List of Executive Summaries of Completed Projects under RE-Division

Sl. No.	File No. /Title of the Project	Name of the PI with full address
	E&WGP	
1.	23/10/94-RE Mapping Plant Diversity in the Eastern Ghats of Tamil Nadu	Dr. S John Britto SJ, Centre for Natural Resources Studies, St. Joseph's College, Tiruchirappalli 620 002, Tamilnadu E-mail: sjcbritto@rediffmail.com
2.	23/3/2002-RE Conservation through micro-propagation and restoration of Endemic, endangered and economically useful plants of the Kolli hills in the Eastern Ghats of Tamil Nadu	Dr. S John Britto SJ, St. Joseph's College The Rapinat Herbarium and Centre for Molecular Systematics, Tiruchirappalli 620 002,Tamilnadu E-mail: sjcbritto@rediffmail.com
3.	23/20/2005-RE Herbivorous arthropod fauna associated with some ferns of Western Ghats of Southern India	Dr. R. W. Alexander Jesudasan, Principal Investigator, Principal & Secretary, Madras Christian College (Autonomous) Chennai-600059. E-mail: alexjesu62@gmail.com principal@mcc.edu.in
4.	23/28/2005-RE Establishment of in vitro gene banks of Nothapodytes foetida (Wt.) Sleumer-A thereatened species of Western Ghats.	Prof. D.H. Tejavathi, Department of Botany, Bangalore University, Bangalore-560056. E-mail: tejavathi_hanu@yahoo.com
5.	23/36/2005-ERS/RE Biodiversity of mites associated with insects in Western Ghats	Dr. K. Ramaraju, Professor of Entomology, Department of Agricultural Entomology, Tamilnadu Agricultural University, Coimbatore-641003. E-mail: kunchiramaraju@yahoo.com
	ERS	
6.	14/40/2002-ERS/RE Status, ecology and conservation of striped hyena (Hyaena hyaena) in Gir National Park and Sanctuary	Prof. Jamal A. Khan, Secretary, Wildlife Society of India, Department of Wildlife Sciences, AMU, Aligarh-202002, (U.P). E-mail: secretarywsi@gmail.com
7.	14/75/2003-ERS/RE Restoration of Certain Mining Sites of Gujarat by Application of VAM Fungi	Prof. Arun Arya, P.I and Head, Department of Botany Faculty of Science, The Maharaja Sayajirao University of Baroda. E-mail: aryaarunarya@rediffmail.com
8.	14/40/2003-ERS/RE Regeneration and Tree Diversity Status along the Disturbance Gradient on Natural Oak (Quercus leucotrichophora A.Camus) Forests in Garhwal Himalaya.	Dr. D.S. Chauhan, Department of Forestry & Natural Resource, Post box-59, HNB Garhwal University, Srinagar Garhwal, Uttarakhand. E-mail: dschauhan2008@gmail.com
9.	14/26/2004-RE Diversity and Ecology of Mites Infesting Medicinal Plants of West Bengal.	Prof. Goutam Kumar Saha, Professor, Department of Zoology, University of Calcutta. E-mail: gkszoo@gmail.com
10.	14/17/2005-RE Diversity and Distribution of Asterinaceous Fungi in India	Dr. V.B. Hosagoudar, Scientist E1, Micro fungi & lichen unit, Tropical Botanic Garden and Research institute, Palode-

		695562, Thiruvananthapuram, Kerala.
	ERP	E-mail: hosagoudar@hot.mail.com
11.	19-6/2002-RE Recovery of value added products from shrimp processing waste.	Sachindra N.M, Scientist, Department of Meat, Fish & Poultry Technology, Central Food Technological Research Institute, Mysore-570020. E-mail: sachiprathi@yahoo.com
12.	19-26/2003-RE Effect of Coastal Water Quality on the Corrosion and Biofouling Characteristics of Marine Engineering Alloys	Dr. G. Subramanian, Scientist-in-Charge, Offshore Platform & Marine Electrochemistry Centre, CECRI Unit, New Harbour Area, V.O. Chidambaranar Port, Tuticorin-628004, Tamilnadu. E-mail: cgscorr@yahoo.co.in
13.	19-3/2004-RE Phyto-removal of heavy metals from industrial effluents.	Dr. Padma S. Vankar, Principal Research Scientist, Facility for Ecological and Analytical Testing, Indian Institute of Technology, Kanpur. E-mail: psv@iitk.ac.in, psvankar@lycos.com
	Policy Research	
14.	24/6/2005-RE Formulation of a sui generis Regime for Traditional Knowledge (Ethnobiology)	Prof. Dr. P. Pushpangadan, director General, Amity Institute for Herbal and Biotech Products Development, 3-Ravi Nagar, Peroorkada P.P, Thiruvananthapuram-695005. E-mail: palpuprakulam@yahoo.co.in
15.	24/8/2005-RE Valuation of Ecological Services of Wetlands in India	Dr. Krishna Mazumdar, Professor, Economic Research Unit, Indian Statistical Institute, 203, B.T. Road, Calcutta 700108. E-mail: mazumdar_Krishna@hotmail.com
16.	24/7/2005-RE Policy, institutional, and legal barriers to economic utilization of fly-ash	Shri S.K. Chand/Prima Madan (ex-TERI employee), TERI, IHC complex, Lodhi Road, New Delhi-110003. E-mail: skchand@teri.res.in
	NNRMS	
17.	13/3/97-EI/RE Evaluation of Natural Resources and Environment of the Koli Hills, Tamil Nadu using Remote Sensing and GIS	Dr. S. John Britto SJ, St. Joseph's College (Autonomous), Tiruchirappalli-620002, Tamilnadu. E-mail: sjcbritto@rediffmail.com
18.	13-20/2004-EI/RE Techniques of Survey and Planning for Conservation and Sustainable Use of Biodiversity in Mizoram, North Eastern Region	Dr. K.D. Singh, Ashoka Trust for Research in Ecology and Environment (ATREE), 1, K Block Commercial Complex, 2nd Floor, Birbal Road, Jangapura Extension, New Delhi-110014. E-mail: karan.singh@umb.edu

