वार्षिक रिपोर्ट
Annual Report
2006-'07

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IISR ANNUAL REPORT
2006-'07

भारतीय मसाला फसल
अनुसंधान संस्थान
कालिकट

Indian Institute of
Spices Research
Calicut

भारतीय कृषि
अनुसंधान परिषद्
नई दिल्ली

Indian Council of
Agricultural Research
New Delhi

Contents

प्राक्कथन

बढ़ती मांग और बाजार मूल्य में वृद्धि के कारण कुछ वर्षों तक मंदी के पश्चात मसाला उत्पादन की अर्थव्यवस्था फिर से तेजी की ओर अग्रसर है। इस पृष्ठभूमि के साथ साथ दसवीं योजना के अंतिम वर्ष की रिपोर्ट होने के कारण 2006–2007 की यह वार्षिक रिपोर्ट काफी महत्वपूर्ण है। मसालों के जीन केंद्र के रूप में भारत की शक्ति को ध्यान में रखते हुए काली मिर्च, इलायची, अदरक आदि के बड़ी संख्या में जननद्रव्य को संरक्षित करना है। अनुसंधान सलाहकार समिति के परामर्श से विभिन्न प्रकार के जैविक और अजैविक दबावों के प्रति सहिष्णु काली मिर्च की किस्मों को विकसित करने के लिए ठोस अनुसंधान कार्यक्रमों की पहल की गई है। जीसी–एमएस अध्ययन के आधार पर किए गए अध्ययनों में भारतीय इलायची की उत्कृष्टता के संकेत मिले हैं। जैवसूचना केन्द्र ने बागवानी फसलों पर *फाइटोफ्थोरा* रोग के लिए एक नया डाटाबेस विकसित किया है। संस्थान के प्रशासन में आधुनिकीकरण के लिए एरिसॉफ्ट एक महत्वपूर्ण उपलब्धि रही है। इस नए सॉफ्टवेयर को तत्कालीन उपमहानिदेशक (बागवानी) डॉ गौतम कल्लू द्वारा लांच किया गया। अखिल भारतीय समन्वित मसाला अनुसंधान परियोजना ने अब तक प्राप्त उपलब्धियों को एकत्रित किया है जो किसानों तक प्रौद्योगिकी के हस्तांतरण के लिए काफी लाभकारी सिद्ध होंगीं।

मैं भारतीय कृषि अनुसंधान परिषद के आदरणीय महानिदेशक डॉ मंगला राय तथा पूर्व एवं वर्तमान उप महानिदेशक डॉ गौतम कल्लू तथा डॉ एच.पी. सिंह का हृदय से आभारी हूं। अनुसंधान सलाहकार समिति (आरएसी) के सभी सदस्यों का उनके उत्कृष्ट सुझावों के लिए कृतज्ञ हूं। डॉ के. वी. रमन्ना, सहायक महानिदेशक (बागवानी–II) को उनके द्वारा दिए गए सहयोग के लिए धन्यवाद देता हूं। डॉ एम. आनन्दराज, परियोजना समन्वयक (मसाला फसलें) को भी धन्यवाद ज्ञापित करता हूं। मैं इस वार्षिक प्रतिवेदन के समय पर प्रकाशन के लिए संपादकीय बोर्ड की सराहना करता हूं।

(वी. ए. पार्थसारथी)
निदेशक

कालीकट
मई, 2007

FOREWORD

Economy of spices cultivation is turning round the corner after a couple of years of slump because of increase in demand and good market price. In this background the Annual Report of Indian Institute of Spices Research for 2006-'07 is very significant besides this being the Annual Report pertaining to the last year of Tenth Plan. India's strength as gene centre for spices has been kept in mind to conserve a large number of germplasm of black pepper, cardamom, ginger, turmeric, vanilla, tree spices etc. With the advise of the Research Advisory Committee (RAC) more focused research programmes have been initiated to develop black pepper varieties tolerant to various biotic and abiotic stresses. Studies have indicated the superiority of Indian cardamom based on the GC-MS study. The bioinformatics Centre has developed a new database for *Phytophthora* diseases of horticultural crops. In the administration of the institute, ARISoft is a significant achievement in the modernization of the administration of the institute. The new software was launched by the then Deputy Director-General (Hort.), Dr. G. Kalloo. The AICRP on Spices has consolidated the achievements, which would go a long way in developing technologies for transfer to farmers.

I place on record my heartfelt gratitude to our respected Director-General, Dr. Mangala Rai and to the former and present Deputy Directors General of Horticulture, Dr. G. Kalloo and Dr. H.P. Singh, respectively. We are grateful to the RAC Members for their excellent suggestions. To Dr. K.V. Ramana, Assistant Director-General (Hort.II), I owe a great deal for his support. Dr. M. Anandaraj, Project Coordinator (Spices) deserves a mention for his support. I appreciate the Editorial Board for bringing out the Annual Report in time.

Calicut,
June 2007

V.A. PARTHASARATHY
DIRECTOR

सारांश

काली मिर्च

आनुवांशिक संसाधन

वर्तमान जननद्रव्य रिपाजिटरी में अटापडी, सिरूवानि, वैगामॉन, वंदीपेरियार, एरूमेली (केरल), मोलेम, वालपोई तथा कोनाकन (गोवा), दापोली (महाराष्ट्र) तथा किसानों के खेतों से लगभग 101 प्रविष्टियां (86 जंगली तथा 13 उगाई जाने वाली) को शामिल किया गया। वैकल्पिक जननद्रव्य रिपॉजिटरी के रूप में केन्द्रीय रोपण फसल अनुसंधान संस्थान, किडू में 100 प्रविष्टियों को लगाया गया। आईपीजीआरआई डिस्क्रिप्टर के आधार पर 50 प्रविष्टियों का अभिलक्षणीकरण किया गया और इस प्रकार अब तक 850 प्रविष्टियों के अभिलक्षणीकरण का कार्य किया जा चुका है। भारतीय मसाला फसल अनुसंधान संस्थान, कालीकट की जननद्रव्य संग्रहालय में 2337 प्रविष्टियां संरक्षित की जा चुकी हैं (1075 जंगली तथा 1272 उगाई जाने वाली)। किसान के पौधालय से एकत्रित किए गए एक अनोखे बहुफलन वाले काली मिर्च के स्पाइक (स्पाइक प्रोलिफिरेशन) में पुष्पन तथा फल प्राप्त किए गए।

कालीमिर्च की नई किस्में

तेईसवीं केरल राज्य किस्म विमोचन समिति ने कालीमिर्च की चार किस्मों के विमोचन को अनुमोदित कर दिया है जिसमें आईआईएसआर–शक्ति, आईआईएसआर –थेवम,आईआईएसआर–गिरिमुंडा तथा आईआईएसआर मालाबार एक्सेल सम्मिलित हैं। आईआईएसआर शक्ति फूट रॉट रोग के प्रति सहिष्णु है। आईआईएसआर थेवम अधिक पैदावार देने वाली तथा इसके वयस्क पौधे फूट रॉट रोग के प्रति सहिष्णु हैं। आईआईएसआर गिरिमुंडा अत्यधिक उपज वाली तथा एंथेक्नोज रोग के प्रतिरोधी है जबकि आईआईएसआर मालाबार एक्सेल अत्यधिक पैदावार के साथसाथ उच्च ओलियोरेजिन (13.6 प्रतिशत) देने वाली है। फूट रॉट प्रतिरोधी दो संभाव्य किस्में एचपी–490 तथा एचपी–521 को नियंत्रित ग्रीन हाउस परीक्षणों में रोगजनक इनोकुलेशन को बनाये रखने वाली किस्मों के रूप में पहचाना गया है।

जैव–तकनीकी

केरल और कर्नाटक राज्यों में 25 हेक्टेयर से भी अधिक क्षेत्र को सम्मिलित करते हुए 100 परीक्षणों में टिशू कल्चर पादपकों का फील्ड मूल्यांकन किया गया जिससे संकेत मिला कि उनमें अच्छी तरह स्थापत्य क्षमता है तथा उनमें से 20 प्रतिशत में अग्र पुष्पन पाया गया। आईएसएसआर मार्कर्स का उपयोग करते हुए आण्विक अभिलक्षणीकरण से टिशू कल्चर्ड पौधों में आनुवांशिक एकरूपता का संकेत मिला। भारत, वियतनाम, मलेशिया तथा इंडोनेशिया से व्यापार हेतु प्रयुक्त काली मिर्च के आरएपीडी आधारित आण्विक प्रोफाइल ने उनके उत्पत्ति दश के साथ एक विशेष क्लस्टरिंग पैटर्न के साथ संगतता पाई गई।

व्यावसायिक कालीमिर्च पाउडर में मिलावट की जांच के लिए पीसीआर तकनीक

व्यावसायिक कालीमिर्च के पाउडर के बाजारू नमूनों मे प्राइमर ओपीजे 09 के उपयोग द्वारा पीसीआर आधारित मालीक्यूलर विधि से जांच करने पर पपीते (केरिका स्पी.) युक्त लगभग 470 बीपी का विशेष बैंड पाया गया। इसके पूर्व कालीमिर्च पाउडर के बाजारू नमूनों में पपीते के बीजों की मिलावट की जांच के लिए एक सीक्वेंस करेक्टराइज्ड एम्प्लीफाइड रीजन (एससीएआर) मार्कर विकसित किया गया।

काली मिर्च की उत्पादकता में सुधार

यूरिया, सुपर फास्फेट, पोटाश तथा मैग्नीशियम सल्फेट मिश्रित पादप पोषण घोल को 4:3:2:1 के अनुपात में सोलेराइज्ड पॉटिंग मिक्चर के साथ प्रयोग करने से कालीमिर्च के पौधों की मजबूती तथा स्वस्थ पौधों की प्राप्ति हुई। बुश पीपर में सल्फेट ऑफ पोटॉश (एसओपी–1.75 ग्राम प्रति पॉट) के दो माह में प्रयोग द्वारा प्रति पॉट 295 ग्राम की सर्वाधिक उपज प्राप्ति हुई जबकि इस क्रम में म्यूरेट ऑफ पोटाश (एमओपी–3. 5 ग्राम) तथा एसओपी (4.5 ग्राम प्रति पॉट) क्रमशः दूसरे तथा तीसरे स्थान पर पाए गए। कालीमिर्च के बागान में एसओपी (500 ग्राम प्रति पौधा) तथा मैग्नीशियम सल्फेट(500 ग्राम प्रति पौधा) के प्रयोग से सर्वाधिक उपज (3.16 किलो प्रति वाइन) प्राप्त हुई जो कि पोटाश की एसओपी के रूप में अनुशंसित डोज के बराबर थी तथा कंट्रोल की तुलना में काफी अधिक थी। पोटॉश के विभिन्न रूपों में पानी में घुलनशील तथा उपलब्ध पोटाश का कालीमिर्च के दानों, ओलियोरेजिन तथा पिपरीन के साथ महत्वपूर्ण सकारात्मक सहसंबंध पाया गया। नाइट्रोजन (70 ग्राम), फास्फोरस (55 ग्राम), पोटाश (270 ग्रम) तथा मैग्नीशियम (200 ग्राम) के साथ एजोस्पिरिलम के प्रयोग से कंट्रोल तथा एनपीके (140:55:270 ग्राम प्रति वाइन) तुलना में कालीमिर्च की लताओं से बढ़ती हुई उपज प्राप्त हुई।

उत्पादकता का कायिकी एवं जैवरासायनिक आधार

अति उपजशील किस्मों में अधिक फोटोसिंथेटिक दर (2.2-3.86μ mole $m^{-2} s^{-1}$) तथा कम उपजशील किस्मों में कम फोटोसिंथेटिक दर (2.0-3.2 μ moles $m^{-2} s^{-1}$) देखी गई। अधिक उपज देने वाली प्रजातियों में तुलनात्मक रूप से कम पर्ण तापक्रम (32.6 to 33.7° सेल्सियस) पाया गया जबकि कम उपजशील किस्मों में यह (32.9 to 33.8° सेल्सियस)

पाया गया। अति उपजशील किस्मों में पूर्व फलनकाल तथा फलनकाल में नाइट्रेट रिडक्टेज सक्रियता अधिक पाई गई जो कि क्रमशः प्रति हेक्टेयर प्रति ग्राम नाइट्रस आक्साइड की 429-921एम मोल्स तथा प्रति हेक्टेयर प्रति ग्राम नाइट्रस आक्साइड की 621.1183 एम मोल्स थी जबकि कम उपजशील किस्मों में यह सक्रियता कम पाई गई जो कि प्रति हेक्टेयर प्रति ग्राम नाइट्रस आक्साइड की 453.814एम मोल्स तथा प्रति हेक्टेयर प्रति ग्राम नाइट्रस आक्साइड की 612.994 एम मोल्स थी ।

काली मिर्च में जैवरासायनिक तथा भौतिक गुण घटकों पर भौगोलिक तथा जलवायवीय प्रभाव

सामान्य तापक्रम से 3 डिग्री सैल्शियस (जो कि कालीकट में एचएडीसीएम3 माडल के आधार पर 2050 में ग्लोबल वार्मिंग के कारण प्रक्षेपित तापमान है) अधिक ऊपरी तापमान पर चार माह तक प्लांट ग्रोथ चैम्बर में उगाए गए कालीमिर्च के पौधों का पर्ण क्षेत्रफल, पौध ऊँचाई तथा प्रकाश संश्लेषण दर सामान्य तापक्रम पर उगाई गई कालीमिर्च के समतुल्य पाई गई।

पाइपर नाइग्रम पत्तियों के पर्ण बाष्पशील आयल तत्वों की कुल संख्या पश्चिमी घाट से संग्रहित प्रविष्टियों में 7–15 के बीच पाई गई तथा जैवरायासनिक घटकों पर भौगोलिक प्रभाव अत्यधिक महत्वपूर्ण था।

मूल्य वर्धन तथा संग्रहण दशाएं

सफेद मिर्च (व्हाइट पीपर) के उत्पादन की प्रकिया का प्रमाणीकरण किया गया है। लगभग 25 से 26 प्रतिशत तक की शुष्क मात्रा प्राप्त हुई। निर्वात दशाओं में पोलीथीन कवर में संग्रहित की गई शुष्क कालीमिर्च में 100 प्रतिशत एन2 तथा 90 प्रतिशत एन2 10 प्रतिशत सीओ2 दशाओं में 240 दिनों तक के अंतर्गत सिवाय 15 प्रतिशत नमी में कमी के अतिरिक्त तेल, ओलियोरेजिन में कोई अंतर नहीं देखा गया ।

कालीमिर्च में राइजोस्फेयर मृदा के मानकों में माइक्रोबियल कम्युनिटी विश्लेषण का उपयोग

एरिथ्रिना–बीपी (48) या आरसीसी पोल –बीपी (50) की तुलना में ग्लिरिसिडिया–कालीमिर्च (बीपी) पद्धति (68) तथा इसके पश्चात गारूगा–बीपी (66) तथा एलांथस–बीपी पद्धतियों (65) में मृदा माइक्रोबियल कम्युनिटी में व्यापक विविधता पाई गई। एलांथस–बीपी (19) में फंगल जनसंख्या अधिक थी जबकि अन्य पद्धतियों में निम्न फंगल विविधता देखी गई। अध्ययन ने संकेत दिया कि कालीमिर्च में सहायक मानकों का मृदाओं में माइक्रोबियल कम्युनिटी संरचना पर राइजोस्फेयर का विशिष्ट प्रभाव होता है।

फाइटोप्थोरा फुट रॉट

कालीमिर्च के *फाइटोप्थोरा* आइसोलेट्स के मारफोलॉजिकल और आण्विक अभिलक्षणीकरण से पता चला कि आइसोलेट्स में *पी. कैप्सिसी* तथा *पी. ट्रोपिकेलिस* दोनों के लक्षण पाए गए। क्लेमिडोस्पोर्स का उत्पादन, 30 डिग्री सैल्शियस पर वृद्धि जैसे लक्षण *पी. ट्रोपिकेलिस* से मिलते पाए गए जबकि कैप्सिकम पर पैथोजेनेसिटी तथा स्पोरेंजियल लक्षण *पी. कैप्सिसी* के समान पाए गए।

जैवनियंत्रण तकनीक

कालीमिर्च में *फाइटोप्थोरा कैप्सिसी* के विरूद्ध प्रभावी पाए गए एंडोफायटिक बैक्टीरिया को *स्यूडोमोनस एरूजिनोसा* (बीपी–35) तथा *पी. पुटिडा* (बीपी–25) के रूप में पहचान की गई है जिसे 16 एसआर डीएनए के न्यूक्लियोटाइड सीक्वेंश द्वारा विश्लेषित किया गया। *स्यूडोमोनस एरूजिनोसा* को एक्साइज्ड सिंगल नोडल शूट में डेंसिटी डिपेंडेंट सिस्टेमिक प्रतिरोधिता प्रेरित करते पाया गया।

एंथ्रेक्नोज

कोलेटोट्राइकम ग्लोस्पोराइडिस के प्रति 11 प्रविष्टियों / प्रजातियों ने प्रतिरोधिता दर्शाई जिनमें पैन्नियूर–5, आईआईएसआर गिरमुंडा, एचपी–780, पंचमी, ऐमप्रिया, शुभकारा, करिमुंडा (ईदुक्की), कोट्टानंदन, जेराकमुंडा (गुदालुर), अराकलामुंडा तथा चोमला सम्मिलित हैं।

स्टंटेड व्याधियां

केरल राज्य के कोषीक्कोड, इडुक्की तथा वयानाड तथा कर्नाटक के कोडागु जिले से ओ आरएफ एक और ओआरएफ तीन के अंश की सीक्वेंस विश्लेषण से पता चला के ओआरएफ एक सीक्वेंस की परिवर्तनीय प्रकृति है जबकि आइसोलेट्स में ओरआरएफ तीन अत्यधिक संरक्षित है।

सूत्रकृमि

भारत में कालीमिर्च को ग्रसित करने वाली नीमेटोड (*रेडोफोलस सिमिलिस*) के आरडीएनए तथा सीक्वेंश एनालिसिस से पता चला कि इसके विश्व में ज्ञात *आर. सिमिलिस* से 98 प्रतिशत समानता पाई गई। यह *आर. सिमिलिस* के भारतीय आइसोलेट्स के आण्विक अभिलक्षण की पहली रिपोर्ट है।

होस्ट प्रतिरोधिता

पी. कैप्सिसी के प्रति सहिष्णु 6 कालीमिर्च लाइंस की *आर. सिमिलिस* तथा *एम इनकगनिटा* के विरूद्ध जांच की गई। ये सभी लाइंस आर. सिमिलस के प्रति ससेप्टेबल पाई गईं जबकि प्राथमिक मूल्यांकन में एम. इनकगनिटा के प्रति दो लाईंस एसीसी 1578 और ओपी प्रोजिनी 04/1533(2) ने प्रतिरोधी प्रतिक्रिया दर्शाई। चार मूल्यांकित पाइपर प्रजातियों में से केवल पी. कोलुब्रिनम ने दोनों नीमेटोड के प्रतिरोधिता दर्शाई। आर. सिमिलिस प्रतिरोधी दो काली मिर्च की लाइंस एचपी 39 तथा सी 820 को अपने रोपण काल के चार वर्ष पश्चात भी अन्य से काफी बेहतर पाया गया ।

जैव नियंत्रण प्रौद्योगिकी

16 एस आरडीएनए सीक्वेंशिंग द्वारा दो आशावान एंडोफाइटिक बैक्टीरिया की प्रजाति पहचान की

गई। *आर. सिमिलिस* को प्रदर्शित करने वाले दो एंडोफाइट्स की पहचान *कट्रोबैक्टीरियम ल्यूटिनम* (टीसी–10) तथा *बैसिलस मेगाटेरियम* (बीपी–17) के रूप में पहचान की गई।

रूट मिलीबग

पिछले तीन वर्षों में किए गए अध्ययन के आधार पर रूट मिलीबग के प्रबंधन के लिए एक समन्वित व्याधि प्रबंधन अनुसूची विकसित की गई जिसमें रूट मिलीबग मुक्त रूटेड कटिंग्ज को फील्ड में रोपना, ग्रीष्म में विशेषकर जब कालीमिर्च के साथ कॉफी को अंतःफसल के रूप में लिया गया हो काली मिर्च की लताओं के मध्य के खाली जगह में खरपतवारों को हटाना, अत्यधिक ग्रसित लताओं में इमिडाक्लोप्रिड 0.0125 प्रतिशत या एसिटामेप्रिड 0.0125 प्रतिशत या कार्बोसल्फान 0.075 प्रतिशत या क्लोरपाइरिफॉस 0.075 प्रतिशत का प्रयोग या मध्यम रूप से ग्रसित लताओं में 3 प्रतिशत तंबाकू का घोल छिड़कना तथा फाइटोप्थोरा तथा नीमेटोड इंफेक्शन के नियंत्रण के लिए निवारक उपाय अपनाना सम्मिलित है।

इलायची

जननद्रव्य और संभाव्य किस्में

केरल (अट्टापडी और वेगामोन) में चलाए गए दो अन्वेषणों में 15 प्रविष्टियां एकत्रित की गईं जिनमें एक प्यूबेसेंट पत्तियों सहित ग्रीन गोल्ड वेरियेंट सम्मिलित है। आईपीजीआरआई डिस्क्रिप्टर के आधार पर 26 कंपाउंड पेनिकल प्रविष्टियों का अभिलक्षणी करण किया गया। इनमें तेल अंश 3.9 से 6 प्रतिशत के बीच पाया गया। अत्यधिक तेल वाली प्रविष्टियों में एनएचवाई–3, एनएचवाई–14, एनएचवाई–15, एनएचवाई–35, आरआर–1 एमबी–3, वीए–1, एएमबी–2, एमए–7 तथा सीसीएस–1 ओपी सम्मिलित हैं।

भारतीय इलायची की कैमेस्ट्री

जीसी–एमएस अध्ययनों ने ग्वाटेमाला और श्रीलंकाई इलायची की तुलना में भारतीय इलायची की उत्कृष्ट इंट्रिन्सिक गुणवत्ता की पुष्टि की। भारतीय, ग्वाटेमाला और श्रीलंका की इलायची में इशेंसियल तेल की उपज क्रमशः 10, 5 तथा 14 प्रतिशत पाई गई। केमिकल प्रोफाइल में भारतीय इलायची में 33 कम्पाउंड, ग्वाटेमाला की इलायची में 26 तथा श्रीलंका की इलायची में 36 कंपाउंड पाए गए तथा इनमें से सभी तीनों निदर्शों मे 22 कामन थे। तेल के जीसी प्रोफाइल से पता चला कि भारतीय इलायची 1,8–सिनेओल तथा अल्फा टरपिनाइल एसीटेट में धनी है। ग्वाटेमाला तथा श्रीलका की इलायची की तुलना में भारतीय इलायची में कम मात्रा में लिनालूल दर्ज किया गया। लिनालूल की कम सांद्रता इलायची के स्वाद को बढ़ाती है।

इलायची के लिए देशी पोषक मोबिलाइजिंग बैक्टीरिया

एजोस्पिरिलम (सीएजेड 3) और फोस्फोबैक्टीरिया (सीपीबी2) के प्रयोग द्वारा पत्तियों, शुष्क भार, कुल एनपीके अपटेक, रूट कॉलोनाइजेशन में सर्वाधिक संख्या तथा रोग प्रभाव में कमी दर्ज की गई। सीएजेड 3 आइसोलेट की नाइट्रोजन स्थिरीकरण क्षमता प्रतिग्राम 7.39 मिलीग्राम मेलेट पाई गई जबकि सीपीबी2 मे प्रति लीटर 220 मिलीग्राम की उच्चतर विलयन दक्षता रिकार्ड की गई।

जैव और अजैव प्रतिरोधिता

आई.आइ.एस.आर. अविनाश, ग्रीन गोल्ड और सी0एस0–893 नमी अभाव के प्रति तुलनात्मक रूप से सहिष्णु है जबकि सी.सी.एस–1 सुग्राही है । सी0एल0–893 और इसके संकर संयोजकों के बेहतर बढ़वार और पैदावार गुण रिकार्ड किए गए । शून्य से 6 रेटिंग पैमाने का उपयोग करके 72 प्रविष्टियों पर पर्ण अंगमारी का प्राकृतिक संक्रमण रिकार्ड किया गया तथा 21 प्रविष्टियां कोलटोट्रॉइकम ग्लिओस्पोरोइडिस के लिए प्रतिरोधी पाई गई ।

अदरक

जननद्रव्य, आनुवंशिक सुधार और आशाजनक किस्में

कम रेशे वाली प्रविष्टियों में प्रविष्टि 164, 558, 246 और 537 में 3 प्रतिशत से कम रेशे के साथ 2 प्रतिशत से अधिक तेल तथा 6.5 प्रतिशत से ज्यादा ओलियोरेजिन था । उच्च तेल वाली किस्मों में प्रविष्टि 162, 50, 57, 411, 225, 201 और 197 में 2 प्रतिशत से अधिक तेल प्राप्त हुआ, प्रविष्टि 50 और 57 में 6.5 प्रतिशत से अधिक ओलियोरेजिन होता है, प्रविष्टि 197, 217, 228, 411 में 3 प्रतिशत से कम रेशा मिला। विदेशी अदरक के संचयनों में नेपाल की प्रविष्टि (प्रविष्टि 581) ने उपज और प्रविष्टि 420 ने उच्च तेल की क्षमता देर्शायी । अदरक की प्रविष्टि –12 (इरेटूपेट्टा) को इसके फ्लोरल लैबेलम के रंग पैटर्न, उच्च पराग अभिरंजकता (27.5 प्रतिशत), पराग दानों का स्वःपात्रे उच्च अंकुरण (10. 44) बेहतर पराग नली बढवार (संबर्धन के 24 घन्टे बाद औसत लम्बाई 1209 यू0एम) और स्व–परागण की वर्तिकाग्र पर पराग दानों का अंकुरण बेजोड पाया गया । यह किस्म बीज जमने को प्रेरित करने हेतु भावी अध्ययनों के लिए उपयुक्त हो सकती है ।

अदरक में लक्षित उपज लेने के लिए पोषकतत्व को इष्टतम करना

द्वितीय कोटि के अनुक्रिया संबधी कार्य के माध्यम से फास्फोरस / जिंक अनुपात का थ्रेसहोल्ड वैल्यू 90 पाया गया । खेत दशाओं के अन्तर्गत इसकी वैधता को 145–223 के परिसर में 60 डी.ए.पी. पर प्रारम्भिक पत्ती के फास्फोरस / जिंक के अनुपात को अगस्त और अक्टूबर के दौरान दो बार जिंक (0.5प्रतिशत) का पर्णीय छिड़काव करने के बाद 69–150 थ्रेसहोल्ड के परिसर में लाया जा सका । अनुपात को 108 से नीचे तक कम करके प्रकन्द की उपज को 20 प्रतिशत तक अधिक प्राप्त किया जा सके । नाइट्रोजन, फास्फोरस, पोटाश और जिंक के प्रारम्भिक मृदा उर्वरता स्तरों पर आधारित 10,15 और 20 कि0ग्रा0 / क्यारी

उपज प्राप्त करने के लिए उर्वरक की मात्राओं का प्रयोग किया गया । पर्णीय छिड़काव के रूप में जिंक सम्पूरित किया गया । अदरक के प्रकन्द की प्राप्त उपज 10.8, 12.4 और 11.4 कि0ग्रा0 प्रति क्यारी थी जो लक्ष्य से 5 प्रतिशत,–17 प्रतिशत तथा–43 प्रतिशत थी । वारदा में कम उर्वरक प्रयोग के साथ संस्तुत मात्रा से लक्षित पोषक तत्व प्रयोग के माध्यम से 14–26 प्रतिशत अधिक उपज प्राप्त की जा सकी । अदरक में पोषक तत्व प्रबन्धन प्रणाली जैसे मृदा जीवाणिवक समूह गठन पर समेकित, जैविक या रासायनिक उपचारों से पता चला कि समेकित प्रणली के अन्तर्गत प्रोकैरियोटिक संख्या अधिकतम थी जबकि समेकित और पूर्ण जैविक दोनों उपचारों में यूकैरियोटिक संख्या अधिक थी । दिलचस्प रूप में रासायनिक उपचार में कवक संख्या अधिक थी ।

अदरक का फीनोलॉजी (घटनाविज्ञान)

अदरक में कुल ग्यारह टिलर के साथ पहला टिलर 646 अंश दिवस पर निकला तथा पौधा 3096.8 अंश दिवसों में पक गया। अदरक में मुख्य तने के साथ पत्ती की बढ़वार के बाद द्विघाती पैटर्न मिला। अदरक में प्रति क्लंप 4092 वर्ग से.मी. का कुल पत्ती क्षेत्र नोट किया गया ।

मृदु विगलन

अदरक में, प्रकन्द विगलन रोग के प्रबन्धन के लिए राइजोबैक्टीरिया (आई.आई.एस.आर–51,आई.आई.एस.आर–6), इण्डोफाइटिक बैक्टीरिया (बी.पी.–35), *टी हर्जियानम* (पी–26), मेटालैक्सिल–मैन्कोजेब 0.125 प्रतिशत और मैन्कोजेब 0.2 प्रतिशत का मूल्यांकन किया गया । इस रोग का प्रभाव जैविकीय उपचार की तुलना में रासायनिक उपचारो से कम था। इसके अतिरिक्त रासायनिक उपचार ने अधिकतम उपज रिकार्ड की।

हल्दी

आशाजनक किस्में

केरल राज्य की तेईसवीं किस्म विमोचन समिति ने खेती के लिए हल्दी की दो उच्च गुणवत्ता वाली किस्में नामत आई.आई.एस.आर–ऐल्लेपी सुप्रीम और आई0आई0एस0आर–केदारम अनुमोदित की है। दोनों किस्में 5 प्रतिशत से अधिक करक्यूमिन के साथ अधिक उपज देने तथा धब्बा रोग की प्रतिरोधिता वाली है।

हल्दी का फीनोलॉजी (घटनाविज्ञान)

हल्दी में कुल 6 टिलर के साथ पहली टिलर1106 अंश दिवसों पर निकली तथा पौधा 3571 अंश दिवसों में पक गया । हल्दी में मुख्य तने के साथ पत्ती की बढ़वार के बाद लीनियर हल्दी पैटर्न मिला। हल्दी में प्रति क्लंप 11867 वर्ग सें.मी. का कुल पत्ती क्षेत्र नोट किया गया।

कुरकुमा प्रजाति का रासायनिक विश्लेषण

कुरकुमा प्रजाति के वाष्पशील तेल का जी.सी. और एम.एस आधारित मात्रात्मक विश्लेषण करने से पता चला कि *सी.ऐरोमैटिक* में तेल की अधिकतम प्रतिशतता (4.8 प्रतिशत), उसके बाद *सी.सीजिया* और *सी. सिल्वेटिका* में (3.6 प्रतिशत) तथा तेल की सबसे कम प्रतिशतता *सी. हैरिथा* (2.4 प्रतिशत) रिकार्ड की गई।

कुरकुमा प्रजाति का विविधता संबंधी विश्लेषण

36 लोकप्रिय किस्मों के आनुवंशिक विविधता संबंधी विश्लेषण से पता चला कि उन्नत किस्में जेक्काड्स एकरूपता इन्डेक्स पर आधारित प्रजातियां किस्म स्तर रूप से गुच्छेदार हैं। अधिकतर प्रजातियां एक भौगोलिक क्षेत्र से जारी की गई कुछ किस्मों के साथ समूहों में होती हैं जिन्हें इन क्षेत्रों से संग्रहित सामग्री के जननद्रव्य चयन के माध्यम से विकसित किया गया ।

मृदु विगलन

पिथियम ऐफैनिडरमैटम को आन्ध्र प्रदेश, तमिलनाडु, केरल और कर्नाटक राज्यों में हल्दी के मृदु विगलन का आकस्मिक जीव पाया गया । यद्यपि पिथियम के साथ आइसोलेशनों में बारंबारता के कारण हल्दी में रोग को फैलाने के लिए कवक *फ्यूजेरियम* और *राइजोक्टोनिया* निष्क्रिय हैं ।

हल्दी के राइजोम विगलन (राइजोम रॉट) के प्रबंधन के लिए मैकाजेब 0.2 प्रतिशत, मैटालैक्सल–मैकॉजेब 0.125 प्रतिशत, टी. हरजेनम (पी–26) (50ग्रा / बैड) की क्षमता के आकलन के लिए खेत में परीक्षण किया गया । तथापि प्लाट में रोग (0 प्रतिशत–1.5 प्रतिशत) का अवांछित प्रकोप देखने में आया था ।

प्ररोह बेधक

वितरण और फसल हानि

केरल के वायनाड तथा कोषिक्कोड जिलों में प्ररोह बेधक (*कोन्जीथेस पूनीक्टीफेलालिस*) का प्रकोप काफी गंभीर (25% से अधिक प्रकोप) था जबकि अन्य राज्यों में किए गए सर्वेक्षण के अनुसार (तामिलनाडु, कर्नाटक तथा आन्ध्र प्रदेश) में यह प्रकोप नगण्य था। 75–100 प्रतिशत प्ररोह की हानि में हासिल की गई फसल सिर्फ 262 ग्राम प्रति क्लंप थी । इसकी तुलना में 0–25 प्रतिशत प्ररोह हानि में हासिल की गई फसल 378 ग्राम प्रति क्लम्प थी। पेरूवन्नामुषी में खेत में हल्दी पर प्ररोह बेधक की सीजनल पापुलेशन पर किए गए अध्ययनों से पता लगा है कि सबसे पहले अगस्त के दौरान नाशीजीव संक्रमण के लक्षण देखे गए और अक्टूबर से नवम्बर के दौरान अधिकतम संक्रमण उत्पन्न हुआ। यद्यपि मरमिथिड नीमेटोड तथा प्ररोह बेधक के प्राकृतिक शत्रु को पूरे फसल मौसम के दौरान देखा गया था तथा उनकी परजीविता अगस्त एवं सितम्बर के दौरान काफी अधिक थी ।

हल्दी में लक्षित पैदावार के लिए पोषण अनुकूलन

हल्दी में 15, 20, 25 कि0ग्रा0 / बैड की पैदावार प्राप्त करने के लिए नाइट्रोजन, फास्फोरस, पोटाश

तथा जिंक के आरंभिक उर्वरक स्तर के आधार पर उर्वरक खुराक को तैयार कर प्रयोग किया गया । जिंक का प्रयोग पर्णीय छिड़काव के रूप में किया गया । हासिल की गई हल्दी प्रकंद की पैदावार 14. 8, 15–8 तथा 16.3 कि0ग्रा0 / बैड थी। साथ ही लक्षित पैदावार अपसरण –1 प्रतिशत, –20 प्रतिशत तथा –34 प्रतिशत था। संस्तुत खुराक की तुलना मे लक्षित पोषण अनुप्रयोग द्वारा पैदावार में 12–20 प्रतिशत की वृद्धि हासिल करने के साथ–साथ उर्वरक उपयोग को कम किया जा सकता है ।

वृक्ष प्रजातियां

जननद्रव्य संग्रहण, संरक्षण तथा मूल्यांकन

पश्चिमी घाट के वनक्षेत्रों से गासीर्निया गुम्मीगुट्टा की 20 तथा 32 इंडिका वनीय प्रजातियों का संग्रहण किया गया। जायफल (नटमैग) की 94 प्रविष्टियों के आकलन में से ए 9/53 की पैदावार बेहतर पाई गई जो 714 फल थी तथा फल का वजन भी अधिकतम था (120 ग्रा0) ।

मिरिस्टिका में मार्कर समर्थित चयन

मिरिस्टिका फ्रेगरंस की उत्कृष्ट प्रविष्टियों की प्रोफाईलिंग से पता लगा कि प्रविष्टियों जैसे ए 9/4, ए 9/50 में विशिष्ट एंम्प्लीकोन (एक उच्च पैदावार वाला ऐपीकोटाइल ग्राफ्ट के साथ प्लैजियोट्रोपिक प्ररोह) जो काफी थिक मेस तथा सेब आकार का सख्त फल वाला है और ए4/2एल जिसमें विशिष्ट लक्षण के उच्च संख्या में इरेक्ट प्ररोह है। अध्ययन में यह भी पता लगा है कि सभी मिरिस्टिका प्रजातियों तथा नीमा एंडामेनिका के साथ दो मुख्य क्लस्टर, एक पृथक क्लस्टर बनाते है जो जिम्नोकैरंथिरा से भिन्न है जो मिरिस्टिका की जेनेरा से संबंधित है। समानरूपी गुणांक 0.58–0.8 के बीच है। *एम. मालाबैरिका* तथा *एम. बेडोमेई* में 80 प्रतिशत सर्वाधिक समरूपता पाई गई । कुछ वनीय प्रजातियों में विशिष्ट मार्करों की पहचान की गई ।

पहचाने गए कीमोटाइप्स

जी.सी–एम.एस का उपयोग करते हुए लीफ ऑयल एनालिसिस के आधार पर सीन्नामोमम वेरम के दो कीमोटाईप्स अर्थात यूजीनोल तथा बेनजील बेंजोएट टाईप की पहचान *सी.बीरियम* के रूप में की गई । संबद्ध प्रजाति *सी. सल्फ्यूरेटम* में भी बेंजाइल बेंजोएट एक प्रमुख घटक के रूप में था ।

