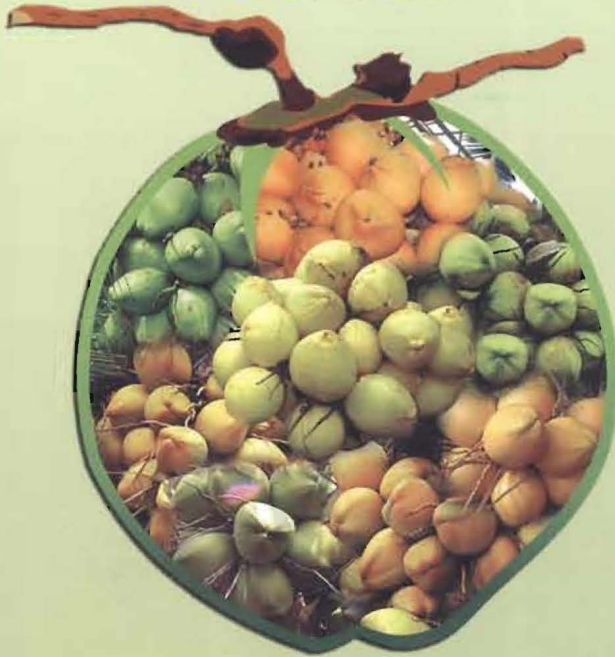




**International
Conference
Coconut Biodiversity
for Prosperity**

Abstracts



Organised at

Central Plantation Crops Research Institute
(Indian Council of Agricultural Research)

KASARAGOD 671 124, KERALA, INDIA



International Conference on Coconut Biodiversity for Prosperity

25-28 October, 2010

ABSTRACTS

Organised by

Central Plantation Crops Research Institute
Indian Council of Agricultural Research
Indian Society for Plantation Crops



In partnership with

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Indonesia



Coconut
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India



National Horticultural
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Confederation of
Horticultural
Association of India



Association
for the Improvement
in Production and
Utilization of Banana



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Bank for Agriculture
and Rural Development



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**International Conference on Coconut Biodiversity for Prosperity
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CONTENTS

TECHNICAL SESSION I

GLOBAL AND NATIONAL SCENARIO OF COCONUT BIODIVERSITY

Lead lecture

- | | | |
|--------------------------|---|----|
| TS1- I01 | Global production and trade scenario of coconut
<i>Romulo N. Arancon, Jr.</i> | 3 |
| TS1- I02 | Promoting multipurpose uses and competitiveness
of coconut sector
<i>Rethinam, P.</i> | 4 |
| TS1- I03 | Current coconut scenario in the Philippines
<i>Carlos B. Carpio</i> | 6 |
| TS1- I04 | Current coconut scenario in Sri Lanka
<i>Jayasekara, C.</i> | 7 |
| TS1- I05 | Current status and scenario of coconut biodiversity
in India
<i>George V. Thomas and Niral, V.</i> | 9 |
| TS1- I06 | The situation of coconut in Latin America and the Caribbean-
Concerns related to phytosanitary issues
<i>Alonso González</i> | 11 |
| TS1- I07 | Status and strategies for enhancing coconut production
in Andaman and Nicobar Islands
<i>Srivastava, R.C.</i> | 13 |
| Oral presentation | | |
| TS1-01 | The International coconut genebank for Africa and
Indian Ocean: Status and prospects
<i>Jean Louis Konan., Roland Bourdeix., Emmanuel August Issali.,
Kuassi Allou and Nicodème Zakra</i> | 15 |

Poster presentation

- | | | |
|----------|--|----|
| TS1-P01 | International coconut gene bank for South Asia - conservation and characterization
<i>Niral, V., Augustine Jerard, B., Samsudeen, K., Patil, D.V., Ananda, K.S., Nair, R.V. and George V. Thomas</i> | 16 |
| TS1- P02 | Exploration for diverse coconut types in Andaman & Nicobar Islands - A report on special coconut types
<i>Augustine Jerard, B., Damodaran, V., Niral, V. and Nair, R.V.</i> | 17 |
| TS1- P03 | Coconut biodiversity in north east region of India
<i>Acharya, G.C., Niral, V., Shakkira, T.K., Kavitha, K.V., Devakumar, K., Augustine Jerard, B., Samsudeen, K., Ray, A.K. and Nair, R.V.</i> | 18 |
| TS1-P04 | Exploration and collection of sweet endosperm coconut 'MOHACHA NARAL' from Maharashtra, India
<i>Samsudeen, K., Nagwekar, D.D., Anitha Karun, Niral, V., Jerard, B.A., Ajith Kumar, P, Devadas, K. and Nair, R.V.</i> | 19 |
| TS1-P05 | Morphological characterization and diversity among natural coconut population of Minicoy, Lakshadweep Islands, India
<i>Augustine Jerard, B., Regi J. Thomas, Rajesh, M.K., Niral, V. and Shanavas, M.</i> | 20 |
| TS1-P06 | Coconut biodiversity in Kanyakumari
<i>Richard Kennedy, R., Thangaselvabai, T., Suresh, S. and Prem Joshua, J.</i> | 21 |

TECHNICAL SESSION II

CONSERVATION AND UTILIZATION OF GENETIC RESOURCES

Lead lecture

- | | | |
|----------|---|----|
| TS2- I01 | Performance of coconut accessions in different agro-climatic regions
<i>Arulraj, S. and Jayabose, C.</i> | 25 |
|----------|---|----|

TS2- 102	Breeding strategies for higher productivity and tolerance to biotic and abiotic stress in coconut <i>Nair, R.V., Jerard, B.A., Niral, V. and Samsudeen, K.</i>	27
TS2- 103	Cryopreservation as a tool for coconut diversity conservation <i>Anitha Karun and Sajini, K.K.</i>	28
Oral presentation		
TS2- 01	Evaluation of coconut genetic resources for yield and seedling traits <i>Niral, V., Augustine Jerard, B., Samsudeen, K., Devadas, K., Kavitha and Nair, R.V.</i>	29
TS2- 02	Genetic uniformity studies on Kalpasree and Kalparaksha varieties of coconut using molecular and morphometric methods <i>Regi J. Thomas, Rajesh, M.K., Jacob, P. M., Mejosh Jose and Nair, R. V.</i>	30
Poster presentation		
TS2-P01	Genetic diversity in coconut germplasm based on morphological descriptors <i>Geethanjali, S., Kumar, M., Meenakshi Ganesan, N. and Rajamanickam, K.</i>	31
TS2- P02	A comparative study on the performance of some indigeneous and exotic coconut germplasm in alluvial plains of West Bengal <i>Ghosh, D. K. and Bandopadhyay, A.</i>	32
TS2-P03	Exploiting variability among dwarf populations of coconut collected from Pacific Ocean Islands <i>Damodaran, V., Singh, D.R., Sankaran, M., Srivastava, R.C., Jaisankar, I. and Jerard, B.A.</i>	33
TS2-P04	Utilization of Annur coconut for hybrid coconut production with desirable characters <i>Balakrishnan, P. C. and Jayaprakash Naik, B.</i>	34

TS2-P05	Performance of coconut hybrids and their parents under Gujarat conditions <i>Kapadiya, P.K., Valia, R.Z., Sarvaiya, R.B. and Kikani, K.P.</i>	35
TS2-P06	On farm genetic diversity in OP progenies and identification of pre-potent mother palms of Arsikere tall coconut cultivar and their characterization in the maidan tract of Karnataka <i>Indiresh, K.M., Basavaraju, T.B. and Umesha, K.</i>	35
TS2-P07	Evaluation of the promising genotypes of coconut and their prepotency at seedlings stage <i>Jayaprakash Naik, B. and Balakrishnan P.C.</i>	36
TS2-P08	Diversity studies in tender coconut <i>Ponnuswami, V. and Parameswari, C.</i>	37
TS2-P09	Performance evaluation of coconut cultivars under rain fed conditions <i>Lissamma Joseph., Anitha, S. and Aravindakshan, K.</i>	38
TS2-P10	Character association and path coefficient studies in coconut (<i>Cocos nucifera</i> L.) <i>Valia, R. Z., Patil, V. K., Kapadia, P.K. and Patel, R.K.</i>	38
TS2-P11	Evaluation of genetic diversity in coconut (<i>Cocos nucifera</i> L.) <i>Acharya, G.C., Chetia, M., Nath, A., Chakrabarty, R., Niral, V. and Ray, A.K.</i>	39
TS2-P12	An assessment of floral diversity in the homestead farms of Kerala, India <i>Krishnakumar V., Regeena, S., Jacob John., Geetha, K. and Reddy, D.V.S.</i>	40
TS2-P13	Stability analysis for yield and yield components in coconut (<i>Cocos nucifera</i>) <i>Natarajan, C., Ganesamurthy, K., Kavitha, M. and Arulraj, S.</i>	41
TS2-P14	Application of spatial technique in field experiments with coconut <i>Jose, C.T. and Ananda, K.S.</i>	42

- TS2- P15 Identification of cold tolerant coconut germplasm in Bastar 42
Agrawal, S., Verma, L.S. and Rao, S.S.
- TS2- P16 Morphometric characterization and diversity analysis 43
of a makapuno coconut population in U.P. Los Baños
*Md. Nazirul Islam., Leon O. Namuco., Teresita H. Borromeo.,
Maria Lourdes O. Cedo. and Edna A. Aguilar*

Plenary lecture

- TS2 PL Biodiversity in the coconut: Implications of biodiversity 44
Nayar, N. M., Regi Thomas, and Jacob, P. M.

**TECHNICAL SESSION III
BIOTECHNOLOGICAL TOOLS IN CROP IMPROVEMENT**

Lead lecture

- TS3- I01 The development of an efficient process for the 47
micropropagation of coconut
*Carlos Oropeza., José Luis Chan., Daniel Zizumbo.,
Nelson Torres and Luis Sáenz*
- TS3- I02 Functional genomics in insect-plant interactions 48
Omprakash Mittapalli

Oral presentation

- TS3-01 Use of arabinogalactan proteins in coconut 49
(*Cocos nucifera* L.) tissue culture: an alternative
approach for improved tissue response
*Fernando, S.C., Samarajeewa, D.A.D.S. and Liyanagedara,
L.G.N.H.K.*
- TS3-02 Genetic relatedness of coconut populations from Andaman 50
and Nicobar Islands traced to the Indian sub continent
using microsatellite markers
*Deva Kumar, K., Naganeeswaran, S., Jerard, B. A.,
Dhanapal, R., Damodaran, V. and Niral, V.*

TS3-03	Evaluation of ten Sri Lankan coconut phenotypes for variation at microsatellite marker loci and fruit morphology	51
	<i>Perera, S.A.C.N., Ekanayake, G.K., Dassanayake, P.N., Everard, J.M.D.T.</i>	
Poster presentation		
TS3- P01	Development of Real-time PCR technique based on SYBR Green Chemistry for detection of coconut root (wilt) phytoplasma	52
	<i>Manimekalai, R., Smita Nair, Soumya, V.P. and George V. Thomas</i>	
TS3- P02	Differential expression of genes regulated in response to water stress in coconut	53
	<i>Bobby Paul, Rajesh, M.K, Kiran, A.G., George V Thomas and Naresh Kumar, S.</i>	
TS3-P03	Analysis of coconut (<i>Cocos nucifera</i> L.) diversity using microsatellite markers	54
	<i>Aslin Joshi, J., Krishnasamy, V., Kumaravadivel, N., Kumar, M., Rajarathinam, S. and Vijayalakshmi, C.</i>	
TS3-P04	Effect of various auxins on high frequency callus induction from coconut plumule explants	55
	<i>Anitha Karun., Bhavyashree, U., Lakshmi Jayaraj, K., Fayas, T.P., Rajamanickam, R., Sajini K.K and Radha, E.</i>	
TS3-P05	Modified pregrowth desiccation for cryopreservation of coconut zygotic embryos	56
	<i>Sajini, K.K. and Anitha Karun</i>	
TS3-P06	Polyamine-induced plantlet regeneration from plumular explants of dwarf cultivars of coconut	56
	<i>Rajesh, M.K., Radha, E., Sajini K.K. and Anitha Karun</i>	
TS3-P07	Effect of gamma irradiation on coconut zygotic embryos - a preliminary study	57
	<i>Jayabose, C., Shreesha Sooraj, Sajini, K.K. and Anitha Karun</i>	

TS3-P08	A fast and versatile molecular tool for detection of root (wilt) phytoplasma in coconut palms <i>Ramjegathesh, R., Karthikeyan, G., Meena, B., Raguchander, T., and Samiyappan, R.</i>	58
TS3-P09	Molecular and morphological diversity of "Komadan" from other popular coconut cultivars <i>Selvaraju, S. and Jayalekshmy, V.G.</i>	59

**TECHNICAL SESSION IV
BIOINFORMATICS APPLICATIONS**

Lead lecture

TS4- I01	Molecular marker database for coconut germplasm management <i>Luc Baudouin and Chantal Hamelin</i>	63
TS4-I02	Locating and mapping coconut genetic diversity <i>Mathur, P.N.</i>	64
TS4- I03	Development of bioinformatics tools and resources for coconut research <i>Manimekalai, R., Arunachalam, V., Rajesh, M.K., Devakumar, K. and George V. Thomas</i>	65

Oral presentation

TS4-01	Alternate genetics and genomics of coconut <i>Arunachalam, V., Jerard, B.A., Manju, K.P. and Niral, V.</i>	66
TS4- 02	Somatic embryogenesis receptor kinase in coconut - isolation, characterization and homology modelling <i>Rajesh, M.K., Bobby Paul, Sreesmitha, V., Santhi, S., Nitya, S. and Anitha Karun</i>	67
TS4-03	A comparative study of coconut area of coastal and inland riverine ecosystem with satellite imagery <i>Utpala Parthasarathy., Parthasarathy, V.A. and Kumaran, P.M.</i>	68

Poster presentation

- | | | |
|----------|---|----|
| TS4-P01 | Comparative approach on genome and proteome of four different strains of phytoplasma
<i>Manimekalai, R., Lijin K.G., Roshna, O.M., Sathiskumar, R. and George V. Thomas.</i> | 69 |
| TS4-P02 | Bioinformatic mining for markers in WRKY sequences of palms
<i>Manju, K.P. and Arunachalam, V.</i> | 70 |
| TS4-P03 | Collection of coconut diseases databases and bioinformatics resources in Coimbatore region
<i>Hari Prasath, B.</i> | 70 |
| TS4-P04 | Bioinformatics approach towards mining of candidate genes for water stress in coconut
<i>Bobby Paul and Rajesh, M.K.</i> | 71 |
| TS4- P05 | <i>In silico</i> prediction of properties of Knox and baby boom proteins in coconut
<i>Nithya, S., Rajesh M.K., Bobby Paul and Anitha Karun</i> | 72 |

TECHNICAL SESSION V

RESOURCE MANAGEMENT AND SUSTAINABLE PRODUCTION

Lead lecture

- | | | |
|----------|--|----|
| TS5- I01 | Achieving higher resource use efficiency and productivity in coconut through drip fertigation
<i>Dhanapal, R.</i> | 75 |
| TS5- I02 | Precision Farming in Coconut
<i>Palaniswami, C., Muralidharan, K., Subramanian, P., Ravikumar, N. and Niral, V.</i> | 76 |

Oral presentation

- | | | |
|---------|---|----|
| TS5- O1 | Annual macronutrient removal by typica x typica coconut palms in a low potential lands in Sri Lanka
<i>Wijebandara, D.M.D.I.</i> | 77 |
|---------|---|----|

TS5- 02	Coconut biodiversity and need for careful management of the biota <i>Napoleon O. Aisueni</i>	78
TS5- 03	A holistic systems approach to identify sustainable perennial crop based systems - a case study <i>Jacob John., Joy, M., Geetha, V. and Sheeba, U.</i>	79
TS5- 04	Yield and quality attributes of black pepper (<i>Piper nigrum</i> L.) varieties/hybrids when grown as mixed crop in coconut garden <i>Maheswarappa, H.P., Srinivasa Reddy, D.V., Krishnakumar, V., Zachariah, T.J. and Dhanapal, R.</i>	80
TS5- 05	Coconut based integrated farming system approach towards effective resource management and sustainable production <i>Subramanian, P., Dhanapal, R., Alka Gupta, Palnaiswami, C., Vidhan Singh, T. and George V. Thomas</i>	82
TS5-06	Plant growth promoting potential of <i>Serratia marcescens</i> KiS II and <i>Enterobacter cloacae</i> RNF 267 isolated from the rhizosphere of coconut palm (<i>Cocos nucifera</i> L.) <i>Priya George., Alka Gupta., Murali Gopal., Litty Thomas, and George V. Thomas</i>	83
Poster presentation		
TS5-P01	Multispecies cropping system in coconut garden of East Coast Region <i>Subramaniam, P.S., Mohandas, S., Marimuthu, R., Gurusamy, A., Natarajan, C. and Arulraj, S.</i>	84
TS5-P02	Integrated nutrient management in ECT coconut through organics <i>Mohandas, S., Subramaniam, P.S., Gurusamy, A., Natarajan, C. and Arulraj, S.</i>	85
TS5-P03	Effect of phosphorus status of major coconut growing soils of Sri Lanka on growth parameters and root nodulation of leguminous cover crop <i>Wijebandara, D.M.D.I.</i>	85

TS5-P04	Second generation coconut based high density multispecies cropping system in Assam <i>Nath, J.C. and Deka, K.K.</i>	86
TS5-P05	Nutritional requirement of hybrid (T x D) coconut with 50% N substitution through organic manure <i>Mohandas, S., Subramaniam, P.S., Gurusamy, A., Natarajan, C. and Arulraj, S.</i>	87
TS5-P06	Prospects of intercropping medicinal and aromatic plants in coconut <i>Mohandas. S., Subramaniam, P.S., Natarajan, C. and Arulraj, S.</i>	87
TS5-P07	Role of green manuring and integrated nutrient management in increasing potentiality of coconut palms <i>Basavanagowda, M.G., Mallikarjuna, B.O., and Devaraja, T.N.</i>	88
TS5-P08	Performance of medicinal and aromatic plants as intercrops in coconut gardens <i>Rajakumar, D., Sathyamoorthy, K. and Rajamanickam, K.</i>	89
TS5-P09	Intercropping with fruits and annual spices in coconut under Konkan condition of Maharashtra <i>Nagwekar, D.D., Desai, V.S., Sawant, V.S., Haldankar, P.M., Arulraj, S. and Jadhav, B.B.</i>	89
TS5-P10	In search of bioinoculants for coconut palm <i>Sheeja Purushothaman, Sunny Thomas and Mathew George</i>	90
TS5-P11	Performance of elite cocoa clones intercropped in coconut <i>Elain Apshara, S.</i>	91
TS5-P12	Integration of meat goats on the productivity of coconut farm <i>Anitha, S., Lissamma Joseph and Aravindakshan, K.</i>	92
TS5-P13	Organic manure production from tender coconut waste <i>Kalpna, M., Ramakrishna, Y., and Gautam, B.</i>	92

TS5-P14	Effect of storage of coconut leaf vermicompost on its microbial and nutrient status <i>Murali Gopal, Alka Gupta and George V. Thomas</i>	93
TS5-P15	Nutrient management in coconut garden through organic manures <i>Valu, M.G., Kapadiya, P.K. and Valia, M.J.</i>	94
TS5-P16	Benefit cost ratio analysis of coconut based cropping systems <i>Girija Devi, L., Gladis R. and Biju Joseph</i>	95
TS5-P17	Yield, physiological and nutritional status as influenced by soil salinity of coconut (<i>Cocos nucifera</i> L.) <i>Valia, R.Z., Patil, V.K., Kapadia, P.K. and Patel, R.K.</i>	96
TS5-P18	Intercropping in coconut for higher production and profit <i>Thangaselvabai, T., Richard Kennedy, R., Suresh, S. and Eraivan, K.</i>	97
TS5-P19	Suitability evaluation of upland rice varieties in coconut based homesteads for food security <i>Ameena, M. and Moossa, P.P.</i>	98
TS5-P20	Effect of coconut tonic on coconut palms in Davanagere district <i>Basavanagowda, M.G., Pradeep, H.M., and Devaraja, T.N.</i>	99
TS5-P21	Utilization of coconut by products for cultivation of oyster mushrooms <i>Lulu Das and Deepa Rani, C.V.</i>	99
TS5-P22	Improving use efficiency of water by integrating fish culture and irrigation in coconut based farming system- A case study <i>Mathew, A.C. and Manoj P. Samuel</i>	100
TS5- P23	Impact of soil management measures on pineapple grown as intercrop in coconut under coastal littoral sandy soil <i>Subramanian, P., Dhanapal, R., Alka Gupta and Palaniswami, C.</i>	100
TS5 -P24	Development of value added products and applications for coir pith <i>Balakrishnan, P.</i>	102

TS5- P25	Screening and evaluation of phosphate solubilizers from diverse group of bacteria isolated from rhizosphere and roots of coconut palms (<i>Cocos nucifera</i> L.) growing in different states of India <i>Priya George., Alka Gupta., Murali Gopal., Litty Thomas and George V. Thomas</i>	103
TS5- P26	Mycorrhizal and other microbial association with coconut palms of Minicoy, Kalpeni and Kavaratti Islands of Lakshadweep Island <i>Viji, M.V., George V. Thomas., Ambili, K., Alka Gupta and Murali Gopal</i>	104
TS5- P27	Effective utilization of bioresources for yield improvement in <i>Plumbago rosea</i> intercropped in coconut garden <i>Nihad, K., Jessykutty, P.C. and Sivaprasad, P.</i>	105
TS5- P28	Coconut based cropping system for Bastar plateau zone of Chhattisgarh <i>Verma, L.S., Agrawal, S., Thakur, A.K. and Rao, S.S.</i>	106
TS5-P29	Use of bio-fertilizers in the production of black pepper (<i>Piper nigrum</i> L.) in mixed cropping system <i>Nagesh Naik, H., Lokesh, M.S. and Hegde, H.G.</i>	107

TECHNICAL SESSION VI
CLIMATE CHANGE - ADAPTATION AND MITIGATION

Lead lecture

TS6- I01	Impact of climate change and adaptation strategies in coconut <i>Kasturi Bai, K.V.</i>	111
TS6-I02	Carbon sequestration in coconut plantations <i>Ranasinghe, C.S. and Thimothias, K.S.H.</i>	112
TS6- I03	Coconut-based farming systems as potential carbon “sinks” in meeting the challenges of climate change <i>Severino, S. Magat</i>	113

Oral presentation

- TS6-01 Crop diversification with tropical tuber crops for food security under changing global climate 114
Ravindran, C.S., Suja, G., Nedunchezhiyan, M. and Naskar, S.K.
- TS6-02 Potential of coconut plantations in mitigating climate change 115
Ranasinghe, C. S. and Thimothias, K. S. H.

Poster presentation

- TS6-P01 Pest outbreak surges in coconut and climate change 116
Ambrosio Raul R. Alfiler
- TS6-P02 Development of water stress tolerant coconut hybrids through selective fertilisation 116
Roy Stephen., Jayaprakash Naik, B. and Manju, R.V.
- TS6-P03 Superoxide Dismutase isozymes and their heat stability in coconut (*Cocos nucifera* L.) leaves 117
Mukesh kumar., Sugatha, P., Muralikrishana, K.S. and John Sunoj, V.S.
- TS6-P04 Pollen selection for assessing the water stress tolerance in coconut 117
Roy Stephen

TECHNICAL SESSION VII

INTEGRATED PEST MANAGEMENT AND EMERGING PESTS

Lead lecture

- TS7- I01 Bio-intensive pest management on key pests of coconut 121
Rajan, P.
- TS7- I02 Approaches and advances in eriophyid mite management in coconut 122
Fernando, L.C.P., Aratchige, N.S. and Kumara, A.D.N.T.

Oral presentation

- TS7-01 Natural enemy complex associated with coconut eriophyid mite, *Aceria guerreronis* Keifer 124
Chandrika Mohan, Rajan, P. and Nair, C.P.R.

TS7- 02	Antibiosis resistance to coconut black headed caterpillar, <i>Opisina arenosella</i> Walker in coconut genotypes <i>Sujatha, A., Emmanuel, N., Gautam, B. and Arulraj, S.</i>	125
TS7-03	Effect of sub lethal dose of insecticides on electrophysiological and behavioural response of <i>Bracon brevicornis</i> Wesmael a parasitoid of coconut black headed caterpillar, <i>Opisina arenosella</i> <i>Subaharan, K., Charles Sahayaraj., Roshan James and Ravikumar, N.</i>	126
TS7-04	Modulation of certain lysosomal enzymes in <i>Proutista moesta</i> (Westwood) fed on coconut palms with root (wilt) disease <i>Josephraj Kumar, A. and Rajan, P.</i>	127
Poster presentation		
TS7-P01	Prevalence of rhinoceros beetle (<i>Oryctes rhinoceros</i>) and coconut stick insect (<i>Graeffea crouanii</i>) and their management in the Fiji islands <i>Aradhana Devi Deesh, Bal Narayan Swamy and Losalini Leweniqila</i>	128
TS7-P02	Biology of coreid bug, <i>Paradasynus rostratus</i> Dist. in different hosts <i>Ambily Paul and Nandakumar, C.</i>	129
TS7-P03	Evaluation of four aggregation pheromone lures against red weevil in Pollachi tract of Tamil Nadu <i>Rajamanickan, K., Meena, B., Sathyamoorthi, K. and Kumar, M.</i>	130
TS7-P04	Integrated management of black headed caterpillar in coconut <i>Basavanagowda, M.G., Prasanna Kumara, N. and Devaraja, T.N.</i>	131
TS7-P05	Design of an ecologically- based IPM programme against coconut slug caterpillar (<i>Macroleptetra nararia</i> Moore) in coastal districts of Andhra Pradesh <i>Sujatha, A., Emmanuel, N., Gautam, B. and Arulraj, S.</i>	131
TS7-P06	Reaction of different coconut genotypes against Eriophyid mite (<i>Aceria gueronis</i>) in Konkan region of Maharashtra <i>Gurav, S.S., Desai, V.S., Nagwekar, D.D. and Narangalkar, A.L.</i>	132
TS7-P07	Integrated management of eriophyid mite in coconut <i>Basavanagowda, M.G., Pradeep, H.M. and Devaraja, T.N.</i>	133

TS7-P08	Survey on natural occurrence of entomopathogenic fungi associated with coconut slug caterpillar (<i>Macroleptera nararia</i> Moore) and field evaluation of <i>Beauveria bassiana</i> <i>Sujatha, A., Naga Lakshmi, T., Gautam, B. and Arulraj, S.</i>	133
TS7-P09	Emerging pests of coconut in India <i>Rajan, P., Josephraj Kumar, A., Chandrika Mohan and Subaharan, K.</i>	134
TS7-P10	Survey and monitoring of Eriophyid mite, <i>Aceria guereronis</i> Keifer of coconut in Konkan region of Maharashtra <i>Gurav, S.S., Desai, V.S., Bhangre, B.N., Nagwekar, D.D. and Narangalkar, A.L.</i>	135
TS7-P11	Survey and monitoring of pest problems of coconut in Konkan region of Maharashtra <i>Gurav, S.S., Desai, V.S., Bhangre, B.N., Nagwekar, D.D. and Narangalkar, A.L.</i>	135
TS7-P12	User-friendly rodent management techniques in coconut plantations - A frontline demonstration in Thrissur District, Kerala <i>Jim Thomas., Mani Chellappan and Haseena Bhaskar</i>	136
TS7-P13	Residues of monocrotophos in coconut water and kernel <i>Chandrasedkaran, S., Ramaraju, K. and Rajamanickam, K.</i>	137

**TECHNICAL SESSION VII
INTEGRATED DISEASE MANAGEMENT**

Lead lecture

TS8- I01	Biopriming of planting materials with PGPR and induced systemic resistance <i>Anandaraj, M.</i>	141
TS8- I02	Exploitation of host plant resistance in the management of coconut root (wilt) disease <i>Jacob, P.M., Regi J. Thomas and Nair, R. V.</i>	143
TS8- I03	Integrated management of fungal diseases of coconut in India <i>ChandraMohan, R.</i>	144

Oral presentation

- TS8- 01 Detection of Weligama coconut leaf wilt disease in Sri Lanka by polymerase chain reaction 146
Perera, L., Meegahakumbura, M.K., Wijesekara, H.R.T., Kalani, N.G.A., Munasinghe, C.E., Fernando, W.B.S. and Dickinson, M.J.
- TS8 -02 Mass production and use of biocontrol agents in the integrated management of coconut leaf rot disease - technology popularization through participatory programmes in disease affected regions 147
Srinivasan, N., ChandraMohanana, R., Bharathi, R., Radhika, N.S. and Shanty Issak
- TS8- 03 Epidemiological and pathological studies on Weligama coconut leaf wilt disease 148
Wijesekara, H.T.R., Nainanayaka, A., Waidyaratne, P., Subhathma, W.G.R., Weerakkody, T. and Hettiarachchi, D.
- TS8- 04 Comparison of superoxide dismutase, succinic dehydrogenase, exochitinase and 1,4- β -glucanase activities between healthy and root (wilt) disease affected palms of two coconut cultivars 149
Chaturvedi, V.K., Srinivasan, N., Sasikala, M., Jacob, P.M., Rajeev, G., Rincy Susan, C., Monisha, M. and Jisha, M.S.
- TS8- 05 Evaluation of genetic diversity among isolates of *Ganoderma* spp. infecting coconut palms using RAMS and RAPD markers 150
Naga Lakshmi, T., Siva Raj, K. and Gautam, B.

Poster presentation

- TS8-P01 The degree of resistance of various coconut varieties to the lethal yellowing diseases in Nigeria 150
Odehale, J. O., Nair, R.V. and Odiowaya, G.
- TS8-P02 Effect of *Pseudomonas fluorescens* and *Trichoderma viride* in the management of basal stem rot disease in coconut 151
Rajappan, K., Surulirajan, M., Natarajan, C. and Arulraj, S.

TS8-P03	Management of stem bleeding disease in coconut with botanicals <i>Yamini Varma, C.K.</i>	152
TS8-P04	Biological management of basal stem rot disease of coconut <i>Rajendran, L., Karthikeyan, G., Raguchander, T. and Samiyappan, R.</i>	152
TS8-P05	Survival of basal stem rot resistant coconut genotype in hot spot location of Karaikal Dt., Puducherry <i>Rettinassababady, C. and Padmanaban, D.</i>	153
TS8-P06	Status of coconut diseases in Andaman and Nicobar Islands <i>Krishna Kumar, Manivannan, S.P, Someshwar Bhagat, Ajanta Birah and Srivastava, R.C.</i>	154
TS8-P07	Current status of the Weligama coconut leaf wilt disease in Sri Lanka <i>Jayasekara, C.</i>	155
TS8- P08	Evaluation of spatial and seasonal variation of phytoplasma associated with coconut root (wilt) disease through polymerase chain reaction <i>Manimekalai, R., Soumya, V.P. and Smita Nair</i>	155
TS8- P09	Stem bleeding of coconut in Assam: Incidence and management <i>Chakrabarty, R., Acharya, G.C. and Ray, A.K.</i>	156
TS8- P10	Phytophthora foot rot (<i>Phytophthora capsici</i> Leonian.) of black pepper management through fungi toxicant and consortium in Western Ghats of Karnataka <i>Lokesh, M. S., Nagesh Naik, Suryanarayana, V. and Basavaraj, N.</i>	157
TS8- P11	Rhizome rot complex of ginger (<i>Zingiber officinale</i> Rosc.) management in Uttara Kannada dist. of Western Ghats of Karnataka <i>Lokesh, M. S., Nagesh Naik Suryanarayana, V., Ravikumar, M. R. and Basavaraj, N.</i>	158

TECHNICAL SESSION IX
POST HARVEST TECHNOLOGY AND VALUE ADDITION

Lead lecture

- TS9- 101 Status and challenges of post harvest processing and value addition in coconut 161
Madhavan, K. and Arumuganathan, T.
- TS9- 102 Nutritional and medicinal value of virgin coconut oil 162
Bawa, A.S.
- TS9-103 Recent advances in the development of value added products from coconut 162
Raju, P.S., Chauhan, O.P., Archana, B.S., Singh Asha., Roopa, N. and Bawa, A.S.

Oral presentation

- TS9-01 Development and performance evaluation of virgin coconut oil cooker 164
Mathew, A.C., Madhavan, K. and Arumuganathan, T.
- TS9-02 Development of novel machines for coconut fibre extraction and segregation for diversified textile applications - A NAIP intervention 165
Chattopadhyay, S.K., Bharimalla, A.K., Bindu Venugopal, Vinod Kadam and Upadhye, D.L.
- TS9-03 Effect of die temperature on properties of cassava and coconut powder extrudates 166
Thajudhin Sheriff, J., Vidhan Singh, T., Sajeev, M.S. and Padmaja, G.
- TS9- 04 Scope for the use of coconut shells in high rate anaerobic bioreactors 166
Joe, L, Bovas, Mary Regina, F., Kamaraj, S. and Shaji James

Poster presentation

- TS9-P01 Studies on post harvest mycoflora of coconut and its management 167
Johnson, I., Meena, B. and Rajamanickam, K.

TS9-P02	Process standardization for production of virgin coconut oil by fermentation method <i>Madhavan, K., Mathew, A.C. and Arumuganathan, T.</i>	168
TS9-P03	Drying kinetics of heat pump dried coconut haustorium <i>Arumuganathan, T., Madhavan, K., Mathew, A.C., Vidhan Singh, T. and Thirupathi, V.</i>	169
TS9-P04	Development of a copra dryer suitable for small scale processing units <i>Vidhan Singh, T.</i>	170

TECHNICAL SESSION X
TECHNOLOGY TRANSFER AND IMPACT OF
DEVELOPMENTAL STRATEGIES

Lead lecture

TS10-I01	Promoting bio-diversity and by-product utilization in coconut for inclusive and sustainable growth <i>Thomas Mathew, M.</i>	173
TS10-I02	Technology delivery mechanism in coconut through Krishi Vigyan Kendras <i>Prabhu Kumar, S., Sairam, C.V., Rayudu, B.T. and Reddy, D.V.S.</i>	174
TS10-I03	Extension approaches and strategies to enhance technology utilization and income generation in coconut farming <i>Thamban, C.</i>	175

Oral presentation

TS10-O1	Diversification for enhancing livelihood security of marginal coconut farmers: Experiences from major coconut growing countries <i>Kalavathi, S., Erlene Manohar., Peyanoote Naka., Vo Van Long., Krishnakumar, V., Thomas, R.J., George V. Thomas and Maria Luz George</i>	177
---------	--	-----

TS10-O2	Trade liberalization, regional trade agreements and commodity crisis: the case of Indian coconut sector <i>Jayasekhar, S., Radhika, C., Thamban, C. and Muralidharan, K.</i>	178
Poster presentation		
TS10-P01	Women empowerment through coconut based micro enterprises - Reflections from Kerala <i>Thamban, C., Jayasekhar, S. and Muralidharan, K.</i>	179
TS10-P02	Sustainable coconut farming in Kanyakumari district- a case study <i>Thangaselvabai, T., Sudha, K.R., Bhuvanewari, S.S.B. and Eraivan, K.</i>	180
TS10-P03	Bio control of rhinoceros beetle in coconut - participatory adaptation of low input multiplication of <i>Metarhizium</i> fungus and bridging adoption gap <i>Anithakumari, P. and Chandrika Mohan</i>	181
TS10-P04	Role of tribal women in agrobiodiversity conservation <i>Srivarva Buddhi Bhuvanewari, S., Athimuthu, P., Ponnusamy, K.A., Raveendaran, N. and Thangaselvaboy, T.</i>	182
TS10-P05	A constructive model for agro biodiversity conservation <i>Srivarva Buddhi Bhuvanewari, S., Athimuthu, P., Ponnusamy, K.A. and Raveendaran, N.</i>	183
TS10-P06	Establishment coconut nursery (var. West Coast Tall) in drought prone area of Namakkal district <i>Mohan, B., Daisy, M., Alagudurai, S. and Sharmila Bharathi, C.S.</i>	184
TS10- P07	Information and communication technology for disseminating coconut cultivation technologies <i>Ravi Kumar, N., Muralidharan, K., Thamban, C., Amarnath, C.H. and Arulraj, S.</i>	185
TS10-P08	Coconut economy of India - challenges and prospects over other oilseeds <i>Jaison. V. Joseph</i>	186

TS10-P09	Issues on farmer led community nursery in coconut bio-diversity <i>Sairam, C.V., Prabhu Kumar, S., Reddy, D.V.S. and Rayudu, B.T.</i>	187
TS10- P10	Impact of training programmes on adoption of vermicomposting technology utilizing palm wastes, among farmers of Kasaragod district, Kerala <i>Rayudu, B.T., Leena S., Manikandan, K., Sanal Kumar, R., Jayashree, M.P. and Manojkumar, T.S.</i>	188
TS10- P11	Integrated watershed development model for sustainability of coconut based production system <i>Manojkumar, T. S., Manikandan, K., Shoba, S. and Jayashre, M.P.</i>	189
TS10- P12	Participatory evaluation of women friendly plant protection measures in banana, a major intercrop in coconut gardens <i>Sivakumar, T., Anithakumari, P. and Muralidharan, P.</i>	190
TS10- P13	Trend analysis and forecasting of coconut production in Assam <i>Shil Sandip., Acharya, G.C. and Paul, S.C.</i>	191

WORKSHOP I COCONUT AND HEALTH

WS1-01	Coconut Oil; its Health Aspects <i>Vasudevan, D.M.</i>	195
WS1-02	Technologies for value addition of coconut inflorescence sap - the untapped health food <i>Giridharan, M.P., Abdul Kareem, K. and Naik, B.J.</i>	196
WS1-03	Modulation of chemically induced diabetes by virgin coconut oil <i>Farhath Khanum and Siddalinga Swamy, M.</i>	197
WS1-04	Coconut oil - Facts and Fallacies <i>Chempakam, B.</i>	198

WS1-05	Production of vegetable oil blends with coconut oil for improving stability and health	199
--------	--	-----

Gopala Krishna, A.G., Bhatnagar, A.S., Prasanth Kumar, P.K., Indira, T.N., Subramanian, R. and Indiramma, A.R.

WS1-06	Nutritional aspects of value-added coconut products	200
--------	---	-----

Arumuganathan, T., Madhavan, K. and Mathew, A.C.

WORKSHOP II ORGANIC FARMING IN COCONUT

WS2-01	Oil base formulation of biocontrol agents, biopesticides and biofertilizers	203
--------	---	-----

Krishan Chandra

WS2-02	Farmer's experience in organic farming in coconut	204
--------	---	-----

Madhu Ramakrishnan

WS2-03	Organic farming: Standards, certification for organic farming	205
--------	---	-----

Mathew Sebastian

WORKSHOP III WILT DISEASES OF PALMS

WS3-01	Recent advances in the study of coconut lethal yellowing disease in the Americas	209
--------	--	-----

Carlos Oropeza., Wayne Myrie., María Mercedes Roca., Estela Aguilar., Luis Sáenz., Maria Narvaez., Ivan Cordova., Ramón Castillo., Carlos F. Ortiz., Daniel Zizumbo., Michel Dollet., Jean-Luc Dzido and Nigel Harrison

WS3-02	Serological detection of phytoplasma associated with coconut (root) wilt disease	210
--------	--	-----

Solomon, J.J.

WS3-03	Diagnostics of phytoplasma - Electron microscopy and staining techniques	211
--------	--	-----

Krishna Reddy, M., Samuel, D.K., Manasa, M., Balasubramanian, S. and Jalali, S.

WS3-04	Phytoplasma detection in coconut palm using conventional and real-time PCR <i>Nejat, N., Sijam, K., Abdullah, S.N.A., Vadamalai, G. and Dickinson, M.</i>	212
WS3-05	Phytoplasma diagnostics - Nanotechnological approaches <i>Makeshkumar, T.</i>	213
WS3-06	Insect transmission of root (wilt) disease of coconut <i>Rajan, P., Nair, C.P.R. and Solomon, J.J.</i>	214
WS3-07	Management strategies for root (wilt) disease of coconut <i>Krishnakumar, V.</i>	215
WS3-08	Characterization of phytoplasma infecting spice crops <i>Bhat, A.I.</i>	217

TECHNICAL SESSION I

**GLOBAL AND NATIONAL SCENARIO OF
COCONUT BIODIVERSITY**



Lead lecture

TS1- I01

Global production and trade scenario of coconut

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Coconut is grown globally over an area of 12.29 million hectares producing 11.04 million MT (copra equivalent) in 93 countries in the world. The 17 member countries of the Asian and Pacific Coconut Community (APCC) account for a major share of area and production occupying 10.7 million ha (87%) and 9.2 million MT of copra equivalent (83%). In copra equivalent terms, Indonesia, Philippines and India are the major producers of coconut in the world.

Globally, the area and productivity of coconut has remained almost at the same level during of past five years (2004-2009). However, there has been an increase in nut production in some APCC member countries as a result of the government's coconut replanting and rehabilitation programs including intercropping and other good agricultural practices involving low cost input management strategies. The major coconut products traded in the world market are coconut oil, desiccated coconut, coconut milk, coconut cream and coconut milk powder, coconut shell charcoal, activated carbon, coir and coir products. The emerging non-traditional coconut products include tender coconut water as sports drink, virgin coconut oil (VCO), coconut flour and oleochemicals. *Nata de coco*, coconut vinegar, coconut sugar, and coconut syrup based products have also entered the international market.

The value added products and by-products that were traded globally in the last five years showed an increasing export volume especially for coconut cream, desiccated coconut, coco chemicals, activated carbon, coir and coir products. The APCC member countries are the main source for the export of copra, desiccated coconut, shell charcoal, coco chemicals and coir products. Coconut oil, copra meal and activated carbon are also exported, but in small quantities, from outside the APCC region.

Market expansion opportunities for coconut value-added products are seen in the following products: a) Virgin Coconut Oil (VCO), b) Fresh Tender Coconut, c) Coconut Flour, d) Biofuel, Oleochemicals and Fatty Acids, e) Desiccated Coconut, f) Coconut Cream, Coconut Milk and Coconut Powder, g) Nata de Coco, h) Coconut Sap-Based Products, i) Coconut Shell Charcoal, j) Coconut Shell, Activated Carbon, j) Coconut Water Vinegar, k) Coir Fibre and others.

Some recommendations on strategies for coconut development to meet the above demands include: a) New Planting/Replanting of Senile Palms, b) Quality Planting Materials and Low Cost Input Management, c) Good Agricultural Practice and Coconut-Based Farming System, d) Transfer of Technology and Capacity Building, e) Product Diversification and Value Addition, f) Product Quality Improvement and Quality Standards, g) New Market and Expansion of the Market and h) Policy Support and Investments conducive to Industry Development and Business Growth.



Lead lecture

TS1- 102

Promoting multipurpose uses and competitiveness of coconut sector

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Former Chairman, Coconut Development Board, Kochi, GOI.*

Coconut, *Cocos nucifera* L., has many meaningful popular names like *KalpaVriksha*, Nature's Super Market, Tree of Life etc., and that itself denotes that coconut has multipurpose uses which are essential for human life as food, drink, shelter, fuel, infant food, nutraceuticals, cosmoceuticals, pharmaceuticals, oleo chemicals, bio fuel, bio lubricant, bio mass energy, bio gas, organic manure etc. However, all over the coconut growing countries coconut means making copra and coconut oil as well as oil cake. This trading is going on for many years. Coconut as source of vegetable oil has to compete with nine other oil seed crops of which many are making fast progress in terms of production. Over a period of five decades coconut oil production had increased from 1.94 million t in 1960 to 3.22 million t in 2009 having a share of 2.4 %. While palm oil made a dent from 1.2 million t to 46.11million t having 33.35% share and palm kernel oil (Lauric oil) from mere 0.42 million t to 6.21 million t having 3.0 % share. This clearly indicates that coconut as a source of coconut oil alone cannot make the industry competitive since it has to compete with many other cheap sources of oil.

Coconut being a versatile crop having the utility right from root to tip of the palm, there are ample opportunities to go for product diversification, value addition, making niche products and by product utilization.

The range of products which can be produced from Inflorescence Sap such as Sugar/Jaggery and Confectionery Jelly, *neera* drink; Coconut Meat for Puddings/Ice Cream and Partially De-fated Coconut Powder, desiccated coconut, Coconut Milk and Milk Powder; tender coconut water, Coconut Water Concentrate and Carbonated/Non carbonated Coconut Water and vinegar; Coconut Oil as Dietary Oil, oleo chemicals and Bio Diesel/Bio Fuel/Bio Lubricants; Virgin Coconut Oil for body oil/baby oil/massage oil, nutraceuticals and Pharmaceuticals; Coconut Shell for shell powder, Activated Charcoal and handicrafts; Coconut Wood for furniture, doors, window frames and floor tiles; Coir Pith for Organic Manure and media for growing Ornamental Plants, husk chips for growing ornamental plants. Geotextile, coir ply composites, coir pith, etc. are having wider application in the fields of soil-water conservation, erosion control and growing horticultural plants. Coir ply composites can be used as crates, collapsible and re-useable containers, building materials, etc. Coir yarns mixed with other natural yarns and synthetics can be used for making high-tech and high value products like safety belts. Emerging applications of shell powder and activated charcoal as alternative to petro-based carbons for industrial and environmental purposes like water desalinization, waste water treatment, air purification, gold recovery purification, wine processing and even specialized black coating for stealth bombers are opening new possibility for shell products.



The domestic consumption at the origin is by the three ways i.e. as natural milk extract for culinary and confectionery preparations, as oil for edible and non-edible applications and young coconut as natural beverage.

The following vital issues are to be addressed effectively to be competitive in the domestic and international markets.

- a. Cost effectiveness in terms of production of raw materials as well as processing.
- b. Quality standards matching with International standards.
- c. Brand names for proper identification.
- d. Attractive packaging without deterioration of products and with proper labeling of its contents and usage.
- e. Adequate market promotional activities.
- f. Continuous market survey, identifying new markets, niche market and assessing domestic market, etc.
- g. Market Research to identify the gaps in the marketing efforts as well as developing effective marketing strategy.
- h. Identifying the proper distribution channel like chain markets: CARREFOUR, LOTUS, HERO, MATAHARI, GIANT and WALL MART which have lot of net work of super markets in the country as well as connecting many countries.
- i. Improving the transport facilities like port development for international carriers.

For making competitiveness in coconut sector, first of all mind set change should come for going to product diversification, value addition and by product utilization. Primarily it has to start from productivity increase at farm level.



Lead lecture
TS1-I03

Current coconut scenario in the Philippines

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The Philippines maintains its supremacy as the leading exporter of coconut oil in the world. Coconut is a major crop in the Philippines with about 27% of the total agricultural land devoted for its cultivation. It is grown extensively in 68 out of 75 provinces in the country. The top export coconut products and by-products are copra, coconut oil, copra meal, desiccated coconut, coconut shell charcoal, activated carbon and oleochemicals. There are other high-value products that can be derived from coconut like VCO, coco flour, coco milk, vinegar, coconut sap sugar, raw nata de coco, bottled young coconut water drink, fibreboard, geotextiles, filtered crude coconut oil, coconut methyl ester among others. The National Coconut Productivity Program (NCPP) serves as a roadmap adopted to pursue a realistic sustainable productivity program which is composed of the Participatory Coconut Planting Project (PCPP), Salt Fertilization Project (SFP) and Plowable Intercropping Project (PIP). The Program aims to promote coconut farm development to address the decline in coconut production and cope up with the increasing and expanding market demand for coconut particularly with the passage of Biofuels Act of 2006. After several years of research, PCA coconut breeders were able to develop a pioneering and improved variety of coconut- the ORGULLO TALL SV San Ramon, through the synthetic variety approach in addition to the 15 coconut hybrids approved by the National Seed Industry Council for mass production. Among the new and emerging products is a water soluble non-starch polysaccharide isolated from Makapuno called the Galactomannan which offers many uses in food and pharmaceutical industries. An integrated pest management approach against *Brontispa longissima*, a destructive and introduced pest of coconut, is being undertaken with the use of biological control agents including entomopathogens *Metarhizium anisopliae* or Green Muscardine Fungus and *Beauveria bassiana* or White Muscardine Fungus, predatory earwig, *Chelisoche morio* and the latest is the parasitoid now identified as *Tetrastichus* sp. similar to the *Tetrastichus brontispae* known to attack *Brontispa* larvae and pupae. This *Brontispa* pest devastated the coconut plantations in Thailand, Vietnam, China, Indonesia, and other Asian and Pacific countries. The renewed interest in coconut also paved the way for a bill submitted to Congress for a strengthened government agency that will formulate and adopt a general program of development towards increased farm productivity. We also have high hopes that the new leadership in the Philippines and at the Philippines Department of Agriculture will bring in new ideas and programs for the improvement and sustained growth of the Philippines coconut industry.