* For further details of the respective project may be contected to PI in their E-mail ID.

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Executive Summaries of Completed Projects under RE-Division

Eastern and Western Ghat Programme (E&WGP):-

1.	23/10/94-RE Mapping Plant Diversity in the Eastern Ghats of Tamil Nadu	Dr. S John Britto SJ, Centre for Natural Resources Studies, St. Joseph's College, Tiruchirappalli 620 002, Tamilnadu

1. Title of the Project : **Mapping Plant Diversity in the Eastern Ghats of Tamil Nadu**

2. Keywords : Mapping, Biodiverisy status, Eastern Ghats, Community structure, Species diversity, Abiotic Factors, Biodiversity Gap Analysis

3. Names and Address of Project Investigator

: PI: **Dr. S John Britto SJ**
Co-PI: **Dr. D.I. Arockiasamy**
Centre for Natural Resources Studies
St. Joseph's College (*Autonomous*),
Tiruchirappalli 620 002
Tamilnadu

4. Executive Summary of the results vis-à-vis objective envisaged originally

Mapping is a pre-requisite to setting priorities for conservation and monitoring of biodiversity and its components at local, national and regional levels. Mapping biodiversity requires intense ground truthing for verification and integration of various sets of data (spatial and non spatial) generated through various techniques.

Remote sensing (RS) and Geographical Information System (GIS) play a key role for mapping and monitoring biodiversity. The capabilities of Remote Sensing are greater than simply mapping habitat types, indeed, many of the factors of resource quality and quantity and of dynamic processes associated with biodiversity can be estimated from Remote Sensing data with integration of GIS. GIS methods have been effectively used to derive many resources based upon the ralationships of mapped environmental variables. GIS can also be used in such situations for sample design; the process of designing the GIS database naturally forms the basis for comprehensive assessments of the knowledge base of biodiversity.

In this context this project becomes meaningful and operational because of the application of RS and GIS. The objectives envisaged for the current project and as given below:

- To enlist the existing species of higher plants (Angiosperms, Gymnosperms and Pteridophytes), estimate their relative frequency and establish the associations, coincidences and dependence among them.
- To associate the variables of climate, topography, geomorphology and biodiversity
- To use geographical information system (GIS) in registering and analyzing the data obtained in all the above components and identify the biodiversity gaps.

The Eastern Ghats extend southwards into Tamil Nadu and cover parts of Dharmapuri, Salem, Vellore, Tiruchirappalli and Villupuram districts. The hill ranges of the

region are Javadi, Elagiri, Shervarayan, Chitteri, Kalrayan, Kolli and Pacchaimalai hills. These ranges form a broken chain of low, flat hills and the Ponnaiyar, Cauvery and Palar rivers dissect them.

Mapping Forest type

The forests exhibit ample diversity in their community structure. Mapping of forest cover is one of the foremost requirement of planners, management and conservation of forests. Remote sensing plays a key role for mapping and monitoring forest cover. The Eastern Ghat under study occupy an area of 5231.32 sq. km of which the forested area is 3511.2 sq.km (76%). The forest classification is based on Champion and Seth (1968). Dry Deciduous Scrub forests occupy a considerable amount of total forest area (43.94%) followed by Dry mixed deciduous (37%) and Semi-evergreen forest types (6.94%).

Mapping Biodiversity

The biodiversity analysis of the various forest ecosystems in Eastern Ghats reports that Dry Mixed Deciduous is the most diverse forest in most of the hills (Javadi, Elagigi, Shervarayan, Chitteri, Kalrayan and Pacchaimalai) except for Kolli hills where the intact Semi-Evergreen pockets boost of richer diversity. Ideally speaking well-balanced diversity is seen in Chitteri hills.

