promotion and P solubilization under greenhouse conditions showed significant increase in yield with 75% recommended P compared to the individual application of IISR TB4, IISR GB7(3) and 75% P. The treatments with combined application of IISR TB4 & IISR GB7(3) +75% P, IISR GB7(3) +75% P and IISR TB4 + 75% P recorded 528.75, 508.75 and 511.25 g/plant, respectively, whereas in treatment with individual application of P @75%, yield recorded was 201.25 g/plant. Increase in physico – chemical parameters *viz.*, organic carbon, available nitrogen etc. and microbial parameters like microbial biomass C, N, and dehydrogenase enzyme activity was observed in PGPR applied soil.

Evauation of multi trait *B. safensis* for plant growth promotion and zinc solubilization in turmeric under greenhouse conditions showed that the treatment combined application of Zn - 5 ppm (source – ZnO) + *B. safensis* was found to be superior with increase in physico – chemical parameters *viz.*, organic carbon, available nitrogen etc. and microbial parameters like microbial biomass C, N, and dehydrogenase enzyme activity in soil. *B. safensis* was evaluated for P solubilization potential and disease antagonism in turmeric under field conditions. Under field conditions, the treatments, application of IISR TB4 alone and in combination of IISR TB4 +75 % P were found to be the best.

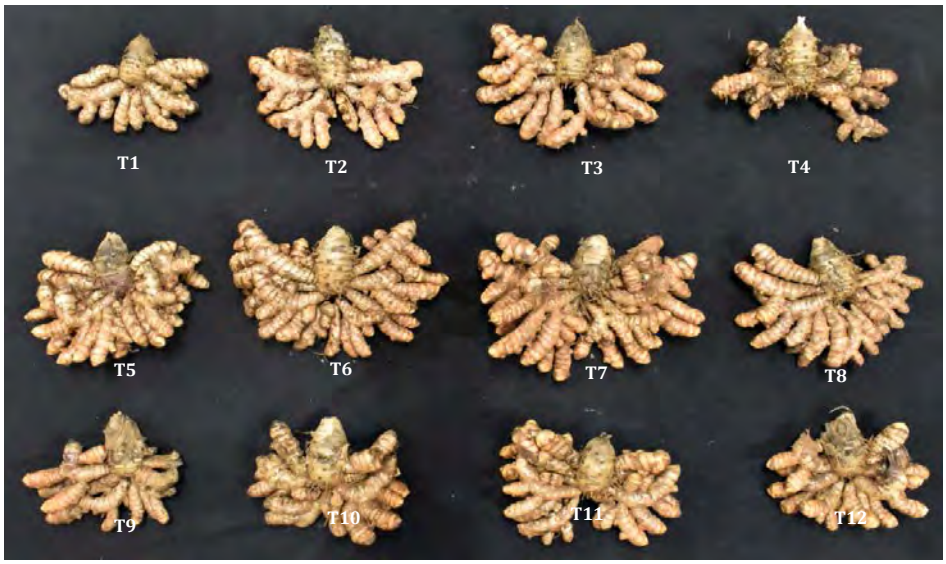


Fig. 19. Evaluation of *Bacillus safensis* for growth promotion and zinc solubilization. T1 – Control -without zinc (Zn), T2- 2.5 ppm Zn, T3- 5 ppm Zn, T4- 10 ppm Zn, T5- *Bacillus safensis* alone, T6- 2.5 ppm Zn + *B. safensis*, T7- 5 ppm Zn + *B. safensis*, T8- 10 ppm Zn + *B. safensis*, T9- GdPal5 (Reference strain), T10- 2.5 ppm Zn + GdPal5, T11- 5 ppm Zn + GdPal5, T12- 10 ppm Zn + GdPal5

*Shoot borer (*Conogethes punctiferalis*)*

Spray schedule optimization of new generation low risk insecticides

Low risk insecticides (chlorantraniliprole, flubendiamide and spinosad), which were found to be effective earlier at two different doses (0.3 and 0.5 ml/l) and a combination treatment of spraying chlorantraniliprole and spinosad alternatively (0.5 ml/l) were screened under field conditions at Peruvannamuzhi farm for spray schedule optimization at two different spray schedules (i.e. 15 and 30 days' interval) against shoot borer infesting ginger and turmeric for the second consecutive year. Trials confirmed that spraying of insecticides at fortnightly intervals is more effective compared to spraying at monthly intervals.

Field evaluation of *Metarhizium pingshaense*

M. pingshaense fungus was tested at three different doses along with an insecticide control, chlorantraniliprole at Chelavoor, Kozhikode at a spray interval of 21 days under field conditions against shoot borer infesting turmeric. Results indicated that spraying of the fungus at a dose of 1×10^7 conidia/ml was effective in managing the pest.

Influence of plant phenology and crop duration on the occurrence of shoot borer

The influence of crop duration and phenology with respect to the seasonal incidence of *C. punctiferalis* infesting turmeric was studied by recording the incidence of the pest at fortnightly intervals. Two short duration varieties (IISR-Pragati and Rajendra Sonia), two long duration varieties (IISR-Prathiba and IISR Alleppey Supreme) and an extra-long duration variety (Acc. 849) of turmeric were used in this study. Results indicated that irrespective of the duration of the crop, the pest incidence started during the first week of August and peak incidence was in October/November.

Plant parasitic nematodes

Evaluation of nematicides against lesion nematodes

Fluopyram and fluensulfone, newly registered nematicides, were evaluated in turmeric fields for management of lesion nematode, *Pratylenchus* spp. Different treatments were imposed at time of sowing and compared with carbofuran (check) and untreated control. All the treatments significantly reduced the nematode population and improved the yield of plants. Among the treatments, application of fluopyram (@0.75 ml/l) was superior in reducing the nematode population both in rhizomes and soil, rhizome rot, enhanced the yield followed by fluopyram 0.5 ml/l and fluensulfone 20 g/bed and carbofuran 20 g/bed (Table 7).

Table 7: Field evaluation of new nematicides against lesion nematode, *Pratylenchus* spp., infesting turmeric

Treatment	Nematode population		No. of tillers/ plant	Rhizome rot %	Yield/bed (kg/bed)
	In soil	In rhizome			
Fluopyram 0.75 ml/l	11.3 (1.04)^{e}	3.3 (0.47)^{d}	4.0 (0.59)^{a}	0.6 (0.20)^{d}	16.0 (1.20)^{a}
Fluopyram 0.5 ml/l	27.0 (1.43)^{d}	5.3 (0.72)^{c}	3.5 (0.52)^{a}	4.0 (0.69)^{c}	11.2 (1.04)^{b}
Fluensulfone 20 g/bed	54.3 (1.73)^{c}	42.0 (1.62)^{b}	3.5 (0.53)^{a}	10.0 (1.02)^{b}	10.2 (1.01)^{b}
Fluensulfone 10 g/bed	72.6 (1.85)^{b}	55.6 (1.74)^{b}	3.3 (0.51)^{a}	35.3 (1.56)^{a}	6.8 (0.83)^{c}
Carbofuran 20 g/bed	52.3 (1.71)^{c}	37.0 (1.56)^{b}	3.1 (0.49)^{a}	12.0 (1.09)^{b}	11.4 (1.05)^{b}
Control	125.0 (2.09)^{a}	105.3 (2.02)^{a}	2.1 (0.33)^{a}	45.0 (1.65)^{a}	5.8 (0.76)^{c}

Figures in parenthesis are log transformed values. Numbers followed by the same alphabets are not statistically different.

VANILLA

Conservation

A total of 65 accessions of *Vanilla planifolia*, 7 *Vanilla* spp. from Andaman Island, one each of *Vanilla pilifera*, *Vanilla aphylla*, *Vanilla tahitensis* and *Vanilla wightiana*, two species from wayanad, one species from Assam, one *Vanilla planifolia* from Senkottai, Tamil Nadu and 3 species from Little Andamans were added to the conservatory.

Field evaluation

The selected 11 accessions (Acc. 4701, Acc. 4714, Acc. 4716, Acc. 4723, Acc. 4738, Acc. 4741, Acc. 4742, Acc. 4760, Acc. 4761, Acc. 4762, Acc. 4772) with >15 cm bean length was multiplied for field evaluation.

Molecular characterization

Molecular characterization of 22 genotypes comprising of Vanilla accessions (11), Andaman collection (2), Wayanad collection (2) and other *Vanilla* spp (7) were done using 20 ISSR primers. A total of 143 scorable alleles were generated by 18 ISSR primers. Among the 18 primers used for ISSR analysis, primers UBC 818 had the highest number of ISSR loci (11) followed by primers UBC 822 with 10 loci (Fig. 20).

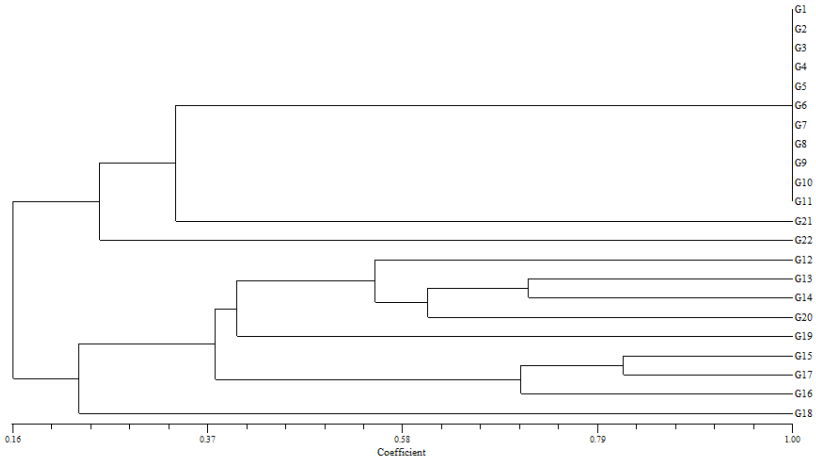


Fig. 20. Dendrogram derived from a UPGMA cluster analysis of ISSR marker using Jaccard' similarity coefficient of *Vanilla sp*. **(**G1: Acc.4701, G2: Acc.4714, G3: Acc.4716, G4:cc.4723, G5: Acc.4738, G6: Acc.4741, G7: Acc.4742, G8: Acc.4760, G9: Acc.4761, G10: Acc.4762, G11: Acc.4772, G12: Acc. JPN 20-69, G13:Acc. JPN 20-58, G14: Wayanad collection 1, G15: *V. pilifera*, G16: Acc.4795, G17: Wayanad collection 2, G18: *V. wightiana*, G19: *V. aphylla*, G20: *V. tahitensis (a)*, G21: *V.tahitensis(b)*, G22 :*V. sp.)*

Quality profiling

The biochemical parameters like total phenolics, total flavonoids and total soluble sugars were studied in *Vanilla planifolia, V. pilifera, V. aphylla* (Table 8.)

Table 8. Quality profile of *Vanilla* spp

Parameter (mg/g)	***V. planifolia***	***V. pilifera***	***V. aphylla***
Total phenolics	13.5 to 18.2	6.7	7.9
Total flavonoids	0.38 to 1.31	0.59	0.49
Total soluble sugars	74.2 to 90.9	85.2	89.9

TREE SPICES

Nutmeg

DNA fingerprinting using ISSR primers was done in nutmeg varieties IISR Viswashree, IISR Keralashree and Sindhushree. About 45 ISSR primers were tried and three primers ISSR 05, UBC 841 and ISSR 01 were identified to produce distinguishable markers.

Application of organic manure and benzyl adenine for maximising yield

To study the influence of benzyl adenine (BA) application and integrated nutrient management on the growth and yield of nutmeg**,** organic manures along with recommended

nutrients were given as basal application for the nutmeg variety Viswashree every year and micronutrients and benzyl adenine were given as foliar spray for selected treatments during May and September. Observations on canopy spread, yield, and scion production were recorded per plant. Pooled analysis of data (2018-2020) revealed that among the treatments, application of coir pith compost (5 kg/plant) during May, soil application of recommended nutrients (250:125:500 g/plant) during June and September, foliar spray of micronutrient (0.5%), and spraying of BA (10 ppm) at June and September recorded maximum canopy growth/plant, scion production and fruit yield per plant.

Eugenol as a potential bioprotectant for aflatoxigenic *Aspergillus flavus*

Eugenol, a major aromatic constituent of clove essential oil was tested for its efficacy in controlling growth and development of aflatoxigenic *Aspergillus flavus* in nutmeg and chilli. Eugenol reduced the emergence of *A. flavus* contamination on chilli and nutmeg for more than 3 months. The data showed that the minimum inhibitory concentration (MIC) of eugenol for spore germination and hyphal growth and development was 0.15 µl/ml and 0.4 µl/ml respectively. Eugenol significantly reduced the germ tube length, dry mycelial weight and size of fungal pellet, when applied to *A. flavus* liquid culture. The *in vivo* production of secreted aflatoxin was significantly reduced due to eugenol treatment at MIC. Quantitative PCR studies carried out to check the differential expression of genes involved in aflatoxin and ergosterol synthesis revealed that genes except erg 25 were found to be down regulated due to eugenol in a dose dependent manner. Eugenol treatment delayed spore germination of *A. flavus* by 33 hours and 48 hours at 0.5 MIC and 1 MIC of eugenol respectively. These findings strongly suggest eugenol as a potential agent for the management of *A. flavus* contamination in chilli and nutmeg.

Cinnamon

Genetic resources

Cinnamomum perrottetii (Fig.. 21), *C. wightii*, *C. sulphuratum* (Fig.. 22) and two unidentified species were collected from reserve forests at Iravikulam, Pettimudi, Rajamala, Mannavan Shola and Anakkulam in Idukki district of Kerala. Another wild species was collected from Senkottai in Thenkasi district. Three cinnamon accessions with high quality from Idukki and another accession from Kozhikode district were also added to the germplasm.

Fig. 21. *Cinnamomum perrotettii*

Fig. 22. *Cinnamomum sulphuratum*

Clove

Surveys were conducted in major clove growing tracts of India during the year and 15 accessions of clove comprising of unique variants and high yielding accessions were

collected. The collection included 6 clove accessions with bold flower buds (King clove), two dwarf types, one semi dwarf type, one small flowered type and five high yielding accessions (Fig. 23). Fresh clove samples collected from clove growing tracts at Thalanadu in Kottayam district, Kalikavu in Malppuram district, Kattippara, Thottilpalam in Kozhikode district, Senkottai in Thenkasi district, Aryankavu, Ambanadu in Kollam district and Nagercoil in Kanyakumari district were analysed during this year and the oil content varied from 12.0 to 17.1%.

Fig. 23. Comparison of the dried flower buds of normal clove and King clove

Garcinia

G.conicarpa (Fig. 24), *G. Pushpangadaniana* (Fig. 25), *G. talbotii*, three endemic species of *Garcinia* in Western Ghats and a bold fruited accession of *G. gummi-gutta* were collected from the reserve forests in Idukki district. Two exotic species namely *G. Warrenii* and *G. puat* were collected from farmer's field. Yield data of *G. gummi-gutta* accessions at Peruvannamuzhi was recorded. The fresh fruit weight varied from 71 to 160 g, fresh fruit to dry rind recovery varied from 8.31 to 11.36 percentage and the dry rind yield per tree varied from 0.63 to 5.15 kg among the accessions.