Lead lecture

TS1-I04

Current coconut scenario in Sri Lanka

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Among coconut producing countries in the world, Sri Lanka maintains fourth position by having a total of 3,94,836 hectares under coconut according to the Agricultural Census in 2002. This total area represents 20% of the cultivable land in the country. Coconut being a smallholder's crop, approximately 75% of the area comes under holdings with an area less than 8 ha. Coconut benefits people of all socio economic strata in numerous ways by its multitude of uses. It is providing livelihood for nearly 500,000 people in three main sectors namely production, processing, and marketing. Annual coconut production in Sri Lanka varies between 2500-3000 million nuts, of which 74% of the production comes from the smallholdings (< less than 20 acres). From the total coconut production approximately 70% is consumed for domestic culinary purposes leaving only 30% for the processing industries. The importance of coconut is more signified by its place as the second most important constituent in the Sri Lankan daily diet and it provides 22% of the caloric requirement and 4% protein of an average citizen. It also accounts for 2.4% of country's exports earnings.

In the past two decades annual coconut production in Sri Lanka recorded very slow growth, despite many positive actions taken by the organizations serving the coconut sector. Currently one of the most serious issues of the coconut industry is the inadequate production to satisfy both the consumer and the manufacturers of export commodities. The estimated current national requirement to satisfy domestic consumption, processing and fresh nut export sector is around 3500 million nuts per annum. High cost of fertilizer and other inputs, eriophyid mite, recent outbreak of Weligama Coconut Leaf Wilt Disease (WCLWD) and leaf rot disease, recurrent droughts, high cost of labour, lack of stable price for coconut are the main contributory factors for the slow growth of the industry. Moreover, the adoption of appropriate coconut cultivation practices by the small holder sector is far below the expectation.

Increasing the national coconut productivity (yield/ha) is the key for sustaining the country's coconut production and this could be effectively addressed by medium and long term development measures. The Coconut Research Institute and its extension arm Coconut Cultivation Board have taken many steps for increasing the productivity and profitability of coconut lands with minimum crop losses for sustainable production in the past decade. The genetic improvement programme of the Coconut Research Institute aimed at enhancing the potential of important economic traits such as yield, precocity, water use efficiency, tolerance to drought, pests and diseases. Narrow genetic diversity of coconut was the main obstacle faced by the coconut breeders in Sri Lanka. In the past decade the Coconut Research Institute took necessary measures to improve genetic diversity by importing exotic germplasm with desirable traits from India, Papua New Guinea, and Ivory Coast. Several new hybrids have been produced by crossing local cultivars with pollen imported from Ivory Coast. Extensive studies conducted at several locations



in the coconut triangle have proved that there is a severe decline in soil fertility in traditional coconut growing areas due to continuous cultivation of coconut for more than 3-4 centuries. Soil fertility improvement by using various organic and low cost nutrient sources has received high priority. Encouraging coconut growers to follow integrated pest management strategies, planting home gardens with high yielding 'hybrid coconut' varieties to meet domestic culinary demand, integration of coconut lands with intercrops and farming systems are some short and medium term strategies we have recommended to increase production. A scope for expansion of the area under coconut also opened up with the cessation of thirty-year war. It has been estimated that nearly 100,000 ha of high potential land suitable for coconut cultivation is available in the North and East. Already necessary steps have been taken to establish coconut nurseries, a seed garden to produce high yielding hybrid coconuts, and to introduce accelerated planting, replanting and rehabilitation programme to increase coconut production in these areas. Tapping the production potential of the Southern mini triangle, introduction of new promising hybrids as well as pest and disease tolerant cultivars, integrated farming; intercropping with short, medium, and long term crops of high value are the other areas that have been recommended to increase the production. Increasing the technology adoption rate was envisaged as the most apt solution for a notable increase in the national coconut production.

The coconut based industries contribute 1.8 % of the GDP. The major contributor for the export earnings of the coconut industry was the kernel sector until the year 2000 and there after it has been taken over by the non-kernel sector and its contribution has continued to show an increasing trend. Coir industry is the major contributor for export earnings. There is an increasing demand for tender King Coconut water as a beverage in the overseas markets. This paper outlines the present situation of the coconut industry in Sri Lanka.



Lead lecture

TS1- 105

Current status and scenario of coconut biodiversity in India

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India with about 1.903 million hectares under coconut with an annual production of 14,743.56 million nuts is one of the major coconut producing countries in the world. Coconut makes a contribution of approximately Rs. 8000 crores to the GDP and Rs. 650 crores to the export earnings of the country and provides direct and indirect employment to more than 10 million people.

Genetic resources form the backbone for undertaking any crop improvement programme. Variability within the gene pool is essential for selection and hybridization for bringing about improvement in the targeted traits. The Indian coconut population harbours a wide range of diversity. The islands of Lakshadweep and Andaman and Nicobar with their natural coconut populations, some of which have established with no human interference, are reservoirs of vast genetic diversity. Majority of the native populations in the traditional coconut growing zones, belong to the wild type with greater proportion of husk while some of the evolved types have lesser husk and more endosperm. Further, introgression between the *Niu Kafa* and *Niu Vai* types in the nature has resulted in the emergence of intermediate types.

The Central Plantation Crops Research Institute, Kasaragod (formerly Central Coconut Research Station) is actively involved in the collection and conservation of coconut biodiversity right from 1920 onwards. CPCRI has collected a total of 266 indigenous coconut accessions, with about 233 tall and 33 dwarf accessions, from almost all coconut growing regions within the country. The variability collected from within the country also includes a few unique types such as Laccadive Mini Micro with very small fruits (e" 5 cm long), *Mohacha Naral* (soft endosperm types with less fibre content), Thairu thengai (similar to Makapuno), Klapawangi (edible husk), pink coconut (pink husked type), aromatic coconut (aroma in tender nut water) are found within the country. In addition to the indigenous coconut germplasm, about 132 exotic collections from 26 countries are also conserved in the field gene bank at CPCRI. Coconut genetic diversity collected from the South Pacific Ocean Islands is conserved at the World Coconut Germplasm Centre (WCGC) located at Sipighat, Andamans. The WCGC was initially envisaged by CPCRI as an off-shore quarantine centre and is now maintained as a germplasm conservation centre by Central Agricultural Research Institute (CARI), Andamans. India also hosts the International Coconut Genebank - South Asia (ICG-SA), at the CPCRI Research Centre at Kidu, Karnataka. Presently 91 accessions, representing indigenous coconut germplasm as well as coconut ecotypes of Philippines, Malaysia, Sri Lanka, Bangladesh, Indian Ocean Islands of Mauritius, Madagascar and Seychelles, Comoros and Reunion, Maldives, Pacific Ocean Islands, Africa and the Caribbean Region are planted in the ICG-SA.

The conserved coconut germplasm is evaluated and characterized for utilization in the coconut improvement programme and Coconut Descriptors have been developed and published for 74



conserved coconut germplasm. Further, the evaluation and characterization data of these conserved accessions is available in the CGRD. Presently, work on characterization of conserved coconut germplasm through SSR analysis is also in progress. In addition to characterization of germplasm, identification of genes/alleles for desirable traits is envisaged in order to develop a list of trait specific donor parents. Screening of coconut genetic resources for identification of drought tolerant cultivars based on accumulation of leaf epicuticular wax, low stomatal frequency, leaf water potential, activity of enzymes like glutamate oxaloacetate transaminase and acid phosphatase is undertaken in the country. A few accessions, viz. West Coast Tall, Federated Malay States Tall, Java Tall and Andaman Giant Tall have been identified as drought tolerant and are being utilized in the drought tolerance breeding programme.

Breeding for disease resistance, especially root (wilt) disease of coconut has resulted in identification of Chowghat Green Dwarf and Malayan Green Dwarf as resistant varieties. Screening of the germplasm for identification of accessions with Eriophyid mite resistance has also been undertaken and fruits of Chowghat Orange Dwarf were found to have minimum mite damage incidence while maximum mite damage were recorded in palms of Laccadive Micro Tall. An in-depth study into the local ecotypes, viz. Kuttiadi, Bedakam, Annur, Komadan etc., prevalent in the traditional coconut growing areas of the country is also in progress to promote in situ conservation of genetic resources in farmer's fields.

Research on identification of markers associated with economically important traits and dwarfness and also for selection of hybrid seedlings in the nursery are in progress. Application of these molecular technologies in coconut improvement will help hasten the breeding programme through marker assisted selection of superior genotypes in the juvenile phase and also help in reducing the time and space required for experimentation.

A number of high yielding varieties of coconut have been released, through selection and evaluation of promising accessions conserved both at the institute as well as the various coordinating centres under the All India Coordinated Project on Palms as well as State Agricultural Universities. So far, 18 varieties and 15 hybrids have been released for cultivation in the various agro-ecological zones of the country.

Further, work on identification and conservation of soft endosperm types (*Thairu Thenga*), genotypes resistant/tolerant to biotic/abiotic stresses, including rare and economically important variability are in progress. Identification of accessions with quality fibres is envisaged to further promote the coir industry as well as benefit the coconut farmer to a greater extent. Similarly, to promote value addition and enhance income generation of coconut farmers, specific genotypes suitable for production of coconut chips, higher recovery of inflorescence sap, and preparation of shell products need to be identified for utilization in the breeding programme. Dual purpose varieties for tender nut and copra production are being developed. At CPCRI, efforts to enrich the coconut gene pool with diverse germplasm for specific traits and screen the available coconut biodiversity and identify accessions to enable development of varieties suitable for different end uses and specific industrial use are in progress. Further, it is envisaged to develop superior genetic stocks, having greater homogeneity with the application of plumule culture technology, using selected mother palms of promising accessions, for utilization in crop improvement programme.



Lead lecture

TS1 I06

The situation of coconut in Latin America and the Caribbean- Concerns related to phytosanitary issues

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Coconut production is dominated by Asian countries (Indonesia, Philippines, and India), and only two LAC countries are within the first 10 countries where coconut is produced, but production volumes are insignificant in relation to Asia production. In LAC, three countries dominate the scenario in area planted in coconut, being Brazil (287016 ha), Mexico (178500 ha) and Jamaica (51000 ha). From the 27 remaining tropical countries in the region, a total of 176500 ha are planted with coconut. These values, all together represents less than half of the coconut area planted in India alone. Despite the low area planted with coconut, the socio-economic impact is similar to the one seen in Asian countries where larger coconut areas are found. Coconut production in both geographic regions is similar, since coconut represents an agriculture alternative for the rural poor, and is suitable for planting in areas where other agricultural crops are not well adapted.

Very few technological developments have been introduced to coconut plantations in recent decades, compared to other oily crops, making coconut production less appealing to large investors. The losses due to pests and diseases is of particular concern considering the time before palms reach production, and the lack of access to high performing and resistant genotypes to major pests and diseases in many producing countries in LAC. The combination of all these factors acts against coconut and do not favour investments in coconut production or rehabilitation of old plantations in countries where other cash crop alternatives become available. In LAC, the presence of two major diseases, namely the lethal yellowing disease and the red ring disease, caused by two unrelated organisms had devastated large coconut areas. Cyclic outbreaks of these diseases are certainly a factor that might have contributed to the lack of interest in investments in this crop in the region.

Lethal yellowing (LY) has caused major losses in Caribbean countries for more than 100 years, but in the early 80's, it devastated large areas in the Atlantic coast of Mexico, as well as in some Island Countries (Jamaica, Cuba). The LY has received more attention and through research some progress has been achieved. LY is caused by a phytoplasma (wall-less bacteria), a microorganism that resides in the phloem cells and is transmitted by *Myndus crudus* Van Duzee a small insect (Insecta: Hemiptera: Auchenorrhyncha: Fulgoroidea: Cixiidae). Genetic resistance to this disease was found in germplasm of diverse origin, including Malayan Dwarf and Pacific Tall in Mexico (CCC). Due to presence of this disease in the region, a major concern for dispersal of this disease has developed. In several Central American countries worries for



the arrival of LY has prompted quarantine measures to restrict movement of coconut plant material, and therefore alternatives are required to importing and multiplying valuable germplasm.

On the other hand, the red ring disease has been observed in the region since the beginning of 1900 when it was first reported by Stockdale in 1906 in Trinidad, and then the nematode was found as the causal agent. The disease is distributed in tropical America and has been reported from the Trinidad, Tobago, Grenada and St Vincent, and from almost all LAC countries where coconut is produced, namely Venezuela, Guyana, Surinam, French Guyana, Colombia, Ecuador, Peru, Mexico, Brazil, Panama, Nicaragua, Costa Rica, Honduras, Belize and El Salvador. The disease is a complex action between a mechanical damage caused by large insects (Coleoptera) and a nematode, *Bursaphelenchus cocophilus*. *B. cocophilus* was initially described in 1919 as *Aphelenchus cocophilus*. The diseased trees die after about three months after being infected with the nematode, which is transmitted/transported by several species of coleoptera (palm weevil, *Rynchophorus palmarum*, sugarcane weevils *Dinamis borassi* and *Metamasius hemipterus*) which transport the nematode, but that are a pest problem in their own right. There are no remedial treatment to recover diseased trees, and plants need to be cut down, destroyed and treated with insecticide to eliminate living larvae of coleopteran, to reduce insect populations. The cost of such treatment is high, but so far no other management alternatives exist.

Despite that the red ring disease has been part of the day to day activities of coconut growers in the region, the socio-economic consequences in certain areas are severe and merit long lasting solutions. The work conducted in the south part of Colombia, where the red ring disease has been recurrent since 1962, and the proposed forward research agenda will be discussed in detail. According to published reports, induction of red ring disease is possible in coconut trees of at least three years of age. However, very little, if any, attempts to explore genetic resistance to this disease has been carried out in a systematic way. The urgent need to find methods to test coconut germplasm for resistance or tolerance to the nematode will be discussed and the possibilities to use participatory approaches to find solutions to diminish the incidence of the complex insect-nematode in the region will be analyzed.



Lead lecture

TS1 I07

Status and strategies for enhancing coconut production in Andaman and Nicobar Islands

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The Andaman and Nicobar Islands comes under the humid tropics with an average rainfall of about 3,000 mm. Out of the total geographical area of 8,249 km², only 6% i.e. 50,000 ha at present is under agriculture. The flora of Andaman and Nicobar Islands are unique and over 2,500 angiosperm species so far are known from these islands of which about 246 are endemic. Coconut is a unique plantation crop of Andaman & Nicobar Islands and has been associated with socio cultural life of the people of these islands. In Andaman & Nicobar Islands, the area under coconut in 1979-80 was 20,787 ha with a production of 67.29 million nuts. During the last two decades, the area has increased to 21,689 ha with a production of 81.90 million nuts and the productivity is 3,749 nuts/ha. Out of 21,689 ha of coconut plantations, the area of 14,556 ha and 7,133 ha are distributed in Nicobar and Andaman islands, respectively. Basically coconut is a small holders' crop and 90% of the total area is with smallholders, with less than 0.2 ha. Under the present situation (where the price fluctuation is too high), growing coconut alone without any component crop/animals cannot bring additional income to farmer's for their satisfactory living. Thus coconut based cropping/farming systems involving cultivation of compatible crops in the interspaces of coconut and its integration with other enterprises like poultry etc. leads to considerable increase in production and productivity per unit area, by more efficient utilization of sunlight, soil, water and labour. The importance of nutrient management in coconut gardens to get profitable returns has been well recognized. However, the consumption of inorganic fertilizers is very low in coconut plantations mainly due to the cost factor and fluctuating price trends of the produce. The use of organics in coconut cultivation is now limited due to non-availability of organic manures in sufficient quantities, higher cost and transportation expenses. Similarly, the intercropping in coconut garden with spices, fruits, tuber crops, vegetables, ground nut and fodder was found to be economical in Andaman and Nicobar conditions. With reference to post harvest and value addition, the Malabar Co-operative Society formed by Kerala Settlers in 1949 is now engaged in extraction of coconut oil. There are seven copra units registered with district industries centres, besides, more than 500 home units which produce copra in home scale especially in Nicobar District. It is estimated that 280 million nuts are available annually for industrial exploitation in Andaman & Nicobar Islands. These nuts can be used for development of a number of industries based upon coconuts such as production of copra, coconut oil of dessicated Coconut. Coconut shell powder which can be used for making thermostat moulding powders such as phenol formaldehyde, and synthetic resin glues, production of Handicrafts items, toys and bowls from coconut shell and production



of Activated carbon. It is estimated that 56,000 M.T. of coconut husk is available annually for exploitation for industrial use in these Islands but only a negligible quantity i.e. 120 M.T. of coconut husk is being utilized presently for making coir products and the rest is wasted or used as domestic fuel. The consumption patterns of coconut in Andaman and Nicobar islands are almost similar except for the use of coconut as pig feed in Nicobar Islands. Most of the plantations are old and farmers are deriving income without incurring any expenditure on maintenance of plantation. One of the major problems of coconut cultivation in Andaman and Nicobar islands is overcrowding of senile and very old palms. Such coconut gardens should be regenerated by replanting with quality seedlings. The Andaman and Nicobar UT administration launched a Car Nicobar Coconut Mission to bring a paradigm shift in coconut production and commercial use. The mission adopts a synergetic approach by bringing the isolated efforts being put forth by different government agencies like Department of Agriculture, NHM, NHB, CDB, CARI, RKVY, NABARD, NAFED, EHL and industries under different programmes/schemes to increase the productivity of coconut. The collection, conservation and sustainable utilization of elite genetic resources remain the important area to be taken care of because of fragile ecosystem. The main focus should be on enhancing the productivity of coconut by supplying good quality seedlings to the farmers. There is no scope to increase the area under coconut as well as for other crops and hence, special attention should be given to demonstrate the mixed/inter/multistoried cropping with Agri-Hort-Silvi technologies to meet various demands of the farmers. There is a need to create awareness among the farming community on scientific coconut cultivation especially providing nutrients and irrigation during post monsoon season to coconut to increase the production and productivity, co-operative farming, integrated pest and disease management, post harvest technologies, value addition and organic production of coconut for tender nut export and attracting more tourism to these islands.



Oral

TS1-01

The international coconut genebank for Africa and Indian Ocean: Status and prospects

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The Centre National de Recherche Agronomique (CNRA) of Côte d'Ivoire hosts the International Coconut Genebank for Africa and Indian Ocean (ICG-AIO) since 1999. This Genebank was established from 1960 to 1984 and contains 99 accessions. These accessions are evaluated based on morphological, physiological, biochemical and molecular analysis for the efficient utilization. The germplasm is used by researchers to develop high producer hybrids such as PB113 improved and PB121 improved. In Côte d'Ivoire's conditions these hybrids can produce upto 6.5 t copra/ha/an. Now most of these germplasm have become so high and difficult to be used for research and development programme. Since 1986, regeneration programme was started. Until now, 66 accessions are regenerated by using controlled pollination for tall coconuts and open pollination for the dwarfs. Molecular analysis is implemented to evaluate the quality of the regenerated material. The germplasm are also available to support any research and development programme in the world and many seednuts, seedlings, pollen and embryos have been supplied to Africa, Asia, Pacific, Euro and the Latin America countries. The efficient embryo culture protocol is helping to share and ship germplasm between coconut growing countries. The implementation of coconut cryopreservation, *in vitro* culture conservation and field multilocation conservation



Poster
TS1-P01

International coconut genebank for South Asia - Conservation and characterization

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The International Coconut Genebank - South Asia (ICG-SA), hosted by India, is located at the Central Plantation Crops Research Institute, Research Centre, Kidu, Karnataka, India. The mandate of International Coconut Genebank is to conserve the nationally, regionally and internationally identified diversity; assess the diversity, evaluate the performance of the germplasm and distribute related information to COGENT member countries; make available germplasm materials to interested COGENT member countries; conduct research and training. Planting of coconut accessions in the ICG-SA was initiated in 1998. Presently 91 accessions are planted in the ICG-SA. These represent indigenous coconut germplasm of the host country as well as Indian accessions representing coconut ecotypes of Philippines, Malaysia, Pacific Ocean Islands, Africa and the Caribbean Region. In addition, exotic coconut germplasm have been collected as zygotic embryos from the Indian Ocean Islands of Mauritius, Madagascar and Seychelles, Comoros and Reunion, Maldives and two ICG-SA member countries viz. Sri Lanka and Bangladesh. Among the 49 designated Indian accessions, in the ICG-SA, flowering has commenced in 41 accessions. In the first batch of exotic germplasm collected as embryos, from the Indian Ocean Islands of Madagascar, Mauritius and Seychelles, initiation of flowering was recorded in all accessions except Guelle Rose Tall and Coco Gra Tall. Among coconut germplasm obtained from Sri Lanka, Sri Lankan Green, Red and Yellow Dwarfs have entered the reproductive phase and among the coconut germplasm collected from Bangladesh, flowering initiation was recorded in the accessions, Kayemkola Tall, Rupdia Tall and BARI Narikel-I. Wide variation in time taken for flowering was observed between the accessions. Juvenile growth characters are being recorded in the ICG-SA and these also showed significant variations between the accessions. Tender nut studies and fruit component analysis are in progress in the ICG-SA. The establishment of the ICG-SA under CPCRI has strengthened the pioneering role played by India in coconut research and improvement.



Poster

TS1- P02

Exploration for diverse coconut types in Andaman & Nicobar Islands - A report on special coconut types

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Coconut is an important subsistence crop of the humid tropical zones and is a life-supporting species in fragile island and coastal ecosystems. Coconut is believed to have originated in the Indo-Malayan region (Indonesia, Malaysia and the Philippines) from where it dispersed, mainly via oceanic currents, to sandy and coralline tropical coasts where it got established. The archipelago of the Andaman and Nicobar (A&N) Islands situated in between the Indian mainland and Malayan peninsula stretches over 800 km in the Bay of Bengal, approximately 1220 km southeast of the coast of West Bengal and 1190 km east of Chennai. It comprises 572 islands, reefs and rocks, of which 38 islands are inhabited. A deep Ten Degree Channel, a wide gap of 155 km with heavy tidal flows, separates the A&N group of islands. About 2100 varieties of plants have been recorded from these islands, out of which 11% is endemic and 1300 do not occur in mainland India. A major part of the island flora is either of the Indo-Myanmarese-Thailand order or the Malaysian-Indonesian order. The Nicobar Islands situated near the northern most part of Indonesian islands are also having wide variety of plants. The diversity of coconut in the A&N Islands is reported to be exceptional. Coconut accessions having horned fruits, beaked fruits, palms with persistent petiole and inflorescence, fused leaflets (*plicata*) and unbranched inflorescence (*spicata*), varying colours of nuts, varying fruit size, special types such as *Thairu Thengai* (similar type to makapuno of Philippines) are found in these islands. These rare types may be potential sources of resistance to pests and diseases, and may prove invaluable in future coconut breeding programme. Utilizing the genetic resources of Andamans, two coconut varieties have been developed and released for commercial cultivation in the mainland. Andaman Ordinary Tall, an accession from South Andaman, has been released as VPM-3 and selection from Andaman Giant Tall, a large-fruited accession from South Andaman region, has been released as 'Kalpa Dhenu'. CPCRI has taken sustained efforts to collect and document the diverse coconut genetic resources from these Island territories. Recent exploration in these islands resulted in identification of special coconut types for dwarfness, soft endosperm types (*Thairu Thengai* - similar to makapuno), giant nuts, red *spicata*, high yielding dwarf cultivars with different nut colours and micro tall with very high number of nuts per bunch, thin husked coconuts etc. The *in situ* observations on morphological traits recorded on the selected types and the data on nut component traits were subjected to diversity analysis. The characterization of the special types from the island territory is enumerated. Results indicate that extensive exploration in the islands would help in strengthening the coconut genetic resources conservation and utilization. As most of the



area under coconut in these islands is situated in the tsunami prone zone, there is urgent need for further efforts on collection and conservation of coconut genetic resources on these islands for the benefit of coconut community.

Poster

TS1- P03

Coconut biodiversity in north east region of India

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With a view to study the diversity in the coconut population of North Eastern region and conserve the population in the gene bank, CPCRI had undertaken a germplasm collection trip to Nagoan, Morigaon and Kamrup districts of Lower Assam and Golaghat and Jorhat districts of Upper Assam and to the neighbouring district of Ri-Bhoi district in Meghalaya. The passport data was recorded and mature fruit samples were collected for recording fruit component traits. Leaf samples were also collected for DNA isolation and genotyping. The present study aimed at characterization of the coconut population of North Eastern region based on the fruit component characters and SSR markers. Analysis of variance for fruit component traits indicated significant differences for most traits except endosperm thickness and husk weight. The average copra out turn in the coconut population of North Eastern India was below 150 g. Cluster analysis, based on fruit component traits, indicated a maximum of seven clusters. Two palms producing large-sized fruits, formed distinct single accession clusters. SSR analysis using eight primers of CAC series reported low heterozygosity, indicating an autogamous nature of pollination unlike tall populations of coconut. Cluster analysis based on Jaccard's similarity coefficient, produced a dendrogram with two major groups and a total of four clusters. The palms collected from different locations were scattered into different clusters indicating absence of geographical affinity. The fact that coconut is a relatively recent crop in the North Eastern states of Assam and Meghalaya, it is likely the majority of the palms sampled may have originated from a single source or a limited set of mother palms. Further, the clustering pattern obtained with SSR banding data and fruit component data were not identical indicating that phenotypically distinct palms can be genotypically similar for the SSR loci studied. A more detailed study on the floral biology and nature of pollination in the coconut population of North Eastern India along with the SSR profiling using a large number of primers has to be undertaken for understanding the diversity and population structure of the coconut population of North Eastern India.



Poster

TS1-P04

Exploration and collection of sweet endosperm coconut 'MOHACHA NARAL' from Maharashtra, India

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C*ocos nucifera* L. evolved as a species adapted to coastal ecosystems of tropical world. It is well adapted to west and east coasts of India and grown in the region for many uses. Besides culinary purposes, coconut endosperm is mostly used for extraction of coconut oil. Endosperm is the solid tissue and white in colour. Certain coconut palms produce jelly like endosperm which is called *Makapuno* in Philippines. Similar types are sporadically reported from India as '*Thairu thengai*'. Another variant with sweet and soft endosperm is now identified and collected from Guhaghar taluk of Ratnagiri district in India. It is locally known as *MOHACHA NARAL* meaning sweet coconut. Exploration of Guhaghar Taluk of Ratnagiri district (N17° 28'55" to N17° 29'50" and E73° 11'03" to E73° 19'50") resulted in the identification of 27 palms of *MOHACHA NARAL*. Another palm was located near Ratnagiri city (N16° 58'15.3" and E73° 19'50.4"). The palms are aged 40 to 80 years and found randomly distributed in the population. The palms are tall in habit with the stem height ranging from 7 m to 27 m. The number of nuts with sweet endosperm per bunch varied from 10 to 77 in different palms. Forty six percent of all the nuts collected from 28 palms during winter season were of sweet endosperm type. The percentage came down to 39 during summer season. Four palms had less than 25% sweet endosperm nuts, 13 palms had 25 to 50% sweet endosperm nuts and 11 palms had more than 50% sweet endosperm nuts. Fruit component traits of sweet and normal nuts of this population were studied. Sweet endosperm types had slightly less fruit and husked fruit weight as compared to normal nuts. Endosperm thickness was similar in both, but the endosperm weight was more in normal types. Embryo weight of sweet endosperm nuts was significantly lower than in normal endosperm. Total soluble sugars were the same in both type of nuts, but organoleptic test showed that water in sweet endosperm nuts was poor in taste. This is the first report of sweet endosperm coconut from India. Farmers of the area get a premium price for sweet endosperm nuts. It is mainly used for raw consumption. Frequency of sweet endosperm nuts in consequent bunches and the seasonal variation in production of nuts with sweet kernel are to be further studied. Influence of pollen on the development of sweet endosperm also needs to be analysed. Seed nuts from identified palms were collected and this population is being conserved at CPCRI, Kasaragod for further evaluation and utilization in the coconut improvement programme. Exploitation of sweet kernel trait will help in product diversification in coconut which will lead to profitability of coconut industry.



Poster
TS1-P05

Morphological characterization and diversity among natural coconut population of Minicoy, Lakshadweep Islands, India

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Lakshadweep group of Islands has large natural populations of coconut. The Laccadive coconut ecotypes have been reported to possess desirable features such as high rate of spathe production, high percentage of oil and the palms are reported to be drought tolerant. Selection from Laccadive Ordinary Tall has been released as 'Chandra Kalpa' for commercial cultivation. Laccadive Micro Tall - a coconut type with small nuts produced in large number has been identified as suitable for ball copra production. It is essential to characterize and further study the genetic diversity available in the Laccadive coconut populations for effective utilization in the coconut improvement programme as these populations are located at remote areas, away from the Indian mainland coconut populations. Survey conducted on the entire coconut population of Minicoy Island revealed four major distinct tall types based on nut size viz., Giant, Ordinary, Micro and Mini Micro and a small proportion of palms with only male flowers. The frequencies of these palms were recorded for the whole Island through inspection of individual palms for their phenotypic traits. Among the coconut populations, 81.47 per cent of palms were identified as Ordinary, 14 per cent as Giant, 3.26 per cent as Micro, 1 per cent as Mini Micro and 0.22 per cent as male palms. Morphological, reproductive and nut component traits were studied for all the types in randomly selected individual palms. The palms of Mini-Micro type which is reported to produce the smallest coconut in the world was found to occur sporadically throughout the island and possess some useful traits such as high number of leaf and bunch production, longer leaf retention on the crown, and high oil content. Though the Mini-Micro palms have been reported earlier, it was reported as a freak type with only one or two palms in the island. The present exploration revealed fairly high number of palms and more number of palms with varying size of small nuts presumably produced through natural crossing with the Mini Micro palms. The Minicoy coconut population showed wide variability for morphological and nut component traits. The mature fruit weight ranged from 31 g to 1148 g, the average nut weight ranged from 5.76 g to 558.4 g and the average copra content varied from 5 g to 294 g per nut in the Minicoy coconut population and this underlines the need for further selection from the population. The amount of variability observed for nut traits of Minicoy coconut populations exceed the nut diversity available for these traits in other coconut growing areas and hence this population could be considered as naturally conserved repository of coconut genetic resources.



Poster

TS1-P06

Coconut biodiversity in Kanyakumari

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Agro biodiversity is crucial for sustainable agricultural development and ensuring livelihood for any agrarian economy. Plant Genetic Resources for Food and Agriculture (PGRFA) are essential resources to meet future food and nutrition security of burgeoning population. Coconut is one of the important multipurpose perennial palms that sustain the livelihoods of millions of resource poor families. Presently, the coconut growers are suffering due to diminishing productivity and unstable market. On the other hand the biodiversity of coconut is also dwindling due to urbanization, calamities and crops shift. Hence the conservation of biodiversity assumes significance for the development of coconut industry in the coming years. In Kanyakumari District, coconut is grown in a wide range of agro climatic and socio cultural - economic conditions. Kanyakumari district is the high rainfall zone of Tamil Nadu located in the southern tip of peninsular India between 77.05 and 77.36°E longitude and 8.03 and 8.35°N latitude. The total area of the district is 1684 sq.km. Based on topography and rainfall the district is divided into two agro ecological zones namely the hill and the surrounding ela region and the plains. The hill and ela region of Kanyakumari district lies 35 km away from the coast and spreads from the east to west. The topography is undulating and this region consists of plateaus, hills and hillocks and the low lying areas called elas. The northern part of this region is covered with thick rain forest. This region receives an annual rainfall of above 1500 mm. The plains extend from the coast to about 20 km in the western side and 35 km in the eastern side. The annual rainfall is less than 1500 mm. The soil varies from sandy loam to red clay loam. Coconut is cultivated in both the climatic zones as a major crop. The proximity to equator and sea, its topography and the other climatic factors favours a wide diversity in both tall and dwarf forms of coconut in Kanyakumari. The most popular coconut types in Kanyakumari are Kulasekharam Yellow Dwarf (KYD), Kulasekharam Orange Dwarf (KOD), Kulasekharam Green Dwarf (KGD), Kulasekharam Tall (KT), Ethamozhi Tall, Thengapattinam Tall, Puthazham type, Rajakamangalam type, Naden, Kappai etc. Certain land races and derivatives of natural hybrids and variants of tall, semi tall, extreme dwarf are also found scattered in the district. The nature of coconut biodiversity and the extent of the diversity needs to be investigated thoroughly and documented for further promotion of the industry.



TECHNICAL SESSION II
CONSERVATION AND UTILIZATION OF
GENETIC RESOURCES



Lead lecture

TS2-101

Performance of coconut accessions in different agro-climatic regions

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Central Plantation Crops Research Institute is endowed with a rich gene pool of coconut that includes 398 accessions collected from different regions of the world. The accessions were characterized and evaluated at the Institute. Based on the preliminary evaluation and selections made in different phases, a few selections were promoted for multilocational trials.

All India Coordinated Research Project on Palms was started in 1972 to identify location-specific technologies for different agro-climatic regions, as the performance of coconut accessions vary under different situations. At present, evaluation of coconut accessions is carried out in 12 Centres representing West-coast region, Konkan region, East-coast region, interior peninsular region, subtropical region and North-East region. Each region is distinct in its characteristics with reference to rainfall, maximum and minimum temperature, diurnal variation, relative humidity, soil type, soil fertility status and cultivation practices adopted by the farmers. Consequently, the performance of different coconut accessions varied widely from region to region. Based on the evaluation trials conducted at different locations, the following coconut varieties/hybrids were recently released for commercial cultivation in different regions.

Kalyani Coconut-1: In addition to better nut yield and oil yield, the tender nut of the coconut accession IND 031 S is recording a higher quantity of 360 ml of nut water as compared to 260 ml in IND 127 S and also higher levels of total sugar, potassium and sodium content in nut water. West Bengal, being a tender coconut production area, IND 031 S suits for dual purpose as a tendernut coconut variety as well as a commercial variety for oil. Hence, IND 031 S is promoted as a dual purpose variety with the name "Kalyani Coconut-1" for Eastern Plateau region.

Konkan Bhatye Coconut Hybrid-1: The IND 003 S x IND 127 S hybrid seedlings, supplied by Ambajipeta and tested at Ratnagiri Centre has yielded 20,300 nuts/ha/annum. The overall mean yield was 116 nuts/palm/year (for the last 10 years). This hybrid is recording 24.5% more nut yield than Pratap, 61% higher than IND 069 S and 73% higher than IND 127 S. The hybrid gives copra yield of 3.43 tonnes/ha and oil yield of 2.30 tonnes/ha. As this hybrid is performing better than the earlier released Pratap variety as well as the 11 other hybrids tested under this project, it is promoted as "Konkan Bhatye Coconut Hybrid-1" for the West-coast plains and Ghat region.

Kalpa Dhenu: The variety is giving 26.07% higher copra yield and 21.44% higher oil yield as compared to IND 069 S. The tender nut quality is also good. The oil extracted from the copra of this variety has higher lauric acid content. The variety is also performing well in both East coast



region and Island ecosystem. Hence, the variety is promoted as a “National variety”.

Kera Keralam: Coconut accession IND 069 S is performing well in West coast, East coast and Eastern plateau regions. In addition, it is also widely cultivated in different regions of the country. The accession responds well to management and any incremental level of management in terms of water and nutrients results in better productivity. Hence, it is promoted as a “National variety”.

Kera Bastar: The Coconut accession IND 004 S has performed well in Ambajipeta (Andhra Pradesh), Ratnagiri (Maharashtra), Veppankulam (Tamil Nadu) as well as in the non-traditional area of Jagdalpur (Chattisgarh). The accession could give a yield of 110 nuts/palm/year with a copra yield of 2.97 t/ha and oil yield of 2.04 t/ha. Under these circumstances, this variety is recommended for East coast, Southern Plateau and Central Plateau region.

Kalpa Pratibha: Based on the good performance of the accession at Kasaragod (Kerala) with higher copra and oil yield of 40.11% and 38.05%, respectively than Coconut accession IND 069 S and better performance at Ambajipeta (Andhra Pradesh) Veppankulam (Tamil Nadu) and Aliyarnagar (Tamil Nadu), accession is promoted as a “National variety” for cultivation in West coast, East coast and Interior Peninsular regions.

Kalpa Mitra: The accession performs well (copra and oil yield was 16.01% and 13.45% higher than IND 069 S) at Kasaragod (Kerala) as well as at Mondouri Centre of AICRP on Palms (West Bengal). The tender nut quality is also good. Hence, it is promoted as a dual purpose “National Variety” for cultivation in West coast and Eastern Plateau regions.

Kalpatharu: It is a selection from Tiptur Tall accession, suitable for ball copra production and cultivation in the states of Karnataka, Tamil Nadu and Kerala. The variety is recommended for release in Deccan plateau region, Interior Peninsular region and West coast region. The palms are drought tolerant with high yield of 116 nuts/palm/year and copra outturn of 3.57 t/ha.

Kalpa Samrudhi: The hybrid IND 376 is superior with high yield (1-17 nuts/palm/year), copra out turn (25 kg/palm/year) and oil yield of 3.04 t/ha under rainfed condition and it is recommended for cultivation in West coast and North east regions. Besides, this hybrid has good tender nut water quality with TSS 6° Brix and quantity (346 ml/nut) and has been found to be relatively drought tolerant compared to other released hybrids.



Lead lecture

TS2 -102

Breeding strategies for higher productivity and tolerance to biotic and abiotic stresses in coconut

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Coconut breeding programme in India started as early as 1916. India perhaps has the oldest and one of the largest organized coconut breeding programmes in the world. Though India is one of the largest producers of coconut in the world, productivity of coconut in India is low. There is vast scope for increasing the productivity of coconut in India through varietal improvement. Traditional methods of mother palm selection followed by seeding selection continue to be widely practiced by coconut farmers for planting material production. Mother palms selected on the basis of progeny testing for seedling characters have been advocated to give more scientific thrust to planting material production.

Strategies for coconut improvement largely involve germplasm collection, evaluation and their utilization either by selection or through single cross hybrids involving tall and dwarf varieties. Organized germplasm collection and evaluation started in 1945 after the setting up of the Indian Central Coconut Committee. The Coconut germplasm collection at CPCRI is presently the largest in the world with 132 exotic and 266 indigenous types, conserved in field gene bank. The exotic collections from 27 countries and indigenous collections from all the major coconut growing States of India are represented in the CPCRI gene bank. Germplasm collections are evaluated to identify high yielding accessions and are also being utilized in crosses between dwarf and tall varieties to exploit the hybrid vigour. Similarly T x T crosses between unrelated lines of tall varieties are also carried out to develop improved varieties with high out turn of good quality copra. Strategies to produce superior hybrids also include selection of parents for crossing on the basis of tests for combining ability involving mating designs. Twenty nine varieties have been so far released for cultivation in India by CPCRI as well as by State Agricultural Universities. Out of the 29 released varieties, 14 were developed by selection and 15 are hybrids. CPCRI alone has released 11 varieties, out of which eight are selections and three are hybrids.

Although coconut improvement is largely aimed towards yield improvement, breeding for biotic and abiotic stresses including product diversification are also to be addressed to make coconut farming sustainable and profitable. Varieties resistant to root (wilt) disease have been identified and two disease resistant dwarf varieties and one tolerant D x T hybrid have been released for commercial cultivation. Efforts are in progress for further evaluation of their resistance and other agronomic attributes in other locations and also to utilize them in crosses with WCT to identify superior disease resistant or tolerant hybrids. Efforts for improvement of disease - free mother palms in farmer's plots located in disease-hotspots through simple recurrent selection are also in progress. Drought tolerant accessions have been identified and efforts are being made to develop drought tolerant varieties.



Advances in embryo culture, tissue culture and molecular biology are also being utilized to complement the breeding strategies adopted in coconut improvement. Out of about 398 accessions at CPCRI, molecular characterization of 117 accessions have been completed. Embryo culture techniques have been standardized and the protocol is being utilized particularly in exotic germplasm collection and also for multiplication of special types such as makapuno which lacks well developed endosperm. Even though tissue culture from somatic tissues of the adult palm have not been successful, plantlet regeneration from plumular tissue of coconut has been achieved. This technique is presently being employed for scaling up of planting material production of the root(wilt) resistant palms and released varieties of coconut.

Lead lecture
TS2- 103

Cryopreservation as a tool for coconut diversity conservation

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To conserve, characterize and utilize the coconut genetic diversity, a number of field gene banks were established and maintained in different parts of the world. However, the field gene banks are faced with many threats, both biotic and abiotic. Complementary conservation strategies are therefore to be evolved for long term conservation of coconut genetic resources. The practice of storage of seeds with low moisture content under low temperature is inapt in the case of coconut as its seeds are big in size and recalcitrant. Cryopreservation represents the only appropriate method for long-term storage of coconut germplasm. Under cryogenic storage, cell divisions and metabolic activities of the tissues are completely arrested and thus can be stored indefinitely without alteration or modification, which serves as a base collection. The relative tolerance to desiccation and freezing render coconut embryos ideal for cryopreservation studies. The effectiveness of various cryopreservation methods on coconut embryos is pivotal in the development of a successful cryopreservation protocol in coconut. At CPCRI, four different cryopreservation methods viz., air desiccation, pregrowth desiccation, encapsulation-dehydration, and solution based vitrification were tested for the recovery of plantlets and subsequent field establishment. The results of these experiments revealed that pregrowth desiccation with sucrose in combination with raffinose and solution based vitrification (PVS3) are most suitable for cryostorage of coconut zygotic embryos. Plantlet retrieval in polybag was observed to be 22.5% in PVS3 based method and 27.5% in pregrowth desiccation procedure. Another strategy for long term conservation of coconut genetic diversity is in the form of cryopreserved pollen. When coconut pollen subjected to cryogenic storage was used for artificial pollination, nut setting was observed to be normal in West Coast Tall (WCT) and Chowghat Orange Dwarf (COD). Studies also indicated that that coconut pollen retained the viability even after three years of cryogenic storage.



Oral

TS2- 01

Evaluation of coconut genetic resources for yield and seedling traits

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Coconut, a major plantation crop of India, is extensively cultivated in the country for the production of copra, extraction of oil, culinary use and consumption as tender nuts. To increase the productivity of the crop, evaluation of coconut genetic resources is undertaken at the Central Plantation Crops Research Institute to identify high yielding accessions and release them for commercial cultivation. In the present study 16 diverse coconut accessions, planted in 1972 in an RBD, was evaluated for nut and copra yield, fruit and tender nut characters and also for seed germination characteristics. Analysis of variance of the 16 year yield data indicated significant differences for annual nut yield as well as annual copra yield. Higher annual nut yield was recorded in IND 030S, followed by IND 082, IND 058S, IND 069S and IND 016S, while the lowest nut yield was recorded in IND 003S. Analysis of the fruit component data also indicated significant differences between accessions for fruit component traits, except percentage of shell over whole fruit weight. The mean copra content was higher in the accession IND 016S followed by IND 018S, IND 003S, IND 004S and IND 022S. Low copra content was recorded in IND 058S, IND 082 and IND 030S. Studies on suitability for ball copra production indicated higher recovery in IND 030S followed by IND 069S, IND 006S and IND 082 indicating the suitability of these accessions for production of ball copra. The seed nut germination characteristics were also studied in these accessions. Early germination was observed in the accessions IND 009S and IND 016S while IND 030S, IND 082 and IND 006S were found to be late germinators. Based on the annual copra and oil out turn, the accessions IND 016S, IND 022S and IND 006S were found to be high yielding than the local check (WCT) and hence recommended for commercial cultivation, under the name Kalpa Pratibha, Kalpa Dhenu and Kalpa Mitra, respectively.



Oral
TS2 -02

Genetic uniformity studies on Kalpasree and Kalparaksha varieties of coconut using molecular and morphometric methods

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Two coconut varieties, Kalpasree and Kalparaksha, with higher yield and resistance to root (wilt) disease were released for cultivation in the disease prevalent tract. 'Kalpasree' is a selection made from Chowghat Green Dwarf (CGD) population cultivated in farmer's plots in the root (wilt) diseased tract. 'Kalparaksha' is a selection from Malayan Green Dwarf population. Molecular analysis was conducted to study the genetic uniformity of CGD and MGD populations. Forty two CGD palms from 'disease hotspots' were analyzed using 43 SSR primers. Monomorphic bands were detected in all the CGD samples with 41 primers which is an indication of its genetic uniformity. A single CGD palm showed polymorphism with two SSR primers. Thirty one MGD palms from DSP Farm, Neriamangalam were analyzed using 24 SSR primers. The bands were scored, similarity matrix was derived and a dendrogram was constructed. The MGD palms clustered at 62% similarity. Analysis of morphological and fruit component characters of CGD and MGD population revealed that both the populations were uniform. Breeding behaviour studies revealed that both CGD and MGD were predominantly self pollinated, like other dwarf varieties of coconut. In almost 96% of CGD palms, there was complete overlapping of male and female phases. In such palms, the male phase prolonged even after completion of female phase, thereby ensuring 100 per cent self pollination. However, only 60% of the MGD palms showed complete overlapping and in the remaining 40% palms there was only partial overlapping of male and female phases. It is concluded that in a crop like coconut, breeding behavior and genetic uniformity are highly correlated. To ensure production of true to type progenies in dwarf varieties, seed nuts should be collected only from mother palms with overlapping of male and female phases. Present study indicates that in coconut, breeders should rely on molecular techniques like SSR analysis to identify the genetically pure mother palms for varietal improvement programme.



Poster
TS2-P01

Genetic diversity in coconut germplasm based on morphological descriptors

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Coconut (*Cocos nucifera* L.) is an economically important crop grown over two million hectares in India mostly by small and marginal farmers. Efforts have been made to collect, conserve and enhance coconut germplasm at Coconut Research Station, Tamil Nadu Agricultural University, Aliyarnagar. A thorough knowledge on genetic diversity and relationships of these accessions are needed for adopting effective gene-banking strategies and germplasm utilisation. A subset of 43 accessions was characterized morphologically using the standard morphological descriptors of coconut. The descriptors included were leaf production, number of functional leaves, girth at permanent mark (cm), height from base (cm), total leaf length (cm), petiole length (cm), leaflet length (cm), leaflet breadth (cm), number of leaflets, nut yield/palm/year, cumulative mean nut yield, weight of the nut (cm), length of the nut (cm), breadth of the nut (cm), weight of the dehusked nut (g), weight of the split nut (g), weight of the kernel (g), thickness of the kernel (g), volume of water (ml), copra yield/nut (g) and copra yield (kg/palm/year). The data were analyzed by mean, range, standard deviation and coefficient of variation. Large differences were observed for most of the traits across genotypes suggesting considerable level of phenotypic diversity in the germplasm collection. Cluster analysis was carried out using standardized data based on Unweighted Pair Group Method with Arithmetic Averages (UPGMA) method. Six clusters could be identified from the dendrogram. Cluster I comprised of genotypes with big sized nuts mostly originated from the Philippines, Andaman & Nicobar islands, Papua New Guinea and Kerala. Cluster II included genotypes from Goa and Kerala. Dwarf genotypes with orange and yellow coloured nuts grouped together in cluster III. Cluster IV comprised predominantly of south Indian genotypes including Tamil Nadu, Karnataka and Kerala. Genotypes originating from the islands of Asia Pacific and Oceania region grouped together in cluster V. Cluster VI included genotypes from the east coast region of Tamil Nadu as well as a genotype from Zanzibar. The results indicated that assessing genetic diversity based on morphological characters could help identify diverse genotypic groups according to their geographic origin and important agronomic traits. The results would be useful in identifying elite diverse genotypes for utilization in coconut hybridization programme.



Poster
TS2- P02

A comparative study on the performance of some indigenous and exotic coconut germplasm in alluvial plains of West Bengal

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The strategies for achieving the goal for improving the production and productivity in coconut garden can be achieved by improving the genetic potential of coconut. Since coconut has a very long productive period, selection of right variety and planting material are of utmost importance. A germplasm evaluation trial was done to assess the performance of indigenous and exotic collections of coconut. The experiment was carried out under AICRP on Palms at Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, West Bengal during 1981 to 2003. The materials were supplied from CPCRI. The coconut palms were spaced at 7.5 x 7.5 m. The study was carried out with 10 germplasm namely Borneo (IND024), B. S. Islands (IND 036), F.M.S. Big (IND10) Gonthebili (IND 051), Jamaican Tall (IND031), Java (CCS 5), San Ramon (IND 034), St. Vincent (IND 053), Zanzibar (IND 037), Hazari (CRP502) in a row trial. The maximum length of petiole was recorded in Java (174.0 cm), average male phase was found maximum in B.S.Islands (22.25 days) and average female phase was maximum in Jamaica Tall (4.50 days). The germplasm Jamaica Tall produced maximum number of bunches per year (8.6/palm) followed by Java (8.3/palm). San Ramon produced the lowest number of bunches 6.1/palm. The nut yield was maximum in Jamaica Tall (84.2/palm) followed by Hazari (71.6/palm) and Java (65.8/palm). The copra yield recorded was maximum in Jamaica Tall (9.2 kg/palm) followed by Hazari (8.3 kg/palm) and Java (7.3 kg/palm). The oil yield was recorded maximum in Jamaica Tall (5.8 kg/palm) as compared to B.S. Island (2.7 kg/palm).