Species Interaction

Biotic associations between two or more species are called species interactions. Results show that in most of the reserved forests in the Eastern Ghats, *Anogiessus latifolia* and *Chloroxylon swietenia* are highly inter dependent on each other and likewise *Anogiessus latifolia* is associated with *Terminalia* species (either *Terminalia arjuna* or *T. bellirica*). In semi-evergreen forest *Nothopegia colebrookiana, Psydrax dicoccos* and *Memecylon edule* are interdependent on each other. In Dry mixed deciduous *Psydrax umbellatum is associated with Commiphora caudata* and Chloroxylon swietenia. This shows uniqueness in the associative patterns in the forests.

Species Diversity and Abiotic Factors

Considering the forest and abiotic factors and their confluence it is found that *Acacia-Anogeissus latifolia* series are found in medium rainfall zone (600-900 mm) and *Memechlon edule Alseodaphne semecarpifolia – Syzygium cumini* series with higher rainfall zone (> 1100). Analysis of Hydrogeomorphology describes forests thriving mostly in composity slopes and structural hill irrespective of the forest types. Riparian forest is confined to Valley fill and structural valley to lesser extent. Evergreen, Semi-Evergreen and Riparian forests are found in moderate and gentle slopes but Dry mixed deciduous, Southern thorn and Dry deciduous scrub are found in exposed steep slopes.

Biodiversity Gap Analysis

Results show that the biodiversity of the Eastern Ghats are vanishing at a faster rate and only in some hills they are (partially) maintained. Chitteri hills have the highest percentage of gaps area (31.0%) followed by Javadi (23.3%), Elagiri hills (16.7%), Shervarayans (7.33%) and Kolli hills (3.86%). Comparatively very less area is recognized as biodiversity gap in Kalrayans (1.0%) and Pacchaimalai hills (1.1%).

5. Results and Conclusions

High interest habitats like lush vegetations (Evergreen, Semi evergreen) Streams (Riparian forest) and highly diversified vegetative components like dry mixed deciduous forest. Habitats with severe human exploitation (1.5 km buffer). (Whilst the path and roadways crisscross at irregular intervals a smaller buffer predicts better zonation of potential hazards on vegetation)

The database which was used in this gap analysis comprise the vegetation, species richness map and Rare-endemic taxa distribution range maps. Results show that the biodiversity of the Eastern Ghats are vanishing at a faster rate than expected. Biodiversity

gaps of different hills are shown in. Only some hills are partially maintained, Chitteri hills have the highest percentage of gaps and area comes under (31.0%) followed by Javadi (23.3%) Elagiri hills (16.7%), Shervarayans (7.33%) and Kolli (3.86%). Very less area is represented as biodiversity gaps in Kalrayans (1.0%) followed by Pacchaimalai hills (1.1%).

6. Recommendation including usefulness of the findings and their application

The following findings are recommended for the use of researchers, Conservationists and foresters.

1. Forest type maps of Javadi Hills, Shervarayan Hills, Chitteri Hills, Kalrayan Hills, Kolli Hills and Pacchaimalai Hills.
2. Flora (families genera and species) of the six hills.
3. Quantitative analysis species richness, stand density, basal area, important value index, diversity index and rarity of trees, herbs and shrubs, in all forest types of six hills.
4. Consolidated account on biodiversity parameters for the six hills.
5. Biodiversity Plant Association Analysis by using Visual Basic 6.0 Microsoft Access 7.0 and Crystal reports adopted.
6. Data on species diversity in relation to abiotic factors.
7. List of plant species distributed in the Tamil Nadu Eastern Ghats and denoted their habit individually.
8. Data for each species on frequency, density, abundance, basal area, relative frequency, density, basal area and important value index.
9. Species interaction for each species in each forest type in all the six hills.
10. Digitized maps for (i) Rain fall; (ii) slope; (iii) drainage density; (iv) hydrogeology; are prepared for all the six hills. Totally twenty four maps are available.
11. Biodiversity gap analysis maps for all the six hills: (i) species richness; (ii) biodiversity gap. Twelve maps are thus available. Thus thirty six (24 + 12) digital products are valuable data for Temporal analysis of the Eastern Ghats.

7. Records of dissemination of project findings to stakeholders (publication in peer-reviewed journal/presented in workshop conference etc.

1. John Britto,S., Balaguru,B., Natarajan,D. and Arockiasamy,D.I. 2000. Studies on the enthnobotany and species diversity of the sacred groves at the foothills of Shevaroys, Eastern Ghats of Tamil Nadu - Journal of Hill Research. **13**: 130-135.

2. John Britto, S. 2000. Estimates of current status of forest types in Kolli hills using remote sensing. Indian Society of Remote Sensing **28** (2 & 3): 141-151.

3. John Britto, S., Soosairaj, S., Natarajan, D. and Arockiasamy, D.I. 2001. Phenology of Exotics and distribution of *Lantana camara* L. in two forest types of Pacchamalai hills. Geobios **28**: 236-238.

4. John Britto, S. 2002. Conserving forests in the Eastern Ghats through remote sensing and GIS – A case study in Kolli Hills. Current Science **82**(10): 1259-1267.

5. John Britto, S. 2002. Estimation of deforestation of forest cover using GIS: Biotic pressure on the forest cover changes in the Shervarayan Hills, Eastern Ghats of Tamil Nadu. Proceedings of the National Conference on IT Enabled Spatial Data Services. Bharathidasan University, Tiruchirappalli. pp: 295-303.