Fig. 24. *Garcinia conicarpa*

Fig. 25. *Garcinia pushpangadaniana*

Allspice

Unique markers were identified in *Pimenta dioica* for distinguishing from *Pimenta racemosa.* Primer ISSR02 provided an unique marker of size 400 bp in the former and 430 bp in the latter (Fig. 26)

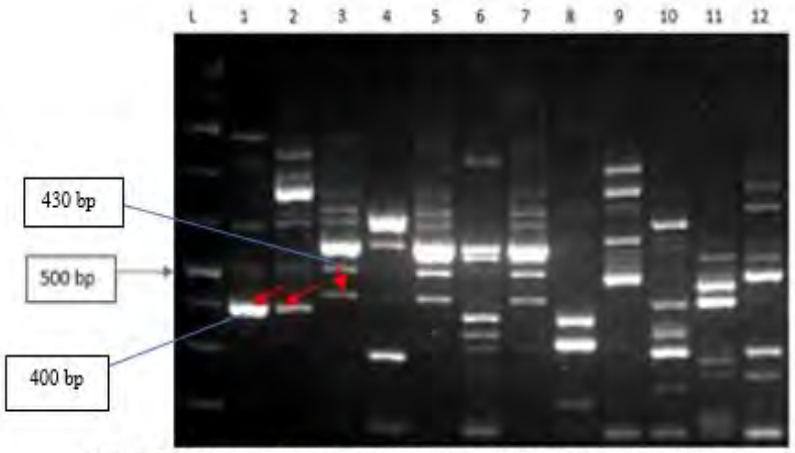


Fig. 1. L-1Kb plus ladder; Lane 1 *Pimenta dioica* Tree 1, Lane 2 *Pimenta dioica* Tree 2 (Peruvannamuzhi farm); Lanes 3 to 12 *P.racemosa* leaf samples from Chelavoor farm; Primer ISSR-02.

Fig. 26. Fingerprint analysis of two *Pimenta* spp

GENERAL

DNA finger printing

DNA fingerprinting and barcoding facility (DNAFF)

DNA profiling of new varieties of turmeric, fennel, coriander, fenugreek, ajwain, nigella *etc.* from the AICRPS centres was carried out and identified unique DNA markers for establishing unique status of new varieties. Details of all new varieties of spices facilitated for registration through CVRC during 2020-21 is provided in Table 9.

Table 9. Details of new varieties of spices fingerprinted

S. No	Crop	Candidate variety	Status of registration under CVRC	Name of the firm/ institute/ person submitting the sample
1	Coriander	JD(S1)-1	Gazette notification No. S.O. 1480(E) dated 1 April 2021	Dept. of Horticulture, JNKVV, Jabalpur
2	Celery	Ajmer Celery-2	Gazette notification No. S.O. 1480(E) dated 1 April 2021	NRCSS, Ajmer
3	Fenugreek	AM-1	Gazette notification No. S.O. 1480(E) dated 1 April 2021	AICRPS, Kota
4	Turmeric	TCP-129	Gazette notification No. S.O. 1480(E) dated 1 April 2021	Uttar Banga Krishi Viswa Vidyalaya, Pundibari
6	Coriander	CG Raigarh Dhaniya-3	DNA fingerprinting report submitted to respective AICRPS Centres	CARS, Raigarh
7	Fennel	RF-289 (UF-289)		SKNAU, Jobner
8	Turmeric	Rajendra Haldi-1		RPCAU, Muzaffarpur

DUS testing facility

ICAR-IISR is the nodal DUS testing centre for black pepper, ginger, turmeric and small cardamom and also the co-nodal centre for nutmeg. At present 21 example varieties of black pepper are being maintained at CHES, Chettalli. Example varieties of black pepper are multiplied and maintained at Peruvannamuzhi. Fifteen cardamom varieties are being maintained at RegionalStation, Appangala. Twenty nine example varieties of ginger and 35 varieties of turmeric are maintained and multiplied at Peruvannamuzhi and Kozhikode. Two ginger, four turmeric, four black pepper and six cardamom farmers varieties are under DUS testing/ onsite evaluation.

This yearthe Authority issued registration certificate for two farmers varieties of black pepper *viz*. Sigandini to Mr. Ramakanth Ramachandra Hegde, Siddapur, Uttara Kannada and Adi pepper (*Piper relictum*) to Mr. Poonacha, Madapura, Madikeri. So far, the authority has issued certificate for 9 black pepper varieties (5 Farmer & 4 VCK) and 9 small cardamom varieties (6 Farmer, 2 VCK & 1 Extant).

Bioinformatics centre

Black pepper genome gap filling

The gapped regions in chromosome PN1 and PN13 were identified comparing with the reference genome of black pepper. In house scripts were developed to identify the sequence of the missing regions. The annotations of gapped regions revealed cytochrome P450 78A7-like and copper methylamine oxidase-like genes in PN1.

Phytophthora-host interaction prediction

Published protein-protein interactions between Phytophthora and its hosts were utilized for developing a model for interaction prediction. Supervised learning algorithms- Support vector machine (SVM) and novel combination of ensemble methods were applied to predict interactions. Different protein features of host and pathogen proteins like amino acid composition, dipeptide composition, pseudo amino acid composition, amphiphilic pseudo amino acid composition, C/T/D, conjoint triads, autocorrelation, sequence order coupling number, quasi-sequence order descriptors were utilized to develop the model for binary classification, and protein interaction. The relative importance of different protein features in the training model was also evaluated. SVM with radial kernel had an accuracy of 75%. Bagging Algorithm Random Forest showed an accuracy of 84.6%. A GLM ensemble of K-Nearest Neighbour (KNN), SVM (radial), rpart and random forest gave an accuracy of 70.1%. The model developed can be trained with more experimentally validated interactions to improve the accuracy. Further, a protein-protein interaction network of host and pathogen proteins was constructed to depict the interaction network operating during pathogenesis.

Post-harvest processing

Optimisation of production of spice based non- dairy oats milk

Spice based flavoured oats milk was prepared by addition of spices in the form of oleoresin to the oats milk optimised with sugar. The spice oleoresins of turmeric (curcumin content 10%), ginger (gingerol content 14%) and cinnamon powder (powdered to 60 mesh) were used to obtain the flavoured oats milk. The highest overall acceptability of 8.37 was obtained for spice flavoured oats milk (unsterilized) prepared at a concentration of 2% oats fortified with turmeric oleoresin. The curcumin content of final product was 63.9 ppm for unsterilized and 51 ppm for sterilised oats milk. The antioxidant activity (IC_{50} value) of sterilised and

unsterilized oat milks were 30.44 µM and 30.44 µM, respectively. From the study, it was concluded that oats milk prepared with 2% concentration of oats powder, enriched with turmeric oleoresin (10% concentration of curcumin) at the rate of 50 mg/100 ml milk, ginger oleoresin (14% concentration of gingerol) at the rate of 10 mg/100 ml of milk and cinnamon powder at the rate 50 mg/100 ml milk, produced the most preferred oats milk with an overall acceptability value of 8.3 (for unsterilised milk) and 8.37 (for sterilised milk).

Optimization and development of spice enriched finger millet cookies

Spice enriched finger millet cookies were prepared by adding different spices in three different concentrations *viz.* cardamom (3, 4 and 5%), black pepper (10, 12.5 and 15%), cinnamon (3, 4 and 5%), nutmeg (4, 5 and 6%), curry leaves (5, 7 and 9%), bird's eye chilli (1, 2 and 3%), fresh ginger paste (30, 35 and 40%) and spice blend (6, 8 and 10%) to get unique flavour of each spice in the fortified cookies.

The results of the study indicated that cookies developed with the addition of finger millet flour up to 40% showed an overall acceptability score of 8.4, moisture content of 3.52%, spread ratio of 5 and hardness of 12.2 N and was comparable to that of marketed refined wheat flour cookies. Flavour of spices was optimized based on the overall acceptability score and the study indicated that the finger millet cookies fortified with 40% finger millet flour and 4% cardamom seed powder obtained the highest overall acceptability score of 8.5. The cardamom flavoured cookies ranked first in sweet flavour category with moisture content of 3.45%, spread ratio of 4.8 and hardness of 9.9 N. Under pungent flavour category, cookies fortified with 40% finger millet flour and 12.5% black pepper powder ranked first with an overall acceptability score of 7.0, moisture content of 3.43%, spread ratio of 4.5 and hardness of 8.39 N.

Soil microbial community under nano zinc contamination

Shifts in bacterial community structure and metabolic functions in nanoZnO contaminated soil

Effects of different concentrations of ZnO nanoparticles (nZnO) on soil bacterial community structure and metabolic functions were investigated in a near neutral soil. Zn was applied as nZnO (nanoZnO) and bulk ZnO (bZnO) at 0 ppm, 10 ppm, 50 ppm, 100 ppm, 200 ppm, 500 ppm and 1000 ppm. The Raw sequence data of dominant bacterial communities generated from Illumina sequencing were processed and analysed using the QIIME. After quality filtration, the sequences were grouped into OTUs and annotated using the SILVA database (ver. 138). Functional annotation was performed using Tax4fun. The results indicated that the relative abundance (RA) of Proteobacteria, Acidobacteria, Planctomycetes, Bacterioidetes, Nitrospirae and Patescibacteria were higher in ZnO treatments than control indicating that they can well adapt to the presence of high levels of both nZnO and bZnO. Members of phylum Firmicutes and Actinobacteria also decreased at higher concentrations of both nZnO and bZnO. The dominant bacterial genera were Bacillus, Sphingomonas, Rubrobacter, Candidatus Udaeobacter, RB1, Microvirgae, Bryobacter, Flavisolibacter, Nocardioides, Candidatus Solibacter, Streptomyces, Nitrospira, Acidibacter, Singulisphaera and Gemmata.

UpSet plot indicated that 18 phyla were shared among all the Zn treatments and control (Fig. 27). Highest number of unique phyla was observed in control (Halanaerobiaeota and uncultured) followed by one each in 1000 ppm Zn (Deferribacteres) as bZnO and 50 ppm Zn as nZnO (Lentisphaerae). Only one phylum was shared among nZnO and bZnO treatments (BRC1). The most abundant pathway (RA>2%) among the 284 pathways affected by the Zn contamination were ko02010 (ABC transporters), ko02020 (Two-component system),

ko00230 (Purine metabolism), ko00970 (Aminoacyl-tRNA biosynthesis), and ko00240 (Pyrimidine metabolism). Cluster heat map analysis of KEGG orthologs (Fig. 28) showed clustering of orthologs at higher concentrations of bZnO and nZnO. The genes that were overrepresented at higher concentrations were underrepresented at lower concentrations of Zn as bZnO or nZnO and in control indicating their role in adapting to the increased stress condition.

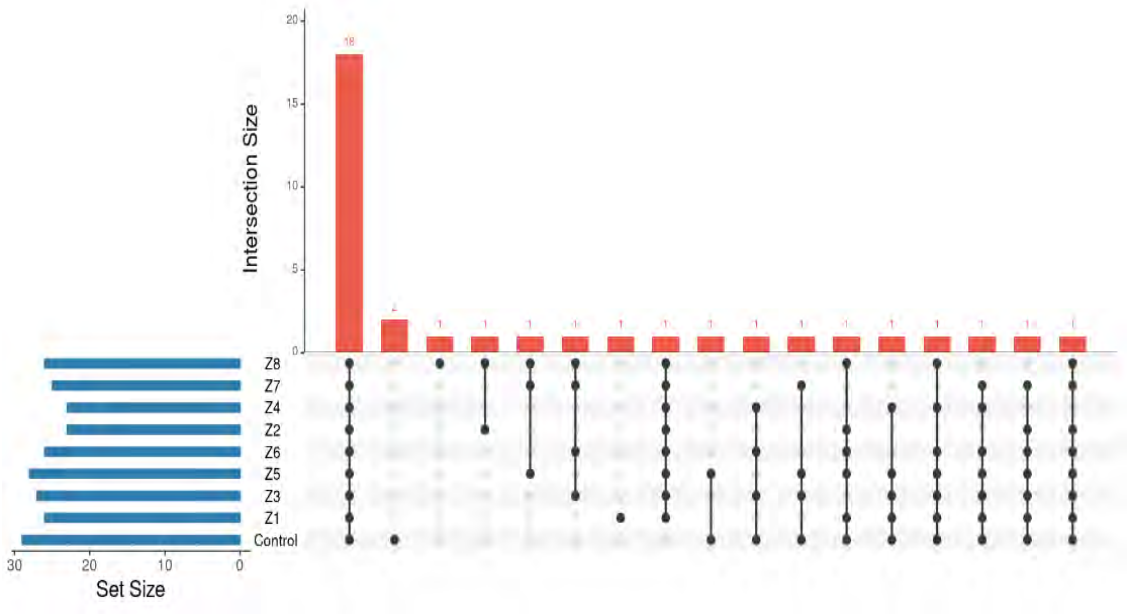


Fig. 27. UpSet plot depicting the number of unique and shared phyla between the treatments [C: Control, (Zn in ppm): Z1- 50; Z2- 200; Z3-500; Z4-1000 ppm as nZnO; Z5-50, Z6-200, Z7-500, Z8-1000 ppm as bZnO].

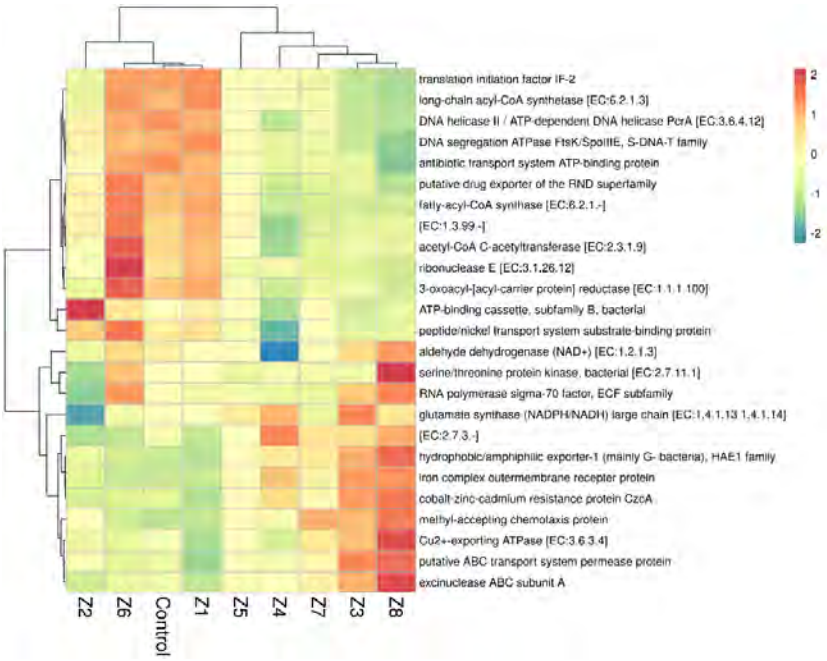


Fig. 28. Cluster heat map of the shared KEGG orthologs among the treatments [C: Control, (Zn in ppm): Z1- 50; Z2- 200; Z3-500; Z4-1000 ppm as nanoZnO; Z5-50, Z6-200, Z7-500, Z8-1000 ppm as bulk ZnO.]

Soil sustainability index under different management system in spices

The sustainability index of the soil was measured with nutrient index, microbial index and crop index and were compared under different management systems for cardamom and turmeric. The nutrient index was highest in conventional management system (1.22) whereas the microbial and crop indices were high under fully organic (1.23) and integrated systems (1.19), respectively. The overall sustainability index was the highest under INM system followed by conventional and organic systems in cardamom. In turmeric, the overall sustainability index was the highest under 100 % organic management (1.99) followed by INM (1.30) with the lowest in conventional management (0.68).

Budgeting Carbon Equivalence (CE) in spices production

The Carbon Equivalence **(**CE) from the shade trees commonly used as black pepper standards (*Glyricidia*, *Ailanthus*, *Garuga*) was worked out based on the FAO norms and existing standard procedures. Among the trees, *Ailanthus* spp. showed the highest C sequestration potential with 2.98 kg C per year (equivalent to 10.94 kg CO_2 sequestration per year) followed by *Glyricidia* spp. with a potential of 1.9 kg C per year (6.99 kg CO_2 sequestration per year) and the lowest in *Garuga* spp. with 0.8 kg C per year (2.93 kg CO_2 sequestration per year).