Poster
TS2-P03

Exploiting variability among dwarf populations of coconut collected from Pacific Ocean Islands

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Coconut is a unique plantation crop of Andaman & Nicobar Islands and has been associated with socio economic facts of these islands. Though the agro- biodiversity of coconut is unique in these islands, the production and productivity is very poor and stagnating since last two decades. Coconut germplasm collection, conservation and evaluation in the country resulted in development of several improved varieties for high yield and quality. The palm is highly heterozygous in nature and hence the progenies produced from any selected generation would segregate making it difficult to maintain the selected lines. Owing to the absence of vegetative propagation methods for coconut, selfing and *inter se* mating are practiced for germplasm multiplication. In the case of exotic germplasm collection, embryos are collected to produce embryo cultured plantlets for the conservation and evaluation. The dwarf accessions of coconut are relatively homozygous for dwarfness and early flowering over tall accessions. Exploitation of dwarf accessions with vigour and high yield are the major focus for decades and several hybrid combinations have been developed and released for commercial cultivation in India. About 24 exotic cultivars from Pacific Ocean Islands comprising of Solomon Islands, Fiji, American Samoa, American Tonga, French Polynesia and Papua New Guinea and six accessions from Nicobar group of islands (Auck chang, Tamaloo, Kimios, Kinmai, Katchal, Cambell Bay) were planted at Sipighat farm in 1983 and 1986, respectively. The present study was carried out to evaluate the variability present in the four dwarf populations viz., Niu Lekha Green Dwarf, Niu Oma Yellow Dwarf, Hari Papua Orange Dwarf and Nikkore Orange Dwarf collected from Pacific Ocean Islands. The exploitation of variability in these dwarf populations resulted in selection of four genotypes CARI-C1 (Annapurna, for high copra content) and ornamental types CARI-C2 (Surya), CARI-C3 (Omkar) and CARI-C4 (Chandan) with distinct features having the commercial importance in islands as well as in other coconut growing regions of India.



Poster
TS2-P04

Utilization of Annur coconut for hybrid coconut production with desirable characters

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The present day coconut hybrids are the crosses of T x D or D x T and the stature of the hybrids so developed are intermediary as compared to their parents. Research is going on to develop short statured coconut hybrid with good yield for easy management by utilizing a locally available ecotype, Annur type. Annur type of coconut possesses desirable attributes such as short inter nodal length, medium crown and fairly good yield as compared to West Coast Tall. Short internodal length is a conspicuous character of the Dwarf coconut varieties. A project to this effect was started in the year 2005 by locating 22 mother palms of desirable Annur types. Crosses were made between the selected Annur type with Chowghat Green Dwarf, Malayan Yellow Dwarf and *inter se* nuts of Annur were also produced during 2005-2006. One hundred and ninety one seed nuts of various crosses were sown in the nursery during 2006-07 along with West Coast Tall seed nuts. Most of the seed nuts failed to germinate since it was stored as usual before sowing. This is an indication that Annur type behaves like Dwarf in relation to short inter-nodal length and lack of seed dormancy. The nuts produced during 2007-08 were immediately sown in the nursery at RARS, Pilicode. The seedlings developed were similar to West Coast Tall and stature wise short as compared to WCT. These seedlings were planted in the field at RARS, Pilicode during August, 2009. The observation on the nursery characters indicates that there are chances to combine desirable attributes such as short stature and moderately high yield with good nut quality.



Poster
TS2-P05

Performance of coconut hybrids and their parents under Gujarat conditions

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On the basis of long term study on performance of coconut hybrids and their parents under Gujarat conditions, it was concluded that the hybrid coconut variety T x D (Mahuva) was found superior in respect of growth parameters, nut yield per palm per year and physical characters of nut and lower growth index of black headed caterpillar (*Opisina arenosella* S.) than its parents and at par with the rest of the hybrids.

Poster
TS2-P06

On farm genetic diversity in OP progenies and identification of pre-potent mother palms of Arsikere tall coconut cultivar and their characterization in the maidan tract of Karnataka

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Genetic diversity is important to sustain the productivity of a crop. In coconut, diversity provides characters for yield, adaptation, disease resistance and high value uses. Rich diversity of coconut varieties exists in farmers' fields, which are untouched by the research methods employed for crop improvement in coconut. There exists tremendous scope for utilizing the genetic diversity of coconut for providing various options and opportunities while formulating strategies for solving the problems of coconut farmers. In Karnataka, Arsikere tall cultivar is the leading coconut cultivar grown in the maidan tract consisting of five districts namely Tumkur, Chitradurga, Hassan, Chikamagalur and Mandya which contribute 76% of total area and coconut production in the state. Because of the cross fertilized nature of this palm and seed propagation, it does not breed true to type and makes the selection of seed nuts and seedlings in the nursery all the more difficult and important as the performance of the new progeny can be evaluated

only several years after field planting. In the present investigation supported by Coconut Development Board, Govt. of India, attempts were made to identify pre-potent mother palms of Arsikere tall cultivar in the maidan tract of Karnataka through extensive survey of the coconut growing region. A total of 11,600 mother palms and 99 pre-potent palms from 33 coconut gardens were identified through extensive surveys carried out from 2007-2010. The detailed characterization of morphological traits, bunch and nut characters, nut quality, copra quality and coconut oil quality of the selected pre-potent mother palms of Arsikere tall cultivar was recorded. The results indicated vast variability for nut yield which ranged from 138.0 in accession BS1 to 210.90 nuts/palm/year in accession SV1. Also, there was lot of variations in the copra content (105.50-217.00 g/nut). Estimation of fatty acid profile of coconut oil extracted from representative samples of different pre-potent elite mother palms exhibited wide variations in lauric, palmitic and other unsaturated fatty acid content. Molecular characterization of the selected elite pre-potent mother palms was also done in order to categorize and utilize the valuable genetic stock for future use.

Poster

TS2-P07

Evaluation of the promising genotypes of coconut and their prepotency at seedling stage

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A study was conducted with 10 exotic and five indigenous types of coconut to identify the superior types suitable for northern Kerala. The experiment was laid out in 1976 with 15 treatments in three replications in lateritic soil at RARS, Pilicode. The treatments included were the genotypes, viz., St. Vincent, Borneo, British Solomon Islands, Kenya, Kudat, Guam II, Seychelles, Philippines Lono, Siam, Kulithali, Kalpavangi, WCT, Andaman Ordinary, Andaman Giant and Laccadive Ordinary. The experimental plants were maintained with good management and irrigation. The zone normally obtains 3500 mm annual rainfall spread over a period of three to four months i.e., June to September. The quantitative characters such as functional leaves, annual female flower production, nut setting percentage, nut yield per palm, copra and oil content were recorded. The occurrence of the pests and diseases were also recorded. In another experiment the open pollinated nuts of the superior types were collected as seed nuts during December to May. About 30 to 40 nuts obtained during the period from each of the three superior accessions were sown in the nursery during June for evaluation of prepotency of the superior types. The morphological characters such as plant height, collar girth, leaf number and the qualitative character petiole colour of the seedlings were studied at the age of nine months in the nursery.

The genotypes, Seychelles, Kudat, Philippines Lono and St. Vincent were found to be on par



and superior to other genotypes in terms of female flower production, nut yield, copra content and copra yield per palm. The genotypes WCT and Phillipines Lono were already recommended for cultivation and seedlings of these were produced for distribution for farmers. The cultivar Seychelles was released as Kera sagara for cultivation in Kerala. The progeny trial with the promising genotypes, viz., Seychelles, Kudat and St. Vincent indicated that the seedlings of the open pollinated seed nuts have expressed mother palm characters. The standard deviation of the morphological characters such as plant height, collar girth and leaf number of the seedlings of the mother palms did not differ significantly. The qualitative character, colour of the petiole was to a large extent similar to that of mother palms of the cultivar. Hence, the open pollinated nuts and their seedlings could be used for raising the planting materials of these superior genotypes.

Poster
TS2-P08

Diversity studies in tender coconut

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Coconut water (liquid endosperm), with its many applications, is one of the worlds most versatile natural product. This refreshing beverage is consumed worldwide as it is nutritious and beneficial for health. There is increasing scientific evidence that supports the role of coconut water in health and medicinal applications. Coconut water is traditionally used as a growth supplement in plant tissue culture/micropropagation. The wide applications of coconut water can be justified by its unique chemical composition of sugars, vitamins, minerals, amino acids, phytohormones and is low in fat, calories and has no cholesterol. It has a caloric value of 17.4 per 100 g of water. The water of tender coconut is a sterile, nutritious, thirst quenching health drink. The varieties suitable for water are Chowghat Orange Dwarf, Chowghat Green Dwarf, Malayan Yellow Dwarf, Malayan Orange Dwarf, Malayan Green Dwarf, Gangabondam and Andaman Dwarf. Among the tender nut cultivars, Chowghat Orange Dwarf (COD) is the best. It yields nuts, which contain on average 350 ml sweet water. The water has 7.1 g total sugars per 100 ml, 4.7 g reducing sugars per 100 ml, and the mineral composition accounts for 20,000 ppm of potassium and 20 ppm of sodium. The volume of coconut water is the highest in 6 month old tender nuts of tall genotypes and 7 month old tender nuts of dwarf genotypes. The tall genotype 'San Ramon' records the highest volume of coconut water (635.4 ml). The heaviest endosperm was observed in the tall genotype 'Andaman Giant' (207.7 g) and dwarf genotype 'AOD' (140.4 g). The total sugar and mean reducing sugar content of coconut water increased with the ageing of nuts, with the dwarf genotypes recording higher total sugar and mean reducing sugar content than the tall genotypes. The mean potassium content decreased, whereas, the mean sodium content and pH of the tender water of both tall and dwarf genotypes increased with the ageing of the nuts. In spite of several developments due to intense research efforts, several gaps exist, which need the attention of scientists for further development of production, productivity and diversified products of tender coconut.



Poster
TS2-P09

Performance evaluation of coconut cultivars under rain fed conditions

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Performance of five tall cultivars (1994 planting) and two dwarf cultivars (1997 planting) of coconut was evaluated under rainfed situations. The number of nuts/palm/harvest was recorded from 2005 onwards. The average yield /palm/year was assessed during the initial bearing period (10-14 years). All the cultivars exhibited a progressive increase with respect to the nut yield/palm/ year. Among the tall cultivars, WCT (Kasaragod) recorded the highest yield of 24 nuts/palm in 2005 followed by Komadan with 23 nuts, whereas, Lakshadweep Ordinary recorded only 10 nuts/palm. Within a span of five years, Komadan recorded 77 nuts/palm/year followed by WCT (Kasaragod and Kuttiyadi) with 74 and 73 nuts/year, respectively. Tiptur tall showed yield increase from 19 to 66 nuts/year in the same period. Among the dwarf cultivars, Chowghat Green Dwarf yielded maximum with 76 nuts/palm in 2006 which declined to 56 nuts by 2009. Whereas, for Gangabondam initial nut yield was 13 which increased to 24 nuts/palm by 2009.

Poster
TS2-P10

Character association and path coefficient studies in coconut (*Cocos nucifera* L.)

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The twelve month old seedlings of coconut were grown at Parbhani during 1987-'88, in pot culture experiments representing different levels of exchangeable sodium percentage (ESP) and salinity (ECe) in addition to control soil and a naturally problematic soil of Purna command area. At the seedling age of one year, 11 different characters including dry matter production of whole plant as dependent variable were measured and were analysed for correlations and path coefficient studies. The correlation studies indicated that except plant



mortality percentage, all the characters had high positive and significant correlation with dry matter production both under ESP and salinity conditions. In path coefficient studies, fresh weight of whole plant influenced dry matter production directly and indirectly. The next indirectly related character was total chlorophyll content. However, the association of all characters with dry matter in presence ESP level was either weak positive or negative nonsignificant. The characters-wise plant mortality, stomata number and rate of transpiration showed negative correlation with most of the characters, but these three were found to be positively related with each other. The interrelationship among other characters was highly and positively significant.

Poster
TS2-P11

Evaluation of genetic diversity in coconut (*Cocos nucifera* L.)

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Coconut, *Cocos nucifera* L., known as 'Tree of Heaven' or 'Kalpavriksha' is a plantation crop with immense importance, comes under the family Arecaceae. An experiment was conducted at CPCRI, Kahikuchi, Assam to ascertain the reliable assessment of the genetic diversity of 13 coconut accessions in field condition. The materials were collected from different parts of NE, Assam in particular (Kamrup and Nagaon District). The genotypes represented a diverse group with respect to their geographical origin. The accessions were planted in a randomized manner with a population size of 11 palms per accession at spacing of 7.5 m x 7.5 m during June, 2003 and maintained as per the recommended package of practices. Morphological growth characters, flowering, inflorescence and nut yield data were recorded periodically on five randomly selected palms from each accession at different palm growth stages. The accessions showed variability for different traits such as trunk height (m), girth of trunk (m), annual leaf production, annual inflorescence production and annual nut production. Among the accessions, KKHC-6 was sturdier with higher stem circumference of 1.56 m followed by KKHC-3 (1.53 m). Earliest flower initiation, during the 4th year (2007-08) of planting, was observed in three accessions viz., KKHC-3, KKHC-8 and KKHC-10, while the rest of the accessions flowered during the 5th year of planting. Annual inflorescence production was greater in KKHC-2 (4.8) followed by KKHC-6 (3). The annual nut yield (mean of two years) data, indicated higher initial nut production in the accession KKHC-10 (18.5 nuts/palm) followed by KKHC-3 (14.5 nuts/palm). However, a more detailed evaluation is required for identification and release of high yielding and superior accessions for cultivation in the North Eastern region of the country



Poster
TS2-P12

An assessment of floral diversity in the homestead farms of Kerala, India

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In various parts of the world, limitation of land resources and ecological imperatives has led to the evolution of the characteristic homestead farming system, wherein farming is concentrated in and around the farmers' residence. An extensive survey on the structure and function of homestead farms covering all the agro climatic zones of Kerala, India was carried out during 2002-04. This paper describes crop species diversity observed in about 2,500 homestead farms in 14 districts of the state. The size of the homestead farms ranged from 0.04-2.40 ha with an average of 0.35 ha. Coconut was the base crop in more than 90 per cent of the homesteads surveyed, in the interspace of which a wide variety of crops ranging from annuals to perennials were cultivated. The total number of species encountered ranged from 117 in the mid zone to 195 in the northern zone with a mean of 154. Among the various crop species, the maximum percentage was noticed in the case of food crops (33.8) which consist of fruit crops (13.4); vegetables (10.2); spices (5.7) and tuber crops (4.5). Various types of ornamental plants occupied 19.1 percentage of the species diversity, followed by timber and miscellaneous trees (14.6 %) and medicinal plants (12.7 %). Weeds constituted 11.5 % of the diversity, while plantation crops as a group represented 3.2 % of the crop species diversity. The most predominant crops are banana (*Musa* spp.), papaya (*Carica papaya*) and guava (*Psidium guajava*) for fruits; brinjal (*Solanum melongena*), chilli (*Capsicum annum*), cowpea (*Vigna unguiculata*), moringa (*Moringa oleifera*) and bitter melon (*Mimordica charantia*) for vegetables; black pepper (*Piper nigrum*), ginger (*Zingiber officinale*), turmeric (*Curcuma longa*) for spices; cassava (*Manihot esculenta*), colocasia [taro] (*Colocasia esculenta*) and amorphophallus (*Amorphophallus paeoniifolius*) for tuber crops. Among the ornamentals, hibiscus (*Hibiscus rosasinensis*), ixora (*Ixora coccinea*), jasmine (*Jasminum* spp.) and marigold (*Tagetes* spp.) are the most common species. In the case of miscellaneous trees, erythrina (*Erythrina* sp.) and vatta (*Macaranga peltata*); among the weeds, eupatorium (*Chromolaena odorata*), cynadon (*Cynadon dactylon*) and cyperus (*Cyperus rotundus*) are the predominant species. Coconut (*Cocos nucifera*) and arecanut (*Areca catechu*) are the most frequently occurring plantation crops. Species like teak (*Tectona grandis*); jack fruit tree (*Artocarpus heterophyllus*), mango tree (*Mangifera indica*) and anjili (*Artocarpus hirsutus*) are dominant among the trees. Various types of food crops are of seasonal nature and their inclusion as components of homestead farming is a definite indication of nutritional security



of farm families being planned under such a system of cultivation. Timber and miscellaneous trees are perennial in nature and are being raised either for augmenting income through sale of wood (timber species) or for household fuel requirement (miscellaneous trees). Though many species of medicinal plants were noticed, none is grown on a commercial basis. However, certain species are ingredients of home remedies. The number of crop species and species composition found in homestead farms may be attributed to the socio-economic conditions of farmers as well as to their needs. The conservation of cultivated plants in homestead farms not only preserves a vital resource for humankind but also provides significant economic and nutritional benefits for the rural farm families. Thus, the homestead farms are complex systems with plant diversity conserved through their use. There is, therefore, an urgent need to develop policies that will continue to support the rich agro biodiversity of these areas, while providing for the nutritional and economic needs of the population.

Poster
TS2-P13

Stability analysis for yield and yield components in coconut (*Cocos nucifera*)

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Environmental factors influence productivity of the coconut palms and contribute to fluctuations in nut yield. Analysis of stability parameters assumes significance as it provides information about adaptability of a genotype to a particular environmental condition. Stability parameters and G x E interactions over the years for yield and yield components of 28 cultivars of coconut were analyzed. The study revealed that the G x E interaction was highly significant indicating differential performance of the genotypes under varied environmental conditions. The stability parameters indicated that the cultivars namely WCT, LCM and Spicata were stable for nut yield with desirable high mean yield.



Poster
TS2-P14

Application of spatial technique in field experiments with coconut

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Experimental error or the unexplained variation is the main concern in field experiments. Experiments with coconut require large area and variation due to positional effect is very high particularly for conducting experiments in farmer's field. Coconut is grown mainly in undulated and hilly areas where getting large homogeneous area to control the experimental error is difficult. In the present study, spatial modeling technique is used to estimate/eliminate the location effect in field experiments. The only assumption about the location effect is that it is a smooth spatial function. The proposed method can also be used to eliminate positional effect from the phenotypic value to select mother palms in breeding program.

Poster
TS02-P15

Identification of cold tolerant coconut germplasm in Bastar

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Coconut is an important perennial oil yielding crop of humid tropics and India has largest acreage as well as largest producer of coconut. The yield of coconut palm is not only depending on the current year climatic pattern, but also on weather pattern of preceding years. In Bastar the temperature goes below 10° C for 2-3 months in winter seasons. Hence, six coconut germplasm which are identified from cold tolerant Bastar region were assessed for their growth and yield performance. Among the germplasm, CRP-723 recorded maximum no. of leaf at crown and spathe production (36 and 13, respectively) followed by germplasm CRP-728 while, minimum no. of leaf (27) at crown under CRP-727 germplasm and in CRP-725 germplasm the spathe production (09). Nut yield and weight of kernel were observed to be the highest (293 and 192 g) in germplasm CRP-723 followed by CRP-728 and lowest (148 and 143 g) in CRP-727. Nut water was found best (343 ml) in germplasm CRP-726 followed by CRP-727 and the lowest (143 ml) under germplasm CRP-728. Sodium was the lowest in CRP-723 and potassium was the lowest in CRP-724 germplasm.



Poster
TS2 -P16

Morphometric characterization and diversity analysis of a makapuno coconut population in U.P. Los Baños

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Genetic diversity of embryo cultured makapuno coconut population maintained at the University of the Philippines Los Baños was assessed from March 2004 to January 2006. The population was developed from heterozygous trees of Laguna Tall. Chi-square tests was used to compare the observed distribution of qualitative characters with their expected distribution. Crown shape, structure of stem base, colour of young inflorescence, and fruits, shape and size of fruit and nut, and leaf morphology differ in their pattern of distribution. High bole, low bole and no bole were equally distributed in the population. The Shannon Diversity Index for both qualitative and quantitative characters showed moderate to high diversity. High phenotypic diversity indices was obtained from fruit and nut characters while moderate from all other characters. Principal Component Analysis revealed that fruit, nut and husk weight account for 99% of the observed variation. The cluster analysis generated six clusters. Cluster VI was the highest cluster which included 24 palms; cluster V was the second highest included 11 palms, while cluster I, II, III, and IV included 3, 2, 7 and 3 palms, respectively.



Plenary lecture

TS2-PL

Biodiversity in the coconut: Implications of biodiversity

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The coconut tree (*Cocos nucifera* L., Arcaceae) is present/cultivated throughout the tropics of the world. No other plant has such universal distribution in the tropics. Coconut is also the most useful tree to humans.

The genus *Cocos* is presently considered monospecific. Earlier, more than 60 species had been included in the genus. They are predominantly South American in distribution. Now, the closest genus to *Cocos* is *Syagrus* (32 species, tropical South America). Molecular biology studies have shown that *Parajubaea* (three species northern South America) has a 'half-sister' relationship, and *Jubaeopsis* (one species, South Africa), *Beccariophoenix* and *Voaniola* (both one species, Madagascar) have the next near-relationship.

The limited morphological and molecular biological studies have shown that the cultivated crop possesses moderately good variability for various characters. Only very few and limited floral and pollination biology work have been done on coconut. They were done 50-80 years ago, except one study. Coconut is described as predominantly cross (Talls) and self (Dwarfs) fertilizing. The very limited genetical observations support this. However, there appears to be significant variations in flowering biology both within a year and the populations.

Coconut flower is adapted to wind pollination, but anaemophily may be occurring only limitedly. Several insects (ants, honey bees, thrips, etc) and animals (bats, birds) have been implicated in pollination. Overall, coconut palm appears to show an opportunistic pollination system.

The implications of the above four observations will be discussed. With the limited available data, the present prognostics of coconut biodiversity appear to be mixed. This calls for initiating systematic studies on these three aspects immediately.



TECHNICAL SESSION III

BIOTECHNOLOGICAL TOOLS IN CROP IMPROVEMENT



Lead lecture

TS3- 101

The development of an efficient process for the micropropagation of coconut

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The deadly disease lethal yellowing has killed millions of coconut palms in several countries in the Americas. So resistant coconuts have been searched and identified in Jamaica and Mexico that include Malayan Dwarf cultivars and Mexican Pacific Tall ecotypes, but then massive and quick propagation of these coconuts is required. As a result, a micropropagation protocol has been developed, based on somatic embryogenesis induced from plumule explants of Malayan Green Dwarf (MGD) cultivar and callus multiplication, which is able to yield one hundred thousand somatic embryos *per* explant. Embryos were able to germinate and convert to plantlets with 10-24% efficiency. After acclimatization in nursery, micropropagated coconut plants were successfully transferred to field conditions with excellent performance. The protocol has been applied to propagate Mexican Pacific Tall (MPT) coconuts as well, and preliminary tests have shown lower yields of somatic embryos obtained *per* explant but greater conversion efficiency in relation to MGD. The MPT plantlets obtained are currently at the stage of nursery acclimatization. Also advances have been obtained in the use of floral tissue explants instead of plumule explants, yielding calli that have been able to multiply and eventually form somatic embryos. In addition, for further improvement in efficiency and the quality of plants (e.g. resistance to diseases), we are starting to try different approaches that include the use of bioreactors and molecular improvement.



Lead lecture
TS3-I02

Functional genomics in insect-plant interactions

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The advent of second-generation sequencing such as Roche® 454 pyrosequencing and Illumina/Solexa offer a unique opportunity to study functional genomics in non-model organisms, wherein little or no molecular knowledge is available. In particular, 454 pyrosequencing has recently enabled to decipher transcriptomic signatures in a broad range of insect and plant species. The emerald ash borer (EAB, *Agrilus planipennis*) is an invasive insect pest in North America that has currently reached “high impact” status. Since its discovery in 2002, it has killed millions of ash trees (*Fraxinus* spp.) and threatens billions more. However, despite the impact little to no functional knowledge (expressed sequence tags) exists for EAB and ash. We have undertaken a functional genomics approach to learn tissue-specific transcriptomics of EAB (midgut and fat body) and ash (phloem) using 454 pyrosequencing. These studies will help lay the foundation for future gene expression studies using cutting-edge genomics tools such as RNA-Seq. Results stemming from these studies will provide fundamental insights into their biology and help identify candidate genes (susceptible metabolic targets and R genes) for future targeted breeding programmes.



Oral
TS3 -01

Use of arabinogalactan proteins in coconut (*Cocos nucifera* L.) tissue culture: an alternative approach for improved tissue response

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Arabinogalactan proteins (AGPs) are extra-cellular proteins involved in plant growth and development. The effects of these proteins on *in vitro* response of different species are well documented. This study assessed for the first time the role of AGPs on tissue culture of coconut, a highly recalcitrant species *in vitro*. Coconut (Sri Lanka Tall) plumules were cultured in CRI 72 basal medium containing 215 μM 2,4-dichlorophenoxyacetic acid (2,4-D) for callogenesis. Initial calli were multiplied by subculturing onto freshly prepared callusing medium. Somatic embryos were induced by transferring of calli to medium with 2/3rd concentration of initial 2,4-D and matured by subsequent transferring to medium without any hormones or with 20 μM 2-isopentyladenine. Embryos were converted in Y_3 medium in the presence of gibberellic acid (0.45 μM). The effect of AGPs on callogenesis and somatic embryogenesis was tested using Arabic gum (1-50 mg l^{-1}) as the main source of AGP. Alternatively, different AGP sources like larch wood gum, carrot seeds, defatted coconut kernel and liquid coconut endosperm were used to assess their effect on coconut somatic embryogenesis. Arabic gum in callusing medium resulted in early callogenesis from 20-40% plumules compared to 10% in the control. However, it did not have a significant effect on final callusing efficiency. Its presence in somatic embryogenesis medium showed a significantly higher mass of well developed embryogenic structures per embryogenic callus clump (33.3-50.5 mg) when compared to the control (26.9 mg). The best result was obtained at 10 mg l^{-1} Arabic gum. However, percentage of embryogenic callus clumps per treatment was not significantly different. Among the alternative AGP sources, defatted coconut kernel (25-50 mg l^{-1}) showed significantly improved results, giving above 68% cultures with well developed embryogenic structures when compared to 37% in control. Although AGP sources showed a positive response to somatic embryo induction, so far their effect on plant regeneration could not be seen.



Oral
TS3- 02

Genetic relatedness of coconut populations from Andaman and Nicobar Islands traced to the Indian sub continent using microsatellite markers

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The coconut genetic diversity and relatedness of the Andaman and Nicobar group of Islands is of interest due to its geographical location between the predominantly cultivated *Niu Vai* (human selected) type of coconuts in the South East Asian region and the *Niu Kafa* (wild) type in the South Asian region. The origin of coconuts in the Nicobar Islands is unclear and it is believed to have been either established itself by natural means through floating in sea from the neighbouring islands or spread through the ancient seafarers. The microsatellite analysis of 26 Andaman and Nicobar coconut populations collected from the far corners of the island show genetic proximity to the Indian and African coconut populations than their neighbourhood South East Asian Coconut populations. Only one accession, Andaman Ordinary Tall (ADOT) showed a genetic relatedness to the South East Asian coconut populations. A total of 51 alleles were detected by eight polymorphic microsatellite primers with an average of 6.3 allele/locus. The 12 Nicobar accessions grouped together as a separate cluster within the Indian sub continental coconut populations while the Andaman accessions were found interspersed among them. The results of our study are significant in defining the geographical boundary of the two genetically divergent coconut populations of the world. This study has implications in understanding the spread of coconuts in the Indian Ocean Islands and factors that led to the genetic divergence of this group of coconut populations from the South East Asian and Pacific populations.



Oral
TS3 -03

Evaluation of ten Sri Lankan coconut phenotypes for variation at microsatellite marker loci and fruit morphology

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Coconut (*Cocos nucifera* L.) is classified within the mono-species genus *Cocos*. Collection, conservation and evaluation of coconut germplasm are important to provide material for genetic improvement of coconut. Wild relatives of the coconut are no longer in existence and thus the farmers' varieties provide the option for coconut diversity. The objective of the current study was to evaluate Sri Lankan coconut phenotypes (Sri Lanka Tall, Green Dwarf, Brown Dwarf, Bodiri, San Ramon, King coconut) including several farmers' varieties (Ran pol, Murusi, Juwan, Bothal thembili) for diversity in fruit morphology and variation at microsatellite marker loci. Fruit components revealed a higher diversity for size and the weights of components. Among the new phenotypes, Ran pol produces the largest and heaviest nuts surpassing even San Ramon, which is an introduction to Sri Lanka from the Philippines. Similarly, the newly identified dwarf Murusi produces nuts that are larger and heavier than the comparative Sri Lanka Green Dwarf. Further, the differences of nut morphology between Bothal thembili and its comparison to King coconut and the unique nut characters of Juwan coconuts were revealed to be noteworthy. A total of 89 alleles were scored at 13 microsatellite loci at an average of 6.84 alleles per loci. The phenetic tree drawn using genotypic data revealed two groups separating tall coconuts from the dwarf group. Bodiri which has been earlier categorized as a tall, but now known to display mixed characters are included in the dwarf group. Further, King coconut which was earlier categorized as an intermediate between tall and the dwarf coconut are also clustered in the dwarf coconut group. All the new tall coconut phenotypes except for Ran pol were found to cluster within the tall group. However, Ran pol grouped within the dwarf group indicating a Pacific or South East Asian origin for Ran pol.



Development of Real-time PCR technique based on SYBR Green Chemistry for detection of coconut root (wilt) phytoplasma

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Phytoplasmas are unculturable, phloem limited plant pathogens and are associated with the root (wilt) disease of coconut. Molecular detection of phytoplasma is based on PCR amplification of 16SrDNA followed by nested PCR because of the low titre of phytoplasma in infected coconut. Real-time PCR methods are being employed for detection of plant pathogens including phytoplasma because of the accuracy, specificity short analysis time and absence of post PCR manipulations that prevents carryover contamination. In the present study, a specific and efficient real time PCR based detection system for coconut root (wilt) phytoplasma was developed using double stranded DNA intercalating dye, SYBR green. Primers RWDF1/RWDR1 were designed to specifically, amplify 218 bp fragment from the 16S ribosomal DNA region of phytoplasma. A melting curve analysis was programmed at the end of the cycling reaction to evaluate the purity of the amplification product. A unique melting peak at 80.71°C was observed for infected coconut and positive control samples. The PCR products were also checked on gel and a single band of expected size was obtained. The negative control and healthy samples showed a different and lower melting peak. The PCR products were further purified and sequenced. The results were analyzed using BLASTn. The sequences showed similarity with Sugarcane white leaf phytoplasma with identities ranging from 93%-99% and results were similar to those obtained in previous work on molecular detection of phytoplasmas associated with root (wilt) disease through nested PCR. The Real Time PCR technique could be effectively used for detection of coconut root (wilt) phytoplasma.



Poster
TS3 -P02

Differential expression of genes regulated in response to water stress in coconut

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Water stress is one of the most imperative abiotic stresses limiting the productive potential of plants and with the advent of molecular and genomic technologies, emphasis is now being placed on deciphering mechanisms of its genetic control. To identify and isolate cDNAs representing transcripts differentially expressed during water stress in coconut, *in vitro* grown coconut plantlets were treated with PEG 6000 to create stress conditions. We have then applied differential display technique to the comparison of PEG 6000-treated and untreated plantlets. Analysis using the 30 primer combinations revealed 39 up-regulated transcripts to be differentially expressed. The transcript derived fragments (TDFs) were eluted, cloned and sequenced. The results of the sequence comparison of the TDFs in BLAST database revealed that several differentially expressed transcripts were significantly homologous to stress regulated genes/proteins isolated from other plant species. Other transcripts identified represented genes related to metabolism, energy, protein biosynthesis, cell defence, signal transduction, transport, and including a few with no known function. The results of this study give an indication of candidate genes which are induced during water stress in coconut.



Poster
TS3-P03

Analysis of coconut (*Cocos nucifera* L.) diversity using microsatellite markers

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Coconut (*Cocos nucifera* L.) is grown throughout the tropics as a plantation crop yielding several agronomic products that are important to export economies in these regions. It is essential to understand the genetic diversity present within the Indian and exotic coconut accessions in order to utilize them effectively for breeding purposes and also for its preservation. Knowledge of relatedness among different coconut cultivars will also help in identifying cultivars and thus avoiding duplication in germplasm conservation. Fifteen SSR markers were used to study the extent of genetic diversity in 39 coconut accessions. A total of 69 alleles were detected, with an average of 4.6 alleles per locus. Fifty alleles were detected in tall coconuts (mean number of alleles/locus = 4.4) compared with only 26 (mean/locus = 2.1) in dwarfs. Analysis of similarity matrices based on allele bands across all loci (Jaccard coefficient) was done. Polymorphism information content (PIC) was relatively higher in the tall coconut than in the autogamous dwarf form of coconut. The unweighted pair group method with arithmetic averages (UPGMA) cluster analysis grouped the accessions according to their geographical locations and breeding behaviour. The UPGMA cluster analysis distinguished clearly between the dwarf and tall coconut accessions and separated tall into major two groups, namely Indian Ocean tall and South-East Asian tall. These results indicate the high potential of microsatellites to detect genetic diversity in coconut germplasm.



Poster

TS3-P04

Effect of various auxins on high frequency callus induction from coconut plumule explants

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Scaling up the production of planting material from elite, disease free coconut palms using plumule culture is being done at CPCRI, Kasaragod. An efficient protocol for the production of high frequency callus from plumule explants has been developed. The effect of various auxins on plumule explants was investigated viz., 2,4-dichlorophenoxy acetic acid (100, 150 and 200 μM), 2,4,5-trichlorophenoxy acetic acid (100 and 200 μM), chlorophenoxy acetic acid (100 and 200 μM), α -naphthalene acetic acid (100, 150 and 200 μM), 3,6-dichloro-2-methoxy benzoic acid (Dicamba) (100, 150 and 200 μM), and 4-amino 3,5,6-trichloropicolinic acid (100, 150 and 200 μM Picloram). The mature zygotic embryos of West Coast Tall (WCT) were allowed to germinate in Eeuwens Y3 medium supplemented with 1 mg/l GA_3 and after 10 days the plumule alone was extracted aseptically and subjected to these callogenic chemicals. Among the auxins tried, 2,4-dichlorophenoxy acetic acid @150 μM was found to be the best for callus induction (62% after 90 days), whereas, Picloram showed direct shoot development. α -Naphthalene acetic acid and Dicamba had no significant effect on callus induction. Pulse treatment of 2,4-dichlorophenoxy acetic acid was done on zygotic embryos using different concentration (100 to 450 μM at 50 μM increment) with different intervals of time (0 to 90 min. at 15 min. interval). It was observed that 2,4-D 200 μM for 60 min. resulted in early callus induction (15 days). The present study revealed that 2,4-dichlorophenoxy acetic acid was found to be the best auxin for production of high frequency callus from plumular explants of coconut.



Poster
TS3-P05

Modified pre-growth desiccation for cryopreservation of coconut zygotic embryos

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Present study investigates the positive effect of raffinose in combination with sucrose for the cryopreservation of coconut zygotic embryos. The mature embryos pre-grown in 0.6M sucrose for 3 days and cryoprotected with 2 M sucrose and 0.25 M raffinose for 24 h resulted in significant post cryosurvival and regrowth. Studies with WCT, MYD and Fiji tall embryos resulted in 21%, 24% and 22% of healthy plantlets, respectively, for potting within 10-11 months of culture initiation. This protocol shows its effectiveness for long-term storage of coconut genetic resources that provide a viable backup for the present field gene bank.

Poster
TS3-P06

Polyamine-induced plantlet regeneration from plumular explants of dwarf cultivars of coconut

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Regeneration of complete plantlets *via* organogenesis and somatic embryogenesis was achieved from plumular tissues of two dwarf cultivars of coconut *viz.* Chowghat Green Dwarf (CGD) and Malayan Yellow Dwarf (MYD). Callus was induced from plumular tissues in Y3 media supplemented with 2,4-D (16.5 mg/l) in combination with TDZ (1 mg/l). The calli developed were sub-cultured at monthly intervals to media containing lower levels of 2, 4-D and a constant level of polyamines (100 μ M spermine and 1 mM putrescine). Somatic embryoids and meristemoids, when formed, were transferred initially to plain liquid Y3 medium without any growth regulators and later to a medium containing BAP (4 mg/l). Significant differences were noticed between varieties for the formation of embryogenic calli. Higher percentage of embryogenic calli was formed in CGD compared to MYD. There were also significant differences for interaction between variety and regeneration medium with respect to formation of somatic embryos. In the case of



MYD, enhanced somatic embryogenesis was noticed in medium supplemented with spermine compared to putrescine. Histological studies of the differentiated tissues confirmed the development of shoot buds (organogenesis) and typical bipolar embryoids (somatic embryogenesis). Well developed plantlets were acclimatized under green house conditions and then successfully established in the field.

Poster

TS3-P07

Effect of gamma irradiation on coconut zygotic embryos - A preliminary study

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Mutation studies of whole coconut have been attempted in early 60's. X-rays and gamma rays were found to be the most convenient and easiest types of radiation to use. Mature West Coast Tall (WCT) embryos were subjected to various gamma irradiation treatments (from 1.5 to 5.5 kr at an interval of 0.5 kr) with Cobalt 60 as a source at IGCAR, Kalpakkam. The treated embryos were *in vitro* retrieved in Eeuwens Y3 medium and observations on growth of the embryos were read at constant intervals. The LD⁵⁰ (2.5 kr) was standardized for the zygotic embryos of coconut. The dose rate was 3.87 kr/hr at the time of irradiation. The growth rate decreased with increase in dose of irradiation. The cellular morphological and anatomical observations revealed that the cytoplasm was well preserved in the cell and the nuclei contained dispersed chromatin region depending upon the irradiation levels. In addition, envelopes of nuclei showed evidence of damages in all the irradiated plants as well as the control. The combination of coconut embryo culture and mutagenesis is relatively inexpensive, simple and efficient.



Poster
TS3-P08

A fast and versatile molecular tool for detection of root (wilt) phytoplasma in coconut palms

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The root (wilt) disease of coconut caused by phytoplasma and is currently threatening the coconut plantations in South India. The disease was first recorded during 1882 in Kerala (India) by Butler and now it is fast spreading to Tamil Nadu, to nearby plantations of Kerala state and causing production constraints in many districts of Tamil Nadu. Accurate detection and identification tools are essential for this pathogen since it is an emerging and fast spreading disease in Tamil Nadu. The phytoplasma is phloem inhabiting organism at low concentration and has an uneven distribution in woody plants. In the present study the latest molecular technique, the real-time PCR (qPCR) assay with species specific primer pair and probe was validated for the detection of root (wilt) phytoplasma in coconut. The real-time PCR proved the specificity rather than commonly used and more laborious nested PCR for the detection of phytoplasma in coconut. The qPCR based method can be automated easily and preliminary results indicated that it is efficient for quantitative estimation of phytoplasma concentration in various parts of coconut palms. The real-time PCR protocol has been developed to detect the phytoplasma directly from the plant tissues of coconut more efficiently. This new molecular tool will be highly useful for both detection and to conduct epidemiology research of this emerging disease of coconut in South India.



Poster
TS3-P09

Molecular and morphological diversity of “Komadan” from other popular coconut cultivars

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Komadan is a local coconut off type, popular in the erstwhile Central Travancore area of Kerala associated with the family history of an old *Tharavadu* called Komattu house. This cultivar is now popular in the southern districts especially Trivandrum. The superiority of Komadan is cited by many authors in literature. In this study five popular coconut cultivars, WCT, Laccadive Ordinary, Natural Cross Dwarf, Chowghat Green Dwarf and Chowghat Orange Dwarf were compared with “Komadan” the popular cultivar of Travancore using 14 biometrical traits and 14 RAPD primers. The group constellations developed based on D^2 totals showed that the local cultivar WCT and NCD clustered together and the well preferred cultivar Komadan clustered along with Laccadive Ordinary, the variety of Lakshadweep released in Kerala as “Chandra Kalpa” for its superiority in performance. Maximum divergence was reported between Komadan and NCD. With regard to the characters chosen for the divergence analysis, it indicated the importance of nut characters in assessing the genetic divergence in coconut. The similarity analysis of the RAPD products showed that the accessions are divergent with respect to RAPD markers. Similarity indices showed that the two accessions, COD and CGD are having 98 percentage similarity. Komadan had 89 percentage similarity with NCD and only 77 and 71 percentage similarity with WCT and Laccadive Ordinary. The dendrogram constructed also depicts the clustering of Komadan along with NCD and dwarfs. The least similarity was noted between Laccadive Ordinary and Chowghat Orange Dwarf. These divergent accessions can be used as parents for exploiting maximum heterosis. Morphological markers clustered Komadan and Laccadive Ordinary together and West Coast Tall along with NCD. But in the RAPD analysis, West Coast Tall and Laccadive ordinary clustered together and Komadan clustered with dwarfs and NCD at 8 per cent similarity. Even though, Komadan is accepted as a superior palm, its pedigree is controversial. A detailed molecular study can give a clear picture.



TECHNICAL SESSION IV
BIOINFORMATICS APPLICATIONS



Lead lecture

TS4 -101

Molecular marker database for coconut germplasm management

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Applications of molecular markers are becoming more and more frequent in plant breeding and genetic resource management. Coconut is a long generation tree crop and molecular breeding makes it possible to optimize selection by combining genetic and phenotypic data. In some cases, it allows a reduction of the length of a breeding generation, thus maximising genetic progress per unit of time. QTLs have already been identified for fruit yield, fruit characteristics and cuticular wax composition.

Another crucial field of application is genetic resource management and characterization, including assessment of rejuvenated gene bank accession, elimination of unnecessary duplication and identification of genetic relatedness among coconut populations.

At the beginning of this century, CIRAD developed a microsatellite kit for coconut cultivar characterization, with 14 microsatellite markers under an IPGRI-COGENT project. Specialists from nine member countries were trained to its use and were provided the results obtained on several hundred genotypes. Several research teams used the kit on genotypes collected during surveys and in rejuvenated accessions. This kit was extended further and other research teams developed their own markers. Finally, an increasing amount of software is developed for population assignment in cross-pollinated species.

In this context and following COGENT recommendations, CIRAD intends to include microsatellite data obtained at CIRAD as well as at other laboratories in its public database Trop GENE, which already contains mapping data. The advantage of such a database (as opposed to simpler molecular data file) is that it can provide comprehensive information on the identity of the germplasm, including information obtained at the time of sample collection, as *a posteriori* assessment. Based on this information, researchers can select the most convenient sub-sample for their own study; identify the institutions, which provided the data; finally, they are also encouraged to provide feedback to the database, once they publish their research, thus enhancing the usefulness of the database for the coconut research community.



Lead lecture

TS4-I02

Locating and mapping coconut genetic diversity

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Cocos is the genus in the family Arecaceae (Palmaceae), subfamily Cocoideae, which includes 27 genera and 60 species. Distributed mainly in the coastal region between 20° N and 20° S, from sea level to 1000 m MSL, the coconut (*Cocos nucifera* L.) only species in the genus, is an important perennial tropical plantation crop with no known truly wild forms. The variability of local coconut types is reported to be highest in South-East Asia. However, it has not been possible to establish either a true centre of diversity or centre of origin for the species. Locating, maintaining and using genetic diversity of coconut present substantial challenges given the wide dispersal of the species, the limited knowledge of the history of that dispersion and of the current extent and distribution of diversity. Therefore, detailed studies are needed, particularly in high diversity areas. These should focus on ecogeographic aspects of the distribution of diversity and on the location of populations and ecotypes with unique useful traits such as resistance to biotic and abiotic stresses.

Mapping of coconut genetic diversity means representing any characteristic of coconut populations on maps, be it their phenotypic or molecular traits; and then studying the links between these traits and any other useful spatial information. According to the needs, the cultivars may be related to their site of origin or to the genebank where they are conserved. This type of analysis can improve the effectiveness of collection, conservation, management and use of coconut genetic diversity. The mapping studies conducted so far have used data on accessions already collected and conserved in germplasm banks around the world to locate under-represented areas, i.e. areas in which the coconut palms can potentially grow, but where collecting has been inadequate or has not occurred at all. Subsequently, it is possible to identify hotspots of diversity and investigate the geographic distribution of specific traits or combination of traits using information such as characterization and evaluation, including molecular markers, of the available genetic resources.

Recent developments in GIS technology for mapping genetic diversity is expected to contribute significantly to identify and fill the gaps in coconut collections, enhance the effectiveness of collecting, better manage them in field genebanks, effectively select parents from geographically distinct regions and expand coconut production through site-genotypic matching. These approaches have been discussed in this presentation.



Lead lecture

TS4-I03

Development of bioinformatics tools and resources for coconut research

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The coconut palm is a major plantation crop in the tropics and provides livelihood security to millions of small farmers in the coastal region. The advancement in research on coconut with the help of bioinformatics assumes great significance to address the issues faced by the crop and to achieve sustainability in farming. During the last one decade bioinformatics research was taken up at CPCRI through the 'Distributed Information Sub-centre' (DISC) and Agri Bioinformatics Promotion Centre (ABPC). Computational approaches enabled to accelerate the research programme in certain critical areas. A number of databases and tools have been developed to aid the research in coconut which include the database on coconut germplasm, coconut cultivar identification, MEMCO (Mining EST of cocoa and oil Palm), coconut microsatellites, coconut diseases, palms, vegetable oils, microbial information systems on plantations crops, pest control management system, stress genes, disease resistance genes, CorPK (Protein kinases), Phytoplasmas, PGPRs (Plant Growth Promoting Rhizobacteria), ESTs of palms and cocoa. Application of computational approaches resulted in development of bioinformatics tools and web servers. Shannon diversity tool helps to analyze the sequence for diversity. PHYTODB, is a comprehensive and user-friendly web server and a knowledge base devoted to the plant pathogen phytoplasma. Tools embedded in PHYTODB like Hlogs, MSalign, GroupIdentifier and PhyloClass are useful for homology search, multiple sequence alignment, phylogenetic analysis and 16S rRNA based group identification of new phytoplasma. At present PHYTODB contains 775 16S rDNA sequences (>1 kb length), 1514 genes and 2102 protein entries. The data has been modified especially for adding taxonomic group information to each entry in 16S group and manually curated genes and protein data to remove redundancies and formatted for data access easiness. This is the first ever phytoplasma specific server for data warehousing and data mining.



Oral
TS4-O1

Alternate genetics and genomics of coconut

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Coconut improvement is traditionally accomplished by exploiting indigenous and exotic germplasm, selection and variety-cross hybrids. Tall and dwarf are the contrasting forms used in making crosses. Geographical variability is also exploited mainly involving exotic accessions. Spontaneous mutants such as plicata, spicata, androgena, macapuno etc., however, occur in coconut and remain under utilized in breeding programmes except the macapuno in Philippines. There are other methods of plant breeding viz., single plant selection, elite pedigree breeding, exploitation of other mutants plicata, spicata and androgena, which can be potentially applied in coconut improvement, are not currently carried out elsewhere. At CPCRI, we have selected three single plants that are progenies of elite single plants with high yield over three generations. We found large variability in the selfed progenies of a single palm at six years of age (A high yield of 40 nuts per palm per year in one palm and no flowering initiation in some of the palms). A plicata mutant was located at Kasaragod and was also selfed. Selfed progenies of a single plicata palm are evaluated and are four years old now, and all are found to be plicata. Wide range of molecular markers are developed and exploited in coconut. As an alternate approach, we have used bioinformatics to develop new SNP markers based on available core nucleotide sequences. Bioinformatics mining of new SNP and indel markers for coconut was attempted. Twenty nucleotide sequences of coconut were mined for SNP and indels. These sequences were assembled to 11 contigs using CAP3 software. We found 838 SNPs, 325 transitions and 454 transversions and 59 indels were located using AUTOSNP software. Primers flanking stretch of SNP sites were designed and are being validated using PCR and re-sequencing. These alternate genetics and genomics research have potential in coconut breeding for evolving new hybrids and desirable traits.



Oral
TS4 -02

Somatic embryogenesis receptor kinase in coconut - Isolation, characterization and homology modelling

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Somatic embryogenesis involves differential gene expression and activation of numerous signal transduction pathways. Little is known about genes expressed during somatic embryogenesis in coconut. *Somatic Embryogenesis Receptor Kinase (SERK)* genes play key roles during somatic embryogenesis in various plant species. Sequence encoding *SERK* were cloned from coconut using a degenerate primer-based PCR approach. Sequence analysis revealed high levels of similarity to other plant *SERKs*, as well as a conserved intron/exon structure which is unique to members of the *SERK* family. Predicted amino acid sequences of *SERK* protein indicated presence of domains characteristic of *SERK* proteins from other species. Physicochemical properties of the selected proteins were determined using the PROTPARAM tools. The Kyte and Doolittle hydropathy plot revealed that the *SERK* protein was highly hydrophilic with a possible transmembrane region. Secondary structure prediction is of α -strands with random coils and the intrinsic disorder probability suggested these are highly unstructured. Function assignments were made based on the structural homologues (2QKW, 2NRY) identified for the test protein. 3-D structure was generated based on the secondary analysis. The structure thus obtained was assessed using PROCHECK. The distribution of residues in the most favoured region of the Ramachandran plot for coconut *SERK* was greater than 90%.