6. John Britto, S. 2002. *Euphorbia fusiformis* Buch. – Ham. ex D. Don (Euphorbiaceae): A new record for Tamil Nadu. J. Economic and Taxonomic Botany 26(2).

7. John Britto, S. 2002. Similarity analysis in two tropical dry evergreen forests in the Eastern Ghats of Tamil Nadu. Journal of Hill Research. **15**(1): 4-11.

8. Jayakumar,S., D.I.Arockiasamy and S.John Britto. 2002. Forest mapping and vegetation analysis in part of Kolli hills, Eastern Ghats of Tamil Nadu. Tropical Ecology **43**(2): 345-494.

9. John Britto,S., S.Soosairaj, B.Balaguru and D.I.Arockiasamy. 2003. Quantitative analysis of Non-timber forest products in four forest types of Pacchaimalai hills Eastern Ghats of Tamil Nadu. Indian Forester **129** (4): 489-494.

10. Balaguru,B., S.John Britto, N.Nagamurugan, D.Natarajan, S.Soosairaj, S.Ravipaul and D.I.Arockiasamy. 2003. Vegetation mapping and slope characteristics in Shervarayan hills, Eastern Ghats using remote sensing and GIS. Current Science **85** (5): 645-653.

11. Natarajan, D, B. Balaguru, S.John Britto, N.Nagamurugan, S.Soosairaj, and D.I.Arockiasamy. 2004. Identification of Conservation priority sites using Remote Sensing and GIS – A case study from Chitteri hills, Eastern Ghats of Tamil Nadu. Current Science **86** (9): 1316-1323.

12. Natarajan, D John Britto, S 2004. Assessment of Hydrogeomorphological Features with Vegetation Structure in the Chitteri Hills in the Eastern Ghats of Tamil Nadu using Remote Sensing Date. Asian Jr. of microbial. Biotech. Evn. Sci. Vol. **6** (4): 545-550.

13. John britto S, Balagru B Natarajan S Soosairaj S and Naamurugan N. 2004. – Ethnobotany of certain Sacred Groves in Tamil Nadu, South India – Journal of Tropical Medicinal Plants – **5**: 55-61.

14. Natarajan D, John Britto S Balaguru B, Nagamurugan N and Soosai Raj S. 2004. – distribution of Sacred Grove forests in the Chitteri Hills of the Eastern Ghats of Tamil Nadu – Indian J. Environment & Ecoplan – **8**: 375-379.

15. Balaguru, B., S John Britto, N. Nagamurugan, D. Natarajan and S. Soosairaj 2006. Identifying conservation priority zones for effective management of tropical forests in Eastern Ghats of India, Biodiversity and Conservation Vol.15: 1529-1543.

16. Natarajan D, Balaguru B, John Britto S, Nagamurugan N, Soosairaj S and Arockiasamy DI. 2004. – Identification of Conservation priority sites using Remote Sensing and Gis:

A case study from Chitteri Hills, Eastern Ghats of TamilNadu – current Science – **86**: 1316-1323.

17. Soosairaj S John Britto S, Balaguru B, Nagamurugan N and Natarajan D. 2004. – Mapping forest Types of Pacchaimalai Hills, Eastern Ghats, India: Using remote Sensing and GIS: Ecology, Environment & Conservation – **10**: 131-135.
18. Soosairaj S John Britto S, Balagru B, Nagamurugan N and Natarajan D 2005. Habitatat Similarity and species distribution analysis in Tropical forests of Eastern Ghats, Tamil Nadu, *Tropical Ecology* **46**: 2.
19. D. Natarajan S. John Britto, K Srinivasan, N. Nagamurugan, C. Mohanasundari and G. Perumal 2005. Anti-bacterial activity of Euphorbia fusiformis – A rare medicinal herb, Journal of Ethnopharmacology vol. **102** (1): 123-126.

8. Total cost of the project and releases made (in `.) `. 10,68,075

2.	23/3/2002-RE Conservation through micro-propagation and restoration of Endemic, endangered and economically useful plants of the Kolli hills in the Eastern Ghats of Tamil Nadu	Dr. S John Britto SJ, St. Joseph's College The Rapinat Herbarium and Centre for Molecular Systematics, Tiruchirappalli 620 002,Tamilnadu

1. Title of the Project : **Conservation through micro-propagation and restoration of Endemic, endangered an economically useful plants of the Kolli hills in the Eastern Ghats of Tamil Nadu**

2. Keywords : Micropropagation, *In vitro* regeneration, Explants, Acclimatization, Kolli hills, Endemic, Endangered and economically useful plants

3. Names and Address of Project Investigator

: PI: **Dr. S John Britto SJ**
St. Joseph's College (*Autonomous*)
The Rapinat Herbarium and
centre for Molecular Systematics
Tiruchirappalli 620 002
Tamilnadu