Production of nucleus planting materials of improved varieties

About 1,00,000 rooted cuttings of improved varieties of black pepper were multiplied from IISR Headquarters, Kozhikode and Regional Station (RS), Appangala and distributed to farmers. Improved varieties of ginger (200 beds) and turmeric (750 beds) are planted and maintained for seed production at Kozhikode Farm and Experimental Farm, Peruvannamuzhi. Ten thousand cardamom suckers were multiplied and distributed from Regional Station, Appangala. Four thousand seedlings of cinnamon varieties and 2500 grafts of nutmeg were produced for distribution to farmers. Farmers participatory seed production of ginger (var. IISR Varada) is being taken up by signing an MOU at four farmer's plots (Mr. Cheriyan, Pulpally, Mr. Lal John Manjiappillil, Pulpally, Mrs. Bindu Jacob, Ambalavayal and Mr. Saju Mathai, Pulpally).
A contiguous area subsumed in Mattilayam watershed, Vellamunda panchayat, Wayanad district, Kerala with approximately 30,000 black pepper vines has been identified and the large-scale demonstration of production technologies namely distribution of new varieties, bio inputs and micronutrient mixtures were taken up. A nursery was established in the area for meeting their continuous planting material requirement.

ECONOMICS & IMPACT ASSESSMENT

Comparative study on productivity trends in spices & plantation crops

The productivity growth of spices and plantation crops remained attractive during the last three decades. The productivity of spices and rubber increased by more than two times during this period. The comparison of yield gains since the turn of this century indicate that except for coffee, all the other crop groups have shown substantial improvement in productivity. The yield growth was highest for spices, both for the overall period and for the period since 2000. The trends in productivity index are given in Table 10.

Table 10. Trend in productivity index (1988=100)

	Spices	Coffee	Tea	Rubber	Coconut
1988	100.0	100.0	100.0	100.0	100.0
1997	133.2	144.9	110.4	154.5	108.5
2007	184.4	149.1	101.6	190.4	126.1
2017	240.7	135.2	128.2	220.3	120.5
Yield growth since 2000 (%)	59.7	(-)19.6	28.4	32.1	13.7

Study on relationship between trade competitiveness and yield gains

Though the yield gains in absolute terms in most of the crops were above the global average gains, the relative export competitiveness as measured by RCA declined in general for these crop commodities. The table below presents the compound annual growth rates in yield and RCA of spices, coffee and tea, where substantial trade volumes were recorded. The results indicate that absolute yield gains alone may not be sufficient for improving trade competitiveness. Both internal and external trade policies like interventions or lack of it by the state, production subsidies, level of tariffs and trade barriers can affect the RCA of a commodity. Therefore, an adverse movement of RCA may be indicative of adverse trade policies or environment and not a reflection of true comparative status. In this context some of the key factors which could have affected the trade competitiveness needs to be studied further to understand the nature of competitiveness in these commodities.

Table 11. Comparative performance of yield growth and trade competitiveness (1988-2017)

Crop	**CAGR of Yield (%)**	**CAGR of RCA (%)**	**Change in Yield (%)**	**Change in RCA (%)**
Spices	2.93	(-) 2.3	107.8	(-) 51.3
Coffee	0.35	(-) 6.7	20.1	(-) 85.8
Tea	0.56	(-) 7.5	27.6	(-) 85.3

Using spice import profile analysis for targeting self-sufficiency in spices

Though spice commodities are aggregated under a common denomination, they vary widely in terms of their bulkiness, value and nature of consumption. These specificities need to be considered while designing policies for strengthening import self-sufficiency in the sector. A framework for using the import profile analysis to identify critical gaps in self-sufficiency was elucidated in spices. The framework for strategy development for self-sufficiency used a composite of parameters like crop diversity, domestic output, import dependence, relative share in imports, relative value of output, ratio of imports to exports, relevant agro-ecological factors and export orientation of commodities to identify the self sufficiency gaps. The methodology employed could bring into focus some of the disguised elements/trends in spice economy of the country, which could have a significant bearing in shaping the self-sufficiency efforts in the country. The study, considering diverse parameters, concluded that the spice economy of the country should focus on specific reasons for high imports in four commodities *viz,* pepper, clove, asafoetida, cinnamon & cassia.

Survey and analysis of clove crop economy

A primary survey was undertaken in major clove growing niche regions in South India. The survey was conducted in Nagercoil and Shenkottai in Tamil Nadu and Kozhikode, Malappuram, Ambanadu and Ponmudi in Kerala among clove plantations from 34 randomly selected clove growers. The initial results from the survey indicate that the profitability of clove plantation is highly sensitive to price fluctuations of the produce. During the last six years alone, the average whole sale price of clove has declined by more than 30 per cent. The cost of cultivation having remained constant or even increased, the profitability of the crop has steadily declined during the recent past. The declining profitability has seen many plantations cutting back on inputs and cultural operations for the crop. The harvest and post-harvest cost is the major contributor in cost of cultivation of clove. Considering the cost of routine crop management activities, the present margins does not present a profitable picture for the clove economy. This is especially worrying since India imports considerable quantity of clove and needs to expand the area under the crop to reduce its import dependence. The silver lining seems to be the considerable latent potential for enhancing profitability of the crop through adoption of scientific strategies for integrated nutrient management, crop protection and crop canopy management.

TRIBAL SUB PLAN (TSP) AND SPECIAL COMPONENT PLAN

Inputs supplied under TSP and SCSP

- Planting material of improved variety of turmeric and ginger (1000 kg seed material of turmeric variety IISR Pragati and 200 kg seed material of ginger variety IISR Varada) was distributed to tribal beneficiaries at resettlement area of Nagarhole Forest on 18 Mar 2021
- Distribution of planting material of turmeric variety IISR Pratibha to SC beneficiaries (3.5 tonnes) and one ton vermi compost at Nediyiruppu Harijan Colony, Malappuram district
- A consignment of 449 kg turmeric seed material and 320 kg ginger seed material (IISR Varada) along with inputs like *Trichoderma* bio-capsules and micronutrient formulation (20 kg) was supplied to tribal beneficiaries located at Periyar Tiger Reserve, Idukki, Kerala
- A total of 15 tonnes of turmeric seed material of IISR Pratibha was arranged for planting at Aralam farm under GoK for the benefit of tribal beneficiaries. The programme was supported jointly under TSP initiatives of both ICAR-CPCRI and ICAR -IISR.
- At Parambikulam wild life sanctuary, the Institute supplied 1000 bio-capsules to the tribal beneficiaries during June 2021
- Distribution of Water tanks to SC organic turmeric cultivators of Chelannur Krishibhavan was undertaken under SCSP programme on 22 June 2021 benefitting 100 SC cultivators
- Distribution of Water tanks and neem cake to SC organic turmeric cultivators of Parappara SC colony was undertaken under SCSP programme on 22 June 2021 benefitting 100 SC cultivators
- 600 nutmeg graft plants of variety IISR Keralasree was provided to Attappady Cooperative Farming Society for establishment of mother garden and for distribution to beneficiaries on 25 June 2021

- Bio capsules of *Trichoderma* and PGPR for black pepper (400 nos each) were supplied to tribal beneficiaries at Pooppara tribal colony, Parambikulam, Palakkad district through the Eco Development Committee of the Department of Forests, GoK on 12 August 2021
- Coconut seedlings (250 nos) were distributed to tribal beneficiaries from Hunsur and HD kote in Karnataka on 29 August 2021
- 2700 vegetable seed packets were distributed to tribal beneficiaries in Cheeyambam tribal region on 09 September 2021
- Under the TSP programme, 1200 black pepper cuttings were supplied to tribal beneficiaries at HD kote on 30 October 2021
- Black pepper planting material (200 nos) distributed to SC beneficiaries from Wayanad district on 7 December 2021

ATIC AND EXTENSION SERVICES

Training programmes

Training programmes of various duration leveraging diverse communication platforms were organized during the year. A total of 64 general training programmes aimed at transfer of technology were organized. These include training programmes conducted under project initiatives, online training programmes, off campus programmes etc. More than 4000 primary producers, processors, entrepreneurs, rural youth and women farmers directly benefitted from these training programmes

Table 12. Details of training programmes

S. No	Details of training programme	Date
1	Resource training on Soil and Plant Health Management under DBT Kisan Biotech Hub Project	05 Jan 2021
2	Resource training on Management practices for profitable black pepper cultivation under DBT Kisan Biotech Hub project	22 Jan 2021
3	Training programme on Value added food products from spices	01 Feb 2021
4	Farmers training programme on marketing strategies and post harvest value addition in spices	03 Feb 2021
5	Training and exposure visit on spice production technologies under ATMA, Bantawala (IISR RS)	19 Feb 2021
6	Training on extraction of oils and oleoresins from spices for personnel of State Warehousing Corporation	26 Feb 2021
7	Post harvest training on Spice food processing technologies	03 Mar 2021
8	Post harvest training on Processing of ginger	04 Mar 2021
9	District level Seminar on “Advances in Production and Processing of Spices” sponsored by MIDH	05 Mar 2021
10	Post harvest training on Processing and value addition in ginger	05 Mar 2021
11	Value addition opportunities through Post harvest processing of ginger	08 Mar 2021
12	District level Seminar on Summer Care of Spice Crops in collaboration with Indian Society for Spices sponsored by MIDH at KVK Kottayam	10 Mar 2021
13	Training on Post harvest technologies for spices	10 Mar 2021
14	Training on Value addition and processing in spices for Kudumbasree beneficiaries	19 Mar 2021
15	Farmers training on Advanced production technologies of major spices sponsored by DASD	24 Mar 2021
16	Collaborative Refresher Training Programme (RTP) on Advances in production, processing and technology commercialization in spices sponsored by MANAGE	29-31 Mar 2021
17	Trainers’ training progrmme on "Good Agricultural Practices and Technology advances in ginger and turmeric cultivation” for field functionaries of PRADAN	20-21 May 2021
18	Mass Awareness campaign on Organic farming in spices: Kerala conducted under NPOF	27 May 2021
19	Training on Spice crops oragnized in collaboration with RARS, Pattambi	04 Jun 2021
20	Training and sensitization programme on Varietal wealth of black pepper	17 Jun 2021

	(IISR RS)	
21	Training and instructional lecture on Nursery techniques in black pepper (IISR RS)	24 Jun 2021
22	Training and instructional lecture on Disease management in black pepper (IISR RS)	02 Jul 2021
23	Training on Monsoon management of spice crops	02 Jul 2021
24	Training and capacity building programme on Pest and disease management in black pepper	08 Jul 2021
25	Webinar and instructional programme on Production technology of black pepper (IISR RS)	15 Jul 2021
26	Training and instructional lecture on Varietal wealth of cardamom (IISR RS)	05 Aug 2021
27	Training to field staff of FPO on Advanced spice production technologies	12 Aug 2021
28	Training & instructional lecture on Planting material production in small cardamom	12 Aug 2021
29	Training on Organic practices for plant protection in spice crops under DBT Kisan Biotech Hub Project	12 Aug 2021
30	Training and instructional lecture on 'Micronutrient technology in spices: Application and entrepreneurship opportunities " in collaboration with Farm Information Bureau, Government of Kerala	19 Aug 2021
31	Training and capacity building on Biotic stress management in small cardamom: Insect pests (IISR RS)	26 Aug 2021
32	Webinar on Food and nutrition (IISR RS)	26 Aug 2021
33	Training and capacity building on Biotic stress management in small cardamom - Diseases (IISR RS)	02 Sept 2021
34	Capacity building programme for farmers on Physiological and agronomical interventions for increased productivity in small cardamom-(IISR RS)	09 Sept 2021
35	Training on Soil health management in spice based cropping system under DBT Kisan Biotech Hub Project	20 Sept 2021
36	Training and capacity building on Biofertilizer & biopesticide preparation & application in spice crops under DBT Kisan Biotech Hub Project	21 Sept 2021
37	Farmers- Scientists Interface Programme and training on Production technologies for spice crops	28 Sept 2021
38	Training on Planting material production in black pepper in connection with Mahila Kisan Divas (IISR RS)	15 Oct 2021
39	Awareness seminar on “Safe food now for a healthy tomorrow” to the farm women and students in connection with World Food Day	16 Oct 2021
40	Scientist-FPOs Interface Programme - Effective use of technologies for coconut prosperity - role of Farmer Producer Organizations”	21 Oct 2021
41	Five days online training on Cultivation and entrepreneurial opportunities in nutmeg in collaboration with Central Training Institute, Kerala Agricultural University-	25-30 Oct 2021
42	Training and exposure visit on Input management in spice crops for DAESI trainees	02 Nov 2021
43	Exposure visit and training on Entrepreneurship opportunities in spices sector for AC&ABC trainees in collaboration with RARS Pattambi, KAU	15 Nov 2021
44	Webinar on Improved varieties of ginger and turmeric (IISR RS)	11 Nov 2021
45	Spice Agro Clinic and Mass Awareness programme on Quality	12 Nov 2021

	improvement in spices at Kattipara under Mera Gaon Mera Gaurav programme	
46	Refresher Training Programme (RTP) on Crop production and business opportunities in spices for established Agripreneurs under AC&ABC Scheme in collaboration with MANAGE	16-18 Nov 2021
47	Webinar on Advanced production practices in ginger and turmeric (IISR RS)	18 Nov 2021
48	Training and exposure visit on Improved spice production and processing technologies for beneficiary farmers under DBT-Kisan Biotech Hub Project	22 Nov 2021
49	Quality improvement training programme on small cardamom	24 Nov 2021
50	Webinar on Improved production techniques in turmeric (Hindi) in collaboration with AICRPS	29 Nov 2021

Table 13. Training programmes under TSP and SCSP components

S. No	Particulars of the training programme
1	Training on Turmeric cultivation and input distribution for SC farmer beneficiaries at Nediyiruppu Harijan Colony Kondotty, Kozhikode on 09 Jun 2021
2	Training and capacity building programme on Organic turmeric cultivation for SC beneficiaries at Parapara SC colony, Kozhikode on 22 Jun 2021
3	Training programme on Input management in turmeric cultivation for tribal beneficiaries at Attapady, Palakkad district, Kerala on 19 Jul 2021
4	Training on Preparation and application of biocapsules for tribal farmers at Parambikulam Pooppara Tribal colony on 12 Aug 2021
5	Training and demonstration on Coconut planting, maintenance and care at HD Kote, Karnataka for tribal beneficiaries on 29 Aug 2021
6	Training on Basics of kitchen gardening for tribal beneficiaries at Wayanad in collaboration with MSSRF on 09 Sept 2021
7	Training programme on Improved spice production technology for 21 SC beneficiaries from Mananthawady on 22 Oct 2021
8	SCSP Training programme on Spice technology and exposure to innovations in spice cultivation on 07 Dec 2021

Sale of technology inputs

The ATIC supported and supplemented the technology dissemination initiatives of the Institute by providing sales and supply services of technology inputs to various stakeholders across the country. The total value of revenue generated from the sale of various technology inputs and quality produce was 49.5 lakhs which includes planting materials, farm produce, diagnostic services, micronutrients, biocontrol agents and biocapsules, publications and miscellaneous.

Trainers' training programme

ICAR-IISR organized a two-day trainers training programme on Good Agricultural Practices and technology advances in ginger and turmeric during 20-21 May, 2021. The training programme benefitted 130 field executives and trainers associated with various FPOs from 75

locations in the country spread across seven states in the country. The programme was organized in connection with 75th anniversary celebrations of Independence of the nation. The training programme was undertaken in collaboration with PRADAN, an NGO with significant grassroot presence across several states in the country. The training programme aimed at diffusion of good agricultural practices and enhance technology adoption in ginger and turmeric in the states of Madhya Pradesh, Odisha, West Bengal, Rajasthan, Jharkhand, Bihar and Odisha.