गार्सीनिया की कैमेस्ट्री

गार्सीनिया इंडिका की छाल से एम.पी.एल.सी. का उपयोग करते हुए प्रमुख ऑग्रेनिक–एसिड, हाईड्रोक्सी साईट्रिक एसिड (एच.सी.ए) की क्वालिफिकेशन के लिए विधि को मानकीकृत किया गया। गार्सीनिया की चार प्रजातियों मे एच.सी.ए में काफी अन्तर पाया गया जहां लाईकोपीन में महत्वपूर्ण अन्तर दिखाई नहीं दिया। गार्सीनिया की विभिन्न प्रजातियों में एच.सी.ए. तत्व भिन्न था अर्थात *गार्सीनिया गम्मीगुट्टा* (2.6), *जी मैंगोस्टेना* (0.27), *जी इंडिका* (5.21), *जी. टिकटोरिया* (3.3) / । गार्सीनिया फलों में लाईकोपिन, गार्सीनिया गुम्मीगुट्टा (0.123), *जी.मैंगोस्टेना* (0.098), *जी.इंडिका* ((0. 093) तथा जी.टिक्टोरिया (0.156) के रूप में पाया गया।

वैनिला

वैनिला के तुलनात्मक शरीर संरचना विज्ञान संबंधी विश्लेषण

अण्डमान और निकोबार द्वीपसमूह तथा *वी. प्लेनीफोलिया* से वैनिला प्रजाति के इंटरनोडल रीजन के तुलनात्मक शरीर संरचना संबंधी विज्ञान विश्लेषण से पता लगा है कि स्क्लेरेनकाइमेटस बेंड के विशिष्ट एक्सेस से फ्लोएम्स और ग्राउंड टिशु पृथक होते है। अंडमान एवं निकोबार से वैनिला प्रजाति की पर्ण सहित वैनिला प्रजाति के समीप थी ।

वैनिला पर बीन कॉमन मोजेक वायरस (बी.सी.एम.वी) का प्रकोप

वैनिला पर नैक्रोसिस तथा मोजेक युक्त एक विषाणु की पहचान बीन कामन मोजेक वायरस आधारित कोट प्रोटीन जीन सीक्वेंस कम्पैरिजन के प्रभेद के रूप में की गई और फाईलोजैनेरिक अध्ययन किए गए ।

पपरीका

जननद्रव्य आकलन

चयनित जननद्रव्य की कलर वैल्यू 100 से 216 ए.एस.टी.ए यूनिट के बीच थी । 216 ए.एस.टी.ए यूनिट की उच्च कलर वैल्यू को आई.सी. बी.डी–17 के रूप में पंजीकृत किया गया इसके बाद ई.सी.31 (193 ए. एस.टी.ए. यूनिट) थी । ओलियोरेजिन तत्व 9.0–22 प्रतिशत के बीच था। सर्वाधिक आई.सी.बी.डी–15 (22.39 प्रतिशत) था। कैप्सेसिन तत्व 0.0–1.34 प्रतिशत था। शून्य कैप्सेसिन युक्त प्रविष्टियां ई.सी. 71 तथा एल.सी.ए–42 थी ।

व्यवसायिक मिर्च पाउडर में मिलावट का पता लगाने के लिए पी.सी.आर तकनीक

लगभग 350 बी.पी के *जिजीफस न्यूमूलेरिया* विशिष्ट बैंड पता मिर्च पाउडर के व्यावसायिक नमूने के बाजार नमूनों में प्राईमट ओ. पी.जे 10 का इस्तेमाल करते हुए आण्विक जांच से पता लगाया जा सकता है।

मसाला उत्पादन पर सामाजिक आर्थिक और कृषि पारिस्थितिकीय परिवर्तनों का प्रभाव

पिछले दशक से सीमांत और छोटे फार्म जोतों का आकार घटने और गैर कृषि प्रयोजन से कृषि भूमि के विविधीकरण के कारण केरल के वयानाड जिले में परिचालन फार्म जोतों के औसत आकार में 3.7 से

3.0 की कमी आई है। अनुमानित मार्कोव ट्रांजिशन मैट्रिक्स से पता लगता है कि इस क्षेत्र की मुख्य फसलों जैसे कॉफी और काली मिर्च के अन्तर्गत आने वाले क्षेत्र का परिवर्तन इस क्षेत्र में सामाजिक आर्थिक, और कृषि पारिस्थितिकीय घटकों में परिवर्तन के कारण गैर–पारम्पारिक फसलों जैसे सुपारी, नारियल, केला और अन्य सब्जी फसलों के रूप में हुआ है।

जैव सूचना केंद्र (बॉयो इंफारमैटिक सेंटर)

नया डॉटाबेस / सॉफ्टवेयर

बागवानी फसलों की *फाइटोफ्थोरा* बीमारी पर एक नया डॉटाबेस फि–डिष तैयार किया गया है, जिसमें संस्थान स्तर पर *फाइटोफ्थोरा* के राष्ट्रीय संग्रह मे संरक्षित *फाइटोफ्थोरा* आइसोलेटों से संबंधित सूचना शामिल है। पौधो के लिए उपयोगी जीवाणुओं में प्रजातीय विशिष्ट के चिह्नों की पहचान करने हेतु एक उपकरण, साइन–ओ–बैक्टीरिया भी विकसित किया गया। आई0आई0एस0आर0 में डी–स्पाइस ओपन सोर्स प्लेटफार्म के उपयोग से एक डिजिटल सांस्थानिक संग्रह कियान्वित किया गया । डी स्पाइस @आई.आई.एस.आर. में आई.आई.एस.आर. से प्रकाशित अनुसंधान लेखों परियोजना रिपोर्टो आदि की पूरी सामग्री उपलब्ध है। बायोइन्फोर्मेटिक्स केन्द्र ने विभिन्न संगठनों के लिए नई वेबसाइट विकसित की है जैसे आई.आई.एस.आर. पुस्तकालय (स्पाइस ई–लिब), अखिल भारतीय समन्वित मसाला अनुसंधान परियोजना (www.aicrps.res.in), राष्ट्रीय बीज मसाला अनुसंधान केन्द्र, अजमेर तथा अ.भा.स. आलू अनुसंधान परियोजना, शिमला ।

ऑफिस ऑटोमेशन

आइ.आई.एस.आर. और मैसर्स फोकज इन्फौटेक, कोचि द्वारा संयुक्त रूप से विकसित नया ऑफिस ऑटोमेशन एरिसॉफ्ट का विमोचन 22 नवम्बर, 2006 को डा.जी. कल्लू, उपमहानिदेशक (बागवानी एवं फसल विज्ञान) द्वारा किया गया ।

अखिल भारतीय समन्वित मसाला अनुसंधान परियोजना

जननद्रव्य

मसाला फसलों के आनुवंशिक संसाधनों मे काली मिर्च की 680 प्रविष्टियां, 273 इलायची की, 63 अदरक की 1326 हल्दी की, 77 वृक्ष मसालों की और 2540 बीज मसालों प्रविष्टियां की वृद्धि की गई है।

काली मिर्च

स्केल कीट का प्रबंधनः पंपाडुमपारा में अ.भा.स. मसाला अनुसंधान परियोजना में किए गए अनुसंधान से पता लगा कि नीम गोल्ड (0.5प्रतिशत) और नीम तेल (0.5 प्रतिशत जैसे बॉयोरेशनल मछली तेल कीटनाशी साबुन (2 प्रतिशत) की तुलना में स्केल कीटो की संख्या को करने के लिए अधिक उपयुक्त पाए गए।

इलायची

पंपाडुमपारा केन्द्र ने एन बी पी जी आर, नई दिल्ली से 73 इलायची प्रविष्टियों (सी आर एस पी 1–73 आर एस पी 73) के लिए आई सी संख्याएं (547920 से 547592 तक) प्राप्त की है। रूट ग्रब कीट के प्रबन्धन के सन्दर्भ में पंपाडुमपारा में अ0भा0स0 मसाला अनुसंधान परियोजना केन्द्र में किए गए परीक्षणों से इलायची के रूट ग्रब के नियंत्रण के लिए एंटोमोपैथोजैनिक सूत्रकृमि, *हेटरारेबडाइटिस इंडिका* (100 आई जे / ग्रब) का प्रयोग ड्रेंचिग के रूप में उपयुक्त पाया गया।

अदरक

अदरक के *पाइथियम, फ्यूजेरियम* और *रैल्स्टोनिया* के एक समेकित प्रबंधन में राइजोम सौरीकरण (45 मि) के पश्चात गर्मपानी से उपचारित करने पर रोग का प्रकोप कम हुआ और उपज में आशातीत वृद्धि हुई। सोलन केन्द्र में सौरीकरण से स्प्राउटिंग में (92.2 प्रतिशत) की वृद्धि रिकार्ड की गई, पाइथियम रॉट में 5.3 प्रतिशत की कमी तथा फ्यूजेरियम येलोज में 4.4 प्रतिशत और रैल्सोनिया विल्ट में 3.1 प्रतिशत तक कमी आई है।

हल्दी

पुन्डीबाड़ी केन्द्र में एक परीक्षण कार्यक्रम में टी सी पी 198, 93, 104, 43, 115 118, 19, 53, 79 को लीफ ब्लॉच और लीफ स्पॉट रोग के प्रति सहिष्णु पाया गया।

सौंफ

सौंफ में 16 एस.आर.डी.एन ए जीन के विश्लषण द्वारा एक नई बीमारी फिलोडी रोग को मूंगफली कवक 16 एस आर–।। समूह से संबंधित फाइटोप्लाज्मा से संबंधित पाया गया।

Executive Summary

Black pepper

Genetic resources

One hundred and one accessions (86 wild and 13 cultivated types) from Attappadi, Siruvani, Wagamon, Vandiperiyar, Erumeli (Kerala), Mollem, Walpoi and Canacona (Goa), Dapoli (Maharashtra) and farmers' fields were added to the existing germplasm repository. One hundred accessions were planted at Kidu Centre of Central Plantation Crops Research Institute, Kasaragod as an alternate germplasm repository. Fifty accessions were characterized based on IPGRI descriptor thus making total number characterized so far to 850. The germplasm conservatory at IISR, Calicut has 2337 accessions (1075 wild and 1262 cultivated). A unique spike proliferating black pepper accession collected from a farmer's nursery flowered and yielded berries.

New varieties

The 23rd Kerala State Variety Release Committee has approved four black pepper varieties *viz.*, IISR-Shakthi, IISR-Thevam, IISR-Girimunda, and IISR- Malabar Excel. IISR-Shakthi is tolerant to foot rot disease. IISR Thevam is a high yielder with adult plant tolerance to foot rot disease. IISR-Girimunda is a high yielder with resistance to anthracnose disease while IISR- Malabar Excel is good yielder with high oleoresin (13.6%). Two promising foot rot resistant black pepper hybrids namely, HP-490 and HP-521 were identified.

Biotechnology

Field evaluation of Tissue Cultured (TC) plantlets in 100 trials covering over 25 ha in the states of Kerala and Karnataka indicated that the TC plants showed good establishment and 20 percent of them showed early flowering. Molecular characterization using ISSR markers indicated genetic uniformity among the TC plants. RAPD based molecular profiling of traded black pepper from India, Vietnam, Malaysia and Indonesia revealed a distinct clustering pattern of the traded black pepper in conformity with the country of origin. Defense related chitinase was found to increase in *Piper colubrinum* after challenge with *Phytophthora capsici* and peak activity was observed at 60 hours after inoculation. An internal fragment of 313 bp of a putative chitinase gene corresponding to 104 amino acids was cloned and showed similarity to known chitinase genes from plants.

PCR technique to detect adulterants in commercial black pepper powder

A papaya (*Carica sp*) specific band of approximately 450 bp was found in PCR based method in the market samples of commercial black pepper powder. Earlier, a Sequence Characterized Amplified Region (SCAR) marker was developed to identify papaya seed adulteration in powdered market samples of black pepper.

Productivity improvement

Application of plant nutrient solution consisting of urea, super phosphate, potash, and magnesium sulphate in 4:3:2:1 proportion at monthly intervals along with use of solarized potting mixture recorded vigorous and healthy black pepper plants. In bush pepper, application of Sulphate of Potash (SOP-1.75g pot^{-1}) at bimonthly intervals recorded the highest yield of 295 g pot^{-1} followed by Muriate of Potash (MOP-3.5g pot^{-1}) and SOP (4.5g pot^{-1}). In a pepper garden, maximum yield (3.16 kg $vine^{-1}$) was obtained with SOP (500g $plant^{-1}$)+ Mg SO_4 (25g $plant^{-1}$), which was on par with recommended dose of K as SOP and significantly higher than control. Among different forms of potash (K), water-soluble and available K had significant positive correlation with berry yield, oleoresin and piperine. Application of *Azospirillum* along with nitrogen (70g), phosphorus (55g), potash (270g) and magnesium (200g) per vine increased yield of black pepper vines (21%) compared to control and application of NPK (140:55:270g $vine^{-1}$) alone.

Physiological and biochemical basis of productivity

High yielders had higher photosynthetic rate (2.2-3.86μ moles m^{-2} s^{-1}) than low yielders (2.0-3.2 μ moles m^{-2} s^{-1}). High yielders recorded slightly lower leaf temperature (32.6 to 33.7 °C) than the low yielders (32.9 to 33.8°C). Nitrate reductase activity was high for high yielders during pre-bearing (429-921 m moles of NO_2 g^{-1} h^{-1}) and bearing periods (621-1183 m moles of NO_2 g^{-1} h^{-1}). Low yielders recorded comparatively low activity (453-814 NO_2 g^{-1} h^{-1}) during pre-bearing and during bearing period (612-994 m moles of NO_2 g^{-1} h^{-1})

Geographical and climatic influence on biochemical and physical quality parameters

Leaf area, plant height and photosynthetic rate of pepper plants grown in plant growth chamber for four months at 3°C above ambient temperature (which is the projected temperature increase due to global warming for Calicut by 2050 based on HadCM3 model) was on par with the growth at ambient temperature.

The total number of leaf volatile oil components of *Piper nigrum* leaf varied from 7-15 among the accessions collected from Western Ghats and the geographical effect on biochemical parameters was highly significant. The percentage of two sesqueterpenes, β-caryophyllene (2.1-6.8%) and Nerolidol (1.4 to 66.3%) significantly varied among all germplasm accessions whereas another component, Pinene (1.53-20.3%) (a common component of berry oil) was recorded from specific latitude 9°29 N'-9°40'N. Pepper harvested from Ambalavayal in Wyanad district recorded high bulk density and oleoresin for Karimunda,IISR-Sreekara,IISR- Subhakara and IISR-Thevam compared to Peruvannamuzhi, Idukki, Yercaud, Dhapoli, Panniyur.

Value addition and storage condition

Process for production of white pepper has been standardized. Dry recovery of about 25.0-26.0 % was achieved. Dried black pepper stored in polyethylene covers under vacuum, 100% N_2, and 90% N_2+ 10% CO_2 for a period of 240 days did not show any significant variation for oil, oleoresin, except for a reduction of 15% moisture content.

Microbial community analysis of rhizosphere soils of standards used in black pepper

Greater diversity in soil microbial community was identified under *Glyricidia*-black pepper (BP) system (68), followed by *Garuga*-BP (66) and *Ailanthus*-BP systems (65) than *Erythrina*-BP (48) or RCC pole-BP (5... systems. Fungal population was higher und... *Ailanthus*-BP (19), while the other syste... registered significantly lower fungal diversi... The study indicated that the standards use... as supports for black pepper cause... distinctive rhizosphere effects on microbi... community structure in soils of the syste... studied.

***Phytophthora* foot rot**

Morphological and molecula... characterization of black pepper isolates o... *Phytophthora* revealed that isolates share... the characters of both *P. capsici* and *P. tropicalis*. Production of chlamydospore... and growth at 30°C matched with *P. tropicalis* whereas the sporangial character... and pathogenicity on capsicum was simila... to that of *P. capsici*. The rDNA sequenc... shared 98% identity with *P. tropicalis* a... *P.capsici*. Interestingly the isolate showe... 100% identity with *P. tropicalis* based o... secondary structure of ribosomal RNA. Further PCR-RFLP analysis revealed high levels of intraspecific and interspecific variability in the ITS regions among the *Phytophthora* isolates from Black pepper.

Biocontrol technology

Endophytic bacteria found effective against *Phytophthora capsici* in black pepper were identified as *Pseudomonas aeruginosa* (BP-35) and *P. putida* (BP-25) by analyzing the nucleotide sequence of 16s rDNA. *Pseudomonas aeruginosa* was found to induce density dependent systemic resistance in excised single nodal shoots. The 16s rDNA sequences of these have been deposited with Gen Bank. A five-year field trial conducted at Peruvannamuzhi revealed the potential of bioconsortia consisting of bacterial isolates IISR 6, 8, 13, 51, 151 and 853 for management of foot rot and slow wilt in cv. Karimunda variety of black pepper.

Anthracnose

Eleven accessions/varieties namely comprising of Panniyur-5, IISR- Girimunda,

HP-780, IISR-Panchami, Aimpiriyan, IISR-Subhakara, Karimunda (Idukki), Kottanadan, Jerakamunda (Gudalur), Arakalamunda, and Chomala showed resistance to *Colletotrichum gloeosporioides*.

Stunted Disease

Sequence analysis of portion of ORF I and ORF III from Kozhikode, Idukki and Wyanad districts of Kerala and Kodagu district of Karnataka revealed variable nature of ORF I sequences and highly conserved ORF-III among isolates. The *Badnavirus* infecting *Piper longum* and *P. betle* were also identified as strains of PYMoV. DAS-ELISA based tracking of PYMoV and CMV in black pepper varieties at monthly intervals indicated that concentration of both the viruses was higher during October to January.

Nematodes

Sequence analysis of ITS region (398bp) of rDNA of burrowing nematode (*Radopholus similis*) population infesting black pepper in India revealed 98% sequence similarity with known *R. similis* populations across the world. This is the first report of molecular characterization of an Indian isolate of *R. similis*.

Host resistance

Six black pepper lines tolerant to *Phytophthora capsici* were screened against *Radopholus similis* and *Melodogyne incognita*. All these lines were susceptible to *R. similis* while two lines *viz* Acc.1578 and Open Pollinated (OP) progeny 04/1533(2) showed resistant reaction to *M. incognita* in the preliminary screening. Among the four *Piper* spp. screened, only *Piper colubrinum* showed resistance to both nematodes. The field performance of two *R. similis* resistant black pepper lines, HP-39 and C-820 was superior to other lines for yield in a four years old garden.

Biocontrol technology

The species identity of two promising endophytic bacteria was confirmed through 16S rDNA sequencing. The two *Radopholus similis* inhibiting endophytes were identified as *Curtobacterium luteum* (TC-10) and *Bacillus megaterium* (BP-17). The bacterial endophytes *Curtobacterium luteum* IISRTC-10 significantly improved black pepper growth characters such as number of leaves, root weight and total biomass of plants besides suppressing *R. similis*. When used as a chitin based formulation, besides sustaining the population at 10^7 cfu g^{-1} after 90 days of storage at 28°C, it successfully reduced the nematode infestation in pepper nurseries. The improvement of vigour of black pepper is an additional benefit of this strain.

Root mealybug

An integrated pest management schedule involving, planting of root mealybug-free rooted cuttings in the field, removal of weeds in interspaces of black pepper vines during summer especially when intercropped with coffee, drenching imidacloprid 0.0125% or acetamaprid 0.0125% or carbosulfan 0.075% or chlorpyriphos 0.075% on severely affected vines or drenching tobacco extract 3% on mildly affected vines and adoption of control measures against *Phytophthora* and nematode infections, was developed for the management of root mealybug, based on studies conducted for the past three years.

Cardamom

Germplasm and promising varieties

Fifteen accessions were collected from two explorations in Kerala (Attappadi and Wagamon), including a variant of green gold with pubescent leaves. Twenty-six compound panicle accessions were characterized based on IPGRI descriptor. The accessions with high husk to seed ratio are NHY-1, CCS-1(S) self & NHY-35. The oil content ranged from 3.9 to 6%. Some of the high oil accessions are NHY-3, NHY-14, NHY-15, NHY-35, RR-1 x MB-3, VA-1, AMB-2, MA-7, and CCS-1(OP).

Chemistry of Indian Cardamom

GC-MS study confirmed the superior intrinsic quality of Indian cardamom over Guatemalan and Sri Lankan cardamom. The essential oil yield of Indian, Guatemalan and Sri Lankan cardamom was found to be 10%, 5% and 14% respectively. Chemical profiling has shown a total of 33 compounds in Indian, 26 in Guatemalan and 35 in Sri Lankan, and 22 of them are common among all three. GC profiling of oil indicated that Indian cardamom is rich in 1, 8-cineole and α-terpinyl acetate. Indian cardamom recorded comparatively low

quantity of linalool as compared to Guatemalan and Sri Lankan. At low concentration, the linalool gives pleasant taste to the cardamom. Linalyl acetate, octyl acetate and trans β caryophyllene were not identified in Indian and Guatemalan cardamoms whereas Z citral, methyl cinnamate, nerol, and 2-decenoic acid were present only in Indian cardamom.

Indigenous nutrient mobilizing bacteria for cardamom

Application of *Azospirillum* (Caz3) and Phosphobacteria (Cpb2) recorded maximum number of leaves, dry weight, total NPK uptake, root colonization and lower disease incidence. The N-fixation capacity of the isolates Caz3 was 7.39 mg g^{-1} malate whereas the phosphobacterial strains Cpb2 recorded higher solubilisation efficiency of up to 220 mg per litre.

Biotic and abiotic resistance

IISR- Avinash, Green gold and CL-893 were comparatively tolerant to moisture stress while CCS-1 was susceptible. CL-893 and its cross combinations recorded better growth and yield characters. Natural infection of leaf blight on 72 accessions was recorded using 0 to 6 disease rating scale and 21 accessions were found resistant to *Colletotrichum gloeosporioides*.

Ginger

Germplasm, genetic improvement and promising varieties

Among the low fibre type accessions, Acc. 164, 558, 246 and 537 had more than 2% oil and more than 6.5% oleoresin, with less than 3% fibre. Among the high oil types, Acc. 162, 50, 57, 411, 225, 201 and 197 are with more than 2% oil. Acc. 50 and 57 contained more than 6.5% oleoresin. Acc. 197, 217, 228, 411 contained less than 3% fibre. Among the exotic ginger collections, accession from Nepal (Acc.581) showed potentiality for yield and the accession 420 for high oil. Ginger accession-12 (Erattupetta) was found to be unique for its colour pattern of the floral labellum, high pollen stainability (27.5%), high *in vitro* germination of pollen grains (10.4), better pollen tube growth (mean length of 1209 µm after 24 h of culture) and germination of pollen grains on the stigma on self-pollination. This cultivar appears to be suitable for future studies to induce seed set.

Nutrient optimization for targeted yield

The threshold value of leaf P/Zn ratio was found to be 90 through second order response function. On validating the same under field conditions, the initial leaf P/Zn ratio at 60 DAP in the range of 145-223 could brought into the threshold range of 69- after foliar spray of Zn (0.5%) twice dur August and October. By lowering the r below 108, increased rhizome yield of u 20% could be achieved. Based on the in soil fertility levels of N, P, K and Zn, fertilizer doses for obtaining yields of 10, and 20 kg per bed were applied. Zinc w supplemented as foliar spray. The achiev ginger rhizome yield was 10.8, 12.4 and 1 kg per bed with a deviation of +0.5%, -1 and -43% from the target. Through target nutrient application increased yield of 1 26% over recommended dose could b achieved in Varada with reduced fertiliz application. The effects of nutrie management system in ginger such a Integrated, Organic or Chemical treatmen on soil microbial community structur revealed that the prokaryotic population wa highest under integrated whereas th eukaryotic population was high in both integrated and fully organic treatments. Interestingly the fungal population was high in chemical treatment.

Phenology

First tiller appeared at 646-degree days with a total 11 tillers and the plant attained maturity at 3096.8-degree days. Leaf growth along the main stem followed the quadratic pattern. Total leaf area per clump of 4092 cm^2 was noted for ginger.

Soft rot

In ginger, rhizobacteria (IISR-51, IISR-6), endophytic bacteria (BP35), *Trichoderma harzianum* (P-26), Metalaxyl-mancozeb 0.125% and mancozeb 0.2% were evaluated for the management of rhizome rot disease. The incidence of the disease was less in the chemical treatments when compared to biological treatments. Besides chemical treatment recorded maximum yield.

Turmeric

Promising varieties

The 23rd Kerala State Variety Release Committee has approved two high quality

turmeric varieties *viz*., IISR-Alleppey Supreme and IISR-Kedaram for cultivation. Both the varieties are high yielding with more than 5% curcumin and resistance to leaf blotch disease.

Phenology

First tiller appeared at 1106-degree days with a total 6 tillers and the plant attained maturity at 3571-degree days. Leaf growth along the main stem followed the linear pattern. Total leaf area per clump of 11867 cm^2 was noted

Chemical analysis of *Curcuma* species

GC-MS based qualitative analysis of essential oils in *Curcuma* species revealed highest oil percentage in *C. aromatica* (4.8 %) followed by *C. caesia* and *C. sylvatica* (3.6 %) and the lowest percentage of oil was recorded in *C. haritha* (2.4 %).

Diversity analysis of *Curcuma* species

Genetic diversity analysis of 36 popular varieties revealed that the improved varieties clustered distinctly from the land races/ cultivars based on Jaccards similarity Index. Most of the land races from one geographical region clustered together with a few released varieties, which were evolved through germplasm selection of material collected from this region.

Soft rot

Pythium aphanidermatum was found to be the causal organism of soft rot of turmeric in the states of Andhra Pradesh, Tamil Nadu, Kerala and Karnataka. Though frequented in the isolations along with *Pythium*, the fungi *Fusarium* and *Rhizoctonia* failed to cause the disease in turmeric.

A trial was laid out in the field to evaluate the efficacy of mancozeb 0.2%, Metalaxyl–mancozeb 0.125%, *T. harzianum* (P-26) (50 g bed^{-1}), endophytic bacteria (BP-35), and rhizobacteria (IISR-51 and IISR-6) for the management of rhizome rot disease of turmeric. However, only stray incidence of disease (0%-1.5%) was noticed in the plot.

Shoot Borer

Distribution and crop loss

The incidence of the shoot borer (*Conogethes punctiferalis*) was serious (above 25% incidence) in Wyanad and Kozhikode districts in Kerala whereas in other states surveyed (Tamil Nadu, Karnataka and Andhra Pradesh) the incidence was negligible. The yield obtained was only 262 g $clump^{-1}$ when 75%–100% of shoots were damaged when compared to 378 g $clump^{-1}$ when the damage was 0% - 25% of shoots. Studies on seasonal population of shoot borer on turmeric in the field at Peruvannamuzhi indicated that the symptoms of pest infestation were first observed during August and maximum new infestations occurred during October to November. Though the mermithid nematode, the natural enemy of shoot borer was observed throughout the crop season, their parasitisation was higher during August and September.

Nutrient optimization for targeted yield

Based on the initial fertility levels of N, P, K and Zn, the fertilizer doses for obtaining 15, 20, 25 kg per bed yield in turmeric were worked out and applied. Zinc was supplemented as foliar spray. The achieved turmeric rhizome yield was 14.8, 15.8 and 16.3 kg per bed with a deviation of -1%, -20% and -34% from the fixed target. Through targeted nutrient application 12-20% increased yield over recommended dose could be achieved in Prathiba with reduced fertilizer application.

Tree spices

Germplasm collection, conservation and evaluation

A total of 20 *Garcinia gummigutta* and 32 *G. indica* wild collections were made from forest areas in Western Ghats. Out of 94 nutmeg accessions evaluated A9/53 performed better yielding 714 fruits and fruit weight was maximum (120 g).

Marker Assisted Selection in *Myristica*

Molecular profiling of elite accessions of *Myristica fragrans* revealed unique amplicon in the accessions such as A9/4 (a very high yielding epicotyl graft with plagiotropic shoots), A9/150, possessing very thick mace and apple shaped bold fruits and A4/22 with unique character of high number of erect shoots. The study further revealed two major clusters with all *Myristica* species and *Knema andamanica* forming a separate cluster distinct from *Gymnocranthera*, a related genera of *Myristica*. Similarity coefficient ranged from 0.58-0.8. *M. malabarica* and *M. beddomei* showed the highest similarity of 80%. Unique markers were identified in some of the wild species.

Chemotypes identified

Based on leaf oil analysis using GC-MS, two chemotypes of *Cinnamomum verum* viz., *eugenol* and *benzyl benzoate* types were identified in *C. verum*. The related species *C. sulphuratum* also contained benzyl benzoate as a major constituent.

Chemistry of *Garcinia*

Method for quantification of a major organic acid, hydroxy citric acid (HCA), using HPLC from rinds of *Garcinia indica* was standardized. HCA showed significant variations among the four species of *Garcinia* whereas lycopene did not show significant variation. HCA content varied in various species of *Garcinia* viz. *Garcinia gummigutta* (2.6), *G. mangostana* (0.27), *G. indica* (5.21), *G. tinctoria* (3.3). Lycopene in *Garcinia* fruits were found to be *Garcinia gummigutta* (0.123), *G. mangostana* (0.098), *G. indica* (0.093), and *G. tinctoria* (0.156).

Vanilla

Comparative anatomical analysis

Comparative anatomical analysis of internodal region of *Vanilla* sp. from Andaman and Nicobar Islands and *V. planifolia* revealed the distinct absence of schlerenchymatous band separating the cortex and ground tissue in the former, which further indicates that *Vanilla* sp. from Andaman and Nicobar Islands, is closer to the leafless species of *Vanilla*.

Occurrence of *Bean common mosaic virus* (BCMV)

A virus associated with necrosis and mosaic on vanilla was identified as a strain of *Bean common mosaic virus* (BCMV) based coat protein gene sequence comparison and phylogenetic studies.

Paprika

Germplasm evaluation

The color value of selected germplasm ranged from 100 to 216 ASTA units. The highest color value of 216 ASTA units was registered with ICBD-17, followed by EC-31 (193 ASTA units). The oleoresin content varied from 9.0-22.0 %, the highest being with ICBD-15 (22.39 %). The pungency (Capsaicin content) varied from 0.0-1.34 %. The accessions with zero pungency were EC-71 and LCA-422.

PCR technique to detect adulterants in commercial chilli powder

A *Ziziphus nummularia* specific band of approximately 350 bp could be detected in a molecular assay in the market samples of commercial samples of chilli powder.

Occurrence of *Cucumber mosaic virus* (CM

CMV associated with Paprika wa characterised based on coat protien gen sequence.

Influence of socio-economic and agro-ecological changes on spice production

Since last decade, the average size of operational farm holdings has reduced from 3.7 to 3.0 in Wyanad District of Kerala owing to reduction in size of marginal and small farm holdings and diversion of agricultural land for non-agricultural purpose. The estimated Markov's transition matrix indicated that there was a transition of area under coffee and black pepper, the predominant crops of the region to non-traditional crops like arecanut, coconut, banana and other vegetable crops due to the change in socio-economic and agro-ecological factors in the region.

Bioinformatics Center

New database/software

PhyDisH, a new database of *Phytophthora* diseases of horticultural crops, which includes information on all the *Phytophthora* isolates conserved in the National Repository of *Phytophthora* at the institute. Sign-O-Bacteria, a tool for identifying the species-specific signatures in plant-associated bacteria was also developed. A digital Institutional Repository has also been implemented at IISR using the DSpace open source platform. DSpice@IISR holds the full text of research articles published from IISR, summary of theses, project reports etc. Bioinformatics center has developed new websites for IISR library (SpicE-Lib), All India Coordinated Research Project on Spices (www.aicrps.res.in), NRC for Seed Spices, Ajmer and AICRP on Potato, Shimla.

Office Automation

ARISoft, the new office automation software developed jointly by IISR and M/s Focuz Infotech, Kochi was launched by Dr. G. Kalloo, former DDG (Hort & CS) on 22 November 2006.

AICRP on Spices

Germplasm

Genetic resources of spice crops have been enhanced with the germplasm holdings of 680 accessions in black pepper, 273 in cardamom, 63 in ginger, 1326 in turmeric, 77 tree spices and 2540 in seed spices.

Black pepper

Management of scale insect: Research conducted at AICRP spices center at Pampadumpara revealed that the biorationals such as Neem Gold (0.5%) and Neem oil (0.5%) were superior to Fish Oil insecticidal soap (2.5%) in reducing the population of scale insects.

Cardamom

Pampadumpara center has obtained IC numbers (547920 to 547992) for 73 cardamom accessions (CRSP 1-CRSP 73) from NBPGR, New Delhi. Root grub management trials conducted AICRP spices center at Pampadumpara confirmed the potential of entomopathogenic nematodes, *Heterorhabditis indicus* (100 IJ grub^{-1}) applied as drenching for control of root grub in cardamom.

Ginger

In an integrated management of *Pythium*, *Fusarium* and *Ralstonia* of ginger, rhizome solarization (45 min) reduced the disease incidence and increased the yield significantly, followed by hot water treatment. Solarization recorded increased sprouting (92.2%), decreased *Pythium* rot by 5.3%, *Fusarium* yellows by 4.4% and *Ralstonia* wilt by 3.1% at Solan center.

Turmeric

In a screening trial at Pundibari center, TCP 198, 93, 104, 43, 115, 118, 19, 53, 70, were found to be tolerant to both leaf blotch and leaf spot diseases.

Fennel

Causal organism of a new phyllody disease in fennel was found to be Phytoplasma belonging to peanut witches broom (16Sr-II) group by analysis of 16S rDNA gene.

Genetic resources of spices at IISR, Calicut

Crop	Number of Accessions
Black pepper	2337
Cardamom	436
Ginger	684
Turmeric	1040
Nutmeg	484
Cinnamon	408
Clove	233
Garcinia	86
All spice	2
Vanilla	93
Paprika	130

List of registered unique germplasm accessions

Crop	IC number	Unique character
Black pepper	IC 547018	High caryophyllene (18.2%)
Cardamom	IC 349541	Compound panicle type, high yield
Cardamom	IC 349544	Basal branching of panicle with green bold capsules
Cardamom	IC 349599	*Katte* resistance
Cardamom	IC 349634	Rhizome rot tolerance
Chinese cassia	IC 370425	High bark oil (4.9%); High cinnamaldehyde content (90.5%)

Introduction

History

Intensive research on spices in the country was initiated with the establishment of a Regional Station of Central Plantation Crops Research Institute (CPCRI) at Calicut, Kerala, during 1975, by the Indian Council of Agricultural Research (ICAR). This Regional Station was upgraded as National Research Centre for Spices (NRCS) in 1986 by merging with it the Cardamom Research Centre of CPCRI at Appangala, Karnataka. 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 Calicut (Kozhikode), Kozhikode District, Kerala, on the Calicut-Kollegal road (NH 212), in an area of 14.3 ha. The research farm is located 51 km North East of Calicut at Peruvannamuzhi (60 m above MSL), on the Peruvannamuzhi-Poozhithode road in Kozhikode District, in an area of 94.08 ha. The Cardamom Research Centre, Appangala (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

- To extend services and technologies to conserve genetic resources of spices as well as soil, water and air of spices agroecosystems.
- To develop high yielding and high quality spice varieties and sustainable production and protection systems using traditional and non-traditional techniques and novel biotechnological approaches.

- To develop post harvest technologies of spices with emphasis on product development and product diversification for domestic and export purposes.
- To act as a centre for training in research methodology and technology upgradation of spices and to coordinate national research projects.
- To monitor the adoption of new and existing technologies to make sure that research is targeted to the needs of the farming community.
- To serve as a national centre for storage, retrieval and dissemination of technological information on spices.

The spice crops on which research is being conducted at the institute include black pepper (*Piper nigrum*), cardamom (*Elettaria cardamomum*), ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), cinnamon (*Cinnamomum verum*), cassia (*C. cassia*), clove (*Syzygium aromaticum*), nutmeg (*Myristica fragrans*), allspice (*Pimenta dioica*), Garcinia (*Garcinia gummi-gutta* and *G. indica*), vanilla (*Vanilla planifolia*) and paprika (*Capsicum annuum*).