4. Executive Summary of the results vis-à-vis objective envisaged originally

The Indian subcontinent has rightly been declared as one of the mega biodiversity centres, because of its abundant bioresources. However owing to severe exploitation and the large scale destruction of original habitats, several valuable species in the hot spots of the country are facing severe threat leading to possible decimation in the future. Indiscriminate destructive collection from the wild is one of the reasons for their predicament. There is a concerted effort by the Governments at the Centre and the States to promote conservation both at the *in situ* and *ex situ* levels. Even before the promulgation of the convention on biological diversity, our country had already begun the process of documentation of the threatened plants and focused attention on their conservation and started planning for strategies for regeneration and reestablishment in the wild. Setting of conservation priority sites has also been taken up recently and subsequently arrived at Rare, endemic and critically endangered species can be saved especially through Micropropagation which serve as one of the effective means to conserve plants threatened with extinction. This project intends to adopt the same strategy on a select 12 important species from the Kolli hills which are considered critical with regard to their continual survival in wild, and are chosen because of their restricted nature and significance from biological therapeutic and economic values.

5. Results and Conclusions

In vitro multiple shoot regeneration of *Moringa concanensis* has been accomplished from hypocotyls explants on MS medium containing BAP and NAA individually and in combination. BAP alone produced 84% frequency of shoots at 2.5 mg/l and BAP with NAA 66% frequency of shoots at 0.4 + 0.4 mg/l. Highest root frequency was achieved at 0.3 mg/l of IBA. With shoot tip explants MS medium with BAP at 0.2 mg/l gave 92% shoot regeneration; KIN at 0.3 mg/l resulted in 84% regeneration. MS medium in combination of

BAP + NAA at 0.2 = 0.2 mg/l yielded 88% shoot regenerating while KIN + NAA gave 88% frequency at 0.3 +0.3 mg/l concentration. BAP+GA3 at 0.3 +0.3 mg/l yielded 88% multiple shoots and KIN =GA3 at 0.3=0.3 yielded 84% shoot regeneration. Using nodal explants, BAP alone at 0.2 mg/l effected 88% shoot regeneration; KIN at 0.3 mg/l 94% regeneration; 2, 4-D at 0.4 mg/l 94% shoot regeneration. The nodes in combination of BAP+NAA at 0.3 +0.3 mg/l effected 88% shoot regeneration; KIN+GA3 at 0.2+0.2 mg/l 88% shoot regeneration. An efficient protocol for rooting also has been evolved.

In vitro multiple shoot regeneration has been effected for *Pseudarthria viscida* through cotyledonary node, shoot tip and nodal explants from *in vitro* seedlings. From BAP, KIN and GA3 supplemented in MS medium individually BAP (1.5-2.5 mg/l) reproduce maximum percentage of shot frequency in cotyledonary nodal explants. IBA at 0,2 mg/l yielded 82 % response in rooting. From nodal explants between BAP and KIN individually BAP (2.0 mg/l) gave 84% shoot frequency; BAP + NAA (0.3 +0.07 mg/l) gave 62% shoot frequency. The IBA (0.3 mg/l) yielded 72% rooting frequency. For shoot tip explants, in MS medium supplemented with BAP, KIN, 2, 4-D individually, BAP (0.2 mg/l) 92% shoot frequency, 2, 4-D (0.3 mg/l) 92% shoot frequency, KIN (0.2 mg/l 88% frequency. For rooting 72% frequency was achieved at 0.2 mg/l/.

Using shoot tip explants, with BAP, KIN, 2, 4-D individually, the results of shoot multiplication were the same as that of nodal explants. The combination of BAP + NAA (0.3+0.03) had 96% shoot multiplication; KIN = GA3 (0.3 +0.03) yielded 92% Highest rooting frequency with IBA (0.6) was 96% and highest root elongation with IBA (0.6) was 96%.

In *Merremia turpethum*, among the cotyledonary mode and shoot tip explants, using MS medium supplemented with BAP, KIN, IAA individually, cotyledonary node in KIN (1.5 mg/l) yielded 92% shoot frequency and rooting in IBA (0.3 mg/l) 90% rooting frequency. For shoot tip explants, among BAP, KIN, IAA, the result was the highest for KIN only and for rooting in IBA and NAA, only IBA (0.3 mg/l) achieved 90% frequency. For the nodal explants, the highest shoot frequency (90%) was achieved in KIN at 1.5 mg/l. For rooting from NAA IBA, only IBA in 2.0 mg/l achieved 78% rooting frequency.

For *Emilia zeylanica* from nodal explant, among BAP, KIN, GA_3, only GA_3 (0.1 mg/l) achieved 96% shooting frequency, followed by BAP (0.1) with 90% Results from inflores- cence nodal explants with BAP, NAA individually and BAP + NAA in combination showed BAP (0.5) with 96% shoot frequency, NAA (0.05) with 96% while BAP + NAA (0.05) with 94% Root induction for NAA in 0.5 mg/l was 86% with IBA in 0.10 mg/l with 90%.