Oral
TS4 -03

A comparative study of coconut area of coastal and inland riverine ecosystem with satellite imagery

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Coconut (*Cocos nucifera* L.) is an important horticultural crop of India. Coconut is a crop of coastal region even though it is found growing well inland like in Assam. The present study is an attempt to compare the coconut cultivation area of Kasaragod District of Kerala and Kamrup district of Assam with the help of Eco-geographic factors and satellite imagery. Kasaragod is the northern most district of Kerala (11° 30' and 12° 48' N latitude and 74° 56' and 76° 30' E longitude) bordered on the north and east by the Dakshin Karnataka district of Karnataka; on the south by the Kannur district of Kerala and on the west by the Arabian Sea. Kamrup district of N.E. State Assam is situated between 25° 43' and 26° 51' N latitude and 90° 36' and 92° 12' E longitude with Brahmaputra river dissecting the district in the middle. Climatologically and geographically Assam is a humid sub tropic with an annual rainfall ranging from 178 to 305 cm with sub tropical rainforest ecosystem. Kerala is a humid tropic with an annual rainfall ranging from 90 to 180 cm. The ecosystem of Kerala is mixed with both tropical rainforest as well as coastal. The soil of Kamrup district is mostly alluvial and only lateritic soil is found in the southern foot hill regions. But the soil of Kasaragod district can be divided into three divisions. In the highland region it is lateritic, in the midland the soil is a red ferruginous loam of lateritic origin with an admixture of clay and sand. The coastal strip is sandy. In both the districts, coconut plants thrive well in well drained soils, as water logging is not good for this plant. The Kamrup district is rich in forest cover, having 10,7750 hectares of land under forest which is 24.77% of its total geographical area. The forest area is dominated by the deciduous species of trees, like Sal (*Shorea robusta*), Sida (*Lagerstromia parviflora*) and Sisoo (*Dalbergia sisoo*) and Teak (*Tectona grandis*). Other than this, the district has plantation forest with *Michelia* (champa) and *Syzygium* (jamun). It has rice as main agriculture and bamboo and coconut arecanut as homestead crops. On the other hand forest area is very insignificant in Kasaragod. The forest coverage has been cleared for coconut and other plantation crops. Among the plantation crops, coconut occupies the major area under cultivation of the district. Rice and tobacco are also grown. The detection and quantitative assessment of green vegetation is one of the major applications of remote sensing for environmental resource management and decision making. Healthy canopies of green vegetation have a very distinctive interaction with energy in the visible and near infrared regions of the electromagnetic spectrum. In the visible regions, plant pigments (most notably chlorophyll) cause strong absorption of energy (red light), primarily for the purpose of photosynthesis. In the near infrared however a very different interaction occurs. Energy in this region is mostly scattered by the internal structure of the leaves, leading to a very high apparent reflectance in the near infrared from the plant canopy. Taking this principle



into consideration, the amount of reflected energy in the red and near infrared regions of the electromagnetic spectrum, a quantitative index have been developed and is termed as NDVI (Normalized Difference Vegetation Index). The index helps to identify vegetation type very correctly as it has a direct correlation with the internal structure or the bio mass of leaf. Using satellite imagery identification technique and systematic ground survey two cropping pattern maps of the two districts were prepared, which gives clear idea of the coconut plantation of the two districts as well as a total agroeconomic pattern of the coastal and inland riverine ecosystem under study.

Poster
TS4-P01

Comparative approach on genome and proteome of four different strains of phytoplasma

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Comparative genome and proteome analysis of four different phytoplasmas, Aster yellows witches' broom (AY), *Candidatus Phytoplasma australiense* (PA), *Candidatus Phytoplasma Mali* (PM) and Onion yellows (OY) revealed conservations and variations among these strains. The protein coding potential of genomes were determined by GeneMark-hmm-p server using species specific parameters of the Markov models of coding and non-coding regions. Protein homologues identification among four genomes using multi proteome differential query system revealed 448 common proteins. Multiple sequence alignment and phylogenetic analysis algorithms were used to find closely related protein from multiple homologies. Two strains OY and AY shared more number of proteins (28). The longest conserved region was predicted in pairwise genome comparison of AY and OY strain using molligen 2 serve and was found to be 250 kb. The global minimum and maximum value in GC-skew pattern produced by GenSkew tool were used to predict the origin of replication (minimum value) and the terminus location (maximum value) for some genes i.e., *plsX* (AY), *pfk* (PA), *dnaA* (PM) and *tra5* (OY). Difference in the *gcpA* (page gene) homology in all strains of phytoplasmas showed that these inserts are from different phage attacks. *Tra5* (transposase) gene distribution predicted a very rare type of transposase (NC_011047.1) which is present in *Ca. mali* genome. ABC (ATP binding cassette) type transporter system that comprises about 30% of phytoplasma proteome and help this pathogen for its virulence and survival was also studied. From comparative analysis of seven different major ABC transport systems, it was observed that presence and number of times the same transporter occupied in the membrane varied among the strains. These comparisons are useful in finding out homology with the coconut root (wilt) phytoplasma which is associated with debilitating root (wilt) disease.



Poster
TS4-P02

Bioinformatic mining for markers in WRKY sequences of palms

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We have retrieved 525 sequences of WRKY genes of (WRKY2, WRKY6, WRKY7, WRKY12, WRKY16, WRKY19, and WRKY21) palms of 334 kb size. EST trimmer was employed to remove the vector and poly A (T) tails. Simple sequence repeats were located in the sequences by using microsatellite identification tool, MISA. Of these 525 sequences, repeats were found in 89 sequences at a frequency of 0.27/kb and 2 sequences of WRKY19 had more than one SSR and both were of compound type. AAT/ATT and AGT/ATC are the predominant repeat motif present (80%). The 525 WRKY sequences were assembled into 35 contigs using CAP3 tool. Single nucleotide polymorphisms (SNP) and insertion/deletions (indels) was detected in contigs using the AUTOSNP software. About 1241 SNPs were found including 374 transitions, 345 transversions and 522 indels. The SNPs were seen at a frequency of 5.8/100 bp in the WRKY sequences of palms. Primers designed flanking these SSR, SNP, indel sites have potential as markers in palms.

Poster
TS4-P03

Collection of coconut diseases databases and bioinformatics resources in Coimbatore region

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Coconut (*Cocos nucifera*) is an important multipurpose perennial oil crop of humid tropics. This crop is highly prone to various diseases caused by microbial agent such as fungi, bacteria and viruses. These diseases make the trees weak and lead to continuous reduction in yield till the palms completely die. Once the diseases start to appear, remedial measures should be taken well in time as other wise the trees may not recover and die eventually causing huge economic loss to the farmer in specific and the nation in general. The database collected on various diseases may be used by the researchers and farmers to devise appropriate and effective control measures to save the crops from complete death.



Poster
TS4-P04

Bioinformatics approach towards mining of candidate genes for water stress in coconut

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Water stress is one of the most critical environmental stresses reducing coconut yield in rainfed areas. It is therefore imperative to understand the molecular basis of genes imparting tolerance to water stress which will help in development of functional markers for identification of coconut cultivars with lower water requirements. We have designed degenerate primers according to conserved sequence motifs of five well-documented genes imparting stress tolerance (*MAPK*, *AP2*, *14-3-3*, *NAC* and *WRKY*) using bioinformatic tools. Reverse-transcriptase PCR (RT-PCR), using the degenerate primers, was used to study the expression patterns of the selected five candidate genes in leaves of two-year old coconut seedlings subjected to water stress. The amplicons were cloned and sequenced and analysis of the deduced amino acid sequences revealed homology to the respective genes from other plant species. All the five genes were found to be up-regulated suggesting that these genes may contribute to adaptation of coconut to water stress. Gene-specific primers were developed based on the sequences. The sequences were also mined for the presence of microsatellites using a fully automated in-house developed sequence analysis tool. These candidate genes are expected to be of potential use in genetic and association mapping and molecular marker-assisted selection for water-stress tolerance in coconut.



Poster
TS4-P05

***In silico* prediction of properties of Knox and Baby boom proteins in coconut**

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Somatic embryogenesis is the developmental restructuring of somatic cells toward the embryogenic pathway and forms the basis of cellular totipotency in higher plants. During somatic embryogenesis, biochemical and morphological changes occur, which is strongly related to alterations in gene expression patterns. Proteins known to be induced during somatic embryogenesis, viz. KNOX and BABY BOOM were characterized using bioinformatic tools. Sequence pattern recognition and determination of modular architecture were done by Interpro analysis based on PROSITE. Physicochemical properties of the proteins were determined using the PROTPARAM tools. Function assignments were made based on the structural homologues identified for the test proteins. 3-D structures were generated based on the secondary analysis. The structures thus obtained were assessed using PROCHECK. Predictions of potential ligands that bind to KNOX and BABYBOOM proteins, as well as critical residues that stabilize ligands were also carried out.



TECHNICAL SESSION V

RESOURCE MANAGEMENT AND SUSTAINABLE PRODUCTION



Lead lecture

TS5 -I01

Achieving higher resource use efficiency and productivity in coconut through drip fertigation

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For any crop production, the most important inputs are water and nutrients. Economical utilization of these inputs are always in question which otherwise adds to the cost of cultivation, water logging/salinity, soil and irrigation water contaminations. Drip fertigation gives solution to all the problems and further increase the overall efficiency. Drip irrigation is an efficient method of providing irrigation water directly in to the root zone of plants and it permits the irrigation to limit the watering closely to the crop water requirements of plants and also permits the utilization of fertilizers, pesticides and other water-soluble chemicals along with the irrigation water. The system applies water at low rate and under pressure to keep the soil moisture within the desired range for plant growth. The system has overall application efficiency around 90% as compared to 25-30% for surface irrigation. Drip fertigation increases the fertilizer use efficiency, saves fertilizer costs, reduces labour requirement, and supplies nutrients according to crop demand during various physiological stages. Moreover, the fertilizer application is uniform, precise and direct to the root zone. Studies on the coconut root absorption indicate that 0.75 m to 1.25 m away from the bole is the active absorption zone and hence it is recommended to place the emitter/micro tubes in the centre of that area (1m away from bole). The subsurface placement wetted 35% more volume than the surface placed emitters. At least four emitters are required for the laterite and red sandy loam soil, whereas for the sandy soil, six emitters are required to wet adequate volume of active root zone to wet a minimum of 15 to 20 percent of the active root zone. The main as well as fine roots were more in the limited area of the wetted zone under drip irrigation; the performance of drip irrigated palms (66% Eo) was on par with basin irrigated palms. The physiological parameters such as photosynthetic rate, transpiration rate, and stomatal conductance were higher under fertigation treatments, especially where 50, 75 and 100% N, P₂O₅ and K₂O applied through drip irrigation. The Fertilizer application at the rate of 50% of the recommended dose of fertilizer through drip irrigation produced an yield equivalent to 100% of the recommended dose of fertilizer applied both by conventional as well as through drip irrigation. Since coconut is a widely spaced crop, fertigation is most suitable /economical through drip irrigation.



Lead lecture

TS5 -I02

Precision farming in coconut

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Although precision farming (PF) started as a technology-led development, it is not just synonymous with yield mapping and variable rate technology (VRT) for managing spatial variability within a field. Instead, PF should be viewed as a systems approach to crop production in which the goal is to reduce decision uncertainty through better understanding and management of uncontrolled variation. Expertise from many disciplines is utilized, often also information technology, to bring data from multiple sources and scales to bear on decisions associated with crop production. If variability is the major source of uncertainty, it must be characterized and managed at the spatial and temporal scales that are most relevant. The appropriate management processes and information needs vary among different environments, but also among different decisions to be made. For example, climate and crop yield potential primarily vary across larger regions and among cropping seasons. Variation in soil nutrient supply may be most significant within a large field, or among many small fields within a landscape. Both spatial and temporal variation must be characterized. Site-specific crop management (SSCM) then aims at improving the input - output characteristics of the soil and crop system as they vary in space and time. This may involve the use of advanced technologies at the sub-field scale, or simply by improving field-level inputs. Practical steps usually include a cyclic process of: (i) characterization: measure extent, scales, and dynamics of variation, (ii) interpretation: assess significance, identify major causes of uncertainty, and formulate management targets, (iii) management: apply inputs at the appropriate scale and in a timely manner, and (iv) monitoring the outcome in a continuous learning process of change. This may be accomplished in discrete steps ("mapping approaches"), as dynamic processes executed in real-time ("sensing approaches", "modelling approaches"), or as combinations of both.

A Management Information System was developed in GIS and RDBMS soft wares. The MIS had seven modules (coconut planting, monthly weather data, harvest, cultural operations, pest and disease incidence and treatment of pest's data base)for the storing and retrieval of information. Detailed soil sampling was done by the integration of GPS and GIS for individual tree. Individual coconut palm yield variation within farm fields were mapped with spatio temporal database. The yield variability was analyzed using GIS. Soil fertility surfaces (maps) were created with geostatistical software. The soil fertility map(s) was combined with yield variation maps in GIS to determine the relationships between fertility variables (e.g., pH, Mineral Nitrogen, Bray-P, Neutral normal Ammonium acetate extractable K, Ca, Mg and DTPA extractable Fe, Zn, Cu and Mn). From the analysis it was observed that application of variable N and P fertilizer will increase the farm profit by 23 %. There is improvement in environmental and economic efficiency of farm management practices by MIS.



Oral

TS5 -01

Annual macronutrient removal by *typica x typica* coconut palms in low potential lands in Sri Lanka

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The potential for coconut production of different lands varies depending on the quality of the land. The S₄ (moderately suitable) lands yielding 5000 to 10000 nuts/ha/yr which is regarded as low potential lands. These lands have limitations which are moderately severe and reduce the coconut productivity. These lands require inputs like fertilizer, contour drains or terracing, husk pits, cover crops and mulch around the palms to bring the profit to moderate level. General fertilizer recommendation of 3 kg Adult Palm Mixture (800 g of urea, 600 g of IRP, 1600 g of MOP) with dolomite 1 kg/palm/yr is one of the important inputs for such lands. Therefore, the objective of the study was to estimate the macro nutrient removal by coconut palms in low yielding lands and to compare nutrient removal with fertilizer inputs and soil reserves. Harvested nuts (husk, shell, nut water, kernel), fallen fronds (petiole, midrib and leaf blade) and fallen inflorescences (spikelets, spathe, female and male flowers) were collected monthly for three years from 10 coconut palms of *Typica x Typica* (CRI 60) grown on moderately suitable (Red Yellow Podzolic) soil and analyzed for N, P, K, Ca, Mg and Na. The results revealed that the major nutrient removed by all plant parts were 64, 53, 32, 22, 19 and 10 kg/ha/yr for K, N, Na, Ca, Mg and P, respectively. The amount of N, P, K and Mg applied annually as fertilizers were 57, 11, 124 and 19 kg/ha, respectively which were adequate to prevent removal of major nutrients. Except the exchangeable K and Mg other macronutrients were present in high quantity in 1 m depth of soil in experimental site. The study showed that existing N, P, K and Mg fertilizer recommendation is enough for *Typica x Typica* coconut plantations in low potential lands to compensate the loss of major nutrients through removal.



Oral
TS5 -02

Coconut biodiversity and need for careful management of the biota

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Coconut biodiversity was given as the “variation of life at all levels of biological organization” which could be measured among organisms present in the ecosystem. Accordingly these groups of living organisms which interact and work together in the ecosystem are the biota and the non living or physical environment - the abiota. Thus in the coconut palm ecosystem, the coconut palm being an autotroph is only one of the living factors. Similarly are the mixed crops and intercrops planted in coconut interspaces which are capable of producing organic materials annually from the sun to feed other living members of the community - the heterotrophs (i.e. consumers and decomposers) which draw energy from the organic materials for their sustenance. In the process, valuable plant nutrients are recycled to meet the nutritional needs of the coconut palm and other living factors. Threat to the safety of these living members by human activities through habitat destruction, habitat fragmentation, over-exploitation and pollution of the environment (land, air, and water) have been on the increase which militate against sustainable crop production and healthy environment. Also was the need to change from chemical agricultural practices to eco-friendly practices through the use of integrated pest and disease management as well as integrated nutrient management for economy and efficiency. Adoption of reduced mechanization; reduced use of fossil based fertilizers and chemicals; use of nutrient fortified compost/manures when necessary, good cropping systems (mixed cropping, inter-cropping and 2 - 3 tier/multistoried/high density multi-species cropping system), mixed farming and use of bio-energy (animal and human wastes) were spotted as the way forward in this paper.



Oral

TS5 -03

A holistic systems approach to identify sustainable perennial crop based systems - a case study

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Coconut and arecanut-based systems are dominant in many parts of the world. Farmers cultivate a host of crops including perennials, annuals and seasonal crops along with coconut, without identifying optimum crop combinations. This emphasis on economics alone decries the importance of several other system attribute properties. Hence, a holistic approach is to be adopted to ascertain the sustainability of the systems, identify and recommended most suitable system. In this context, a study was undertaken in farmers' plots of Mannarkkad and Sreekrishnapuram Blocks of Palakkad District from 2005-07. The sustainability of eight arecanut based systems viz., arecanut monoculture, arecanut+banana, arecanut+banana+colocasia, arecanut+black pepper, arecanut+ black pepper+coffee, arecanut+vanilla vanilla trailed on *Gliricidia* sp. and arecanut), arecanut+vanilla (vanilla trailed on rubber tyre tied to arecanut), arecanut+vanilla (vanilla trailed on *Gliricidia* sp. only) and 11 coconut based systems viz., coconut monoculture, coconut+arecanut+ black pepper, coconut+arecanut+black pepper+banana, coconut+arecanut+black pepper+nutmeg, coconut+arecanut+black pepper+nutmeg+vanilla (systematic), coconut+arecanut+black pepper+nutmeg+vanilla (mixed), coconut+arecanut+black pepper+vanilla, coconut+black pepper+banana+ nutmeg young, coconut+black pepper+cocoa, coconut+black pepper+nutmeg (bearing), coconut+ black pepper+vanilla were evaluated using two approaches. The first approach was based on four easily quantified indicators of agricultural sustainability viz., species diversity, bio-resource recycling, resource system capacity, and economic efficiency. In the second approach, the most sustainable system for the region was identified based on several parameters ranked through farmer participatory approach. The parameters, in order of rank, were profit, total cost of cultivation, system pest score, system disease score, labour cost, input cost (external), biomass generated, biomass recycled, bioresource cycles, system soil fertility, scope for crop diversification based on photosynthetically active radiation (PAR), system nutrient balance, biodiversity, beneficial microorganisms, total soil microbial load and system energetics. Based on the first approach, the most sustainable cropping system for the region is coconut+arecanut+black pepper+nutmeg+vanilla. However, according to the second approach the most sustainable cropping system for the region based on all the parameters ranked by farmers is coconut+black pepper+nutmeg.



Oral
TS5- 04

Yield and quality attributes of black pepper (*Piper nigrum* L.) varieties/hybrids when grown as mixed crop in coconut garden

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Coconut (*Cocos nucifera* L.) is a versatile crop providing food, medicine, health drink, shelter, fuel, timber and fibre. Studies have revealed that the roots of coconut planted 7.5 m apart effectively use only 22.3 % of land area occupied by the crop, while the average air space utilization by the canopy is about 30%. One of the feasible ways of increasing the production is to raise additional crops in the interspaces. Coconut based cropping systems, involving cultivation of compatible crops in the interspaces of coconut offer considerable scope for increasing productivity per unit area, time and inputs by more efficient utilization of resources like sunlight, soil, water and labour. Black pepper (*Piper nigrum* L.), the king of spices, is one of the major export earners among the various crops grown in India. Pepper is raised exclusively as mixed crop in homestead gardens in Kerala and Karnataka and over 90 per cent pepper is trained on coconut and arecanut trunks. In recent days, many new black pepper varieties/hybrids have been developed in the country and hence field screening of these varieties as mixed crops in coconut garden is necessary to assess the performance in terms of yield and quality. In view of this, a field experiment was undertaken at CPCRI, Kasaragod, Kerala (India) from 2002 to study the performance of black pepper varieties/hybrids as mixed crop under irrigated condition in coconut garden aged about 30 years and grown in red sandy loam soil. The treatments comprised of varieties such as: T1: Panniyur-1, T2: Panniyur-2, T3: Panniyur-3, T4: Panniyur-4, T5: Panniyur-5, T6: Sreekara, T7: Subhakara (KS27), T8: Panchami, T9: Kottanadan, T10: HP-780 , T11: HP-105, T12: HP-1411, T13: HP-813 (IISR Malabar Excel), T14: HP-34, T15: OPKM, T16: Collection 1041 replicated three times. The experiment was laid out in a RBD with the plot size of four palms (four pepper vines) per treatment. The rooted cuttings were planted 1m away from the bole of coconut in North-East direction. Growth and yield observations were recorded from all the vines, mean was worked out and subjected to statistical analysis. Essential oil, oleoresin and piperine contents were estimated by adopting standard procedures.



In general, wilt disease incidence was observed in Panniyur-2, 3, Kottanadan, OPKM, HP 34 and HP 780 varieties/hybrids. Collection 1041 (Thevam collection) recorded significantly higher number of spikes (in 1 m column height) (207.9) and the lowest was recorded in HP780 (20). The spike length was higher in Panniyur 5 (15.4 cm) and was on par with Panniyur 1 and 2, HP 1411 and OPKM varieties. The spike length was lowest in Sreekara (8.7 cm) and was on par with Subhakara and HP34. Number of berries per spike were significantly higher in Panchami (86.7) and was on par with Panniyur 1 to 5 (73.3 to 83.6). The lowest number of berries was recorded in Subhakara (45.3) and Sreekara (46.5). Four years average spike yield (2007 to 2010) indicated that, Thevam had recorded significantly higher dry spike yield (1.71 kg/vine) compared to other varieties. Panniyur 1, 4 and 5, Sreekara, Panchami, also recorded higher dry spike yield (0.60 to 0.79 kg/vine) compared to other varieties/hybrids. Panniyur 2, 3, HP 780 and HP 34 recorded significantly lower dry spike yield. With regard to quality parameters, Panchami recorded higher essential oil (5.6%) and oleoresin content (12.6%) and was on par with Panniyur 4, Kottanadan, HP 1411 and OPKM. The piperine content did not differ significantly among the varieties/hybrids and was ranged between 2.68 to 4.97%. Coconut yield did not differ among treatments. There was improvement in the yield of coconut compared to pre-experimental yield. The general mean yield of coconut in the plot during 2008-09 was 111.8 nuts/palm/year compared to pre-experimental yield of 97.8 nuts/palm/year.

From the study, it can be derived that, varieties like Collection 1041 (Thevam), Panchami, Sreekara, Panniyur 1, 4 and 5 and hybrid IISR Malabar Excel (HP813), were found to perform well and can be recommended for growing in coconut garden as mixed crop.



Oral
TS5- 05

Coconut based integrated farming system approach towards effective resource management and sustainable production

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Mono cropping of coconut does not provide adequate returns to farm family and has several limitations like poor resource efficiency, low productivity and inadequate utilization of family labour. Coconut groves offer excellent opportunities to adopt coconut based integrated mixed farming system to exploit the inter-space potential in the garden for maximizing returns per unit area. Keeping this in view, an experiment was carried out during 2004-2009 in Central Plantation Crops Research Institute, Kasaragod, Kerala in the existing mixed farming system model which was originally initiated during the year 1989 to assess the benefits of integration of coconut with intercropping of fodder grass, dairy, poultry, Japanese quails and aquaculture.

In the present investigation, the sustainability and profitability of coconut based farming system comprising coconut, pepper trailing on the coconut trunk, banana in the border of the plots, fodder grass (hybrid Bajra Napier Co 3) in the interspaces of coconut, dairy unit (7 cows of Holstein Friesian and one Jersey cross breed), poultry(100 broiler birds/batch) , Japanese quails (100 layers) and aquaculture (1000 finger lings) are assessed in a coconut stand of 35 years old maintained in the soil type *Arenic paleustult*. Organic recycling in the coconut fodder grass system was achieved through cow dung and dairy shed washings, poultry and quail bird droppings, etc and vermicomposting of coconut leaves. The dry coconut leaves and other plant wastes are converted into vermi-compost employing the earthworm *Eudrilus* sp.

To study the effect of organic recycling on fodder grass and coconut yield the experimental plot was divided in to four treatments viz., T_1 - Mono cropping of coconut with recommended fertilizer as inorganics, T_2 - Coconut based integrated farming system comprising coconut, hybrid Bajra Napier grass, black pepper, banana, dairy, poultry and aquaculture components (pepper intercropped in the basin, banana in the border of plots and Hybrid Bajra Napier Grass(CO 3) in the inter space of the coconut palms) along with application of 50 per cent of the recommended nutrients through organic manures produced from the system and 50 per cent through inorganics, T_3 - Coconut based integrated farming system with application of 100 per cent of the recommended nutrient as organic manure produced from the system, and T_4 - Coconut based integrated farming system with application of 100 per cent of the recommended nutrient as inorganic fertilizer and results revealed that green foliage yield of hybrid Bajra Napier - CO 3



was significantly increased with the application of 50 per cent recommended nutrients through inorganics + 50 per cent through organics and was comparable with fully organic treatments. Similar results obtained in coconut yield also.

The results of the study revealed that from one ha of coconut based integrated farming system 20869 coconuts, 14976 litres cow milk, 859 kg broiler chicken, 6749 numbers of quail bird eggs, 18 kg quail birds, 1961 kg of banana and 295 kg of pepper were obtained. Around 98 per cent of the revenue was derived from coconut, dairy and poultry components. The coconut based integrated farming system with organic recycling positively influenced the physical, chemical and biological properties of soil and brought out significant improvement in soil health than the mono cropping with inorganic nutrient management. Integrated farming systems primarily based on the concept of effective linkage among the different components present in the system enables utilization of all the resources available in the system effectively utilized in a sustainable manner and satisfies many necessities of the farmer. Integrated farming system with integrated nutrient management is the best option to achieve optimum utilization of resources and to enhance the productivity from coconut plantations.

Oral

TS6-06

Plant growth promoting potential of *Serratia marcescens* KiS II and *Enterobacter cloacae* RNF 267 isolated from the rhizosphere of coconut palm (*Cocos nucifera* L.)

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There is a great diversity of microorganisms inhabiting the plant rhizosphere and exerting an influence on their development. In the present study, we attempted to reveal the plant growth promoting potential of two native bacterial isolates and to study their influence on the growth of coconut seedlings. Gram negative bacterium isolate no. KiS II and RNF 267 isolated from rhizosphere of coconut were tested for plant growth promoting attributes. Both of the bacteria exhibited phosphate solubilization, ammonification, production of indole acetic acid (IAA), α -1, 3 glucanase activity and ACC-deaminase activity. Besides these, the isolate KiSII could grow on N-free agar medium, produced siderophores and antibiotics and exhibited chitinase activity. Seed bacterization with these isolates remarkably increased the growth parameters of short duration plants over uninoculated control in plant growth chamber and green house assays. Inoculation of coconut seedlings resulted in significant increase of all length parameters i.e., leaf length, shoot length, root length and seedling length. Number of leaves and dry weight of coconut seedlings also increased on inoculation. Other growth parameters



showed variations with these two isolates. Studies revealed that they could significantly increase the beneficial microbial population in the rhizosphere region compared to uninoculated control. These plant growth promoting bacterial isolates were identified as *Serratia marcescens* KiS II and *Enterobacter cloacae* RNF 267 as determined by morphological, physiological and biochemical tests. The present study, therefore, suggests that the use of bacterial isolates *S. marcescens* KiS II and *E. cloacae* RNF 267 as bioinoculants might be beneficial for raising coconut seedlings as they possessed multifarious plant growth promotion traits and enhanced the growth of short duration crop plants as well as coconut seedlings.

Poster
TS5-P01

Multispecies cropping system in coconut garden of East Coast region

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The field experiment comprising seven models with coconut mono-cropping was carried out in 36 year old ECT palms during June 2003 to September 2009 at Coconut Research Station, Veppankulam. The trial was non replicated and the plot size was 18 cents/model i.e., 7 coconut palms/plot. In each model, coconut tree is having two black pepper vines planted in either side of the tree. Two banana suckers are planted in between two palms along the row at 2.5 m spacing. The component crops were raised in the respective seasons in the 50 per cent interspaces available (3.5 m width) between two coconut rows. Mannuring, irrigation and other cultural operations were done separately for each component crop as well as for coconut as per the recommendations. In general, among the VIII models tested, the model IV (Coconut + black pepper + banana + E.F. Yam + coriander) recorded consistently higher BC ratio followed by the model II (Coconut + Banana + black pepper). The nutrient status of soil in model III (Coconut + Banana + black pepper + bhendi) recorded the higher soil available NPK when compared to other treatments. In the case of microbial population, model IV (Coconut + black pepper + banana + E.F. Yam + coriander) recorded the maximum fungal and bacterial population. By considering the above advantage and the field feasibility, marketability and economic viability, model IV (Coconut + black pepper + banana + E.F. Yam + coriander) is the most suitable intercropping system in coconut garden for the east coast region.



Poster
TS5-P02

Integrated nutrient management in ECT coconut through organics

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A field experiment was conducted at Coconut Research Station, Veppankulam during 2006-09 to study the effect of integrated nutrient management (INM) on coconut nutrition. The experiment was conducted in 29 year old ECT palms. The experimental results proved that the integrated use of plant nutrient sources for coconut palm viz., 50% nitrogen through fertilizers and remaining 50% through composted coir pith (CCP) recorded comparable mean annual nut yield (111 and 117 nuts/palm/year, respectively) and other yield contributing parameters viz., no. of functional leaves, no. of bunches and female flowers numbers to that of 100% NPK through fertilizers. Similarly, the benefit cost ratio was found on par for the above treatments (2.03 and 2.17). Considering the sustainable soil health in coconut nutrition, 50% N can be substituted through organics and this may pave way for total replacement of chemical fertilizers in coconut garden.

Poster
TS5-P03

Effect of phosphorus status of major coconut growing soils of Sri Lanka on growth parameters and root nodulation of leguminous cover crop

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Effect of phosphorus status of major coconut growing soils in the intermediate zone of Sri Lanka on growth parameters and root nodulation of *Pueraria phaseoloides* as a leguminous cover crop in coconut lands were studied using green house, pot and field experiments. In the green house pot experiment, *P. phaseoloides* was treated with phosphorus at the rate of 1g of Triple Super Phosphate per pot (T₁) along with a control (T₀) treatment. In the field experiment, *P. phaseoloides* was grown on beds with application of Eppawela Rock Phosphate @ 912 kg per ha (T₁) along with a control (T₀) treatment. The relationships between the Relative Increase



(RI) of each crop parameter (X) due to phosphate treatment, which is defined by $[T_1(X) - T_0(X)] / T_0(X)$ and the initial available soil phosphorus determined by the 2.5 % acetic acid and Olsen's bicarbonate were studied. The critical level for available soil phosphorus was determined by fitting the data in above relationships to the Cate and Nelson model. The results of the pot experiment showed that *P. phaseoloides* significantly responded to P fertilizer application on soils containing available phosphorus less than 5 mg kg⁻¹ by both extraction methods. In the field experiment, the limiting value of soil phosphorus was 10 mg kg⁻¹ as determined by 2.5% acetic acid. Results revealed that inherent phosphorus level of most of the coconut growing soils were below the limiting values and phosphate fertilizer application to *P. phaseoloides* is essential to enhance its growth and root nodulation.

Poster
TS5-P04

Second generation coconut based high density multispecies cropping system in Assam

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A field experiment was conducted during 2003-04 to 2007-08 to study the effect of different intercrops on yield and monetary benefits of main and intercrops in coconut garden at Horticultural Research Station, Kahikuchi under the All India Coordinated Research Project on Palms. The different intercrops imposed under coconut plantation (28-year-old) comprised of T₁: Coconut + black pepper + ginger, T₂: Coconut + black pepper + turmeric, T₃: Coconut + black pepper + brinjal, T₄: Coconut + black pepper + banana, T₅: Coconut + black pepper + pineapple and T₆: Coconut + black pepper (control). The results revealed that the highest nut yield, intercrop yield in terms of coconut equivalent yield as well as per cent increase in nut yield were recorded in coconut + black pepper + turmeric (T₂) intercropping system followed by coconut + black pepper + ginger (T₁) and the lowest in control (coconut + black pepper). The soil fertility status in respect of pH, OC, N, P and K in the interspaces of coconut and the leaf nutrient content (N, P, K) of the main crop were found to be higher in all the intercropping system as compared to control. Similarly, higher soil microbial population (bacteria, fungi and actinomycetes) was also observed under different intercropping system than the control. Among various intercrops, coconut + black pepper + turmeric (T₂) recorded the highest net return of Rs. 1, 46,549/ha with a benefit cost ratio of 2.20.



Poster
TS5-P05

Nutritional requirement of hybrid (T x D) coconut with 50% N substitution through organic manure

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A field experiment was conducted at Coconut Research Station, Veppankulam during 2006-09 to evaluate the nutritional requirement of hybrid coconut (T x D) with 50% N substitution through organic manure. The experiment was conducted in 35 year old hybrid palms (VHC 2). From this experiment, it is inferred that for hybrid coconut, a fertilizer level of 1000:250:2000 g NPK/palm/year along with 50 kg of organic manures achieved economically the highest mean annual nut yield of 169 nuts/palm/ year besides sustaining the soil fertility at higher level. Considering consistent nut yield and sustainable soil health, 50% of recommended N may be supplied through organic manure of either vermicompost or composted coir pith (CCP) and the remaining 50% N may be applied as inorganic fertilizer. The organic manure that carries 50% nitrogen can satisfy the organic matter requirement of organically poor coastal coconut soils.

Poster
TS5-P06

Prospects of intercropping medicinal and aromatic plants in coconut

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Based on the earlier experiment conducted at Coconut Research Station, Veppankulam on screening of medicinal and aromatic plants suited for growing as intercrop in coconut, a confirmative field experiment was conducted with selected herbal plants at Coconut Research Station, Veppankulam between 2006-2009 to explore the possibility of raising medicinal and aromatic plants as intercrop in coconut garden. The experiment was conducted in 36 year old coconut garden. The plot size for each crop was 15x4 m in between four coconut palms leaving 2 m from the base of the palms. The interspace was ploughed and FYM was incorporated @ 12.5 t/ha and the herbal plants were raised. The design of the experiment was RBD and replicated thrice. The crops were raised organically. The yield of economic parts of each herbal plant was



recorded after processing and finally the economics of raising individual medicinal and aromatic plants as intercrop in coconut were worked out. Among the three medicinal and two aromatic plants tested under sandy loam soil, *Alpinia galanga* (Sitharathai), *Aloe vera*, *Ocimum sanctum* (Tulsi), *Symbopogan flexuosus* (Lemon grass) and *Pogestemon patchouli* (Patchouli) are the best suited intercrops in adult coconut garden. The Sitharathai recorded an yield of 3.26 t of dry tuber ha⁻¹. *Aloe vera* and Tulsi recorded 12.75 and 16.0 t of fresh leaf ha⁻¹, respectively. In the case of lemon grass, the yield was 7.34 t of dried leaf ha⁻¹ and for Patchouli it was 1.24 t of dried leaves ha⁻¹. Sitharathai recorded a net return of Rs. 89,898 ha⁻¹ and a B: C ratio of 1:3.2, whereas, *Aloe vera* and Tulsi recorded the net returns of Rs. 1,41,058 and 43,280 and the B:C ratios of 1:3.8 and 1:3.0, respectively. The lemon grass recorded a net return of Rs. 16,085 ha⁻¹ and B:C ratio of 1:2.1 and Patchouli recorded a net return of Rs. 19,010 and B:C ratio of 1:2.1.

Poster

TS5-P07

Role of green manuring and integrated nutrient management in increasing potentiality of coconut palms

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Coconut is a monoecious perennial monocotyledon and belongs to monotypic genus *Cocos*. It is an important plantation crop grown in the district. In Davanagere district it is growing in an area of 17,321 ha with production of 1,990.14 lakh nuts. Incidence of mites, black headed caterpillar and poor quality nut are the main constraints of the district. This is because of poor fertility status of the soil and poor nutrition in coconut gardens. Front line demonstration was conducted by Krishi Vigyan Kendra, Davanagere, Karnataka during 2007-08 to 2008-09 to assess the performance of coconut gardens with recommended dose of fertilizers, use of micronutrients and green manuring in the coconut gardens. Soil analysis of the five farmers gardens were carried out before incorporation of treatments. It is evident from the results that average number of nuts per palm has increased in demonstration plot (121 nuts/palm) as compared to the control plot (78 nuts/palm). Per cent incidence of button shedding was also lower in demonstration plot (< 10) than in control plot (> 18-19). From the experiments it is concluded that practicing green manuring in the coconut gardens enriches the fertility status of the soil, thus increasing fertilizer use efficiency. Applying fertilizers based on soil test results helps in obtaining better yields.



Poster

TS5-P08

Performance of medicinal and aromatic plants as intercrops in coconut gardens

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Studies on the performance of selected, promising medicinal and aromatic plants as intercrops in the coconut system of Pollachi tract of Tamil Nadu has been conducted at Coconut Research Station, Aliyarnagar during the period from 2007 to 2009. Three medicinal plants, Karisalangani (*Eclipta prostrata*), Siriyanangai (*Andrographis paniculata*), Sitharathai (*Alpinia galanga*) and two aromatic plants, Patchouli (*Pogostemon patchouli*) Lemon grass (*Cymbopogon flexuosus*) were taken as intercrops. Among the medicinal plants, sitharathai (*Alipinia galanga*) and among the aromatic plant, lemon grass (*Cymbopogon flexuosus*) performed well in terms of yield and economics. Sitharatai (*Alipinia galanga*) recorded a significantly higher rhizome yield upto 5.95 and 6.02 t/ha with a net income of Rs. 27,750/ha and Rs. 29,650/ha and B:C ratio of 2.40 and 2.43 during the years 2007-08 and 2008-09, respectively, than Karisalankanni and Siriyanangai. Lemon grass (*Cymbopogon flexuosus*) registered significantly higher leaf yield of 6.81 and 7.17 t/ha with a net income of Rs. 21,110/ha and Rs. 23,270/ha and B:C ratio of 2.06 and 2.17 during the year 2007-08 and 2008-09, respectively, than Patchouli.

Poster

TS5-P09

Intercropping with fruits and annual spices in coconut under Konkan condition of Maharashtra

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A field experiment was conducted at Regional Coconut Research Station, Bhatye, Ratnagiri (MS) during 2004-2009 to develop an appropriate cropping system compatible with the coconut crop with fruits and annual spices. The yield of coconut increased from 8 to 56 per cent after planting the different intercrops viz., banana, pineapple, ginger, turmeric and tapioca. The net returns was maximum in coconut + turmeric (Rs. 1,29,450/ha) followed by coconut +



banana (Rs 1,00,300/ha), coconut + ginger (Rs. 84,700/-ha), coconut + tapioca (Rs. 57350/- ha) and coconut + pineapple (Rs. 48230/-ha). The B:C ratio was maximum with intercropping of banana (2.02) followed by turmeric (1.83), tapioca (1.75), pineapple (1.65), ginger (1.56) where as coconut alone recorded B:C ratio of 1.47. Considering the performance of different intercrops and market demand, turmeric, banana, pineapple and tapioca are recommended as intercrops in adult Coconut plantation in Konkan region of Maharashtra.

Poster
TS5-P10

In search of bioinoculants for coconut palm

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The sole dependence on chemical input for agriculture is not sustainable. As such integrated nutrient management with fertilizer, green manure and bioinoculants is deemed essential for coconut production, devoid of disturbance to soil health. The coconut palm is largely grown as a rainfed crop on nutritionally poor acidic soils of the tropics. The palm responds to input of fertilizers. Yet most of the cultivation is without use of fertilizers. This is particularly true in the case of small holdings in Southern districts of Kerala where root (wilt) disease is rampant. In the current craze for organic as well as low cost cultivation, Vedic preparation of 'Panchagavya' through Karve's super manure to Paleker's 'Jeevamrutham' is adopted. The benefits vouched by farmers can only be attributed to the agency of microbes developed through fermentation, considering the minuscule quantity applied to field. Taking cue from the reported composition of ingredients of the preparations an attempt is made to formulate slurry of composite beneficial microbes using available media ingredients. Four different compositions using cow dung as the main ingredient, supplemented with different oil cakes and nutrients were tried for growth of microbial functional groups. Among them a composition with cow dung, cow's urine, jaggery and ground sprouted pea registered maximum count on microbial enumeration. The shade dried inoculum was checked for viability of organisms at fixed intervals. The inoculum remained viable for over three months. There is a gradual reduction in the colony forming units of the organisms till 60th day but then it levelled off. Although much has been heard now about the craze for organic cultivation and super manure, this is perhaps the pioneer attempt to streamline the super manure in a microbial context, facilitating preparation of the biofertilizer in the homestead.



Poster

TS5-P11

Performance of elite cocoa clones intercropped in coconut

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Coconut plantations in India provide a conducive environment to grow Cocoa which is a shade loving crop. It was reported as a profitable mixed crop in coconut gardens of Malaysia and Indonesia, with its higher litter fall and prunings which improved the organic matter content, soil fertility and microbial activity in the coconut-cocoa ecosystem. Kerala stands first in area and production of cocoa under coconut and its expansion in states like Tamil Nadu and Andhra Pradesh with its huge demand in chocolate industry. At CPCRI, during 1970's research was conducted on single and double hedge system of planting cocoa in coconut gardens which was found to be highly beneficial and remunerative. Cocoa clones identified so far as best yielders were from trials under arecanut. So, to assess their feasibility under coconut nine clones were selected and planted as grafts during 2001 in a double row system with 2.7 x 2.7 m spacing between two rows of coconut cultivar Laccadive Ordinary Tall spaced at 7.5 x 7.5 m. Both cocoa and coconut were separately fertilized and drip irrigated. Twenty growth and yield characters were recorded to assess the performance of cocoa clones under coconut. Among the elite clones, NA 33 x ICS 89 showed vigorous growth. Most of the clones exhibited more number of branches and significant canopy spreads. The hybrid II-67 x NC-29/66 showed optimal canopy volume to hold more pods (around 40) at the age of 10 years and dry bean yield of 1 kg per tree per year. Pod weights of clones ranged from 235.4 to 485.2 g. Number of beans per pod ranged from 28.4 to 43.4. Pods of all clones exhibited husk thickness of more than 1 cm. Five clones recorded favourable single dry bean weight of >1g, 10-15% shell, high recovery percentage and >50% fat content. Compared to monocropped palms, coconut intercropped with cocoa gave increased nut yields. With this study it was observed that cocoa had a positive effect on micro and macro environment of coconut garden encouraging sustained production of both these crops.



Poster
TS5-P12

Integration of meat goats on the productivity of coconut farm

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In India coconut is being cultivated for the past over 4000 years. Despite enormous potential of the crop, coconut farmers suffer due to decreasing farm productivity and income. Integrated farming is a viable option to enhance the farm productivity and income. An unreplicated study on integration of meat goats with coconut was conducted in a 10 year old coconut plantation (8 hectare area planted in 8 m x 8 m square patterns-156 palms ha⁻¹) at Coconut Development Farm, Campus Development of the Kerala Agricultural University from 2005-2009. A unit of 10 goats (Alpine x Malabari x Boer) for meat purpose was introduced ha⁻¹ of coconut farm utilizing the natural feeds available in the farm. Results revealed that there was a progressive increase in coconut production from 2005 (24 nuts palm⁻¹ year⁻¹) to 2009 (42 nuts palm⁻¹ year⁻¹). Considering all the expenses involved a net income from goats increased from Rs. 2788 ha⁻¹ year⁻¹ to Rs. 6138 ha⁻¹ year⁻¹. Integration of meat goats increased the total profitability of the farm from Rs. 14152 ha⁻¹ year⁻¹ to Rs. 26058 ha⁻¹ year⁻¹ during the study period. In addition to this there was effective utilization of farm resources. Integration of meat goats with coconut is a sustainable model suitable for small scale coconut farmers.

Poster
TS5-P13

Organic manure production from tender coconut waste

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Andhra Pradesh is one of the major coconut growing states in the country and the state commands an area of nearly 1.02 lakh hectares with annual production of 1092.7 million nuts. Nearly 30-40% of the production is utilized for tender nut water consumption in the state. The consumption of tender nut during peak summer season is approximately 3,71,350 nuts/day and the disposal of empty nuts is creating lot of sanitary problem in towns and cities. Under natural conditions, decomposition of empty shells will take more than two years, because, the



tender nut consist of high Ligno-cellulose material which is tough and hard to decompose. In order to avoid this problem, a study was conducted during 2007-09 at Horticultural Research Station, Ambajipeta on "production of high quality organic manure from tender nut waste using effective organisms and earthworms. An experiment was laid out in RBD with seven treatments in three replications viz., (TCW + *T. viride*, TCW + *Pleurotus sajor caju*), TCW + *P. flourescens*, TCW + *T. viride* + *Pleurotus sajor caju*, TCW + *T. viride* + *P. flourescens*, TCW + *Pleurotus sajor caju* + *P. flourescens* and TCW + cow dung + earthworms. Before microbial inoculation, the six treatments were pre soaked for one month in urea, then single super phosphate, green leaf, cow dung, lime and microbial culture was inoculated. The epigeic earthworm *Eudrilus eugineae* was released after one month of incubation of raw material with cowdung slurry. The results of the study revealed that the biodegradation and decomposition of tender nut waste with earthworms *Eudrilus eugeniae* was achieved within 68-90 days with compost recovery of 58% of the substrate. The data on CN ratio, lignin and cellulose percentage revealed that there was a considerable decrease in CN ratio from 64.26 to 15.35, cellulose from 21.56 to 10.70% and lignin from 17.5 to 4.28%. Nutrient composition of vermicompost varied from 1.36-1.72% N, 0.20 - 0.27% P and 1.68 -2.04% K, respectively. The vermicompost was also rich in micronutrients viz., manganese (164 ppm), iron (8,381 ppm), zinc (135 ppm) and copper (38 ppm). Higher total microbial load was observed in vermicompost (486.61 cfu/g) compared to microbial compost (391.14 cfu/g).

Poster
TS5-P14

Effect of storage of coconut leaf vermicompost on its microbial and nutrient status

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Freshly harvested coconut leaf vermicompost contains very high counts of microorganisms and moisture content. Addition of vermicompost helps in improving the diversity and population of the microorganisms and nutrient content of the soils. However, if the vermicompost is not applied immediately and used after a period of time, there is a possibility of its biological properties undergoing some change. Therefore, to study the impact of storage on the vermicompost microbial and nutrient properties the population densities of general and plant beneficial microbial communities and the concentrations of major nutrients, N, P, K, in the coconut leaf vermicompost was studied for a period of 120 days when stored at ambient conditions. It was observed that the population of microbial communities decreased significantly after 30 days and it was mainly dependent upon the moisture status of the vermicompost which

progressively declined during the storage period. Among the various microbial communities studied, those related to specific functions like nutrient mineralization, plant growth promotion and protection were highly sensitive to the moisture stress. Hydrated vermicompost, on the other hand, could retain higher population of the microbes for a longer period. The available NPK concentrations, contrary to response by microbial populations, increased marginally after 120 days of storage. However, the organic carbon content and C: N ratio declined during the last estimation compared to the initial stage. The study suggests that if the vermicompost is to be used as a nutrient source it can be stored for 120 days until application. But for maximizing the health and fertility of soils, farmers must apply it afresh or within 30 days period.

Poster
TS5-P15

Nutrient management in coconut garden through organic manures

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A field trial was conducted at the Agricultural Research Station (Fruit Crops), Junagadh Agricultural University, Mahuva during the year 2004-2009 to study the nutrient management in coconut garden through organic manures cv. West Coast Tall. The experiment was laid out in a Randomized Block Design with three replications. There were 10 treatments comprising of application of organic and inorganic fertilizers. The analysis of five years pooled data revealed that the treatment T7 (50 % RDF i.e. N.P.K. 200-160-750 + 50 % N from castor cake) recorded significantly higher yield (78.33 nuts/palm/year), weight of nut (896.40 g), weight of kernel (105.33 g) and volume of nut (1017.87 ml) with improvement in soil fertility and highest net return (Rs.37,063/ha) as compared to the rest of the treatments



Poster
TS5-P16

Benefit cost ratio analysis of coconut based cropping systems

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A field experiment was conducted to study the performance of 10 different coconut based cropping systems. The different cropping systems tried in the study were T_1 - coconut + nendran banana + elephant foot yam + vegetable cowpea, T_2 - coconut + cassava + elephant foot yam + vegetable cowpea, T_3 - coconut + nendran banana + ginger + vegetable cowpea, T_4 - coconut + cassava + elephant foot yam + ginger + vegetable cowpea, T_5 - coconut + nendran banana + turmeric + vegetable cowpea, T_6 - coconut + cassava + elephant foot yam + turmeric + vegetable cowpea, T_7 - coconut + nendran banana + cassava + vegetable cowpea, T_8 - coconut + nendran banana + cassava + elephant foot yam + vegetable cowpea, T_9 - coconut + nendran banana + cassava + ginger + vegetable cowpea and T_{10} - coconut + nendran banana + turmeric + vegetable cowpea. The economic analysis of the study revealed the superiority of cropping systems resulting in BC ratio of more than one. The highest BC ratio of 1.74 was recorded in the treatment T_4 involving cassava; elephant foot yam, ginger and vegetable cowpea in coconut garden. The net income was found to be the highest in cropping system T_3 involving banana, ginger and vegetable cowpea. Cropping systems involving banana and cassava produced the lowest BC ratio of 1.02, their net incomes were also found to be the lowest among the systems (T_7 and T_9 , respectively).