Organization

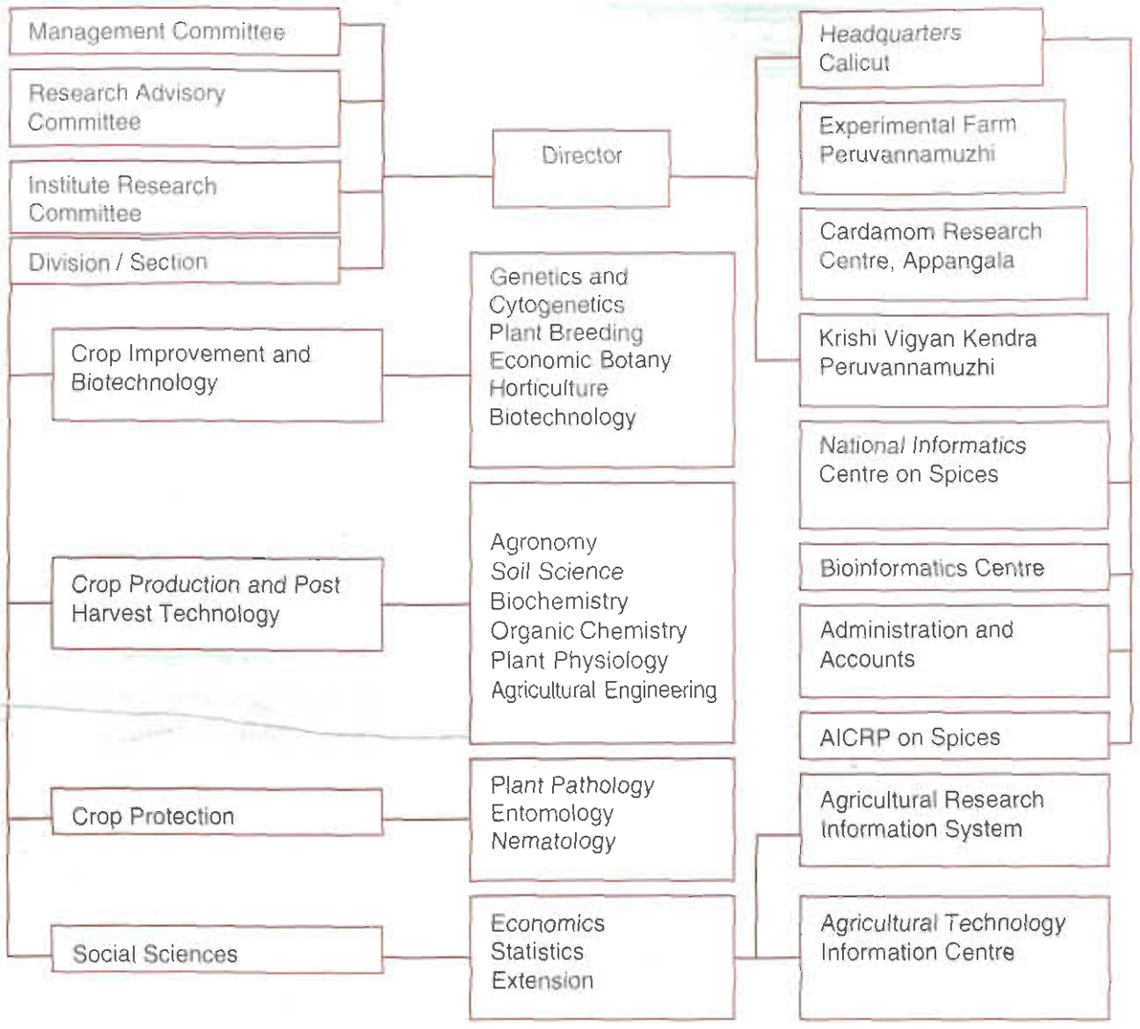
The Director is the administrative head of the institute. The Institute Management Committee, Research Advisory Committee and Institute Research Committee assist the Director in matters relating to management and research activities of the institute

Research on various aspects of the mandate crops is conducted in three divisions, namely, Division of Crop Improvement & Biotechnology, Division of Crop Production & Post Harvest Technology and Division of Crop Protection and Social Sciences Section. The other facilities available at the institute include Agricultural Technology Information Centre, Agricultural Research Information System, Bioinformatics Centre and Krishi Vigyan Kendra. The institute also functions as the headquarters of the All India Coordinated Research Project on Spices, and Indian Society for Spices. The institute has linkages with several universities, research institutes, and developmental agencies for collaborative research and developmental activities in spices.

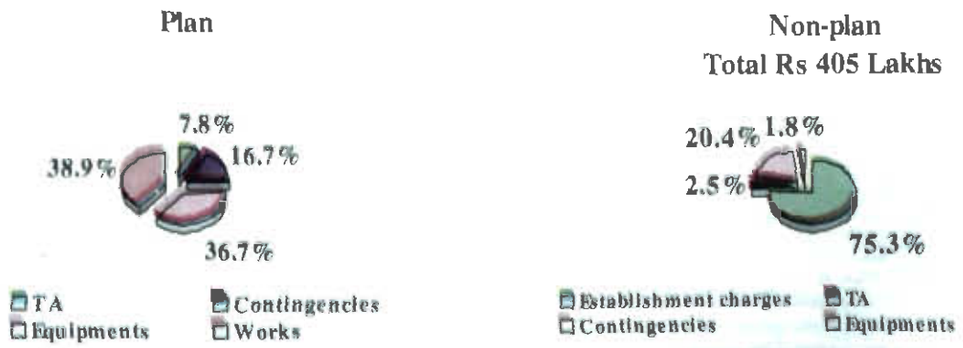
Budget

The total budget of the institute was Rs. 495.0 lakhs during the year, which included Rs. 90.0 lakhs under Plan and Rs.405.0 lakhs under Non Plan. In addition, Rs. 180.0 lakhs was also received as funds from other agencies.

Homepage of **www.spices.res.in** - The **official website of Indian Institute of Spices Research**



Organization of Indian Institute of Spices Research



Budget of the institute

Resource generation: Institute earned a total of Rs. 22,84,804/- through sale of planting materials, biocontrol agents, training, publications and consultancy services.

Staff: The institute has a sanctioned strength of 42 scientific, 19 administrative, 36 technical and 61 supporting staff.

Staff position of the institute

Category	Sanctioned	In position			Vacant
		Calicut (HQ)	Peruvannamuzhi (Farm)	Appangala (RC)	
Scientific	43	28	3	4	8
Technical	36	17	13	5	1
Administration	19	17	-	1	1
Supporting	61	27	14	18	2
Total	**159**	**89**	**30**	**28**	**12**

Staff position of KVK

Category	Sanctioned	In position			Vacant
		Calicut (HQ)	Peruvannamuzhi (Farm)	Appangala (RC)	
Scientific	-	-	-	-	-
Technical	7	1	4	-	2
Administration	2	1	1	-	-
Supporting	2	-	2	-	-
Total	**11**	**2**	**7**	**-**	**2**

PAST ACHIEVEMENTS

Black pepper: Germplasm collections obtained over the years through explorations are being maintained at IISR as well as in other alternate sites for developing improved varieties for yield, quality, abiotic and biotic stresses. The genetic stock has resulted in release of several improved varieties such as IISR-Sreekara, IISR-Subhakara, IISR-Panchami, IISR-Pournami, PLD-2, IISR-Thevam, IISR-Girimunda, IISR-Malabar Excel and IISR-Shakthi. Some of the unique accessions are registered with NBPGR at New Delhi. Putative transgenic black pepper plants with osmotin gene conferring resistance to drought and *Phytophthora capsici* has been developed. *In vitro* and *in vivo* propagation methods were standardized. Plantlets developed through micropropagation were established in farmers field in Kerala and Karnataka. Gene conferring resistance against *Phytophthora capsici* was isolated by targeted gene amplification using degenerate primers from *Piper colubrinum*. The spacing, nutrient and water requirements were standardized for different soil types of pepper growing regions. High production technologies and mixed cropping systems were developed for increasing productivity. Among different forms of potash, water-soluble and available K had significant positive correlation with berry yield, oleoresin and piperine. Organic production technology for black pepper has been standardized. Cost effective method for production of disease free rooted cuttings was developed. Mathematical models for optimum climatic

factors for high production of black pepper have been developed.

Major pests, pathogens, viruses & 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) is 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 Badnavirus in a single reaction was standardized. Phytoplasma with phyllody symptoms was most closely related to members of aster yellows group (16Sr I) of Phytoplasma.

Integrated strategies involving cultural methods, biocontrol agents, plant products and resistant varieties were developed for the management of pests and diseases including nematodes that resulted in substantial increase in yields and pesticide free produce. Large-scale multiplication of biocontrol agents such as *Trichoderma* and *Pseudomonas* for distribution to farmers for management of disease was also undertaken. These organisms were deposited in the national repository of microorganisms at IMTECH, Chandigarh for future reference. Species-specific primers were developed for detection of *R. similis* in soil and plant samples. Black pepper accession HP-39 and Acc. 1090 were found to be resistant to nematodes besides being rich in caryophyllene. Endophytic bacteria found effective against *Phytophthora capsici* and *R. similis* in black pepper have been found. An integrated pest management schedule for management of root mealy bug has been developed. Post harvest technologies for drying, processing and production of value added product like white pepper production were standardized.

Cardamom: Four unique accessions were registered with NBPGR, New Delhi. IC numbers have been obtained for all the available 436 cardamom germplasm accessions. Molecular profiling of Indian Cardamom revealed existence of two genetically distinct clusters such as "Kerala cluster" and "Karnataka cluster' among the germplasm collections. Improved varieties such as IISR-Vijetha, IISR-Avinash and IISR-Suvasini have been developed. Two of them are mosaic or rhizome rot resistant and have been popularized among the farmers. Coupled with production technologies, these varieties resulted in the productivity increase in cardamom. New high yielding varieties such as APG293, 398, 416 and 250 are found to be promising. Characterization of export grade cardamom from India, Sri Lanka and Guatemala based on physical, biochemical parameters and molecular techniques revealed the superiority of Indian produce for the physical parameters such as seed to husk ratio, weight of 100 capsules, number of capsules in 100g, bulk density and moisture content. High production technology has been standardized. Drip irrigation and sprinkler irrigation once in 12 days recorded significantly higher number of tillers per clump, more number of leaves per tiller and more number of panicles per plant. Soil-water conservation measure has been standardized in cardamom based cropping system. Cardamom accessions APG 257, APG 414, APG 434 have been found to be promising for drought tolerance. High quality (more than 40% α- terpinyl acetate) cardamom such as NHY-14, MB-3, NHY-18 and OP-28 have been identified. The screening programme against leafspot and leaf blotch resulted in several moderately resistant types.

Ginger: Ginger germplasm repository at IISR is one of the largest collections with several exotic collection and high quality accessions. These accessions have been routinely used in the genetic improvement programme. An *in vitro* gene bank was established for conservation of germplasm. Three ginger varieties IISR-Varada, IISR-Rejatha and IISR-Mahima were released for high yield and quality. Ginger oil components have been characterized by GC-MS. A relationship between leaf P/Zn ratio and soil

P/Zn ratio to rhizome yield of ginger has been established. Post harvest technologies for processing and technologies for preparation of value added products such as salted ginger were standardized. Bacterial wilt pathogen, *Ralstonia solanacearum* in North Eastern States, Sikkim and Kerala were found similar in a molecular fingerprinting indicating strain migration from one place to another. Ginger strain of *R. solanacearum* was found to infect turmeric, cardamom, *Curcuma aromatica*, *C.zedoaria*, *Kaempferia galanga*, *Zingiber zerumbet* and tomato. 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*. Techniques for ginger seed rhizomes treatment (for elimination of bacterial wilt pathogen) and integrated disease management strategy for soft rot & bacterial wilt diseases and shoot borer were developed. 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 publication, training programmes and demonstrations. Large-scale multiplication and distribution of elite planting material were also undertaken.

Turmeric: The germplasm collected over the years have been characterized for yield, quality, resistance to pests, diseases and drought. Molecular genetic fingerprints of sixteen *Curcuma* species using RAPD and Inter Simple Sequence Repeats (ISSR) technique revealed high degree of polymorphism among the accessions. Seven high curcumin and high yielding varieties, IISR-Suvarna, IISR-Sudarsana, IISR-Suguna, IISR-Prabha, IISR-Prathiba IISR-Alleppey Supreme and IISR-Kedaram were released for commercial cultivation. 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. Three different curcuminoids (Curcumin, De Methoxy curcumin and Bis De Methoxy curcumin) could be separated from oleoresin of turmeric rhizomes by employing chromatographic techniques. Turmeric oil components have been characterized by GC-MS. A PCR based method was developed to detect adulteration of turmeric powder with wild *Curcuma* species. The optimum spacing, nutrient and water requirement were standardized for different soils. Organic farming system was developed for turmeric. Basic data on distribution, bioecology, population dynamics of *Conogethes punctiferalis* & its natural enemies and crop loss due to shoot borer was generated. The improved varieties and technologies were disseminated to farmers and other agencies through publications and demonstrations.

Tree spices: The germplasm holdings of important tree spices include nutmeg, clove, cinnamon including cassia, garcinia and allspice. IC Numbers for cinnamon, clove, nutmeg and all spice 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 accessions. Two high quality cinnamon varieties, IISR-Navashree and IISR-Nithyashree and a nutmeg variety, IISR-Viswashree were released. Various improved lines with high yield and quality were developed that had a great impact in increasing the production and productivity of these crops in the country. Nutmeg accession A11/25 was found to be promising for high yield. 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. Drying and processing methods for cinnamon, nutmeg and mace have been developed. Vegetative propagation techniques were standardized for nutmeg, cassia and cinnamon. Major pests and pathogens of 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 consisting of 93 accessions are being maintained in the repository. This include a flower colour variant collected from Andaman and Nicobar islands. Interspecific hybridization was made between *Vanilla planifolia* and *V. aphylla*. Over 1000 seed progenies of *V. planifolia* are being field-tested for yield and disease resistance. Protocols for micro propagation through direct shoot multiplication as well as callus regeneration were standardized. Root rot and wilting were found to be a major problem 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 (*Vanilla planifolia* Andrews) 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.

Paprika: Several accessions including hybrids were added to the repository mainly through the network project on paprika. The germplasm was characterized for yield and quality such as oleoresin, pungency and colour value. Substantial amount of variability was observed in capsaicin content (pungency) of selected paprika accessions. Accessions with high yield and colour values were also identified.

Black Pepper

Black Pepper

1. GENETIC RESOURCES

Collection, maintenance and multiplication: One hundred and one accessions including 86 wild and 13 cultivated types were collected from forests of Western Ghats, Attappadi, Siruvani, Wagamon, Vandiperiyar & Erumeli in Kerala, Dapoli in Maharashtra and Mollem, Walpoi & Canacona in Goa. Cultivars such as Chomala, Kuriyilamundi, Muttuchiramunda, Jeerakamundi and Vadakkan found surviving in farmers field were collected and added to the repository. At present, the germplasm holdings of the conservatory include 2337 accessions. New planting was carried out in the wild germplasm field. Fifty more accessions were planted at Kidu center of CPCRI.

Registration of germplasm: Fifty accessions were characterized morphologically based on IPGRI descriptor. A black pepper accession rich in caryophyllene was registered as a unique germplasm (INGR 06026).

Biodiversity: Total chlorophyll, total carotenes, phenol and biomass were estimated in 148 accessions of *Piper nigrum* leaves. Total chlorophyll varied from 0.0389- 0.176 mg g^{-1}, carotenes from 0.021-0.075 mg g^{-1}, total phenol from 0.314-1.188 mg g^{-1} and biomass from 15.25- 29.5%. It was found that phenol and biomass gave significant relation with environment. Cluster analysis using SPSS soft ware gave five clusters. Factors responsible for the segregation of the cluster were found by principal component analysis. First component extracted 91 and 92% of chlorophyll and carotene percentage respectively, whereas the second component extracted 77 and 68% of biomass and phenol respectively. The five clusters were in conformity with biomass and phenol concentration, the analysis revealed.

Spike proliferating black pepper: A unique black pepper accession with 'proliferating spike' collected from a farmer's field flowered and spiked in the black pepper repository at Indian Institute of Spices Research farm, Peruvannamuzhi.

2. CROP IMPROVEMENT

Conventional approaches

Varieties Released: The 23rd Kerala State Variety Release Committee has approved four Black pepper varieties *viz.*, IISR- Thevam, IISR- Girimunda, IISR-Malabar Excel and IISR-Shakthi. Besides being suited to high altitudes, IISR- Thevam is high yielder and having adult plant tolerance to foot rot disease, IISR- Girimunda is high yielding and resistant to anthracnose disease while IISR- Malabar Excel is good yielder with high oleoresin (13.6%). IISR-Shakthi is found tolerant to foot rot disease.

Breeding for high quality: Crosses between IISR-Subhakara as female and the short-listed high caryophyllene lines such as CLTP 123,122, 24 and 7 were carried out. The quality attributes of the high caryophyllene lines are furnished below.

Breeding for resistance to biotic and abiotic stress: Seedlings obtained from the

Quality attributes of high caryophyllene black pepper lines

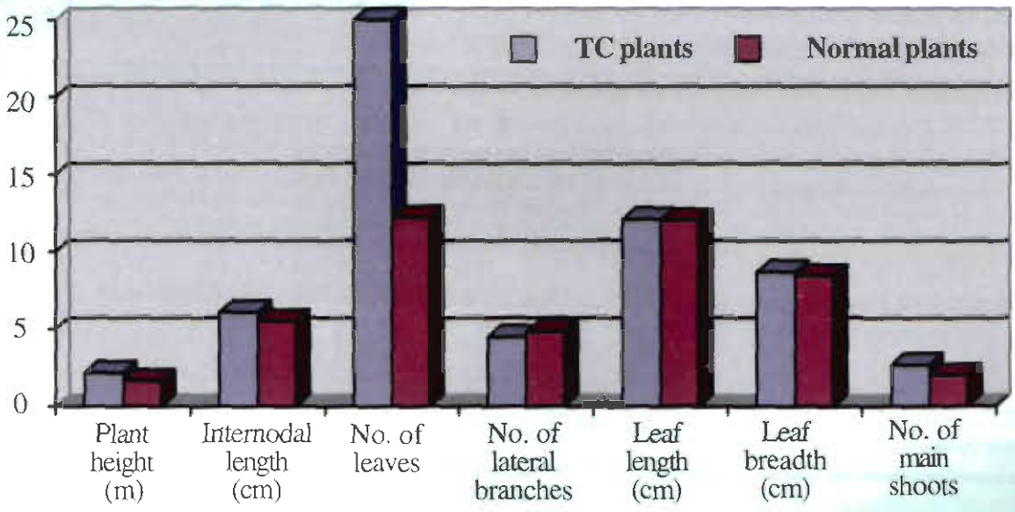
Accession	Bulk density ($g L^{-1}$)	Oil	Oleoresin	Piperine (%)	Caryophyllene
CLTP-122	534	2.3	7.7	3.62	17.0
CLTP-7	537	3.6	8.3	3.6	15.4
CLTP-24	569	3.3	8.9	2.57	19.4
CLTP-123	525	3.3	8.6	3.28	18.2

crosses between IISR-Subhakara x HP 39 and thirty seedling progenies of induced Polyploid C5 were maintained for evaluation for nematode resistance. The pollu tolerant lines such as Coll. 816, 841, 1084, 114 and progenies from IISR-Subhakara x *P. attenuatum* were crossed with IISR-Subhakara. Several progenies obtained were raised for preliminary evaluation against pollu beetle infestation. Inter-varietal hybridization for drought resistance initiated with IISR-Subhakara and Coll. 1435, 937, 813 yielded berries in all the crosses. About 100 seedling progenies of natural polyploid 'Vadakkan' were raised using the seeds collected from Sandalkad Estate, Mercara.

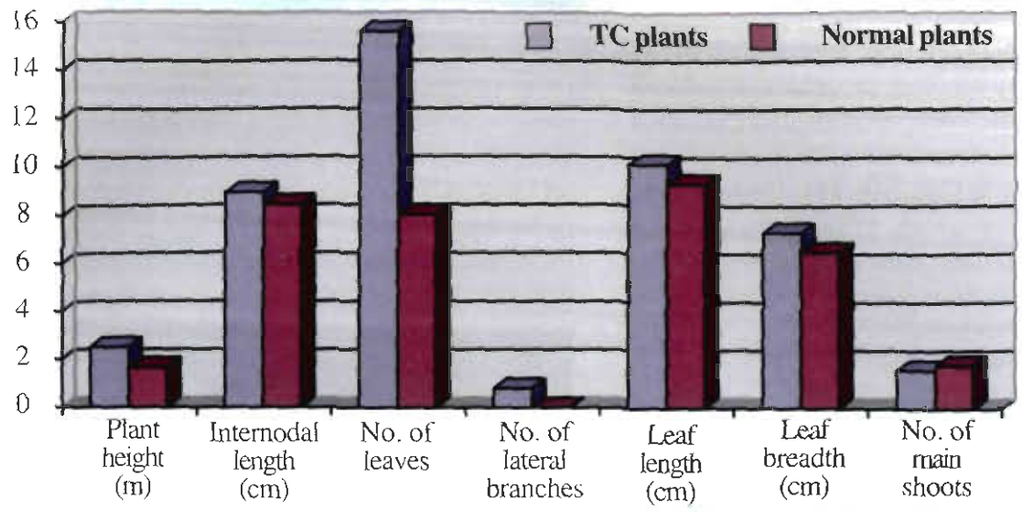
Biotechnological approaches

Evaluation of tissue cultured black pepper plants: Tissue Cultured (TC) plantlets (10,000) were field evaluated in 100 trials covering over 25 ha in the states of Kerala (69 ha) and Karnataka (31 ha). The TC plants showed good establishment and 20% of them showed early flowering. Twenty nine percent of the TC plants were planted on Silver Oak followed by Arecanut (27%), Coconut (16.4 %) and *Erythrina* (16.3%). Good establishment was observed in Kasaragod District followed by Kannur and Wayanad. The establishment of TC plants was better in Kerala than Karnataka. Molecular characterization using ISSR markers indicated genetic uniformity. Observations on growth characters of tissue culture plants supplemented with biocontrol agents revealed that the biological control agents were performing well with TC plants than that of normal plants.

Performance of tissue cultured black pepper variety, IISR-Panchami in field



Growth parameters of tissue cultured IISR-Panchami

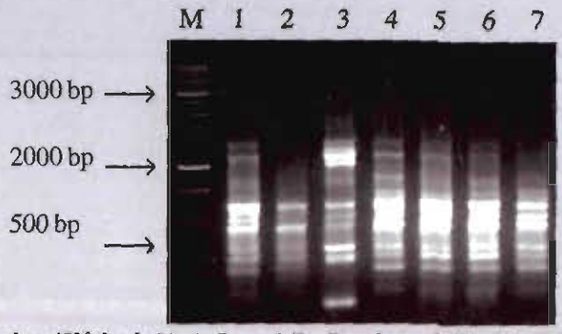


Growth parameters of tissue cultured IISR- Subhakara

Early flowering in tissue culture derived plants: Twenty percentage of the tissue culture plants produced lateral branches and spikes within a year after planting. Laterals emerged after the monsoon and spike formation was noticed in the months of July to August. The length of spike ranged from 9.8 to 10.7 cm in IISR-Panchami and 2.5 to 4.2 cm in IISR-Subhakara. Only one spike could be observed per lateral. Early flowering and production of spikes were found to be more in irrigated plots than the plants under rain fed conditions. The inter-simple sequence repeats (ISSR-Primer IS10: 5'-gTgTgTgTgTCC-3') based genetic stability analysis revealed that the TC black pepper plants were genetically stable.

Molecular tools for varietal discrimination

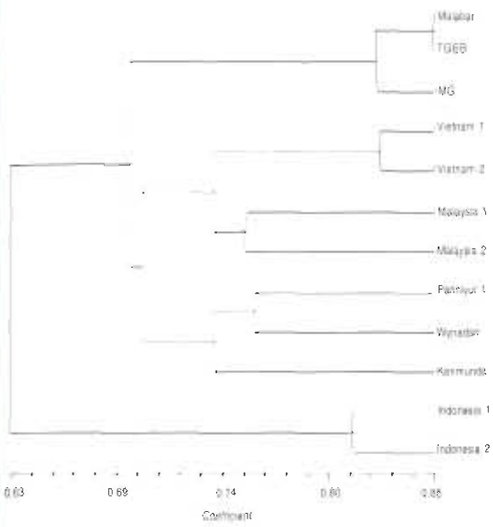
Three primers such as ISSR-20T/16, ISSR-16/14, ISSR-02T/16, among the twenty ISSR primers used for molecular analysis of seven released varieties, yielded good number of polymorphic bands. Unique bands were obtained in IISR-Shakthi with various primers (ISSR-07-2800bp, ISSR-3G/16-300bp, and ISSR-4T/17-2000bp). Cluster analysis showed unique nature of IISR-Shakthi, which showed 93% identity with IISR-Malabar excel. PCR based identification of hybrids has been standardized. The ISSR based molecular profiling could clearly distinguish four of the released varieties.



M-Marker (500 bp ladder), Lane 1-7: Panniyur- 4, Panniyur- 7, IISR-Shakthi, IISR-Malabar Excel, IISR-Pournami, IISR-Sreekara, IISR-Girimunda

Varietal discrimination by PCR based method

Molecular characterization of traded black pepper : Molecular characterization (RAPD) of the traded black pepper from India, Indonesia, Vietnam and Malaysia was completed. One hundred percent polymorphism was observed in primers OPJ13 and OPJ18. The UPGMA dendrogram constructed based on the similarity coefficient revealed a distinct clustering pattern of the traded commodities in conformity with the country of origin.



Dendrogram of the traded samples of black pepper obtained by UPGMA cluster analysis

Cloning and sequencing of a gene confering resistance: PCR based gene walking in *Piper colubrinum* by amplifications using degenerate random primers and R gene specific primers from the cloned fragment of 252 bp was attempted. Targeted amplification of chitinase gene was achieved from mRNAs isolated from *P. colubrinum* inoculated with *Phytophthora capsici*. Cloning and sequencing of the amplified fragment (313bp ~104 aminoacids) was done using standard protocols. Sequence comparison of the deduced amino acid sequence of the fragment was done with NCBI-BLAST 2 and revealed to be closely related to different classes of chitinase genes isolated from other plants.

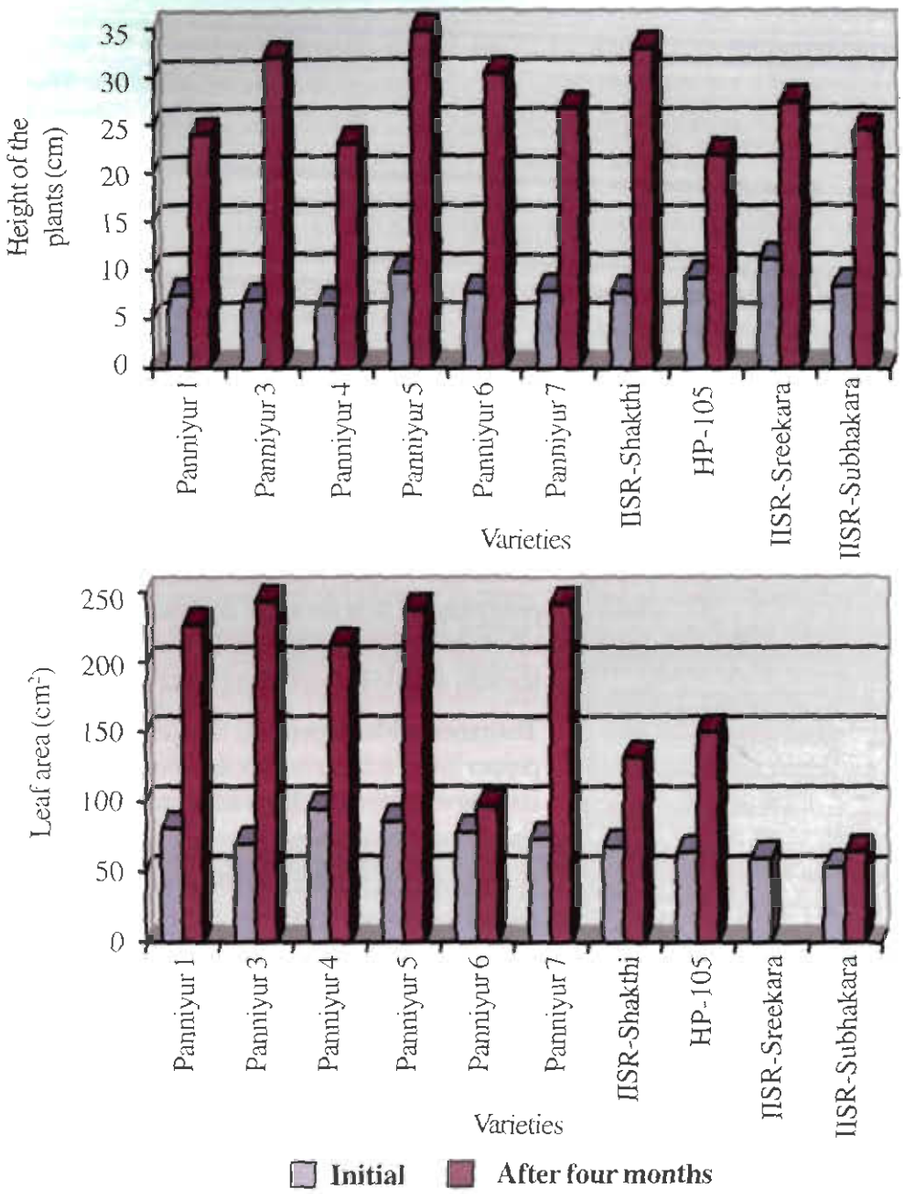
A marked increase in chitinase activity in the inoculated leaves was observed, with maximum activity after 60 hours of inoculation and gradually decreased thereafter. Older leaves showed more chitinase activity than young leaves. The level of chitinase in black pepper upon inoculation was found to be substantially high when compared to *P. colubrinum*. RT-PCR using chitinase specific primers revealed differential accumulation of mRNA in *P. colubrinum* leaves inoculated with *P. capsici*.

Molecular Mapping: 115 lines of mapping population of IISR-Subhakara X Panniyur 1 were maintained in the field. Additional 70 lines were also planted in the field this year. 97 progenies of first set were analysed by ISSR profiling. A block of mapping population was developed with IISR-Shakthi and IISR-Sudhakara for crossing.

Transgenic black pepper: One hundred transgenic black pepper lines carrying transgene, Osmotin, was developed and is being multiplied for large scale screening for *Phytophthora* and drought resistance.

3. CLIMATIC AND PHYSIOLOGICAL FACTORS IN RELATION TO PRODUCTIVITY

Response of black pepper to increased temperature: Based on HadCM3 RCM predictions for 2020 and 2050 for the grid covering Calicut for A2a scenario, the increase in T_{max} for Calicut would be about 1.7 degrees for 2020 and 2.7 degrees for 2050. Similarly, increase in T_{min} would be about 0.5 and 1.5 degrees respectively. Based on this, an experiment was set up with 10 varieties of black pepper in growth chamber with set temperatures of 2.7 and 2 degrees increase (over 20 years average) in day and night temperatures respectively. The percentage variation in growth parameters (plant height and leaf area) was less than 10 after 4 months of growth at elevated temperatures. Growth parameters such as height of the plant and leaf area were not affected by elevated temparature. When assayed for photosynthetic rate there was very little deviation between plants grown at normal and elevated temperatures indicating that elevated temperatures of 2-3 degrees may not have much impact on the growth of black pepper.

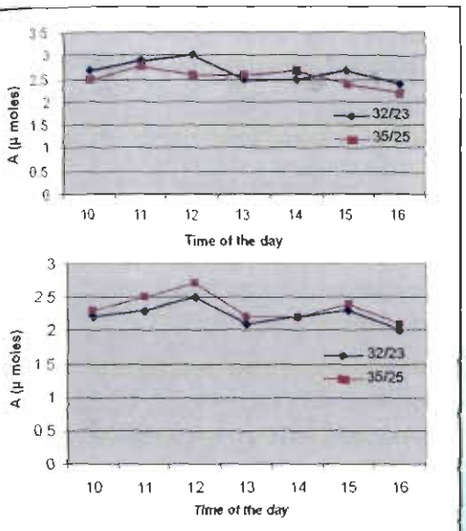


Effect of elevated temparature on growth of black pepper

Quality analysis of black pepper berries collected from 95 locations covering major black pepper growing regions of Kerala, Karnataka and Tamilnadu indicated that oleoresin content did not vary significantly in varieties among the localities. The mean temperatures (T_{max}) of different coastal districts of Kerala varied from 31 to 34 degrees during the collection, which further confirmed that temperature did not influence oleoresin content. Interestingly samples from higher elevations of Kerala, Karnataka and Tamilnadu showed slightly lower oil and piperine content.

Physiological and biochemical basis for productivity : Nitrate reductase (*NR*) activity was assayed in leaves and berries of high and low yielding black pepper accessions during pre and bearing periods. *NR activity was significantly higher in leaves* compared to the berries in all the accessions both in high and low yielders. Further, the activity was more in leaves during bearing period than pre bearing period. HP 1411

showed highest NR activity while lowest activity was seen in IISR-Girimunda during pre bearing and accession 840 during post bearing stages. Among berries, accession 1535 showed highest activity and HP 780 the least. Sucrose phosphate synthase activity also differed significantly wherein high yielders



Photosynthetic rate of Panniyur 1 and IISR - Sreekara at varying temparature

showed higher activity than the low yielders during both the periods. Among the gas exchange parameters, the mean photosynthetic rate of high yielders was higher (3.1 µ moles) than that of low yielders (2.7 µ moles). The highest photosynthetic rate was observed in Panniyur -1 (3.9 µ moles) while accession 4112 showed lowest photosynthetic rate (2.0 µ moles). The mean transpiration rate (1.3 and 1.3 m moles in high and low yielders respectively), stomatal conductance (0.06 and 0.05 respectively) and the mean leaf temperature (33.2 and 33.6°C respectively) did not vary significantly among high and low yielders. Similarly, isozyme profiles of SOD, Glucose-6-phosphatase and Leucine Amino Peptidase also did not show any relationship with productivity. Correlation among productivity and different parameters revealed that starch content in the berries had significant positive correlation (r=0.75) while leaf temperature showed significant negative correlation (r=-0.58). Photosynthesis and SPS activity showed weak positive correlation indicating their non-influence on productivity.

4. NUTRITIONAL TRIALS AND ORGANIC FARMING

Comparison of nutritional systems: Integrated, organic and chemical systems were compared for black pepper cultivation. Highest average fresh yield (2.1 kg vine^{-1}) was observed in integrated system, which was on par with chemical system. The organic system recorded the lowest yield (1.4 kg vine^{-1}). Mortality of black pepper vines due to disease incidence was high under organic system.

Evaluation of Sulphate of Potash (SOP) as potassium source on yield and quality: In bush pepper, application of Sulphate of Potash (SOP-1.75g pot^{-1}) at bimonthly interval recorded the highest yield of 295 g pot^{-1} followed by Muriate of Potash (MOP-3.5g pot^{-1}) and SOP (4.5g pot^{-1}). In a pepper garden, maximum yield (3.16 kg vine^{-1}) was obtained with SOP (500g plant^{-1})+ Mg SO_4 (25g plant^{-1}), which was on par with recommended dose of K as SOP and significantly higher than control. Among different forms of K, water-soluble and available K had significant positive correlation with berry yield, oleoresin and piperine.

The efficacy of organic amendments in nutrient release and its uptake: Efficiency of organic amendments in reducing the P fixation capacity of Peruvannamuzhi soil series was studied under lab conditions. Addition of organic manures like FYM, vermicompost, leaf compost and Neem cake increased the availability of organic and residual P fraction in soil and the order of availability of different P fractions was Residual/ Organic P > Ca-bound P ~ Reductant soluble P > Fe/ Al P > loosely bound P. Among the sources, vermicompost and FYM applications recorded higher buildup of available P in surface and sub surface layers of Panniyur and Karimunda varieties of bush pepper on par with that of chemical fertilizers. Neem cake recorded the lowest P buildup. Available P content showed highly significant positive correlation with Al-P (0.97**) followed by Residual P (0.712**) and Ca-P (0.649**). Significantly higher yield was recorded in vermicompost application in both Panniyur and Karimunda varieties of bush pepper. Al-P showed significant positive correlation with yield (0.62**) and P uptake (0.45**). Step

wise forward regression analysis showed that Fe-P and Available P as the best predictor for yield (= 46.25 + 1.034 Fe-P + 0.570 Avl. P) with an R^2 of 0.611**.

5. SOIL QUALITY UNDER SPICES BASED CROPPING SYSTEMS

Soil samples (0-30 cm) collected from the rhizosphere of *Erythrina indica*-BP, *Garuga pinnata*- BP, *Glyricidia sepium*- BP, *Ailanthus malabarica*- BP and Reinforced Cement Concrete (RCC) pole- BP systems were analysed for physico-chemical parameters such as pH, organic carbon, available N, Bray P, exchangeable K, DTPA-extractable Zn, -Cu, -Mn and –Fe. Biochemical (microbial biomass carbon (C_{MIC}), Basal respiration (CO_2 evolution), metabolic quotient (qCO_2), dehydrogenase activity and microbial community structure were also analysed.

Physico-chemical parameters such as pH, available N, and DTPA-Fe did not vary significantly among various *standard*-BP whereas organic C levels were relatively higher under the tree supports- BP systems (mean 2.3%) compared to the RCC pole- BP system (mean 1.9%). Though variations in the levels of organic C, Bray P, NH_4OAc-K, exchangeable Ca & Mg and DTPA-Zn, -Cu and –Mn were observed among the various sites which was not consistent with the type of standards employed as support for black pepper.

All biochemical parameters related to microbial activity in soils showed marked variations among the standard-BP sites. Microbial biomass carbon (C_{MIC}) was significantly higher in the *Glyricidia*- BP *rhizosphere* (474 µg g^{-1}) and least in the RCC pole- BP rhizosphere (205 µg g^{-1}). On an average, C_{MIC} levels in soils under the tree standards-BP were higher by 51-57% compared to the level in the rhizosphere of the RCC pole- BP system. CO_2 evolution was higher by 56-64%, qCO_2 levels by 6-28% and dehydrogenase activity by 45-48% in soils under tree supports- BP systems.