A reproducible Micropropagation has been successively achieved in *Plectranthus barbatus* using node, shoot tip and internodal explants for induction of multiple shoots:

Node:	BAP	: 3.0 mg/l	76% shoots
	NAA	: 2.0 mg/l	60% shoots
	BAP+ NAA	: 2.0+2.0 mg/l	92% shoots
	IBA + NAA	: 3.0+NAA	84% rooting
Shoot tips:	BAP	: 3.0 mg/l	68% shoots
	NAA	: 2.0 mg/l	52% shoots
	BAP+NAA	: 2.0+2.0 mg/l	84% shoots
	IBA+NAA	: 3.0+1.5 mg/l	84% rooting
Internode:	BAP+NAA	: 4.44+0.5 mg/l	88% shoots
	IBA	: 2.22 Mg/l	96% rooting

In *Cayratia pedata* a protocol for rapid *in vitro* propagation has been achieved using shoot tip and node as explants.

Shoot tip	BAP+KIN	: 3.0+1.5mg/l	92%	shoots
	IBA	: 1.6 mg/l	92%	rooting
	NAA	: 1.6 mg/l	80%	rooting
	IBA+NAA	: 2.2+1.0 mg/l	88%	rooting
Node	BAP	: 2.0 mg/l	84%	shoots
	KIN	: 1.5 mg/l	80%	shoots
	NAA	: 1.0 mg/l	80%	shoots
	BAP+KIN	: 3.0+1.5 mg/l	92%	shoots
	IBA	: 1.0 mg/l	92%	rooting
	IAA	: 1.6 mg/l	84%	rooting
	IBA+IAA	: 1.6+1.0 mg/l	88%	rooting

In *Canvalia mollis*, *in vitro* propagation has been accomplished using nodal and shoot tip explants.

Node	BAP	:0.8 mg/l	92%	shoots
	GA3	0.2 mg/l	92%	shoots
	BAP+KIN :	0.4+0.2	92%	shoots
	BAP+NAA:	1+0.7	92%	shoots
	IBA :	0,4 mg/l	84%	rooting
Shoot tip	BAP :	1.5 mg/l	86%	shoots
	KIN :	2.0 mg/l	88%	shoots
	NAA :	2.0	80%	shoots
	BAP +KIN :	1.0+2.0	92%	shoots

In vitro Micropropagation has been evolved for *Celastrus paniculatus* using shoot tip, node, internode and petiole as explants

Shoot tip node	BAP	: 1.0 mg/l	92%	shoots
	KIN	: 0.5 mg/l	80%	shoots
	NAA	: 1.0 mg/l	84%	shoots
	IAA	: 1.0 mg/l	84%	shoots
	IBA	: 1.0 mg/l	70%	roots
	IAA	: 1.5 mg/l	90%	roots
Internode	BAP	2.0 mg/l	94%	shoots
	KIN	1.0 mg/l	88%	shoots
	IAA	1.0 mg/l	92%	roots
	IBA	0.1 mg/l	87%	roots
	NAA	0.1 mg/l	93%	roots
Petiole	BAP	2.0 mg/l	83%	shoots
	KIN	4.0 mg/l	94%	shoots

In vitro Micropropagation protocol has been successfully accomplished for *Pueraria phaseoloides, by* using Hypocotyl, Cotyledon and Cotyledonary node maximum percentage.

In *Strychnos colubrina* and *Salacia reticulata* effective protocols for *in vitro* regeneration has been achieved by using Shoot tip and Nodal explants.

In vitro propagation for *Caesalpinia bonduc* has been achieved by using stem and pulvinus explants.

6. Recommendation including usefulness of the findings and their application

Restoration

Data obtained in this project in all species in this project reinvigorate the feasibility of using nodal and shoot tip explants for successful callus free axillary bud proliferation and clonal multiplication of species that are threatened, endemic and endangered. During the tenure of the project, the regenerated plants have been handed over to the Forest Department operating in the kolli hills. The Principal investigator and his research team have reestablished them in the shola forests and grasslands (for herbs) adjacent to solakaadu hamlet since they are easily accessible for regular monitoring. Some regenerated plants have been sheltered in the Sacred Grove areas with the understanding reached with local villages. About 80-9.2% percentage of these plants have been successfully established with least disturbance to natural vegetation.

The imperative need for using every available technology including plant tissue culture to assist in augmenting this endangered or threatened resource has long been recognized for effective *ex situ* curation of given species, an integrated programme comprising propagation of large number of plants using seed and vegetable sources including plant tissue culture, reintroduction and restoration are important. The present investigation has successfully reintroduced and restored selected eleven taxa.

Likely impact of the work on the scientific potential of our country

1. There is a global recognition that India as one of the mega diversity entres in the world possesses enormous wealth of bioresources in its reserved forests. However with the fast degradation of virgin forests, diversity of hot spot regions has diminished and needs to be conserved. Micropropagation is a handy tool to propagate the critically endangered and vulnerable species and together with restoration aspects, the latter specie will be back again in original habitats.

2. State Governments especially the Tamil Nadu government through its research wing in the Forest Department is looking for protocols for reestablishment of the endemic and endangered plants. This project will prove as an essential component in the restoration scheme with native species.