Yield, physiological and nutritional status as influenced by soil salinity of coconut (*Cocos nucifera* L.)

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Tolerance of coconut (*Cocos nucifera* L.) tree to soil salinity was evaluated on the performance of seedling in naturally saline soil [ECe 14.0 dSm⁻¹] and artificially salinized soils of ECe ranging from 4 to 20 dSm⁻¹ for one year under pot culture experiment in greenhouse at MAU, Parbhani (MS). Growth parameters, fresh and dry weight and chlorophyll content decreased progressively with increase in salinity levels, whereas, the reverse was true for number of stomata and rate of transpiration. Thus, high concentration of salinity appeared to increase the adverse effect on plant growth, and physiological parameters in saline soils. The fresh and dry weight significantly decreased by 49.55% and 31.97% under salinity 14 ECe as compared to control plant. There were no visual injury symptoms observed up to ECe 12. Salinity 20 dSm⁻¹ started showing mortality symptoms right from 240 days after planting. All nutrients like N, P, K, Ca and Mg were depleted in leaves and roots except Na. A significant decrease in micronutrients (Zn, Fe, Mn and Cu) in leaves and roots were noticed under each higher salinity level i.e. 20 dSm⁻¹ as compared to control plant. The salinity tolerance index for 10% and 20% growth depression were found to be ECe level 51.97 and 86.65, respectively. Since these observations were recorded under laboratory condition, further field studies are suggested to confirm these results.



Poster
TS5-P18

Intercropping in coconut for higher production and profit

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In Kanyakumari district coconut occupies an area of 25,000 ha in which more than 75 per cent of the holdings are below one ha and the average yield realized is only 50-60 nuts/ha. The income derived from such small holdings is quite insufficient to sustain even small families. With little scope for further expansion of area under coconut as well as a lower per capita land holding size, crop intensification and diversification are viable options to promote the agrarian economy. Integrating banana and tuberous vegetables like yams and aroids can substantially enhance the food production and profitability in the existing coconut based cropping systems, since the crops are adapted to the same ecological conditions as plantation crops. Therefore, a companion intercropping study was carried out in coconut to find out the compatibility, productivity and profitability of different intercrops in coconut. The investigation was carried out at Krishi Vigyan Kendra, Kanyakumari during 2004-2006 in Randomized Block Design with four inter cropping treatments and five replications. The treatment details were T₁ - coconut monocrop, T₂ -coconut+banana, T₃ - coconut+banana+cowpea and T₄ coconut+banana+ elephant foot yam+mango ginger. Observations on yield and yield attributes and economics of coconut and different intercrops were recorded. The study revealed that integration of crops like banana, elephant foot yam and mango ginger recorded the highest productivity and net returns of Rs. 1,02,550/ha.



Poster
TS5-P19

Suitability evaluation of upland rice varieties in coconut based homesteads for food security

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Agriculture in Kerala is unique in the sense that homegardens or homesteads, with coconut as the base crop is the prevailing form of land-use which has sustained the population through centuries. However, Kerala's position with regard to the availability of food is below the national average leading to the characterisation of the state as a 'food deficit' one. Coconut being the major crop spread over an area of 9 lakh ha inter cropping, if possible, one third of this area with upland rice can alone double the area under rice and can bring a revolutionary change in rice production scenario of the State. Currently the upland rice cultivation is limited to some traditional isolated patches which are on the verge of extinction and to rejuvenate this, so as to ensure food security, finding a variety suitable for these non conventional areas like coconut garden, needs prime attention. In this backdrop, a field experiment was conducted during the kharif season of 2009 in coconut based gardens above the age of 25 years in farmer participatory mode with eight indigenous and eight released upland rice varieties. Thottacheera and Swarnaprabha selection recorded higher yields (1.94 and 1.87 t/ha). Chomala was the second best variety among other varieties recording significantly higher yield (1.85t/ha) than Swarnaprabha (1.72 t/ha). However, the indigenous variety Chomala, with small, slender reddish straw coloured grain and white kernel was the preferred variety by farmers as it has good grain and straw yield, suitable growth duration and non lodging nature which attribute to low bird and rodent attack.



Poster
TS5-P20

Effect of coconut tonic on coconut palms in Davanagere district

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On farm test (Technology Assessment) was conducted at Taralabalu Krishi Vigyan Kendra, Davanagere, Karnataka during 2007-08 to 2008-09 to evaluate coconut nutritional tonic on coconut palms. The trial was conducted at five different coconut gardens of the district. Three technological options were tried in the same garden with 10 palms in each treatment. Coconut nutritional tonic comprised of major nutrients, micro nutrients, growth regulators like ascorbic acid, salicylic acid as components. Root feeding of tonic was done at 200 ml/palm at 6 months interval along with organic manures, chemical fertilizers and neem cake. Per cent mite infestation was reduced in technology option three (39.6 per cent) compared to other two options. Use of balanced nutrition helps in increasing the soil fertility status as well as in increasing the fertilizer use efficiency.

Poster
TS5-P21

Utilization of coconut by products for cultivation of oyster mushrooms

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The inedible coconut plant parts namely leaves, bunch waste, petioles, saw dust and the byproduct coir pith were evaluated for assessing the growth and yield of Oyster Mushrooms which is the third largest commercially cultivated mushroom in the world. Oyster mushrooms (*Pleurotus* spp.) can degrade various crop residues rich in cellulose, hemicellulose and lignin with the help of various ligno cellulolytic enzymes. Three potential strains namely *P. florida*, *P. sajor caju* and *P. eous* were screened for their production on these abundantly available coconut plant parts. *P. eous* was found to be the best yielder and suited for round the year cultivation on these inedible coconut plant parts under our agro climatic conditions. Spawn run period, time taken for first appearance of fruiting bodies, number of flushes, size of fruiting bodies and total yield are dealt with in detail in this study.



Poster
TS5-P22

Improving use efficiency of water by integrating fish culture and irrigation in coconut based farming system- A case study

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The farmers and local communities identified rainwater harvesting as a workable technology option for providing a dependable source of drinking as well as irrigation water and also for preserving the vital ground water reserves. More farmers need to be educated further on the problems crippling the conventional sources and the need for the “shift”. In the present paper, the Rain Water Harvesting initiative of an innovative farmer in north east Kerala was studied. The field experience in mitigating the ill effects of drought and providing security against future droughts were brought together apart from exploring out new avenues for profitable agriculture through integrated fish farming. The financial analysis indicated that such an integrated system is not only financially and economically viable to the farmer but lead them to a sustainable farming approach. Based on the estimated annual costs and returns, all the financial viability criteria (IRR, NPV and BCR) were found favourable for investment on plastic lined water harvesting tank integrated with micro-irrigation system and fish farming. The approach to harvest rainfall in bulk quantity, as explained in this paper, for drought proofing with generation of additional income through integrated farming could be considered as a model and more such type of locally adaptable and sustainable on-farm technologies should be identified and explored.

Poster
TS5- P23

Impact of soil management measures on pineapple grown as intercrop in coconut under coastal littoral sandy soil

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The coastal sandy soil, which occurs all along the coastal tract of the West and East coasts of the Peninsular India lying mostly in Kerala, Karnataka, Tamil Nadu, Andhra



Pradesh, Orissa and Maharashtra is the most predominant soil type with respect to coconut cultivation. The physical and chemical properties of coastal sandy soil are unsuitable for growing pineapple as intercrop in coconut without proper crop management practices. Keeping this in view a field experiment was conducted at the Central Plantation Crops Research Institute, Kasaragod during 2005-09 to study the feasibility of growing pineapple as intercrop in coconut garden with soil moisture conservation measures using husk/coir pith under coastal sandy soil. The experiment was conducted on West Coast Tall, the popular coconut variety. The age of palms was 40 years. The treatments were (T1), one layer dried coconut husk burial in the trenches and planting of pineapple, (T2) coir pith application in the trenches and planting of pineapple and (T3) control (planting of pineapple with out any soil moisture conservation measures). The experiment was conducted in Randomized Block Design with seven replications. The palms were irrigated. Marutius variety of pineapple was tried as intercrop. Soil drawn from husk and coir pith treatments retained higher soil moisture content during the rainless period (Nov- May) compared with that in control plots. The incorporation of organic sources husk/coir pith was found to increase the organic carbon (%), total nitrogen, available phosphorus and available potassium content compared to control. The soil samples collected from the grass rhizosphere of coconut palms at two depths (0-25 and 25-50 cm) under different were analyzed for microbial population of bacteria, fungi, actinomycetes, free living nitrogen fixers, cellulose degraders, phosphate solubilizers and *Azospirillum*. In general higher microbial load was observed under husk/coir pith incorporation treatments compared to control. Between the husk and coir pith incorporation treatments, the population of bacteria, fungi, actinomycetes, cellulose degraders, phosphate solubilizers and *Azospirillum* were higher under husk incorporation whereas fluorescent pseudomonads population was higher under coir pith incorporation Pineapple suckers grown under husk/coir pith incorporation produced higher yield of fruits. The results showed that the husk and coir pith application as amendments significantly influenced fruit size and fruit weight. Higher fruit yield was obtained under husk application and it was on par with coir pith application and significantly different from the control.



Poster
TS5-P24

Development of value added products and applications for coir pith

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Coir pith (Coco peat) is a byproduct of coconut husk extraction process. This material has been transformed to organic manure by a *phyto-transformation* process by planting *Rhizobium* treated seeds of *Calapagonium mucunoides* in 100 l shallow cement containers filled with coir pith and supplemented with fishmeal @5 g/kg of coir pith. The plant yielded biomass that is equal in quantity to that obtained in soil:sand:farm yard manure mixes. The plants were pulled out along with roots, chopped into pieces and mixed with the growth medium. It was then subjected to aerobic composting with fresh cow dung @1 kg/100 l. The product was analyzed for pH, organic carbon and NPK contents. The product quality conformed to acceptable standards and plant bioassay with tomato seedlings confirmed its suitability as organic manure. This could be a very good method for enhancing nitrogen content (reducing C:N ratio) of the ligno-cellulosic material naturally, without using synthetic fertilizers.

Fresh coir pith has been used as substrate for edible oyster mushroom (*Pleurotus sajor-caju*) cultivation. The material containing 75% water is sterilized by autoclaving at 15 psi pressure for 20 minutes, cooled and used for spawning by adopting the recommended method (KAU). Spawn run took 10 days and buds appeared on third day after opening the bed. Buds matured into *basidiocarps* in 48 hours were harvested, weighed and bio-efficiency was found to be 48%. The substrate has been used for commercial cultivation.

Old (10 years) coir pith has been used for preparation of carrier-based *Trichoderma* formulation. The material has been pulverized and its pH adjusted to 6 by adding sufficient quantity of Calcium carbonate. Spore suspension of *Trichoderma* is added to this medium, mixed and packed in LD polyethylene pouches @ 200 g/pouch, sealed and incubated for six months. Number of CFUs were then analyzed by dilution plating. It was 4×10^8 per gram; the count was better than reported.

Fresh coir pith has been used as growth medium for potted vegetables and ornamental plants by applying nutrient solution. Yield of vegetables was at par with soil:sand:farmyard manure mix 3:1:1.



Poster

TS5- P25

Screening and evaluation of phosphate solubilizers from diverse group of bacteria isolated from rhizosphere and roots of coconut palms (*Cocos nucifera* L.) growing in different states of India

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Microorganisms have the ability to solubilize the insoluble phosphates and maintain soil health and quality. It is reported that phosphate solubilizing microorganisms are widely distributed in coconut growing soils. In an attempt to develop an effective phosphate solubilizing bacterial inoculum for improving P uptake by plants, isolated numerous rhizospheric and endophytic (roots) bacteria from coconut palms growing in various ecological zones of Kerala, Tamil Nadu, Karnataka, Andhra Pradesh and Maharashtra were isolated. Qualitative phosphate solubilization ability of 512 heterotrophic bacteria was verified and it was found that 56% (284) isolates were able to solubilize phosphate in the Pikovskaya's agar medium. A total of six potent isolates including three fluorescent *Pseudomonas* spp., two *Bacillus* spp., and one unidentified bacterium were selected with phosphate solubilization efficiency ranging from 100% to 333%. Quantification of phosphate solubilization revealed that all isolates could solubilize inorganic phosphorous in the medium ranged between 84.18 µg/ml and 244.17 µg/ml with variations among different isolates at different intervals of incubation. *Pseudomonas* spp. was more active in releasing soluble phosphorous among the isolates. A common trend of drop in pH (up to 3.7) was accompanied by the solubilization of tricalcium phosphate in the liquid medium. Among the six isolates *Pseudomonas* sp. KnSF 227 (244.17 µg/ml) was found as the best in solubilizing phosphorous in liquid medium followed by RNF 267 (217.525 µg/ml) and *Pseudomonas* sp. HSF 132 (200.065 µg/ml). Biochemical identification of the potent phosphate solubilizers revealed that the unidentified isolate RNF 267 was *Enterobacter cloacae* and *Pseudomonas* sp. KnSF 227 was *Pseudomonas plecoglossicida*. And *Pseudomonas* sp. HSF 132 was identified as *P. viridilvida* by using BIOLOG system. These bacteria have the potential to increase the available phosphorus *in vitro* which will be useful in designing strategies to use these native strains as bioinoculants for sustainable and organic farming of coconut without causing harm to the environment and farmers.



Poster
TS5-P26

Mycorrhizal and other microbial association with coconut palms of Minicoy, Kalpeni and Kavaratti Islands of Lakshadweep Island

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Lakshadweep islands are a string of enchanting islands in the Arabian Sea and the smallest Union Territory of India. Coconut is the main crop cultivated in Lakshadweep islands. The symbiosis of plant with Arbuscular Mycorrhizal Fungi (AMF) is the most widely spread mutualistic symbiosis in natural ecosystems. The beneficial effects of mycorrhizal association have been reported in coconut palm, However there is less knowledge about the AM fungal association with coconut palms in Lakshadweep islands. The present work is focused to find out the distribution of mycorrhizal association along with other beneficial microbes with coconut palms of Lakshadweep Island. Microscopic studies revealed AMF colonization in coconut roots from all the three islands. Frequency of root colonization recorded the same i.e., 61% in Kalpeni and Minicoy islands and Kavaratti Island with 53%. However, spore load was more in Kalpeni (81/10g) followed by Minicoy (70/10g) and Kavaratti with 63 spores/10g soil. *Glomus* was the most predominant genera in all the three islands followed by *Gigaspora*. Five different morphotype of *Glomus* was distributed in Kalpeni Island along with two different morphotypes of *Gigaspora*. However, *Gigaspora* abundance was at par with *Glomus* in Minicoy. Species richness was less in Kavaratti. Coconut rhizosphere was also associated with soil microbes like bacteria, fungi, actinomycetes, Phosphate solubilizers, Fluorescent pseudomonads, bacilli and N-fixers. Population of nitrogen fixers was more in Kalpeni Island where as Fluorescent pseudomonads was more in Minicoy.



Effective utilization of bioresources for yield improvement in *Plumbago rosea* intercropped in coconut garden

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P*lumbago rosea* L. (Family: Plumbaginaceae), known as Rosy flowered lead wort or fire plant in English, is an important medicinal plant, the root of which is used in more than 100 ayurvedic formulations such as *Chitrakasava*, *koduvelisudhachoorina* etc. The roots are useful in fever, cough, ring worms, leucoderma, dyspepsia, skin diseases, scabies and anaemia. Eventhough the crop is cultivated in isolated pockets in the state; the domestic production is insufficient to meet the ever increasing demand. In Kerala, there is ample scope for introducing it as an intercrop in coconut and rubber plantations. *Plumbago rosea* has already been identified as a potential intercrop in coconut plantations. An experiment was carried out at College of Agriculture, Vellayani, Kerala, India with 12 treatments and one control in RBD with three replications to study the effective utilization of bioresources consisting of three different organic manures (Farm Yard Manure, Neem Cake and Vermi Compost) alone and in combination with microbial inoculants mixture (Arbuscular Micorhizal Fungi (AMF), *Azospirillum* and Phosphobacteria) on the yield improvement of *Plumbago rosea*. The nutrient requirement of the crop (50:50:50 kg NPK ha⁻¹) based on Nitrogen equivalents were calculated and supplied to the plants as 100%, 75% and 50% of recommended dose of nitrogen (RDN) through organic manures and additional P and K as rock phosphate and wood ash, respectively. The treatments supplying 75% and 50% of the nitrogen requirement were supplemented with equal quantity of microbial inoculants mixture consisting of AMF (*Glomus* spp.), *Azospirillum* and Phosphobacteria (*Bacillus megatherium*). AMF was well mixed with top soil @ 200 g m⁻², *Azospirillum* and phosphate solublizers (*Bacillus megatherium*) applied as soil drench (each @2 kg ha⁻¹). Full dose of organic manures and microbial inoculants as per the treatments were applied as basal dose before planting. In the control plot (T₁) fertilizers (50:50:50 kg NPK ha⁻¹) and FYM (10 t ha⁻¹) were applied as per POP recommendations of KAU. The study revealed that treatment supplying 50 % RDN through Farm Yard Manure and Neem Cake along with the microbial inoculants mixture recorded the highest root characters such as root length (80.1 cm), root girth (3.03 cm), fresh root weight (86.33 g/plant), dry root weight (33.03 g/plant) and fresh root yield (7.6 t/ha). This treatment also recorded highest benefit cost ratio (2.73). This experiment shows that use of Neem Cake and FYM in the ratio 1:4 along with the microbial inoculants as basal dose has a long term effect on the nutrient supplying capacity of the soil thus reducing the cost of production of organic cultivation and enhancing benefit cost ratio of farmers.



Coconut based cropping system for Bastar plateau zone of Chhattisgarh

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Coconut cultivation is gaining popularity in Bastar plateau zone of Chhattisgarh from last two decades. The profitability of coconut as sole crop is low in India but intercropping with different economical crops have proved beneficial under coconut. A experiment under 20 year old coconut garden was laid out in the year 2006 to determine the best cropping system under coconut in Bastar plateau zone of Chhattisgarh. The experiment was laid out in RBD with four replications and six treatments viz. T1 = Coconut (Control), T2 = Coconut + Stevia, T3 = Coconut + Amahaldi, T4 Coconut + Sarpagandha, T5 = Coconut + Tikhur and T6= Coconut + Patchouli. The nut yield of coconut increased with intercropping compared to coconut alone. The data on yield of intercrops recorded was maximum in Amahaldi (6571 kg/ha), followed by Tikhur (4857 kg/ha) and was minimum in Sarpagandha (714 kg/ha). The mean yield of intercrops and the yield of whole system was converted into coconut equivalent yield and was the highest in Coconut + Tikhur (41787 nuts/ha) followed by Coconut + Amahaldi (40997 nuts/ha) and Coconut + Sarpagandha (24536 nuts/ha), respectively. Coconut alone recorded the minimum coconut equivalent yield of 6195 nuts/ha. The B:C ratio was maximum with Tikhur intercropping (2.28), followed by Amahaldi (2.06) and Patchouli (0.99) whereas minimum B:C ratio was found under Stevia intercropping (0.31).



Poster
TS5-P29

Use of biofertilizers in the production of black pepper (*Piper nigrum* L.) in mixed cropping system

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Two experiments using bio-fertilizers viz., *Azospirillum* and P solubilizer separately were conducted in farmer's field at Korklakatta village, Sirsi taluka in Karnataka state during 2000-01 to 2004-05. The objective was to derive information on role of bio-fertilizers on the yield of black pepper in mixed cultivation system and to develop an appropriate nutrient package to improve the productivity of the crop. Results from five years (2000-01 to 2004-05) revealed that the fresh berry yield of the vines differed significantly as influenced by various treatments. Application of *Azospirillum* @ 50 g as well as P solubilizer @ 50 g separately along with recommended 100 per cent inorganic NPK fertilizer (RDF) and 10 kg FYM per vine in respective experiment recorded the highest fresh berry yield (6.83 kg and 6.81 kg, respectively) compared to RDF alone (6.12 kg and 6.25 kg, respectively). These treatments also resulted in obtaining maximum C:B ratio (1:3.29 and 1:3.30, respectively). This was followed by the vines provided with 50 g *Azospirillum* along with recommended 75 per cent N, full dose of P, K fertilizer and 10 kg FYM per vine (6.57 kg) as well as 50 g P solubilizer along with recommended 75 per cent P, full dose of N, K fertilizer and 10 kg FYM per vine (6.43 kg).



TECHNICAL SESSION VI

CLIMATE CHANGE - ADAPTATION AND MITIGATION



Lead lecture

TS6-I01

Impact of climate change and adaptation strategies in coconut

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Plantation crops, being perennial in nature, have to face the impact of climate change even during a single generation or in a standing plantation since they are grown under ecologically sensitive areas such as coastal belts, hilly areas and areas with high rainfall and high humidity. Hence it is important that the impact of climate change on plantation crops is understood well. For example a seedling of coconut, in all livelihoods, faces the increased CO₂ concentrations, temperatures, etc. in next 50 years of its economic yield producing life span. Since the plantation crops can be used as the efficient carbon sequesters, they also form important component of any mitigation strategy that can be implemented at global level.

In India, coconut is grown in large areas of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and provide sustenance to millions of farmers across these states. Effects of weather are evident at all stages of development but the influence of weather depends on the stage of development. When other external factors such as fertility, management, pest and diseases are non-limiting, the yield variation can be explained mainly based on influence of weather parameters such as rainfall, evapotranspiration, temperature, solar radiation, sunshine hours, relative humidity and wind velocity, which are the major climatic variables that influence the coconut yield.

The ideal mean annual temperature for coconut growing is usually considered to be in the region of 29°C (27 - 32°C), with abundant sunshine and a well-distributed annual rainfall. Higher temperatures than the optimum are tolerated and are harmful only when they coincide with low humidity, possibly aggravated by hot dry wind. Coconut palms, as rainfed crop, are exposed to drought of different intensities and durations in various parts of the country. Based on weather data, drought was characterized in different agro-climatic zones which indicated variations in length and number of dry spells in each zone. Apart from this they also differed for rainfall, temperature regimes and light intensities, thus bringing about the different intensities of drought. Significant reduction in nut yield in each centre during 1 or 2 years either consecutively or alternatively indicated dependence of yield on the rainfall pattern and length of dry spell. Drought affects coconut and the impact can be seen from the year of drought till four years. Studies conducted at CPCRI on impact of climate change on coconut indicated general warming trends in most of the coconut growing areas. Coconut productivity increased over past 50 years except declining trends in Maidan parts of Karnataka and Coimbatore district of Tamil Nadu due to consecutive droughts. Impact assessment and future climate change projections was carried out as per different HadCM3 model scenarios and for the first time a coconut simulation model was developed. Using coconut simulation model, yields were simulated for 13 agro-



climatic zones. Analyses based on coconut simulation model studies indicate that coconut productivity is projected to go up over current yields only due to climate change in west coast of India. However, in east coast, yields are projected to decline due to climate change. Spatial variations exist for these projections.

Coconut has adaptive strategies to withstand or overcome these changing atmospheric conditions at morphological, physiological, biochemical, anatomical and molecular levels. Obviously all these are either the manifestation of genetic setup of a cultivar alone or in interaction with the environment (G x E interaction). Response of coconut seedlings to elevated CO₂ and temperature indicate significant changes in all the above parameters as compared to the control seedlings. Socio-economic analysis on impact of climate change in coconut growing areas indicated that soil moisture conservation treatments improved coconut yields in different agro-climatic zones of India. Recently simulation model for coconut was developed which can be used for climate change studies and efforts are being made to quantify the impact of climate change. A detailed understanding on the overall impacts of climate change on coconut with reference to production, productivity and quality is not only essential for planting suitable cultivars but also for planning the area and production since the commitment is perennial. Efforts are also required to develop simulation models suitable for climate change studies in perennial crops. Studies also indicated that coconut palms are very good candidates as carbon sequestrers for carbon trade under Clean Development Mechanism as per UNFCCC frame work.

Lead lecture

TS6-I02

Carbon sequestration in coconut plantations

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Carbon inputs (Gross Primary Production, GPP), carbon outputs (plant and soil respiration), carbon balance and carbon stocks (coconut palms, grass cover and top soil) of plantations under S₂ and S₄ soils in wet (WL₃), intermediate (IL_{1a}) and dry (DL₃) zones of Sri Lanka were estimated. GPP of palms varied from 1.2 to 2.9 mg C ha⁻¹ month⁻¹. The palm respiration varied from 0.473 mg C ha⁻¹ month⁻¹ (S₄ soils of DL₃) to 0.958 mg C ha⁻¹ month⁻¹ (S₂ soils of DL₃). Soil respiration varied from 0.3 mg C ha⁻¹ month⁻¹ (S₂ and S₄ of DL₃ and S₄ of WL₃) to 0.8 mg C ha⁻¹ month⁻¹ (S₂ and S₄ of IL_{1a} and S₂ of WL₃). The rate of carbon sequestration by coconut plantations varied from 0.4 to 1.9 mg C ha⁻¹ month⁻¹ under different growth conditions. C stock of the palms in S₂ soils of WL₃, IL_{1a} and DL₃ and S₄ of IL_{1a} was 24-25 mg C ha⁻¹ whilst that of S₄ in WL₃ and DL₃ was 17-18.7 mg C ha⁻¹. Soil C stock in S₂ and S₄ of the WL₃ and S₂ of the IL_{1a} was 35-44 mg C ha⁻¹ and that in S₄ of IL_{1a} and S₂ and S₄ of DL₃ was 14-19 mg C ha⁻¹. Consequently, C stock of the ecosystem was highest in WL₃ (63 mg C ha⁻¹), followed by IL_{1a} (54 mg C ha⁻¹) and lowest in DL₃ (37 mg C ha⁻¹). The carbon sequestration potential of coconut plantations has potential in mitigating the impacts of climate change.



Lead lecture

TS6-I03

Coconut-based farming systems as potential carbon “sinks” in meeting the challenges of climate change

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Coconut farms could be utilized in many ways to reduce CO₂ emissions via C capture or sequestration in the crop-soil system, enhancing this natural process through either coconut mono-cropping or inter-cropping plantation farming systems, eventually conserving the C sinks in the ecosystems. Being a palm tree having a woody perennial crop with a single main stem it meets the FAO's criteria of a forest tree. The total biomass yield of the coconut tree was found to vary from 15-50 t/ha/yr, influenced by the interaction of crop variety, environmental conditions, farming practices and growth stage.

The average C content of biomass components (stable trunk, temporary or unstable fruit-nuts, leaf fronds and other vegetative parts) is about 44%, lower than the 50% C content of most hardwood forest trees. With almost constant % C, its stored C averaged 5.74 t/ha and 24.1 t/ha, for pre-bearing and productive bearing palms in Eastern-Central Philippines, respectively. Compared to rice, sugar cane, grasslands ecosystems, coconut has more stable C storage, being a perennial with almost no field-burning of farm residues. A short term 2-yr study revealed the annual C sequestration rate of a local coconut tall variety: 4.78 t C/ha (=17.54 t CO₂/ha/yr), while a South Pacific (Vanuatu) study in 2001- 07 revealed the potential C balance or net ecosystem productivity (NEP) with a C sequestration rate of 20-yr old hybrid coconuts ranged from 4.7 to 8.1 t C/ha or 3.4 to 6.8t C/ha, if C biomass from coconut copra exported from the field is excluded.

Taking into account the soil organic C (SOC) “sink” based from the soil organic matter (SOM) for every 1% increase in SOM at 15 cm soil depth (about 2 M kg soil/ha), the estimated SOC stored: 10 t C/ha or 20 t C/ha at 30 cm depth. Stable soil sequestered C would require at least 20 years in soil storage. An indicative potential annual cash value of C sequestered (5.1 t C/ha of stable biomass + 15 t C (50% of SOC, 30 cm depth, with 4 M soil/ha) = 20.1 t C/ha/yr, valued at USD 301.5/ha/yr (@USD15/t C). This value could easily double if coconut lands are intercropped with fruit trees and other biomass-rich perennial crops.



Oral
TS6-01

Crop diversification with tropical tuber crops for food security under changing global climate

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In future, agricultural systems will be guided not only by the compulsion for attaining food security but also by the concerns for environmental protection and sustainability. Increasing the cropping intensity by way of feasible cropping systems is considered to be one of the strategies contributing to slowing or mitigating climate change by sequestering green house gases, especially CO₂. Tropical tuber crops have great prospects in this regard. Tropical tuber crops viz., cassava, sweet potato, yams (lesser yam, greater yam and African white yam), aroids (elephant foot yam, taro, tannia), Chinese potato, arrowroot etc. form an important staple or subsidiary food ensuring nutritional security of one-fifth of the world population, particularly in rural livelihoods. They have higher biological efficiency and capacity to amass higher dry matter. They can tolerate drought and shade, are adapted to marginal environments, low input situations, adverse soil and climatic conditions and also have great flexibility to thrive in mixed farming systems. They also have immense industrial uses, in the production of starch, sago, alcohol, as a source of raw material for poultry and animal feed and also have medicinal properties. Tuber crops are compatible inter crops in diverse cropping systems like coconut, rubber, banana, mango etc. Short duration pulses and vegetables can also be accommodated in tuber crops. Groundnut, French bean, okra and vegetable cowpea are feasible intercrops in cassava. Growing maize as an intercrop in yam reduces anthracnose incidence and enhances yield. Close growing pulse crops like green gram and black gram are ideal intercrops in elephant foot yam. Tuber crops like lesser yam, elephant foot yam etc. can also be grown in association with cassava. Cassava, sweet potato, elephant foot yam or taro can be grown as sequential crops in rice fallows. In such systems, the main crop provides cash income, tuber crops serve as insurance crop against risk and natural calamities, enhance the resource use efficiency, meet the food and feed requirements of the farm family and help to enhance the farm level income and employment opportunities (250-280 man days ha⁻¹). The scope of such crop associations, growth performance and production potential of tuber crops in such systems, management practices for realizing higher root yield and economic feasibility of the systems are briefly reviewed in this paper.



Oral
TS6-02

Potential of coconut plantations in mitigating climate change

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The study focused to quantify carbon sequestration rate and carbon stock of a 25 year-old coconut plantation (TallxTall, *Cocos nucifera* L. variety typica) under different growth conditions. Carbon inputs (Gross Primary Production, GPP), carbon outputs (plant and soil respiration), carbon balance and carbon stocks (coconut palms, grass cover and top soil) of plantations under S_2 and S_4 soils in wet (WL_3), intermediate (IL_{1a}) and dry (DL_3) zones of Sri Lanka were estimated using eight coconut palms and sample plots per site. GPP of palms varied from 1.2 to 2.9 mg C ha⁻¹ month⁻¹. The palm respiration varied from 0.473 mg C ha⁻¹ month⁻¹ (S_4 soils of DL_3) to 0.958 mg C ha⁻¹ month⁻¹ (S_2 soils of DL_3). Soil respiration varied from 0.3 mg C ha⁻¹ month⁻¹ (S_2 and S_4 of DL_3 and S_4 of WL_3) to 0.8 mg C ha⁻¹ month⁻¹ (S_2 and S_4 of IL_{1a} and S_2 of WL_3). The rate of carbon sequestration by coconut plantations varied from 0.4 to 1.9 mg C ha⁻¹ month⁻¹ under different growth conditions. C stock of the palms in S_2 soils of WL_3 , IL_{1a} and DL_3 and S_4 of IL_{1a} was 24-25 mg C ha⁻¹ whilst that of S_4 in WL_3 and DL_3 was 17-18.7 mg C ha⁻¹. Soil C stock in S_2 and S_4 of the WL_3 and S_2 of the IL_{1a} was 35-44 mg C ha⁻¹ and that in S_4 of IL_{1a} and S_2 and S_4 of DL_3 was 14-19 mg C ha⁻¹. Consequently, C stock of the eco-system was highest in WL_3 (63 mg C ha⁻¹), followed by IL_{1a} (54 mg C ha⁻¹) and lowest in DL_3 (37 mg C ha⁻¹). The study congregated quantitative information on carbon sequestration potential of coconut plantations under different growth conditions and recognized the potential of coconut plantations in mitigating the impacts of climate change.



Poster
TS6-P01

Pest outbreak surges in coconut and climate change

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The coconut cropping system has been found to be vulnerable to increased threats from insect pests due to climate change. The multiple impacts of climate change could significantly reduce the effectiveness of current IPM strategies leading to higher crop losses. This paper documents pest outbreaks on coconut in the Philippines as a result of climate change.

Poster
TS6-P02

Development of water stress tolerant coconut hybrids through selective fertilisation

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In-vitro pollen germination is an important technology not only for understanding the fundamental problems concerning pollen function but also in many areas of pollen biotechnology. Ability to separate germinated and un-germinated pollen in a selection medium provides a better tool for identifying stress tolerant and stress sensitive alleles carried by their pollen grains. An experiment was conducted to develop water stress tolerant coconut hybrids through pollen selection and selective fertilization. Different genotypes of coconut were screened for critical water potential at which 20-30 per cent of the pollen germinates. The Seychelles and WCT were found to be more drought tolerant and dwarf types were susceptible. The pollen from selected male parents was incubated at critical water potential for 3 hours and the germinated pollen which are drought tolerant were used for fertilization. The hybrid nuts thus developed were sown on plastic bags. One year old seedlings were subjected to three level of soil moisture stress for three months along with normal hybrids and WCT. The stress tolerance of these seedlings were assessed using an index based on epi-cuticular wax content, relative water content, leaf water potential and ROS scavenging enzyme activity at the end of stress period. The hybrids developed through selective fertilization using selected pollen were significantly tolerant to water stress. This technology can be used to develop water stress tolerant coconut hybrids without any additional cost to face the challenges under the scenario of climate change.



Poster
TS6-P03

Superoxide dismutase isozymes and their heat stability in coconut (*Cocos nucifera* L.) leaves

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The possible isoforms of Superoxide Dismutase (SOD: EC 1.15.1.1) and its stability against heat treatment at various temperatures (50°C to 100°C) in three year old seedlings of West Coast Tall (WCT) cultivar of coconut were investigated. To identify SOD activity, crude extract from coconut leaves were subjected to native polyacrylamide gel electrophoresis followed by staining with nitroblue tetrazolium (NBT) and riboflavin. From our study, we found out 13 isoforms for Superoxide Dismutases in coconut. Treatment with SOD inhibitors indicated the presence of five Cu/Zn-SOD, four Mn-SOD and two Fe-SOD. In this experiment, we also found the presence of two higher molecular weight SOD isoforms, which were resistant to both the SOD inhibition treatments (Cu/Zn-SOD, Mn-SOD and Fe-SOD inhibitors), were very unstable to heat treatment and completely lost their activity only at 60°C. Under sequential heat treatments, SOD specific activity decreased linearly from 6.82 to 1.88 up to 80°C but increased at 100°C to 4.38. This may be due to the activation of some new SOD isoforms at higher temperature. Out of 13 isoforms, nine isoforms lost their activity at 80°C. Only four isoforms (two each for Cu/Zn-SOD and Mn-SOD) were stable at 80°C, and at 100°C two existing isoforms of Cu/Zn-SOD were stable but two new isoforms of Cu/Zn-SODs also developed.

Poster
TS6-P04

Pollen selection for assessing the water stress tolerance in coconut

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Male gametophytic competition for fertilisation reflect the genetic differences between individual microgametophytes. Separation of germinated and ungerminated pollen after selective treatment provide a better tool for identifying stress tolerant and stress susceptible alleles carried by their pollen grains. Thirty different genotypes of coconut were screened for stress tolerance in terms of pollen germination at critical water potential. Significant genetic variation existed for critical water potential. Seychelles and WCT recorded maximum tolerance with critical water potential of -6.0 bars and dwarf types were susceptible.



TECHNICAL SESSION VII
**INTEGRATED PEST MANAGEMENT AND
EMERGING PESTS**



Lead lecture

TS7-I01

Bio-intensive pest management on key pests of coconut

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Bio-intensive pest management has become the need of the present era as it has a conceptual consideration for ecological sustainability. Among the various components of IPM, the most effective tool for ecological sustainability is the biological pest suppression that utilizes the natural enemies of the pest viz., entomophaga and entomopathogens. Bio-intensive pest management relies on a range of preventive tactics and biological control methods to keep the pest population at acceptable levels. The non-chemical and bio-rational methods of pest management are ideal, eco-friendly and feasible in a sustainable crop production system. Coconut palms grown mainly under homestead gardens in India suffer heavy damage due to infestation by various pests. The key pests of coconut in India are the rhinoceros beetle (*Oryctes rhinoceros* L.), red palm weevil (*Rhynchophorus ferrugineus* Oliv.), black headed caterpillar (*Opisina arenosella* Walk.), eriophyid mite (*Aceria guerreronis* Keif.) and the white grub (*Leucopholis coneophora* Burm.). Integrated Pest management (IPM) strategies have been developed for combating all these major pests. A bio-intensive management strategy without using any chemical pesticides is recommended for suppression of rhinoceros beetle. Two entomopathogens viz., a virus (*Oryctes rhinoceros* virus [OrV]) and a fungus [*Metarhizium anisopliae* (Metschnikoff) Sorokin] are employed for the bio-suppression of the pest in the field. Large scale field validation of biocontrol technology using these two potential biocontrol agents could be successfully demonstrated in mainland as well as in Island ecosystems. The black headed caterpillar, *O. arenosella* is well managed by biocontrol agents especially entomopathogens. Release of stage specific parasitoids at appropriate doses based on the population density of the pest is recommended for the management of the pest. The larval parasitoids viz., *Goniozus nephantidis* and *Bracon brevicornis*; the pre-pupal parasitoid *Elasmus nephantidis* and the pupal parasitoid, *Brachymeria nosatoi* are the major parasitoids employed against the pest. The technology utilizing these parasitoids could be implemented with success stories in endemic areas of coastal and backwater tracts in Kerala and Karnataka. Eriophyid mite is managed in the field by the application of botanical pesticides either by spraying or root feeding integrating with adequate nutrient management. Currently emphasis is focused for developing biocontrol strategies for the management of this pest with the conservation of predatory mites and field level utilization of the acaropathogenic fungus, *Hirsutella thompsonii*. Sustained surveillance on pest infestation and adoption of sanitational and preventive methods are essential steps for management of red palm weevil. Trapping of red palm weevil using aggregation pheromone lures in food-baited bucket traps forms an important component of the IPM strategy against the pest. On account of



the concealed nature of the pest, an effective biocontrol agent is lacking and the feasibility of entomopathogenic nematodes (EPN) belonging to *Heterorhabditis* sp. in the suppression of the pest is currently under investigation. White grubs pose serious threat to coconut palms in sandy loam tracts. Trapping of adult beetles during their emergence period in May-June is one of the effective strategies for management of white grubs. Investigations are also in progress on the utility of EPN (*Steinernema* sp.) for the management of the pest.

Lead lecture
TS7 -102

Approaches and advances in eriophyid mite management in coconut

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Invasion of coconut mite, *Aceria guerreronis* Keifer into the Indian sub-continent, particularly India and Sri Lanka around 1998 and possible risk of its further spread to other major coconut growing countries in East Asia and the Pacific alarmed the world coconut industry. Despite repeated use of highly toxic insecticides, no sustainable and environmental friendly management method has been developed for this serious pest until then. It is well acknowledged that *A. guerreronis* is an extremely difficult pest to manage due to its' hidden habitat underneath the bracts of coconut fruits, which makes many insecticides/chemicals and natural enemies less accessible. Therefore, it has been a challenge to the coconut scientists world over to find effective and sustainable management methods for *A. guerreronis*.

In the last decade more active research has been undertaken in understanding many aspects of the biology, ecology and behaviour of the pest and utilizing low toxic insecticides/chemicals and natural enemies in its management. Neem-based insecticides and other low-toxic chemicals have been widely tested in India and Sri Lanka. These chemicals applied by different methods has given only up to about 70% reduction in pest population requiring repeated applications at short intervals to maintain low damaging levels of the pest as in the case of highly toxic insecticides used in the past. Studies in Sri Lanka showed that a mixture of 20% vegetable oil and 0.5% wettable sulphur reduces pest population by over 90% and damage on harvested fruits below economical levels and also application interval could be extended up to 6 months.

Attempts in using biological control methods have been mainly focussed on the entomopathogenic fungus, *Hirsutella thompsonii* Fisher until recently. Although, different isolates of the fungus and formulations were evaluated, results have been inconsistent. Exploration of the widely spread predatory mite of *A. guerreronis*, *Neoseiulus baraki* (Athias-Henriot) (Phytoseiidae) as a prospective bio-control agent was initiated in Sri Lanka and followed by other countries. A preliminary study in Sri Lanka, in which a single inundative release of 1000 predatory mites per palm reduced *A. guerreronis* population significantly, prompted further



studies. Mass rearing of *N. baraki* in the laboratory in a tray-type arena and a polypropylene sachet was successful giving a 250-fold increase in *N. baraki* numbers in six weeks. A field release technology for *N. baraki* was developed in Sri Lanka. Release of *N. baraki* at the rate of 5000 per palm at 2- and 4-monthly intervals significantly reduced the coconut mite density, percentage of infested fruits and smaller sized fruits at the harvest. Further, possible utilization of the exotic predatory mite *Proctolaelaps bickleyi* Bram (Ascidae) imported from Brazil was evaluated. Due to its inability to enter the mite habitat through the narrow gap between the bracts and the fruit surface of coconut and its predating on *N. baraki* discouraged further studies. Nevertheless, it is being currently evaluated in Brazil and search for effective natural enemies from the origin of the pest is being made.

It has been established that coconut cultivars/ varieties respond differentially to coconut mite infestation. Fruits with a round shape of which the bracts are tightly adhered to the fruit surface escape infestation completely or partially. Research on this aspect should be strengthened to develop tolerant cultivars/ varieties.

Since, *A. guerreronis* could not be completely controlled by any single method developed so far, integration of low-toxic chemicals, use of predatory mites and cultivation of tolerant cultivars/ varieties considering the seasonal pest dynamics and the locality would provide effective and cost-effective management of the pest.



Oral
TS7 -01

Natural enemy complex associated with coconut eriophyd mite, *Aceria guerreronis* Keifer

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The coconut eriophyd mite *Aceria guerreronis* Keifer (Acari: Eriophyidae) is one of the major pests of coconut (*Cocos nucifera* Linn.) in South America, Caribbean Islands, Africa, India and Sri Lanka. The microscopic size of the mite and its hidden habitat underneath the tepals of developing young coconuts has hindered effectiveness of pest management programmes. Various chemical and botanical pesticides are currently recommended for management of the pest which induce only short term effect to mite management. The chemical pesticides are hazardous to humans, pollinators, natural enemies and in a long way to the environment. Hence studies were conducted to catalogue natural enemies associated with coconut eriophyd mite from various coconut growing tracts of India with an aim to select the most promising one for an effective, long lasting field level biocontrol. Result of the investigations for the period during 2000-2010 is presented in the paper. The natural enemy fauna primarily consisted of predators (mites and insects) and pathogens. *Neoseiulus baraki* Athias-Henriot, *N. paspalivorus* De Leon, *Typhlodromus* sp., *Chelacaropsis moorei* Baker, *Cheletogenes ornatus* Canestrini & Fanzag and *Bdella* sp. are the major predators found in association with mite colonies. *N. baraki* was the most predominant predator observed in samples collected from all the areas surveyed with average incidence in 72-85 % of the total nuts observed in various districts. Seasonal incidence of *N. baraki* showed persistence throughout the year with peak during April. The average percentage of nuts lodging predators showed as steady increase over the years (37.09 during 2001 to 82.7 during 2006). The insect predators observed in the studies include a thrips, syrphid and coccinellid which are of very low occurrence. Among the microbial pathogens, *Hirsutella thompsonii* Fisher was isolated from Kerala, Karnataka and Orissa. A total of 42 isolates could be collected. Differences in morphology (synnematous and non synnematous) and colony colour (white to ash) were observed in the isolates. Variations in growth rate (radial growth of 1.68 cm to 3.71 cm/10 day) and sporulation (5 to 175×10^4 cfu/ml) were also observed among the isolates. Pathogenicity in laboratory screening indicated 60-84% mite mortality with various isolates.



Oral
TS7 -02

Antibiosis resistance to coconut black headed caterpillar, *Opisina arenosella* Walker in coconut genotypes

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Coconut black headed caterpillar, *Opisina arenosella* is a serious pest of coconut and often assumes severe proportion on the coastal, backwater tracts and coconut fishpond ecosystems. Studies were conducted by artificial diet and fresh leaf methods in the laboratory to explore the antibiotic effects against coconut black headed caterpillar using different coconut genotypes viz., East Coast Tall (ECT), Gauthami Ganga (Gangabondam), Kera Bastar (Fiji), Double Century (Philippines Ordinary), Godavari Ganga (ECT x GBDG) with control ECT fresh leaves. Through the artificial diet incorporation method, the highest larval mortality was observed when the larvae fed on Kera Bastar (80%) and Double Century (70%), whereas, Gauthami Ganga recorded the least larval mortality (30%). Adult emergence inhibition was found lowest in Kera Bastar (100%), followed by Double Century (80%). The larval period was longest with Godavari Ganga (46.6 days) and the maximum pupal period of 14.5 days was recorded on both ECT and Godavari Ganga. The total development period ranged from 39.5 days (Kera Bastar) to 55 days (Godavari Ganga). When the neonate larvae fed on the fresh leaves of various varieties, the maximum larval mortality was observed on Double Century (60%) and minimum with ECT (47.5%), further the adult emergence inhibition was maximum in Kera Bastar (80.6%). The highest larval and pupal periods were recorded as 39.8 days (ECT) and 12 days (Kera Bastar). The total developmental period ranged from 44.6 days (Godavari Ganga) to 51.3 days (ECT). Higher larval mortality, adult emergence inhibition and prolonged development period of the pest in both the artificial diet incorporation and fresh leaf methods, indicates antibiosis mechanism of resistance against coconut black headed caterpillar in Double Century and Kera Bastar genotypes. Hence, these genotypes can be utilized in the breeding programme for insect resistance.



Oral
TS7 -03

Effect of sub lethal dose of insecticides on electrophysiological and behavioural response of *Bracon brevicornis* Wesmael, a parasitoid of coconut black headed caterpillar, *Opisina arenosella*

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The black headed caterpillar (*Opisina arenosella* Walker) is a major pest of coconut. *Bracon brevicornis* Wesmael is an important parasitoid used in inundative releases against *O. arenosella* to manage this pest. During outbreaks the chemical insecticides are used in combination with the release of parasitoids. Traditionally the effect of pesticides on beneficial arthropods was relied mainly on determination of acute toxicity. In addition to direct mortality caused by insecticides, the sublethal effect on parasitoids sensory physiology and their behaviour must be considered for complete analysis of their impact. The present study aims to investigate the relationship between the dose of insecticide to which the parasitoids are exposed and the subsequent ability of these parasitoids to respond to host-related cues. Electrophysiological antennal responses of *B. brevicornis* adults to volatiles reveal that the chemoreception by female was better than in males. Among the volatiles tested, the host frass and host hemolymph was most preferred by both sexes. In case of female the leaf damaged by larvae showed enhanced antennal response as compared to the odour from the mechanically damaged leaf. Among the chemical insecticides tested for acute toxicity to *B. brevicornis* the organophosphates (monocrotophos and malathion) were more toxic as compared to carbamates. The adult *B. brevicornis* exposed to sublethal dose of malathion (LD_{20}) had maximum residence time on the frass of its host. In contrary those exposed to LD_{20} monocrotophos were not attracted to the host frass. Information gained on the lethal and sub lethal dose will determine the safety period for release of *B. brevicornis* in pesticide treated fields.



Oral
TS7 -04

Modulation of certain lysosomal enzymes in *Proutista moesta* (Westwood) fed on coconut palms with root (wilt) disease

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Root (wilt) disease (RWD) is a major debilitating disease of coconut which provides livelihood securities to more than 10 million people in 18 States and 3 Union Territories of India. Phytoplasma (16SXI group) has been found associated with the disease by electron microscopy, transmission and Polymerase Chain Reaction based molecular detection studies. The disease is transmitted by two insect vectors viz., lace bug, *Stephanitis typica* Distant and plant hopper, *Proutista moesta* (Westwood) in nature. The present investigation aimed to understand the modulation of certain lysosomal enzymes in *P. moesta* that are field collected, artificially reared using oil palm bunch waste as well as those insects that have fed on RWD palms for >30 days, the time required to acquire sufficient titre of pathogen from diseased palm and ability to transmit the pathogen known as acquisition access and incubation period (A+I). Acid phosphatase and α -galactosidase, the two marker enzymes of lysosomal system that regulates histolysis and histogenesis during cell remodeling in insects was studied in *P. moesta*. Acid phosphatase activity was found to be higher (952.12 ± 3.17 nanomole *p*-nitrophenol released /min/ g tissue) in field collected *P. moesta* than those insects that had completed (A+I) period (677.74 ± 3.17 nanomole *p*-nitrophenol released/min/g tissue). β -Galactosidase activity was also found to be higher (89.4 nanomole *p*-nitrophenol/min/g tissue) in field collected *P. moesta* than those insects that had completed (A+I) period (69.8 nanomole *p*-nitrophenol/min/g tissue) as well as freshly emerged *P. moesta* (78.2 nanomole *p*-nitrophenol/min/g tissue). A similar trend was also observed in protein concentration. β -Galactosidase activity in *P. moesta* was found to be 8-10 times lower than acid phosphatase activity. Changes in the electrophoretic profile of at least six peptides were observed between the three different groups of *P. moesta*. Results suggest the activity of two lysosomal enzymes is altered in *P. moesta* by feeding continuously on RWD palms for >30 days affecting cell remodeling involved in growth and reproduction.