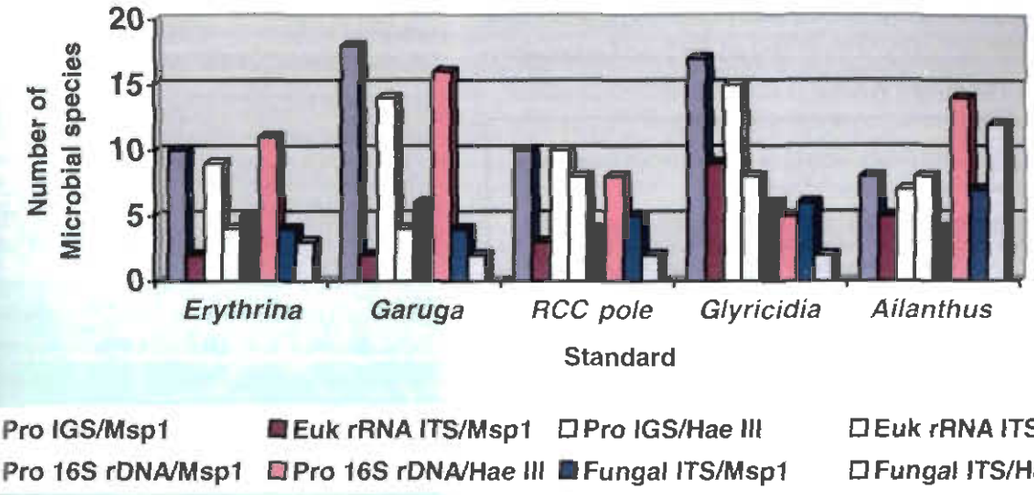
PCR-RFLP analysis of soil microbial community structure in the rhizosphere of various BP systems revealed that maximum number of species was scored in *Glyricidia*-BP system (68), followed by *Garuga*- (66) and *Ailanthus*- BP systems (65). *Erythrina*- and RCC pole- BP systems registered low levels of diversity of 48 and 50 respectively. The rhizosphere soils of RCC pole-BP system showed a reduced microbial population compared to tree standards-BP systems.

Microbial biomass- C (C_{MIC}), -N (N_{MIC}), -P (P_{MIC}) and ratios of various microbial indices in soils under live (tree species) and non living support (RCC pole) of black pepper

Parameters	*Ailanthus malabarica*	*Glyricidia sepium*	*Garuga pinnata*	*Erythrina indica*	*RCC pole*
C_{MIC} (µg g^{-1})	423c	474a	454ab	415cd	205e
N_{MIC} (µg g^{-1})	28b	32a	29ab	29ab	11c
P_{MIC} (µg g^{-1})	14.7a	13.6a	14.2a	14.0a	7.2b
CO_2 evolution (µg CO_2-C $g^{-1}day^{-1}$)	39.0bc	34.0b	39.0a	32.0bc	14.0d
C_{MIC}: organic C (%)	1.96a	2.10a	2.00a	1.60b	1.10c
C_{MIC}: N_{MIC}	15.1b	14.8b	14.6b	14.3b	18.6a
C_{MIC}: P_{MIC}	28.8a	34.8a	32.0a	29.6a	28.4a
qCO_2 (mg CO_2-C (g biomass C)$^{-1}$ day^{-1})	92a	72cd	86b	77c	68de

Means followed by the same letter in a row are not statistically significant at P < 0.05

Relatively higher population of bacteria was found under BP systems of *Garuga* (54), followed by *Glyricidia* (43), while *Erythrina* (35), *Ailanthus* (33) and RCC pole (32) registered the lowest. Fungal population was high under *Ailanthus*-BP system (19), while the other systems registered significantly lower fungal diversity (6-8). The dendrogram generated by UPGMA of banding profiles revealed that the rhizosphere soils in RCC pole- BP and *Glyricidia*- BP systems were similar by 80%. Soils in the *Ailanthus*- BP rhizosphere was found to be distinct and showed only 50% similarity with the rest of the systems. Thus, soils in the *Ailanthus*- BP rhizosphere appeared to be the most phylogenetically distinct.

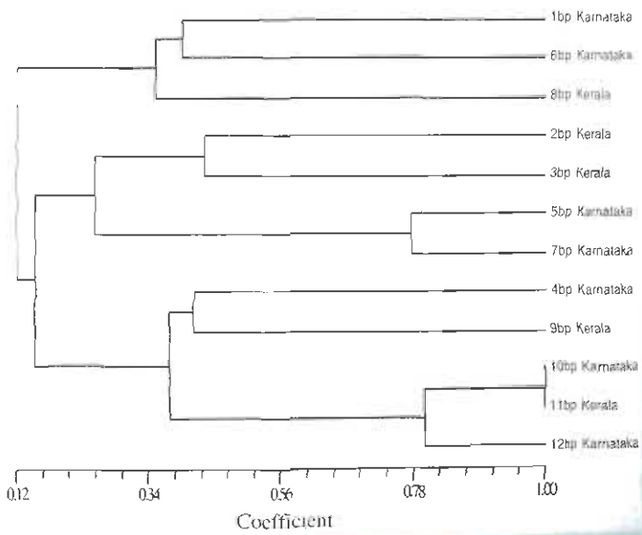


Microbial community analysis of various black pepper rhizospheres

6. *PHYTOPHTHORA* FOOT ROT

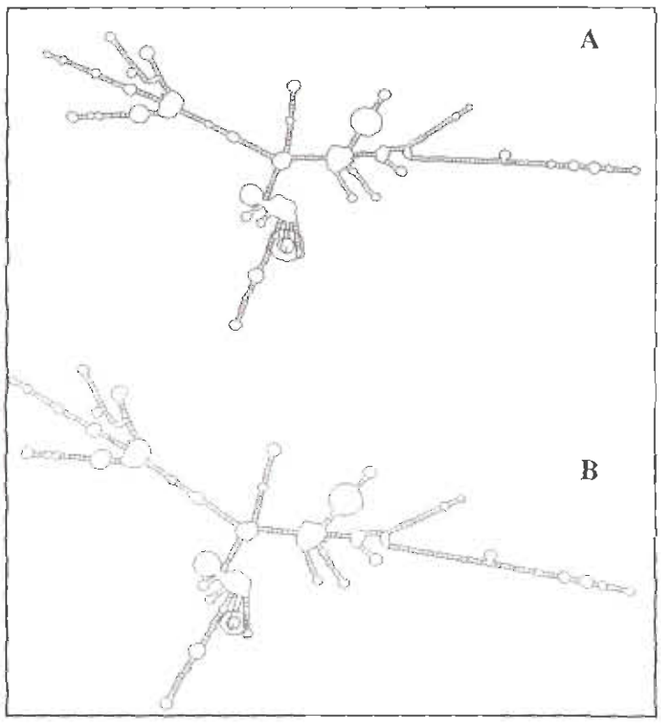
Molecular Characterization of *Phytophthora capsici:* Twelve black pepper isolates were characterized by analyzing the Internally Transcribed Spacer (ITS) regions of the nuclear rDNA using the primers ITS-6 and ITS-4. The amplified products were digested with three restriction enzymes for PCR-RFLP analysis. These isolates were also characterized morphologically based on sporangial morphology and caducity. The sporangial ontogenies were umbellate and sympodial. All the isolates produced papillate sporangia, obpyriform, ellipsoid or distorted in shape. The size of the sporangia ranged from 39.0-83.2 µm x 16.2 -27.0 µm and a pedicel length of 82.0– 138.0 µm. Mating or compatibility type was determined for these isolates by the single unknown isolate method of which eight were A1 mating type and four were sterile.

These *Phytophthora* isolates of black pepper exhibited significant differences in their pathogenicity on black pepper. High levels of intraspecific variability was observed in the ITS regions of all the isolates.



Phylogenetic relationships among *Phytophthora* isolates based on PCR-RFLP

Morphological and molecular characterization of black pepper isolates of *Phytophthora* further revealed that isolates shared the characters of both *Phytophthora capsici* and *P. tropicalis*. Characters like production of chlamydospores, growth at 30°C matched with *P. tropicalis* whereas the sporangial characters and pathogenicity on capsicum was similar to that of *P. capsici*. The rDNA sequence shared 98% identity with *P. tropicalis* or *P.capsici*. Interestingly the isolate showed 100% identity with *P. tropicalis* based secondary structure of ribosomal RNA.



Secondary structure of rRNA of *P. tropicalis* (A), *Phytophthora* from black pepper (B)

Host Resistance: Twenty-two hybrids short-listed as moderately resistant against *Phytophthora* in the preliminary screening were screened by root inoculation in a sick soil artificially inoculated with the pathogen along with IISR-Subhakara as a susceptible check. The infection ranged from 0 to 100% and the number of days taken for mortality ranged from 4 to 45 days. Among them HP 490 and HP 521 survived in *Phytophthora* sick soil. Hybrids such as HP 1238, HP 1706, 04-K17 and HP 1383 showed 30% mortality and HP 13, HP 820 and HP 920 showed 50% mortality by *Phytophthora*.

Reaction of black pepper accessions to *Phytophthora capsici*

Infection (%)	Accession
0	HP 490, HP 521
10-30	HP 1238, HP 1706, 04-K17, HP 1383
50	HP 13, HP 820, HP920
75	HP 987, HP1389, HP1357, Sreekara
100	HP 206, HP 437, HP 900, HP 34

Multiple Resistance: When evaluated in nematode sick soil, the moderately resistant lines short-listed earlier in 2005-06 namely, P24-04-1 and 1533(2) and 1533 (3), did not show resistance to *Radopholus similis* whereas accessions 04-1533(2), 1578, 1610 and 4077 were resistant to *Meloidogyne incognita*.

Screening short listed accessions for nematode resistance

Accession	Reaction against *Meloidogyne incognita*
04-1533(2)	Resistant
P24-01-04	Susceptible
Acc. 951	Susceptible
Acc. 1578	Resistant
Acc. 1610	Resistant
Acc. 4070	Susceptible
Acc. 4077	Resistant

Selection from open pollinated seedlings: Eighty-two out of 32,338 open pollinated progenies representing 40 accessions survived in a sick soil inoculated with *Phytophthora capsici*.

Disease Management

Biocontrol

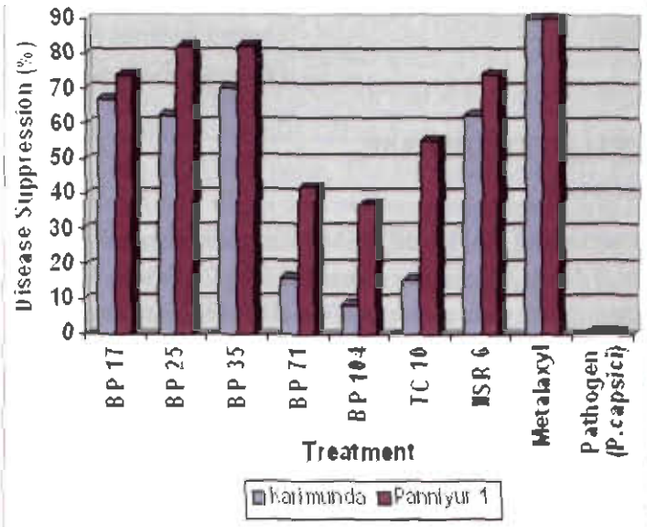
Multiple antagonistic potential of biocontrol agents: The antagonistic potential of *Phytophthora* suppressive bioagents such as IISR 6, IISR 8, IISR 13, IISR 51, IISR 151, PB 21C, PIAR 6, IISR 853, IISR 859 and MTCC 5178 were evaluated against other pathogens such as *Pythium aphanidermatum, Rhizoctonia solani* and *Fusarium oxysporum* f. sp. *vanillae* infecting other spices. The isolate IISR 853, a nematode antagonistic (*Radopholus similis* and *Meloidogyne incognita*) bacteria was suppressive to other targeted pathogens tested.

Compatibility of antagonists: As a prerequisite to form a consortium of microbial candidates, an assay for compatibility of promising bacterial isolates was conducted. The data revealed that all bacterial isolates were compatible with each other. Bacterial isolates IISR 8, 11SR 13, PB-21C and PIAR-6 were compatible with *Trichoderma harzianum*, whereas IISR 859 and IISR 51 were not compatible. *Pochonia chlamydosporia* was not compatible to any of the bacterial antagonists or *T. harzianum*. When evaluated in *vivo*, the combination of IISR 6 and MTCC 5178 performed better than the other combination.

Field evaluation of bioconsortia: A field experiment on effect of bacterial consortium on foot rot and slow decline is underway at IISR Farm, Peruvannamuzhi. Pooled data of three years on disease severity index and pathogen population recorded at regular intervals showed that plant stand and vigour was better in a consortium of IISR 6, 8, 13, 51, 151 PB21C and 853 in the variety Karimunda.

Bacterial endophytes against *Phytophthora capsici*

Endophytic bacteria found effective against *Phytophthora capsici* in black pepper were identified as *Pseudomonas aeruginosa* (BP-35) and *P. putida* (BP-25) by analyzing the nucleotide sequence of 16s rDNA. *Pseudomonas aeruginosa* was found to induce density dependent systemic resistance in excised single nodal shoots. The 16s rDNA sequences of these have been deposited with Gen Bank. The isolates performed consistently well for *P.capsici* suppression in Karimunda and Panniyur varieties in green house trials.



Perfomance of bacterial endophytes for *Phytophthora* suppression in rooted cuttings

Bioactive compounds: Two aromatic carboxylic acids were isolated from the fungitoxic fractions of *Chromolaena odorata* leaves, which exhibited 100% inhibition of mycelial growth of *Phytophthora capsici*. When tested individually caused 35% inhibition of mycelial growth of the pathogen at 1000 ppm concentration

7. ANTHRACNOSE

Host resistance: The natural incidence of anthracnose disease caused by *Colletotrichum gloeosporioides* was recorded in 26 accessions of black pepper including 4 hybrids, 10 selections and 18 cultivars. Panniyur-5, IISR-Girimunda and HP 780 were highly resistant

Reaction of pepper accessions to anthracnose disease

Disease index (%)	Category	Field tolerant accession	Resistant accession
0 – 5.0	Highly Resistant	Panniyur-5, IISR- Girimunda, HP-780	Nil
5.1-10.0	Resistant	IISR-Panchami, Aimpiriyan, IISR-Subhakara, Karimunda (Idukki), Kottanadan, Jeerakamunda (Gudalur), Arakalamunda, Chomala	Panniyur-5, IISR- Girimunda, HP-780, IISR-Panchami, Aimpiriyan, IISR-Subhakara, Karimunda (Idukki), Kottanadan, Jeerakamunda (Gudalur) Arakalamunda, Chomala
10.1-20.0	Moderately Resistant	IISR-Sreekara, Chetalli, IISR-Malabar Excel, Vadakan, IISR-Thevam, Kalluvally-1, Panniyur-6, Panniyur-7, Narayakodi	IISR-Malabar Excel, Vadakan, IISR-Thevam, Kalluvally-1, Panniyur-6, Panniyur-7, Thevanmundi

8. STUNTED DISEASE

Detection

Detection of CMV and PYMoV in planting material : A RNA virus, *Cucumber mosaic virus* (CMV) and a DNA virus, *Piper yellow mottle virus* (PYMoV) are associated with stunted disease of black pepper. Since both viruses differ in the nature of their genome, a reliable protocol was developed for the co-isolation of total nucleic acids (both DNA and RNA) from black pepper. A single tube multiplex RT-PCR (mRT-PCR) was developed for the simultaneous detection of both the viruses. Unique PCR primers designed for amplifying 650 bp from the coat protein gene of CMV and 450 bp from the open reading frame (ORF) I of PYMoV were used in the reaction. The method was successful for the detection of both the viruses infecting black pepper in nursery and field samples. The method was cost effective, reliable, and sensitive requiring only small tissue sample for effective detection and can aid in rapid screening of large number of plants for both the viruses. This is the first report on the simultaneous detection of RNA and a DNA virus infecting black pepper.

Distribution of CMV and PYMoV in plants during different seasons: Variation in the concentration of PYMoV and CMV in five cultivars/varieties (HP-34, IISR-Girimunda, Karimunda, Panniyur- I and IISR-Panchami) of black pepper during different months was studied through double antibody sandwich (DAS) ELISA. Samples were collected from plants of these varieties at monthly intervals (April to March) and subjected to DAS-ELISA. The results showed varying concentrations of both PYMoV and CMV during different months. In general, the concentration of both the viruses was found to be higher during October to January. During March no virus could be detected through ELISA in two cultivars namely, HP 34 and IISR-Girimunda. Among the different cultivars/varieties tested, the concentration of the viruses was higher in Panniyur I followed by HP-34 and IISR-Panchami.

Characterisation

Comparison of ORF I and III of PYMoV isolates from different regions : Variability in the PYMoV isolates collected from various geographical regions (Calicut, Idukki and Wyanad districts of Kerala and Kodagu district of Karnataka) were studied. The portion of ORF I and ORF III from these isolates were amplified using specific primers. The products were cloned and sequenced. The sequenced region contained 694 to 710 nucleotides in different isolates for ORF I. Analysis using ORF I sequences showed high variability (38.9% to 97.9%) among different

isolates. With other recognized species of badnaviruses, the identity ranged from 16.6% to 26.9%. The sequence phylogram constructed based on nucleotide sequences also showed similar phylogenetic relationships. Idukki and Calicut isolates showed close relationship with PYMoV from Sri Lanka followed by Wyanad.

In contrast to ORF-I, ORF-III sequences showed high conservation among isolates. The sequenced region contained 596 to 600 nucleotides in different isolates. Pair wise comparison of the nucleotide sequences of ORF III of PYMoV isolates infecting black pepper in India showed an identity ranging from 95.1 to 97.8%. Among the four isolates compared, Calicut and Idukki isolates were more close to each other. The identity with other badnaviruses used in the comparison ranged from 29.8 to 60.1%.

Identification of Badnavirus infecting *Piper longum* and *P. betle* : *Badnavirus* infecting betel vine (*Piper betle* L.) and Indian long pepper (*P. longum* L.) were identified using primers designed for amplifying a portion of ORF III by PCR. The amplicon obtained were cloned and sequenced. The sequenced region of ORF III contained 597 nucleotides in both the isolates. Sequence analysis revealed that *Badnavirus* infecting *P. betle* and *P. longum* had highest sequence identity (> 89.1% at nucleotide level and >93.4% at amino acid level) with an Indian black pepper isolate of *Piper yellow mottle virus* (PYMoV). A relatively low identity of < 72.8% at nucleotide and < 68.3% at amino acid level was observed with ORF III region of other distinct *Badnavirus* species. Pair wise comparison of ORF III nucleotide sequences of *Badnavirus* isolates infecting betel vine and Indian long pepper showed an identity of 88.7% at nucleotide level and 93.9 at amino acid level. Phylogenetic analyses of ORF III nucleotide and amino acid sequences revealed close clustering of *Badnavirus* infecting betel vine and Indian long pepper with PYMoV black pepper isolate. Based on the sequence identity and phylogenetic relationship studies, it was concluded that *Badnavirus* infecting *P. betle* and *P. longum* in India is a strain of PYMoV.

Disease management

Preparation of CMV CP gene construct in plant transformation vector : Coat protein gene of *Cucumber mosaic virus* (CMV) infecting black pepper was amplified through RT-PCR, cloned in TA vector and its nucleotide sequence determined. The CP gene consisted 657 bases potentially coding for 218 amino acids. The CP gene was then amplified from the TA vector and sub cloned in plant transformation vector, pBI 121 at *Bam* H1 and *Sac* 1 sites by replacing the GUS gene. The recombinant pBI 121 harbrouring CMV CP gene was then used to transform *E. coli* DH 5α cells. The presence of the transgene (CMV CP) in recombinant pBI 121 was confirmed through both restriction and PCR analysis. The positive recombinant pBI 121 was then mobilized into *Agrobacterium tumefaciens* through Freeze- thaw method. The plasmid isolated from *A. tumefaciens* was again subjected to restriction and PCR analysis to confirm the presence of recombinant pBI121 containing CMV CP gene. This transformed *A. tumefaciens* was then used in the transformation of black pepper tissues.

9. NEMATODES

Characterization: The burrowing nematode (*Radopholus similis*) infesting black pepper in India was characterized by analyzing ITS region of rDNA. The size of the PCR fragment was of 398 bp and it showed 98% sequence similarity with known *R. similis* populations across the world. Molecular characterization of an Indian isolate of *R. similis* is done for the first time.

Host resistance: Among the four *Piper* spp. screened only *Piper colubrinum* showed resistance to *Radopholus similis* and *Meloidogyne incognita* both nematodes. The field performance of two *R. similis* resistant black pepper lines, HP- 39 and C-820, was superior to other lines even four years after planting.

Field evaluation of nematode resistant lines

Accession	Yellowing Index	Dry Yield (g)	Nematode g^{-1} (root)			
			R.similis	Incidence	*M.incognita*	Incidence
HP 39	0.00	285.0	0.0	0/4	0.0	0/4
HP 60	0.50	67.5	12.0	2/4	340.0	1/4
HP 290	1.00	0.0	16.7	2/4	0.0	0/4
C 812	0.75	0.0	0.0	0/4	0.0	0/4
C 820	0.75	315.0	7.7	2/4	250.2	2/4
C 1047	2.75	0.0	0.0	0/4	0.0	0/4
C 1090	0.00	32.5	27.0	2/4	0.0	0/4
C 1204	1.25	0.0	0.0	0/4	566.5	2/4
C 4103	1.00	0.0	20.3	1/4	20.2	1/4
Panniyur I	0.75	27.5	25.6	2/4	40.6	1/4

Biocontrol

Molecular characterization and bioefficacy of endophytes : The species identity of two promising endophytic bacteria was confirmed through 16S rDNA sequencing. The two *R. similis* inhibiting endophytes were identified as *Curtobacterium luteum* (TC-10) and *Bacillus megaterium* (BP-17). The bacterial endophytes *Curtobacterium luteum* (TC-10) significantly improved black pepper growth characters such as number of leaves, root weight and total biomass of plants besides suppressing *R.similis*. When used as a chitin based formulation, besides sustaining the population at 10^7 cfu per gram after 90 days of storage at 28°C, it successfully reduced the nematode infestation in pepper nurseries. The improvement of vigour of black pepper is an additional benefit of this strain. The bacteria could be tracked inside the plant tissue as endophyte with concomitant reduction in nematode colonization.

Effect of different formulations of endophytic bacteria on growth of black pepper rooted cuttings

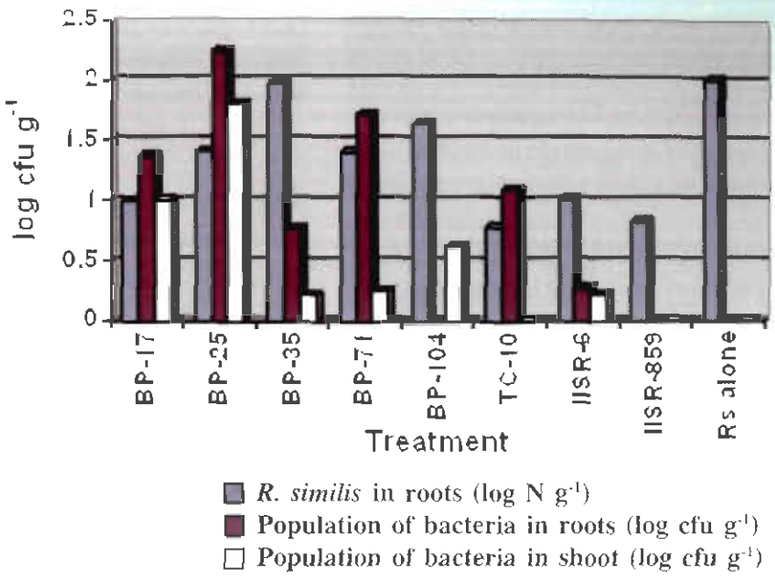
Treatment	Biomass (g)				Root rot index			
	Chitin	Talc	NB	Mean	Chitin	Talc	NB	Mean
BP17	34.0	67.0	19.4	40.1bc	2.8	1.2	4.7	2.9a
BP35	27.9	32.0	43.7	34.6c	3.0	3.2	4.0	3.4a
TC10	87.5	72.5	35.0	65.0a	0.0	2.2	2.4	1.5b
IISR6	62.5	51.2	46.0	53.2abc	2.2	2.7	3.6	2.9a
859	52.1	40.8	35.8	42.9bc	2.7	3.5	4.7	3.6a
Carrier	64.0	75.0	33.3	57.4ab	2.2	2.6	4.8	3.2a
Control	58.3	55.6	64.6	59.5ab	1.5	2.8	2.9	2.4ab
Mean	55.2a	56.3a	39.7b		2.1b	2.6b	3.9a	

NB. Nutrient Broth. Data with same letter designation are not significantly different according to DMRT at P=0.05

Untreated black pepper rooted cuttings.

***Curtobacterium luteum* IISRTC10- the bacterium successfully prevented nematode infection.**

***Bacillus megaterium* IISRBP17- the bacterium successfully prevented nematode infection.**



Endophytic colonization of black pepper shoots and roots by promising bacteria

10. PEST MANAGEMENT

Root mealybug

Management of root mealybug: Evaluation of promising insecticides (imidacloprid 0.0125%, acetamaprid 0.0125% and carbosulfan 0.075%) in the field at Peruvannamuzhi indicated that drenching affected vines with imidacloprid 0.0125% or acetamaprid 0.0125% or carbosulfan 0.075% was promising in reducing the population of root mealybugs up to 60 days after treatment. Evaluation of promising organic products (neem leaf extract 2%, custard apple seed extract 1% and tobacco extract 3%) in the field at Peruvannamuzhi indicated that drenching mildly affected vines thrice at 21 day intervals with tobacco extract 3% was promising in reducing the population of root mealybugs.

IPM package for mealybug: An integrated pest management schedule involving, planting of root mealybug-free rooted cuttings, removal of weeds in interspaces of black pepper vines during summer, drenching tobacco extract 3% on mildly affected vines or drenching imidacloprid 0.0125% or acetamaprid 0.0125% or carbosulfan 0.075% or chlorpyriphos 0.075% on severely affected vines and adoption of control measures against *Phytophthora* and nematode infections, is to be adopted for the management of root mealybugs in the field.

Pollu beetle

Resistance: Screening of 66 cultivars and 76 hybrids of black pepper available in the Germplasm Conservatory against pollu beetle (*Longitarsus nigripennis*) indicated that all the accessions were susceptible to the pest. The percentage of berries infested in the cultivars ranged from 1.6 to 30.6% and in the hybrids from 3.3 to 52.6%.

11. DROUGHT TOLERANCE

Screening germplasm for drought tolerance as been standardised. Those accessions which maintained >70% RWC and <9% membrane leakage after 12 days of stress were identified as tolerant. Among the 70 accessions screened three *viz.*, 4216, 4226 and 873 were identified as tolerant. In order to tag the drought tolerance to certain biochemical parameters, super oxide dismutase was analysed in tolerant and susceptible accessions. No specific band representing tolerance could be identified. Photosynthesis and gas exchange parameters were also analysed among the tolerant and susceptible lines. Photosynthesis, transpiration and stomatal conductance reduced drastically while leaf temperature increased due to stress. Tolerant accessions maintained slightly higher photosynthetic rate than susceptible accessions during the stress period.

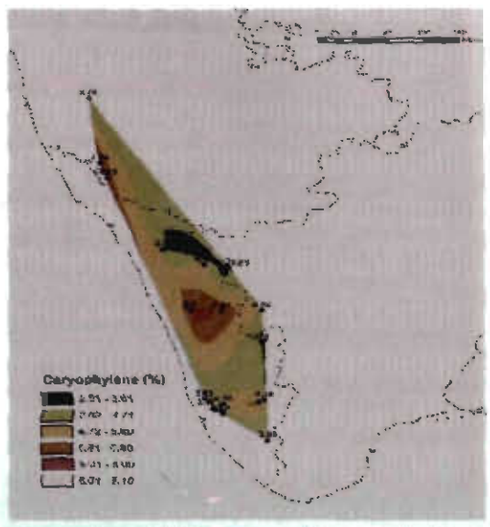
12. QUALITY EVALUATION AND POST HARVEST TECHNOLOGY

Drying and storage: Drying of three black pepper varieties IISR-Sreekara, Panniyur-5 and Karimunda in mechanical driers at 55-60°C did not affect the chemical or physical quality of the berries. Slight reduction in essential oil and moisture content was observed among different quality parameters only after 180 days of storage in polyethylene containers under vacuum, 100% nitrogen and 90% N_2+ 10% carbon dioxide.

Geographical influence on biochemical and physical quality parameters

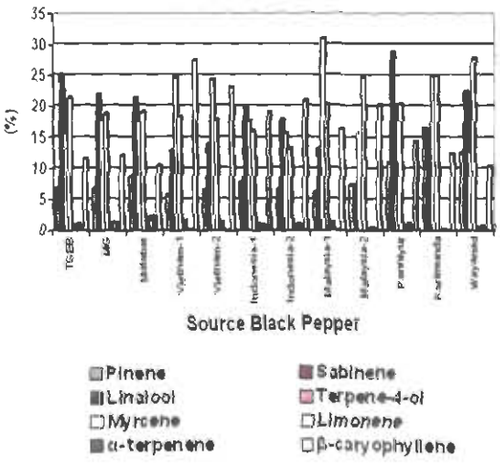
Physical Quality: Pepper berries harvested from Ambalavayal was found to be superior for size (4.2mm), than berries obtained from other locations such as Pampadumpara (Idukki), Yercaud (TN), Panniyur (Kannur) and Dapoli (Maharashtra) which indicated the geographical influence on the physical quality of black pepper. Bulk density (weight L^{-1}) of pepper cultivars ranged from 450 to 640 g L^{-1} at various locations. Ambalavayal recorded more bulk density for cultivars such as Karimunda, IISR-Sreekara, IISR-Subhakara and IISR-Thevam. Pepper from Panniyur recorded bulk density above 600 g L^{-1} for Karimunda and IISR-Girimunda. Pepper from Yercaud recorded 640 gL^{-1} for the variety Panniyur-1.

Chemical Quality: Among the locations, Ambalavayal recorded maximum oleoresin for various cultivars. Panniyur-2, Panniyur-4, IISR- Panchami, IISR-Subhakara and Panniyur-1 recorded more than 10% oleoresin. IISR-Sreekara, IISR-Subhakara, HP-34, HP-105 and IISR-Girimunda recorded more than 3% oil at various locations. β-caryophyllene, the major aroma constituent in black pepper oil showed wide variability at various locations for the different cultivars. Cultivars Panniyur-1 recorded 25% β-caryophyllene at Peruvannamuzhi, Panniyur and Dapoli, while it recorded 9.7% at Yercaud, 14.3% at Pampadumpara and 16% at Ambalavayal. The Geographical influence was further confirmed through GIS study. The total number of volatile oil components of leaf varied from 7-15 among the accessions collected from Western Ghats and the geographical effect on biochemical parameters was highly significant. The percentage of two sesqueterpenes, β-caryophyllene (2.1-6.8%) and Nerolidol (1.4 to 66.3%) significantly varied among all the germplasm accessions whereas another component, Pinene (1.53-20.3%) (a common component of berry oil) was recorded from specific latitude between the latitudes 8°.89 - 9°.39'N and 10°.58' - 10°.59'N. The study also indicated that total number of components is highest in the latitude between 10°.40' - 11°.09' and Nerolidol is highest in latitude 11°. 09'N - 12°.50'N.



Geographical influence on β-caryophyllene content (%) in leaf of *P. nigrum*

GC analysis of essential oil : GC profile of the essential oil of export grade black pepper from India, Vietnam, Indonesia and Malaysia did not reveal any significant superiority of Indian produce.

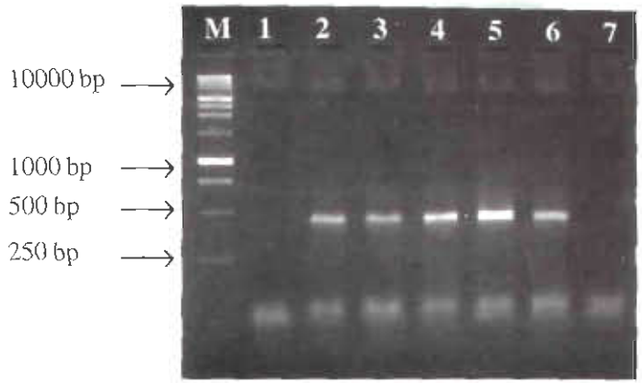


GC profile of volatile oil of black pepper

Production of white pepper and quality evaluation: Production technology for white pepper was scaled up. All the treatments yielded complete decortication into white pepper in five days. The recovery of white pepper was in the range of 19.6-26.8%. There was no variation on the quality parameters such as piperine, oleoresin, oil and starch and also in the oil profile among the white pepper produced by fermentation. However, slight decrease in these quality parameters is observed in the white pepper when compared to black pepper. The reduction of quality parameters in white pepper is 20.1% for Oleoresin, 8.9 % for Piperine, 26.6 % for Oil, 11.5 % for Limonene and 26.6% for Caryophyllene. Starch content was high (26.9%) in white pepper when compared to black pepper. The promising fermenting bacterial isolates were identified based on nucleotide sequence of conserved 16s rDNA.

Molecular methods for detection of adulteration

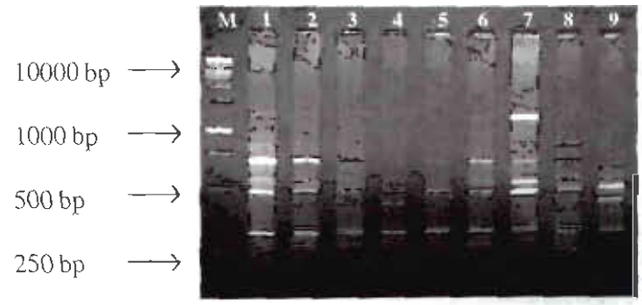
Development of SCAR marker : Sequence characterized amplified region (SCAR) marker was developed to detect papaya seed powder as adulterant in powdered market samples of black pepper. The papaya specific amplicon was identified using RAPD analysis with the primer OPJ-09. Earlier the specific amplicon of 450 bp was cloned and sequenced which was used for designing primers for detection of the adulterant. Black pepper powder samples mixed with varying concentrations of powdered papaya seed (2-20%) were screened for SCAR marker. A 450 bp band was obtained in all black pepper samples adulterated with papaya seed powder.



M: 1 Kb ladder, Lane 1: black pepper, Lane 2-5: simulated black pepper powder with ground papaya seed in different concentrations, Lane 6: papaya seed, Lane 7: negative control

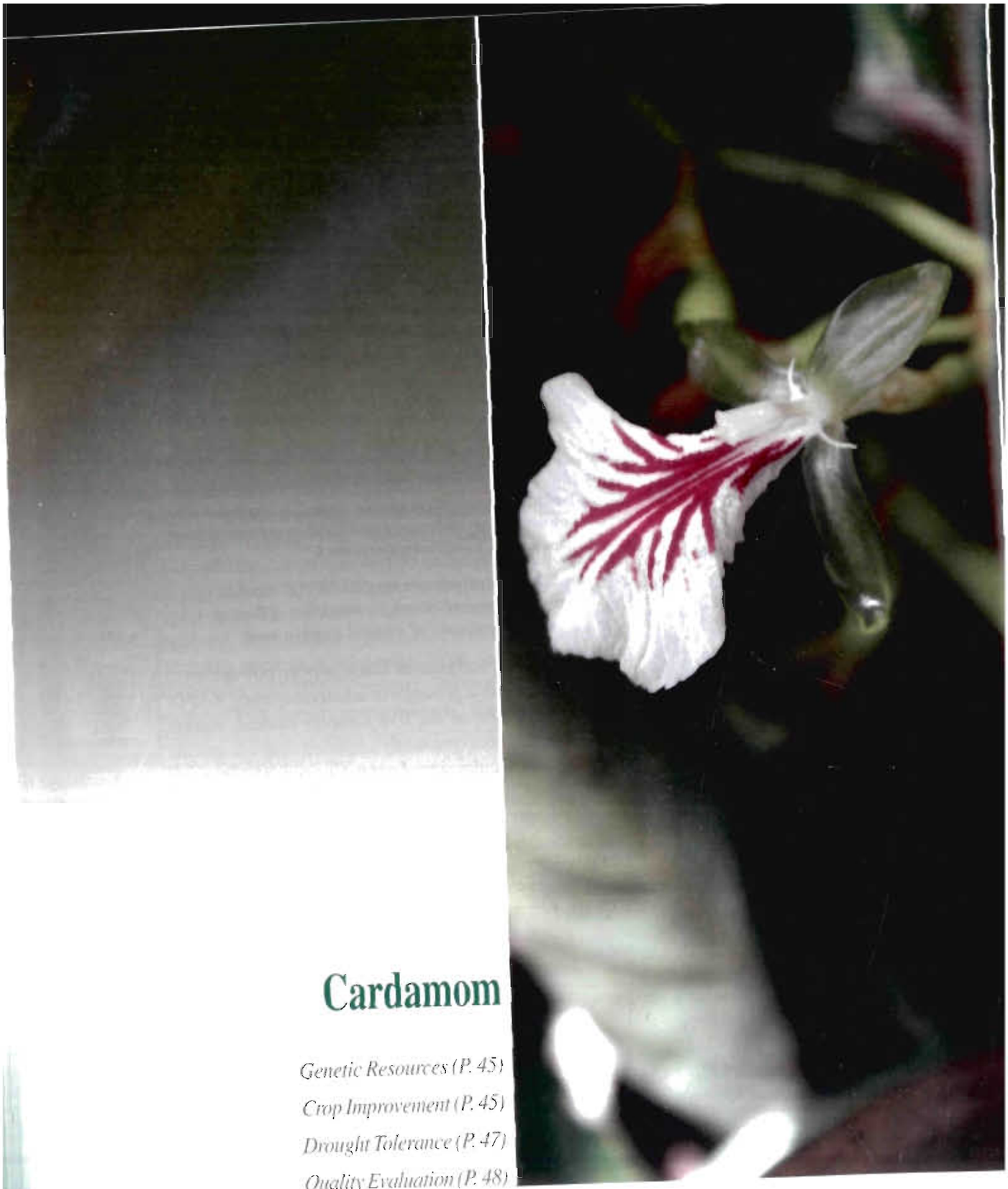
Amplification of papaya specific SCAR marker in simulated pepper powder containing different concentrations of ground papaya seed

Five commercial samples of black pepper powder were analyzed for possible presence of adulterants using RAPD/ ISSR markers. Out of the five samples studied, market samples two & three consistently amplified a papaya specific band with a molecular size of approximately 450 bp using primer OPJ 09.