ICAR-ALL INDIA COORDINATED RESEARCH PROJECT ON SPICES (AICRPS)

The XXXII Annual Group Meeting of ICAR-All India Coordinated Research Project on Spices (AICRPS) was held during 22-24 September 2021 at ICAR-Indian Institute of Spices Research, Kozhikode in virtual mode. The workshop was inaugurated by Prof. Jeet Singh Sandhu, Hon'ble Vice Chancellor, Sri Karan Narendra Agriculture University (SKNAU), Jobner. Dr. A. K. Singh, DDG (Horticultural Science), ICAR presided over the function. Dr. Vikramaditya Pandey, ADG (Horticultural Science), ICAR was the Guest of Honour during the occasion. During the inaugural session the "Best AICRPS Centre Award 2020-21" was presented to AICRPS centre at Chaudhary Charan Singh Haryana Agricultural University, Hisar. Ten booklets/pamphlets on spices production technologies from different AICRPS centres were released during the occasion. Six new varieties of different spice crops were recommended for release during the Group Meeting (Table 14 & Fig. 29).

Table 14. New varieties recommended for release

Crop	Name of the variety	Developer	Recommended for	Salient features
Fenugreek	HM 273	Chaudhary Charan Singh Haryana Agricultural University, Hisar	Haryana, Rajasthan, Chhattisgarh, Uttarakhand, Tamil Nadu and Gujarat	High yielding (20-25 q ha^{-1}) and shows resistance against downy mildew and powdery mildew diseases
Fenugreek	Gujarat Methi 3	Sardarkrushinagar Dantiwada Agricultural University, Jagudan	Rajasthan, Andhra Pradesh, Uttar Pradesh, Bihar, Chhattisgarh, Uttarakhand, Tamil Nadu and Gujarat	High yielding (23.50 q ha^{-1}) with more number of pods per plant and shows resistance against powdery mildew disease
Coriander	Chhattisgarh Raigarh Dhaniya 3	Indira Gandhi Krishi Viswavidyalaya, Raigarh	Bihar, Chhattisgarh, Madhya Pradesh, Rajasthan, Uttar Pradesh, Haryana, Gujarat, Uttarakhand, Tamil Nadu and Andhra Pradesh.	Suitable for both leafy as well as seed purpose. The grains are having high volatile oil content (0.47%) and exhibits moderate resistance to powdery mildew and aphids
Fennel	RF 289	Sri Karan Narendra Agriculture University, Jobner	Rajasthan, Madhya Pradesh and Gujarat	High yielding and high quality (2.18% essential oil) variety and moderately tolerant to *Ramularia* blight
Ajwain	Lam Ajwain 3	Dr. YSRHU, Guntur	Rajasthan, Gujarat and Andhra Pradesh	High yield (8.13 q ha^{-1}), bold seeds with attractive brown colour and rich in volatile oil content (7.8%)
Turmeric	Chhattisgarh Raigarh Haldi 3	Indira Gandhi Krishi Viswavidyalaya, Raigarh	Chhattisgarh, Andhra Pradesh, West Bengal, Odisha, Uttar Pradesh, Gujarat and Tamil Nadu	Early maturing (187 days) with 25.8 % dry recovery, 3.78 %, curcumin, 4.8 % essential oil and 10.64 % oleoresin and has moderate resistance to *Colletotrichum* leaf spot and *Taphrina* leaf blotch.

		
HM 273	GUJARAT METHI 3	LAM AJWAIN 3
		
CG RAIGARH DHANIYA 3	RF 289	CG RAIGARH HALDI 3

Fig. 29. Varieties recommended for release during XXXII AGM of spices

New technologies

- Spraying propiconazole (0.1 %) at the initiation of the disease followed by second spray 15 days after first spray was recommended for the management of coriander powdery mildew (*Erysiphe polygoni)*
- A ready mixture of fungicidal formulation containing Azoxystrobin 11% + tebuconazole 18.3% SC has been recommended for management of stem gall disease of coriander.
- Rhizome treatment with propiconazole (0.1%) and foliar spray of propiconazole (0.1 %) was recommended for the management of turmeric foliar diseases - leaf spot (*Colletotrichum capsici*) and leaf blotch (*Taphrina maculans*).

New initiatives

- New research trial on aromatic turmeric (*Curcuma aromatica*) and black turmeric (*Curcuma caesia*), trait-specific new CVTs in coriander, cumin, fennel and fenugreek and evaluation of plant growth promoting rhizobacteria, *Bacillus safensis* for phosphorus (P) and zinc (Zn) solubilization potential in ginger and turmeric were initiated.
- A demonstration-cum-seed production unit of pure block of turmeric varieties, Megha Turmeric and IISR Pragati is being established in all the centres located in the NE region to facilitate the availability of pure seeds of most popular turmeric varieties in the NE region.

KRISHI VIGYAN KENDRA (KVK)

Trainings

KVK conducted 28 on-campus, 14 off-campus and 18 online mode capacity building trainings during the period in different disciplines, benefitting 2219 participants. Diverse topics like plant propagation, bush pepper production, seasonal vegetables cultivation, mushroom production, *Loranthus* management, organic inputs production, ornamental fish production, aquarium construction, edible fish culture, bee keeping, value addition of tubers, spices, goat rearing, indigenous medicines for dairy animals and dairy management were covered for the benefit of participants. Three days paid training programme on breeding and culture of ornamental fishes, mushroom spawn production and HORTICORP associated trainings on bee keeping were also conducted as per the demand of the farmers.

Special Capacity Building programmes

Two ICAR sponsored trainings on broiler goat rearing and coconut based integrated farming system were conducted for the benefit of total 100 farmers. Women master trainers were selected by *Kudumbashree* mission from all block Panchayats of Kozhikode district and they were trained by KVK on establishment of nutrition garden, its management, kitchen waste management and production of organic manures and organic pest and disease management in nutrition gardens. Such trained farmers will further provide training and technical support to beneficiary farmers from all the panchayats to promote vegetable cultivation. Initial seed material was provided by KVK and further assistance will be given by *Kudumbashree* mission. The programme was inaugurated by Dr. J. Rema, Director, ICAR- Indian Institute of Spices Research, Kozhikode and led by Dr. P. Ratha Krishnan, Programme Coordinator, KVK, Calicut. Technical sessions were handled by Dr. C. K. Thankamani, Dr. R. Praveena, Dr. P. S. Manoj, Dr. K. M. Prakash and Dr. K. K. Aiswariya.

KVK in association with Block Resource Centre, Kunnummal organized Innovative Horticulture Therapy programme through cultivation of cool season vegetables. The programme was conducted for 40 differentially abled children and their parents, which covered different aspects of cool season vegetables with a follow up hands on practical training at KVK campus. Planting materials of cool season vegetables were also supplied to the beneficiary group for initiating the programme on a group approach. The programme was inaugurated by Dr. R. Bindu, Minister for Higher Education, Government of Kerala in online mode.

On Farm Trials (OFTs) and Front Line Demonstrations (FLDs)

During 2021, KVK, IISR implemented four on farm trials on assessing the performance of onion varieties *viz*., Arka Ujjwal and CO(On) 5 in the plains of Kozhikode district; strawberry varieties *viz*., Sweet Charlie, Winter Dawn and Chandler in high altitude areas of Kozhikode district; improved green gram varieties in summer rice fallows and efficacy of lithium antimony thiomalate for *Bovine papillomatosis* (Warts).

Front line demonstrations of technologies like High yielding and CMD resistant variety of cassava *viz*., Sree Reksha, Sampoorna, KAU Multimix for improvement in yield and quality parameters in vegetable crops, eco-friendly cultivation of amaranthus, integrated management of Tanjore wilt of coconut, production of healthy ginger seeds, trisodium citrate in subclinical mastitis in milch cows, brackish water aquaculture using plankton plus, scientific shrimp farming with water acidity management, scientific farming of improved

strains of Nile tilapia were implemented. Farm Field School on quality seedling production of WCT coconut cultivar Kuttiady Local with involvement of 20 farmers was also implemented.

Celebration of important days

- As a part of Technology Week 2021, International Womens' Day was celebrated on 8 March 2021 at KVK, Peruvannamuzhi. Smt. Rekha, T. Kozhikode who bagged ICAR, New Delhi award for progressive women farmer from Southern Zone was felicitated at KVK. Along with her, thirteen farm women from different parts of the district were also honored, who have marked their presence in agriculture and allied fields. Live telecast of Women's Day felicitation award ceremony organized by ICAR, New Delhi was shown to the participants and a training on 'Mushroom value added products development' by Ms. A. Deepthi was also conducted.
- Seminar on "Water management at household level" was organized with expert talk on "Water management" by Dr. Manoj P. Samuel, Director, Centre for Water Resources Development and Management, Kozhikode and special address by Smt R. Indumathy, President, OISCA Women's Chapter, Perambra. Classes on "Water management for efficiency agriculture and fish culture" were conducted by Dr. K.M. Prakash and Dr B. Pradeep, SMS, KVK, IISR.
- World Soil Day seminar was organized at Kavumthara. During the occasion, soil health cards and black pepper micronutrient mixture were distributed by Shri T.P. Dhamodharan, President, Naduvannur Grama Panchayat. An expert class on "Healthy soil for healthy crop" was also conducted by Dr. K.M. Prakash, SMS, KVK, IISR.

Special Mass Awareness programmes

As part of 75th Year of Independence, KVK, IISR organized events and participated in live webcasting programmes of ICAR *viz*., Hon'ble PM's inaugural address of PMKMY and Seminar on "Sustainable Agriculture"; Nutri-cereals Multi-stakeholders Mega convention, Poshan Vatika and Tree plantation Campaign on 17 September 2021 and Natural Farming "Pre-Vibrant Gujarat Summit 2021" and address by Hon'ble PM of India on 16 Dec 2021.

Special Swachhta campaign with the theme "wealth from waste" was conducted at Kottur, Kavil and Maruthonkara villages in which cleaning, demonstration of compost making, planting of saplings in farmer's field and distribution of vegetable seed packets and seedlings were held for the benefit of more than 150 farmers. Six 'catch the rain' campaigns were organised with the involvement of experts from CWRDM, ICAR-IISR and KAU. Two Energy management seminars were also organized as mass awareness on solar pump set usage in association with Energy management Centre, Kochi.

Fig. 30. Activities of KVK

INSTITUTE TECHNOLOGY MANAGEMENT - BUSINESS PLANNING AND DEVELOPMENT (ITM-BPD) UNIT

- ITMU-BPD unit commercialized eleven technologies from January 2021 to December 2021 (Table 15). An amount of Rs. 25.5 lakhs was earned as revenue through technology commercialization.
- ICAR-IISR entered into a MoA with District Kudumbshree Mission, Kozhikode, on 1 July 2021 for handholding women entrepreneurs through commercial production of spices planting materials, training, capacity building, etc., for value added product development.
- Under PMFME scheme, a tripartite agreement was executed between Keladi Shivappa Nayaka University of Agricultural & Horticultural Sciences, Shivamogga and Karnataka State Agricultural Produce Processing and Export Corporation Limited and ICAR-IISR as mentoring institute for the establishment of Common Incubation Center.
- A MoU was executed between ICAR-IISR and CSIR-Institute of Himalayan Bioresource Technology for rural development in Himachal Pradesh through transfer of technologies and capacity building in cinnamon.
- National Biodiversity Authority approval was obtained for two technologies namely “A novel method of storing and delivering PGPR/Microbes through biocapsules” and “An antimicrobial composition for coating rhizomes and tubers and a process for its preparation”.
- ITM-BPD unit facilitated three consultancy visits, one contract research on effect of nano urea (liquid) in reducing the application of conventional urea in increasing crop productivity and profitability.
- ITMU-BPD unit has developed an e-commerce platform www.spiisry.com with payment gateway for supporting sales and marketing of startups products.
- During the occasion of ICAR-IISR foundation day on 1 July 2021, products of a startup incubatee of ITM-BPD unit, M/s RLCO Innovative Agri Pvt Ltd, were released. The products were: Spizaar super chilies, Gatha Ginger- Cardamom Squash, Enjineer: Ginger extract, Instant Tea (cardamom & ginger flavor), Kaachi hair cream. Further, a licensee of ICAR-IISR micronutrient technologies was honored with best startup award.
- Nine startups/ entrepreneurs were enrolled as incubatees during the year 2021 for development of spices based food products by availing spice processing facility of ICAR-IISR.
- ITMU-BPD unit organized one day “Capacity Building and Entrepreneurship Development program on Value Addition of Ginger”.
- Online Collaborative Refresher Training Programme (RTP) on Spices Cultivation and Business Opportunities in collaboration with MANAGE, Hyderabad was conducted during 29-31 March 2021 & 16-18 November 2021.
- An online training for Kudumbashree members of Attapady tribal JLG groups was conducted on “Good Agricultural Practices of Ginger & Turmeric” and “Establishment of Seed Hubs of Ginger and Turmeric”.
- ITMU-BPD unit initiated a new business model involving Tulunad Ecogreen FPO on stingless honeybee cultivation and sixty honey boxes with small honey bees were fixed at different locations of ICAR-IISR Headquarter’s farm.
- An amount of Rs. 21.2 lakhs worth planting materials were sold in 2021 by the Krishi Dhan nursery managed by BPD unit of ICAR-IISR.

Table 15. Commercialization of technologies

S. No	Name of technology/ Know-how	Name of contracting party	Revenue earned (Rs.)
1	Turmeric- IISR Prathibha	Harithasree Self Help Group (SC), Kozhikode, Kerala	50,000
2	Ginger- IISR Varada	Harithasree Self Help Group (SC), Kozhikode, Kerala	75,000
3	Turmeric-IISR Alleppey Supreme	Chembakam Joint Liability Group (JLG), Mannampetta, Thrissur, Kerala	50,000
4	A micronutrient composition for black pepper and a process for its preparation	Assistant Director Horticulture, Leaf Analysis Laboratory Shivamogga, Karnataka	2,50,000
5	A micronutrient composition for ginger and a process for its preparation (for soil pH>7)	Assistant Director Horticulture, Leaf Analysis Laboratory Shivamogga, Karnataka	2,00,000
6	A micronutrient composition for black pepper and a process for its preparation	Senior Assistant Director of Horticulture Dakshina Kannada, Mangalore, Karnataka	3,00,000
7	A novel method of storing and delivering PGPR/microbes through biocapsule	Krishna Agro Bio Products, Hyderabad, Telangana	10,00,000
8	A micronutrient composition for black pepper and a process for its preparation	BHOOMI BIO INDUSTRIES, Magadi Bangalore, Bengaluru Karnataka	3,00,000
9	A micronutrient composition for cardamom and a process for its preparation	ESAF Swasraya Producers Company Ltd, Thrissur, Kerala	3,00,000
10	Curry Masala Recipes	Thanima Oil and Flour Mill, Kannur, Kerala	20,000
11	Noodles Masala	Tasty Tribes Pvt Ltd, Pune, Maharashtra	5,000
		Total	**25,50,000**

Table 16. Patents granted

S. No	Invention	Patent no & Grant date
1	A novel method of storing and delivering PGPR/microbes through biocapsule	361021 12-03-2021
2	A micronutrient composition for black pepper and a process for its preparation	367654 26-05-2021
3	Bacterial fermentation technology for production of high quality 'off-odour-free' white pepper from matured green pepper (*Piper nigrum* L)	369407 16-06-2021

Fig. 31. ITM – BPD Unit activities

AGRICULTURAL KNOWLEDGE MANAGEMENT UNIT (AKMU)

AKMU facilitates IT and ICT related activities of the institute and ensures uninterrupted internet connectivity to all divisions/sections and VPN connectivity to IISR Regional Station, Appangala, IISR Experimental Farm and Krishi Vigyan Kendra, Peruvannamuzhi. It also takes care of network security aspects, developing websites, updation of the institute website and maintenance of social media profile of the Institute. Technical support to online meetings, webinars, online workshops and Trainings, etc., were done. Apart from this AKMU assists in analyzing and interpreting geographical data using ArcGIS & DIVA GIS and statistical analysis of scientific data using SAS, JMP and other statistical softwares. New website for AICRP on Spices, online seed portal and online applications for the selection of young professionals and research fellows were also developed.