Poster
TS7-P01

Prevalence of rhinoceros beetle (*Oryctes rhinoceros*) and coconut stick insect (*Graeffea crouanii*) and their management in the Fiji islands

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Coconut palms are highly susceptible to pests and disease in tropical countries due to favourable weather conditions. The two serious pests of concern in Fiji Islands are rhinoceros beetle (*Oryctes rhinoceros*) and coconut stick insect (*Graeffea crouanii*). To control the population of these serious pests of coconut palms in Fiji Islands, biological control methods are applied, such as rearing of biological control agents in laboratory to disseminate in infested sites for controlling damage to coconut palms. For control of rhinoceros beetle, two specific pathogens, a baculovirus and an entomopathogenic fungus (*Metarhizium anisopliae*) are used while for stick insect, egg parasitoids (*Paranastatus nigriscutilatus*) are used to suppress the population and presence in order to minimize their impacts on food security and income for Fiji Island, a highly agricultural dependent country. The introduction of *Oryctes rhinoceros* virus particularly has markedly suppressed the beetle population and has helped to revive the copra industry. The results show that continuous augmentation of pest control methods into the pest infested areas is needed for effective pest control in tropical Island countries. This paper highlights some of the coconut pest management activities undertaken in the past and present and results obtained in Fiji. In addition, the strengths and limitations of the application of these bio-control methods in the Fiji Islands are also highlighted.



Poster
TS7-P02

Biology of coreid bug, *Paradasynus rostratus* Dist. in different hosts

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The coconut palm is prone to infestation by a large number of insect and non insect pests. Of late, the coreid bug, *Paradasynus rostratus* Dist. has gained notoriety as a major pest of coconut in Kerala. Apart from coconut, coreid bug attacks other crops and these alternative hosts play an important role in the population build up of this pest. However, the studies on the duration of lifecycle of coreid bug in different hosts should be done for developing a management strategy against this pest. Studies on the life cycle of *P. rostratus* on coconut and alternative hosts viz., guava, cashew and neem were conducted in the Department of Entomology, College of Agriculture, Vellayani. The adult bugs collected from the field were confined in cylindrical glass jars (20 x 50 cm). The observations on mating, egg laying and egg period, nymphal periods were noted. The adult female laid eggs in clusters containing an average of 43 yellowish oval shaped eggs per cluster. The egg period was 8.20, 8.40, 7.60 and 8.40 days when reared in guava, neem, cashew and coconut, respectively. The first instar nymphs were ant like, and they took 3.60, 4.60, 3.80 and 3.60 days to moult into second instar when reared in guava, neem, cashew and coconut, respectively. The second instar nymphs were 4.50 mm long and 1.00 mm wide. The second instar nymphal period recorded in the different hosts guava, neem, cashew and coconut were 4.20, 4.00, 3.80, 4.20, respectively. The third instar nymphs measured 6.70 x 1.50 mm. The head was as long as the thorax. The antenna was 9.00 mm in length and reddish brown in colour. The instar took 4.20, 4.00, 3.80 and 4.20 days in guava, neem, cashew and coconut, respectively, to moult into the next instar. The fourth instar nymphs were 8.50 mm long, 2.00 mm wide and dark reddish brown in colour. The duration of the fourth instar nymph was 5.60, 5.00, 6.40 and 5.20 in guava, neem, cashew and coconut, respectively. The fifth instar became adult in 4.80, 5.60, 5.40, and 5.40 days in guava, neem, cashew and coconut, respectively. The fourth and fifth instar nymphs caused severe damage to the crops they infested. The instar was completed in 39.00, 40.20, 39.40 and 28.00 days in guava, neem, cashew and coconut, respectively. No significant difference was observed in the life cycle of the pest when reared on the host crop and alternative hosts Knowledge on the biology of the bug on different host plants is essential to determine the population buildup of the bug in an area with a heterogeneous mix of crops susceptible to bug infestation and also to predict the number of generations completed per year.



Poster
TS7-P03

Evaluation of four aggregation pheromone lures against red weevil in Pollachi tract of Tamil Nadu

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The red palm weevil (*Rhynchophorus ferrugineus* Oliv.) is the most dreaded pest of juvenile coconut palms. Mass trapping of adult weevils with food baited aggregation pheromone traps is one of the important eco friendly components in IPM programme to check RPW infestation in coconut plantations. Among the four types of aggregation pheromone lures (Chem tika, Brookland, PCI and CPCRI) evaluated, Chem tika lure trap with sugarcane molasses was found to be significantly superior in trapping maximum number of adult red palm weevils upto 206.8/month followed by Brookland lure trap (158.0), PCI lure trap (138.6) and CPCRI trap (116.4) when compared to control (food bait alone) with 41 only. It is also observed that average catch of red weevils was found to be the highest in Chem tika lure trap up to 34.46 adults/trap and CPCRI trap (19.40 adults/trap) as against control (6.9 adults/trap). Sex ratio of four pheromone lures trapped red weevils revealed that they were female dominated. For every male weevil captured, 1.75 females were trapped in Chem tika lure followed by Brookland lure 1:1.5, PCI lure 1:1.33 and CPCRI lure, 1:1.2 as against mere food baited trap 1:1.03. The levels of RPW infestation also declined in experimental area after setting up of pheromone traps. Mass trapping of adult weevils in endemic pockets with food baited (sugarcane molasses) aggregation pheromone traps makes an ideal IPM component which is eco friendly safer and economically viable in checking the populations of red palm weevil.



Poster
TS7-P04

Integrated management of black headed caterpillar in coconut

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Due to heavy incidence of black headed caterpillar in Davanagere district, farmers were removing coconut gardens and switching over to paddy and arecanut cultivation. In order to work out a solution for this problem, a front line demonstration on integrated management of black headed caterpillar in coconut was conducted during 2007-08 to 2008-09 in two villages of district. Manual collection and destruction, root feeding of azadirachtin (15 ml/ palm, 3 times, Jan-Feb, Apr-March and Sept-Oct) and release of parasitoid *Goniozus nephantidis* (50/palm, 4 times at 15 days interval) during summer months were used as the integrated management practices for the study. Among all the management practices, root feeding with azadirachtin at proper time and dosage, community management practices, release of parasitoid resulted in reduced incidence of this pest. During the study 20 per cent reduction in the incidence of the pest was noticed in the demonstration plot compared to untreated plot. Newly emerging leaves were free from pest attack.

Poster
TS7-P05

Design of an ecologically- based IPM programme against coconut slug caterpillar (*Macroleptra nararia* Moore) in coastal districts of Andhra Pradesh

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Coconut slug caterpillar, *Macroleptra nararia* Moore, causes severe yield losses with outbreaks in summer since one decade in the coastal areas of Andhra Pradesh. The studies were conducted with different approaches: (a) use of bioagent, (b) pesticidal application through root feeding as well as foliar application, (c) mass trapping and destruction of adult moths by installing light traps, (d) sanitation by cutting and burning the infested and dried leaves and crown cleaning to manage the pest. Spraying of entomo-pathogenic fungus, *Beauveria bassiana* proved effective under field conditions by causing 70 per cent mortality of the pest. Root feeding with monocrotophos 36% SL @ 10 ml + 10 ml water/palm, caused 95 per cent larval



mortality. A maximum number of 685 moths in a duration of 6 h (7.00 pm to 1.00 am) could be trapped and destructed by using light trap (200/500 watts). Sanitational measures like cutting and burning the infested and dried leaves, removal and destruction of pupal cases from the crown, spraying on hedge plants and other weeds which are harbouring the pest also contributed towards the reduction in the pest population in the infested garden. When all these components were implemented independently, it resulted in successful suppression of the pest. Integration of all measures like root feeding/spraying of pesticide, bioagents like *Beauveria bassiana*, use of light traps and sanitation would be definitely effective in management of the coconut caterpillar. Hence, integration of compatible strategies depending on the stage of pest available in the infested garden would form a successful IPM against coconut slug caterpillar.

Poster
TS7-P06

Reaction of different coconut genotypes against eriophyid mite (*Aceria guereronis*) in Konkan region of Maharashtra

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Coconut eriophyid mite, *Aceria guereronis* has become a major threat to coconut palms. It has been reported from Thane district in Maharashtra. Of late it is noticed distributed throughout Konkan belt of the state. In order to know the reaction of different coconut genotypes against eriophyid mite, 10 coconut genotypes at Regional Coconut Research Station, Bhatye were screened under natural infestation from July 2008 to July 2009 (5 harvests). The nuts from 10 trees in each genotype were observed for the mite damage at each harvest. Observations are converted into the mean damage grade index score. Based on the mean damage grade index score none of the coconut genotypes were found to be resistant to mite. However, the genotypes British Solomon Islands, Seychelles Tall and T X D were found to be moderately resistant with a mean damage grade index score of 2.49, 2.37 and 2.53 respectively. On the other hand, all other seven genotypes viz., San Ramon (3.32), Borneo (3.27), Jamaica Tall (2.74), Kenya (2.87), Guam (2.99), Lono (3.04) and Cochin China (3.17) were found to be susceptible to mite attack.



Poster
TS7-P07

Integrated management of eriophid mite in coconut

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On farm test (Technology Assessment) was conducted at Taralabalu Krishi Vigyan Kendra, Davanagere, Karnataka during 2007-08 to 2008-09 to manage the eriophid mite incidence in coconut gardens of the district. Five farmers were selected for the study and all the three treatments were imposed on the same plot of each farmer. In technology option 1 (Farmers practice) the incidence of mites was 87 per cent, whereas in technology option 2 (UAS, Bangalore) the incidence was 72 per cent. This was reduced to 37.2 per cent in Technology option 3 (Alternative practice). Average number of nuts per palm has been increased tremendously in Technology option 3. From the experiment it is concluded that integration of organic farming, RDF, Neem cake, TNAU coconut nutritional tonic helps to impart resistance in coconut palms thus increase the productivity of the garden.

Poster
TS7-P08

Survey on natural occurrence of entomopathogenic fungi associated with coconut slug caterpillar (*Macroleptra nararia* Moore) and field evaluation of *Beauveria bassiana*

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Coconut slug caterpillar (*Macroleptra nararia* Moore), a sporadic pest of coconut, has turned up into an endemic form causing serious yield losses under east coast conditions. Roving survey conducted in the slug infested coconut gardens in coastal districts of Andhra Pradesh revealed 10-90% foliage damage causing yield losses upto three years. From the infected pest samples collected from slug infested gardens, certain entomopathogenic fungi viz., *Aspergillus flavus*, *Aspergillus niger*, *Penicillium* spp. and *Beauveria bassiana* were isolated and these entomopathogens are causing the mortality of the pest to an extent of 70% under field conditions. Field efficacy studies of *Beauveria bassiana* foliar spray recorded 100% mortality of the larval population of coconut slug caterpillar. The study paves a path towards bio control of coconut slug caterpillar which can fit as a one of the components of integrated pest management.



Poster
TS7-P09

Emerging pests of coconut in India

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Emerging pests are those pests that have newly appeared in the population or have existed but are rapidly increasing in incidence on a geographic range. Emergence is usually associated with increased population densities resulting from ecological changes consequent to alterations in the environment. Apart from this, changes occurring in cropping patterns, adoption of modern agro-techniques and indiscriminate use of chemical pesticides also add to the biotic imbalance and consequent emergence of new pest problems. Recent reports on the incidence of a few insects on coconut plantations in different parts of India attaining the status of emerging pests are presented in this paper. The widespread occurrence of coreid bug, *Paradasynus rostratus* Dist. was reported as a serious emerging pest on coconut from Southern districts of Kerala. The bug causes heavy crop loss by shedding of developing buttons and immature nuts ranging from 18.2-66.4% in endemic gardens. In Eastern and Western Godavari districts of Andhra Pradesh the outbreak of coconut slug caterpillar *Macroplectra nararia* M was recorded during March-May 2009 and the level of infestation ranged from 5-85%. High temperature (>39°C) coupled with high relative humidity favoured emergence of the pest in higher population. An outbreak of slug caterpillar, *Conthyla rotunda* was reported from Payyannur, Kerala during February 2010 causing complete defoliation of the leaves resulting in drastic reduction in nut yield. Occurrence of a bag worm, *Metisa plana* feeding on mature coconut/oil palm leaflets was observed in West Godavari district of Andhra Pradesh and Kottayam district of Kerala. Incidence of whiteflies viz., arecanut whitefly *Aleurocanthus arecae* and spiraling whitefly, *Aleurodiscus dispersus* were noticed in coconut palms from Kerala, Tamil Nadu and Lakshadweep Islands. Increasing levels in population of coccids viz., mealy bugs and scales are seen in several parts of South India. Sporadic occurrence of ash weevil *Mylloceris* sp. and aphids were observed in coconut nurseries during pre-monsoon period. Small weevil *Amorphoidea coimbatorensis* and a slug, *Mariaella dussumieri* were noticed at moderate levels on coconut inflorescence especially of dwarf coconut cultivars.



Poster
TS7-P10

Survey and monitoring of eriophyid mite, *Aceria guereronis* Keifer of coconut in Konkan region of Maharashtra

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The incidence of coconut mite (*Aceria guereronis* Keifer) in Maharashtra was recorded for the first time in the year 2001 in Thane District. Since then, surveys have been conducted to visualize the condition of mite infestation in different areas in Konkan region of Maharashtra. For recording the intensity of infestation of Eriophyid mite in Konkan region, a survey was carried out in Raigad, Thane, and Ratnagiri and Sindhudurg districts from April 2003 to January 2008. Minimum of two villages from each tehsil and minimum two farmers from each village were selected randomly for recording the infestation. From the field surveys, it was found that the eriophyid mite severity was higher in Thane district (29.10%) in April 2003. Later on the damage progressively increased and attained a peak of 74.54 % in May-June 2006 with declining trend observed thereafter. In Sindhudurg district, the mite intensity increased steadily and reached upto 100 % in May-June 2006 and then started declining. In Raigad and Ratnagiri districts it was medium. These modulations in the mite incidence are attributed to the role of natural enemies and changes in weather conditions.

Poster
TS7-P11

Survey and monitoring of pest problems of coconut in Konkan region of Maharashtra

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Rhinoceros beetle, Red palm weevil and Black headed caterpillar are important pests of coconut in Konkan region of Maharashtra. Field surveys were conducted to realize the pest situation in different areas in Konkan region of Maharashtra viz., Raigad, Thane, Ratnagiri and Sindhudurg districts from April 2003 to January 2008. Minimum of two villages from each



tehsil and two farmers were selected from each village randomly for recording the infestation. From the field surveys, it was observed that the infestation of rhinoceros beetle and red palm weevil was recorded in almost all the four districts of the region. Black headed caterpillar infestation (25.36 %) was recorded only in Thane district during February-March 2005, which declined further during the subsequent years.

Poster
TS7-P12

User-friendly rodent management techniques in coconut plantations - A frontline demonstration in Thrissur District, Kerala

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The widely experienced economic loss due to tender nut fall in coconut plantations in the Mathilakom Block Panchayat areas during the past years (2000-2005) was alleged to be due to some unknown animals or bat attack as complained through the mass media in Thrissur District. But the technical study team from Kerala Agricultural University has established and affirmed that it was primarily due to the rodent attack followed by bat feeding as a secondary effect in the extensive nut fall in the region. Hence, it was deduced by the concerned experts that the primary causal agent is but rodent species and the bats and flying foxes are of secondary predators. The rats belonging to the genus *Rattus* and species *R. rufescens* and *R. wroughtoni* (roof rat or tree rat) and *R. norvegicus* (Port rat) are of primary concern in coconut systems. Therefore, in order to convince the farmers about the cause of the malady and the efficacy of some adhoc management strategies based on the bio-ecology and ethology of these vertebrate species, four frontline demonstrations were organized in four panchayats, viz., Mathilakom, Kodungalloor, Perinjanam and Kaipamangalom areas in Mathilakom Block jurisdiction during 2007-08. The measures adopted in selected number of palms under study consisted of 1) manual disinfestation by clearing and sanitizing the coconut crowns, 2) wrapping the coconut stems with specially designed self sticking plastic sheet of 40 μ thickness over 45 cm width at a height of 1.5 m above the ground level, and 3) application of bromodiolone based rodent bait cakes in the crown as well as on the trunks (tied up at the basal region). The results out of the observation for two months from the respective sites in all the four panchayaths as well from the pooled mean data revealed that there was a drastic reduction (86-92%) in the nut fall and damage due to the rodent infestation with the technique of wrapping up the tree trunk with the self sticking plastic band preventing the climbing access of the ground dwelling rodents. This data amply highlighted the importance of the mechanical exclusion principles to prevent the access of the climbing rodents onto the palms to reach the crown for tender nut damage by boring and feeding. The potential of the bromodiolone bait cakes applied in the crown as well as fastened around the tree trunk below might have also played their role in reducing the population of the



rodents and consequent low nut damages. Hence it could be inferred that the ground dwelling rats are the primary causal agent for the coconut loss and that the same could be economically and ecologically managed by banding technique with low cost self sticking polythene sheet at the ground level without a climber's assistance.

Poster

T S7-P13

Residues of monocrotophos in coconut water and kernel

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Three field experiments were conducted, one each at ARS, Aliyarnagar, ARS, Bhavanisagar, and farmers holding at Cheripalayam village to study the persistence of monocrotophos residues in coconut water and kernel following root feeding of monocrotophos for the management of eriophyid mite. In the Aliyarnagar experiment, monocrotophos root feeding @10 ml and 15 ml/ tree (1:1 v/v with water) was given twice at 60 days intervals to 10 years-old palm in mound system. Residues could not be detected both in coconut water and kernel at the lower dose (10 ml root feeding) upto 60 days following first and second round of application. But at the recommended dose (15 ml/palm as root feeding), residues were detected on 15 and 30 days after first and second application in coconut water (0.0200 - 0.0497 $\mu\text{g/g}$) and kernel (0.197 - 0.2830 $\mu\text{g/g}$). But no detectable residues were found on 45th day after application in coconut water and kernel. In the Bhavanisagar and Cheripalayam experiments, the effective dose of 15 ml monocrotophos + 15 ml water root feeding was administered to 20 -25 year old trees. No detectable amount of residues were found in coconut water and kernel in Cheripalayam experiment, whereas the experiment at Bhavanisagar, the residues were found in coconut water (0.0373 $\mu\text{g/g}$) and kernel (0.0275 $\mu\text{g/g}$) 15 days after application. Hence, considering MRL for related crops as 0.1 $\mu\text{g/g}$, a waiting period of 45 days can be strictly adhered for safe consumption. Two experiments were conducted as spot application of monocrotophos. At ARS, Aliyarnagar, two rounds of monocrotophos at the rate 1.5 and 3.0 ml/l /tree were applied as spray against eriophyid mite. At Vellalur village, one round of monocrotophos @ 5 ml/l/tree was sprayed. In both the places, no residue of monocrotophos could be detected in coconut water as well as in kernel upto 60 days after application.



TECHNICAL SESSION VIII

INTEGRATED DISEASE MANAGEMENT



Lead lecture

TS8- I01

Biopriming of planting materials with PGPR and induced systemic resistance

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Plant surface provides a specialized niche for micro organisms and several organisms are adapted to survive on phyllosphere and rhizosphere. These organisms besides surviving on the surface depending on the host exudates for their energy requirements also helps the host plant by mobilizing vital nutrients and augmenting the defence of the plants against invading pathogens. Among soil organisms intense activity is found in and around rhizosphere of plants because of the presence of the secreted nutrients such as carbohydrates, amino acids and other cellular components present at the growing tip of roots. These root colonizing micro organisms form symbiotic, associative or parasitic relationship with the plants. These organisms have evolved mechanisms to occupy and reside in the specialized niche. These mechanisms are often utilised both for growth enhancement and disease suppression. The host also plays an important role in selecting its own microflora for the rhizosphere similar to the probiotic microflora of human gastrointestinal tract. In addition, there are also endophytes comprising of fungi or bacteria that occur inside the plant tissues without causing any apparent symptoms. The micro fungi that grow asymptotically in healthy plant tissues for all or the most of their life cycle is termed fungal endophytes and have been reported in most plant species. Some of the antagonists of pathogen such as *Trichoderma* spp. also enter the host tissue and live as endophytes. A large number of bacteria are also adapted to reside inside plant tissues as endophytic bacteria. A majority of the bacteria reside in the rhizosphere and gain entry in to the tissues through natural openings. Among the root inhabiting organisms, fluorescent pseudomonads constitute a major successful colonizers followed by bacilli. It was Kloepper and Schroth (1978) who reported that certain root-colonizing bacteria could promote growth in greenhouse and field trials and named the bacteria plant growth-promoting rhizobacteria (PGPR). The enhanced growth is both by mobilizing nutrients and protecting against pathogens. For the plants, the first line of defence against soil borne pathogens is provided by the rhizosphere micro organisms. In order to retain this niche, these organisms have evolved mechanisms to actively colonize the roots and prevent other competitors including pathogens and trigger defence system of the host plant.

Plants have mainly three types of protection against pathogens, namely, non host type of resistance, constitutive and induced defence expressions. In case of non host type of defence, the environment is inhospitable for the pathogens to survive as several layers of resistance are present. In constitutive defence expression, there is the presence of structural barriers and



accumulation of preformed chemicals against pathogens. In the case of induced defence expression, defences are activated after pathogen enters the host by synthesising certain warding of compounds like phytoalexins and pathogenesis related proteins (PR proteins). Such a defence reaction triggered by pathogen is also referred to as systemic acquired resistance (SAR) and they mainly depend upon certain signal molecules. Salicylic acid and its derivatives are involved in pathogen infection and jasmonic acid and ethylene in case of insect pests. There is yet another method of defence described as induced systemic resistance (ISR) brought about by rhizobacteria hence also referred to as rhizobacteria mediated induced systemic resistance (RISR). The major difference between the SAR and ISR is that in case of SAR, the PR proteins are accumulated in the tissues farther away from the site of infection to prevent pathogen invasion. Whereas in case of ISR there is no accumulation of PR proteins but the plants are primed to produce these chemicals when there is an attack. The hypersensitive response and cell death, oxidative processes that limit biotrophic pathogens, generally act to exacerbate disease symptoms induced by necrotrophic organisms. Although pathogenesis-related proteins can be expressed in roots during pathogen challenge, salicylic acid has not been implicated in root-mediated interactions. Jasmonic acid and ethylene have been found to mediate parallel as well as synergistic pathways that confer partial tolerance to necrotrophic pathogens, as well as induced systemic resistance to root and foliar pathogens. It has been demonstrated in *Arabidopsis* that volatile organic compound such as 2, 3 butanediol activate ISR. This signalling pathway is dependent on ethylene independent of SA and JA pathways.

Seed priming is done to break the dormancy and initiate the process of germination. In vegetatively propagated crops, induction of rooting is done by altering physical and physiological conditions. Biopriming with beneficial organisms such as PGPR is done to exploit the beneficial effects of microbes. These mechanisms involve growth promotion and disease suppression. Growth promotion is achieved by producing growth hormones and by increased mobilization of nutrients such as Phosphorus, Potassium and other micro nutrients. Disease suppression is by both reducing the damages caused by pathogens and triggering internal defences (ISR) of host plants. The success depends upon isolation of efficient strains, their multiplication, formulation and effective delivery systems.



Lead lecture

TS8- 102

Exploitation of host plant resistance in the management of coconut root (wilt) disease

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Root (wilt) disease is the most serious and economically important limiting factor affecting production and productivity of coconut in Kerala State and to some extent in the neighbouring states of Tamil Nadu and Karnataka. Though non lethal, it is a debilitating malady which may occur anytime during the life time of the palm. The phytoplasmal etiology of the disease has recently been reconfirmed by molecular technique. As phytoplasmal diseases are not amenable to conventional plant protection measures, exploitation of host plant resistance is the only practical and long standing solution to tackle the disease.

Attempts to identify varieties resistant/tolerant to root (wilt) disease was initiated as early as 1934. Subsequently the coconut germplasm available at CPCRI, Kasaragod was screened at CPCRI, Kayamkulam for resistance to root (wilt) disease. However, the screening trials did not yield positive results. Survey conducted in 'disease hotspots' during 1987-88 revealed the occurrence of isolated disease-free and high yielding West Coast Tall (WCT) palms in the midst of disease affected coconut palms. Chowghat Green Dwarf (CGD) palms which are fever in distribution in 'hotspots' were also found relatively resistant to root (wilt) disease with only 25% disease incidence as against 85-90% in the case of WCT.

A comprehensive breeding programme to develop a root (wilt) resistant/ tolerant variety was initiated during 1989 involving the disease-free WCT and CGD mother palms located in disease hotspots. The following cross combinations *ie.*, WCT (*Inter se*), WCT (Self), WCT (Mixed Pollen), WCT (Open Pollinated) and CGD x WCT were planted since 1991 at CPCRI Regional Station, Kayamkulam for screening against root (wilt) disease. The CGD x WCT hybrid flowered 3 to 4 years after planting and started expressing disease symptoms by 7 to 8 years after planting. Evaluation of CGD x WCT for the past 18 years revealed that in spite of 68% of the hybrid palms contracting the disease it gave a ten cumulative average yield of 84 nuts/palm/year. Considering its yield performance and early flowering habit, CGD x WCT hybrid was recommended for release as 'Kalpa Sankara' during the AICRP (Palms) workshop held in 2009. Kalpa Sankara is the first coconut hybrid recommended for cultivation in the root (wilt) disease prevalent tract. The WCT x WCT progenies planted since 1994 started flowering during 2001 and the percentage of root (wilt) disease incidence ranged from 55-60%. The disease-free and high yielding S_1 progenies have been identified after fifteen years of evaluation and selfing/*inter se* mating of S_1 progenies have been initiated with a view to upgrade the level of resistance in the next generation.

Taking into consideration the low incidence of disease in CGD, this variety was recommended



for release during 2009 as 'Kalpasree' for cultivation in the homesteads of disease endemic areas. Based on the data collected from five dwarf cultivars planted at CDB Farm, Neriamangalam, a selection from Malayan Green Dwarf (MGD) was found relatively resistant to root (wilt) disease and subsequently the same was released during 2007 as an ideal planting material for the root (wilt) affected areas in the name 'Kalparaksha'.

Lead lecture

TS8- I03

Integrated management of fungal diseases of coconut in India

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Coconut cultivation runs the risk of being affected by various diseases in many parts of the world. The palm is susceptible to a number of diseases and pests. Some of them are fatal while others reduce its vigour and finally resulting in economic loss. It has been reported that 830 insects and mites, 173 fungi and 38 nematodes are associated with coconut. But only a few of them cause any serious damage to the crop. Among the fungal diseases affecting coconut palm in India, bud rot, leaf rot, stem bleeding and basal stem rot are the major problems owing to the nature of disease and extent of damage.

Bud rot of coconut was first reported in 1906 by E.J. Butler. The disease occurs commonly in West and East Coasts of India. *Phytophthora palmivora* is the causal organism of bud rot disease of coconut. Recently wide spread and severe incidences of the disease have been noticed in endemic areas of Kasaragod, Kannur, Kozhikode and Wayanad districts of Kerala state.

The primary visible symptom of bud rot is the withering of the spindle. On dissecting such affected trees, rotting of internal tissues could be observed. The affected spindle can easily be pulled out. The inner leaves also fall away one by one, leaving only fully matured leaves in the crown. The rotting tissue emits a foul smell. The palm ultimately succumbs to the disease. When the disease is diagnosed in the early stages, curative measures can save the palm. The appropriate period would be the stage when the spindle has just started showing symptoms of withering. The on-going large scale field trial indicates that placing mancozeb sachets in the innermost leaf axils around the spindle leaf is a better prophylactic method of disease control. Cut and removal of palms which are in the advanced stage of bud rot or palms died due to the disease are very important operations to be carried out in all affected gardens for better management of the disease.

Leaf rot, caused by fungi mainly *Exserohilum rostratum* and *Colletotrichum gloeosporioides*, occurs superimposed on root (wilt) affected palms. Leaf rot causes drastic reduction in photosynthetic area, which in turn causes reduction in yield. Hexaconazole and mancozeb were found to be very effective in leaf rot management. Recent studies on disease management with



Pseudomonas fluorescens and *Bacillus subtilis* have given promising results. The integration of leaf rot management with insect pests and general cultivation practices is very effective in improving the health of the palms and thereby increasing the yield.

Stem bleeding disease is known to occur in all coconut growing regions in the tropics. In the early stages of the disease, there is not much yield loss. However, in late stages, there is a steady yield decline causing considerable loss and in advanced stages even death of affected palms occurs. A dark reddish brown liquid exudes from the longitudinal growth cracks present on the stem bark and form irregular streaks of exudation. These streaks may coalesce and form larger lesions. No oozing is seen from old lesions. The exudates eventually dry up to form black encrustations. The tissues beneath the discoloured patch show decay. The outer whorl of leaves becomes yellow rather prematurely, droops and finally dries up.

Thielaviopsis paradoxa (de Seynes) von Hohnel is the causal organism of the disease. The perithecial stage (*Ceratocystis paradoxa* (Dade) Moreau) has also been recorded from the affected palms. In advanced stages of the disease, infestation with *Diocalandra* weevil can be seen which quickens the deterioration of the palms. Recently, very effective management practices have been developed. The disease can be effectively managed if control measures are adopted in early stages of infection.

Basal stem rot/ Ganoderma Wilt is a serious problem in Tamil Nadu, Andhra Pradesh and some parts of Karnataka. *G. applanatum* and *G. lucidum* were isolated from roots irrespective of the extent of bleeding symptom. The pathogenicity of *G. lucidum* has been established by inoculating the fungus in the trunk region. Five distinct stages of symptom development can be recognized in the development of Ganoderma wilt. Yellowing of the leaves of the lowest leaf whorl and decay and death of fine roots are the symptoms in the initial stage of disease development. In the second stage, bleeding patches appear at the base of the stem near the ground level; the lesions gradually extend upwards; roots decay extensively and there is no new bunch production. Bleeding patches extend in the stem, leaves droop in the outer whorl followed by heavy button shedding and barren nuts. As stem decay traverses upwards; outer leaf whorl dries and drops off; other leaves also droop except the spindle leaf and surrounding two or three young leaves which remain erect and healthy. Ultimately all the leaves droop and fall off leaving the decapitated stem. The disease can be effectively contained by following an integrated approach with cultural, chemical and biological methods.

Immature nut fall in coconut has been attributed to several factors. Severe incidence of immature nut fall due to rotting of mite infested nuts has been observed in the coconut growing areas of India especially in the Southern states. Rotting starts from the point of mite infestation on the nut surface near the perianth as dark brown to black discoloration and gradually extends to the entire surface area. *Lassiodiploida theobromae* is the main causal organism of rotting and immature nut fall of mite infested nuts. Rotting and immature nut fall caused by *L. theobromae* can be controlled by spraying carbendazim (Bavistin 0.1%) to bunches of the affected palms. If coconut is cultivated under the organic farming system, spraying of garlic bulb extract (10%) can be recommended for the management of the disease.

The profitability and sustainability of coconut production can be enhanced by the adoption of



integrated disease management strategies. IDM includes selection of disease-free planting materials, field and plant sanitation, weed management, integrated nutrient management through application of compost or other organic manures along with the recommended dose of chemical fertilizers, bio-control of pathogens etc.

Oral
TS8- 01

Detection of Weligama coconut leaf wilt disease in Sri Lanka by polymerase chain reaction

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A sudden outbreak of a rapidly spreading non-lethal disease condition in coconut palms was reported in the Southern part of Sri Lanka in 2006. This disease condition was named as Weligama Coconut Leaf Wilt Disease (WCLWD) as it was first reported in the Weligama area. The striking symptoms of the disease are flattening and downward bending of leaflets (flaccidity), marginal necrosis of leaflets and intense yellowing. As the disease progresses the crown becomes smaller, trunk begins to taper and the palm becomes unproductive. DNA extracted from spear leaves subjected to Nested PCR with universal phytoplasma specific primers; R16F2n/R16R2 and R16mF2/R16R2 nested with rU3/fU5; and P1/P7 nested with Chrfor/rU3, gave PCR products of expected sizes (880bp and 350bp, respectively) consistently from diseased palms. The sequences generated on the PCR products (EU635503 & GQ121047) blasted in the NCBI database reveal that a phytoplasma belonging to the 16SrXI 'Ca. *Phytoplasma oryzae*' group appears to be associated with WCLWD, based on its 16S rRNA sequence (acc. No EU635503). This group of phytoplasmas is commonly found in sugarcane, and the WCLWD phytoplasma was found to be highly similar to sugarcane white leaf phytoplasma (99%) and sugarcane grassy shoot phytoplasma (99%). In addition, primer pair Pc399 and P1694 also gave positive results in a direct PCR approach producing PCR products of expected size (1290bp) from diseased palms. Two 16SrXI group specific primer pairs were designed on the WCLWD phytoplasma sequences; NGS for 1, NGS rev 1 which amplify a 440bp PCR product & NGS for 2, NGS rev 2 which amplify a 370 PCR product for the improved detection of the WCLWD phytoplasma. With these newly designed primer pairs we were able to increase the sensitivity of detection. This is the first report of a phytoplasma disease associated with coconut in Sri Lanka.



Oral

TS8- 02

Mass production and use of biocontrol agents in the integrated management of coconut leaf rot disease - technology popularization through participatory programmes in disease affected regions

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Coconut is an important social crop of livelihood concern for millions of medium-small farmers. Leaf rot disease in association with root (wilt) is a major threat to coconut in southern districts of Kerala, Tamil Nadu etc. CPCRI has evolved biological control technology for integrated management of leaf rot for improving the health of disease affected palms. Application of biocontrol agents in disease affected areas was aimed at creation of widespread awareness on eco-friendly disease management, crop sustenance and in realizing human resource potential. Effective strains of biocontrol agents - *Bacillus subtilis*, *Pseudomonas fluorescens* and *Trichoderma viride* were evolved, their multiplications in media including coconut water standardized and the antagonists' processed into bioformulations (totally 2000 kg. talc formulations evolved distributed/utilized). Coconut gardens and rural groups in various districts of southern Kerala (Thiruvananthapuram, Kollam, Alappuzha, Pathanamthitta, Kottayam, Idukki, Ernakulam and Thrissur), various blocks in Theni district, besides specified blocks in Dindigul district of Tamil Nadu were selected. Through effective contacts with extension-developmental agencies, coconut R&D meetings etc. reached out to rural people and implemented the technology of mass production-use of antagonists, and imparted knowledge to rural people. Conducted trainings and allied programmes by on-campus trainings (396 beneficiaries), off-campus trainings (1854 beneficiaries), household/field contacts of rural people (689 beneficiaries) and other awareness programmes encompassing lectures, interfaces, field schools (661 beneficiaries) and enlightened women, rural people, youths representing various locations (totally 3600 beneficiaries in three years). Field demonstrations of disease management with biocontrol agents in coconut gardens (55 units) besides clusters-compact gardens (1850 coconut palms) were also done besides developing promotional materials to various stakeholders. An innovative participatory programme implementation approach for technology transfer was the outcome of the work. Creation of widespread awareness, percolation of knowledge on biocontrol agents to women and other rural people could be visualized that would go a long way in managing the disease.



Oral
TS8 -03

Epidemiological and pathological studies on Weligama coconut leaf wilt disease

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Weligama coconut leaf wilt disease (WCLWD), a phytoplasma disease was first noticed in Weligama area of the Matara district of southern Sri Lanka in the latter part of 2006. The symptoms associated with affected palms resemble that of Kerala wilt disease; flattening and downward bending of leaflets, yellowing of leaflets of lower whorl of fronds followed by drying starting from tips and margins. The disease patches occurred in jumps of few kilometers apart and there were continuous fronts in some cases.

One experiment was formulated in two hectares of land area to understand the spreading pattern of WCLWD and the sequence of symptom development. Symptom development in each palm was monitored at six monthly intervals. In the second experiment five lands in the mildly affected area were selected and seed-hole maps were drawn. Affected palms were removed at half yearly intervals to identify the effect of removal on fresh incidence of WCLWD. In the third experiment another four sites were selected and affected palms were categorized according to their disease severity stage as apparently healthy, mild, moderate, and severe leaf rot, to evaluate the impact of the disease severity on the yield of affected palms. The total number of nuts and button scars in each bunch was counted and each bunch was tagged according to their age. Newly formed bunches were tagged and nuts were counted at three monthly intervals. The affected palms showed a clustered distribution pattern in selected lands and the flaccidity symptom was less prominent in many severely affected palms. Yellowing symptom started as tiny spots, translucent blotches or elongated patches. Yellow colouration in leaflets was orangish-yellow in palms with reddish or brown coloured nuts than green colour forms. WCLWD affected palms showed 40% - 60% yield loss with the advancement of the disease. Removal of affected palms initially reduced new incidence of disease by 0-7.5% but in the second year fresh incidence was higher 1.7-12.5% in two estates. Spread of disease was observed only in particular lands where affected palms had already been removed, while no fresh incidence was detected in unaffected adjacent lands.



Oral
TS8 -04

Comparison of superoxide dismutase, succinic dehydrogenase, exochitinase and 1,4- β -glucanase activities between healthy and root (wilt) disease affected palms of two coconut cultivars

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Activities of four enzymes - Superoxide dismutase (SOD), Succinic dehydrogenase (SucDH), Exochitinase (Cht) and 1,4- α -Glucanase (Gluc) - were studied for assessing their diagnostic potential, if any, in detection of, or their role in imparting resistance against root (wilt) disease (RWD). The enzymes were determined in spindle leaf of healthy and RWD adult palms using disease tolerant Chowghat Green Dwarf (CGD) and susceptible West Coast Tall (WCT) coconut cultivars. SOD, SucDH and Cht activities, their specific activities and soluble protein contents of SOD and SucDH enzyme extracts were similar in both healthy and RWD palms, irrespective of the cultivar. Soluble protein content in the chitinase enzyme extract was significantly lesser at advanced stage of RWD as compared to healthy or early diseased stage, in CGD palms whereas no such differences were seen in WCT palms. Glucanase activity and its specific activity were significantly higher in advanced stage of RWD in CGD palms as compared to healthy palms but no such difference was observed in case of soluble protein content in this enzyme extract. In WCT palms, glucanase activity, its specific activity and soluble protein content in this enzyme extract were similar in both healthy and diseased palms. Mean SOD activity and soluble protein content in this enzyme extract as well as SucDH activity and its specific activity and soluble protein content in this enzyme extract were significantly higher in CGD palms as compared to WCT palms but the reverse was true in case of SOD specific activity. Chitinase and glucanase activities, their specific activities and the soluble protein contents in these enzyme extracts were similar in both CGD and WCT palms. The study pointed out certain variations in four enzymes, but these variations did not offer either distinct diagnostic potential or role in imparting resistance against the disease.



Oral
TS8-05

Evaluation of genetic diversity among isolates of *Ganoderma* spp. infecting coconut palms using RAMS and RAPD markers

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Genetic diversity among the 12 isolates of *Ganoderma* spp. collected from infected roots of coconut palms from endemic areas of Andhra Pradesh (5 Isolates) and Karnataka (7 isolates) were determined by using Random amplified microsatellite (RAMS) and random amplified polymorphic DNA (RAPD) techniques. RAPD analysis using 7 random decamer primers (RFu2 & RFu4-RFu10) produced 81 fragments with 100% polymorphism. The genetic similarity among the *Ganoderma* isolates varied from 0 to 75% indicating that they were genetically heterogeneous. The isolates Gwilt1, Gwilt2 and Njl showed maximum genetic similarity among them, whereas the isolates Gl and G13 showed 100% genetic diversity. A total of 52 amplified fragments were produced by four RAMS primers (5'GAC(ACA)₅3', 5'GAC(CAC)₅3', 5'GAG(CGA)₅3' & 5'ATCGTGTGTGTGTG3') among the isolates with 100% polymorphism indicating existence of microsatellite motifs abundantly in the genome of *Ganoderma* isolates. All RAMS primers produced specific bands to various isolates and the genetic similarity among the 12 *Ganoderma* isolates varied from 0 to 72%. Dendrograms from cluster analysis based on UPGMA of RAPD and RAMS data showed that the isolates Gl and Ga1 were different from other isolates and grouped separately. The high degree of genetic variation could be due to the different geographical location from which the isolates were obtained or it could indicate that the isolates may have originated from same species with a wide genetic base or from closely related species.

Poster
TS8-P01

The degree of resistance of various coconut varieties to the lethal yellowing diseases in Nigeria

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Observation on degree of tolerance/resistance on percentage survival basis among coconut palm varieties in a 10 hectare plantation, over 15 years of cyclic LYD infection under natural condition was conducted. The study showed that in the first five years of infection, tolerance/resistance levels ranged from 92.6% in the West African Tall (WAT) to 100% in the Green Dwarf (GD). The degree of resistance of the Malayan Yellow Dwarf (MYD) (78.2% and



49.6%) was better than that of the Malayan Orange Dwarf (MOD) (77% and 44.3%) between the 7th and 9th year of infection. However, between the 11th and 15th year of infection, the resistance of the MYD came down from (11.1% and 5.6%) to half the value of the resistance of the MOD (17.7% and 10.6%). It is noteworthy that the WAT resistance came down from 92.6% in the 5th year to 0.6% in the 15th year while that of the Green Dwarf (GD) came down from 100% in the 5th year to 82.1% in the 15th year. Interestingly, the tolerance level of the Green Dwarf rose from 68.4% in the 11th year to 82.1% in the 15th year due to good agronomic practices. In conclusion, the WAT is very susceptible to the LYD, more than all the other varieties. However, with good agricultural management, the tolerance or resistance of the Green Dwarf coconut can be further improved, although there may be reduction of tolerance or resistance in the MYD after the 11th year.

Poster
TS8-P02

Effect of *Pseudomonas fluorescens* and *Trichoderma viride* in the management of basal stem rot disease in coconut

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In an effort to find an alternate to the chemical fungicide in the management of basal stem rot disease in coconut caused by the fungus *Ganoderma lucidum*, rhizosphere soil samples of coconut palms were collected from different locations. The soil samples were processed and isolations were made. *Pseudomonas fluorescens* and *Trichoderma viride* colonies were identified and purified using King's B Agar (KBA) and Trichoderma Selective Medium (TSM). Ten isolates each in *Pseudomonas fluorescens* and *Trichoderma viride* were tested for their inhibitory effect against *Ganoderma lucidum* under laboratory conditions. Per cent inhibition in the growth of *Ganoderma lucidum* by *Pseudomonas fluorescens* isolates ranged from 61 to 77. The isolates *P. fluorescens*-A, *P. fluorescens* -T, *P. fluorescens*-P and *P. fluorescens* -Ss caused 66 per cent inhibition on the growth of basal stem rot pathogen. The inhibitory effect of *Trichoderma viride* isolates ranged from 74 per cent to 80 per cent. Five isolates namely *T. viride* -S, *T. viride* -Pt, *T. viride* -Bs, *T. viride* -Bsm and *T. viride* -Ja caused 80 per cent reduction on the growth of *Ganoderma lucidum*, while two isolates viz., *T. viride* -A, and *T. viride* -Ts showed 76 per cent inhibition. The isolates *T. viride* -Vs, *T. viride* -Ac and *T. viride* -Ss provided 74 per cent inhibition over control. Root feeding of culture filtrates of *P. fluorescens* and *T. viride* was found to arrest the further spread of the disease and increased the nut yield. When soil application was combined with root feeding, the effect was more pronounced in terms of yield increase besides increasing the rhizosphere population of both the biocontrol agents.



Poster
TS8-P03

Management of stem bleeding disease in coconut with botanicals

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Stem bleeding disease caused by *Thielaviopsis paradoxa* (de Seynes) von Hohnel is one of the important diseases of coconut (*Cocos nucifera* Linn.) reported from all the coconut growing countries of the world. In Palakkad district of Kerala, India, a field trial was conducted to test the efficacy of certain materials as sealants in controlling coconut stem bleeding disease. This experiment was conducted during 2005-2008 period, in an area of one hectare, in Anakkara village. The infected bark tissues of affected palms were removed and the following materials were applied as a sealant on the chiselled surface. Neem oil (1%), Palmarosa oil (1%), cashew nut shell oil (1%) were tried along with the recommended practice of application of Calixin 5% as fungicidal check, and hot coal tar as control treatment, two times per year. Hot coal tar does not kill the pathogen completely since it can not penetrate the affected inner tissues. Also this treatment is not advisable to palms below the age of 10 years, as it is phytotoxic. Therefore, in the present study, three botanicals which are non phytotoxic and having fungicidal effect were tried. Observations after 4 years of treatment showed 72% inhibition of lesion size and highest nut yield of 80 nuts/palm/year in Calixin 5% treatment and 67% inhibition of lesion size and a nut yield of 72 nuts/palm/year in cashew nut shell oil (1%) treatment. Palmarosa oil (1%) and Neem oil (1%) were less effective as sealants. The results showed that cashew nut shell oil at 1% concentration can be used as an alternative to Calixin treatment.

Poster
TS8-P04

Biological management of basal stem rot disease of coconut

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Coconut is an important oilseed as well as a plantation crop in India, occupying 1.9 million hectares with an annual production of 12141 million nuts. Among the diseases affecting



the coconut palm, basal stem rot (BSR) disease, caused by *Ganoderma lucidum*, is the most devastating one. Towards the biological management, 55 isolates of endophytic bacteria comprising fluorescent *Pseudomonads*, *Bacillus subtilis* were isolated and screened *in vitro* for the inhibition to *G. lucidum* and plant growth promotion. The *Bacillus* strains viz., EPC 5, EPC 8 and *Pseudomonas fluorescens* (Pf1) increased the vigour index (in rice) and exhibited higher inhibition to *Ganoderma* followed by *Trichoderma viride* (Tv1). The extra-cellular diffusible antibiotic was extracted, characterized partially by thin layer chromatography. The results showed many spots throughout the chromatogram after iodine vaporization. The extracellular, methanol soluble, ninhydrin-negative spot showed a Rf value of 0.49. Based on the *in vitro* inhibition and growth promotion, talc based bioconsortia formulation with *P. fluorescens* (Pf1), *Bacillus subtilis* (EPC5) and *Trichoderma viride* (Tv1) has been developed for the management of BSR disease in coconut. Field trials were conducted at two different locations to test verify the efficacy of bioconsortia under field conditions of disease endemic area. The observations on the initial and final disease severity were recorded from both the field trials at different time intervals. The results revealed that the soil application of bioconsortia @ 300 g with 5 kg farm yard manure per palm at three months interval resulted in significant suppression of BSR disease with significant increase in nut yield of both the trials.

Poster

TS8-P05

Survival of basal stem rot resistant coconut genotype in hot spot location of Karaikal Dt., Puducherry

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Basal stem rot (BSR) or Thanjavur wilt disease of coconut caused by *Ganoderma lucidum* is a lethal disease limiting coconut production in the U.T. of Puducherry and other coconut growing states in the country. This disease was first noticed in Thanjavur district of Tamil Nadu following the cyclones of 1952. The pathogen is a soil-borne fungus causing significant damage to the palms. The visible symptoms of the disease can be noticed only after the invasion of the pathogen in the roots and stem. Exudation of reddish brown, viscous fluid from the basal portions of the stem, which gradually extends upwards, severe root rotting, decay and discolouration of internal tissues of the stem, drooping of leaves and death of the palm are the characteristic symptoms of the disease. Though various integrated disease management practices including cultural, chemical and biological methods are available, they cannot offer complete control of the disease. Treatment of diseased palms with fungicides does not offer a permanent cure to the affected tree. Hence, developing a disease resistant coconut genotype is highly essential to



manage the disease and to increase the coconut production. A field experiment was laid out in Karaikal District of Union Territory of Puducherry with two genotypes viz., hybrid (RB seedlings) and East coast tall (ECT) to screen them against BSR disease of coconut. Observations revealed that the hybrid RB seedlings registered maximum survival (65 per cent) compared to ECT (34 per cent).

Poster
TS8-P06

Status of coconut diseases in Andaman and Nicobar Islands

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The coconut palm (*Cocos nucifera* L.) is one of the important and useful plantation crops in the world. In India, coconut plays an important role in the socio economic and cultural activities of people. Andaman and Nicobar Island archipelago system is known for its coconut production with minimal area for cultivation and coconut is regarded as a remunerative crop of the Island. In 2008-2009, productivity and production of the Bay Islands was 81.90 million nuts and 3776 nuts per hectare, respectively. Though the agro bio diversity of coconut is unique in these Islands but the production and productivity is very poor and stagnating since last two decades. The causes attributed to the low production are poor genetic makeup of plantations, uncertified seedling populations of existing plantation, overcrowding/dense planting (400-500 palms/ha), planting on hill slopes having shallow/eroded soil, inadequate plant protection measures, inadequate soil and nutrient management, no irrigation during dry spell, inadequate knowledge and poor adoption of technologies. Out of which very little work have done to diagnose diseases and the loss causing potential of different diseases occurring in these Islands. Medium to high incidence of grey leaf blight, *Ganoderma* wilt, stem bleeding and bud rot have been recorded during post-*Tsunami* in Andaman and Nicobar Islands. Though, only two diseases ie, stem bleeding and grey blight is so far reported from these Islands, grey blight incidence is so high during dry season that it accounts for 90% incidence of the plantations; nevertheless Central Agricultural Research Institute, Port Blair has advised farmers during the month of March and the preceding rainy season to be aware of bud rot incidence.