M : Marker 1 kb ladder, Lane 1: *Piper nigrum*, Lane 2-6: Different Market Samples, Lane 7: *Piper attenuatum*, Lane 8: *Piper galeatum*, Lane 9: Papaya

RAPD analysis of genuine pepper powder, market samples of pepper and possible adulterants amplified by primer OPJ 09



Cardamom

Cardamom

1. GENETIC RESOURCES

Collection, conservation and registration of germplasm: A total of 17-cardamom germplasm including large cardamom were collected from cultivated and forest areas of Idukki, Attappadi, Wagamon and North East. The germplasm included a variant of green gold with pubescent leaves, wild cardamom collection and lower elevation adapted accessions. The large cardamom varieties are Green golsey, Bharlangay and Seremna. The present *ex-situ* gene banks consists of 436 collections, hybrids and disease resistant selections. Four accessions were registered with national repository at NBPGR, New Delhi. Passport data have been compiled and IC numbers obtained for all the available cardamom germplasm accessions.

Characteristic cardamom germplasm registered with NBPGR, New Delhi

Regn. No.	Unique Characters
IC 349541	Compound panicle type, high yield
IC 349544	Basal branching of panicle with green bold capsules
IC 349599	*Katte* resistance
IC 349634	Rhizome rot tolerance

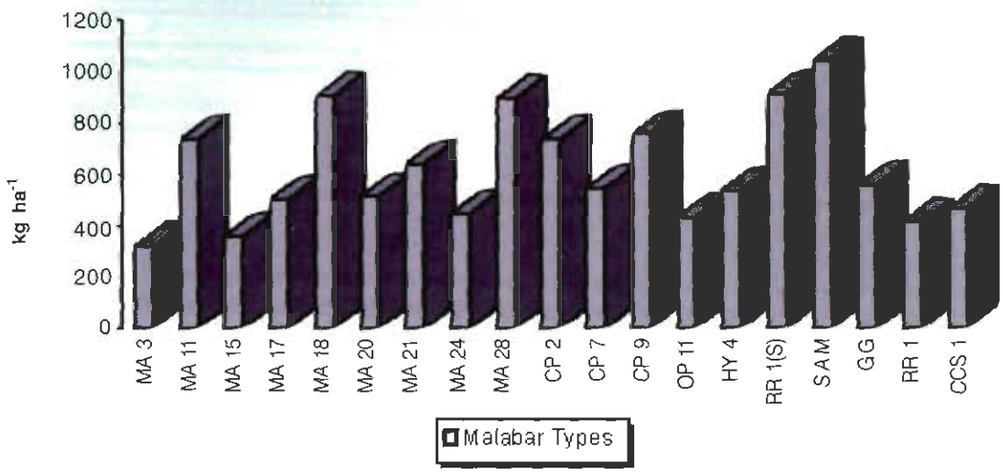
Characterization of germplasm: Twenty-six compound panicle accessions have been characterized for morphological, panicle and yield characters based on IPGRI descriptor. More variability was observed in plant and panicle characters than that of capsule characters. Variability was found to be maximum for number of branches per panicle (49.4 %) followed by flowers per panicle (47.5%) and minimum for seed weight per cent (4.7%). Two promising accessions (APG 445 and APG 250) were identified with desirable yield contributing characters. Accession APG 260 was found to branch extensively at the terminal portion of the panicle whereas APG 411 was found to retain its dark green capsules even after processing. Sixty other accessions have been characterized for morphological characters. Natural incidence of leaf blight and leaf blotch was recorded in 49 accessions.

APG 260 - a unique accession with branching at terminal portion of panicle

2. CROP IMPROVEMENT

Cardamom being a vegetatively propagated crop, the heterosis can be exploited at F_1 generation. Large number of hybrids between high yielding and disease resistant selection have been evaluated under various trials for yield and disease resistance. Based on preliminary evaluation trials (1995-2002), 59 selections and 11 hybrids were short listed for evaluation under Comparative Yield Trials (CYT). Morphological, yield and quality characters have been recorded in four CYT's (CYT I, II, III and IV). The genotypes with significantly high yield compared to local checks and green gold were short listed and promoted for Multi Location Trials (MLTs).

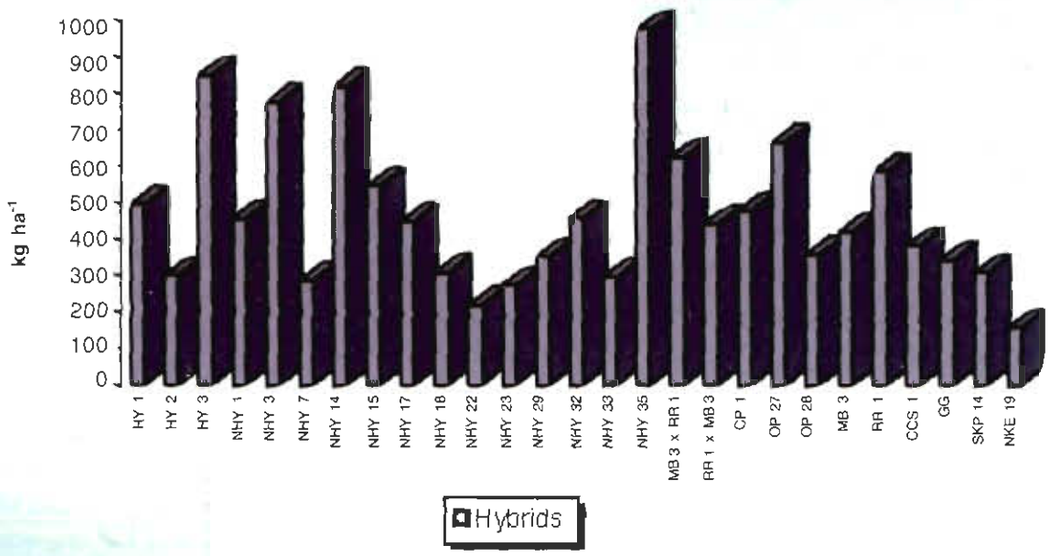
CYT I (2004-07): The trial was laid out during the year 2002 and among the 16 accessions, the highest mean yield per hectare over three crop seasons was recorded in the accessions, SAM followed by RR 1(S), MA 18 and MA 28 with 1037.11, 907.8, 898.4 and 883.6 kg ha^{-1} respectively. The yield level was significantly higher than RR 1, CCS 1(Local checks) and the popular Green Gold.



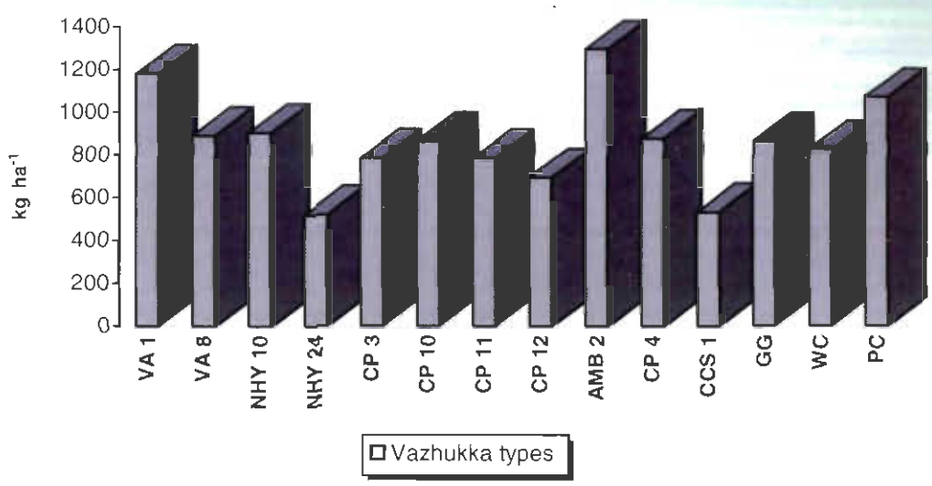
Comparative performance of promising Malabar accessions for yield (kg ha^{-1})

CYT II (2004-07): The CYT II was laid out during 2002 with the objective to evaluate the performance of hybrids and open pollinated progenies for yield and disease resistance. Among the 18 hybrids and four open pollinated progenies, three hybrids (NHY 35, NHY 14 and Hy 3) out yielded checks over the cumulative yield of three cropping seasons. The hybrid between *katte* resistant and high yielding accession, NHY 35 has recorded significantly high yield of 975.5 kg ha^{-1} compared to green gold (343.5 kg ha^{-1}).

CYT IV (2005-07): Popular varieties of cardamom such as Green gold, Wonder cardamom and Palakuzhi selection were compared with AMB2 and VA1 in CYT IV to understand the performance of these varieties in high altitude regions of Karnataka. Among the three farmers varieties, high yield was recorded in Palakuzhi selection with mean dry yield of 1086 kg ha^{-1}. Among the other promising selections, AMB 2 and VA 1 recorded the highest yield of 1297 and 1179 kg ha^{-1}respectively.



Comparative performance of promising hybrids for yield



Comparative performance of farmer's varieties for yield

Preliminary Yield Evaluation trials (PET I and II): Progenies of direct & reciprocal cross between two mosaic resistant selections (APG-306 and APG-310) and high yielding green gold (APG-259), evaluated in PET led to the identification of two hybrid combinations with high yield (MB 5 x NKE 19 and NKE 19 x GG).

3. DROUGHT TOLERANCE

Biochemical mechanism: Physiological (relative water content, specific leaf weight and chlorophyll fluorescence) and enzymatic changes (catalase, peroxidase and SOD) due to moisture stress were studied in selected tolerant (RRI, green gold, CI-893, APG-18) and susceptible lines (CCS-1, NKE-19, NKE-12, NKE-19). No significant variation was recorded for many parameters except catalase and peroxidase activity, which was high under stress. SOD showed lower activity under stress.

Breeding : Three genotypes (RR1, CL-893, green gold) relatively tolerant to moisture stress and CCS-1, a susceptible genotype were crossed to develop drought tolerant varieties with good yield and quality characters. Growth parameters such as plant height, number of tillers per clump, number of bearing tillers per clump and total number of leaves per clump of the progenies showed significant variation. Plant height ranged from 201 cm (CCS1 self) - 261 cm (GG op), number of tillers per clump ranged from 23.7 (CL 893 x CCS-1)-38.7 (CCS-1 x 893), number of bearing tillers per clump ranged from 8.5 (CL 893 x RR1) - 23.8 (CCS1 x 893) and total number of leaves per clump ranged from 163.6 (893 x RR1) - 248.5 (CCS1 x 893). CL-893 and its cross combinations recorded better growth characters. Yield parameters also recorded significant variation. Number of panicles per clump ranged from 10.8 (RR1 self) – 40 (CCS1 x 893), panicle length (cm) ranged from 34.1 (RR1- OP) - 51 (893 self), number of capsule per clump ranged from 276.7 (RR1 self) - 1018.9 (CCS1 x 893) and capsule dry yield (g clump^{-1}) ranged from 48.8 (RR1 self) – 207.5 (893 OP).

Cardamom hybrid - high yield with tolerance to drought

Evaluation of four cross combinations of cardamom (hybrids and selfed seedlings) for yield parameters

Genotypes	Panicle clump^{-1}	Panicle length (cm)	Capsule clump^{-1}	Capsule dry yield (g clump^{-1})
893OP	35.7	53.9	966.9	207.5
893 self	30.1	51.0	953.4	200.6
CCS1 self	32.7	38.5	965.8	178.4
GG x CCS1	30.9	34.6	734.2	174.3
CCS1 x 893	40.0	38.9	1018.9	188.7
S.E	2.98	2.67	119.9	20.29
C.V %	16.5	8.36	22.7	19.72
CD at 5%	6.04	5.41	242.8	41.1

Oil yield ranged from 3.9% (893 x RR1) - 6.0% (CCS1 OP), chlorophyll fluorescence yield ranged from 0.64 (893 x RR1) - 0.78 (893 OP) and stomatal count ranged from 5.57 (CCS 1 x 893) - 12.07 (CCS1 x RR1). CCS1 x GG recorded 62 panicle, 2696 capsule and 2520 g fresh capsule yield per clump with 70 per cent bold capsule with synchrony in flowering while GG x 893 recorded 21 panicles, 633 capsules and 730 g fresh weight of capsule with bold green colour. GG self plant recorded multiple branching with good capsule setting.

4. QUALITY EVALUATION

Analysis of the Cardamom essential oil: GC-MS study confirmed the superior intrinsic quality of Indian cardamom over Guatemalan and Sri Lankan cardamom. The essential oil yield of Indian, Guatemalan and Sri Lankan cardamom was found to be 10%, 5% and 14% respectively. Chemical profiling has shown a total of 33 compounds in Indian, 26 in Guatemalan and 35 in Sri Lankan, and 22 of them common among all three samples. GC profiling of oil indicated that Indian cardamom is rich in 1, 8-cineole and α-terpinyl acetate. Indian cardamom recorded comparatively low quantity of linalool as compared to Guatemalan and Sri Lankan. At low concentration the linalool gives pleasant taste to the cardamom. Linalyl acetate, octyl acetate and trans β caryophyllene were not identified in Indian and Guatemalan cardamoms whereas Z citral, methyl cinnamate, nerol, and 2-decenoic acid were present only in Indian cardamom.

Sri Lankan Cardamom Indian Cardamom Guatemalan Cardamom

GC-MS based comparison of essential oil chemistry of Indian, Guatemalan and Sri Lankan cardamom

Peak no	Compound	RT	Indian	Guatemalan	Sri Lankan
1	α-phellandrene	4.22	0.37	ND	0.33
2	α -pinene	4.36	2.37	2.30	2.50
3	Sabinene	5.23	4.93	4.61	4.32
4	Myrcene	5.64	2.62	2.56	2.34
6	Octanal	5.95	0.14	0.14	0.17
7	α -terpinene1,8-cineole	6.32	0.28	0.24	0.22
8	1,8-cineole	6.86	27.59	26.99	26.85
9	Trans β-ocimene	7.25	0.09	0.17	0.19
10	γ-terpinene	7.56	0.62	0.51	0.19
11	Cis sabinene hydrate	7.82	0.29	0.10	0.18
12	Tri cyclo heptane	8.00	ND	ND	0.17
13	α -terpinolene	8.46	0.36	0.49	0.37
14	Linalool	8.87	1.23	6.99	5.44
15	4,8-dimethyl-1,3,7-nona triene	9.44	0.20	ND	0.15
16	2-cyclohexen-1-ol	9.59	0.20	0.20	0.19
17	δ-terpineol	11.27	0.13	0.19	0.17
18	Terpineol-4	11.67	2.78	2.98	2.70
19	β -fenchyl alcohol	12.21	2.97	6.61	4.23
20	Octyl acetate	13.15	ND	ND	0.11
21	Z-citral	14.19	0.36	ND	ND
22	Neral	14.25	ND	0.33	0.36
23	Nerol	14.84	2.56	ND	ND
24	β -ocimene	14.90	ND	4.44	ND
25	Linalyl acetate	14.94	ND	ND	5.60
26	Geranial	15.46	0.56	0.51	0.69
27	Delta-terpinyl acetate	17.31	0.44	0.25	0.36
28	2,6--octadienoicacid	17.61	0.37	ND	0.28
29	α -terpinyl acetate	18.89	41.65	35.18	35.27
30	Neryl acetate	19.31	ND	0.30	0.45
31	2-decenoicacid	19.54	0.17	ND	ND
32	Methyl cinnamate	19.87	0.14	ND	ND
33	Geranyl acetate	20.10	0.86	1.50	1.42
34	Trans –β caryophyllene	21.29	ND	ND	0.13
35	Camphene	22.05	0.30	0.23	0.17
36	β -selinene	23.90	1.55	0.30	1.29
37	α -selinene	24.26	0.51	ND	0.37
38	α -amorphene	25.02	0.32	ND	0.27
39	Germacrene	26.58	0.14	ND	0.12
40	Nerolidol	27.08	1.78	1.88	1.97

ND : Not Detected

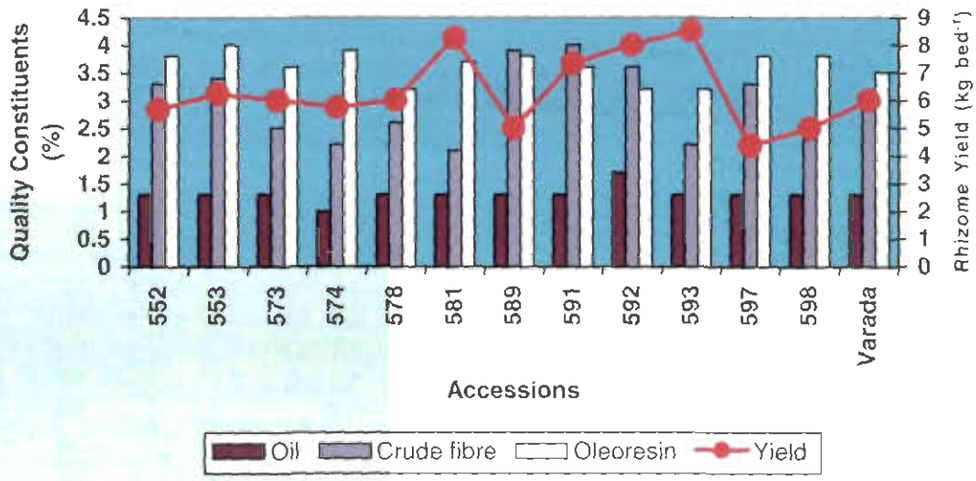
Ginger

Ginger

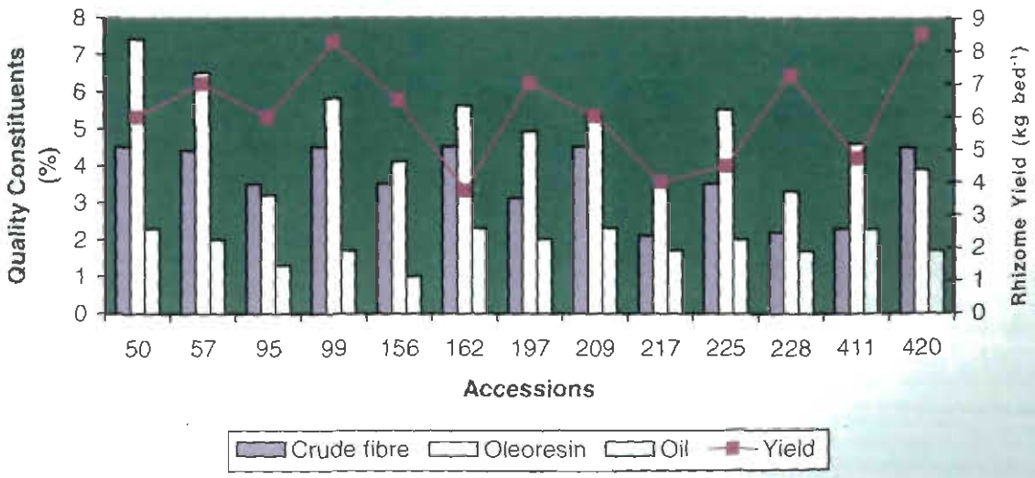
1. GERMPLASM EVALUATION

A comparative yield and quality evaluation trial on exotic collections from Nepal revealed that none of the accessions were superior to other accessions. Yield ranged from 4.4 to 8.3 kg bed^{-1}, crude fiber ranged from 2.1-4.0%, Oleoresin ranged from 2.2-4.0% and oil ranged from 1.0-1.7%. Among the exotic ginger collections, accession from Nepal (Acc.581) performed superior to other varieties for quality parameters.

A comparative yield and quality evaluation trial on high oil type ginger revealed that none of the accessions was superior to the others. Yield ranged from 3.8-8.5 kg bed^{-1}, crude fiber ranged from 2.1-4.5%, Oleoresin ranged from 3.2-7.4% and oil ranged from 1.3-2.3 %.



Performance of exotic germplasm



Performance of high oil type

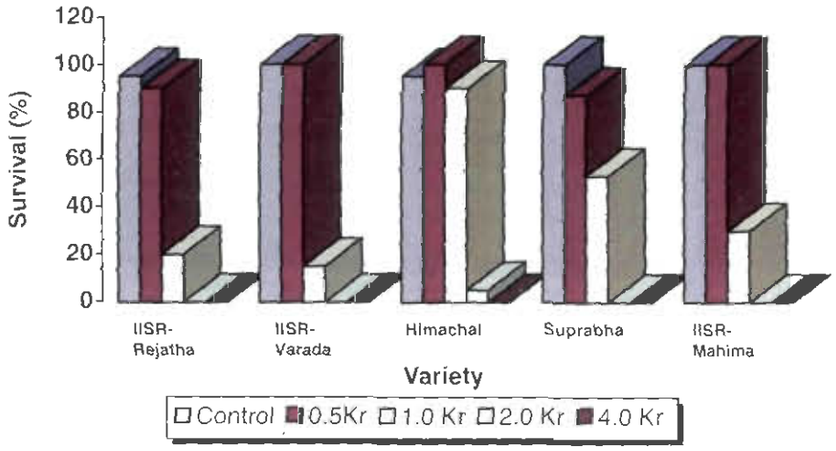
2. CROP IMPROVEMENT

Variety suitable for germination: Ginger accession-12 (Erattupetta) was found to be unique for its colour pattern of the floral labellum, high pollen stainability (27.5%), high *in vitro* germination of pollen grains (10.4), better pollen tube growth (mean length of 1209 µm after 24 h of culture) and germination of pollen grains on the stigma on self-pollination. This accession appears to be suitable for future studies to induce seed set.

Polyploidy induction and mutagenesis: Juvenile buds of four cultivars were treated with 0.1% colchicine for three days and planted. The survival of the sprouts ranged from 55-86.7%. Similarly sprouting buds of five ginger cultivars were treated with four doses of gamma radiation ranging from 0.5 to 4.0 kr. At higher dose none of the sprouts germinated indicating the lethality of the high dose of gamma rays. Few surviving sprouts were found to be chlorophyll variant.

Pollen fertility assessed by stainability, *in vitro* and *in vivo* germination in ginger cultivars

Accession	Cultivar	Pollen fertility based on stainability (%)	Pollen fertility based on *in vitro* germination (%)	Status of *in vivo* germination on self pollination
2	Baharica	7.8	<1.0	Nil
5	*Biturkatta*	5.2	<1.0	Nil
9	China	5.0	<1.0	Nil
12	Erattupetta	27.5	10.4	Few pollen germinated
24	Maran	11.5	4.0	Nil
25	Ambalavayal	12.4	4.6	Nil
26	Maran Pottangi	9.5	2.4	Nil
31	Nadan	11.6	5.0	Nil
38	PGS-6	5.9	<1.0	Nil
49	PGS-15	11.8	3.4	Nil
74	PGS-31	7.3	<1	Nil
76	Thinladium	18.4	2.8	Nil
91	Vengara	2.2	<1.0	Nil
106	Bokalia	12.6	3.1	Nil
----	Jamaica	23.0	Not tested	Not tested



Effect of varying doses of gamma rays on survival of sprouts

3. NUTRITIONAL TRIALS AND ORGANIC FARMING

Optimum P/Zn nutritional ratio for increasing productivity: The threshold value of leaf P/Zn ratio was confirmed to be 90 through second order response function (R^2=0.499**). On validating the same under field conditions, the initial leaf P/Zn ratio at 60 DAP in the range of 145-223 could be brought down to the threshold range of 69-150 after foliar spray of Zn (0.5%) twice during August and October. By lowering the ratio below 108, increased rhizome yield up to 20% could be achieved.

Optimization of P/Zn ratio for increasing the ginger productivity

Leaf P/Zn	Soil P/Zn	Yield (kg bed^{-1})
69.7	4.9	8.4
77	5.7	9.1
101	4.4	9.5
108	4.0	10.6
136	5.4	7.8

Nutrient requirement for targeted yield: Based on the initial soil fertility levels of N, P, K and Zn, the fertilizer doses for obtaining yields of 10, 15 and 20 kg bed^{-1} were applied. Zinc was supplemented as foliar spray. The achieved ginger rhizome yield was 10.8, 12.4 and 11.4 kg bed^{-1} with a deviation of +0.5%, -17% and -43% from the target. Through targeted nutrient application increased yield of 14-26% over recommended dose could be achieved in IISR-Varada with reduced fertilizer application.

Organic Farming: Ginger was cultivated organically by applying FYM, vermi compost, ash, rock phosphate, *Azospirillum*, phosphobacteria as nutrient source. *Trichoderma* & *Pseudomonas* sp. as bio control agents for disease control. The mean yield recorded in ginger (var. IISR-Varada and Mahima) 10.2 kg bed^{-1} was high under integrated system, which is 29.7% and 14.5% higher over chemical and organic farming, respectively. Organic farming resulted in a mean yield of 8.8 kg bed^{-1} recording 13% higher yield over chemical practices. Foliar infection with *Phyllosticta* sp. disease was the major constraint noticed. Soil nutrient buildup and microbial biomass carbon were observed to be high in organic and integrated managements as compared to conventional system. FYM+ NC+ Vermicompost/Coir pith compost application recorded higher yield on par with FYM application alone.

Microbial community structure on rhizosphere under different nutrient management regimes

The data on soil physico-chemical parameters revealed considerable variations in the levels of organic C, available N, Bray P, NH_4OAc-K, exchangeable Ca & Mg, DTPA-Zn, -Cu, -Mn and -Fe among integrated, fully organic and chemical treatments. Available N level was markedly higher in the chemical and integrated treatments, while Bray P and exchangeable K was higher in the organic and integrated treatments respectively. Among the secondary nutrients, exchangeable -Ca and -Mg levels and among the micronutrients DTPA-Zn and -Cu levels were markedly higher in the integrated treatment. The chemical treatment, however, favored the accumulation of DTPA-Fe and DTPA-Mn in soils indicating variable effects on nutrient accumulation in soil.

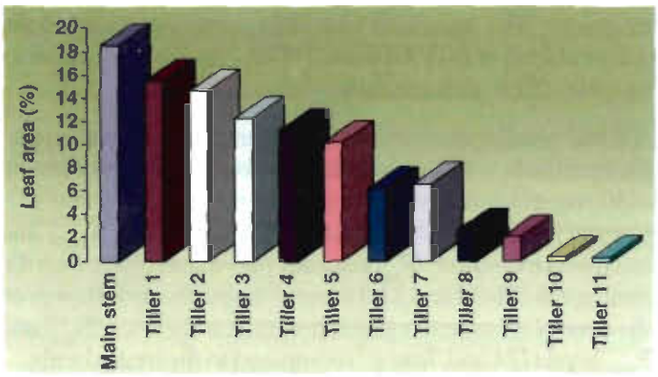
Soil microbial biomass carbon (C_{MIC}) varied significantly among the treatments, with the maximum levels in integrated treatment (480 mg g^{-1}) followed by organic treatment (460 mg g^{-1}). Contrary to C_{MIC} levels, microbial biomass N (N_{MIC}) and microbial biomass P (P_{MIC}) did not vary markedly among the treatments (31-33 and 11-14 mg g^{-1} respectively). However, the control treatment registered significantly lower N_{MIC} and P_{MIC} levels (24 and 7 mg g^{-1}) compared to the treated soils.

Soil basal respiration (measured as CO_2 evolution) ranged from 25-36 mg CO_2-C g^{-1}day^{-1} and was greatest in organic and integrated treatments (35 and 36 mg CO_2-C g^{-1}day^{-1} respectively). Contrarily, basal respiration (qCO_2) was relatively lower in the organic and integrated treatments (61 and 60 mg CO_2-C (g biomass C)$^{-1}$ day^{-1} respectively) compared to the chemical and control treatments (65 mg CO_2-C (g biomass C)$^{-1}$ day^{-1}).

The effects of nutrient management system on soil microbial community structure revealed that the prokaryotic population was highest under integrated whereas the eukaryotic population was high in both integrated and fully organic treatments. Interestingly, the fungal population was high in chemical treatment.

4. GROWTH AND PHENOLOGY

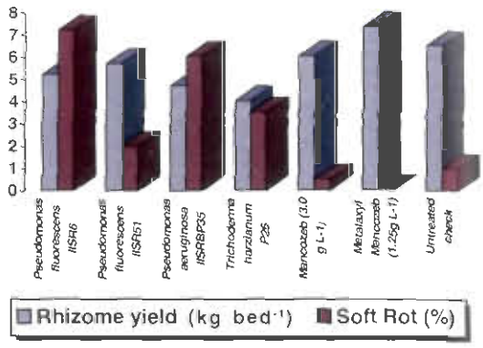
Growth characteristics of ginger were observed and analysed statistically. First tiller appeared at 646-degree days with a total 11 tillers and the plant attained maturity at 3096.8-degree days for ginger. Leaf growth along the main stem followed the quadratic pattern in ginger. Total area of 4092 cm^2 per clump was noted. There were 174 leaves per clump in total and the last leaf emerged on 150th days after planting (DAP). The total leaf area of a clump was 4886.7 cm^2. There existed a positive relation between leaf emergence and Growing Degree Days (GDD) as well as leaf area development and GDD. Tiller, an important yield contributing factor, first appeared after 51 DAP and there were 11 tillers in total. The last tiller emerged on 117 DAP. The main shoot produced a maximum of 23 leaves and subsequent tillers produced less leaf. The last two tillers had each three leaves. Similar to leaf production per tiller, total leaf area per tiller also decreases. The main shoot had a maximum leaf area of 910.2 cm^2 and it declines gradually in the tillers produced later reaching the minimum of 14.0 cm^2. The share of total leaf area of individual shoot to the total leaf area of a clump varied. Main shoot contributed maximum (18.5%) and the last two tillers contributed minimally.



Contribution of individual shoots for total leaf area

5. INTEGRATED DISEASE MANAGEMENT

Biological and chemical control: A field trial consisting of treatments such as bacterial antagonists IISR 51, IISR 6 & BP 35 and fungal antagonists *Trichoderma harzianum* were compared with Metalaxyl mancozeb, mancozeb and a check in IISR Farm, Peruvannamuzhi for field control of soft rot of ginger. The chemicals were applied thrice at 30 days interval between them starting from the day of the planting. The trial indicated that treatment with Metalaxyl-mancozeb recorded less disease incidence with maximum yield among the treatments.



Integrated management of rhizome rot

Effect of agrochemicals on *Ralstonia solanacearum*: Four agrochemicals namely, potassium phosphonate, cheshunt compound, copper oxychloride, 2-bromo 2-nitropropane 1,3, diol (commercial SAR inducer) at different concentrations and bordeaux mixture were tested under *in vitro* and *in planta* conditions against *R. solanacearum*. All the chemicals affected the growth of *R. solanacearum* under *in vitro* conditions but no appreciable reduction in disease could be achieved with any of the chemical at any tested concentrations

6. QUALITY EVALUATION

Among the low fibre type accessions 164, 558, 246 and 537 are accessions with more than 2% oil and 6.5% oleoresin. Among the high oil types, accessions 162, 50, 57, 411, 225, 201 and 197 have above 2% oil. Accessions 50 and 57 contained above 6.5% oleoresin where as accessions 197, 217, 228, 411 contained below 3% fibre.

Among the 47 ginger germplasm accessions CI 465, 431, 434, 493, 445 contain above 2% oil. Accessions with high oleoresin are CI- 431 (7%), CI- 434 (6.9%), CI- 445 (6.6%), CI- 436 (6.2%) and CI- 486 (6.0%). Accessions CI- 445, 489, 447, 443, 429, 472 contain above 3.5% fibre and the rest are low fibre types. Ginger from AICRP centres ACC-35, V1S1-2, SG-682, ACC-17 and V1C1-8 from Solan were relatively low in oil, oleoresin and fibre content. Acc IG-2, ACC-35, V1S1-2, IG-1 and SG-554 grown at Raigarh recorded more oleoresin and fibre.

Turmeric

Turmeric

1. GERMPLASM EVALUATION

Characterization of *Curcuma* germplasm

Cytological analysis: Number of chromosomes were found to be in the range of 78-84 among the seedling progenies of turmeric.

Chemical Fingerprinting: Chemical fingerprinting by GC-MS based qualitative analysis of hydro-distillate and volatile distillate of fresh rhizomes of eleven *Curcuma* species such as *C. aromatica, C. amada, C. caesia, C. comosa, C. haritha C. malabarica, C. montana, C. pseudomontana, C. raktakanta, C. sylvatica* and *C. zedoaria* revealed that *C. aromatica* recorded highest oil percentage (4.8%) followed by *C. caesia* and *C. sylvatica* (3.6%) and the lowest percentage of oil was recorded in *C. haritha* (2.4%). Other compounds detected from the analysis are furnished below.

Molecular fingerprinting : Genetic diversity analysis of 36 popular varieties and cultivars of turmeric (*Curcuma longa* L.) *viz*, Alleppey, Nandyal type, Amalapuram, Rajapuri, Amrithapani, Sugandham, Armoor, Vondimitta, Jabedi, Wynad local, Dhagi, Aiswal, Katergia, Ayur, Chayapasupu, Basar Along, Avanigadda, Gaspani, Dindigam, Hajo, Ethamkula, Jorhat, GL Puram, IISR-Suvarna, Karhadilocal, IISR-Sudarsana, Kasturi, IISR-Kedaram, Kodur, IISR-Suguna, Kuchipudi, IISR-Prathibha, Manonthody, IISR-Prabha, Muvatupuzha and IISR-Alleppey Supreme was done using ISSR/RAPD markers. A total of four major clusters were produced by the UPGMA dendrogram according to Jaccards similarity Index. Most of the improved varieties clustered distinctly from the land races/ cultivars. Further, most of the land varieties, collected mainly based on vernacular names, from one geographical region clustered together along with few released varieties, which were evolved through germplasm selection of materials collected from the same region.

Chemical characterisation of selected *Curcuma* species

Species	Highest observed compound	Relative level of highest observed compound (%)
Curcuma aromatica	L camphor	22.24
Curcuma amada	Myrcene	74.97
Curcuma caesia	1,8 cineole	20.60
Curcuma comosa	6 methyl xanthotoxin	27.17
Curcuma haritha	6 methylxanthotoxin	56.59
Curcuma malabarica	Xanthorrhizol	39.20
Curcuma montana	Epicurzerenone	25.83
Curcuma pseudomontana	6 methylxanthotoxin	61.73
Curcuma raktakanta	6 methylxanthotoxin	31.30
Curcuma sylvatica	Epicurzerenone	49.87
Curcuma zedoaria	Xanthorrhizol	38.13

UPGMA dendrogram constructed based on the Jaccards Similarity Index indicated that the eleven *Curcuma* species studied formed a single cluster and showed maximum similarity (0.615) between *C. montana* and *C. comosa*. *C. caesia* formed a separate cluster.

2. CROP IMPROVEMENT

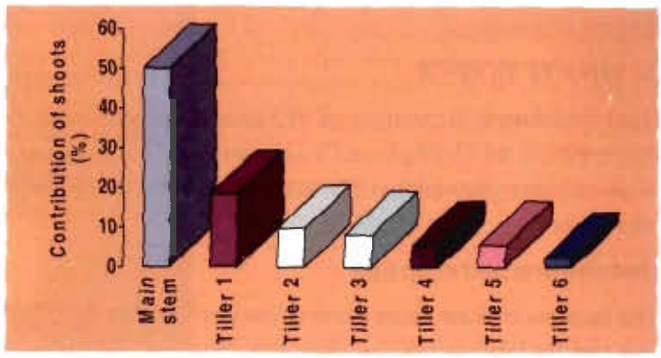
Varieties released: The 23rd Kerala State Variety Release Committee has approved two high quality turmeric varieties *viz.*, IISR-Alleppey Supreme and IISR-Kedaram for cultivation. Both the varieties are high yielding with more than 5% curcumin and resistance to leaf blotch disease.