Fig. 32. Seed portal of ICAR-IISR, Kozhikode

हिंदी अनुभाग

राजभाषा कार्यान्वयन समिति की बैठक

राजभाषा कार्यान्वयन समिति की बैठक प्रत्येक तिमाही में (20 जनवरी 2021, 22 जून 2021, 29सितंबर 2021 और दिसंबर 2021)आयोजित की गयी। समिति ने राजभाषा कार्यान्वयन की गतिविधियों की समीक्षा करके सुधारने के लिए सुझाव दिया गया।

हिंदी कार्यशाला

वर्ष 2021 में भाकृअनुप-भारतीय मसाला फसल अनुसंधान संस्थान के अधिकारियों तथा कर्मचारियों के लिए चार कार्यशालाएं आयोजित की गयीं। इन कार्यशालाओं में राजभाषा नीति एवं हिंदी टिप्पणी, हिंदी को लोकप्रिय बनाने के लिए तकनीक प्रगति, राजभाषा, पारिभाषिक शब्दावली और बोलचाल की हिंदी तथा हिंदी टिप्पणी एवं पत्र लेखन के बारे में विभिन्न विशेषज्ञों ने कक्षा चलायी। श्री. के. राजेष, वरिष्ठ प्रबंधक. यूनियन बैंक ऑफ इंडिया, कोषिक्कोड, श्री के. अनिलकुमार, उप प्रबंधक (राजभाषा) भारतीय स्टैट बैंक, तिरुवनंतपुरम, श्रीमती जोमोल, कनिष्ठ हिंदी अनुवादक, भारत संचार निगम लिमिटड, तिरवल्ला तथा श्री धर्मेन्द्र कुमार, सहायक निदेशक (राजभाषा), राजभाषा विभाग, हिंदी शिक्षण योजना, कोचिन ने क्रमशः 17.02.2021, 28.06.2021, 01.09.2021, 20.12.2021 को विभिन्न कार्यशालाओं में व्याख्यान दिया।

हिंदी पखवाडा

भाकृअनुप-भारतीय मसाला फसल अनुसंधान संस्थान, कोषिक्कोड में 14-28 सितम्बर 2021 को हिन्दी पखवाडा मनाया। संस्थान के निदेशक डॉ. जे रमा ने 14 सितंबर को हिंदी पखवाडे का उद्घाटन किया। उद्घाटन समारोह में निदेशक एवं सभी अधिकारियों एवं कर्मचारियों द्वारा राजभाषा प्रतिज्ञा लीगयी। इस अवसर पर संस्थान के अधिकारियों, कर्मचारियों, उनके बच्चों तथा फील्ड कॉन्ट्राक्ट स्टाफ के लिए हिंदी टिप्पणी एवं मसौदा लेखन, निबंध लेखन, भाषण, श्रुत लेखन, अनुच्छेद लेखन, कविता रचना, कहानी लेखन , गीत, रसोई बाग की वीडियो आदि विभिन्न प्रकार की प्रतियोगिताओं का आयोजन किया गया।

हिंदी पखवाडे का समापन समारोह 28 सितंबर 2021 को संपन्न हुआ। डॉ. जे. रमा, निदेशक समारोह के अध्यक्ष थी। डॉ. एन. के. लीला, प्रधान वैज्ञानिक एव हिंदी अधिकारी ने सबका स्वागत किया। समारोह की मुख्य अतिथि डॉ. जे. रेणुका, उपनिदेशक (राजभाषा), भाकृअनुप-केंद्रीय मत्स्य प्रौद्योगिकी संस्थान, कोचिन ने ऑनलाइन रूप में भाग लिया। उन्होंने अपने भाषण में हिंदी भाषा के ही नहीं सभी भारतीय भाषाओं के महत्व पर प्रकाश डाला। इसके अलावा राजभाषा अनुपालन के लिए हिंदी अधिकारियों के कर्तव्य पर ज़ोर दिया। संस्थान के

निदेशक डॉ. जे. रमा ने विजेताओं को नकद पुरस्कार वितरित किए। श्रीमती एन. प्रसन्नकुमारी, वरिष्ठ तकनीकी अधिकारी ने हिंदी पखवाडे की रिपोर्ट प्रस्तुत की। डा. के. अनीस, वैज्ञानिक ने धन्यवाद ज्ञापन किया।

हिंदी में वेबिनार

भाकृअनुप-भारतीय मसाला फसल अनुसंधान संस्थान, कोषिक्कोड द्वारा अखिल भारतीय समन्वित मसाला अनुसंधान परियोजना के सहयोग से 29 नवंबर 2021 को बिहार तथा उत्तर प्रदेश के किसानों के लिए **हल्दी की नवीन उत्पादन प्रौद्योगिकी** पर हिंदी में एक वेबिनार आयोजित किया। इसमें डॉ. ए. के. मिश्रा, वैज्ञानिक राजेंद्र प्रसाद केंद्रीय कृषि विश्वविद्यालय, बिहार, डॉ. प्रदिप कुमार, वैज्ञानिक, नरेंद्र देव कृषि प्रौद्योगिकी विश्वविद्यालय, उत्तर प्रदेश तथा डॉ. के. अनीस, वैज्ञानिक, भाकृअनुप-भारतीय मसाला असल अनुसंधान संस्थान, कोषिक्कोड ने क्रमशः हल्दी की उत्पादन तकनीकी, हल्दी का रोग प्रबंधन, हल्दी का प्रसंस्करण एवं व्यावसायिक अवसर आदि विषयों पर व्याख्यान दिया।

नराकास गतिविधियों में सहभागिता

डॉ. जे. रमा, निदेशक एवं सुश्री एन. प्रसन्नकुमारी, वरिष्ठ तकनीकी अधिकारी ने दिनांक 21 अप्रैल 2021 को आयोजित नगर राजभाषा कार्यान्वयन समिति की ऑनलाइन बैठक में भाग ली।

डॉ. एन. के. लीला, प्रधान वैज्ञानिक एवं हिंदी अधिकारी तथा सुश्री एन. प्रसन्नकुमारी, वरिष्ठ तकनीकी अधिकारी ने दिनांक 24 सितंबर 2021 को आयोजित नगर राजभाषा कार्यान्वयन समिति की ऑनलाइन बैठक में भाग ली।

डॉ. एन. के. लीला, प्रधान वैज्ञानिक एवं हिंदी अधिकारी, डॉ. ई. राधा, मुख्य तकनीकी अधिकारी, श्रीमती सी. के. बीना, निदेशक का निजी सचिव, श्रीमती एन. रबीना, उच्च श्रेणी लिपिक, श्रीमती एन. कार्तिका, तकनीशियन ने नगर राजभाषा कार्यान्वयन समिति द्वारा आयोजित ऑनलाइन टिप्पणी प्रतियोगिता में भाग ली।

डॉ. ई. राधा, मुख्य तकनीकी अधिकारी, श्रीमती एन. रबीना, उच्च श्रेणी लिपिक, श्रीमती एन. कार्तिका, तकनीशियन ने नगर राजभाषा कार्यान्वयन समिति द्वारा आयोजित ऑनलाइन राजभाषा प्रश्नोत्तरी प्रतियोगिता में भाग ली।

श्रीमती एन. कार्तिका, तकनीशियन ने नगर राजभाषा कार्यान्वयन समिति द्वारा आयोजित ऑनलाइन अनुशीर्षक लेखन प्रतियोगिता में भाग ली।

हिंदी प्रशिक्षण

डॉ. एन. के. लीला, प्रधान वैज्ञानिक एवं हिंदी अधिकारी तथा श्रीमती एन. प्रसन्नकुमारी, वरिष्ठ तकनीकी अधिकारी ने दिनांक 15-19 मार्च 2021 को केंद्रीय हिंदी प्रशिक्षण संस्थान, नई दिल्ली द्वारा आयोजित ऑनलाइन अभिमुखी कार्यक्रम में भाग लिया।

डॉ. एन. के. लीला, प्रधान वैज्ञानिक एवं हिंदी अधिकारी, डॉ. शारोन अरविंद, वैज्ञानिक, डॉ. अलगुपलमुतिरसोलई, वैज्ञानिक, श्रीमती एन. कार्तिका, तकनीशियन ने हिंदी शिक्षण योजना द्वारा आयोजित पारंगत पाठ्यक्रम में भाग लिया। डॉ. गोबु, वैज्ञानिक ने हिंदी शिक्षण योजना द्वारा आयोजित प्रबोध पाठ्यक्रम में भाग लिया।

श्रीमती एन. प्रसन्नकुमारी, वरिष्ठ तकनीकी अधिकारी ने दिनांक 25-30 नवंबर को राष्ट्रीय कृषि अनुसंधान प्रबंधन अकादमी, हाइदराबाद द्वारा भारतीय कृषि अनुसंधन परिषद के तकनीकी अधिकारियों के लिए मोटिवेशन, पोसिटीव तिंकिंग, कम्यूणिकेशन स्किल पर आयोजित प्रशिक्षण में भाग लिया।

हिंदी प्रकाशन

मसाला समाचार जुलाई-दिसंबर 2018
मसाला समाचार जनवरी-दिसंबर 2019
मसालों की महक 2020
मसालों की महक 2021
अनुसंधान के मुख्य अंश 2019
संचालन का कलेंडर - काली मिर्च
संचालन का कलेंडर - अदरक
संचालन का कलेंडर - हल्दी
वार्षिक प्रतिवेदन का कार्यकारी सारांश 2020
एआईसीआरपीएस वार्षिक प्रतिवेदन का कार्यकारी सारांश 2020
इलायची मोबाइल एप

LIBRARY

IISR Library strives towards ensuring excellent academic services through online and offline to the users. Library has a collection of 5653 books and 6010 bound journals.

CeRA

IISR Library is part of the Consortium of electronic Resources in Agriculture (CeRA) and more than 3500 full text journals on agriculture and allied subject are accessible. We also provided document delivery service to CeRA users and request from other partners.

Journals

Library has subscribed 25 Indian Journals and 8 Foreign Journals during the year in addition to journals accessible under CeRA.

KOHA

Library added 278 publications to its stock and all the newly added publications were brought in to the Library Automation software 'KOHA' database.

ICAR Krishi Portal

More than 200 Institute publications were added to the ICAR Krishi Portal.

DSpice

The Institutional Digital repository software 'DSpice' was also updated with Institute publications

Plagiarism Detection

Library also provided other academic service like detection of plagiarism in research thesis for Institute users.

Other Services

Library provided Institute Annual Report to ICAR Institutes and other Institutes. Library also provided computer and internet facilities to the users.

HUMAN RESOURCE DEVELOPMENT

Table 17. Training and capacity building of IISR employees

Name	Training particulars	Duration	Institute
Scientific Staff			
Ms. Sona Charles	Artificial Intelligence	19-29 January 2021	NIELIT, Kozhikode
Dr. A. Jeevalatha Dr. Sharon Aravind	Online programme on Integrated Scientific Project Management for Women Scientist/Technologists	18-22 January 2021	Centre for Organization Development, Hyderabad
Dr. C. M. Senthil Kumar	Artificial Intelligence	11-21 May 2021	NIELT, Kozhikode
Dr. Aarthi S. Dr. Honnappa Asangi Mr. Gobu R.	Plant Genetic Resources Management and Utilization	19 July 2021 to 01 August 2021	ICAR-NBPGR, New Delhi
Dr. C.M. Senthil Kumar Dr. A. Jeevalatha	Virtual training programme on Transcriptomic Data Analysis	28-30 September 2021	ICAR-Indian Agricultural Statistics Research Institute
Dr. E. Jayashree	DST sponsored online training programme on Leadership and Organization Developed for Women Scientist Technologists	25-29 October 2021	Centre for Organization Development, Hyderabad
Dr. D. Prasath	DST sponsored online training programme on Managing Technology Value Chains	25-29 October 2021	Administrative Staff Collage of India (ASCI) Hyderabad
Administrative Staff			
Mr.V.C. Sunil	Administrative Vigilance: Role of IO/PO	11-15 January 2021	ISTM, New Delhi
Ms. M. Seema	Public Procurement through GeM Portal	5-6 August 2021	National Productivity Council, New Delhi
Mr. P. Sundaran	Online training programme on Assets Management	06-08 October 2021	ICAR-IARI, New Delhi
Ms. N. Rebeena	Online training programme on Accrual Accounting.	22-26 November 2021	ICAR-NRRI, Cuttack
Technical Staff			
Mr. R. Bharathan	Handling Parliamentary Matters	28-29 January 2021	ISTM, New Delhi

Mr. Jayarajan K.	Workshop on e-Office	25-26 February 2021	ISTM, New Delhi
Mr. Jayarajan K.	One day generic online training in Cyber Security for Central Government Ministries /Department	29 April 2021	Ministry of Electronics & Information Technology, Govt. of India
Mr. P. Vijesh Kumar	Artificial Intelligence	11-21 May 2021	NIELIT, Kozhikode
Mr. Jayarajan K.	3 Days course on ArcGIS Pro: Essential Workflows	7-9 July 2021	ICAR-IISR, Kozhikode
Ms. O. Shajina	Appropriate Sampling Techniques	02-07 August 2021	ICAR-IARI, New Delhi
Mr. C.M. Nikhil Mr. P. B. Ranjith	Good Agricultural Practices (GAPs) for Higher Productivity, Profitability and Resources Use	02-16 August 2021	ICAR-IARI, New Delhi
Mr. Jayaprakash P. T.	Government e-Marketplace (GeM) Training program cum Interactive session (virtual)	27 August 2021	ICAR-IASRI, New Delhi
Mr. Jayarajan K.	Training programme on E-Governance Application in ICAR for Technical Staff	6-10 September 2021	ICAR-IASRI, New Delhi
Mr. O.G. Sivadas	Three days Online Workshop on MS-Word (MS-W-08)	20-22 October 2021	ISTM, New Delhi
Dr. Priya George	Experimental Data Analysis	20-29 October 2021	ICAR-IASRI, New Delhi
Mr. Jayarajan K.	Online training programme on Statistical Techniques for Data Analysis in Agriculture	4-13 October 2021	ICAR-IASRI, New Delhi
Ms. Prasanna Kumari	Online training programme on Motivation, Positive Thinking and Communication Skills for Technical Officers (T-5 and above)	25-30 November 2021	ICAR-NAARM, Hyderabad

Table 18. Seminar/Symposium/Conferences attended by employees

Name	Seminar/symposium/conference	Duration	Venue
Dr. J. Rema Dr. Santhosh J. Eapen Dr. C. K. Thankamani Dr. R. Dinesh Dr. N. K. Leela Dr. R. Ramakrishnan	International Symposium on Spices as Flavours, Fragrances & Functional Foods (SYMSAC X)	09-12 February 2021	Indian Society for Spices, ICAR-IISR, Kozhikode