3. Several of the species cited in the Red Lists of the country and of FRLHT have been decimated because they have been harvested in the wild for economical, commercial and medicinal exploitation. To arrest this trend and to offer alternate means Micropropagation techniques offer better methods and means for productions of rapid propagules.

4. Besides offering benefit as conservation measures, tissue culture techniques for these plants will help in the extraction of increased quantity of secondary metabolites which will be exploited by the pharmaceutical industry.

5. Consistent use of Micropropagation in plants of horticultural / floricultural / medicinal value has a great potential in transformation of wastelands into production zones, besides offering employment opportunity to several low-income groups.

In fine these species also have genetic value as they are endemic regionally or nationally. Their gene pool irrespective of their usefulness or otherwise is restored to posterity as a valuable asset. With the development of rapid multiplication protocols for *ex situ* conservation of rare and critically endangered plants, conservation of these precious plants is assured.

1. Forest department of State and Central Governments can apply the protocols for restoration of degraded forests under their control.
2. Afforestation departments of various State Governments can avail the technology.
3. Departments of the Indigenous systems of medicine can use this technology to procure plant materials.
4. Wasteland Development Boards at various levels can employ the technology
5. NGOs and voluntary organizations can make use of the technology to provide employment opportunities to rural masses, in large scale cultivation.
6. Self-help groups can use these technologies for earning their livelihood.

Conservation biologists of various universities and national laboratories can easily apply the technology to other endangered plants.

7. Records of dissemination of project findings to stakeholders (publication in peer-reviewed journal/presented in workshop conference etc.

1. **Philip Robinson, J., S. John Britto, Joseph Sebastinraj, D. Vinothkumar and S. SenthilKumar 2006**. Micropropagation of *Emilia zeylanica* C.B.Clarke, by using explants of inflorescence rachis *J. Biological Research* Vol. **5**: 109-113.
2. **Vinothkumar,D.**, **John Britto, S. Sebastinraj,J. Philip Robinson, J. and S. Senthilkumar**. 2009. *Callus regeneration from stem explants of Pseudarthira viscid (L.) Wight and Arn. – a vulnerable medicinal plant* African Journal of Biotechnology **8**: (17). pp 4048-41, 1 September 2009.
3. **Philip Robinson, J. John Britto, S and S. Senthilkumar**. 2009. *Comparative Anatomical Studies on Emilia zeylanica C. B. Clarke with in vitro Regenerated Plants.* Middle-East Journal of Scientific Research **4** (3): 140-143, 2009 ISSN 1990-9233 © **IDOSI** Publications

8. Total cost of the project and releases made (in `.) `. 17,74,560.

3.	23/20/2005-RE Herbivorous arthropod fauna associated with some ferns of Western Ghats of Southern India	Dr. R. W. Alexander Jesudasan, Principal Investigator, Principal & Secretary, Madras Christian College (Autonomous) Chennai-600059.

1. Title of the Project

Herbivorus arthropod fauna associated with some ferns of Western Ghats of Southern India

2. Key Words

Herbivorus arthropod fauna, ferns, Western Ghats, Southern India

3. Name and address of Project Investigator

Dr. R. W. Alexander Jesudasan,
Principal Investigator
Principal & Secretary
Madras Christian college

(Autonomous)

Chennai 600 059

4. Executive Summary

Around 73 species of ferns were identified of which 35 species were found to be associated with herbivorous arthropods. Among the 35 species, 17 ferns were of medicinal importance. The dominant insect herbivores were *Labioproctus poleii Green, Saissetia coffeae* Walker, *Heliothrips haemorrhoidalis* Bouche, *Selenothrips rubrocinctus* Giard, *, Pyrrarchtia isabella* Walker, *Schenklingia* sp., *Chrysophtharta* sp. and *Apion cyanitinctum.* Representaties of fern families Thelypteridaceae, Pteridaceae, Aspleniaceae, Dennstadiaceae, Blechnaceae, Dryopteidaceae and Athyriaceae were found to show maximum association with arthropods.

Biology of *Callopistria duplicans* on the host plants *Christella parasitica* and *Christella dentate* w was studied. They were not gregarious and were found to feed on *Christella parasitica* and *Christella dentate* and rarely on *Pteris biaurita.* In case of *P.isabella,* they were found to feed on host plants *Pteridium aquilinum, Diplazium esculentum* and *Nephrolepis multiflora.* The duration of different stages of all the four laral instars showed statistically significant difference. The larval instars of *P.isabella* were voracious and polyphagous feeders. While studying the lifecycle of S. coffeae on *Asplenium polyodon* and *Polystichium moluccense* an interesting observation was made. The honeydew secreted by the nymphs and adult of the scale invited species of ants such as *Tachynomyrmex* sp. That fed on the honey dew. This protected the fern and also the scale from other predators thus allowing the scale to multiply in great numbers. During the course of studying *L. poleii*, male of the *L. poleii* was observed and recorded for the first time in India. The brightly brick coloured male had a prepupal stage before being transformed into the adult and this phase was spent inside the cocoon.