Poster
TS8-P07

Current status of the Weligama coconut leaf wilt disease in Sri Lanka

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Weligama Coconut Leaf Wilt Disease (WCLWD) was first reported from Weligama area in Matara District in late 2006. Over the time, the disease has gradually spread to adjoining areas and now present in all coconut growing areas in Matara District and some coconut areas in Galle and Hambantota Districts covering an area of approximately 4000 ha. The initial symptoms of the disease is flattening and bending of leaflets (flaccidity), which is very difficult to distinguish from a normal palm. Yellowing of leaves and extensive root rot manifests as the infection progresses. So far farmers have reported 30 - 40% yield reduction from affected palms. The worst consequence of WCLWD is predisposing of the palm to the fungal infection that causes the leaf rot disease leading to death of the palm in a few months. CRI determined the casual agent of the disease as a phytoplasma by molecular methods (PCR method) in November 2007. The sequence of the phytoplasma DNA was identified by a molecular laboratory in Korea. WCLWD is much similar to Kerala Wilt Disease (KWD) in its manifestation. Coconut Research Institute in collaboration with the Coconut Cultivation Board maintains a disease free buffer zone to prevent the disease spreading to other areas of the country to curb the WCLWD threat. As a long term measure collective decision has been taken to uproot affected palms in these areas and to introduce crop diversification programme, until such time that a resistant cultivar for WCLWD is developed.

Poster
TS8- P08

Evaluation of spatial and seasonal variation of phytoplasma associated with coconut root (wilt) disease through polymerase chain reaction

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Coconut root (wilt) disease causes extensive damage to coconut plantations. The microscopic, molecular and serological evidence reveals phytoplasma as a pathogen associated with root (wilt) disease. The success in the molecular diagnosis of phytoplasma depends on sampling the correct tissues and time of sampling. As there is a variation in the



distribution of phytoplasma in coconut palm and the titer depends upon the season, there is a need to standardize the tissue to be used for sampling and also the time of sampling. The objective of the present study is to analyze the spatial and seasonal variation of the phytoplasma from root (wilt) diseased coconut palm through polymerase chain reaction (PCR). The DNA from root (wilt) coconut palms was extracted through phytoplasma enrichment protocol. The specific primers designed for root (wilt) phytoplasma, the primer pair 1F7/7R3 and nested primer pair 1F7/7R2 were used to amplify 16SrDNA. The amplified DNA was cloned and sequenced. DNA was extracted from four tissues (spindle leaf, mature leaf, inflorescence and root) from 13 palms during the month of November, December (2008) and June 2009. The PCR was repeated thrice. Sugar cane sample was taken as positive control and water was taken as negative control. The study revealed that the PCR amplification is higher when tissues were sampled during December month. In tissue wise analysis, DNA from spindle and mature leaf samples showed more positive amplification than root and inflorescence samples. However, the DNA extraction from mature leaf was much difficult when compared to spindle leaves. This study showed that spindle leaves are the most suitable sample for diagnosis of root (wilt) coconut phytoplasma through PCR.

Poster

TS08- P09

Stem bleeding of coconut in Assam: Incidence and management

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The commercial cultivation of coconut in North East India is a recent trend. Among the seven North Eastern States, coconut is widely grown in Assam and Tripura. Further, in neighboring states like Nagaland, Manipur and Arunachal Pradesh, coconut is now introduced on a commercial scale. Among the main hindrances to coconut production due to diseases, stem bleeding is most destructive, causing severe loss to the production and economy. Survey carried out in five different districts of Assam revealed that the incidence of stem bleeding varied from 2.01% to 15.00%. High water table and high relative humidity prevalent in Assam favours the development of the disease. Moreover, the disease spreads consistently owing to lack of proper awareness and phyto-sanitation practices. Due to hazardous nature and high cost of fungicides and development of resistant strain of fungi; management of the disease through bio-agents and botanicals plays an important role. Accordingly, an experiment was undertaken with three different bio-agents (*Trichoderma harzianum*, *T. viride*, *T. virens*) and 50 locally available botanicals (aqueous extracts) under *in vitro* condition against *Thielaviopsis paradoxa*, causal organism of the stem bleeding of coconut, in CPCRI, Research Centre, Kahikuchi, Guwahati. Results revealed that among the bio-agents, *Trichoderma viride* was most effective in inhibiting



(61.54% inhibition over control) mycelial growth of the fungus followed by *T. harzianum* and *T. vires*. Among the botanicals, the aqueous extract of garlic (*Allium sativum*) showed complete inhibition of mycelial growth after 120 hours of incubation. The above study will help for better management of the disease to an economic threshold level and can be used as a component in Integrated Disease Management Practices.

Poster

TS08 -P10

***Phytophthora* foot rot (*Phytophthora capsici* Leonian.) of black pepper management through fungi toxicant and consortium in Western Ghats of Karnataka**

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Black pepper (*Piper nigrum* L.), high valued spice and widely used in ayurvedic preparations, has been under cultivation traditionally in arecanut and coconut mixed cropping systems since long time in Western Ghats of Karnataka. During monsoon and post monsoon, the crop is severely infected by *Phytophthora* foot rot (*Phytophthora capsici* Leonian.) at Sirsi, Uttara Kannada, Karnataka. Soil borne pathogen causes infection to leaves, stem, collar, root, inflorescence, berries and the mortality of the vines ranges from 34-65 per cent, resulting in huge monetary loss of more than 46 per cent to farmers. The disease can be managed effectively by application of Potassium phosphonate (@ 0.3 per cent) as spraying (@ 2 l/vine) and drenching (3 l/vine) and bioagent *Trichoderma harzianum* (MTCC 5179) (50 g with one kg of neem cake) as soil application, during first week of June and third week of August, to the root zone. With this treatment the Black pepper vines recorded least leaf infection (12.00 PDI), least yellowing (11.33 PDI), least defoliation (9.33 PDI) and least death of vines (8%). However, 1% Bordeaux mixture as spray (@ 2 l/vine) and copper oxychloride (0.1% a.i.) drenching twice during June and August 2008 was also effective in checking the disease with less leaf infection (16.00 PDI), less yellowing (14.00 PDI), less defoliation (12.00 PDI) and less death of vines (14 %). However, bioagents application i.e., Consortium of bacteria @ 10⁸ cfu/g (for growth, nematode and *Phytophthora* suppression -IISR-6 & IISR 859) as spray (@ 2 l/vine) and drenching (@ 3 l/vine) and *Trichoderma harzianum* (MTCC 5179) 50 g with one kg of neem cake as soil application around the root zone of the vine twice (June and August) also significantly reduced the disease with respect to less leaf infection, less yellowing, less defoliation and less death of vines.



Poster

TS08- P11

Management of rhizome rot complex of ginger (*Zingiber officinale* Rosc.) in Uttara Kannada district of Western Ghats of Karnataka

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Ginger (*Zingiber officinale* Rosc.), medicinally important, annual spice crop of high demand is under huge loss (more than 60 per cent) by soil borne fungal cum bacterial pathogen associated rhizome rot complex. Integrated field level management was done with nine treatments, each replicated thrice in a field dimensions of three sq.mt. Rhizome rot was least (4.33%) in 30 minute pre-sowing seed rhizome treatment with 0.05% streptocycline + 0.02% copper oxychloride (T1) followed by soil drenching with 0.2% bleaching powder + 0.1% Metalaxyl MZ at 20 days interval of disease inception. The treatment with pre-sowing rhizome treatment with 0.6% Metalaxyl MZ + soil drench with 0.3% copper oxychloride suppressed the rot complex to an extent 92%. The average plot yield was 6.69kg/3m² (13.65t/ha). The effect of Treatment (T1+ soil drenching with 0.2% bleaching powder alone) was on par with the above treatment though it showed a suppression of 90%. But, the other treatments, usage of bioagents or organic amendments or FYM in combinations were found to show no significant effect in suppressing the pathogens. However, unprotected rhizome and bed recorded the highest disease incidence (55.00%) with least average plot yield of 3.40 kg/3m² and projected yield of 6.94 t/ha.



TECHNICAL SESSION IX

POST HARVEST TECHNOLOGY AND VALUE ADDITION



Lead lecture

TS9 -101

Status and challenges of post harvest processing and value addition in coconut

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Coconut occupies a prominent place among the plantation crops grown in India. It is an important food and oilseed crop grown and India is the third largest country after Philippines and Indonesia in the production of coconuts. The Indian consumption pattern indicates that 56% of the produce is utilized for domestic and religious purposes, 35% for coconut oil production, 7% for making edible copra and 2% for manufacturing desiccated coconut and other products. The kernel of the mature coconut is the most valuable product which is used for edible and non-edible purposes. The dried kernel, known as copra is the richest source of vegetable oil. Coconut water has a substantial amount (3%) of sugar that makes it suitable for fermentation. Products like coconut vinegar, Nata-de-coco can be made from coconut water. Coconut oil cake is a valuable feed for the livestock and source of vegetable protein. The shell is used for making handicrafts, ice cream cups and other commercial products like shell powder, shell charcoal and activated carbon. The husk yields fibre which is converted into coir and coir products. The coir pith obtained from the defibring process serves as an ideal soil conditioner and soil amendment for all types of soils. However, the coconut based economy, today continues to be unstable, being wholly dependent on the fluctuating price trend of a single product i.e. coconut oil. It therefore becomes highly essential to open new avenues by means of diversified coconut products and by-product utilization. Technologies are available for commercial production of desiccated coconut powder, coconut chips, coconut milk powder and coconut cream. Promoting integrated coconut processing complex with modern technologies for manufacture of spectrum of coconut products like coconut chips, coconut oil, virgin coconut oil, copra, desiccated coconut, coconut water squash, coconut pickle, coconut vinegar, etc., in the vicinity of coconut clusters is very much essential for the overall growth of the coconut processing industry. Establishing tender nut parlours with snowball tender coconut machine, tender coconut punch and cutter, at selected places across the country will create awareness on tender coconut, which is considered as the next generation health drink. Developing new technologies for evolving new and non-traditional coconut products alone will not sustain the coconut processing industry. Effective market promotion activities are to be organized by way of organizing exhibitions, workshops and trade fairs in order to create consumer awareness and boost the demand of coconut products to keep the wheel of the coconut industry to accelerate fast against the present slow pace of development.



Lead lecture
TS9- 102

Nutritional and medicinal value of virgin coconut oil

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Virgin coconut oil (VCO) is coined as emerging functional food oil. The term 'virgin' comes out from the method of extraction of oil which leads to the retention of more biologically active components. Presently public awareness has increased on the functional food/oil and it is expected that VCO will gain dramatic growth in the market. In contrast to RBD coconut oil, VCO is produced through wet method via coconut milk. As per definition, virgin oils never go through the refining steps and this is the only reason for their better quality. VCO can be prepared by wet extraction, fermentation and enzymatic methods. It has many health benefits such as preventing the oxidation of low density lipoprotein, increasing the antioxidant enzymes, helps in foot crack healing, scar removal and reducing the cholesterol and triglyceride level. Among all the carrier oils, VCO has high potential as carrier oil for aromatherapy. VCO contains phenolic compounds like caffeic acid, *p*-coumaric and ferulic acids. VCO itself contains beneficial natural antioxidants namely tocopherols which can protect the oil against atmospheric oxidation and rancidity. VCO contains more unsaponifiable components like vitamin E and polyphenols than RBD coconut oil, resulting in an increased level of antioxidant enzymes and a reduced lipid peroxide content in both *in vitro* and *in vivo* conditions. VCO and RCO can be differentiated by using P^{31} NMR study, as 1-monoglycerides were higher in VCO (0.04%) than RCO (0.019%) and total sterols are more in VCO (0.096%) as compared to RCO (0.032%) while diglycerides are lower in VCO (1.55%) than RCO (4.10%). Virgin coconut oil is considered as good frying oil as it has relatively high oxidative stability.

Lead lecture
TS9- 103

Recent advances in the development of value added products from coconut

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India is one of the prolific producers of coconut and the cultivation is widespread all across the Western and Eastern coasts and also south interior areas. Coconut is one of the few plantations where every part of the tree has economic use such as nuts, coir, leaves, stem, etc. However, there is inadequacy in the utilization of coconut in terms of value addition. The coir



is being used in the manufacture of geo-textiles, ropes, etc. and the nut shell is being used for the production of activated charcoal and handicrafts. Value added products in terms of food processing from the nuts are largely restricted to cream and dehydrated coconut as such. The recent developments include successful processing of several products i.e. packaged tender coconut water with and without fruit juice/flavours, stabilized mature coconut water with and without fruit juice/flavour, stabilized tender coconut water with suspended kernels, jams from tender pulp and also coconut milk, coconut water/coconut milk based yoghurts, structured coconut, dehydrated coconut chutney, hurdle technology based ready-to-eat coconut chutney, defatted coconut meal based nutritional supplement and compressed bars. Beverages based on coconut milk are also being investigated. The advantages associated with coconut are unique as the pulp and water are potential sources of nutrients inclusive of carbohydrates, short/medium chain fatty acids, and minerals. The phytochemical content with health promoting features includes phenolics and flavonoids apart from iso-citrates.

Defence Food Research Laboratory, Mysore is actively involved in the development of above mentioned value added food products by using various postharvest technologies. The stabilization of mature/tender coconut water is based on restricted thermal process with the aid of bio/approved preservatives depending on the magnitude of thermal process required without adversely affecting the flavour profiles. Concepts of hurdle processing were incorporated to minimize the use of preservatives and thermal processing. Jam making from coconut requires inputs for proper setting by means of addition of hydrocolloids and the fat oxidation shall be taken care of by incorporation of approved antioxidants. Structured coconut pulp makes use of appropriate gelling agents and acidulants and the process is controlled by means of regulated release of calcium ions under appropriate pH conditions. Ready-to-eat coconut chutney is based on hurdle processing and the hurdles involved are water activity regulation, acidification and in-pack pasteurization. Dehydrated coconut chutney is an instant product and highly useful for various target consumers. Coconut meal after the extraction of virgin coconut oil can be used for the manufacture of several value added products. A nutritional supplement and compressed bar were developed which are wholesome with adequately energy dense profile. These products are suitable for a variety of activities such as child feeding programmes. All the products mentioned above are adequately shelf stable to an extent of 3-6 months under ambient conditions. Coconut products will get more popular with growing awareness among the consumers and certain misconceptions with regards to the belief that the products may cause cardiovascular problems need to be further addressed. Fatty acids such as lauric and capric acids are health promoting and the same needs to be popularized amongst the consumers.



Oral
TS9-01

Development and performance evaluation of virgin coconut oil cooker

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Virgin Coconut Oil (VCO) is the highly priced purest form of coconut oil obtained from fresh, mature coconut endosperm by mechanical or natural means, with or without applying heat, but without chemical refining, bleaching or deodorizing. This oil retains the characteristic scent and taste of coconut and is suitable for human consumption without any further processing. One of the different processes involved in VCO production is the hot process wherein the coconut milk is heated to produce coconut oil. A VCO cooker with a capacity of 125 l per batch has been designed and fabricated for the purpose. VCO cooker is a double walled stainless steel container, which is open in top, with a diameter of 98 cm and a height of 38 cm. Thermic fluid is filled in between the outer and inner walls of the cooker at the bottom and the coconut milk in the cooker gets heated up by heating the thermic fluid at bottom of the cooker. The VCO cooker was found suitable for preparation of VCO by hot process class A and class B VCO can be produced. The class A virgin coconut oil is water clear having the aroma of steamed coconut. Class B oil is slightly brownish in colour and can be used for external applications. In the present study, fresh and matured coconut was grated and the milk was extracted from the grated coconut using a coconut grating machine and a semi hydraulic milk extractor, respectively. Coconut milk is an emulsion of oil and water that is stabilized by protein. To recover the oil from coconut milk, the protein bond has to be broken either by heat or by enzymes or some other mechanical means. In the present study, the extracted coconut milk was allowed to stand for maximum 3 h so that the cream could be separated from the skim milk. The cream was cooked in the VCO cooker under controlled temperature till class A oil is obtained. The residue was further cooked to produce class B oil. The capacity of the VCO cooker was found to be 125 l and it could produce 18.6 l of virgin coconut in 3 h cooking time.



Oral

TS9- 02

Development of novel machines for coconut fibre extraction and segregation for diversified textile applications - A NAIP intervention

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The year 2010 has been declared as the International Year of Biodiversity. Agricultural Biodiversity supports livelihoods and contributes to resilient agro-ecosystems worldwide. Research in this area should consider newer mechanization to alleviate the drudgery existing in the present system. The use of natural resources like coconut fibre processing and conversion to value added products is an example of coconut biodiversity generating economic benefits, employment opportunities and sustainable livelihood for the farmers. Despite India being the largest producer of coconuts, coconut fibre industry has not changed for the better for so many years. Mainly production of good quality fibre has not been addressed. Under the scope of National Agriculture Innovation Project (NAIP), surveys were conducted to study the existing coconut fibre extraction process. It has been observed that the existing coconut fibre extraction processes are not energy efficient, eco friendly and less productive involving human drudgery. The present paper describes designing of newer generation of fibre extraction and segregation machines. The genesis of this development lies in testing of husk for mechanical properties and using the information appropriately to design effective, energy efficient and ergonomic machines. The new disintegrator machine separates entangled fibre mass with minimum human intervention and fibre breakage. For the first time, the concept of segregation of coconut fibre into different quality grades has been mechanized for producing clean and fine fibres with high outturn. Eventually, the reported developments are expected to enhance productivity and quality generating more rural employment particularly for women's groups with better work environment. Diversified product development and value addition from improved quality of coconut fibre will enhance the synergy with biodiversity.



Oral
TS9-03

Effect of die temperature on properties of cassava and coconut powder extrudates

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Three combinations of cassava and coconut powder (85:15, 90:10 and 95:5) were conditioned to 16% moisture content and extruded. The extrusion experiments were carried out in a single-screw laboratory extruder with a screw diameter of 19 mm, a length/diameter ratio of 25:1, a nominal compression ratio of 2:1 and a die opening of 2 mm (Model: KE 19, Stand alone Extruder, M/S Brabender measuring and control systems, Germany). The temperatures of feed zone, compression zone and metering zone were set at 60°C and 80°C, respectively. The extruder screw speed was fixed at 80 rpm. The temperature of die zone varied from 180 to 200°C.

The volumetric flow rate was highest at 190°C die temperature for 90:10 cassava-coconut powder blend and the mass flow rate was high for 85:15 cassava-coconut powder blend at 180°C die temperature. The expansion ratio was highest for 95:5 cassava-coconut powder blend extruded at 180°C of die temperature. Low bulk density and high porosity were obtained for 90:10 cassava-coconut powder blend extruded at 190°C of die temperature. Low water absorption index and high water solubility index were obtained for 90:10 cassava-coconut powder blended extrudates at 190°C of die temperature. Hardness and toughness were lowest for 90:10 cassava-coconut powder blend extruded at 200°C of die temperature.

The study showed that cassava and coconut blend is a suitable blend for the production of good quality snack food extrudate.

Oral
TS9-04

Scope for the use of coconut shells in high rate anaerobic bioreactors

Joe, L., Bovas, Mary Regina, F., Kamaraj, S. and Shaji James

Anaerobic digestion of organic waste waters has a positive environmental value as it combines energy production with waste water treatment. High rate anaerobic bioreactors incorporating the concept of cell immobilization could surpass the major disadvantage viz., slow operation of anaerobic systems. In fixed film and hybrid systems, a matrix for cell immobilization is used. Scope for utilization of coconut shells in lieu of synthetic material has



been investigated. Preliminary investigations in batch digesters for anaerobic digestion of cassava starch factory effluent revealed that coconut shells are likely to cause an inhibition to the micro-organisms due to the leaching of phenolics. Preliminary treatments can lessen this effect and hydraulic characteristics of high rate reactors can upset this effect. Further investigations has proved that coconut shells are equally good as PVC pall rings for use as matrix for cell immobilization in bioreactors for treatment of cassava starch factory effluent. Preliminary studies on hybrid anaerobic bioreactors for the treatment and energy conversion of rice mill effluent has also given a positive result indicating the scope for utilization of coconut shells in this unconventional sector.

Poster

TS9-P01

Studies on post harvest mycoflora of coconut and its management

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An *in vitro* study on the post harvest mycoflora of coconut was conducted at Coconut Research Station, Aliyarnagar. Unhusked and husked nuts as well as copra were collected from different godowns for isolation of associated mycoflora. Various fungal pathogens viz., *Aspergillus niger*, *Aspergillus flavus*, *Rhizopus* sp. *Penicillium* sp. and *Botryodiplodia* sp. were isolated from the nuts stored at ambient room temperature. Among them, the *A. flavus* was found to be a predominant pathogen. *In vitro* studies on the efficacy of *Trichoderma viride* against the five post harvest pathogens was conducted. The results revealed that the highest percent inhibition in mycelial growth of *A. flavus* (68.54%) and *A. niger* (64.0%) over the respective control. Several chemical preservatives were also evaluated against the predominant pathogen *A. flavus* at 500 ppm concentration. Of which, potassium metabisulphite and benzoic acid were found to be effective against the mycelial growth of *A. flavus* and showed 73.0 and 68.5 per cent inhibition over the control, respectively while the glacial acetic acid was found to be the least effective.



Poster

TS9-P02

Process standardization for production of virgin coconut oil by fermentation method

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Virgin Coconut Oil (VCO) is the oil obtained from fresh, mature endosperm (kernel-meat) of the coconut by mechanical or natural means, with or without use of heat, no chemical refining, bleaching or deodorizing and maintains the natural aroma and nutrients. It is called "virgin" because the oil obtained is pure, raw and pristine. Virgin coconut oil is suitable for human consumption in its natural form. It is the purest form of coconut oil, crystal clear, contains natural vitamin E and with very low, free fatty acid content (0.1%). It has a fresh coconut aroma ranging from mild to intense depending on extraction process. CPCRI has standardized the protocol for production of virgin coconut oil. This paper deals with the procedure of preparation of VCO, its quality and other benefits. Fermentation method comprises three stages of operation; extraction/preparation of coconut milk, fermentation of the milk and separation of the oil. Fully matured nuts of 11-12 months old are selected for VCO production. The shells are removed using a specially designed chisel and testa by using a testa remover machine developed by CPCRI. The coconut meat free from testa is fed to a mechanical grating machine. Alternatively coconut may be grated manually using a coconut grating machine. Coconut milk is extracted from the grated coconut meat using manually operated CPCRI hydraulic coconut milk press. The diluted coconut milk is kept in specially designed fermentation tank for 20 to 24 hours under controlled atmospheric conditions at a temperature of 35°-40°C and RH 75-80%. During fermentation the protein bond is broken and oil is formed along with skim milk and cream in different layers. By carefully separating the distinct layers, the VCO can be separated. Oil recovery is 16-18% of the coconut grating by weight. The fermentation process can be made faster, by adding previously prepared skim milk to the coconut milk at the rate of 30 ml per litre. This not only hastens the fermentation process (16-18 hours) but also result in comparatively high recovery (18-20%) of VCO. The separated oil contains some adhering particles of fermented curd and it needs to be filtered before drying and packing. Under small scale, the oil is filtered through sterilized cotton wool or filter paper or filter cloth placed in the hole of a big funnel and for large-scale operation, a pressure filter with filter cloth is recommended to increase the filtration rate. Storage study was conducted by storing the VCO in PET bottles, HDPE bottles and HDPE amber coloured bottles and it was found that quality parameters such as PV, FFA, TBA and RI were within limits upto a period of 12 months.



Poster

TS9-P03

Drying kinetics of heat pump dried coconut haustorium

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Coconut haustorium or coconut apple is a spongy ball like growth that develops inside the unhusked coconuts when the coconuts are stored for long period in humid climate condition. The coconut haustorium is sweet in taste and is a delicacy. It is rich in nutrition in terms of protein (2.19%), sugars (9.28%) and minerals (0.84%). The haustorium, which is yellowish on the surface but white inside with fibres running longitudinally, is highly perishable in nature due to its high moisture content of 85.8 per cent. Hence, there is a need for its preservation using a suitable post harvest technology for its long term utilization. Drying is one of the most cost effective means of preservation of highly perishable materials. Mechanical drying has the advantages over traditional sun drying in producing a better quality product with less drying time. However, mechanical dryers are not cost effective compared to sun drying as it consumes more energy. In order to reduce the energy consumption, it is necessary to select an efficient heating system. The heat pump dryer is an effective alternative due to its low energy consumption and better quality product. Its advantages include higher energy efficiency due to the high coefficient of performance and better product quality due to their controlled drying condition. Studies were conducted on drying of coconut haustorium so as to get a good quality dried product which can help to diversify the products from coconut and also to produce haustorium powder that can be used in preparation of healthy foods and in the preparation of bakery foods like breads, biscuits etc. Fresh coconut haustorium slices of 10 mm thickness were dried at 50, 55 and 60°C drying temperature using a heat pump dryer. The drying characteristics of coconut haustorium were determined. The time taken for drying haustorium from initial moisture content 85.8% (w.b) to the final moisture content in the range of 10-12% (w.b) took 12, 10.5 and 8 hours for the corresponding temperature of 50, 55 and 60°C, respectively. The high drying rate was observed in heat pump dryer because of the low relative humidity (19-21 %) maintained inside the drying chamber. It was also observed that the colour value 'L value' was more (light color) for heat pump dried haustorium (86.21) when compared to tray dried haustorium (70.21). The colour values of heat pump dried haustorium were on par with the freeze dried haustorium (86.68) and fresh haustorium (88.36). The color values decreased (dark color) when the haustorium was dried at high temperature (60°C) in tray drier. To conclude, heat pump drying resulted in distinctly bright coloured dried product at 60°C drying temperature for 8 hours of drying time.



Poster

TS09- P04

Development of a copra dryer suitable for small scale processing units

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A copra dryer using coconut shell as fuel was designed and developed to dry 500/250 nuts in 24 hours. The drying air temperature in the drying chamber was maintained at 80°C with bed thickness of 30cm for obtaining good quality copra. The quality of copra obtained was light brown in colour. The oil content was in the range of 62.48 to 63.55 % indicating no loss of oil. The microbial studies on stored copra at room temperature by different conventional drying methods indicated higher levels of fungal as well as bacterial population in copra compared to the copra dried in newly developed coconut dryer. Coconut shell is used as fuel for heating using indirect heating method. The fuel tray requires about 80 half shell for producing heat for about six hours. The dryer requires 320 half shell to dry 500 coconuts and 160 shell to dry 250 nuts. The cost of dryer is Rs.21, 000 for 500 nuts capacity and Rs. 15000 for 250 nuts capacity and the cost of drying was worked out to be Rs.0.93/nut.



TECHNICAL SESSION X

**TECHNOLOGY TRANSFER AND IMPACT
OF DEVELOPMENTAL STRATEGIES**



Lead lecture

TS10 -I01

Promoting biodiversity and by-product utilization in coconut for inclusive and sustainable growth

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The integrated development of coconut cultivation and industry coupled with a stable market are the determining factors for the sustainability of coconut economy in general and the rural economy of many states in particular. The climate change and the resultant agrarian distress on account of global warming, opening of the domestic market for global players for market exploitations, acute shortage of labour on account of displacements of agricultural labour for more wage oriented areas like construction, sand mining etc., sudden price crash at the time of peak production season aggrieved with the surge in import of cheap substitutes, epidemic and endemic outbreak of pests and diseases and other biotic and abiotic stress are the major factors responsible for causing considerable damage to these sectors. By adopting appropriate coconut based cropping systems which are socially and economically beneficial and promoting byproduct utilization for value addition are inevitable for achieving inclusive growth and sustainable developments. The growing diminution in the size of operational holdings and the persistence of large number of homestead gardens are the constraints for adopting viable coconut based farming systems and hence become the major reason attributed to the low rate of returns per unit area. The decline in the productivity of coconut holdings due to poor investments, lack of optimum utilization of interspaces, absence of rational use of available natural resources like water and sun light and non-adoption of soil and moisture conservation measures are the prime reasons for the domestic coconut industry becoming unremunerative and not competitive. Promoting biodiversity in coconut farming system, product diversification and byproduct utilization of coconut are therefore the core areas of development for inclusive growth of the industry. To boost farm investment, capital formation and enhance the gross income and productivity of the fragmented holdings across the country, the Coconut Development Board adopted a new strategy involving the consolidation of fragmented and scattered individual holdings to increase the power of economy and subsequently employing the production function tools with the participation of all farmers in the group. The new approach was helpful in determining the level of input use and extend to which production could be increased from the existing natural resource stock including the static plant stocks. The consolidation of holdings to bring in scale of economy proved a thriving agriculture in a coconut based farming system. The interventions of the Coconut Development Board with technology disseminations and financial support has paid rich dividend.



Lead lecture

TS10 -102

Technology delivery mechanism in coconut through Krishi Vigyan Kendras

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Krishi Vigyan Kendras (KVKs) also known as Farm Science Centres are the integral component of the National Agricultural Research System, which aims for development and promotion of location specific technology modules in agriculture and its allied enterprises, through Technology Assessment, Refinement and Demonstrations. At present there are 585 KVKs in the country and 77 in Zone VIII comprising of Karnataka, Kerala, Tamil Nadu, Goa, Puducherry and Lakshadweep.

The major mandate of the KVKs includes Technology Assessment and Refinement through On Farm testing, popularization of technologies through Frontline Demonstrations to prove their production potential. Conducting skill oriented training programmes to farmers and farm women, rural youths and extension personnel mostly focussing the technologies assessed/refined or demonstrated, conducting vocational training programmes for rural youth, popularization of technologies through various extension programmes so as to reach the masses, production and supply of good quality seeds, planting material and other bio-products to the farming community.

Coconut is a major small holder's plantation crop of all the states/Union territories in Zone VIII. Zone VIII has 16.26 lakh ha under coconut including the land of coconuts viz., Kerala and Lakshadweep, and the annual production is 13554.9 million nuts and the average productivity widely varies between 5005 nuts/ha in Goa to 19630 nuts/ha in Lakshadweep and the Zonal average is 10930 nuts/ha.

During 2009-10, under Technology Assessment and Refinement, several technologies under different thematic areas were assessed for finding their location specificity. Some of them includes coconut climbing machine, intercropping in homesteads, Integrated Crop Management in coconut, management of stem bleeding disease in coconut, on farm production of organic manure in coconut, micro nutrient management in coconut using TNAU coconut tonic, management of eriophyid mite and red palm weevil in coconut. In addition other technologies including improving shelf life of coconut based vinegar were also assessed.

During the same period, 155 Frontline Demonstrations were conducted in 55 ha of land in the states of Kerala and Tamil Nadu and in Puducherry on technologies under Integrated Nutrient Management, pest management and crop management. Training programmes on crop production and management, coconut processing, production of input at site were conducted for farmers and farm women, rural youth and extension personnel.

KVKs located in Kerala and Tamil Nadu assist farmers for production and sale of elite planting materials of coconut. They also provide necessary technical advice to the farming community



for production and sale of coconut varieties and hybrids suitable for their region.

KVKs also play a major role in increasing productivity of crops like coconut through large scale adoption of technologies. For example, micronutrient management in coconut using TNAU coconut tonic is a technological intervention from KVK Salem and has made significant change in improving coconut yield in senile and unproductive gardens which were severely affected by micronutrient deficiencies. The success of this technology is also spreading to neighbouring states like Kerala. Similarly low cost vermi-composting technologies using coconut waste and other farm wastes are being popularized by the KVKs through training programmes and Frontline Demonstrations.

Zonal Project Directorate in coordination with the Directorate of Extension, TNAU has developed Expert System for coconut. The major content includes planting season and agro-climatic conditions for coconut in Kerala, Karnataka and Tamil Nadu, coconut varieties and hybrids, nursery management, cultivation practices, technologies on crop management, crop protection and processing. In addition, details on marketing and cost of cultivation are also provided in this expert system.

Lead lecture

TS10- 103

Extension approaches and strategies to enhance technology utilization and income generation in coconut farming

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Coconut plays a vital role in the agrarian economy of many regions in the world, and provides livelihood to millions of families either directly or indirectly. Though large numbers of technologies have been generated for enhancing income from coconut farming, farmers are not able to exploit the production potential from these technologies to the extent desirable. The present scenario of technology adoption in coconut calls for the technology generation and dissemination programmes based on viable extension strategies with the active participation of beneficiaries. On campus/off-campus training programmes for farmers and extension personnel on specific topics related to technologies to improve coconut scenario form an important component of TOT programmes to enhance their knowledge and skill for better technology utilization. Evaluation of training programmes organized for coconut farmers revealed that there was significant gain in knowledge and skill on the topics dealt for the farmers trained. Frontline demonstration of various improved coconut production technologies with the active participation of farmers has proved to be an effective method to transfer of technology for improving the yield and income from coconut farming. Traditional extension methods including utilization of mass media, publication of extension literature, organizing exhibitions, group discussions, farmers' meetings, seminars, etc., are also important in creating awareness and knowledge about improved technologies among coconut growers. The innovative



group management approach in which coconut farmers are organized into Community Based Organizations (CBO) for sustainable income enhancement with the objective of efficient management of farmers resources to reduce cost of cultivation and to increase productivity through integration of technologies in small fragmented farm holdings have been demonstrated by CPCRI under projects sponsored by agencies like NAIP (ICAR), COGENT/IPGRI, IFAD, CDB etc. Development schemes for promoting coconut farming implemented by agencies such as Coconut Development Board also now employ group management approaches. Participatory technology transfer approach (PTT) for technology assessment and Farmer Field Schools (FFS) for IPM were also found to be very effective in technology transfer in coconut. The experiences and impact of organizing the Entrepreneurship Development Programme on value addition in coconut for women under the COGENT-IPGRI project implemented by CPCRI clearly indicated the scope and importance for enhancing the income of resource-poor coconut farmers and socio-economically disadvantaged rural women through product diversification in coconut. Pioneering efforts of CPCRI to organize Research-Extension-Farmer Interface facilitated through Cyber Extension Programmes as an innovative extension approach for coconut development has been found to be very effective. Group video conferencing system facilitate interaction between farmers, extension personnel and entrepreneurs located in various parts of the country and scientists of CPCRI and other research and development organizations for enhancing technology utilization in coconut. Replying to queries from farmers, extension personnel and entrepreneurs through e-mail, CD ROMs as interactive software packages on different technologies, IT enabled kiosk, etc., also strengthen the cyber extension activities of CPCRI for technology transfer in coconut. The innovative extension approaches pilot tested through action research with farmers' participation utilizing information and communication technology, group approach and farmer participation have proved to be effective for technology transfer and capacity building of the farming communities of resource poor coconut growing regions.



Oral

TS10 -01

Diversification for enhancing livelihood security of marginal coconut farmers: Experiences from major coconut growing countries

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Marginal coconut growers from most of the coconut growing countries are striving hard to sustain their families' livelihoods from coconut-derived income. Diverse interventions coupled with maintenance of coconut genetic resources play an important role in sustaining the livelihood and improving the quality of life of the coconut farmers. Sustainable Coconut Based Farming Systems (CBFS) approach integrating diversification of intercrops and allied enterprises as well as effective utilization of all coconut parts including by-products through Community-based Organizations (CBOs) was tested and proved to be highly successful under the IFAD/COGENT/Bioversity Project on Overcoming Poverty in Coconut-Growing Communities: Coconut Genetic Resources for Sustainable Livelihoods. The project assisted in the provision of high quality planting materials and inputs through a micro-credit scheme. In addition, the CBO members were supported through provision of appropriate technologies, village level equipment, and training and capacity building. Effective linkages were established with various agencies for technological support, input supply and credit facilities. The project was implemented in 19 communities of 10 coconut growing countries. Pre and post data related to demographic, socio-economic as well as food security and nutrition aspects of the clients and income from coconut, intercrops, livestock and household level processing were recorded independently in each country, using a standardized questionnaire template during 2005-06 and 2007-08. Data collection was done through personal interview with about 450 CBO members and supplementary data was recorded from the profitability records kept by them. The data was analysed using SPSS. Findings from four major coconut growing countries, which had significant project outcome - India, Philippines, Thailand and Vietnam - are discussed in the present paper. All the four major coconut growing countries recorded a significant difference in total household income before and after the project. Influence of the project in bringing the change in income was statistically worked out by second-stage regression with ordinary least square and found to be positive. Among the four countries, India and Philippines had a significant difference in mean income derived from intercrops, India and Thailand for livestock integration and India and Vietnam for off-farm activities. Herfindahl index for indicating economic diversity of households revealed a significant diversification of income at the global level. A higher level of education and more available land also positively influenced total income. In general, improvements in income



were better with bigger-sized farms and households with male household heads. Significant improvement in food and nutritional security was observed at global level with clearest impacts in India and Philippines due to project efforts. Participation of women in trainings and interventions was the highest in India, followed by Thailand.

Oral
TS10 -02

Trade liberalization, regional trade agreements and commodity crisis: the case of Indian coconut sector

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Analysis of coconut sector in India in the light of recent policy issues, especially the ASEAN free trade agreement was attempted. It was observed that the likely impact of free trade agreement couldn't be undermined for three reasons. Firstly, the present context should be seen as a continuation of evolving trade liberalization regime and the effects of such a regime on the agrarian sector, especially plantation crops sector. Secondly, although coconut and coconut oil is put under the negative list, the tariff reduction in palm kernel oil, which is a close substitute of coconut, would turn up detrimental in the near future. The surging palm oil imports over the recent years are noteworthy and substantiate this argument. Thirdly, the agreement is an evolving one and the tariff rates fixed are ceiling rates (the maximum level to which tariff can be fixed), thus the fixation of tariff is flexible all through the period. Although coconut and coconut oil is in negative (exclusion) list of ASEAN agreement the price wedge between domestic and international coconut oil is very high (though of late it tends to integrate). On the other hand, analysis of coconut oil import on domestic prices revealed that the coconut oil imports do not have much impact on domestic price fluctuations. Moreover the import intensity (import as a percentage of total production) of coconut oil was hovering around 5 percent, which is not a sufficient quantum to have any effect on domestic price fluctuations. Thus, once again it reinforces that the price fluctuations in coconut and coconut oil is very much linked to the trade movements and supply of other edible oils. Having said this, it is important to bear in mind that the FTAs like ASEAN would facilitate the cheap imports in long run (as of now it is in negative list).



Poster

TS10-P01

Women empowerment through coconut based micro enterprises - Reflections from Kerala

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Production and marketing of diversified high-value coconut products from all parts of coconut the kernel, husk, shell, wood, water and leaves; are a potential source of income and employment for the rural women. The documentation of outputs of the COGENT sponsored project on 'Developing sustainable coconut based income generating technologies in poor rural communities' revealed that women members of the Community Based Organisations under the project increased their income by 3-5 times through the production and marketing of coconut high value products. Equally important, this project intervention provided employment opportunities to rural women resulting in enhanced self esteem, and economic and social empowerment. In India, there are many women's self help groups promoted by State Poverty Alleviation Projects, Panchayat Raj Institutions and other agencies involved in managing coconut based micro enterprises. An analysis of such units revealed that micro enterprises on shell charcoal, copra and coconut oil, toilet soap, washing soap, coconut based food products, coir yarn spinning, virgin coconut oil etc. are the major types of enterprises. Kerasree units by the women's self help groups for the production and marketing of coconut oil ranked first with respect to the number of coconut based micro-enterprises. Thrissur District has the maximum number of coconut based micro-enterprises run by the women's self help groups, while Malappuram District has maximum number of members involved. Wayanad and Pathanamthitta Districts did not have any coconut based micro-enterprises units. Majority of the microenterprises were started since 2002. On an average, there were eight members in each of the coconut based microenterprise activity group. Majority of the members belonged to the age group of 35-45 years. About 98 per cent of the members were literate and 40 per cent of them had education up to 10th standard. Kudumbasree, the State Poverty Alleviation Project and SUBICSHA were the important sources of information about the potential of coconut based microenterprises. CPCRI, Coconut Development Board and Kudumbasree were the important agencies that provided training for the women SHGs on coconut based microenterprises. Local self Governments, Kudumbasree project and Coconut Development Board provided subsidies/incentives to the SHGs. Initial investment required for starting the coconut based micro enterprise was highest for virgin coconut oil. Benefits of the units as perceived by the members of SHGs were a) economic empowerment - On an average profit share of Rs 25,000-30000 per year for each member besides wage earnings b) better self- esteem, self confidence and influencing power within the household and c) better social interactions and communication skills. The members of women SHG on production and marketing of minimally processed tender coconuts perceived that lot of drudgery and hence there is a need to develop simple machineries for pressing the heated coconut gratings to reduce drudgery to women involved. Limited role in decision making



with regard to various aspects of enterprise management was another constraint felt by the members of the unit. The success story of SUBICSHA (Sustainable Business Development of Innovative Coconut Based Microenterprises for Holistic Growth and Poverty Alleviation), a special project under SGSY implemented by Perambra block panchayat in Kozhikode District in Kerala State since 2003 stands out. About 26 value added coconut products are being produced and marketed by SUBICSHA. The total sales turnover of the SUBICSHA company for the year 2009 was Rs. 3.2 crores. The women entrepreneurs perceive difficulty in marketing of the products as the most important constraint in running the coconut based micro enterprises.

Poster
TS10-P02

Sustainable coconut farming in Kanyakumari district - a case study

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Coconut farming in Kanyakumari district is not quite profitable, due to inefficient farming practices and socio economic constraints. In a situation where the coconut industries are threatened with recurring uncertainties the need for timely and sustained transfer of technologies and field adoption of the recommended practices that augments the coconut farming as a profitable venture becomes very essential and most urgent. Thus, the KVK made a study to analyse the constraints in coconut farming and provided recommendations to overcome the problems and make the coconut farming as a remunerative one. Initially a survey was conducted in all the nine blocks of the district and the information about the management and socio-economic constraints in coconut farming were collected from the farmers, extension officials and coconut traders through pre-tested questionnaires. Among the management problems, use of poor quality planting material, inefficient resource management practices (space, nutrient, water), and pests and disease viz., red palm weevil, scale insect and Ganoderma wilt and under socio economic problems high labour cost and lack of skilled labour for coconut harvest were considered as serious threat to coconut farming in Kanyakumari district. Based on the severity and need of the problem, technological solutions were provided for coconut based cropping system approach, nutrient and water management and pest and disease management since 2005 through well organized trainings and large scale demonstrations. The impact of the demonstrated technologies were analysed. The impact study revealed that, IPM package, intercropping, *in situ* green manuring and root feeding of TNAU coconut tonic and the coconut harvesting device have gained popularity among the coconut farmers with 30-42% adoption in the District. The KVK interventions rejuvenated coconut farming in Kanyakumari District by enhancing the productivity and profitability.



Poster

TS10-P03

Bio control of rhinoceros beetle in coconut - participatory adaptation of low input multiplication of *Metarhizium* fungus and bridging adoption gap

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Coconut (*Cocos nucifera*) is a major crop in India providing livelihood to lakh of resource poor farmers, occupying an area of 1.9 million hectares with total production and productivity of 14743.56 million nuts and 7747 nuts per hectare respectively. The low productivity is attributed to the fragmented holding restricting scale of economy, incidence of pests and diseases, low level of awareness adoption of recommended practices and fluctuating price of primary product. Rhinoceros beetle is the major pest present in all coconut growing countries and infests all stages of coconut palm i.e., nursery, seedlings, juvenile and adult palms. The pest causes 10 per cent reduction in yield of affected palms. Farmer field schools (FFS) conducted during 2007 for educating farmers on bio control methods indicated that 69.8 per cent of the participants expressed willingness to use *Metarhizium anisopliae* if made available. Moreover data collected in field survey (2008-09) in 1000 ha area covering 2000 palms showed that average infestation by rhinoceros beetle in adult palms were 22.7 per cent (with 36.17 per cent of fronds with symptoms), juvenile palms were 22.74 per cent (29.3 per cent fronds with symptoms) and seedlings were 48.31 per cent (26.1 percent fronds with symptoms) under farmers field conditions. The data also revealed that knowledge on identification of the pest (68.7 per cent) and symptoms (64.05 per cent) were on the higher level whereas the adoption of IPM was very low. Simple and effective measure promoted by CPCRI for the incorporation of *Clerodendron infortunatum* plant in vermicompost pits to avoid rhinoceros beetle breeding was being adopted by 28.9 per cent of the farmers. None of the farmers surveyed had any knowledge on use any bio control agent for managing rhinoceros beetle. The principal constraint was the non availability of bio agent for adoption. Getting farmers to produce the bio agents was rated as better strategy for promoting participation and adoption of bio control among the resource poor farmers. Hence, an action research was taken up with the following objectives.

1. To establish alternative, farmer managed, feasible and low cost multiplication units of *M. anisopliae* fungus for wider adoption.
2. To bridge the gap in awareness and adoption of bio control of rhinoceros beetle among coconut farmers in participatory and gender sensitive approach. The target group was selected based on surveys and meetings held in collaboration with the stakeholders. The sophisticated tools were replaced with readily available materials and media tried with options available locally. The units could produce 30-35 *M. anisopliae* packets and they were used for inoculation of 264 breeding sites with participation of rural women self help group members. Four groups



were entrusted with site inoculation and recording of perceptions on *M. anisopliae* application. The farmers were convinced about the results as they could observe grubs infected within two weeks. The method was rated as women friendly and found to be suited for vermicomposting units without harming earthworms. Farmer to farmer dissemination of knowledge/skill and bioagent could be achieved in this programme. This reduces the time gap in technology uptake, more participation, gender sensible and scalable with low cost and effectiveness.

Poster

TS10-P04

Role of tribal women in agrobiodiversity conservation

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A study on the role of tribal women in agro biodiversity conservation was carried out in the Nilgiris district of Tamil Nadu State with the following objectives: (i) to assess the extent of participation of tribal women in agro biodiversity conservation, (ii) to study the relationship of tribal women characteristics with their participation in agro biodiversity conservation, (iii) to analyze the constraints experienced and the suggestions offered to overcome the same in the conservation of agro biodiversity. A sample of 120 tribal women was selected. Data were collected using a well constructed interview schedule and analysed with suitable statistical techniques. This study reveals the profile of the tribal women, level of participation of tribal women in *in situ* on-farm conservation and *ex situ* conservation. The variables, age, extension agency contact, economic motivation, occupational status, progressiveness and religious belief showed significant association with the participation in *in situ* on-farm conservation. The variables educational status and occupational status showed a positive significant contribution towards participation in *in situ* on-farm conservation. The variables, age, occupational status, conservativeness, progressiveness, traditionalism, religious belief, occupational status and family type had shown significant contribution towards participation in *ex situ* conservation. The major constraints faced by tribal women were technological constraints. Ensuring technical guidance, developing tools and implements which can reduce the drudgery of tribal women and providing inputs at subsidized rate were expressed as the valuable suggestions by most of the respondents to overcome constraints.



Poster

TS10-P05

A constructive model for agrobiodiversity conservation

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Presently, agricultural policies are formulated by the policy makers at the macro level without analysing their relations and consequences on micro level on-farm management and utilization of diverse genetic diversity. Some of the policies relevant to agricultural development formulated at the macro level is only partially being implemented at the grassroots level. Farmers and local communities perceive different policy interpretation as compared to decision-makers in policy making level. Lack of integration of macro-level policy with micro-level issues, users are less aware of policy incentives at the field level, while policy makers are less informed about policy constraints and gaps in the implementation of the programme. Good policy always depends on good information, and this is particularly true for crop genetic resources. A constructive model for conserving agrobiodiversity was developed based on the objectives formulated and findings derived in this study. The investigation was carried out in the Nilgiris district of Tamil Nadu State. This study aimed to document the Indigenous Technical Knowledge (ITK) of tribal women in agrobiodiversity conservation, to assess the extent of participation of tribal women in agrobiodiversity conservation, to analyze the constraints experienced and the suggestions offered to overcome the same in the conservation of agrobiodiversity. Based on the results of the study, a constructive model for conserving agrobiodiversity was developed. This model may serve as a possible basis for applied measures to promote sustainable environmental management and agrobiodiversity conservation practices. In this model very significant critical measures to achieve a biodiverse, productive and self reliant agricultural system were delineated under research and extension system, which comprises government, non-government and private organizations.