Nair Dr. S.J. Ankegowda Dr. K. Kandiannan Dr. K. S. Krishnamurthy Dr. A. Ishwara Bhat Dr. K. V.saji Dr. P. Rajeev Dr. V. Srinivasan Dr. T. E. Sheeja Dr. E. Jayashree Dr. D. Prasath Dr. C. M. Senthil Kumar Dr. Lijo Thomas Dr. C. N. Biju Dr. Anees K. Dr. Divya P.S. Dr. R. Praveena Dr. Jeevalatha A. Dr. C. Sarathambal Dr. M. Alagupalamuthirsolai Dr. M. Balaji Rajkumar Dr. C. Sellaperumal Dr. Sharon Aravind Dr. S. Aarthi Dr. Honnappa Asangi Dr. Akshitha H. J. Dr. Mohammed Faisal Peeran Mr. V. A. Muhammed Nissar Ms. R. Sivaranjani Dr. M. S. Shivakumar Mr. Gobu R. Ms. Sona Charles Dr. P. Rathakrishnan			
Dr. S.J. Ankegowda Dr. K.S. Krishnamurthy Dr. M. Alagupalamuthirsolai Ms. R. Sivaranjani	International Plant Physiology Virtual Symposium 2021	11-12 March 2021	ICAR-Sugarcane Breeding Institute, Coimbatore
Dr. C. K. Thankamani Dr. M. S. Shivakumar Ms. R. Sivaranjani	ISCAR International Symposium on Coastal Agriculture	16-19 March 2021	ICAR-CCARI, Goa
Ms. Sona Charles	Bioinformatics (GLBIO) conference	10-13 May 2021	Great lakes Bioinformatics Consortium, USA

Dr. C.M. Senthil Kumar	International Congress on Invertebrate Pathology and Microbial Control (Virtual) International Conference on Global Perspectives in Crop Protection for Food Safety (GPCP 2021)	28 June 2021 to 2 July 2021 9 December 2021	Tours, Loire Valley, France TNAU, Coimbatore
Dr. S. Aarthi	International Conference on Future challenges and prospects in plant breeding	6-7 October 2021	TNAU, Coimbatore
Dr. J. Rema Dr. K. S. Krishnamurthy Dr. Sharon Aravind	International Conference on Saffron and Seed Spices	7-8 November 2021	SKUAST, Srinagar
Ms. R. Sivaranjani Mr. V. A. Muhammed Nissar	2nd Agro Biodiversity Congress (Virtual)	15-18 November 2021	Rome
Dr. D. Prasath	9th Indian Horticulture Congress	18-21 November 2021	CS Azad University of Agriculture and Technology, Kanpur
Dr. A.I. Bhat Dr. C.N. Biju Dr. R. Praveena Dr. A. Jeevalatha Dr. M.F. Peeran	IPS south zone	1-3 December 2021	ICAR-CPCRI, Kasargod
Dr. J. Rema Dr. C.K. Thankamani Dr. C.N. Biju Dr. N.K. Leela Dr. S.J. Ankegowda Dr. Sharon Aravind Dr. K. Anees Dr. M.S. Shivakumar Dr. E. Jayashree Dr. S. Aarthi Ms. E. Radha Dr. P.S. Divya	PLACROSYM XXIV	14-16 December 2021	Spices Board, Kochi

Ph. D. registrations

Name of the student	Guide/Co guide	Subject	University
Ms. Aiswarya Babu	Dr. Santhosh J. Eapen Dr. C. Sellaperumal	Zoology	University of Calicut
Ms. Gayathri Pavithran	Dr. C. K. Thankamani	Botany	University of Calicut
Ms. Greeshma M	Dr. A. IshwaraBhat	Botany	University of Calicut
Ms. Blessy Peter	Dr. C. Sarathambal	Biotechnology	University of Calicut

	Dr. T. E. Sheeja		
Mr. Silaru Raghuveer	Dr. D. Prasath	Horticulture	YSR Horticulture University
Ms. P. Saleena	Dr. E. Jayashree	Food Science and Technology	Kerala University of Fisheries and Ocean Studies
Ms. Archana Ravindran	Dr. E. Jayashree	Food Science and Technology	Kerala University of Fisheries and Ocean Studies
Mr. Shabad M.K.	Dr. Lijo Thomas	Management, Humanities & Social Sciences	Kerala University of Fisheries and Ocean Studies
Mr. Shiyas K.J.	Dr. Lijo Thomas	Management, Humanities & Social Sciences	Kerala University of Fisheries and Ocean Studies

Ph. D. awarded

Student	**Topic**	**University**	**Guide**
Ms. Bijitha P. K.	Diversity and host preference of *Pythium* species infecting major Zingiberaceous spices	Kannur University	Dr. R. Suseela Bhai

ANNUAL REPORT 2021

MAJOR EVENTS 2021

MAJOR EVENTS 2021

DASD sponsored Farmers Training Programme at Appangala

ICAR- Indian Institute of Spices Research, Regional Station, Appangala organized farmers training programme on "Advanced production technologies of major spices (black pepper, cardamom and ginger)" on 24 March 2021 sponsored by Directorate of Arecanut and Spices Development, Kozhikode. Mr. Muraleedhar, Senior Liaison Officer, Coffee Board, Somwarpet, Mr. Mohammed Raza, Progressive planter, Kodlipet graced the occasion. Dr. S. J. Ankegowda presided over the function. During the occasion cardamom extension folder was released. An exhibition showcasing the technologies developed by ICAR-IISR was also arranged. A training program on improved varieties of spices, quality planting material production, advanced production technologies, disease and pest management in spices was conducted by scientists of Regional Station. More than 80 farmers from different regions of Karnataka attended the training programme and 30 participants attended the technical session through online mode.

National Science Day

ICAR-Indian Institute of Spices Research (IISR), observed National Science Day on 27 February 2021 with the virtual demonstration of models and inventions by college students. A keynote lecture on "Revisiting Raman" on National Science Day was also held as part of the event. Dr. Manoj Komath, Scientist (G), Sree ChitraThirunal Institute of Medical Sciences and Technology was the Chief Guest and delivered lecture recalling the life and scientific temperament of Nobel Laureate C V Raman. Dr. J Rema, Director, ICAR-IISR presided over the programme. Dr. D Prasath and Dr. C Sarathambal also spoke on the occasion.

International Women's Day

ICAR- Indian Institute of Spices Research Kozhikode, Observed International Women's day on 8 March 2021 with a webinar highlighting the theme 'Women Leadership in Agriculture: Entrepreneurship, Equity and Empowerment'. Giving focus to women in agriculture sector and the incubation supports available under ICAR- institutions, ICAR-IISR urged more women to take up agripreneurship. Dr. Sudha Mysore, CEO of Agri Innovate and Lakshmi Menon were the Guest of Honour and Chief Guest respectively during the occasion. Dr. J Rema, Director, ICAR-IISR presided over the programme. Many successful women entrepreneurs from different ICAR institutions shared their experience during the deliberations. Dr. T. E. Sheeja and Dr. S Aarthi also spoke on the occasion.

World Environment Day

ICAR-IISR observed World Environmental Day on June 5, 2021. Director and staff participated and planted tree spices saplings in the office premises. On the occasion, Director distributed planting materials to K.P. Govindankutty Memorial Library, Cherukulathur, Calicut as part of Social activity of World Environmental Day.

Fifth Y R Sarma Memorial Lecture

Dr M K Naik, Vice Chancellor, University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka delivered the fifth Dr Y R Sarma Memorial lecture on "Research advances in prevention and management of aflatoxins are of vital importance to food safety" organized by ICAR - Indian Institute of Spices Research in association with Dr Y R Sarma memorial trust on 15 June 2021. More than 200 participants from various parts of the country

participated in the lecture. The programme was chaired by Dr J. Rema, Director, ICAR IISR. Dr Y. Anuradha Sarma proposed vote of thanks.

Institute Foundation Day

The 26th Foundation Day of ICAR-Indian Institute of Spices Research, Kozhikode was celebrated with various programs on 1 July 2021. Dr. Beena Philip, Mayor, Kozhikode was the chief Guest of the function. Dr. A K Singh, Deputy Director General, ICAR, New Delhi presided over the function. The foundation day lecture was delivered by Dr. Athulya G Ashokan, Associate Professor, Pushpagiri Institute of Medical Sciences on the topic "Management of post covid syndrome".

During the programme, the institute launched the e-commerce platform for the sale of good quality spices from verified sources and products from incubatee entrepreneurs associated with the Institute. In a new initiative aimed at supporting women entrepreneurs, the Institute entered into an agreement with the Kozhikode District Kudumbasree Mission to provide support for development and marketing of value added products, production of quality planting materials and delivery training services. The Institute also executed two technology commercialization agreements for the turmeric variety IISR Alleppey Supreme and black pepper micronutrient mixture. Marking the occasion, the Institute conferred spice excellence awards for significant contribution to the spices sector. Mr. Kanthraj. K M, Kodagu district, Karnataka and Rajesh E M from Kozhikode were the farmers honoured with the awards for their achievements in spice production. M/s R L Innovative Agri Pvt Ltd, an agri-startup company was also honoured with the award.

The staff recreation club of the Institute donated ten mobiles and tablets to support online education of students from under-privileged sections of the society as part of its outreach activities.

The Institute released five extension folders and three technical bulletins on various aspects of spices cultivation to mark the foundation day. Dr J Rema, Director, ICAR IISR welcomed the gathering. Dr. Vikramaditya Pandey, Assistant Director General, ICAR offered felicitations. More than 200 participants including former directors of the Institute, staff members, farmers and representatives from various institutions took part in the online event.

75th Independence Day Celebration

The 75th Independence Day was celebrated at all the campuses of the Institute. At the Headquarters, the national flag was unfurled by Dr. C.K. Thankamani, Director (Acting). In commemoration of 75th Anniversary of Indian Independence, patriotic song competition was organized for the wards of staff and prizes were distributed to the winners on the occasion of Independence Day celebration.

ICAR-Foundation Day Celebration

On 16 July 2021 ICAR-IISR, Kozhikode celebrated 93rd ICAR Foundation Day in commemoration of 75th year of Indian Independence, by planting cinnamon and nutmeg saplings in the campus. At IISR Experimental Farm, Peruvannamuzhi saplings of fruit trees

were planted during the occasion. In Appangala 16 different species of plants belonging to *Piperaceae* and *Zingiberaceae* family were planted to mark the occassion.

Small Cardamom Field Day

ICAR- Indian Institute of Spices Research Regional Station, Appangala organized "Small Cardamom Field Day" on 16.09.2021 in commemoration of 75th Anniversary of India's Independence. Dr. S. J. Ankegowda, Principal Scientist & Head, ICAR-IISR RS, Appangala gave detailed presentation on advances in production technology of small cardamom. Mr. M. G. Rajender, Director – Plantations, Landscape & Training, Euro Nutrinuts, Chikkamagalur also spoke on the occasion. Participants were taken to the cardamom experimental and multiplication blocks. Exhibition showcasing varieties of cardamom, black pepper and other technologies was also arranged. About 24 farmers from Kodagu, Chikkamagalur, Mysore and Hassan districts participated in the field day. Dr. Akshitha, H. J. welcomed the gathering and Dr. Mohammed Faisal Peeran proposed vote of thanks.

Online Workshop on R for Biologists

A three days hands-on workshop on R for Biologists was organized by the Bioinformatics Centre, ICAR- Indian Institute of Spices Research, Kozhikode during 6-8 October 2021 for PG students, research scholars and project fellows / JRFs. The sessions were handled by Ms. Sona Charles, Dr. Divya P.S., Dr. Santhosh J. Eapen from ICAR-IISR and Dr. Sreekumar J from ICAR-CTCRI, Thiruvananthapuram. The workshop included theory as well as hands-on sessions on basic Bioinformatics, introduction to R, statistics using R and data visualization using R packages. Forty eight participants selected from over 150 applicants attended the workshop.

World Food Day

ICAR- Indian Institute of Spices Research, Regional Station, Appangala celebrated World Food Day by organizing a lecture on "Safe food now for a healthy tomorrow" to the farm women and students on 16 October 2021 by Dr. M. S. Shivakumar. Drawing competition on the theme "Safe food now for a healthy tomorrow" was organized for wards of staff and prizes were distributed during the occasion.

Mahila Kisan Diwas

ICAR- Indian Institute of Spices Research, Regional Station, Appangala conducted Mahila Kisan Diwas by organizing exhibition and training/demonstration on bush pepper technology and grafted pepper technology on 15 October 2021. Participants were given hands on training on the production of bush pepper for homestead cultivation. Demonstration of grafting in black pepper using *Piper colubrinum* as rootstock was given to the participants. During the demonstration scientists explained about the role of grafted pepper in curtailing foot rot disease. Around 50 women consisting of farm women, members of Mahila Sangha (SHG) residing in the nearby villages around the Institute participated in the programme.

Vigilance Awareness Week 2021

Vigilance Awareness Week was observed from 26 October 2021 to 1 November 2021 in ICAR-IISR Headquarters, Kozhikode, Regional Station, Appangala and Experimental Farm, Peruvannamuzhi. The week started with the Integrity Pledge taken by all the staff members of the Institute at 11.00 am on 26 October 2021. Shri Anupam Mishra, IAS, District Development Commissioner, Kozhikode was the Chief Guest on the occasion. Various programmes were organized to promote integrity, transparency and accountability in public life and also to bring awareness on the harmful effects and gravity of corruption and the need for having a self-reliant India based on this year's theme "Independent India @75: Self Reliance with Integrity. All staff and research scholars of the Institute took E-pledge on the occasion. The valedictory function of the Vigilance Awareness Week 2021 was conducted on 1 November 2021 at the ICAR-Indian Institute of Spices Research Kozhikode, Kerala. Shri Ganesh Kumar N, Inspector of Police, Special Cell, Vigilance and Anti-Corruption Bureau, Kozhikode, was the Chief Guest on the occasion. He addressed the staff members and presented prizes for the winners of various competitions held as part of VAW-2021. Dr. J. Rema, Director of the Institute presided over the function. Dr A.I. Bhat, Vigilance Officer of the Institute welcomed the gathering and presented the report on various activities conducted during the week. Shri R. Bharathan, Chief Technical Officer proposed vote of thanks.

At Regional Station, Appangala slogan writing (English and Kannada), essay writing (English and Kannada) and poster writing competitions on the theme "Independent India @75: Self Reliance with Integrity" were conducted. The valedictory function of the VAW 2021 was held on 1 November 2021 at 3.00 pm in the station. Dr. Akshitha, H. J. welcomed the gathering and Dr. Shivakumar, M. S., Chairman, Vigilance Awareness Committee-2021 gave a presentation on the various activities conducted during VAW-2021 in the station. Dr. S.J. Ankegowda, Head, ICAR- IISR, RS, Appangala gave the presidential address. Prizes were distributed to the winners during the valedictory function. Dr. Shivakumar, M. S. proposed vote of thanks.

Refresher Training Programme

The National institute of Agricultural Extension Management (MANAGE) conducted three days online Collaborative Refresher Training Programme (RTP) on Promoting spices crop cultivation and business opportunities at ICAR-Indian Institute of Spices Research, Kozhikode. The three days training programme inaugurated by Dr. J Rema, Director, ICAR – IISR had 55 trainees from various states of India. The valedictory function was chaired by Dr. P. Rajeev. Dr. K SaiMaheswari, Dr. T E Sheeja, Dr. E Jayashree and Mahesh N Mane attended the valedictory function.