3. NUTRITIONAL TRIALS AND ORGANIC FARMING

Organic Farming: Turmeric (IISR-*Alleppey Supreme* and IISR-Prathiba) was cultivated organically by applying FYM, vermi-compost, ash and rock phosphate, *Azospirillum* & Phosphobacteria and *Trichoderma* & *Pseudomonas* sp. as biocontrol agents for disease control. Integrated system recorded a higher mean yield of 15 kg bed^{-1}, which is 12.8% higher compared to the organic system. Organic system showed on par yield as that of conventional (chemical) farming. Soil nutrient buildup and microbial biomass carbon were observed to be high in organic and integrated managements as compared to conventional system. FYM + Neam Cake+ Vermicompost / Coir pith compost application recorded higher yield on par with FYM application alone. All the biocontrol agents were equally effective in controlling rhizome rot of turmeric and produced yield on par with chemical control.

4. GROWTH AND PHENOLOGY

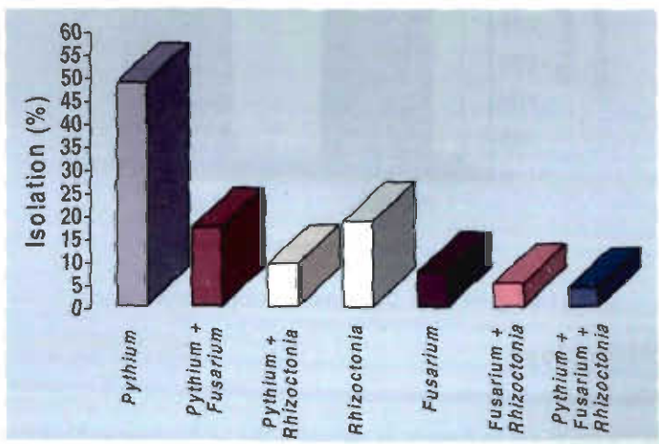
The leaf area of first leaf was 47.1 cm^2 and area of subsequent leaf gradually increased reaching a maximum of 753.0 cm^2 (12th leaf). The turmeric leaf growth along the main shoot followed a linear trend. There were 33 leaves in total and the first leaf was produced at 18 DAP and last produced at 160 DAP. The Growing Degree Days (GDD) had positive association with leaf production. The cumulative GDD required for full maturity was 3570-degree days. There were six tillers in total. Main shoot emerged at 18 DAP and last tiller appeared at 136 DAP. The logarithmic growth model fits well to describe the growth of tiller emergence in turmeric. The relative contribution of total leaf area of shoots to the total leaf area of a clump varied. The maximum contribution (50.0%) was noted from main shoot.



Contribution of individual shoots for leaf area

5. INTEGRATED DISEASE MANAGEMENT

Etiology of rhizome rot: Surveys conducted in turmeric growing areas of Andhra Pradesh, Karnataka, Tamil Nadu and Kerala revealed the predominance of *Pythium* spp. as a causal organism for rhizome rot of turmeric. *Pythium* spp dominated the isolations from Andhra Pradesh, Tamil Nadu, Kerala, Karnataka (72.9%) followed by *Rhizoctonia* spp. (30.5%) and *Fusarium* spp. (27.1 %).



Fungi associated with rhizome rot of turmeric

The pathogenicity of 12 isolates of *Pythium* spp. was established on turmeric. Among them nine were identified as *P. aphanidermatum*. Though frequented in the isolations along with *Pythium*, the fungi *Fusarium* and *Rhizoctonia* failed to cause the disease.

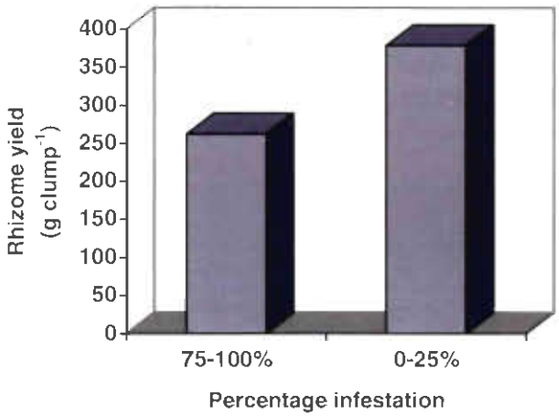
Integrated management: A field trial was conducted at IISR Farm, Peruvannamuzhi for management of softrot. The treatments consisted of mancozeb (0.2%), Metalaxyl–Mancozeb (0.125%), *T. harzianum* (P26-50 g bed^{-1}), endophytic bacterial isolate BP 35, and bacterial isolates IISR 51 and IISR 6. However, only negligible incidence of soft rot disease was noticed.

6. SHOOT BORER

Host resistance: Screening of 915 accessions of turmeric maintained in the Germplasm Conservatory for the incidence of shoot borer showed that 170 accessions were free of pest infestation.

Distribution and crop loss

The incidence of the shoot borer (*Conogethes punctiferalis*) was serious (above 25% incidence) in Wyanad and Calicut districts in Kerala whereas in other states surveyed (Tamil Nadu, Karnataka and Andhra Pradesh) the incidence was negligible. The yield obtained was only 262 g per clump when 75–100% of shoots were damaged when compared to 378 g per clump when the damage was 0- 25% of shoots.



Yield loss due to shoot borer infestation

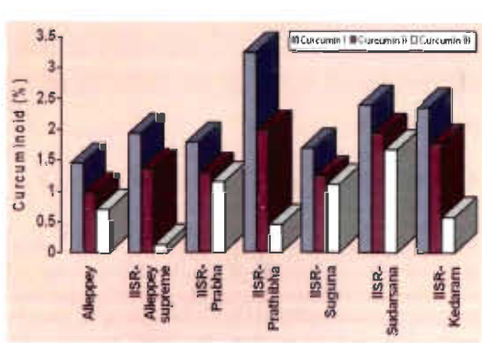
Bioecology

The incidence of shoot borer was recorded in various turmeric growing areas in Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. The pest incidence was serious (above 25% incidence) in Wyanad and Calicut districts in Kerala. The pattern of distribution of shoot borer in the field during various seasons was studied at Peruvannamuzhi. The pattern of distribution was random during August to October and became more aggregated during November and December. The seasonal population of shoot borer on turmeric in the field was studied at Peruvannamuzhi. The symptoms of pest infestation were first observed during August (1.7% new shoots infested) and were high during October to November (7.7% and 10.2% new shoots infested).

Mermithid nematodes were recorded as the most common natural enemy of the shoot borer in the field. Parasitisation of larvae of the pest was higher during August and September (42.9% and 37.5% larvae parasitised).

7. QUALITY EVALUATION

Analysis of curcuminoids: Distribution of curcuminoids in the released varieties and a few high curcumin accessions showed variation. Varieties like IISR-Prathiba, IISR-Sudarsana and IISR-Kedaram contained higher content of curcumin II and I. IISR-Alleppey supreme, IISR-Kedaram and IISR-Prathiba had lower content of curcumin III. Accession from Manipur (Acc. 119) and Assam (Acc.77) had higher total curcuminoids, while accession 117 from East Sikkim had low levels of all three forms of curcuminoids.



Curcuminoids in turmeric varieties

Tree Spices

Tree Spices

1. GENETIC RESOURCES

Germplasm collection: A total of 29 *Garcinia gummigutta* collections, 23 *G. indica* collections, three *Myristica* sp. and seven collections of *Cinnamomum* sp. were collected from forest areas in Western Ghats and added to the germplasm repository. Eleven *M. malabarica* accessions, 10 *M. beddomei*, 22 IISR-Viswashree, 36 Garcinia, one Konkan Amruta and one Sediapur were newly planted in the field germplasm. The germplasm holding consists of 484 *Myristica*, 408 *Cinnamomum*, 233 *Syzygium*, 86 *Garcinia* and two *Pimenta* accessions.

Germplasm registration: In Chinese cassia, elite line D3 (IC number 370425) has been registered (Registration number 06031) with NBPGR, New Delhi for its high bark oil content (4.9%) and high cinnamaldehyde content (90.5).

Germplasm collection	
Areas surveyed	Species collected
Kidu (Dakshina Kannada) Badiadkka (Kasaragod)	*G. gummigutta* - 9 *G. indica* -14 *Myristica* sp.-2
Attappadi (Palakkad)	*G.gummi-gutta*-11 *Cinnamomum* sp.- 3 *Myristica* sp. 1
Erumeli, Wagamon (Kottayam); Vandiperiyar, Elappara, (Idukki)	*G. gummi-gutta*- 9 *Cinnamomum* sp.-3
Dapoli (Ratnagiri) Canacora, Mollem (Goa)	*Garcinia indica*- 9
Maniyoor (Calicut)	*Cinnamomum verum* -1

2. CROP IMPROVEMENT

Nutmeg

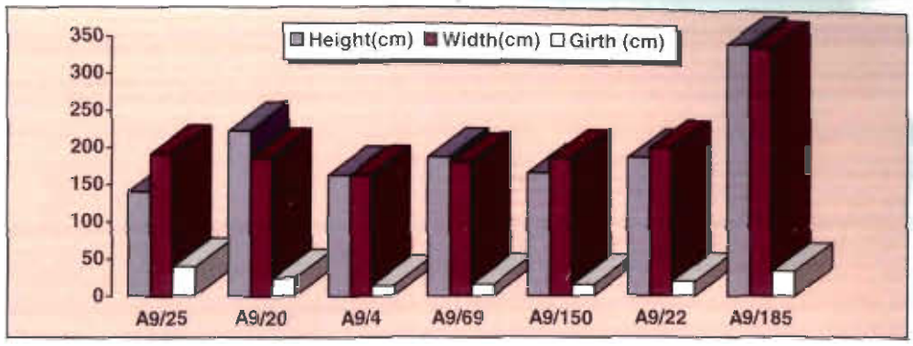
Evaluation of germplasm, clones of elite lines and grafts

Germplasm : Ninety-four nutmeg accessions have been evaluated for yield and out of these A9/44 and A9/53 recorded the maximum of 729 and 714 fruits per tree respectively. Other promising accessions were A11/25 (581 fruits) A11/29 (553 fruits) A11/5 (520 fruits) and A9/18 (495 fruits). Other characters such as fruit weight was high for A9/53 (120 g); followed by A9/86 (110 g), seed weight was high in A11/12 (15 g), followed by A11/21 (14 g), A11/8 (13.5 g), A9/20(13 g), A9/53 (13 g) and A9/76 (13 g). With regard to aril weight, A9/150 recorded the maximum (7.4g), followed by A9/69(6.1g). A9/53 was found to be a good yielder.

Clones of elite lines : In another trial significant difference for plant height was observed among the seven clones of elite lines. A9/185 recorded the maximum height (343 cm). A9/20 was found to be a good performer for yield.

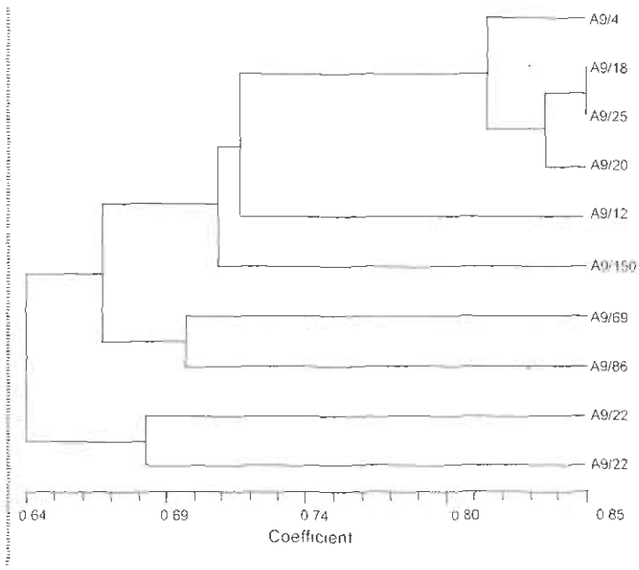
Grafts: The performance of nutmeg scions, A9-4 and A9-69, grafted on *Myristica malabarica* performed better than other rootstocks, *M. fragrans* and *M. beddomeii*. The growth of *M. malabarica* rootstock was faster than other rootstocks evaluated. The scion had an influence on the shape of the canopy as evident by the growth of the graft. A9-69 had an upright growth when compared to A9-4, which had more of a spreading canopy.

Evaluation plagiotropic and orthotropic grafts: The morphological observations on various growth parameters of orthotropic and plagiotropic grafts and seedlings of the elite line A4-20b revealed that the growth of orthotropic grafts was good in the initial years, whereas early flowering was observed in plagiotropic grafts.



Clonal evaluation of elite lines of nutmeg

Marker Assisted Selection in *Myristica:* ISSR, RAPD and 18 s rDNA RFLP based molecular profiling revealed unique amplicon in the accessions such as A9/4 (a very high yielding epicotyl graft with plagiotropic shoots), A9/150, possessing thick mace and apple shaped bold fruits and A4/22 with unique character of high number of erect shoots. The study further revealed two major clusters with all *Myristica* species and *Knema andamanica* forming a separate cluster distant from *Gymnocranthera*, a related genera of *Myristica*. Similarity coefficient ranged from 0.58-0.80. *M. malabarica* and *M. beddomei* showed the highest similarity of 80%. Unique markers were identified in some of the wild species. An average genetic distance of 25.5% was observed among the accessions.



Dendrogram showing the genetic relatedness of the ten elite nutmeg accessions based on ISSR and RAPD

Garcinia

Evaluation of *Garcinia:* Flowering was observed in 19 accessions at Chelavoor Farm, among them fruits were harvested from *Garcinia tinctoria*, *G. indica* and *G. gummigutta*. The Mizoram collection yielded two female flowers and one male flower two years after planting The fruits are red in colour, acidic and ripened in March. The plant has small reddish leaves with bushy habit. Interestingly *G. hombroniana* flowered after 4-5 years of planting of which three were female and one was male flower.

Agrotechiques in *Garcinia:* Grafting of *G. indica* on *G. cowa* was standardized with 30 % success. Soft wood grafting of *G. gummigutta* was confirmed as possible on *G. cowa* rootstock with 92% success.

Cassia

Clonal evaluation of elite lines: Morphological observations like plant height, width, girth and number of main branches were recorded for the progenies of four elite lines, *viz.* A2, C1, and D1and D3. Significant difference was observed only for number of branches per plant, with A2 recording the maximum of 7.6 branches per plant.

Effect of age of tree on yield and quality : A trial on effect of age of tree on yield and quality of cassia revealed that three-year-old bark was better than five-year-old tree.

3. QUALITY EVALUATION

Nutmeg

Storage of nutmeg and mace in different atmospheres: Quality evaluation of nutmeg and mace stored in polyethylene covers under 100% vacuum, 100% N_2 and 90% N_2 + 10% CO_2 for about 120 days showed reduction in oleoresin content.

Cinnamon

Evaluation of leaf oil content and composition: Eighty-eight accessions were evaluated for leaf volatile oil constituents. The leaf oil content of *Cinnamomum* germplasm ranged from 0.25% to 4.2%. Accession 461 recorded the highest oil yield. Based on the leaf oil composition two chemotypes such as eugenol and benzyl benzoate were identified. Majority of the accessions contained eugenol as the chief constituent. Among the accessions the eugenol content ranged from 2% to 92.9%. In eugenol type oil, the eugenol content ranged from 55% to 92.9%. Accessions predominated by benzyl benzoate (42.9%) were accessions 3, 7, 67, 68 and 88. The related species *C. sulphuratum* leaves collected from Appangala yielded 0.11% oil which was found to contain 45.9% benzyl benzoate as the major constituent. Other constituents were γ-elemene, 2-methyl benzyl benzoate, 2-hydroxy phenyl methyl benzoate.

Evaluation of bark oil and oleoresin contents: The oil content of accessions of *Cinnamomum verum* varied from 0.33% to 3.34% whereas the oleoresin content ranged between 3.4% and 11.7%. Majority of the accessions yielded 0.3% to 0.8% volatile oil. Accession number 199 recorded the highest oil yield. Accession 199 was found promising based on high oil and oleoresin contents. The chief constituent of the bark oil namely cinnamaldehyde varied from 30% to 64%. Other major constituents were eugenol (0.6-23%), benzyl benzoate (0.8-19%), β-caryophyllene (2-14%) and linalool (0.9-14%).

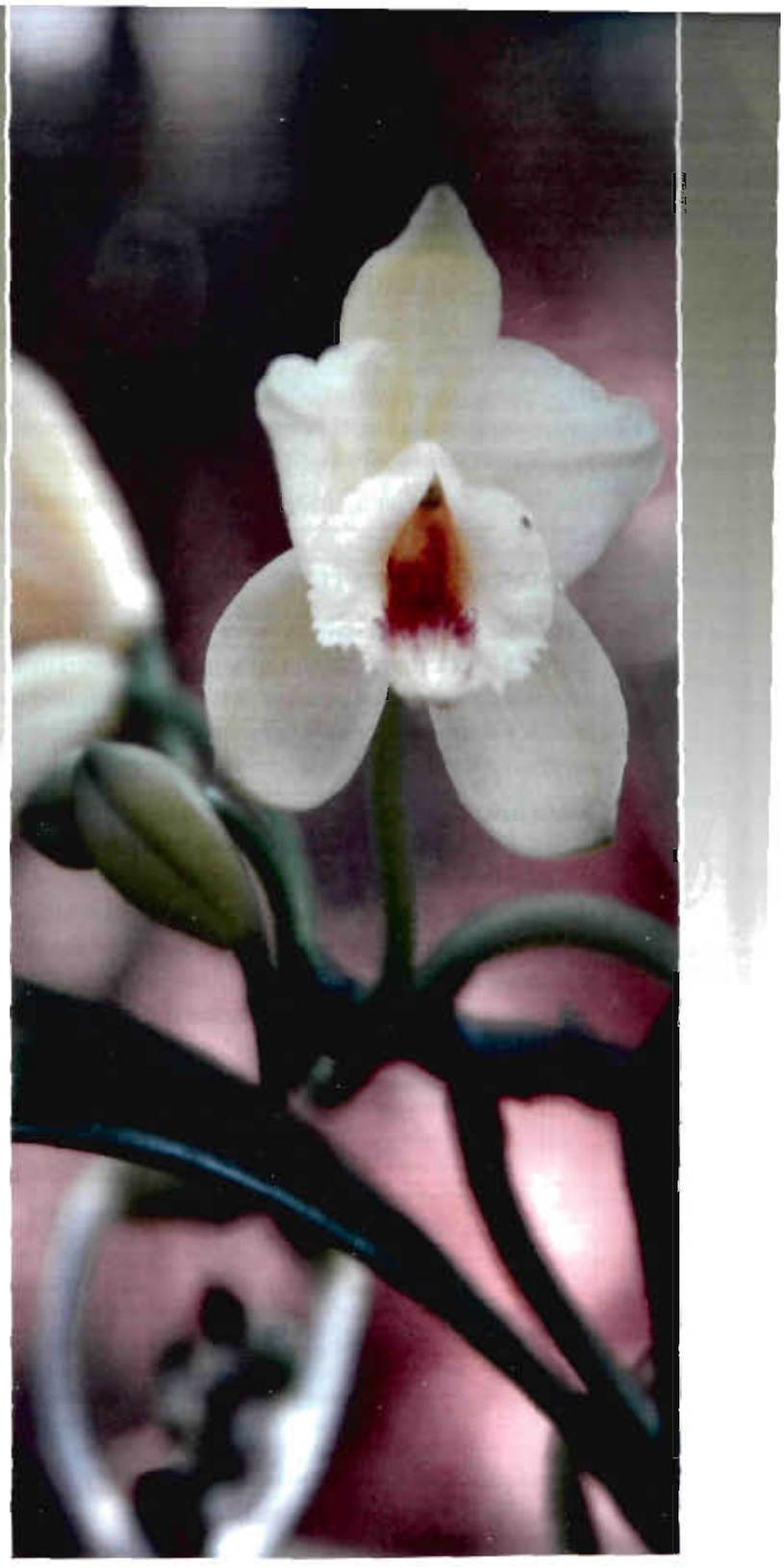
Cassia

The oil yield was determined in the leaves, petiole, and twigs of *C. cassia*. Petiole contained higher oil (1.12%) and cinnamaldehyde contents (74.80%) compared to the leaves and twigs.

Garcinia

Chemistry of *Garcinia*: Method for quantification of a major organic acid, hydroxy citric acid (HCA), using HPLC from leaf and fruits of *G. indica* was standardized. HCA showed significant variations among four species of *Garcinia* whereas lycopene did not show significant variation. HCA content varied in various species of *Garcinia viz. G. gummigutta* (2.6), *G. mangostana* (0.27), *G. indica* (5.21), *G.tinctoria* (3.3). Lycopene in *Garcinia* fruits were found to be *Garcinia gummigutta* (0.123), *G. mangostana* (0.098), *G. indica* (0.093), and *G. tinctoria* (0.156).

Elite Chinese Cassia D3 - registered with NBPGR, New Delhi for high bark oil and Cinnamaldehyde



Vanilla

Vanilla

1. GENETIC RESOURCES

Ninety-three collections of vanilla including 80 cultivars and 13 wild were maintained. The collection consisted of species such as *Vanilla planifolia* (80), *V. andamanica* (8), *V. pilifera* (1), *V. aphylla* (1), *V. tahitensis* (1), *V. vatsalae* (1), *V.* sp. (leafless) (1). Twenty-nine seedling progenies of vanilla were also multiplied vegetatively and planted in the field.

2. CHARACTERIZATION

Cytological analysis: Twenty accessions were cytologically analysed to determine the chromosome numbers. The most frequent chromosome number in all of them found to be 2n=28. Preliminary results indicate that the chromosome number in *Vanilla pilifera* is 2n=40.

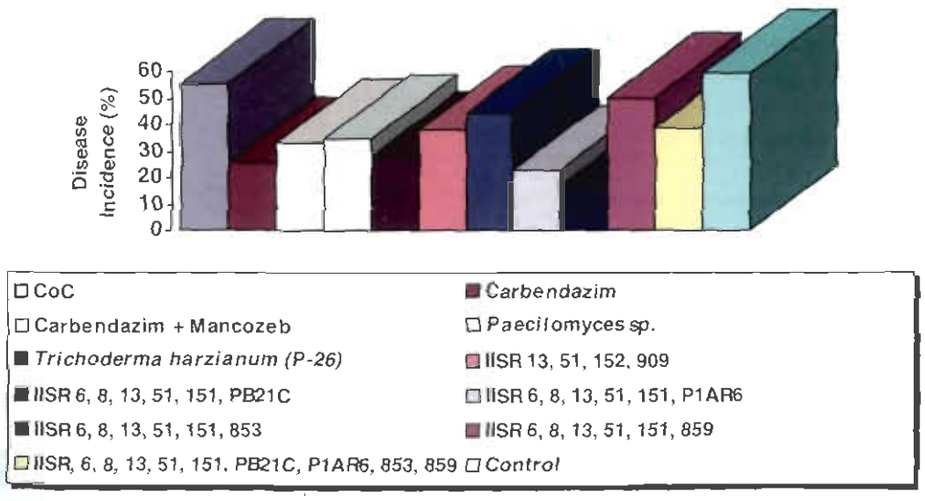
Anatomical studies: Sections of the internodes of *Vanilla planifolia* and *Vanilla* sp. from Andaman and Nicobar Islands were stained with Heidenhain's Iron-Alum-Hematoxylin as well as saffranin. The most contrasting difference found was the presence of sclerenchymatous layer separating cortex from the ground tissue in *V. planifolia* and its absence in *Vanilla* sp. from Andaman and Nicobar Islands. This indicates that the latter is more close to the leafless species of *Vanilla*.

***In vitro* pollen germination and pollen tube growth in *Vanilla planifolia*:** Germination of the pollen collected from freshly opened flowers of accession 4777 studied indicated that pollen grains of vanilla germinated in distilled water *in vitro*. Sucrose, a common ingredient in germination studies, is found not essential for germination. Good germination and pollen tube growth was observed in Brewbaker and Kwack medium without sucrose. However, addition of sucrose enhanced the germination and pollen tube growth. Frequency of pollen germination and tube length was higher after 6 hours of culture.

3. DISEASE MANAGEMENT

Management of root rot: A field experiment revealed the effectiveness of fungicides and bioagents for management of root rot disease caused by *F. oxysporum* f. sp *vanillae*.

Inorganic salts for management of root rot: Under *in vitro* conditions, the inorganic salts such as sodium chloride, potassium chloride, sodium nitrate and sodium



Management of Root rot disease of vanilla

metabisulphite were inhibitory to the pathogen at varying concentrations. NaCl and KCl were inhibitory at 2.25 M and its combination was inhibitory at 1.75 M. $NaNO_3$ was inhibitory at 0.75 M and $Na_2S_2O_5$ at 0.05 M. The concentrations inhibitory to the mycelial stage were inhibitory to conidial germination also. Only 3.3% germination could be observed in 1.75 M of NaCl when compared to 44.3% in control. Germination was totally absent in 2.25 M in all the chemicals.

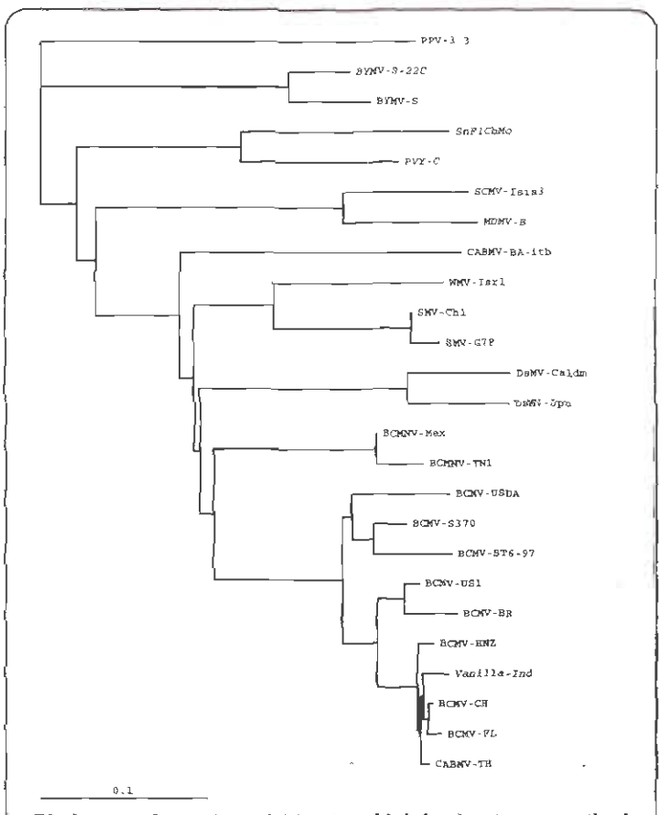
Immature bean shedding: A study on immature bean shedding indicated that the disease was predisposed by high atmospheric temperature and low relative humidity. Under these circumstances the causal organism *Colletotrichum* was found to be infecting the beans.

Viral Diseases

Detection and characterization of Potyvirus: The diseased vanilla plants showing typical symptoms were subjected to RT-PCR using primers designed for the conserved region of NIb and coat protein (CP) region of *Potyvirus*. A ~1000 bp RT-PCR amplified fragment was consistently seen in infected plants suggesting the association of a *Potyvirus* with the disease. The amplified fragment was purified from the gel, ligated to a TA vector and its nucleotide sequence determined. Sequenced region contained 1033 nucleotides comprising part of NIb and coat protein gene of the virus.

Bean common mosaic virus is one of the virus associated with stem necrosis in vanilla

The CP gene sequence of the potyvirus from vanilla was compared with CP gene of other potyviruses from diverse geographical areas at nucleotide and amino acid levels. Pairwise comparison clearly showed that the vanilla potyvirus is a strain of *Bean common mosaic virus* (BCMV) as it showed an identity of > 90% with strains of BCMV. Identity with other potyvirus species was < 82%. Phylogram illustrating phylogenetic relationship of vanilla potyvirus with other potyvirus species also clearly showed that the virus is a strain of BCMV as potyvirus from vanilla clearly clustered together with several BCMV strains. This is the first report of occurrence of BCMV on vanilla from India.



Phylogram drawn by neighborhood joining bootstrap method in clustal X (1.81) illustrating phylogenetic relationships based on the multiple sequence alignment of the coat protein amino acid sequence of isolates of distinct potyviruses and vanilla isolate of potyvirus (Vanilla-Ind)

Paprika

Paprika

1. GENETIC RESOURCES

Nineteen accessions of paprika obtained from IIVR, Varanasi were added to the repository. With this addition the strength of paprika germplasm is 130.

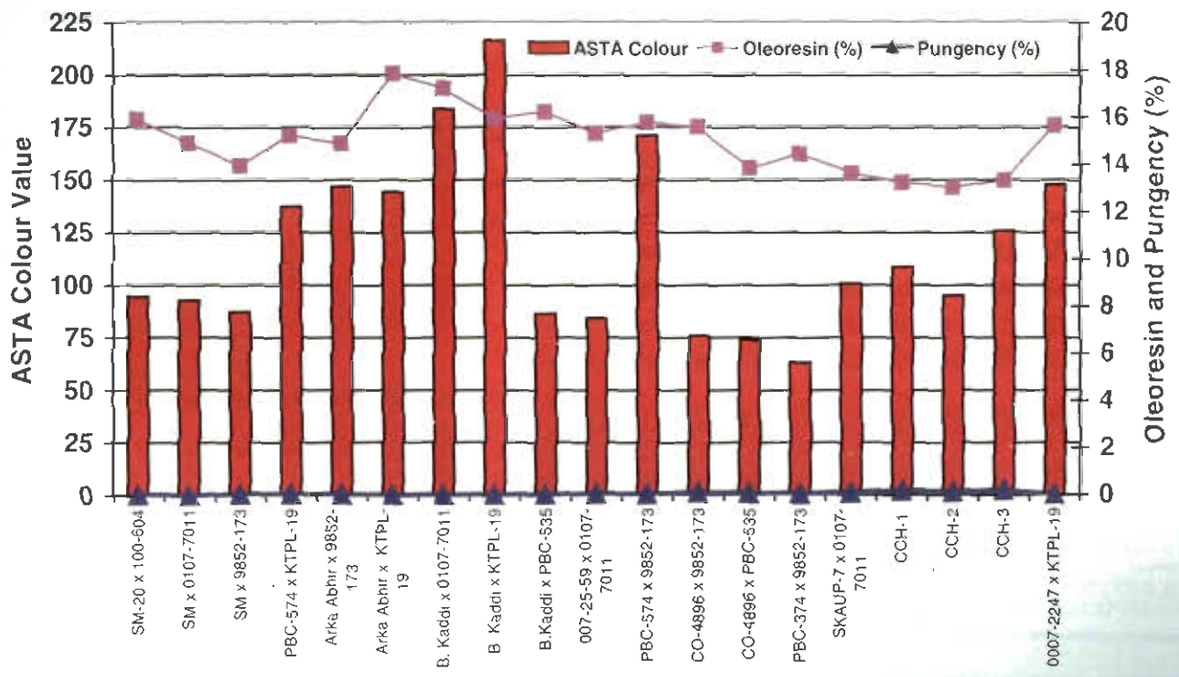
2. GERMPLASM EVALUATION

The new germplasm accessions were purified for 'True to Type" and their quality analysed. The color value ranged from 100 to 216 ASTA units. The highest color value of 216 ASTA units was seen in ICBD-17, followed by EC-31 (193 ASTA units). The oleoresin content varied from 9.0 to 22.0%, ICBD-15 (22.4%) recorded high colour value. EC71 and LCA422 recorded zero pungency (capsaicin content).

Among the hybrids of paprika, progenies of B.Kaddi x KTPL-19, B. Kaddi x 0107-7011 and PBC-574 x 9852-173 were found to be promising as they recorded high colour value, (218, 183.4, 171.1 ASTA colour value), high oleoresin (17.2, 15.5 and 15.7%) and minimum pungency (0-0.02%).

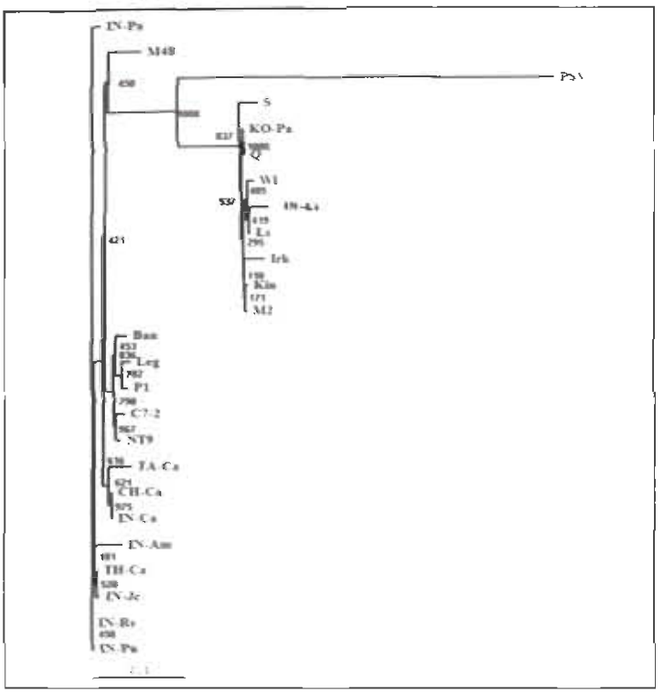
3. VIRAL DISEASES

Detection, identification and characterization of CMV: *Cucumber mosaic virus* (CMV) causing mosaic, leaf distortion and stunting on paprika (*Capsicum annuum* L.) was detected by DAC-ELISA and RT-PCR. CP gene of the virus was amplified, cloned and sequenced. Sequenced region contained a single open reading frame of 657 nucleotides potentially coding for 218 amino acids. Amino acid and nucleotide sequence analyses of CMV CP with members of subgroup IA, IB and II revealed that CMV infecting paprika showed maximum identity with members of subgroup IB. The identities of amino acid and nucleotide sequence ranged from 95% and 91%-92% with members of subgroup IA, 94%-99% and 91%-97 % with subgroup IB isolates and 78%-82% and 75%-76% with members of Subgroup II, which



Promising paprika hybrids with high colour and low pungency

was further confirmed through phylogram based on multiple sequence alignments of coat protein gene sequence.



Phylogram drawn by neighborhood joining bootstrap method in clustal X (1.81) illustrating phylogenetic relationships based on the multiple sequence alignment of the coat protein amino acid sequence of isolates of CMV (subgronp 1 and II) and paprika isolate of CMV (IN-Pa). Boot strap values are given at the nodes. PSV was used as outgronp

4. POST HARVEST TECHNOLOGY

Molecular methods for detection of adulteration : Six branded commercial samples of chilli powder were analyzed using RAPD/ISSR markers for detection of adulteration. Out of the six samples studied, market sample five consistently amplified a *Ziziphus nummularia*, specific band with a molecular size of approximately 350 bp using primer OPA10.

NATIONAL HORTICULTURAL MISSION

Production and distribution of planting material : Eighty thousand rooted black pepper cuttings, 5000 cardamom seedlings, 1000 cardamom suckers, 2.5 kg cardamom capsules, five tonnes of ginger seed rhizomes, six tonnes of turmeric seed rhizomes and 6500 nutmeg grafts were produced for distribution to farmers and augmentation of production.

MANAGEMENT OF MYCOTOXIN

Samples of black pepper, turmeric, ginger, nutmeg, mace and chillies collected from warehouses, markets, farm houses and godowns in different places of Kerala were found to be contaminated predominantly with *Aspergillus niger* followed by *A.flavus* and *A. parasiticus*. Aflatoxin could be detected in these samples. In order to standardize optimum storage conditions, for preventing mycotoxin contamination in dried samples of black pepper, ginger, turmeric, nutmeg and mace, various storage conditions such as (i) different moisture regime (8.0 to 18.0%) in the product, (ii) packing materials, (iii) plant products, (iv) plant materials and (v) various atmospheres like Vacuum, Nitrogen and Carbon dioxide were evaluated. Quality parameters such as moisture, oleoresin, and essential oil did not show any significant difference during the first three months among different storage conditions, which further recorded low fungal contamination. Internally Transcribed Spacer (ITS)-PCR based method for characterization of *Aspergillus* was standardized.