Poster

TS10-P06

Establishment of coconut nursery (var. West Coast Tall) in drought prone area of Namakkal district

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The coconut has spread across much of the tropics of Tamil Nadu especially the river belt area of Tamil Nadu which is concentrated with coconut plants. Due to drought condition, non availability of labour, farmers are slowly shifting to cultivate annual or perennial crops even in non river belt areas. Among the perennial crop, coconut is a versatile, promising, economically feasible crop among farmers. Non availability of genuine varieties of coconut seed nuts and saplings has forced farmers to raise saplings from their own seed nuts which are harvested from their own farm. In this background during 2006, on trial basis, 400 seed nuts were purchased from Coconut Research Station, Vepankulam (TNAU) and sown in trenches of 30 cm depth, in a spacing of 40 x 30 cm, in raised sand bed during North East monsoon period. Upto 70 percentage of germination was obtained and the saplings were sold. Subsequently, in 2007, 100 coconut saplings (Variety: West Coast Tall) were planted under drip irrigation in 1.5 acre area for the purpose of establishing a seed garden. During 2009 Krishi Vigyan Kendra, Namakkal obtained a project to establish coconut nursery with 40,000 nuts with a subsidy of Rs. 2.00 lakhs from Coconut Development Board, Cochin. In the first stage 10,000 seed nuts were sown and around 90% germination was seen in nursery bed. In second stage 87 % of germination was seen. After germination, the sprouted nuts were transferred in 400 gauge poly bags containing pot mixture in the ratio of 2:1:1.



Poster

TS10- P07

Information and communication technology for disseminating coconut cultivation technologies

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Information and communication technology (ICT) has emerged as a potential tool for dissemination of farm innovations. Applications of ICT for Transfer of Technology was initiated at CPCRI during 1999 by hosting its website www.cpcri.nic.in, which has now been brought under Government of India domain as www.cpcri.gov.in. Around 15000 visitors per year have visited this website to access cultivation technologies of mandate crops and each user spent on an average 2.03 minutes. Data from web analytics shows that the user base is increasing 72% per month for the site. Farmers and extension personnel sought information on coconut technologies through online query facility provided in the website. On an average, the website administrator receives 1372 such online queries per year and answers for the same are replied by the scientists. By making use of the economic edge of digital medium over print media, this institute had brought out four interactive CDs on coconut viz., e-manual on coconut cultivation, Integrated Pest Management in coconut, Coconut descriptor and Integrated Diseases Management in coconut wherein large number of images and video clippings were included. Cyber Extension programmes in this institute have been started by establishing the group video conferencing facility for conducting interface between farming community located in various parts of the country and scientists of CPCRI. This facility is installed with four 1:1 BRI ISDN lines and ICAR's VPN connectivity. Research Extension farmer interface programme facilitated by video conference are being organized by CPCRI in collaboration with agencies such as ICAR's institutes, Kerala IT mission and Coconut Development Board (CDB) covering Andhra Pradesh, Tamil Nadu, Orissa, West Bengal, Karnataka and Kerala states. So far 40 Research Extension-Farmer Interface programmes were conducted. The experience of CPCRI indicated that ICT applications could be used as effective tool for disseminating coconut cultivation technologies.



Poster

TS10-P08

Coconut economy of India - challenges and prospects over other oilseeds

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Coconut (*Cocos nucifera* L.), nature's supermarket as well as Gods gift to man-kind is grown in more than 93 countries. The analysis of the area, production and productivity, says that the major coconut-producing countries in the world are India, Indonesia and Philippines. The coconut cultivation in India is more adapted to coastal agro-ecosystem. The analysis of the area, production and productivity scenario of coconut shows that the major coconut growing state is Kerala, whose role in coconut production is decreasing as result of the emergence of new coconut producing states like Karnataka, Tamil Nadu and Andhra Pradesh. The analysis of the growth performance of a number of crop aggregates at all Kerala level shows a tremendous decline in area under the cultivation of rice, pulses, food grains, tapioca and cashew and a sharp increase in the cultivation of black pepper, coconut, coffee, and rubber in all districts over the period of analysis. However, growth rate of coconut is deteriorating in the last few years due to a structural shift in favour of rubber due to good price signal.

A region wise analysis of coconut shows that, even though the percentage increase in area, production and productivity is high in the south Malabar districts, the contribution of area effect and yield effect to the increase in production is superior in the north Malabar districts of Kerala (Kannur, Kasaragod and Wayanad). Thus, to recapture the losing importance of Kerala in the coconut economy of India, Govt. should take adequate steps to promote coconut cultivation in these districts.

Copra making is a traditional coconut processing activity in the major coconut growing states in India. In the early 1990s, around 90% of the production of milling copra in India was confined to Kerala and at present the states share is only 58%. Indian vegetable oil economy is the fourth largest one in the world after USA, China and Brazil. The share of coconut oil in India's vegetable oil market is just 8.36% as against 69% by the three cheap substitute oils comprising soyabean, mustard and groundnut oil. To increase the consumption of coconut oil a strong campaign should be undertaken for creating awareness about the health aspect of coconut oil. The share of coconut oil to the import of vegetable oil is 0.33% in 1995-96 and 0.27% in 2004-05. It means that a structural shift has not happened in favour of the consumption of coconut oil where as a positive shift has happened in case of other oils especially palm oil. Because of these import surges, the demand for coconut oil in the edible sector as well as in the industrial applications has eroded significantly, mainly because of price advantage and the availability of cheap substitutes.



A survey among 750 families in Kannur district of Kerala indicated that the average per capita consumption of coconut oil in Kannur District is 8.97 kg and it is high in the rural areas of the district. The persons living in urban centres with good financial background purchase branded and packed oils.

Thus, the policy makers and administrators should take serious steps to correct the imbalances in the cropping pattern of the oilseed economy in particular and the agricultural scenario in general to solve this problem.

Poster

TS10- P09

Issues on farmer led community nursery in coconut biodiversity

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Changing global and Indian agricultural scenario necessitates Indian farming for shifting from less marketed oriented agriculture towards commercial agriculture. In this situation, strategic planning is inevitable for achieving sustainable growth in the Indian plantation crop sector. Coconut is an important small holder's plantation crop widely cultivated in an area of 18.94 lakh ha mainly in peninsular India. The annual production of 15729.7 million nuts and the productivity of 8303 nuts/ha is the highest in the world in terms of nut equivalent. However, more than 70% of the existing coconut plantations are senile and poor yielding as compared to several high yielding varieties and hybrids released by the National Agricultural Research System. Moreover, in order to access the valuable results of the breeding research, requirement of elite and good planting material is essential. In this context, there is an increasing demand for elite and good planting material of coconut. However, there is a wide gap between their demand and supply. Community based nursery is one among the means of bridging the gap. Several farmers' based and commodity based community nurseries exist in different states. But their sustainable success depends on technical, economic and social issues. This paper depicts those issues related to farmer led community nurseries and their role in coconut biodiversity and the ways and means to tackle those issues with the help of Krishi Vigyan Kendras of the National Agricultural Research System.



Poster

TS10- P10

Impact of training programmes on adoption of vermicomposting technology utilizing palm wastes, among farmers of Kasaragod district, Kerala

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Vermicompost technology utilizing palm wastes developed by Central Plantation Crops Research Institute (CPCRI) is being promoted and popularized through the Krishi Vigyan Kendra of the institute by way of training programmes and other transfer of technology activities. An evaluation study was conducted to know the effectiveness of the training programmes on vermicomposting technology conducted by the Krishi Vigyan Kendra of CPCRI, Kasaragod and to study the impact of the technology in the farming situation of the district. Keeping in view the fact that the trained participants are distributed in all the 39 panchayats of Kasaragod district, one panchayat each from four blocks of Kasaragod district was selected purposively and from each panchayat, one village was selected randomly. The results obtained from the study with selected sample population indicate that there is significant difference on knowledge about vermicomposting technology between trained and untrained farmers. Further, it clearly revealed that the training programmes organized by the KVK on vermicomposting technology has created significant impact both qualitatively and quantitatively towards the betterment of socio-economic conditions and farming situation of the farmers of Kasaragod district.



Poster

TS10- P11

Integrated watershed development model for sustainability of coconut based production system

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In India, about 5000 million tones of fertile top soil is lost annually due to soil erosion alone. In Kasaragod district of Kerala, more than 70% of the rainfall is being carried away to the sea as run-off. In some susceptible areas without soil and water conservation measures, soil erosion has reached an alarming rate of 16 ton/ha/yr. Sediment load of runoff ranges between 0.95 to 2.5 kg/m³ depending on the intensity of rainfall and the cultivation practices. This has become a major cause of concern to many farmers of coconut plantations. Soil and water conservation measures increase the soil health, nutritional status, water holding capacity of the soil and reduce runoff. Soil and water conservation measures through integrated watershed approach are an ideal solution to land degradation problem. The agronomic practices like mulching, taking basins around coconut palms, husk burial in the basins and engineering structures like terraces, contour bunds, contour trenches, etc., are found to be effective in reducing runoff and soil erosion. In addition to the in situ moisture conservation, rain water harvesting systems were found to be ideal for irrigation and ground water recharge. By adopting suitable soil and water conservation measures an average increase in yield of 34% has been observed in coconut plantations. Multiple land use through integration of crops, livestock and aquaculture can give the best and optimum production from unit land area. In other words, integrated farming system is a resource management strategy to achieve economic and sustained production to meet the diverse requirement of farm household while preserving resource base.



Poster

TS10- P12

Participatory evaluation of women friendly plant protection measures in banana, a major intercrop in coconut gardens

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Banana, a major fruit crop in Kerala, is extensively cultivated in Alleppey district except in water logged areas. Women groups engaged in agricultural activities mainly focus on banana- vegetable cropping system in leased garden lands, mainly as an intercrop in coconut gardens. Nendran, Palaymkodan and Njalipooan are the popular banana varieties cultivated as intercrop in coconut gardens especially during early stages of establishment. The crop is infested by more than twelve insect pests, pseudostem weevil being the major one among them causing crop damage even up to 50 per cent. Lack of proper knowledge and skill in scientific management of crops coupled with drudgery involved in plant protection measures was observed as the main hurdle in successful banana cultivation by farm women. A field evaluation on choice of chemicals, effectiveness of different sprayers and different extension methods were conducted in a participatory mode among selected women groups in Chettikulangara village. The evaluation showed that farm women preferred powder formulations (WP) to liquid formulations (EC) and hands- on trainings over simple method demonstrations, as both the parameters had got the highest value in matrix scoring. Sprayer with less weight and extendable lance proved to be superior over conventional metal sprayers in reducing drudgery involved in safe application of chemicals. More number of plants (155/hour) could be covered with low drudgery parameters as revealed by scoring on different parameters. It also resulted in reduced pest infestation as low as 4.4 per cent. It was concluded that use of powder formulations of insecticides by using high density plastic sprayers with extendable long lance could reduce pest incidence and drudgery, thus turning out to be a women friendly technology in coconut based farming systems.



Trend analysis and forecasting of coconut production in Assam

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India is one of the leading countries of the world in area and production of coconut with an estimated area of 1.9 million hectare and productivity of 8303 nuts per hectare. Coconut, an important crop of southern states of India, is now emerging as an important commercial/cash crop in North Eastern India, particularly Assam. Going through the old reviews i.e. earlier to 1990's, coconut was designated as a negligible crop in Assam. But with the advancement of time and spread of awareness, it has been presented as a thrust crop. Current cultivation aspects reveal that the area under coconut cultivation in Assam is 18.753 thousand hectares with productivity of 9,598 nuts per hectare whereas in 1976 the corresponding figures were 4.923 thousand hectares (area) and 5,092 nuts per hectare (productivity). There was a linear trend of expansion of area under coconut cultivation in the period of 1976 to 2003 and after that the area maintains 18.935 ± 0.126 thousands hectare. But the productivity has shown an increasing trend of productivity with 7133.76 ± 1006.81 nuts per hectare up to 2004 with a maximum of 10754 nuts per hectare and thereafter, maintains a parallel productivity line with 8692.60 ± 1131.67 nuts per hectare. Percentage increase in area, production and productivity calculated are, 281, 618 and 88, respectively, during the period 1976 to 2009. During the study period, the percentage increase in area (76) and production (93) was the highest during 1995-2000 and percentage increase in productivity was the highest during 2000-2005. It has been forecasted with the coconut production data of 1976-2009 that the projected coconut production in Assam may reach 2,030 lakh nuts during 2020.



WORKSHOP 1

COCONUT AND HEALTH



Coconut oil; its health aspects

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Epidemiological studies attribute an increased risk of coronary artery disease (CAD) to elevated levels of serum cholesterol, which in turn is related with increased intake of saturated fats. A fear complex has been created among the general public that consumption of coconut oil results in elevated cholesterol levels. This myth was primarily due to equating coconut oil with saturated fat. However, now we know that saturated fats in coconut oil are of the short chain and medium chain fatty acids. On the other hand, the fats that cause heart disease are saturated fats with long chain fatty acids.

The medium chain fatty acids (of coconut oil) are absorbed directly into the blood stream and then enter into the cells and is subsequently metabolized immediately. On the other hand, long-chain fatty acids (of other oils) are transported in blood with the help of lipoproteins, which are eventually deposited into various organs, including heart vessels. In other words, coconut oil is the most easily digestible and absorbed class of fat and is not deposited.

There are dozens of animal and human studies in world literature to disprove allegations about coconut oil enhancing the risk of a CAD. There is not even one paper in the whole literature directly showing that coconut oil increases cardiac diseases. In fact, coconut oil is neutral with respect to atherogenicity (plaque formation).

At Amrita Institute of Medical Sciences we have analysed serum from normal healthy persons, consuming coconut oil or sunflower oil. Further, lipid profile was analysed in coronary artery disease patients, consuming coconut oil or sunflower oil. There was no statistically significant difference in the cholesterol, HDL or LDL levels in coconut oil consuming population versus sunflower oil consuming population. Plasma fatty acid composition reflected no changes with dietary fat source.

In another study conducted at Amrita Institute of Medical Sciences, 71 samples of plaques (from diseased coronary arteries) were analysed. Most of the fatty acid content of the plaques were of polyunsaturated fatty acids; and very little of the variety seen in coconut oil. Surprisingly, the fatty acid content of the plaque did not show any difference between coconut oil consumers versus sunflower oil consumers.

The lauric acid in coconut oil is used by the body to make the disease-fighting monolaurin in the skin. Coconut oil has been reported to inhibit various microorganisms including bacteria, yeast, fungi, and enveloped viruses, including HIV, measles, herpes simplex and cytomegalovirus. The major fat in mother's milk is the same lauric acid that is seen in coconut oil. In short, the advantages of coconut oil are: It does not affect serum cholesterol (neutral); it increases



serum HDL cholesterol (beneficial); it produces very little free radicals, as opposed to other oils (beneficial); it is rapidly absorbed, rapidly oxidized and is not deposited (beneficial); it helps in resisting invading micro-organisms.

Panel discussion

WS1-02

Technologies for value addition of coconut inflorescence sap - the untapped health food

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“Palm sap can be converted to jaggery. This jaggery is superior to cane jaggery, delicious and gives mineral salts too. I always eat palmgur. It can be produced worth crores of rupees in the cottages. This is the way to banish poverty from the land. This is an antidote to poverty”. - Mahathma Gandhi

(From the speech delivered at the opening of the village industry exhibition on 3.5.1933)

In diversified utility no other tree can surpass the coconut palm. Among the various coconut products, processed inflorescence sap deserves special attention not only as the highest income generating venture but as a health promoting food. Vascular sap extracted from the unopened coconut inflorescence is a unique health drink. It can be promoted as a natural drink and would be a better choice in the midst of an array of artificial drinks available in the beverage market. Fresh coconut sap is also valued for its medicinal properties.

The research conducted at the Regional Agricultural Research Station, Pilicode showed wide variation in the inflorescence sap yield of coconut palms. Genetic make up of the cultivar, skill of the sap collector, weather conditions and soil moisture status are observed to be the major determinants of this variation. The average sap yield at Nileshtar campus recorded during 2000-2005 varied from 39.04 litres/ palm/month to 118.62 litres/palm/month. Highest sap yield was recorded during the month of July followed by June.

The nascent coconut inflorescence sap is a nutrient rich food. It is a good source of sucrose (16.5%), minerals and all the essential amino acids except methionine. The coconut sap also contains vitamins such as thiamine, riboflavin pyridoxine, pyridoxal, panthothenic acid, nicotinic acid, biotin, folic acid, inositol, choline and ascorbic acid. Though in small amount, coconut inflorescence sap provides reducing sugar (0.3%), protein (0.18 g/100 ml) fat (0.04 g/100 ml) phenols (10.3 mg/100 ml) and pectin (30 mg/100 ml). The nascent coconut sap is traditionally popular as next only to breast milk among the rural community of Kerala and has been used to feed infants in the absence of breast milk.



Being an ideal nutrient media the nascent coconut sap is highly vulnerable to microbial contamination. To prevent the nutrient loss the nascent coconut sap requires post harvest techniques to preserve its pristine quality. Research conducted at Regional Agricultural Research Station, Pilicode resulted in developing technologies for value added products such as preserved coconut inflorescence sap (CIS health drink), popular as *Kerasudha*, coconut inflorescence sap concentrate (CIS honey) and granulated coconut inflorescence sap (CIS granules). Jagerry is a traditional product from coconut sap.

Panel discussion

WS1-03

Modulation of chemically induced diabetes by virgin coconut oil

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The prevalence of diabetes is rapidly increasing all over the globe at an alarming rate. Over the past three decades, the status of diabetes has changed from being considered as a mild disorder of the elderly to one of the major causes of morbidity and mortality affecting the youth and middle aged people. It is important to note that the rise in prevalence is seen in all six inhabited continents of the globe. India leads the world with largest number of diabetic subjects earning the dubious distinction of being termed the “diabetes capital of the world”. According to the Diabetes Atlas 2006 published by the International Diabetes Federation, the number of people with diabetes in India currently around 40.9 million is expected to rise to 69.9 million by 2025 unless urgent preventive steps are taken. Virgin coconut oil has recently been shown to possess health beneficial properties and there are unconfirmed speculations that it can reduce blood glucose levels. In this study, virgin coconut oil was evaluated for its anti diabetic effects in streptozotocin - induced diabetic rats. Rats were randomly divided into four groups of eight rats each, group I served as control, group II was diabetic, group III and IV were forced fed with cold extracted (CEVCO) as well as hot extracted (HEVCO) virgin coconut oil, respectively, for a period of 21 days. Food intake, weight gain and blood glucose levels were monitored weekly. Water intake and urine output were monitored daily. At the end of the experimental period, the rats were sacrificed under mild anesthesia, organs were quickly excised and analyzed. Blood was analyzed for glucose and products of lipid peroxidation, while the liver and kidney were analyzed for TBARS and antioxidant enzymes. The results demonstrate that both CEVCO and HEVCO possess anti diabetic properties. Both the VCO types reduced weight loss, blood glucose levels and increased the activities of antioxidant enzymes in liver and kidney. HEVCO fed animals showed a 49% reduction in blood glucose levels. HEVCO inhibited lipid peroxidation more efficiently than CEVCO.



Panel discussion

WS01-04

Coconut oil - Facts and fallacies

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Coconut oil assumes much importance among the vegetable oils in India as well as in the world. About 4.9% of the world production of oils and fat comes from coconut oil. India accounts for 22.34 per cent of the world's coconut production and is one of the major players in the world's coconut trade. Current area of cultivation under coconut is 1.91 million ha with an annual production of nearly 13000 million nuts. Of this, 50% finds use in households for toiletry purposes, leaving 35% for edible uses and the remaining 15% for industrial applications.

Until a few decades ago, coconut oil was the main fat in large parts of the world. When other vegetable oils like palm oil, soybean, sunflower, corn and cotton seed oils appeared in the world market, coconut oil was pushed back with the alleged reason that it is hypercholesterolaemic, thus increasing the risk of 'atherosclerosis'. People gave a red signal to its consumption due to its highly saturated nature. However, the situation is quite different now. Recent efforts for a deeper insight into the chemistry of dietary fats reveal that serum cholesterol levels do not depend on the degree of saturation, but on the fatty acid chain length and related metabolism. Coconut oil has also got the property to dissolve the lipids and phospholipids enveloping the viruses, thus inactivating them. HIV virus, measles virus and herpes simplex virus-1 all belong to this category. Two entirely independent research groups found that lauric acid - a common biological compound in coconuts, as well as in mother's milk - kills the Human Immunodeficiency Virus (HIV). In fact, monolaurin formed from lauric acid, is the antiviral, antibacterial, and antiprotozoal monoglyceride used by the human or animal to destroy lipid coated viruses such as HIV, herpes, cytomegalovirus, influenza, various pathogenic bacteria including *Listeria monocytogenes* and *Helicobacter pylori*, and protozoa such as *Giardia lamblia*. Some studies have also shown some antimicrobial effects of the free lauric acid.

A great deal of research remains to be done in analyzing the effects of dietary fatty acids on human health. It would be an unfortunate irony if consumers are deferred from buying products containing coconut oil on health grounds, misled by advertisements, when the most recent medical evidence suggests that coconut oil is more beneficial than hydrogenated and polyunsaturated fats. As such, an attempt is made here to dispel the prevailing misconceptions about coconut oil and to label it as energy giving, non-fattening edible oil.



Production of vegetable oil blends with coconut oil for improving stability and health

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Coconut oil is being consumed in tropical countries for thousands of years. It has a characteristic sweet smell, mainly consumed by the people of coastal regions of India. Coconut oil is rich in saturated fatty acids (92%) and contains a small amount of unsaturated fatty acids (8%) and hence is a stable oil. Among the saturates, medium chain saturated fatty acids form the major components (75.4% with 55% lauric acid) in the oil. The good effects of medium chain fatty acids are that these are easily absorbed in the human body, thus making coconut oil a easy to digest oil. On the otherhand, vegetable oils lack medium chain fatty acids and have high unsaturation and tend to be less stable. Hence keeping all this in view, an attempt was made to prepare coconut oil blends with the objective of providing the health benefits of medium chain fatty acids (MCFA) present in the coconut oil to a larger population of India who do not consume directly the coconut oil in their food and are called non-coconut oil consumers. This was achieved by using coconut oil in refined form which does not contribute coconut flavor to the blends. After carrying out laboratory trials at 100g-4kg batches, seven vegetable oil blends with 20% refined coconut oil for non-coconut oil consumers were prepared at pilot scale (14kg batches) and the process of production including packaging, storage optimised, oil evaluation by consumers carried out. Radical scavenging activity of the prepared blends to determine the efficacy of antioxidants in the blends were also carried out. The results showed that the blends had 11 - 13% of medium chain fatty acids, 16 - 49% of monounsaturates, 22 - 55% of polyunsaturates, 367 - 929 mg / Kg of total tocopherols and 20 - 49% of DPPH scavenging activity. The sunflower oil + coconut oil blends and rice bran oil + coconut oil blends have shown 36.7%-89.7% and 66.4%-80.5% reduction in peroxide formation respectively over a period of 42 days in comparison to sunflower oil and rice bran oil individually. It was concluded that blending different amounts of coconut oil with other vegetable oils not only provided medium chain fatty acids but also improved the oxidative stability and retained the radical scavenging activity. Hence, blending of coconut oil with other vegetable oils improves stability and health. If more non-coconut oil consumers(major population) start eating such blends, then there is a possibility of increased utilization of coconut oil directly for food purposes which inturn increases the demand for the oil in India. The beneficial effects of consumption of medium chain fatty acids present in coconut oil in terms of non-accumulation of coconut fat in the body and obesity management need to be emphasised for the non-coconut oil consumers.



Panel discussion

WS1-06

Nutritional aspects of value-added coconut products

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Coconut is an excellent source of natural as well as processed form of food. It is a highly nourishing, strengthening and fat rich food and is considered as nearly perfect diet as it contains almost all essential nutrients needed by a body. The kernel of the coconut contains 35-45 per cent of oil, about 15 per cent of carbohydrates and a little less than 5 percent of proteins. A spectrum of value-added products namely coconut oil, virgin coconut oil, coconut testa oil, VCO meal, coconut squash, coconut sap, coconut vinegar, snowball tendernut, tender coconut water, coconut haustorium and coconut chips can be obtained from this divine fruit. The health benefits of coconut oil can be attributed to their unique fatty acid composition. Virgin coconut oil (VCO) is the purest form of coconut oil, water white in colour, contains natural vitamin E, and has not undergone any hydrolytic or atmospheric oxidation as attested by its very low free fatty acid content and peroxide values. The concentration of the lauric acid, the major component of the fatty acids in virgin coconut oil has ranged from 50.394 to 51.35 percent depending on the method of preparation. Coconut testa is produced as by-product in the process of coconut chips making and has potential oil content about 61.33 %. It is observed that the dominant FFA lauric acid concentration in coconut testa oil was 38.07 % and it was followed by myristic acid (21.03 %) and palmitic acid (13.77 %). The derivative of myristic acid (ester isopropyl myristate) is used in cosmetic and topical medicinal preparations where good absorption through the skin is desired. Hence the coconut testa oil could be used as potential formulation in the cosmetic and topical medical preparations. The residue obtained in VCO production is known as VCO meal and it highly rich in dietary fibre. The snowball tendernut and tender nut water are good source of growth promoter, enzymes, antioxidant and antiageing agent. Coconut Sap is a sugar-containing juice, contains minerals, proteins, vitamins and high amounts of essential elements such as N, P, K, Mg and micronutrients (B, Zn, Fe, Cu). The coconut haustorium is also rich in protein (2.19 %), sugars (9.28 %) and minerals (0.84 %). Due to the presence of many beneficial compounds in coconuts and its products, the health attributes obtained on consuming coconut products is immense.



WORKSHOP II
ORGANIC FARMING IN COCONUT



Panel discussion

WS2-01

Oil base formulation of biocontrol agents, biopesticides and biofertilizers

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One key obstacle in the development of soil/aerial inoculants is the extremely heterogeneous nature of soil and its often unpredictably harsh environment for introduced organisms. There are few unoccupied niches in the soil for the introduced species. A keen competitive war may immediately develop among the introduced and indigenous species for their ecological space. These organisms however, are highly stressed, alien to the natural soil environment, and often physiologically not ready to compete in soil with the indigenous species that have had time, often generations, to adapt to the specific ecological niche. Many formulations specifically address these issues by including a massive amount of carriers, selective food sources, suppressants for indigenous species, buffers and other ingredients which can transiently alter the microphysical environment of the soil to provide a temporary safe haven for the introduced species. These adjust physiologically to the new environment, and propagate. A successful formulation allows the introduced species to establish itself on or inside host roots or, at least temporarily to shift biota dynamics in the soil to favour host development in a timely manner.

To achieve a desirably long shelf life and the required ease of transport and storage, most organisms in commercial products for soil application are propagated in a rich medium, and later packaged as concentrates with the organisms driven to a dormant or a semi-dormant physiological state. These products are able to survive six months to two years depending upon formulation. The recent development of oil base formulation reveals that all the biofertilizers like *Azotobacter*, *Azospirillum*, *Rhizobium*, Phosphate Solubilizer, Potash Mobilizer, Zinc Solubilizers; biocontrol fungus like *Trichoderma*, *Beauveria*, *Metarhizium*, *Verticillium*, etc., and bacteria like fluorescence, *Bacillus subtilis*, *Bacillus thuringiensis*, etc., have minimum four years shelf life, highest cell count (minimum 10^{10} /ml) and better results on all types of crops.



Panel discussion

WS2-02

Farmer's experience in organic farming in coconut

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Farmer's think that by switching over to the organic farming, the production of a coconut farm will decrease. Though it is true, the loss will be for 2-3 years only. Once carbon content of the soil is built up, the production will be sustainable, and will increase year after year. Most of the coconut tree wastes can be used as feed for earth worms and microbes, resulting in the gradual improvement in the fertility status of the soil. Finally, there will be considerable economic benefit on long term basis and farmer will get rid of maladies associated with the market purchased inputs.

Perennial crops like coconut are most suitable for easy conversion to organic farming with more and more inter crops and bio diversity. The coconut being a direct food, there is no fear of residual poison, when we follow the organic farming principles. Since nature supports more for organic production, the loss due to pests and diseases will not be a big problem.

Panel discussion

WS2-03

Organic Farming: Standards, Certification for organic farming

Mathew Sebastian

Executive Director, INDOCERT

Certification is needed in order to ensure that products labeled as "organic" are produced and handled in accordance with specified organic standards. Minimum requirements for a farm or product to be certified as 'organic' are precisely defined by organic standards. There are organic standards on the national as well as international level. For certification, the standards of the target market or importing country are relevant. Many countries have formulated their own national regulations or standards for organic production like India's National Programme for Organic Production (NPOP), USDA's National Organic Programme, and European Union's Regulation EC No. 834/2007, Japanese Agricultural Standards (JAS) etc.

National Standards for Organic Production: In 2000, the Government of India released the National Standards for Organic Products (NSOP) under the National Programme for Organic Production (NPOP). The compliance of this standard is a mandatory requirement for any organic product to be exported from India.



0Major International Standards

United States Department of Agriculture (USDA) National Organic Programme (USDA/NOP): The production rules for organic production according to the U.S. Standards have been laid down in the National Organic Program (NOP) of the United States Department of Agriculture (USDA).

EU Regulation EC No.834/2007: The regulation governs organic agriculture for European Union member states, set out for a complete set of objectives, principles and basic rules for organic production. This regulation is most relevant for exports to Europe.

Japanese Agricultural Standards (JAS): Japanese Agricultural Standards are the standards for the agriculture industry maintained by the Japanese Government. They are comparable to Japanese Industrial Standards for food and agricultural products.

Certified organic products are those whose production, processing, handling and marketing have been verified by an accredited certification body as being in conformity with specified organic standards. Once a product is certified organic, it can be labeled as organic. The certification process includes inspection to verify that production and handling are carried out in accordance with the standards against which certification is to be done; and certification to confirm that production and handling conforms to those standards. Producers and exporters will have to obtain certification against organic standards applicable in those markets, in which they intend to sell their products with an indication that they are organic.



WORKSHOP III
WILT DISEASES OF PALMS



Recent advances in the study of coconut lethal yellowing disease in the Americas

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Studies on lethal yellowing (LY), a phytoplasma disease that has killed millions of coconut palms (*Cocos nucifera*) in Latin America and the Caribbean region, were undertaken within a project supported by the Common Fund for Commodities. The studies include: screening of coconut for LY resistance with the identification of cultivars and hybrids that are withstanding the disease; development of novel methods for the detection and quantification of phytoplasma DNA in host tissues based on real time-PCR and TaqMan assay techniques that target various phytoplasma genes; analysis of phytoplasma diversity with the identification of 16SrIV subgroup A and D phytoplasmas in different geographic locations and palm species; a reassessment of the geographic distribution of LY in project participating countries and neighbouring regions; analysis of potential alternative host plants of LY with the finding of several palm and non palm species harbouring group 16SrIV phytoplasmas with or without symptom development; vector transmission studies that have provided a description of Mexican homopteran entomofauna, while revealing evidence of several planthopper species containing LY phytoplasmas; transmission of LY phytoplasmas by *Myndus (Haplaxius) crudus* to coconut plantlets under *in vitro* conditions, although so far transmission trials of LY disease with this insect to older coconuts in the field have failed; and seed transmission studies that have provided evidence that some embryos rescued and germinated from fruit of diseased palms contain detectable phytoplasma concentrations at both the shoot and plantlet stage, even though transmission of the disease itself has not been proved. Collectively, these results in conjunction with previous findings have provided new insights for an integrated management program to control LY disease that is currently being implemented at the farm level in Jamaica.



Panel discussion

WS3-02

Serological detection of phytoplasma associated with coconut root (wilt) disease

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Phytoplasmas being sub-microscopic organisms and not amenable to culturing *in vitro*, pose problems in reliable diagnosis and detection. Electron microscopic detection of the mollicutes in phloem tissues as well as use of histochemical light microscopic staining reactions indicative of accumulation of DNA in extra nuclear sites confirmed the presence of phytoplasma. However, electron microscopy is laborious, time consuming and only limited number of cells in a tissue could be examined at a time. Low concentration and uneven distribution of phytoplasma in coconut palms compounded further the difficulty in identifying the organism in all diseased palms. Similarly, light microscopic staining techniques in vogue are indirect and non-specific and cannot differentiate one phytoplasma from another. Another indirect method of phytoplasma detection is by differential chemotherapy performed on diseased palms. This tool however, is also not reliable as all the palms treated with tetracycline do not show remission of symptoms.

Serological detection of root (wilt) diseased palms in earlier years of the investigation was by isolation of a partially purified abnormal nucleoprotein from leaves of diseased palms and using it as an immunogen for production of antiserum. The common antibodies in the antiserum were removed by intra-gel cross absorption and used for double diffusion test and Enzyme Linked Immunosorbent Assay (ELISA). The antiserum thus raised was not phytoplasma specific but against an aberrant nucleoprotein present in diseased palms. The disease status of palms could be identified with this antiserum, 6-24 months before expression of foliar symptoms. Detection of phytoplasma exclusively in tissues of root (wilt) diseased palms, establishing its constant association with the disease by electron microscopy and experimental transmission through insect vector and dodder, demonstrated it to be the etiological agent of the disease warranting preparation of a root (wilt) phytoplasma specific antiserum. The phytoplasma associated with root (wilt) diseased palms was purified by discontinuous Percoll density centrifugation method. The morphological identity of the fractionated phytoplasma was confirmed by ultra-structural and biochemical studies. A polyclonal antiserum against the isolated phytoplasma has been prepared. The specificity of the antiserum to detect root (wilt) phytoplasmal infection in palms was studied by screening leaf extracts from large number of healthy and diseased palms of varying disease intensity and from various locations and agro-ecological situations. Employing the root (wilt) phytoplasma specific antiserum, a highly sensitive, simple and rapid Direct Antigen Coated (DAC) indirect ELISA technique has been standardized. With the modified protocol, by using leaf disc as antigen *in lieu* of leaf extracts, results could be obtained within seven hours. This immunodiagnostic method is now being routinely used for identifying root (wilt) disease free/phytoplasma free, high yielding healthy palms to be used as mother palms for breeding for disease resistance. It is also used for tracking fresh root (wilt) disease outbreaks in new frontiers.



The scope of sero-diagnosis using phytoplasma specific antiserum in insect vector(s) identification and transmission studies holds further promise. Future research programmes complementing serological studies with molecular studies needs to be taken up. Another priority area requiring attention is preparation of monoclonal antibodies and standardizing techniques such as immunocapture PCR, immunofluorescence etc. for reliable diagnosis of phytoplasma in plant and putative insects.

Panel discussion

WS3-03

Diagnosics of phytoplasma - Electron microscopy and staining techniques

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Phytoplasmas were observed for the first time in 1967, in the sieve tubes of plants affected by various yellow diseases. They are pleiomorphic, morphologically and ultra structurally as revealed by electron microscopy. Since then, many authors have used light and electron microscopy to reveal phytoplasmas in the phloem tissues and to study cytological interactions between these pathogens and their hosts. Phytoplasmas are plant-pathogenic mollicutes restricted to phloem. They belong to several groups in a unique phylogenetic clade. Non-related phytoplasmas may infect the same plant species, often with similar symptoms. Hence methods are needed to specifically localize phytoplasmas and to study their multiplication and movement in their hosts and vectors. But, because of their pleomorphism, it was impossible to distinguish and classify the different phytoplasmas by means of the traditional morphological techniques. In recent times, immunological techniques applied to light and electron microscopy enables the different phytoplasmas to be characterized *in situ*. Recently, the potential of microscopy techniques as investigative tools in plant cell biology has increased, because of development of confocal laser scanning and video microscopy, computerized image processing and analysis, and an increasing array of fluorescent probes that can be applied to living cells. Phytoplasmas cause disease in more than 300 plant species representing 98 families. 16S rDNA sequences were determined and used in the late 1990s to classify the phytoplasmas into 20 phylogenetic clusters or groups. In 1994, Murray and Schleifer proposed that uncultured bacteria for which sufficient molecular characterization had been carried out, be designated by a '*Candidatus*' genus and species name. The electron microscope techniques can only aid in physical identification of Phytoplasma but not for naming and classification of phytoplasma. The aim of this paper is to indicate the most important microscopy techniques and the new approaches used in diagnosis and in studying of the cellular relationships between phytoplasmas, host plants and insect vectors and application of EM for the diagnosis of coconut root (wilt) phytoplasma.



Panel discussion

WS3-03

Phytoplasma detection in coconut palm using conventional and real-time PCR

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Coconut cultivation faces a strong phytopathological constraint caused by the phytoplasmas. Phytoplasmas are phloem-limited cell wall-less bacterial pathogens with very small genomes which also have extremely low levels of the nucleotides guanine plus cytosine (G+C) that can cause devastating losses in crops and natural ecosystems worldwide and most prevalent in tropical and sub-tropical regions of the world. The uneven distribution and low concentration of phytoplasmas in the phloem of the infected woody plants, variations in titre according to the season and plant organ are important obstacles for efficient diagnosis. Detection and identification of phytoplasmas is necessary for accurate disease diagnosis. Polymerase Chain Reaction (PCR) is the most versatile tool for detecting phytoplasmas in their hosts. Whilst real-time PCR method has many advantages over the conventional PCR in terms of accuracy, dynamic range, short analysis time, high automation capability, high-throughput capacity, and absence of post-PCR manipulations that prevents carryover contamination. Hence, conventional and real-time PCR have been done to compare the phytoplasma detection sensitivity in infected coconut palm. Tissue samples were collected from 20 MYD coconut palms showing symptoms of the coconut yellow decline (CYD) disease. Total nucleic acid was extracted from coconut palms using the small scale DNA-extraction procedure. Phytoplasma DNA was amplified from total DNA extracts using direct, nested and real-time PCR. For conventional PCR, primer pairs such as P1D P7, R16F2nD R16R2, fU5/rU3 and 16SCYDf/16SCYDr primer pair and TaqMan qCYD 16S probe were used for real-time PCR. No amplification products were visible after the first round of amplification from the DNA of CYD infected MYD samples using the universal primer pairs P1/P7. However, PCR products of 1250 and 900 bp were amplified from 12 of 20 symptomatic MYD samples with primers R16F2n/R16R2 and fU5/rU3, respectively. In comparison, the real-time PCR assay reliably detected the CYD phytoplasma in DNA from 18 of 20 symptomatic MYD coconut palms ecotype. The analysis of field-collected coconut samples showed significantly higher diagnostic sensitivity of real-time PCR in comparison to conventional nested PCR by revealing some false negative nested PCR results from plants showing typical symptoms of CYD disease. Real-time PCR revealed greater sensitivity in the detection of phytoplasmas than nested PCR. The real-



time PCR was at least as sensitive and fast as the commonly used and more laborious nested PCR for detection of the pathogen.

Panel discussion

WS3-05

Phytoplasma diagnostics - Nanotechnological approaches

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Diseases caused by phytoplasmas occur worldwide in many economically important crops: there are more than 300 distinct diseases associated with these pathogens. Phytoplasmas are wall-less prokaryotes, pleomorphic in shape, belonging to the Class Mollicutes; they are bound by a trilaminated unit membrane, contain ribosome and DNA and range up to 1.2 μ m in diameter. Their shape may be helical, filamentous, beaded or simply spheroid. They are obligate parasites, uncultivable *in vitro* therefore grow and reproduce in the phloem of the host plants and in the vector insects.

Early methods of diagnosis of phytoplasmas were dependent on characterization of plant symptoms and observation of phytoplasmas in ultra thin sections of diseased plants. The development of molecular probes and PCR primers for phytoplasmas (universal and group specific based on 16S rRNA gene, 16S-23S intergenic spacer region, *rp* gene and elongation factor EF-Tu) has increased diagnostic ability. More recent development of 16S rRNA-based diagnostic tools include the use of an oligonucleotide microarray that can detect all phytoplasmas that were tested and quantitative real-time PCR for the detection and quantification of phytoplasmas.

Nanotechnology-the creation and utilization of materials, devices, and systems through the control of matter on the nanometer-has been applied to molecular diagnostics. Nanotechnologies enable the diagnosis at single cell and molecule level and some of these can be incorporated in the current molecular diagnostics. The broad range of nanotechnologies applied to pathogen detection can be categorized according to the technologies, i.e., nanoarrays, nanofluidics and nanotransducers. Each of these type of nanotechnologies, while fundamentally different, has been shown to improve sensitivity, specificity, and throughput while decreasing analysis time and sample volume. Quantum dots (QDs), gold nanoparticles (AuNPs), and superparamagnetic nanoparticles are the most promising nanostructures for *in vitro* diagnostic applications. These nanoparticles can be conjugated to recognition moieties such as antibodies or oligonucleotides for detection of target biomolecules. Nanoparticles have been utilized in immunoassays, immunohistochemistry and DNA diagnostics. These technologies will extend the limits of current molecular diagnostics and enable cost effectiveness and reduction in detection time. Advances in nanotechnology have now begun to play an important role in pathogen detection, and improving the detection limit, operational simplicity and cost-effectiveness of disease diagnostics. Application of different nanotechnologies available for phytoplasma diagnostics is discussed.



Panel discussion

WS3-06

Insect transmission of root (wilt) disease of coconut

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Root (wilt) disease, a non-lethal but debilitating malady of coconut palms is prevalent in the entire state of Kerala in different degrees of intensity. The disease occurs in a contiguous manner in the eight southern districts of the state and is observed sporadically in the remaining six northern districts. Epidemiological investigations revealed spatial distribution or galaxial outbreaks of the disease suggesting involvement of aerial vectors in the spread of the disease. Constant association of phytoplasma with diseased palms and their total absence in the healthy palms warranted an intensive search for insect vectors, as phytoplasmal diseases are known to be spread in nature through insects. A systematic inventory of insects of transmission significance namely the auchenorrhyncha fauna in the root (wilt) affected tracts revealed the presence of a plant hopper *Proutista moesta* (Westwood) and a leaf hopper *Sophonia greeni* (Distant). The lace bug *Stephanitis typica* (Distant), a known vector of the disease from the earlier transmission experiments was also included in the studies for the ability to acquire and transmit the phytoplasmas. Investigations on these putative vectors revealed the presence of phytoplasma in the salivary glands of *S. typica* and *P. moesta* which were given specific acquisition access and incubation periods but no conclusive lead could be obtained with leaf hopper *S. greeni*. Electron microscopic studies revealed the presence of phytoplasma in salivary glands of lace bugs which were given acquisition access and incubation period (A+ IP) ranging from 18-23 days and in plant hopper with A + IP of 30 days and more. Phytoplasma was not observed in these insects collected from disease free areas such as Minicoy in Lakshadweep and also in insects offered less A + IP specific periods. The vector role of these two insects was proved experimentally on coconut seedlings kept under insect proof conditions. The lace bug inoculated seedlings showed the presence of phytoplasma between 9 and 27 months after first inoculation and by 17th month after inoculation, 50% of the inoculated seedlings showed flaccidity, the diagnostic symptom of the disease. In the case of plant hopper, 6/8 inoculated seedlings showed the presence of phytoplasma in 5-24 months after first inoculation and 5 of the seedlings exhibited flaccidity symptom confirming the transmission of the disease. The control plants in both the experiments remained free of the organisms and disease symptom.



Panel discussion

WS3-07

Management strategies for root (wilt) disease of coconut

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Coconut (*Cocos nucifera* L.) plays a significant role in the overall agrarian economy of Kerala with an area of 7.88 lakh ha under cultivation and production of 5,802 million nuts (2008-09). The productivity of coconut in Kerala is 15% lower than that at national level on account of many reasons, one among them being the prevalence of root (wilt) disease. Though this disease was reported to be present only in small pockets of South Kerala (India) during the early periods since 1882, it is now seen in varying intensities in eight southern districts of Kerala and also has been reported in isolated pockets in northern districts and in a few districts of Tamil Nadu and Karnataka bordering Kerala and Goa. Root (wilt) disease is a non-lethal and debilitating malady and is caused by phytoplasma. The important symptoms of the disease are abnormal bending or ribbing of leaflets (flaccidity) in leaves from the mid whorl and downwards as well as general yellowing followed by marginal necrosis of the leaflets. Other symptoms like abnormal shedding of buttons, reduced leaves and crown and gradual reduction in yield are also observed. Often leaf rot disease is also seen superimposed in root (wilt) disease affected palms and if left neglected, productivity of such coconut palms will be considerably lowered. As there is no therapeutic control measure available for this disease, maintaining health of palms through various management programmes including recycling of crop residues and cropping system approach is very important.

Research studies conducted in the Regional Station have helped to evolve various agro management practices to improve and maintain health of palms and sustain productivity. The integrated agro management practices consist of application of balanced fertilizers, addition of organic matter and recycling of farm waste biomass, raising green manure crops in the basin and incorporation, soil moisture conservation and irrigation, weed control, intercropping and mixed farming, leaf rot control etc. In general, apparently healthy and those coconut palms in the early stage of disease respond better to management practices. Effective utilization of inter space in the coconut garden by inclusion of various crops as inter/mixed crops shall also constitute an ideal approach to improve the health and productivity of coconut palms. Disease advanced and uneconomical palms that yield less than 10 nuts per year and that contract the disease early during the pre-flowering stage are to be removed and replanted with high yielding and disease free seedlings.



Based on the available experimental findings, the following management practices are recommended.

1. Apply balanced doses of fertilizers (500 g N, 300 g P₂O₅, 1000 g K₂O and 500 g MgO/palm/year) in two splits. One-third dose is to be applied during April-May and two-thirds during September-October for rainfed palms and in four splits during January, April, July and October for irrigated palms. Also apply 1 kg magnesium sulphate per palm per year along with other fertilizers.
2. Adopt control measures for disease (leaf rot) and pest (rhinoceros beetle) as detailed below.
 - a) Cut and remove leaf rot affected portions of only spindle and two top most fully opened leaves. Apply Hexaconazole (Contaf 5 EC) @ 2 ml or Dithane M-45/Indofil M-45 @ 3 g per palm in 300 ml water by pouring around the base of spindle leaf.
 - b) As an integrated prophylactic measure against pests, apply a mixture of 200 g sand with equal quantity of Marotti/neem cake or 20 g phorate or 30 g furadan in the spindle axis. Apply this during April-May and October-November. Treat manure pits and other possible breeding sites of rhinoceros beetle with *Metarhizium* culture and plants of *Clerodendron infortunatum*.
3. Recycle the available biomass in the coconut garden. Apply 50 kg organic manure in the form of farm yard manure or vermicompost per palm per year.
4. Grow green manure crops, *Peuraria phaseoloides*/*Vigna unguiculata* in coconut basins during April-May to September-October and incorporate the biomass.
5. Adopt cropping system approach by raising intercrops in rotation/adopting mixed cropping/mixed farming with recycling of organic matter.
6. Adopt soil moisture conservation measures by mulching during November to May. Irrigate the palms during summer months with water @ 250 l/palm/week. Avoid water logging and provide proper drainage wherever necessary.
7. Remove juvenile palms showing symptoms of root (wilt) disease irrespective of its intensity. In mildly affected areas, all disease affected palms, irrespective of the intensity of disease and yield of palms, should be removed to eliminate the foci of infection.
8. Restructure the canopy of other perennial tree crops to provide maximum light for the coconut palms.

Panel discussion

WS3-09



Characterization of phytoplasma infecting spice crops

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Spices have been considered important in the culinary art from time immemorial. They are used for flavouring, seasoning and imparting aroma in foods. Their antioxidative activity helps to preserve foods from oxidative deterioration increasing their shelf life. Phytoplasmas are wall-less non helical mollicutes causing diseases characterized by flower malformation, growth aberrations, yellowing and decline in many plant species. Based on phylogenetic analysis of 16S rDNA sequences and /or RFLP analysis of PCR amplified 16S rDNA, 15 distinct phytoplasma groups were identified. The Phytoplasma Working Team of the International Research Project for Comparative Mycoplasmology (IRPCM) adopted the "*Candidatus Phytoplasma*" genus for formal classification of phytoplasmas and based on diversity within '*Ca. Phytoplasma*' several species level taxa were identified.

Of the different spices, phytoplasma diseases are reported in black pepper, celery, garlic, fennel and onion. In black pepper, affected plants showed malformation of vegetative and floral parts. The affected vines showed conspicuous tufts of malformed branches giving a witches broom appearance and the flowers are transformed into small leaf like structures. The 1.2 kb DNA fragment encoding the portion of phytoplasma 16S rDNA sequence from infected black pepper showed its closeness to members of aster yellows group (16Sr I) (>98% identity) while identity with other groups ranged from 87 to 96%. Based on this, phytoplasma causing phyllody in black pepper may be considered as a strain of the "*Candidatus Phytoplasma asteris*"

In celery, onion and garlic, phytoplasma affected plants showed typical yellows symptoms. Based on PCR-RFLP, the causal phytoplasma was identified as member of aster yellow group (16Sr I) and hence may be considered as a strain of the "*Candidatus Phytoplasma asteris*". In paprika, symptoms of leaf size reduction and yellowing, proliferation, and shortening of internodes were observed. The 16S rDNA sequences of phytoplasmas detected in these plants showed the highest identity of 99% with the members of phytoplasma group 16Sr III (X-disease).

In phyllody affected fennel plants first observed in Gujarat, India during 2003, the entire inflorescence is malformed and that gives witches' broom appearance. The peduncle is shortened and pedicel is enlarged measuring up to 10 cm. From individual flowers, further branching occurs and flower like structures are borne on long stalks. In some cases, the filament gets elongated up to 2 cm instead of normal 2 mm and produce sagitate anthers. At times part of the stamen is modified into leaf like structure and a single elongated anther lobe can be seen attached to a leaf like structure. On the basis of 16S rDNA sequence identity and phylogenetic relationship, it was concluded that fennel phytoplasma belongs to peanut witches' broom group and may be considered as a strain of the "*Candidatus Phytoplasma aurantifolia*".