Quality Improvement Training Programme on Small Cardamom

In commemoration of 75th Anniversary of India's Independence, "Quality Improvement Training Programme on Small Cardamom" was organized jointly by Spices Board, Madikeri and ICAR- Indian Institute of Spices Research, Regional Station, Appangala on 24.11.2021 at ICAR-IISR RS, Appangala. Dr. S. J. Ankegowda, Head, ICAR-IISR RS, Appangala in his inaugural address gave brief note on the research activities being carried out by Regional Station, Appangala. Sh. M. R. Shivaprasad, Progressive Planter, Dwaraka Estate gave the presidential address. Sh. S. S. Biju, Assistant Director, Divisional Office, Spices Board, Madikeri spoke on the mandates and role of Spices Board and the services or facilities available at Spices Board, Madikeri. In the technical session there were three lectures *viz.*, Production technology of small cardamom, Disease management in small cardamom and Pest management in small cardamom by Dr. S. J. Ankegowda, Dr. Mohammed Faisal Peeran and

Dr. Balaji Rajkumar of ICAR-IISR RS, Appangala, respectively. Dr. Honnappa Asangi, Scientist, ICAR-IISR RS, Appangala welcomed the gathering and Sh. N. B. Lokesh, Field Officer (i/c), Spices Board, Madikeri proposed vote of thanks. About 50 famers attended the training programme.

INSTITUTE MANAGEMENT COMMITTEE

1	Dr. J. Rema Director, ICAR-IISR, Kozhikode, Kerala	Chair person
2	Director of Agriculture Department of Agriculture Development and Farmers Welfare, Vikas Bhavan, Trivandrum, Kerala	Member
3	Director (Horticulture) Chennai, Tamil Nadu	Member
4	Associate Director RARS, Pattambi, Kerala	Member
5	Sri. T. P. Jayachandran Master Kerala	Member
6	Sri. Nanjundan Bojan Tamil Nadu	Member
7	Dr. Makesh Kumar Principal Scientist ICAR-CTCRI, Trivandrum, Kerala	Member
8	Dr. Madhavi Reddy Principal Scientist ICAR-IIHR, Bengaluru, Karnataka	Member
9	Dr. A. Ishwara Bhat Principal Scientist ICAR-IISR, Kozhikode	Member
10	Dr. Vinayaka Hegde Principal Scientist ICAR-CPCRI, Kasaragod	Member
11	Dr. Vikramaditya Pandey Assistant Director General (HS-I) ICAR, KAB-II, Pusa, New Delhi	Member
12	Mr. K. Krishna Kumaran Finance & Accounts Officer ICAR-CTCRI, Trivandrum	Member
13	Administrative Officer ICAR-IISR, Kozhikode	Member Secretary

RESEARCH PUBLICATIONS

Aarthi S, Muhammed Nissar VA and Prasath D. 2021. *Curcuma* as a natural source of starch. Indian Journal of Arecanut and Spices. 22(3): 13-17.

Ahamedemujtaba V, Atheena PV, Bhat AI, Krishnamurthy KS and Srinivasan V. 2021. Symptoms of piper yellow mottle virus in black pepper as influenced by temperature and relative humidity. Virus Disease. 32:305–313.

Anisha Babu P, Leela NK, Venkatesh J and Prasath D. 2021. Variability of exotic ginger (*Zingiber officinale* Rosc.) accessions for quality traits. Journal of Plantation Crops 49(2): 111-120.

Asangi H, Saxena SN, Kattimani KN, Kulkarni MS, Kotikal YK, Mastiholi AB, Jameel Jhalegar MD and Siddappa R. 2021. Genetic variation in essential oil constituents of ajwain (*Trachyspermum ammi* L. Sprague) varieties at varying nitrogen levels under semiarid tropics of Northern Karnataka, India. Journal of Essential Oil Bearing Plants. 23(6):1324-1333.

Biju CN, Jeevalatha A, Peeran MF, Suseela Bhai R, Fadla Basima, Muhammed Nissar VA, Srinivasan V and Lijo Thomas. 2021. Association of *Lasiodiplodia theobromae* with die-back and decline of nutmeg as revealed through phenotypic, pathogenicity and phylogenetic analyses. 3 Biotech. 11:422. https://doi.org/10.1007/s13205-021-02961-y.

George JK, Shelvy S, Fayad AM, Shabeer ATP, Umadevi P, Kale R, Angadi UB, Iquebal MA, Jaiswal S, Rai A and Dinesh K. 2021. *In silico* assisted identification of peppery aroma compound 'rotundone' backbone genes from black pepper. Journal of Biomolecular Structure and Dynamics. DOI: 10.1080/07391102.2021.1883113.

George JK, Shelvy S, Fayad AM, Umadevi P, Angadi UB, Iquebal MA, Jaiswal S, Rai A and Dinesh K. 2021. *De novo* transcriptome sequencing assisted identification of terpene synthases from black pepper (*Piper nigrum*) berry. Physiology and Molecular Biology of Plants. 27: 1153–1161. https://doi.org/10.1007/s12298-021-00986-4

Jeevalatha A, Biju CN and Suseela Bhai R. 2021. Ypt1 gene-based recombinase polymerase amplification assay for *Phytophthora capsici* and *P. tropicalis* detection in black pepper. European Journal of Plant Pathology. 159:863–875. https://doi.org/10.1007/s10658-021-02211-0.

John JK, Pradheep K, Jaisankar I, Nissar VAM and Jerard BA. 2020. Logistics planning for plant genetic resources collecting from Nicobar Islands of India. Indian Journal of Plant Genetic Resources. 33(2): 132-145.

Krishnamurthy KS and Kandiannan K. 2021. Source sink relationship, dry matter and starch partitioning in developing ginger rhizomes during different growth stages. Journal of Plantation Crops. 49 (1): 14-19

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Prashina, Mol P, Aparna RS, Sheeja TE and Deepa K. 2021. Novel bHLH and WD 40 transcription factors from turmeric (*Curcuma longa* L.) as putative regulators of curcumin biosynthesis. Journal of Plantation Crops. 49(1): 20-27.

Praveena R, Biju CN and Sujatha AM. 2021. Deciphering primary incident of rot complex of small cardamom plant by sequential inoculation of pathogens. Indian Phytopathology. (1): 48-58.

Rincy MK, Praveena R and Eapen SJ. 2021. A modified semi-selective medium for isolation and enumeration of *Pochonia chlamydosporia* (Goddard) Zare & W. Gams. Journal of Spices and Aromatic Crops. 30(1): 117-125. https://doi.org/10.25081/josac.2021.v30.i1.6923

Santhosh J Eapen. 2021. Spices for taming the COVID-19 pandemic: Prospects and perspectives. Journal of Spices and Aromatic Crops. 30 (1): 01-23.

Sarathambal C, Dinesh R, Srinivasan V, Sheeja TE, Jeeva V and Muhammed Manzoor. 2021. Changes in bacterial diversity and composition in response to co-inoculation of arbuscular mycorrhizae and Zn solubilizing bacteria in turmeric rhizosphere. Current Microbiology. 79(1): 4. https://doi.org/10.1007/s00284-021-02682-8.

Sarathambal C, Sivaranjani R and Rona Viswanathan. 2021. Mechanism of antioxidant and antifungal properties of *Pimenta dioica* (L.) leaf essential oil on *Aspergillus flavus*. Journal of Food Science and Technology. 58(7): 2497-2506.

Senthil Kumar CM, Jacob TK, Devasahayam S, Geethu C and Hariharan V. 2021. Characterization and biocontrol potential of a naturally occurring isolate of *Metarhizium pingshaense* infecting *Conogethes punctiferalis*. Microbiological Research. 243: 126645.

Shivakumar MS, Krishnamurthy KS, Saji KV and Sasikumar B. 2021. Pericarp as a new berry trait to define dry recovery and quality in black pepper (*Piper nigrum* L.). Scientia Horticulturae. 281:109923.

Sivaranjani R, Zachariah TJ and Leela NK. 2021. Phototherapeutic potential of bi-herbal extract of cinnamon and turmeric: *In vivo* antidiabetic studies. Clinical Phytoscience. 7: 38.

Snigdha M and Prasath D. 2021. Transcriptomic analysis to reveal the differentially expressed miRNA targets and their miRNAs in response to *Ralstonia solanacearum* in ginger species. BMC Plant Biology. 21: 355. https://doi.org/10.1186/s12870-021-03108-0.

Snigdha M, Vidhya V and Prasath D. 2021. Unravelling the differential expression of potential microRNAs in bacterial wilt-resistant and susceptible ginger species. Physiology and Plant Molecular Pathology 115, 101666. https://doi.org/10.1016/j.pmpp.2021.101666.

Suseela Bhai R, Riya A, Vadivukkarasi P and Shivakumar MS. 2021. Peroxidase activity as a marker to evaluate resistance in black pepper against *Phytophthora* infection. Indian Phytopathology. https://doi.org/10.1007/s42360-021-00335-1

Vidya V, Prasath D, Snigdha M, Gobu R, Sona C, Maiti CS. 2021. Development of EST-SSR markers based on transcriptome and its validation in ginger (*Zingiber officinale* Rosc.). PLoS ONE 16(10): e0259146. https://doi.org/10.1371/journal.pone.0259146.

ON-GOING PROJECTS

Mega project I: Characterizing genetic resources to identify core collections and their long-term conservation

1. Gen. XXVIII (813): Conservation and characterization of *Piper* germplasm (2008-2025) [Dr. K.V. Saji, Dr. M.S. Shivakumar, Dr. Honnappa Asangi & Mr. R. Gobu]
2. Gen. XIX (813): Conservation, characterization, evaluation and improvement of Zingiber and Curcuma sp. (2007-2023) [Dr. D. Prasath, Dr. S. Aarthi, Dr. HJ Akshitha & Dr. N. K. Leela] (External support: Dr. C. N. Biju)
3. Gen. XXXIII (813): Identification of core collection, characterization and maintenance of cardamom germplasm (2012- 2025) [Dr. Honnappa Asangi, Dr.H. J. Akshitha, Dr. S. J. Ankegowda, Dr. Mohammed Faisal Peeran & Dr. M. Balaji Rajkumar]
4. Gen. XXXVI (813): Genetic resources management in tree spices (2018-2023) [Mr. V. A. Muhammed Nissar, Dr. J. Rema, & Dr. Honnappa Asangi] (External support: Dr. Shivakumar M.S., & Dr. Anees K)
5. Gen. XXXVII (813): Conservation of Vanilla spp. and their utilization in crop improvement (2018-2023) (Dr. S. Aarthi, Mr. V. A. Muhammed Nissar & Ms. R. Sivaranjani)

Mega Project II: Genomics assisted breeding for trait specific varieties in spices

6. Gen. XXXI (813): Breeding black pepper for high yield, quality and resistance to stresses (2012-2022) [Dr. M.S. Shiva Kumar, Dr. K. V. Saji, Mr. R. Gobu & Dr. K.S. Krishnamurthy] (External support: Dr. A. Jeevalatha)
7. Gen. XXVI (813): Evolving high yielding and high-quality nutmeg clones by selection (2007-2022) [Dr. J. Rema, Dr. K.V. Saji & Mr. V.A. Muhammed Nissar] (External support: Dr. N. K. Leela & Dr. S. Aarthi)
8. Gen. XXXVI (813): Evolving high yielding, biotic and abiotic stress resistant cardamom lines through selection and hybridization (2018 - 2023) [Dr. H. J. Akshitha, Dr. S. J. Ankegowda, Dr. M. Balaji Rajkumar & Dr. M. S. Shivakumar] (External support: Dr. Honappa Asangi)
9. Biotech. XIV (813): DNA fingerprinting and barcoding in spices (2018 - 2023) [Dr. T.E. Sheeja & Dr. P. S. Divya] (External support: Mr. R. Gobu)
10. Biotech. XV (813): Identification & characterization of gene editing targets for Ralstonia resistance in ginger (2021-2024) [Dr. P. S. Divya, & Dr. C.N. Biju]
11. DBT- CIB VIII: Survey, identification and characterization of unique ginger and turmeric land races endemic to North Eastern Region of India (2018-2021) [Dr. D. Prasath & Mr. V.A. Muhammed Nissar]
12. DBT-CIB IX: Quality enhancement of turmeric through comparative evaluation of genotypes for nutritional and quality profiles for sustainable turmeric production (2019-2023) [Dr. D. Prasath, Dr. N. K. Leela & Dr. S. Aarthi]
13. ICAR-CIB-III: Genomics-assisted identification of trait-specific markers for major biotic and abiotic stresses and development of core collections of black pepper (2020-2023) [Dr. Santhosh J. Eapen, Dr. A.I. Bhat, Dr. K.S. Krishnamurthy, Dr. T. E. Sheeja, Dr. A. Jeevalatha, Dr. M.S. Shivakumar, Dr. U.B.Angadi & Dr. Sunil Kumar] (External support: Ms Sona Charles & Mr R. Gobu
14. DUS project (2010-2023) [Dr. K. V. Saji, Dr. J. Rema, Dr. D. Prasath & Dr. S. Aarthi] (External support: Dr. M. S. Shivakumar)

Mega Project III: Enhancing input-use efficiency and productivity in spices through smart farming

15. Phy. X (813): Evaluation of black pepper and cardamom elite lines for yield and quality under moisture stress (2010–2023) [Dr. S.J. Ankegowda, Dr. K.S. Krishnamurthy, Dr. M. Alagupalamuthirsolai] (External support: Dr. H. J. Akshitha and Dr. M.S. Shivakumar]
16. SSC VI (813): Nutrient cycling and soil C sequestering potential of spice crops under different management systems (2011-2022) [Dr. V. Srinivasan, Dr. R. Dinesh, Dr. S.J. Ankegowda, Dr. A. Ishwara Bhat, Dr. C.N. Biju, Dr. K.S. Krishnamurthy & Dr. M. Alagupalamuthirsolai]
17. ICAR-NASF-1: Risk assessment of nanoparticle accumulation in soils: Effects of metal oxide nanoparticles on soil bacterial communities, soil microbial processes and evaluation of phytotoxicity using genomic approaches (2020-2023) [Dr. R. Dinesh, Dr. V. Srinivasan, Dr. T. E. Sheeja TE & Dr. C. Sarathambal] (CCPI: Dr. V. Sajith, NIT-K)
18. ICAR Mega Seed Project (Agr. XXXVII (813): Production of nucleus planting materials of improved varieties of spice crops (2006-2022) [Dr. V. Srinivasan, Dr. K. Kandiannan, Dr. S.J. Ankegowda, Dr. K.V. Saji, Dr. P. Rajeev, Dr. Sharon Aravind, Dr. M. Alagupalamuthirsolai, Dr. Ljio Thomas, Dr. & Honnappa Asangi] (External support: Dr. J. Rema, Dr. D. Prasath, Dr. R. Praveena & Mr. V. A. Muhammad Nissar)
19. AGR. XXXI (813). Development of fertigation schedule for better productivity in black pepper (2015-2023) [Dr. C.K. Thankamani and Dr. M. Alagupalamuthirsolai]
20. Phy. XII (813): Physiological interventions for yield improvement in small cardamom (Elettaria cardamomum Maton) under weather extremities (2016-2022) [Dr. M. Alagupalamuthirsolai, Dr. S.J. Ankegowda, Dr. Sharon Aravind and Dr. M. Murugan]
21. Biochem. X (813): Study on spike abscission: Developing chemically induced method for harvesting black pepper (Piper nigrum L.) (2018-2022) [Dr. Anees, K., Dr. K.S. Krishnamurthy & Dr. C. N. Biju]
22. Development of drought mitigating physiological strategies in black pepper (2020-2025) [Dr. M. Alagupalamuthirsolai, Dr. C. K. Thankamani] (External support: Dr. K. S. Krishnamurthy & Dr. C. Sarathambal C)
23. Hort. VII (813): Evaluation of nutmeg for its suitability for high density planting (2011-2022) [Dr. J. Rema, Dr. Sharon Aravind & Dr. C.K. Thankamani]
24. ICAR-CPPHT-1: Network project on organic farming (2014-2025) [Dr. C.K. Thankamani, Dr. V. Srinivasan, Dr. R. Praveena, Dr. C. Sarathambal, Dr. S. Shanmughavel & Dr. B. Pradeep]
25. ICAR-CPPHT-2: Network on Organic Farming in Horticulture Crops (2014-22) [Dr. V. Srinivasan, Dr. K. Kandiannan, Dr. R. Dinesh, Dr. J. Rema, & Dr. Honnappa Asangi] (External support: Dr. S.J. Ankegowda, Dr. C.N. Biju &Dr. C.M. Senthil Kumar)

Mega Project IV: Value addition in spices through post-harvest interventions and product diversification

26. CPPHT X (813) Investigation on bioactive phytochemicals from spices (2021-24) [Dr. N. K. Leela, Ms. R. Sivaranjani, Ms. Sona Charles] (Dr. K Anees – External support)
27. Biochem. IX (813): Evaluation of chemo-diversity and microencapsulation of selected spices (2018-2023) [Ms. R. Sivaranjani] (External support: Dr. N.K. Leela & Dr. Anees K.)