Detection of aflatoxin in market samples of spices

Spices	Aflatoxin (B1) in chillies, mace & nutmeg	
	Retention Time	Concentration (ppm)
Standard	22.850	1.000
Chillies	23.192	0.198
Mace	22.425	0.098
Nutmeg	22.750	0.046

Detector A (Ex: 365 nm, Em: 464 nm)

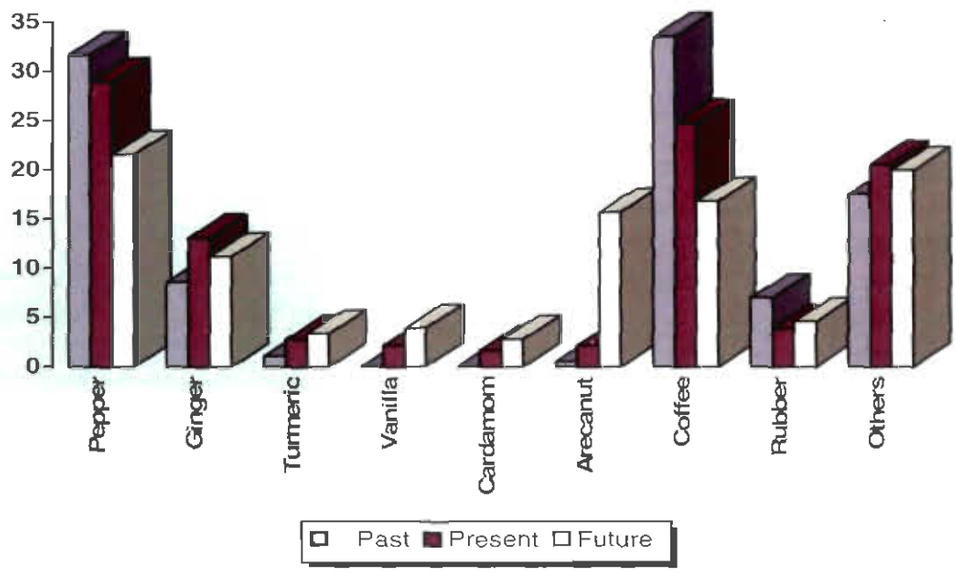
Influence of Socio-Economic and Agro-Ecological changes on Spice Production

The average size of operational farm holdings reduced from 3.7 to 3.0 in district of Wyanad in Kerala owing to reduction in size of marginal and small farm holdings and diversion of agricultural land for non-agricultural purpose. The estimated Markov's transition matrix indicates that, there was a transition of area under coffee and black pepper, the predominant crops of the region to non-traditional crops like arecanut, coconut, banana and other vegetable crops due to the change in socio-economic and agro-ecological factors in the region.

There was a marked change in the land use and land cover in the spice district (Wayanad) of Kerala with area under forest cover remains unchanged. (While there was a marginal increase in number of large (>10 acres) and medium (4-10 acres) holdings, number of semi-medium (2-4), small (1-2 acre) and marginal (<1 acre) holdings was decreased in the fast changing agricultural landscape.) There was a transition of area under one crop to another due to the impact of socio-economic and agro-ecological factors. The matter of concern in the observed transition was the fall in area under coffee and black pepper, the predominant crops of the region and increase in area under non-traditional crops like arecanut, coconut and banana.

Major factors found responsible for changes in spices production were:

There was less fluctuation in prices of major agricultural inputs like chemicals, fertilizers and pesticides etc. with a positive growth rate over the period, while there was a high instability (>33%) in prices of agricultural outputs.



Percent share of crop area during different periods

Prices of major spices have shown a negative trend in the post-economic liberalization period. Prices of predominant spice crop of black pepper registered maximum instability index of 94% with a sharp fall in price.

While more than 26% farmers do not apply chemical fertilizer for their pepper vines, among others, there was a reduction of around 68 kg acre^{-1} in fertilizer application. However, there is a substantial increase in application of FYM.

All India Co-ordinated Research Project on Spices

The All India Co-ordinated Research Project on Spices (AICRPS) is vested with the mandate to conduct and coordinate research in 12 spice crops with its headquarter at Indian Institute of Spices Research, Calicut. AICRPS has at present 19 Coordinating Centres spread over 14 states in 15 State Agricultural Universities (SAUs). In addition, four Voluntary Centres including Indian Cardamom Research Institute (Spices Board) are collaborating with this project. The X Plan budget of AICRPS was Rs. 700 lakhs with an Revised Estimate (RE) of Rs. 115.46 lakhs (ICAR share) during 2006-07. About 110 Research Programmes covering 12 mandate spice crops are being conducted at various centres.

Under the programme on assessment of technology in farmer's field, a total of 20 proven technologies in spices are being operated in 13 AICRPS centres. At present, eight ICAR ad-hoc schemes are being operated at SAUs/other organizations under AICRPS. The major achievements and the technologies developed under AICRPS during the period are summarized below:

Spice Genetic Resources

Genetic resources of spice crops have been enhanced with the germplasm holdings of 680 accessions in black pepper, 273 in cardamom, 63 in ginger, 1326 in turmeric, 77 in tree spices and 2540 in seed spices. At present, a total of 5529 accessions of spices germplasm are being conserved at various centres of AICRPS. The promising spices germplasm are being evaluated through Initial Evaluation Trials (IETs) and Comparative Varietal Trials (CVTs) at various centres.

1. Black pepper

Performance of Varieties

In black pepper germplasm evaluation, the variety Karimunda III recorded the maximum spike yield of 4.570 kg vine^{-1}, followed by TMB IV (4.090 kg vine^{-1}) at Panniyur centre, whereas PN-57 recorded the highest yield of 2.95 kg vine^{-1} at Yercaud centre. Under CVT, HB 813 recorded the maximum average spike yield of 8.01 kg vine^{-1} and the highest dry yield of 3.220 kg vine^{-1} at Panniyur centre.

Organic farming

In organic farming trial, the maximum average spike yield was obtained with fully organic treatment (22.17 kg vine^{-1}), followed by inorganic (15.88 kg vine^{-1}) at Panniyur centre. Inorganic N 100% + *Azospirillum* 50g+10 kg FYM recorded the maximum spike yield of 3.767 kg vine^{-1}.

Pest and Disease management

Among the biorationals evaluated, neem gold (0.5%) and neem oil (0.5%) were found to be superior to fish oil insecticidal soap (2.5%) in reducing the population of scale insects in black pepper at Pampadumpara centre. Solarized potting mixture fortified with *Trichoderma harzianum* @1 g kg^{-1} and vesicular arbuscular mycorrhiza (VAM) @ 100cc kg^{-1} potting mixture was found effective for the management of *Phytophthora* infections in black pepper nursery in Pampadumpara, Chintapalle and Dapoli centres. Application of Potassium phosphonate (Akomin, 3 to 5 ml L^{-1}) as spray and drench during pre- monsoon (first week of June) and post-monsoon (second week of August) periods along with soil application of *Trichoderma harzianum* (10^7 cfu, @ 50g vine^{-1}) with 1 kg of neem cake is recommended by the Sirsi, Mudigere, Pampadumpara, Panniyur and Ambalavayal centers for the management of *Phytophthora* foot rot.

2. Cardamom

Promising varieties: Five promising cardamom types (Mohini 1, Mohini 2, SB 1, SB 2 and Elapara 1) and a Vazhukka type

with bold capsules and more number of seeds (Elapara 1) were collected from Idukki District. High yielding cardamom cultivars namely Panikulankkara 1 and 2 were collected from Vattiyarkallar, (selected from open pollinated seedlings of Vazhukka type) Idukki District by Pampadumpara centre. These accessions were found to be performing even under less shade condition with least incidence of foliar infection. IC numbers (547920 to 547992) were obtained for 73 cardamom accessions (CRSP 1-CRSP 73) from National Bureau of Plant Genetic Resources (NBPGR), Delhi by Pampadumpara centre.

Pest and Disease management: Early stages of the cardamom root grub, *Basilepta fulvicorne* (Jacoby) that are usually present in soil during April/May and September/October can be managed by soil drenching of Imidacloprid 0.015% (5 liters plant^{-1}) or Chlorpyriphos @ 0.07% (5 liters plant^{-1}) or application of Carbofuran @ 3.0 g a.i. clump^{-1} (10-15 cm around the plant). Removal of mulch/weed cover and forking of soil prior to application of insecticides produced better results at Pampadumpara. The local strains of *Heterorhabditis indicus* from Cardamom Research Station (CRS), Pampadumpara were found to infect cardamom root grub under field condition. Highest mortality of cardamom root grub was observed in plants drenched with entomopathogenic nematodes, *Heterorhabditis indicus* (100 IJ grub^{-1}) and Imidacloprid 0.01% at Pampadumpara centre. Shoot and capsule borer was parasitized by *Ichneumonid* and dipteran parasitoids. Predatory mites are found to be associated with phytophagous tetranychid mites.

3. Ginger

Promising varieties: In ginger germplasm evaluation, out of 286 collections, SG 705 and SG 933 gave maximum rhizome yield (9-10 kg bed^{-1}) at Solan centre.

Disease management: In an integrated management for *Pythium, Fusarium* and *Ralstonia*, rhizome solarization (45/min) reduced the disease levels and increased the yield significantly, followed by hot water treatment. Solarization increased sprouting (92.2%), decreased *Pythium* rot by 5.3%, *Fusarium* yellows by 4.37% and *Ralstonia* wilt by 3.1% at Solan centre. A survey for ginger disease incidence carried out in the hill region of West Bengal (Three blocks of Kalimpong) has revealed heavy loss of up to 80% in some places due to rhizome rot - wilt complex

Nutrient mangement: Application of $ZnSO_4$ @ 2.5 kg ha^{-1} and borax @ 20 kg ha^{-1} produced maximum rhizome yield in ginger at Solan centre.

4. Turmeric

Promising Varieties: In turmeric highest fresh rhizome yield of 41.4 t ha^{-1} was recorded with PTS-59, followed by RH-5 (39.1 t ha^{-1}) at Jagtial. In a screening trial, TCP 198, 93, 104, 43, 115, 118, 19, 53, 70 were found to be tolerant to both leaf blotch and leaf spot diseases at Pundibari centre.

Disease management: Seed treatment as well as spraying with mancozeb + carbendazim (0.2% each) was found effective against leaf blotch and leaf spot in Pundibari centre. Seed treatment as well as soil application of *Trichoderma viride* and *Pseudomonas fluorescens* @ 12.5 kg ha^{-1} and 25 kg ha^{-1} as basal & top dressing along with application of recommended NPK + FYM was the best treatment against rhizome rot in Coimbatore.

5. Coriander

Promising Varieties: In coriander, LCC - 216 recorded significantly highest yield of 563 kg ha^{-1}, followed by LCC-170 (554 kg ha^{-1}) and JCO-340 (554 kg ha^{-1}) at Guntur. Coriander DH-228 gave highest leaf yield, which was closely followed by DH-202, when compared to Pant Haritima (check) at Hisar.

Crop Production: Two sprays at 40 and 60 days after sowing (DAS) with NAA 10 ppm recorded significantly higher yield (600 kg ha^{-1}) along with Triacontanol @ 1ml (580 kg ha^{-1}) at Guntur.

6. Cumin

Disease Management: *Trichoderma* + FYM and Mancozeb spray @ 0.25% was found effective against wilt with maximum seed yield 475 kg ha^{-1} at Jobner.

7. Fenugreek

Promising Varieties: Fenugreek accessions, UM-352 and UM-351 were found free from powdery mildew disease and RTP-9, RTP-10 and RMT-1 were found resistant to root knot nematode under field conditions at Jobner.

In fenugreek, LFC-84 recorded maximum grain yield of 1069 kg ha^{-1}, followed by LFC-87 (994 kg ha^{-1}), which were significantly superior to check, Lam Seln.-1 (826.0 kg ha^{-1}) at Guntur.

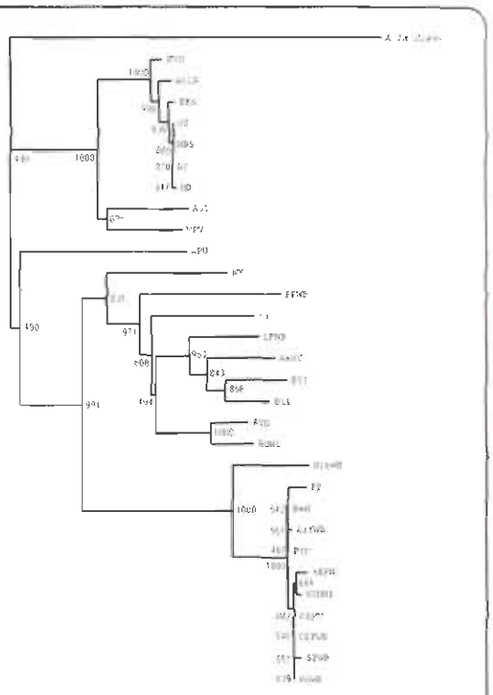
Disease management: Soil application of *Trichoderma viride*@ 5 kg ha^{-1} 20 days before sowing and soil application of neem cake @ 150 kg ha^{-1} is recommended for biocontrol of root rot in fenugreek.

8. Fennel

Promising Varieties: Out of 117 accessions of fennel, 13 accessions yielded better than the check variety RF-125. Some of the promising accessions identified on the basis of yield performance were UF-114, UF-157, UF-136, UF-177, UF-189, UF-20, UF-79, UF-138, UF-145, UF-153 and UF-187.

New disease in fennel: A Phyllody disease in fennel is described for the first time. The symptoms range from yellowing and stunting of the vegetative phase of the plant to malformation of inflorescence, flowers and floral parts. The Phytoplasma etiology was confirmed by PCR and the analysis of 16S rDNA gene sequence revealed that the phytoplasma infecting fennel belong to peanut witches broom (16Sr-II) group.

Phyllody disease of Fennel



Phylogram drawn by Neighborhood Joining Bootstrap method in Clustal X (1.81), illustrating phylogenetic relationships based on the multiple alignments of 16S rDNA sequences from 29 distinct isolates of phytoplasma including fennel isolate (FP). *A. laidlawii* was used as the outgroup

9. Clove

Promising Varieties: In CVT , among the ten accessions evaluated, Sel. 10 was found to be promising with the highest yield of 1.325 kg $tree^{-1}$ at Pechiparai centre.

Krishi Vigyan Kendra

A total of 1575 farmers visited KVK during the period for consultation, purchase of planting materials and other inputs from KVK.

Training programmes

The Kendra has conducted 100 training programmes on various subjects during the period under report. A total of 2710 persons have benefited out of the programmes.

Long duration vocational training programmes: The Kendra has conducted two long duration vocational training programmes for rural youth on 'Repair and maintenance of farm implements' The programmes were of three months duration organised in collaboration with the Government Community Polytechnic College, West Hill, Calicut. A total of 39 unemployed rural youth have benefited out of the trainings.

Revolving Fund Programme

The Kendra has a strong revolving fund programme to generate

Discipline-wise training programmes conducted

Discipline	Number of courses	Participants			SC/ST participants
		Male	Female	Total	
Crop Production	50	841	514	1355	128
Horticulture	11	145	75	220	73
Animal Science	38	676	425	1101	17
Agrl.-Engineering	2	22	17	39	9
Total	**101**	**1684**	**1031**	**2715**	**227**

income for productive uses. Under this programme, high quality planting materials of various crops were produced and made available to public at affordable rates. At present all spice seedlings, Coconut seedlings, Pathimukam seedlings, Bush pepper plants, Garcinia graft, Mango graft, Guava layer, Arecanut seedlings etc. are available for sale. An amount of Rs. 6.62 lakhs has been realised through this scheme.

The Kendra operates a Plant and Animal clinic offering various services to the farmers. An artificial insemination facility is also maintained at the centre to upgrade the genetic stock of livestock. The centre offered consultation, treatment and doorstep services charging nominal fee. In addition to the various treatments, the centre also provided vaccination facility and organised animal health camps in association with the state animal husbandry department. The various activities taken up by the Clinic during the period are as follows:

- Animals treated and advisory services provided – 817
- Artificial Insemination carried out in cattle using exotic frozen semen– 289
- Animal Health Campaign/ Infertility camps organised– 5
- Vaccination against Foot and mouth disease: 1060
- Ksheerothsavam programme attended: Block level: 3, District level: 1
- Rumenatomy performed: 2
- Surgical correction of chronic luxation of patella: 5
- Dehorning of calves using electric dehorner-28
- Controlled Intra-vaginal Drug Release (CIDR) treatment-3
- Synchronisation of estrus using PGF2 alpha-11
- Birds immunized against Ranikhet disease-1061 Fouls

Kisan mela and exhibitions

KVK regularly participated in exhibitions and seminars within the district. In addition, the Kendra also participated in exhibitions and seminars outside the district in association with the host institute. During the period under report, KVK has participated in the following exhibitions/Kisan melas.

1. At IISR, Calicut in connection with AICRP (Spices) Workshop from 24 to 27th May 06
2. At Acharya Ranga Agricultural University, Hyderabad in connection with Second National Conference on KVKs from 26 to 27th November 06.
3. At Calicut in connection with Calicut flower show 2007 from 8th to 14th February 07.

Farmers' study tours:

Five study tours were arranged for the farmers during the period. The details are given below.

Place of visit	Date (s)	Participants
Sikkim and West Bengal	2.5.06 to 17.5.06	30
Goat Farm, Kommery	20.7.06	17
KLDB, Dhoni, Palakkad	17.2.07	28
KLDB, Dhoni, Palakkad	20.2.07	30
CPCRI, Kasaragod	15.3.07	31

Maintenance of demonstration blocks/units

The KVK maintained model demonstration blocks/units in its farm for "Seeing is Believing" by the farmers. The details of the units are shown below:

Demonstration blocks / units	Area (acre) / No.
Areca nut garden	1
Homestead garden	0.75
Medicinal plants	0.50
Anthuriums	200 No.
Cashew	3
Black pepper varietal collection	0.50
Sapota	1
Guava	0.50
Vanilla	1
Poultry unit	1
Mushroom production unit	1
Quail unit	1
Dairy unit	1

Other Activities

Collaborative activities: KVK is conducting its many mandatory activities in association with NGO's such as Centre for Overall Development (COD), Vikas Volunteer Vahini Club (VVV), and INFAM.

Front Line Demonstration (FLD) Programme

FLD programmes conducted by the Kendra during the period are detailed below:

1. Demonstration of Apiculture as a profitable enterprise in Homesteads
2. Introduction of high yielding varieties of ginger
3. Introduction of a high yielding variety of *Amorphophallus* namely *Sree Padma*
4. Demonstration on milk production performance in dairy cattle by feeding with silage under scarcity conditions.
5. Introduction of Chincilla rabbits in cage rearing for meat with balanced ration.

On Farm Testing (OFT) Programmes

The major OFT programmes carried out during the period are listed below:

1. Testing the efficiency of organic composting of coir pith by TNAU method
2. Management of Sigatoka leafspot of banana using *Pseudomonas fluorescens*.
3. Broiler goat production
4. The effect of treatment with a GnRH analogue on conception rate in repeat breeder cows.

Training on organic waste management- a session in progress on compost preparation.

Silage preparation to tideover the feed crisis for cattle- an alternate feed for dairy animals

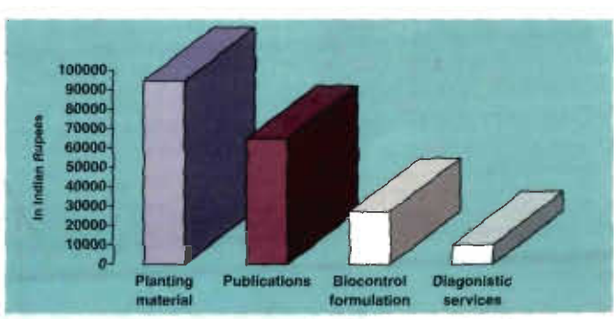
Agricultural Technology Information Centre

The ATIC at IISR started functioning in the year 1999 as an NATP project. With the cessation of NATP funding in 2003, the center became an institute project. As per mandate, the centre is involved in technology dissemination functions through a single window, coordinating with various divisions of IISR. The major activities carried out by the center are

- Production and distribution of quality planting material
- Production and distribution of printed literature
- Farm advisory services including crop diagnostic services
- Information dissemination through multimedia, video and interactive databases
- Providing audio visual aid support to the institute activities
- Organizing technology dissemination services like exhibitions, seminars to farmers and other users

1. Products, Services and Information dissemination

Sale of planting material registered an increase of 42.3% compared to the average sale over past three years whereas for publications it is 45.2%. *Trichoderma* formulation for Rs 8692 and *Pseudomonas* formulation worth Rs 18,503 were distributed to farmers. There is 51% decline in the sale of biocontrol agents as compared to distribution over past three years, which could be attributed to the establishment of entrepreneurs across the spice growing regions. The total income generated from the centre registered an increase of 25% over the average income during the past three years.



Resource generation through ATIC

During 2006-07, ATIC was frequented by farmers, students and research workers from Kerala and other states. There is an increase of 21.7 % in the number of visits to the institute as compared to the average over past three years.

2. Extension Services

Out Reach

The centre participated in following *seminars/exhibitions*

- National conference of KVKs at Hyderabad & Exhibition 26-27th November 2006.
- North East Agriculture Fair at ICAR Research Complex for NEH Region, Barapani 5-7th March 2007

Local programmes

The centre participated in following seminars/exhibitions.

- National seminar on Organic spices and aromatic crops at Calicut from 1-2nd February 2007.
- Fruits and Flower show Calicut from 8-14th February 2007.
- Farmers meet at Sholayur, Palakkad on 19th February 2007

3. VSAT- Village Resource Expert Center Project

The Satellite Technology based Village Resource Centre (VRC) Scheme sponsored by the Kerala State Planning Board has been commissioned by ISRO. The scheme envisages interactions between experts in identified knowledge centers and farmers enrolled in resource centres in Wyanad district of Kerala through Video conferencing. Four resource centres are functioning in Wyanad district.

4. Training for Development

The partnership services offered by the institute include Training, Consultancy and Contract research. The Institute offers training programme on demand from various agencies targeted for field extension functionaries of line departments and research workers of other ICAR Institutes and State Agricultural Universities (SAU). The modules for these training programmes are prepared based on technologies developed by the institute and research achievements. The topics covered included spices production technology, nursery, pest and disease management in major spices, post harvest technology and computer and statistical applications in research and development.

Participation of IISR in North East Agricultural Fair at Barapani, Meghalaya

Technology Mission for Integrated Development of Horticulture for Northeastern states including Sikkim

Releases were made by the Department of Agriculture and Cooperation, Government of India through ICAR to the Indian Institute of Spices Research under the Central Sector Scheme Technology Mission for Integrated Development of Horticulture for NE state including Sikkim. The identified component was training on Spices production management for the NE states for the benefit of extension functionaries and farmers. Accordingly, two workshops on Production management and Post harvest technology in ginger were organized in collaboration with Department of Horticulture, Sikkim at Gangtok and Jorethang districts in Sikkim during 12-16th March 2007.

Training on Post harvest techology for ginger at Sikkim

Demonstration of planting methodology in ginger at Sikkim

Training programme organized during the year 2006-07

Title of the course	Period	Participants	Target group
Good Agricultural Practices	05-07 June 2006	22	Rural youth
Production management and value addition in major spices	22-29 August 2006	13	National level extension officers
Spices research and development	25-27 November 2006	7	Field officers of Spices Board
Production management and value addition in major spices	20-22 November 2007	16	North Eastern States
Production management in ginger, turmeric and chillies	27-29 December 2006	12	National Horticulture Mission for Uttar Pradesh
Production management in ginger, turmeric and chillies	10-12 January 2007	14	National Horticulture Mission for Uttar Pradesh

Education and Training

Postgraduate studies

Ph.D

K. Maya, Biochemical variability in nutmeg (*Myristica fragrans*) and related taxa. University of Calicut.

K. V. Saji, Taxonomic and genetic characterization of black pepper and related species. University of Calicut.

MoU between IISR, Calicut and TNAU, Coimbatore for Ph.D degree

Under this MoU, staff members of IISR, after securing admission to PhD, will be allowed to do research work at IISR after completing their course work at TNAU.

M.Sc projects

Nineteen students from various universities carried out their M.Sc project work in Biotechnology, Biochemistry, Microbiology and Plant Pathology under the guidance of the scientists of the institute.

Post M.Sc Training

Six M.Sc graduates were trained on various techniques of Microbiology and Biotechnology under Post MSc Training programme of the institute.

Summer training for M.Sc students

Thirty students from various universities attended the one-month summer training programme on Techniques in Biochemistry and Biotechnology.

Training programmes attended by staff

Name	Training/Workshop	Institute	Period
S. Shanmughavel	Action Plan Meeting of KVKs of Zone VIII	TNAU, Coimbatore	April 07-08, 2006
D. Prasath	Awareness course on intellectual property rights	IGNOU, New Delhi	May- July 2006
S. Hamza	Managerial skills for technical officers	ISTM, New Delhi	May 22-26, 2006
M. K. Sachidanandan V. L. Jacob	IT sensitization	CMFRI, Kochi	June 26-30, 2006
C. K. Sushama Devi	Institutional Repositories	IIM, Kozhikode	July 17-19, 2006
K. Jayarajan	PERMISnet and intelligent reporting system	IARI, New Delhi	July 21-22, 2006
A. I. Bhat	Intellectual Property rights and World Trade	ASCI, Hyderabad	July 31- August 04, 2006
T. J. Zachariah	Organization related issues Vision 2015- Strategy and action plant for Food processing)	KINFRA, Calicut	September 02, 2006

Name	Training/Workshop	Institute	Period
T. K. Jacob	Sensitization workshop on process of knowledge management	KVK, Trivandrum	September 12-15, 2006
K. Jayarajan	Information security for Government officers	DOEEACC Centre, Calicut	September 18-22, 2006
K. N. Shiva	Breeding for resistance to disease and insect pests in plantation crops	CPCRI, RS, Kayamkulam	October 16-Novermber 10, 2006
N.K. Leela	IPR and WTO related issues	ASCI, Hyderabad	October 30-November 03, 2006
K. M. Prakash	Annual Review Meeting of KVKs of Zone VIII	CPCRI, Kasaragod	November 01- 04, 2006
Dr. T.K. Jacob, K.M. Prakash	Second National Conference on KVKs	Acharya Ranga Agricultural University, Hyderabad	November 26 -27, 2006
T. K. Jacob	Training on ICT	MANAGE, Hyderabad	October 30-November 3, 2006
K. Abhirami	Diagnostics and molecular characterization of pathogens of horticultural crops and their biocontrol organisms	IISR, Calicut	December 1-21, 2006
D. Prasath	DUS testing for plant variety protection-principles and procedures	IARI, New Delhi	February 19-24, 2007
T. E. Sheeja K. N. Shiva	IPR workshop	RRL, Trivandrum	March 1-2, 2007
Utpala Parthasarathy	GIS based decision support system for sastainable Agriculture	NAARM, Hyderabad	March 1-21, 2007
C. K. Thankamani	Advanced irrigation systems for intensive crop production	IARI, New Delhi	March 15-25, 2007

Training / Meetings organized by the Institute

- Summer training programme on Techniques in Biochemistry and Biotechnology for M.Sc students, May 05 to June 03, 2006.
- Summer training programme on Bioinformatics for M.Sc students, May 05 to June 03, 2006.
- National Biennial group meeting of research workers of AICRP on spices, May 25-27, 2006.
- Good agricultural practices for Rural Youth, June 5-7, 2006.
- Soil, plant and water analysis to technical officers/ training associates of south zone, KVK, June 19-23, 2006.
- Library resource sharing meeting, July 26, 2006.
- Bioinformatics: tools and Applications, November 14-18, 2006.
- Group meeting of cardamom research workers, February 8, 2007.
- Winter school on Diagnostics and molecular characterization of pathogens of horticultural crops and their biocontrol organisms, December 1-21, 2006.

Distinguished visitor

The Union Minister of State for Commerce, Shri. Jairam Ramesh visited the Indian Institute of Spices Research, Calicut on 23 March 2007. The Minister also visited the Agricultural Technology Information Centre of IISR and had a close interaction with the scientists of the Institute.

Summer training programme on Techniques in Biochemistry and Biotechnology

Visits Abroad

M. Anandaraj: Visited Sri Lanka to deliver a keynote address on IPM at the 34th annual meeting of IPC, 04-07 September 2006

M. Anandaraj: Visited IPC Secretariat, Jakarata, Indonesia to participate in the group meeting on drafting good agricultural practices (GAP) for pepper, 15-17 November 2006

Awards

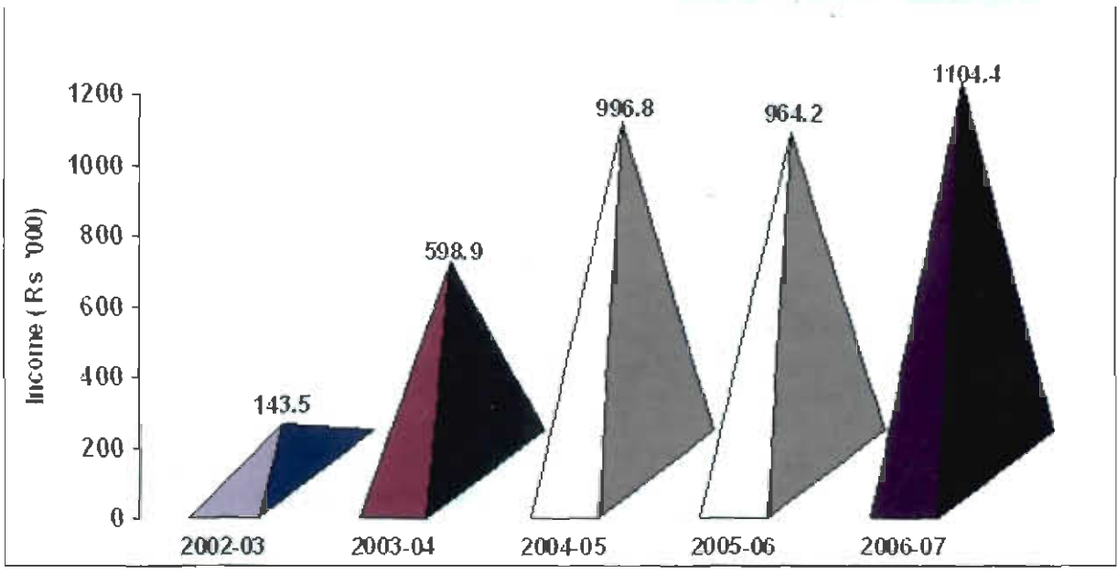
Dr.J.S.Pruthi Award 2006 for the best research paper entitled "Evaluation of composted coir pith with chemical and biofertilizers on nutrient availability, yield and quality of black pepper (*Piper nigrum* L.)" (Srinivasan, V., Hamza, S. and Sadanandan A.K. 2005, Journal of Spices and Aromatic Crops, Vol. 14: 15-20.

Dr.J.S.Pruthi Award 2006 for the best research paper entitled "Antagonistic mechanisms of fluorescent pseudomonads against *Phytophthora capsici* in black pepper (*Piper nigrum* L.)" (Diby Paul, Anandanraj, M and Kumar, A. 2005, Journal of Spices and aromatic Crops, Vol. 14: 122-129.

Consultancy Processing Cell

As a part of contract service, the consultancy processing cell took up various analytical services for the public and private entrepreneurs. Services included analysis of chemical and organic fertilizers, plant and soil samples for nutrients, analysis of commercial samples for *Trichoderma*, *Pseudomonas*, *Azospirillum*, Phospho-bacteria, analysis of samples for biochemical constituents etc. Based on the request by Government of Grenada, West Indies, two Principal Scientists were deputed to Grenada to provide technical consultancy on nutmeg cultivation and improvement. Sale of cultures, contract research, field visits based on planter's requests and organization of training programmes were some of the other activities of the cell during the year.

During 2006-07, the total revenue generation through consultancy activities was around 10.00 lakhs. The major share (55 %) came from analysis of samples for nutrients from Kerala State Land Use Board, Krishi Bhavans and private entrepreneurs. Some of the other samples analysed were biocontrol agents, biochemical constituents etc. The share of revenue through contract research was 32%. International consultancy contributed around 11%. Two training programmes each on Techniques on Bioinformatics and Biotechnology for M.Sc. Students and efficient use of soil and plant analysis lab for KVK personnel were organized under consultancy mode.



Income generation through consultancy service at IISR, Calicut during 2002-'07

Bioinformatics Centre

Research

During the reporting period the major research initiatives of the Bioinformatics Centre were the following.

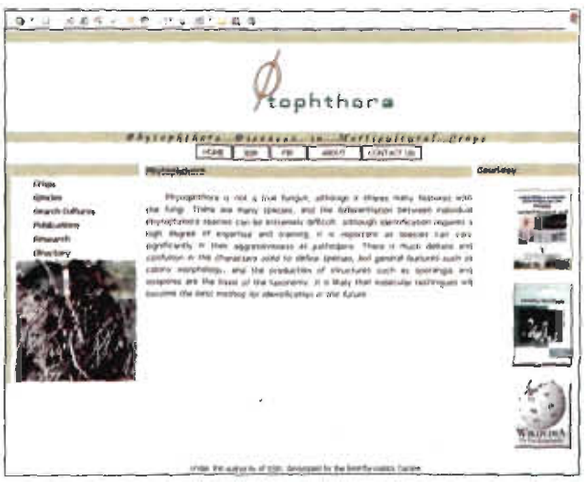
- Database for *Phytophthora* Diseases of Horticultural crops [*PhyDisH*] (http://www.spices.res.in/phydish/) - PhyDisH, includes information on all the *Phytophthora* cultures conserved in the National Repository of *Phytophthora* at the institute.
- Sign-O-Bacteria, a tool for identifying the species-specific signatures in plant-associated bacteria.
- Phylogeny of Badna viruses.

Training

- Summer training programme in Biotechnology and Bioinformatics, 05 May to 03 June 2006, 20 trainees.
- Training programme 'Bioinformatics: Tools & Applications, 14th – 18th November 2006, 19 trainees.
- The Centre has also actively supported the Winter School on Diagnostics organized at the Institute from 1-21 December 2006.
- Bioinformatics Centre collaborated with NIT, Calicut and offered Bioinformatics as an elective subject for M.Tech. (Computer Science) students.
- Three M.Sc. Bioinformatics students carried out their project work at the Centre.
- Two candidates were given post M.Sc. training.

Services

- Computational and Information support to various R&D projects of the institute.
- Maintenance and updating of the institute website www.spices.res.in.
- Designing and developing customized databases and software.
- Sustaining the intranet 'SPICENET' and the email facility 'Spicemail', E journals etc.
- Providing round the clock access to Internet, Bioinformatics tools through the facility called E-Lab.
- Designing, development and hosting of websites
- E-publishing – online journals, institute repositories etc.



Bioinformatics tool- PhyDisH- A database for *Phytophthora* researchers

Bioinformactic tool-Sign O bacteria - An unique software for guiding microbiologists

Agricultural Research Information System

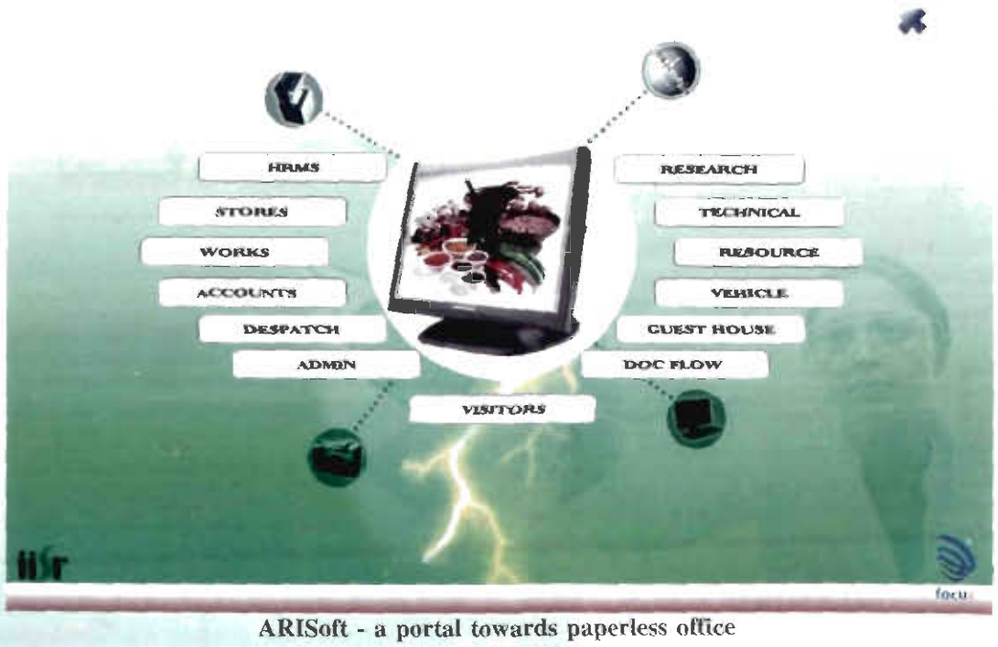
During 2006-07, ARIS center has spearheaded the development of an office automation software called 'ARISoft'. It is a fully integrated system, which automates multifarious functions of IISR that helps the management of day-to-day operations and decision-making process. The software guides the Document flow, Personnel, Activities of Administrative, Finance & Accounts, and Stores such as Purchase, Distribution, Contracting, Tour management, File Tracking system, Intranet Messaging etc. and it was launched by Dr. G.. Kalloo, former DDG (Hort.& CS), ICAR on 22 November, 2006 As a regular endeavor of imparting computer awareness among the staff, ARIS continued training programme this year too. It provided training to all staff of IISR for using ARISoft. Besides, necessary actions were taken for the proper functioning of Local Area Network in the institute. ARIS maintained and updated on regular basis information on all the staffs of the Institute by accessing and editing PERMIS net. It serves as a service centre for various purposes like Internet browsing, Statistical analysis of data, documenting and multimedia programes developed on various activities of the Institute.

Besides, ARIS has developed

(i) **E-book for 'Completed Projects-Salient Findings'**

(ii) **E-book of Indian Institute Spices Research**

(iii) Modified the software **INSTInfo** (Institute Information Bank - A software for storing and retrieving institute details) and distributed it to all horticultural and crop science institutes of ICAR



ARISoft - a portal towards paperless office

Library

The library of the institute was set up to provide support to research activities of the Institute and to function as a national information storage, retrieval and dissemination system for spices and related areas. At present, it has a collection of 4188 books, 33451 bound volumes 2298 reprints, 898 technical reports, 167 CDs, 124 theses and 139 project reports. The library is subscribing to 36 foreign journals and 84 Indian journals in addition two CAB CD databases (Horticultural database and Plant protection database) and J Gate (Agricultural and biological sciences), the e journal portal. The library provides bibliographic services (published in Journal of Spices and Aromatic Crops and database services apart from publishing "Agri-Science Tit Bits" at quarterly intervals. The additions during the year include 111 books, 800 bound volumes of journals 43 technical reports, three theses, 11 project reports and six reprints.

Sharing of resources between the libraries of Central Plantation Crops Research Institute, Kasaragod, National Research Center for Cashew, Puttur and IISR, Calicut, was continued. Access to online journals and content page service was provided through institute website to respective users. Internet facility is provided in the library for literature search, web search, checking e-mails etc. SpicE-Lib, the library website, was launched during this year, wherein access points are provided to various library resources and services. Links are also provided to online journals and open access journals in the web site. Hands on training are given on information retrieval and documentation to the participants of various training programmes organized by the institute. During the year National Agricultural Innovation Project, ICAR provided free access of three databases SCOPUS, Science Direct and Annual Reviews.

Women Empowerment Programme

Visit to private farm in Wyanad involved in the production of white pepper

International Women's day was observed on 9th March 2007. Dr. Irene Hunt ex-Principal Malabar Christian College, Calicut was invited as chief guest. She delivered a talk on mother hood and related issues confronting women in the modern era. The KVK organized a training programme on processing of vanilla and pepper for women employees of the institute at Wayanad. The members of women's cell visited a private farm involved in processing white pepper at Wayanad on February 2007. The Women's cell also joined hands with the Recreation club of the institute in organizing the Communal Harmony week during November 2006. Classes on Glass painting and doll making were also arranged for the staff.

Official Language Implementation Activities

Quarterly meetings of Official Language Implementation Committee were held four times during the year 2006-07. During this period we have conducted four Hindi Workshops on Noting and Drafting, Spoken Hindi, Basic Knowledge of Hindi Computer for the benefit of staff members. Smt. N. Prasannakumari, Hindi Translator attended TOLIC Sub Committee meeting on 17. 4. 2006 at State Bank of Travancore, Zonal Office, Calicut. Sri. B. Krishnamoorthy attended TOLIC meeting on 26.4.2006. Sri. B. Krishnamoorthy, Smt. N. Prasannakumari, Sri. V.C. Sunil, Smt. P.V. Sali, Sri. P. S. Harish and Sri. B. T. Velayudhan have attended TOLIC meeting and Hindi Fortnight valedictory function on 19.10.2006 at Hotel Asma Tower, Calicut.

Hindi Week was celebrated with various Hindi Programmes. On 14.9.2006 Hindi Day / Hindi Week was inaugurated. A film show was presented for the staff members after the inauguration. Various competitions such as Hindi song, elocution, essay writing, paragraph reading and calligraphy, noting and drafting, extempore speech were conducted during this week. Prizes and certificates were distributed in the valedictory function on 21.9.2006.

Hindi word/phrase and the equivalent English word/phrase were displayed both in the white board and in the IISR web site daily. During this period we have nominated nine staff members for Hindi Pragya Examination November 2006 conducted by Hindi Teaching Scheme, Calicut and all of them passed the examination. Hindi section has nominated Sri. R. N. Subramanian, Assistant and Sri. K. Ananda, Technical Assistant, Cardamom Research Centre, Appangala for Hindi Computer training from 8 to 12 January, 2007 at Bangalore.

Sri A. P. Sankaran, Assistant Administrative Officer was nominated for attending Hindi Workshop conducted by TOLIC on 18.7.2006 at SBT, Calicut. Hindi version of the half yearly publication of Spices News volume 17(1) January–June 2006 was published separately. Executive summary of Project Coordinator's report and executive summary and preface of Annual Report were translated in Hindi and incorporated in both annual reports.

Institute Management Committee

Director, IISR, Calicut, Chairman

Assistant Director General (PC), ICAR, New Delhi, Member

Dr. S Devasahayam, Principal Scientist, IISR, Calicut, Member

Mr. P A Mathew, Principal Scientist, IISR, Calicut, Member

Dr. George V Thomas, Head, Crop Production, CPCRI, Kasaragod, Member

Dr. K V Nagaraja, Principal Scientist, NRC For Cashew, Puttur, Member

Sri. Sanjay Mariwala, Kochi, Member

Sri. K Mukundan, Wyanad, Member

Assistant Administrative Officer, IISR, Calicut, Member Secretary

Research Advisory Committee

Dr. S. Kannaiyan, Chairman
National Biodiversity Authority, Chennai

Dr. A. N. Mourya, Member
Emeritus Scientist,
Banaras Hindu University, Varanasi

Dr. A. Manickam, Member,
Professor,
Centre for Plant Molecular Biology,
Tamil Nadu Agricultural University,
Coimbatore

Dr. Narayan Rishi, Member,
CCS Haryana Agricultural University, Hisar

Dr. Kuruvina Shetti, Member
Professor & Head, Biotechnology,
University of Agricultural Sciences,
Dharwad

Dr. A. K. Misra, Member, Consultant
Small Farmers Agribusiness Consortium,
Ministry of Agriculture,
New Delhi

DR. M.Anandaraj, Member (Secretary)
Project Coordinator, AICRP (Spices),
Indian Institute of Spices Research,
Calicut

Recommendations and Action Taken Report of RAC - 2006

SL.No.	Recommendations- 2006	Action taken
1.	A holistic approach to manage Phytophthora foot rot problem in black pepper must be made. In this regard, it was suggested to form a working group led by Dr M. Anandaraj.	The progress of work on *Phytophthora* foot rot disease of black pepper was reviewed at regular intervals. The work under progress include : characterization of *Phytophthora* spp.; Identification of genotypes with multiple resistance to *Phytophthora* and nematodes; assay for multiple antagonistic potential against soil-borne pathogens of black pepper including *P. capsici*; compatibility of promising antagonists; evaluation of promising antagonists under greenhouse conditions against *P. capsici*; development of consortium of bioinoculants for management of *Phytophthora* foot rot disease; varietal reaction of black pepper to biocontrol agents; root stock interventions for managing *Phytophthora* foot rot disease; induction of systemic resistance using salicylic acid; and integrated strategy.
2.	A strategy to identify factors responsible for curcumin synthesis and ways to increase its synthesis in turmeric by means of genetic manipulation and agro technique should be evolved. A working group led by Dr V.A. Parthasarathy may be formed to address the same.	Action has been initiated and a working group was formed.

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Sl.No.	Recommendations- 2006	Action taken
3.	A working group on IPM strategies for the management of pests and diseases in ginger to be formulated with Dr S. Devasahayam as leader of the group.	The progress of work under IPM strategies for the management of pests and diseases of ginger was reviewed at regular intervals. The work under progress include : field trials for the management of soft rot disease with promising rhizobacterial strains and chemical fungicides; *in vitro* and greenhouse evaluation of mustard leaf macerate. potassium phosphonate, commercial systemically acquired resistance inducer such as 2-bromo-2-nitropropane-1,3, diol, cheshunt compound, copper oxychloride and Bordeaux mixture against *Ralstonia solanacearum* and *Pythium myriotylum*; and evaluation of root exudates of *Curcuma amada* in inhibiting the growth of *R. solanacearum in vitro*.
4.	In view of low productivity in spice crops, it was suggested to look into various soil factors such as soil nutrients including micronutrients and weather factors influencing productivity. A working group with Dr B. Chempakam as leader may be formed to research into all aspects.	Programmes were chalked out based on the following three thrust areas : i) Budgeting of major and micronutrients for targeted yield production and organic farming in major spices-Included as one of the technical programme in the ongoing project.ii) Sustainable spices based cropping systems for enhancing productivity and soil qualityTwo new projects were proposed:Agr. XXV (813): Evaluation of legumes as intercrops in black pepper plantation. Agr.XXVII(813) : Enhancing the productivity in black pepper by intercroppingiii) Physiological and climatic factors influencing productivity. The objectives will be met in the already existing externally funded project on Climate change.
5.	Impact analysis including economics of selected technologies developed by IISR and its transfer to farmers need to be studied. Dr M. S. Madan and Dr P. Rajeev may discuss with concerned scientists and evolve a time bound programme to address the issue.	A project entitled 'A Study on diffusion, adoption and impact of varieties released from IISR and scientific crop management practices' has been proposed by Dr.P.Rajeev and data collection process is in progress after completing the questionnaire and sampling.
6.	In order to get variability in spices, somaclonal variation and mutation breeding may be attempted.	Utilization of mutagenesis and somaclonal variation to induce and enhance variability in spices is being taken up.Ginger- Sprouting buds of five ginger varieties were treated with different doses of gamma radiations starting from 0.5kR. M1 generation raised from these buds had shown chlorophyll variegation in a few plants. M_2 generation will be raised.
7.	In view of superiority of Indian cardamom, the unique RAPD band obtained with Indian cardamom may be cloned and sequenced in order to develop in to a SCAR marker to differentiate Indian cardamom from the rest.	A band of size 400bp & 700bp (OPA 19) specific to the traded /Indian cardamom is being eluted and cloned.
8.	Micro nutrients should also be taken into account (in addition to NPK) in nutrient targeting experiments.	It is included under project "SSC IV (813) Nutrient budgeting for improved varieties of spices" as along term objective.
9.	A few more parameters may be added to refine the yield prediction formula in black pepper to get better yield prediction. Model may be developed based on site specific actual data.	More weather parameters viz., temperature, relative humidity are included and models are developed with site specific actual data of yield and weather obtained from RARS, Ambalavayal, Wynad Dist. Kerala, one of the efficient black pepper producing district under the project "Agr.XXII(813): Biometeorological investigation and modeling in black pepper".
10.	Basic studies with *Azospirillum* and micronutrients may be taken up in spice based cropping system	Compatibility studies of *Azospirillum* with micronutrients assigned to Ph D Student.
11.	A detailed study on the enzymes responsible for curcumin 1, 2, & 3 syntheses may be carried out.	The programme has been included under the existing project on 'Characterization of turmeric germplasm for curcuminoids'.

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SL.No.	Recommendations- 2006	Action taken
12.	A detailed study on the post monsoon soil moisture management and its impact on the yield in spices may be taken up.	Earlier experiments in black pepper showed that drip irrigation @ 7 litres / day / vine during October to May proved better for black pepper. .Drip irrigation @ 8 litres / day / clump during post monsoon period recorded higher yield. Sprinkler irrigation once in 12 days is also equally effective. In cardamom, trench system of planting reduced the run off and conserved more moisture than other systems of planting Based on these observations, a project on "Productivity enhancement in black pepper by managing irrigation and fertilizer" is presented to Kerala State Council for Science Technology and Environment for consideration.
13.	An in depth study to isolate and characterize all *Aspergillus* spp. from spice produce need to be taken up.	Isolation and Characterization of all *Aspergillus* spp. is an ongoing programme under the ICAR Net work project on Mycotoxins.92 isolates collected from spice samples during the survey in spice growing areas are maintained and are being tested for toxigenicity.
14.	Surface flora of black pepper berries need to be studied. Further, quality analysis of white pepper produced using different organisms may be studied. In addition, cultivars amenable for white pepper production keeping in view uniform maturity of berries may also be taken up.	When initial isolation is made, we have isolated 45 bacteria and 8 fungi from black pepper pericarp surface, decomposed black pepper, soil used for decomposing the pepper and the white pepper itself. These isolations have significantly contributed good isolates with multiple hydrolytic enzymatic potential. Four of the isolates produced four well known hydrolytic enzymes such as Pectinase, cellulase, amylase and protease. These isolates are being evaluated in large-scale trials now. In order to rectify the problems of immature berries being fermented, the pepper berries were sieved through standard berry sieves and the trial is being conducted. Another varietal trials is in progress. Chemical quality white pepper developed using different microorganisms (ten different organisms) did not show any variation in oleoresin, Piperine, starch and essential oil content. Starch content in white pepper is about 30% more when compared to black pepper. Among the essential oil constituents Limonene and ß-caryophellene showed a reduction of about 25% compared to black pepper control. In sun dried white pepper the surface flora ranged from 15×10^2 to 23×10^2 cfu/gm and in oven dried the same ranged from 8×10^3 to 10×10^4 cfu/gm.
15.	Major factors responsible for increased cost of production and strategies to reduce the same in spices may be worked out.	To address the problem a new project entitled 'Assessing Sustainability of Cropping System Involving Spices' has been proposed as an institute project.
16.	Studies on the effect of single virus alone and synergistic effect of both the viruses associated with stunted disease in black pepper may be taken up. Search for other additional viruses in black pepper may also be looked into.	CMV and PYMV alone and in combination were inoculated onto healthy black pepper seedlings. Appearance of symptoms and presence of virus (es) were confirmed through PCR/RT-PCR. Regarding search for additional viruses, nucleic acid isolated form virus infected plants were subjected to RT-PCR/PCR for presence of Sobemo, Luteo and Nano viruses. However, none of these three viruses were present in infected black pepper samples.
17.	The RAC suggested to engage all promising materials obtained after screening against biotic and abiotic stresses in improvement programmes.	Following promising lines were identified as sources of tolerance/resistance to biotic and abiotic stresses: *Phytophthora* : P24, Coll.1041 *R.similis* : C820, HP39 *Pollu* : Coll. 816, 841, 1084, 1114 High caryophyllene : Coll. 122, 123, 7 Drought : Coll.813,1495,931
18.	A detailed study on the basic characterization of endophytic bacteria controlling nematodes should be taken up.	The above materials are being incorporated in the breeding programme.Rhizome rot resistant & katte resistant types in cardamom are used as donors in cardamom breeding. The promising endophytic bacterial strains were identified based on species-specific primers. Isolate BP35 was identified as *Pseudomonas fluorescens*, BP17 as *Bacillus* sp. and BP25 as *Pseudomonas* sp. Nematode suppressive isolate TC10 is yet to be identified. Identification based on sequencing of 16s ribosomal DNA is in progress. Biolog System has been proposed for purchase in the XI Plan.

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SL.No.	Recommendations- 2006	Action taken
19.	Salicylic acid may also be included as one of the treatments in management experiments as it is known to induce resistance.	A trial on effect of methyl salicylic acid (MeSA) was initiated in the green house with various concentrations namely, 10 gl^{-1}, 1.0 gl^{-1}, 0.1 gl^{-1}, 0.01 g l^{-1} and 0.001 g l^{-1} for their inhibitory activity against *Phytophthora capsici* infection and mycelial growth of the fungus *in vitro*. MeSA @ 10gl^{-1} caused phytotoxic symptoms on the leaf instantaneously. In general *P. capsici* infection could be seen in all the treatments irrespective of concentrations of MeSA used. However, MeSA *per se* was toxic to the fungus and as the concentration increased there was a proportional decrease in the mycelial dry weight. Trials on the effect of MeSA on *P. capsici* infection in rooted cuttings and excised shoots (single nodal cuttings) is in progress.
20.	Based on the previous data, futuristic trading software may be developed for all spice crops keeping in view of its potential for commercialization.	An attempt would be made as and when the vacancies of scientists in 'Agricultural statistics' and 'Computer application' are filled.
21.	In view of low variability in some of the spice crops, efforts may be made to obtain germplasm from other producing countries.	NBPGR New Delhi has been contacted for introducing germplasm from exotic sources. List of spices materials to be introduced from foreign countries has been sent to NBPGR.
22.	Before initiating organic farming experiments, site characterization need to carried out.	Site characteristics of soils like physico chemical and biological properties are done as suggested.
23.	Farmers may be educated on IPR and Farmers rights, seed act etc.	Farmers/students are educated on IPR Seed Act through farmers ' seminar/trainings as invited speakers. Lectures /classes taken: by Dr. B.Sasikumar1. IPR issues in Agriculture. Nagarjuna University, Guntur 10 Nov.20052. Seed Bill- boon or bane. Agriculture seminar. St. Joseph's College, Devagiri.3. Seed Bill- An appraisal Farmers' seminar, KVK, Peruvannamuzhi.4. IPR issues in agriculture- Farmers and agricultural officers. KVK, Peruvannamuzhi.
24.	In order to get precise data, yield loss on turmeric shoot borer need to be conducted in different geographical locations	The incidence of the shoot borer was recorded in various turmeric growing areas in Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. The pest incidence was serious (above 25%) in Wyanad and Kozhikode districts only in Kerala.

List of Publications 2006-'07

1. Anil Kumar, R., Velayudhan, K.T., Vasu, K., Ramachandran, V., Suseela Bhai, R. and Unnikrishnan (2006) Interaction of potassium phosphonate in laterite soil. Journal of Environ. Science & Engg. 47: 276-285

2. Balaji, S., Kalpana, R. and S. J. Eapen (2006) PIR Pairwise Alignment – A slip up for signal peptides. Bioinformation 1: 188-193

3. Dhirendra, S., Jain, U.K., Rajput, S.S., Khandelwal, V. and K.N. Shiva (2006) Genetic variation for seed yield and its components and their association in coriander (*Coriandrum sativum* L.) germplasm. Journal of Spices and Aromatic Crops 15: 25-29

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List of Projects

I. Institute Projects

Mega Project-1: Collection, conservation, characterization and cataloguing of germplasm of spice crops for yield and other economically important characters. [Project Leader: P. A. Mathew]

1. Gen. I (813): Collection, conservation, cataloguing and evaluation of black pepper germplasm [1972–2008] [K. V. Saji, Johnson K. George and Utpala Parthasarathy]
2. Gen. IX (813): Collection, conservation, cataloguing and evaluation of cardamom germplasm [1976-2007] [D. Prasath and M.N. Venugopal]
3. Gen. II (813): Collection, conservation, cataloguing and evaluation of germplasm of ginger and turmeric [1976–2007] [B. Sasikumar, Johnson K. George, K. V. Saji and R. Ramakrishnan Nair]
4. Gen. XIV (813): Characterization of turmeric germplasm for curcuminoids [2004-2007][B. Chempakam and N. K. Leela]
5. Gen. VI (813): Collection, conservation, cataloguing and evaluation of germplasm of tree spices [1976–2007] [B. Krishnamoorthy, J. Rema, P. A. Mathew and D. Prasath]
6. Gen. XVI (813): Maintenance, enhancement and characterization of genetic variability in vanilla (*Vanilla planifolia* Andrews) (2005-2010) [R. Ramakrishnan Nair and P. A. Mathew]
7. Hort. III (813): Collection, characterization, evaluation and maintenance of paprika and paprika alike chillies [2004-2009] [KN Shiva, T.J. Zachariah and M. Anandaraj]

Mega Project-2: Breeding improved varieties of spice crops for yield, quality, drought and resistance to pests and diseases [Project Leader: B. Krishnamoorthy]

1. Gen. XVII (813): Breeding black pepper for high yield, quality, biotic and abiotic stress [2006–2011] [V. A. Parthasarathy B. Sasikumar, T. John Zachariah, K. Nirmal Babu, R. Suseela Bhai, Johnson. K. George, Santhosh .J. Eapen, K. V. Saji, S. Devasahayam, K. S. Krishnamurthy, R. Ramakrishnan Nair and T.E. Sheeja]
2. Gen. X. (813): Breeding cardamom for high yield and resistance to 'katte' disease. [1976–2007] [M. N. Venugopal and D. Prasath]
3. Gen.XV. (813): Investigations on the reasons and solutions for the absence of seed set in ginger (*Zingiber officinale* Rosc.) [2005-2010] [R Ramakrishnan Nair]
4. *Biotech. VII (813): ISSR markers for black pepper* improvement [2004-2007] [Johnson K. George and B. Sasikumar]
5. Biotech. VIII (813): Molecular characterization and *in vitro* propagation in *Myristica* sp. [2004-2007] [T.E *Sheeja and B. Krishnamoorthy]*
6. Hort. IV (813): Rootstock-scion interactions in tree spices [1998–2008] [J. Rema, P. A. Mathew K. S. Krishnamurthy and T. E. Sheeja]
7. Biotech. IX (813): Development of transgenics for resistance to *Phytophthora* and drought in Black pepper [2006-2011] [K. Nirmal Babu]

Mega Project-3: System approach for sustainable production of spices [Project Leader: K. Kandiannan]

1. SSC. IV (813): Nutrient Budgeting For Improved Varieties of Spices [2005-2010] [V. Srinivasan, R. Dinesh, C.K. Thankamani, K. Kandiannan, S.J. Anke Gowda and S. Hamza]
2. SSC. III (813): Assessment of quality of soils under spices based cropping systems [2005-2008] [R. Dinesh, B. Chempakam, V. Srinivasan, T.E. Sheeja, and S. Hamza]
3. Agr. XXIV (813): Phenology studies in ginger and

turmeric [2006-2009] [K. Kandiannan and Utpala Parthasarathy]

4. Agr. XXV (813): Evaluation of legumes as intercrops in black pepper plantation [2006-2010] [K. Kandiannan, R. Dinesh and S. Hamza]

Mega Project-4: Production physiology of spice crops [Project Leader: B. Chempakam]

1. Phy. VII (813): Physiological and biochemical basis for productivity in black pepper [2003-2008][K. S. Krishnamurthy and B. Chempakam]
2. Phy. VIII (813): Mechanism of drought tolerance in cardamom and black pepper [2005-2008] [S.J. Anke Gowda and K.S. Krishnamurthy]

Mega Project-5: Value addition and post harvest processing of spices [Project Leader: T. John Zachariah]

1. PHT. III (813): Studies on drying and storage parameters in black pepper, ginger, turmeric and nutmeg [2004-2007] [E. Jayashree and T. John Zachariah]
2. PHT. IV (813): Evaluation for physical and biochemical quality of spices. [2005-2009] [T. John Zachariah, N.K. Leela and K.N. Shiva]

Mega Project-6: Production of nucleus planting materials of improved varieties of spice crops [Project Leader: C. K. Thankamani]

1. Agr. XX (813): Production of nucleus planting materials of improved varieties of spice crops [2005–2010] [C. K. Thankamani, P. A. Mathew, K. Kandiannan and S. J. Ankegowda, K. S. Krishnamurthy and R. Dinesh]

Mega Project-7: Identification, characterization and development of diagnostics against pests, pathogens nematodes of spice crops [Project Leader: M. N. Venugopal]

1. Path. XV (813): Investigations on diseases of vanilla [2003-2008] [A. Ishwara Bhat, R. Suseela Bhai and M. N. Venugopal]

Mega Project-8: Conventional and molecular approaches for developing pest, pathogen and nematode resistance in spice crops [Project Leader: R. Suseela Bhai]

1. Crop Prot. 1.4 (813): Identification of Black pepper genotypes with multiple resistance against *Phytophthora* and nematodes [2006-2009] [R. Suseela Bhai and Santhosh. J. Eapen]

Mega Project-9: Developing integrated pest and disease management strategies in spice crops [Project Leader: S. Devasahayam]

1. Path XVI (813): Etiology and management of rhizome rot complex in ginger and turmeric [2004-2009] [A. Kumar, R. Suseela Bhai, S.J. Eapen and K.N. Shiva]
2. Org. Chem. II (813): Characterization of bioactive compounds with pesticide properties [2002-2009] [N. K. Leela]
3. Biocontrol II. (813): Development of consortium of bioinoculants for management of pests, diseases and nematodes in spices [2004-2008] [M. N. Venugopal, S. Devasahayam, R. Suseela Bhai, Santhosh J. Eapen and A. Kumar]
4. Ent XII (813): Bioecology and integrated management of shoot borer *Conogethes punctiferalis* Guen. infesting turmeric [2005–2009] [S. Devasahayam and T. K. Jacob]
5. Hort V (813): Rootstock intervention to manage root infection of *Phytophthora* and nematodes in black pepper [2006-2009] [P. A. Mathew, R. Suseela Bhai and Santhosh. J. Eapen]
6. Path. XVII (813): Characterization, epidemiology and management of *Colletotrichum* spp. Infecting black pepper, cardamom and turmeric [2006-2009] [M. N. Venugopal and D. Prasath]

Mega Project-10: Economics, statistics and modeling [Project Leader: M. S. Madan]

1. Econ. III (813) : Remote sensing and GIS in evaluating the impact on socio-ecological changes on spices production

in Western Ghats region [2003-2008] [M. S. Madan and Utpala Parthasarathy]

Mega Project-11: Extension and training [Project Leader: P. Rajeev]

1. Ext. IV (813): Training of research and extension workers [2005-2010][P. Rajeev and T. K. Jacob]
2. Ext. VI (813): Agricultural Technology Information Centre [2004-2007] [P. Rajeev]
3. Ext. VII (813): A study on diffusion, adoption and impact of varieties released from IISR and scientific crop management practices [2006-2009] [Rajeev. P]

Mega project-12: Developing customized software and expert systems on spices [Project Leader: K. N. Kurup]

1. Stat. I (813): Development of databases and software [2004-2007] [P. Rajeev, Santhosh. J. Eapen and K. Jayarajan]

II. Externally Funded

i. Department of Biotechnology, New Delhi

1. DBT- SS 1: Distributed Information Sub-Centre (Bioinformatics Centre) [2000-2007] [Santhosh .J. Eapen]
2. DBT- CP 2: Endophytic bacteria for biological system management of *Radopholus similis*, the key nematode pest of black pepper (*Piper nigrum* L.) [2003-2008] [Santhosh J. Eapen, R. Ramakrishnan Nair and A. Kumar]
3. DBT- CP 1 (813): Molecular characterization of viruses causing stunted disease in black pepper and development of PCR based methodology for their detection [2003-2006] [A. Ishwara Bhat and R. Suseela Bhai]
4. DBT-CIB 2: Determination of purity of powdered market samples of major spices using PCR techniques, protein profiling and / or HPLC techniques. [2004-2007] [B. Sasikumar and B. Chempakam]
5. DBT- CIB 1: On farm evaluation of tissue culture derived black pepper plants [2002-2006] [K. Nirmal Babu, M. Anandaraj, V. Srinivasan and R. Ramakrishnan Nair]
6. DBT -CIB 3: Development of microsatellite markers and characterization of *Curcuma* spp [B. Sasikumar and T.E. Sheeja]
7. DBT-CP 3: Genetic transformation of black pepper to confer resistance against viruses [2006-09] [AI Bhat and R. Suseela Bhai]

***ii.* Indian Council of Agricultural Research, New Delhi**

1. ICAR-Ext-1: Central Sector Scheme: Technology mission for integrated development of NE states including Sikkim [2005-2008] [P.Rajeev]
2. ICAR – CP 3: Bioecology and integrated management of root mealybug (*Planococcus* sp.) infesting black pepper [2003-2006] [S. Devasahayam and M. Anandaraj]
3. ICAR-CP 2: Molecular characterization and maintenance of National Repository of *Phytophthora* [2004-2007] [M. Anandaraj, R. Suseela Bhai and A.I. Bhat]
4. ICAR–CP 1: Identification and development of diagnostics for the viruses causing stunted disease in black pepper [2003-2006] [A. Ishwara Bhat and R. Suseela Bhai]
5. ICAR- CPPHT- 5: Prevention and management of Mycotoxin contamination in commercially important Agricultural commodities [2004-2007] [B.Chembakam, M. Anandaraj, T. John Zachariah, N.K. Leela and E. Jayashree]
6. ICAR- CPPHT-2: Impact, Adaptation and Mitigation of Climate Change Effects on Growth and Productivity of Plantation Crops with Special Reference to Coconut and Black pepper. [2004 –2007] [Co-PIs- K.S. Krishnamurthy, K. Kandiannan and B.Chembakam, Main Centre- CPCRI, Kasaragod, Sub Centre- IISR, Calicut]
7. ICAR – CPPHT- 1: Network Project on Organic Farming [2004-2007] [V. Srinivasan, C. K. Thankamani, A. Kumar and T. John Zachariah]
8. ICAR-CPPHT- 3: Development of chilli (*Capsicum annuum* L.) hybrids for paprika (oleoresin) production [2004-2007] [T. John Zachariah and K. N. Shiva]

9. ICAR-CPPHT- 4: Chemical characterization of *Cinnamomum* germplasm [2005-2008] [N. K. Leela & J. Rema]
10. ICAR-CIB 2: Cloning of *Phytophthora* resistance and defense genes from *Piper colubrinum* [2004-2007] [Johnson George K and M. Anandaraj]
11. ICAR- CIB 1: Strengthening the cause of Geographical Indication of major spices using molecular, morphological and quality profiling techniques. [2004-2007] [B. Sasikumar and T. John Zachariah]
12. ICAR-CP4: Application of Microrganisms in Agriculture and Allied sectors: Nutrient management, Bio control and PGPR [2006-07] [M. Anandaraj, R. Dinesh and A. Kumar]

iii. Kerala State Council for Scieuce, Technology and Environment project

1. Kerala State Council for Science, Technology and Environment project: Production of white pepper through fermentation technology (KSCSTE- CPPHT-1) [2005-2008] [T. John Zachariah, A. Kumar and E. Jayashree]

iv. Indian Potash Limited

1. IPL - CPPHT 1: Evaluation of Sulphate of Potash (SOP) as Potassium Source on Growth, Yield and Quality of Black pepper [2004-2007] [K. Kandiannan and V. Srinivasan]

v. Ministry of Environment and Forest

1. MOEF. 1 (813) Biodiversity in *Piper* and *Garcinia* and Identification of spots of species richness in Western Ghats (Using GIS and molecular markers) [2006-2009] [P. A. Mathew, Utpala Parthasarathy, Johnson. K. George and K. V. Saji]

vi. National Horticultural Mission

1. NHM-CPPHT-1 : Production of planting materials of improved varieties of spice crops [2005-2010] C.K. Thankamani and S.J. Anke Gowda]

Personnel

HEADQUARTERS

I. SCIENTIFIC

Name and Designation

1. Dr. V.A. Parthasarathy, Director
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5. Mr. B. Krishnamoorthy, Principal Scientist (Plant Breeding)
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3. Mr. Azgar Sheriff P.,
Technical Officer (Lib.) (T7-8)
4. Dr. (Mrs.) Utpala Parthasarathy,
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5. Mr. M.M. Augusthy,
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6. Mr. K. Jayarajan,
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7. Mr. M. Vijayaraghavan,
Technical Officer (T5) (Workshop)
8. Mr. K.T. Muhammed,
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9. Mr. V. Sivaraman,
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IISR EXPERIMENTAL FARM, PERUVANNAMUZHI

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3. Mr. K. Kumaran,
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KVK TECHNICAL

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IISR CARDAMOM RESEARCH CENTRE, APPANGALA

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1. Dr. M.N. Venugopal,
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2. Dr. S.J. Anke Gowda,
Sr. Scientist (Plant Physiology)
3. Dr. R. Senthil Kumar,
Sr. Scientist (Horticulture)
4. Dr. D. Prasath,
Scientist (Sr. Scale) (Horticulture)

Weather data

Cardamom Research Center, Appangala, Kodagu District, Karnataka

Month	Maximum temperature (°C)	Minimum temperature (°C)	Rainfall (mm)	No. of rainy days
January	28.8	11.1	0.0	00
February	31.3	11.9	0.0	00
March	31.4	14.3	15.0	02
April	31.8	16.4	46.5	07
May	30.0	17.4	527.0	16
June	26.5	16.8	467.0	19
July	23.8	16.4	653.6	27
August	24.9	17.9	446.1	20
September	26.8	16.0	235.2	20
October	27.5	16.8	126.0	13
November	27.1	14.2	68.9	08
December	28.0	12.7	0.0	00

Indian Institute of Spices Research, Main Campus, Calicut, Kerala

Month	Maximum temperature (°C)	Minimum temperature (°C)	Rainfall (mm)	No. of rainy days
January	32.8	23.3	0.0	0
February	32.9	22.9	0.0	0
March	33.9	32.0	80.0	2
April	34.2	27.0	11.0	1
May	32.7	25.8	680.0	11
June	30.5	24.4	983.1	21
July	30.1	23.9	621.2	28
August	30.0	23.9	448.3	17
September	29.7	24.0	657.5	19
October	31.4	24.1	301.0	15
November	31.6	24.6	153.4	10
December	32.7	22.5	0.0	0

Indian Institute of Spices Research, Farm, Peruvannamuzhi, Kerala

Month	Maximum temperature (°C)	Minimum temperature (°C)	Rainfall (mm)	No. of rainy days
January	34.2	19.9	8.0	2
February	35.3	17.4	0.0	0
March	35.8	21.5	47.2	2
April	35.4	23.5	81.8	4
May	32.8	23.8	802.8	14
June	30.2	22.6	1240	24
July	28.7	22.7	1001.2	29
August	29.7	22.7	689.4	23
September	29.7	22.0	792.6	21
October	30.9	22.6	565.8	24
November	31.7	22.5	274.2	15
December	33.0	18.5	6.6	0

Abbreviations & Acronyms

AICRP	:	All India Coordinated Research Project on Spices
ARIS	:	Agricultural Research Information System
ASCI	:	Academic Staff College of India
ASTA	:	American Spices Testing Association
ATIC	:	Agricultural Technology Information System
BCMV	:	Bean Common Mosaic Virus
BLAST	:	*Basic Local Algorithm Search Tool*
CMV	:	Cucumber Mosaic Virus
CoD	:	Centre for Overall Development
CPCRI	:	Central Plantation Crops Research Institute
CP-gene	:	Coat Protein- gene
CV	:	Coefficient of Variation
CYT	:	*Comparative Yield Trial*
DAC-ELISA	:	*Direct* Antigen Coated-Enzyme Linked Immunosorbent Assay
DAS ELISA	:	Double Antibody Sandwich Enzyme Linked Immunosorbent Assay
DMRT	:	Duncan's Multiple Range Test
DOEACC	:	Department of Electronics for Accreditation of Computer Courses
FLD	:	Front Line Demonstration
FYM	:	Farmyard Manure
GC-MS	:	Gas Chromatography-Mass Spectrometry
GDD	:	Growing Degree Days
GIS	:	Geographical Information System
HCA	:	Hydroxy Citric Acid
HPLC	:	*High Performance Liquid Chromatography*
IARI	:	Indian Agricultural Research Institute
ICAR	:	Indian Council of Agricultural Research
ICBD	:	Indigenous Collection of Bydagi Dappi
IGNOU	:	Indira Gandhi National Open University
IIM	:	Indian Institute of Management
IISR	:	*Indian Institute of Spices Research*
IPC	:	International Pepper Community
IPGRI	:	International Plant Genetic Resources Institute
ISSR	:	Inter Simple Sequence Repeat
ISTM	:	Institute of Secretariat Training and Management
ITS	:	Internally Transcribed Spacer Region
KINFRA	:	Kerala State Industrial *Infrastructure* Development Corporation
KVK	:	*Krishi Vigyan Kendra*
MLT	:	*Multilocation Trial*
MoP	:	Muriate of Potash
NAARM	:	National Academy of Agricultural Research Management
NBPGR	:	National Bureau of *Plant Genetic Resources*
NCBI	:	National Centre for Biotechnology Information
OFT	:	Onfarm Trial
ORF	:	Open Reading Frame
PET	:	Preliminary Evaluation Trial
PYMoV	:	Piper Yellow Mottle Virus
RAC	:	*Research Advisory Committee*
RAPD	:	Random Amplified Polymorphic DNA
RCC	:	Reinforced Cement Concrete
rDNA	:	Ribosomal Deoxyribo Nucleic Acid
RFLP	:	Restriction Fragment Length Polymorphism
RRL	:	Regional Research Laboratory
RT-PCR	:	Reverse Transcription- Polymerase Chain Reaction
RWC	:	Relative Water Content
SCAR	:	Sequence Characterized Amplified Region
SD	:	Standard Deviation
SE	:	Standard Error
SoD	:	Super Oxide dismutase
SoP	:	Sulphate of Potash
SPSS	:	Statistical Package for Social Sciences
TC	:	Tissue Culture
TNAU	:	*Tamil Nadu Agricultural University*
VVV	:	Vikas Volunteer Vahini Club

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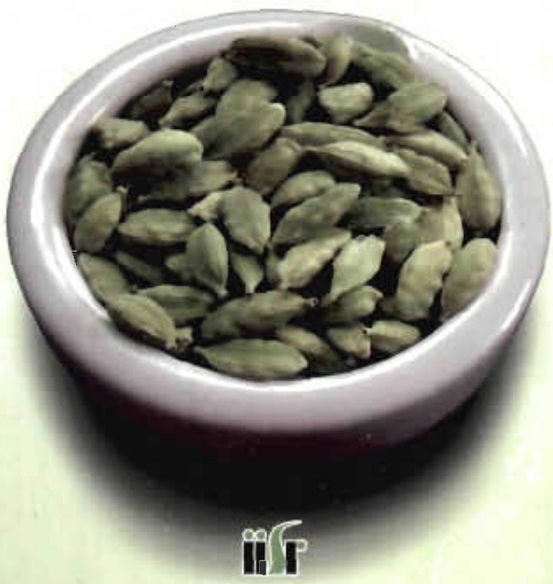

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