28. CPPHT IX (813): Functional product development of spices through value addition and by-product utilization (2020-2025) [Dr. E. Jayashree, Dr. Anees, K., & Dr. B. Dayakar Rao (ICAR-IIMR, Hyderabad)]

Project V: Ensuring food safety in spices through value chain management

29. CPPHT VIII (813): Pesticide residue monitoring of major spices (2020-2024) [Dr. Anees K., Dr. N. K. Leela, Dr. C. M. Senthil Kumar & Dr. M. Balaji Rajkumar]
30. DST-CPPHT-1: Aflatoxin management in spices: Development of novel preventive methods (2021-2023) [Dr. Anees K., Dr. E Jayashree, Dr. C. Sarathambal, Dr. Muhammed Fahim Ansari]

Mega Project VI: Bio-intensive management of pests and diseases in spices

31. ICAR-CP 1. ICAR-Consortium research project on borers in network mode (2014-2023) [Dr. C.M. Senthil Kumar & Dr. M. Balaji Rajkumar]
32. Integrated management of mealy bug (Pseudococcidae: Hemiptera) infesting black pepper (2019 – 2022) [Dr. M. Balaji Rajkumar & Dr. C. M. Senthil Kumar]
33. KSCSTE-CP-1: Development of a Metarhizium sp.-based bio-pesticide formulation for the control of shoot borer, Conogethes punctiferalis infesting cardamom, ginger and turmeric (2021-2024) [Dr. C. M. Senthil Kumar, Dr. M. Balaji Rajkumar & Dr. R. Praveena]
34. Nema. VII (813): Prevalence of lesion nematodes in turmeric growing tracts of India and their economic significance (2018-2022) [Dr. C. Sellaperumal, Dr. Santhosh J Eapen & Dr. R. Praveena]
35. Path. XXVII (813): Development of microbial biostimulants for growth promotion and disease resistance in major spices (2018-2023) [Dr. C. Sarathambal, Dr. A. Jeevalatha& Ms. R. Sivaranjani] (External support: Dr. Mohammed Faisal Peeran]
36. Path. XXVIII (813): Novel strategies for managing bacterial wilt and soft rot diseases of ginger (2018-2022) [Dr. C. N. Biju & Dr. Mohammed Faizal Peeran]
37. Path, XXIX (813): Strategic approaches for management of black pepper diseases (2019 – 2024) [Dr. C. N. Biju, Dr. A. Ishwara Bhat, Dr. A. Jeevalatha, Dr. Mohammed Faisal Peeran, Dr. C. Sellaperumal, Dr. R. Praveena, Dr. Santhosh J. Eapen] (External support: Dr. V. Srinivasan)
38. Path. XXX (813): Development and formulation of Plant Beneficial Rhizosphere Microorganisms (PBRMs) for disease antagonism, soil nutrient solubilization and plant growth promotion (2020-2024) [Dr. R. Praveena, Dr. R. Dinesh & Dr. C. Sarathambal] (External support: Dr. V. Srinivasan)
39. Path. XXX1 (813) Development of off- and on-site detection techniques for major pathogens of spice crops. (2020-2025) [Dr. A Jeevalatha, Dr. A. Ishwara Bhat, Dr. C. N. Biju & Dr. Mohammed Faisal Peeran]
40. Path XXXII (813) (2021-2024): Bacillus spp.-based formulation for the management of rhizome rot disease in small cardamom (2021-2024) [Dr. Mohammed Faisal Peeran, Dr. C. Sarathambal] (External support: Dr. R. Praveena)

Mega Project VII: Empowering spice stakeholders through skilling, entrepreneurship management and policy inputs

41. Ext. VI (813). Capacity building and front-line intervention programmes for spice sector development in NE states and tribal empowerment (2014-23) [Dr. P. Rajeev & Dr. Lijo Thomas]
42. Eco. IV (813): Developing models for enhancing technology and policy impact in spices sector (2020-2025) [Dr. Lijo Thomas, Dr. P. Rajeev & Mr. K Jayarajan]

43. DBT - Kisan Biotech Hub Project (2020-2022) [CPI- Director, ICAR-IISR; Dr.V. Srinivasan, Dr. Lijo Thomas & Dr. P. Rajeev]

New externally funded projects

1. KSCSTE: Development of a *Metarhizium* sp. based bio-pesticide formulation for the control of shoot borer, *Conogethespunctiferalis* infesting cardamom, ginger and turmeric (2020-2024) [Dr. C.M. Senthil Kumar]
2. RKVY: Production and popularization of orthotropic shoots and bush pepper for increasing black pepper productivity (2021-2024) [Dr. Shivakumar MS, Dr. Honnappa Asangi, Dr. Akshitha HJ, Dr. Ankegowda SJ, Dr. Mohammed Faisal Peeran & Dr. Saji KV]
3. RKVY: Establishment of an advanced facility for production of beneficial micro flora for sustainable spice production in Malnad region (2021-2024) [Dr. Mohammed Faisal Peeran, Dr. Ankegowda SJ & Dr. Balaji Rajkumar]
4. RKVY: An Advanced Centre for Mass Production of Beneficial Microflora for Sustainable Agriculture (2021-2024) [Dr. Santhosh J Eapan, Dr. Praveena R, Dr. C.M. Senthil Kumar & Dr. C. Sarathambal]

STAFF LIST

ICAR-IISR, CHELAVOOR, KOZHIKODE

SCIENTIFIC STAFF

1.	Dr. J. Rema	Acting Director
2.	Dr. Santhosh J. Eapen	Head in charge, Division of Crop Protection
3.	Dr. C.K. Thankamani	Head in charge, Division of Crop Production & PHT
4.	Dr. R. Dinesh	Principal Scientist (Soil Science) & Head (General Administration)
5.	Dr. N.K. Leela	Principal Scientist (Organic Chemistry)
6.	Dr. R. Ramakrishnan Nair	Principal Scientist (Genetics & Cytogenetics) (Upto 30.11.2021)
7.	Dr. K. Kandiannan	Principal Scientist (Agronomy)
8.	Dr. K.S. Krishnamurthy	Principal Scientist (Plant Physiology)
9.	Dr. A. Ishwara Bhat	Principal Scientist (Plant Pathology)
10.	Dr. K.V. Saji	Principal Scientist (Economic Botany)
11.	Dr. P. Rajeev	Principal Scientist (Agricultural Extension)
12.	Dr. V. Srinivasan	Principal Scientist (Soil Science)
13.	Dr. T.E. Sheeja	Principal Scientist (Biotechnology)
14.	Dr. E. Jayashree	Principal Scientist (Agricultural Engineering)
15.	Dr. D. Prasath	Principal Scientist (Horticulture)
16.	Dr. C.M. Senthil Kumar	Principal Scientist (Entomology)
17.	Dr. Lijo Thomas	Senior Scientist (Agricultural Economics)
18.	Dr. C.N. Biju	Senior Scientist (Plant Pathology)
19.	Dr. R. Praveena	Senior Scientist (Plant Pathology)
20.	Dr. A. Jeevalatha	Senior Scientist (Plant Pathology)
21.	Dr. C. Sarathambal	Senior Scientist (Agricultural Microbiology)
22.	Dr. Divya P.S.	Senior Scientist (Biotechnology)
23.	Dr. Anees K.	Scientist (Plant Biochemistry)
24.	Dr. M. Alagupalamuthirsolai	Scientist (Plant Physiology)
25.	Dr. C. Sellaperumal	Scientist (Nematology)
26.	Dr. Sharon Aravind	Scientist (Spices Plantation Medicinal and Aromatic Plants)
27.	Dr. S. Aarthi	Scientist (Spices Plantation Medicinal and Aromatic Plants)
28.	Mr. V.A. Muhammed Nissar	Scientist (Spices Plantation Medicinal and Aromatic Plants)
29.	Ms. R. Sivaranjani	Scientist (Plant Biochemistry)
30.	Mr. Gobu R.	Scientist (Genetics and Plant Breeding)
31.	Ms. Sona Charles	Scientist (Agricultural Bioinformatics)
32.	Dr. Neethu K.C.	Scientist (Agricultural Process Engineering)

ADMINISTRATIVE STAFF

1.	Sri. T.E. Janardhanan	Senior Administrative Officer
2.	Sri. T.D.S. Prakash	Finance & Accounts Officer (Upto 13.10.2021)
3.	Ms. Beena C.K.	Private Secretary
4.	Mr. P. Muraleedharan	Assistant Administrative Officer (Upto 24.12.2021)
5.	Mr. P. Sundaran	Assistant Administrative Officer
6.	Mr. Suniv V.C.	Assistant Administrative Officer

7.	Mr. Neela Megha Shyamala Kannan	Personal Assistant
8.	Mr. V.V. Sayed Mohammed	Assistant
9.	Ms. Seema M.	Upper Division Clerk
10.	Ms. Rabeena N.	Upper Division Clerk
11.	Mr. P.K. Rahul	Lower Division Clerk

TECHNICAL STAFF

1.	Mr. M.P. Ramesh Kumar	Chief Technical Officer (Upto 30.04.2021)
2.	Mr. John George	Chief Technical Officer
3.	Mr. R. Bharathan	Chief Technical Officer
4.	Dr. E. Radha	Asst. Chief Technical Officer
5.	Mr. K. Jayarajan	Asst. Chief Technical Officer
6.	Ms. N. Prasannakumari	Senior Technical Officer
7.	Mr. A. Sudhakaran	Senior Technical Officer
8.	Mr. K. Krishnadas	Technical Officer
9.	Ms. P.K. Chandravally	Technical Officer
10.	Ms. Priya George	Senior Technical Assistant
11.	Mr. Vijesh Kumar I.P.	Technical Assistant
12.	Ms. N. Karthika	Senior Technician (Laboratory Technician)
13.	Mr. O.G. Sivadas	Senior Technician
14.	Mr. V.S. Binoy	Senior Technician
15.	Mr. Vishnu B.	Technician
16.	Ms. Shajina O.	Technician

SUPPORTING STAFF

1.	Ms. C.M. Kamalam	Skilled Support Staff
2.	Mr. M.K. Purushu	Skilled Support Staff (Upto 01.04.2021)
3.	Mr. Abhi Balagopal	Skilled Support Staff

IISR EXPERIMENTAL FARM, PERUVANNAMUZHI

TECHNICAL STAFF

1.	Mr. E.S. Sujeesh	Senior Technical Officer
2.	Mr. T.R. Sadasivan	Senior Technical Assistant
3.	Ms. Rejina P. Govind	Senior Technician
4.	Mr. Hareesh B.T.	Senior Technician
5.	Mr. Rasmish A.R.	Senior Technician
6.	Mr. Nikhil C.M.	Technician

SUPPORTING STAFF

1.	Ms. P.N. Kausalya	Skilled Support Staff
2.	Mr. Vijesh V.	Skilled Support Staff

KRISHI VIGYAN KENDRA, PERUVANNAMUZHI

SCIENTIFIC STAFF

1.	Dr. P. Ratha Krishnan	Programme Coordinator

ADMINISTRATIVE STAFF

1.	Mr. K. Faisal	Stenographer Gr. III

TECHNICAL STAFF

1.	Dr. P.S. Manoj	Chief Technical Officer (SMS-Hort.)
2.	Dr. S. Shanmugavel	Chief Technical Officer (SMS -Vet. Sc.)
3.	Dr. K.M. Prakash	Chief Technical Officer (SMS - Agro.)
4.	Dr. B. Pradeep	Asst. Chief Technical Officer (SMS - Fisheries)
5.	Ms. A. Deepthi	Asst. Chief Technical Officer (SMS - H. Sc.)
6.	Dr. K.K. Aiswariya	Asst. Chief Technical Officer (SMS - Pl. Prot.)
7.	Mr. T.C. Prasad	Technical Officer (Driver-cum-Mechanic)
8.	Mr. C.K. Jayakumar	Technical Officer (Programme Assistant) (Computer)

SUPPORTING STAFF

1.	Mr. C. Ravindran	Skilled Support Staff

IISR REGIONAL STATION, APPANGALA

SCIENTIFIC STAFF

1.	Dr. S.J. Ankegowda	Head (I/C) Regional Station
2.	Dr. Balaji Rajkumar	Scientist (Agri. Entomology)
3.	Dr. Muhammed Faisal Peeran	Scientist (Plant Pathology)
4.	Dr. H.J. Akshitha	Scientist (Spices Plantation Medicinal & Aromatic Plants)
5.	Dr. Honnappa Asangi	Scientist (Spices Plantation Medicinal & Aromatic Plants)
6.	Dr. M.S. Shivakumar	Scientist (Genetics & Plant Breeding)

ADMINISTRATIVE STAFF

1.	Mr. P.T. Jayaprakash	Upper Division Clerk

TECHNICAL STAFF

1.	Mr. H.C. Rathish	Senior Technical Assistant
2.	Ms. H.D. Praveena	Senior Technical Assistant
3.	Mr. N. Cholurappa	Senior Technician
4.	Mr. Ranjith P.B.	Technician

SUPPORTING STAFF

1.	Ms. B.M. Lalitha	Skilled Support Staff (Upto 30.09.2021)
2.	Mr. Marigowda	Skilled Support Staff
3.	Mr. Sachin K.P.	Skilled Support Staff

WEATHER DATA

ICAR- Indian Institute of Spices Research, Chelavoor, Kozhikode

Month	Temperature (ºC)		Rainfall	
	Maximum	Minimum	Total rainfall (mm)	Rainy days
January	33.8	21.2	108.4	6
February	34.6	20.4	7.2	2
March	35.4	22.6	29.6	2
April	35.2	23.3	36.0	3
May	35.7	22.7	349.0	14
June	33.0	22.4	371.4	18
July	29.8	23.9	286.4	12
August	30.3	20.6	331.6	22
September	30.4	24.4	184.0	11
October	32.0	23.7	573.0	17
November	33.4	22.0	186.0	16
December	34.1	21.4	18.8	2

ICAR- IISR, Regional Station, Appangala, Madikeri

Month	Temperature (ºC)		Rainfall	
	Maximum	Minimum	Total rainfall (mm)	Rainy days
January	26.3	9.8	64.0	4
February	26.8	9.1	64.0	3
March	27.5	11.2	00	0
April	29.2	12.2	156.6	8
May	29.8	11.6	324.8	16
June	29.0	11.1	475.0	19
July	27.9	10.7	724.6	23
August	25.9	10.3	400.6	25
September	25.4	10.4	386.6	23
October	25.5	10.3	342.4	22
November	25.5	10.3	219.6	19
December	25.5	10.5	3.0	1

वार्षिक प्रतिवेदन Annual Report 2021






भाकृअनुप
ICAR

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