Feeding damage analysis revealed that the damage was more in the pre-monsoon period than post-monsoon. Statistical analysis of the feeding damage by the mealy bug, *L. poleii* revealed that there was significant difference in the consumption rate between young and matured leaves in pre-monsoon period whereas in post-monsoon there was no significant difference. In the Pre-monsoon they preferred mature leaves whereas in the post-monsoon they preferred the young. The grasshopper *Chitura* sp. Caused maximum damage to both young and matured leaves in pre-monsoon than the post-monsoon.

In the pre-monsoon, the Hemiptera and Coleoptera caused the highest percentage (32%) of infestation whereas in post-monsoon though Hemipterans maintained the same trend, the Orthopterans showed greater strength (26%) followed by Coleopterans.

Goniozus sp. (Bethylidae: Hymenoptera), a gregarious ecto-parasitoid was found to parasitize *P. isabella* collected from Kerala in the year 2007 in the post-monsoon period. The Bethylidae is a family that is distributed worldwide, from the tropics to the sub-Artic regions (Terayama, 2003).

Macromesus sp. was found to parasitize the *H. bipunctalis* larva inside the nest constructed by the larva. The larva was paralyzed and did not grow. It showed sluggish movement and finally the larvae of the hymenopteran ruptured the lepidopteran skin and projected out with its base attached to the lepidopteran body. Among the four, *Campyloneura* sp. was found in abundance and was found to effectively reduce the thrips infestation. The next significant predator is *Rodolia amabilis* Kapur as they found to feed on the nymphs of the mealy bug, *L. poleii. L.poleii* has been reported to infest *Citrus sinensis* and Mangoes (USDA, 2006) in India and thus this coccinellid beetle could be a good biocontrol agent. Though parasitoids were observed their population was too low to be mass reared and studied.

Considering the inadequacy existing in the knowledge of the herbivorous arthropods infesting ferns such an in depth study was initiated. Information accrued on this line of investigation in the past has been comprehensively documented in the study and the lacunae have been addressed.

5. Results & Conclusions

A study of this magnitude gains paramount importance since pteridophytes are interesting group of flora, a few number of this group have appeared in serious dimensions in some ecological zones leading to devastation. One such example is of the invasive climbing fern, whose origin is from south-east Asian countries and has become an invasive weed in moist habitat viz., Southern Florida (Pemberton and Ferriter, 1998) and classified as a category I invasive species by Florida Weed Council (Langeland and Burks, 1998). This fern was found to be naturalized in Florida in 1965, and later had explosive growth and spread rapidly, and started to dominate over the native vegetation. Considering the harmful effects of use of synthetic herbicides in the control of invasive weed *Lygodium microphyllum* on the environment, an exploration of herbivorous arthropods foraging this fern was carried out. Such instances can be suitably encountered using appropriate agents, which can biologically eliminate the fern weeds. Fern species that were previously targeted in biological control programme includes Bracken fern, *Pteridium aquilinum* (Kirk, 1977) and red water fern, *Azolla filiculoides* (Hill, 1998). The weevil, *Stenopelmus rufinasus* Gyllenhal was released in South Africa to control red water fern, and the initial results were found to be promising (Hill, 1999). This weevil was originally collected from *Azolla caroliniana* Willd in Florida. Thus the need for controlling the weeds or invasive plants using the herbivorous arthropods formed a basis for the present venture

6. Recommendations and usefulness of the findings and their application:

A study of this magnitude gains paramount importance since pteridophytes are interesting group of flora, a few number of this group have appeared in serious dimensions in some ecological zones leading to devastation. Invasive species such as *Aleurodicus dispersus*, Eryophid mite and *Bemisia tabaci* (B biotype) and weeds such as *Proscopsis* have entered our country and are now posing threat to agriculture and environment. Such instances can be suitably encountered using appropriate agents, which can biologically eliminate the fern weeds. Detailed investigations on these lines including the biochemical interactions are essential in order to advise environmentalists in making suitable decisions. Further, attempts should be made to record biological control agent against the invasive species so that efforts could be made to stock them for multiplication and release them for the control of invasive species after performing relevant experiments in regard to the safety of such organisms to the environment and also obtaining necessary clearance from appropriate bodies such as the National Biodiversity Authority.. This strategy would ensure minimizing our dependence on synthetic organic chemicals for pest control and maximizing our reliance on biological control of invasive and other pests of importance.

Si. No.	Sub-heads	Amount
1.	**Salary**	**6,16,880**
2.	Permanent equipment	2,50,000
3.	Expendable	50,000
4.	Travel	1,25,000
5.	Contingency	50,000
6.	**Institution charges**	**1,54,944**
	Total	**12,46,824**

7. Records of dissemination of project findings

In this study it was observed that certain species of ferns are least affected by herbivorous arthropods. This gives a cue that these ferns have some insect repellant properties which could be exploited to control the household and agricultural pests. It has been observed that the residents of Coorg have been using ferns like *Pteridium aquilinum* extracts for treating gastro-intestinal problems. The pharmacological companies may explore this resource to develop a product to act against gastro – intestinal diseases.

Duration of the Project : Three years

Date of Commencement : 17. 04. 2006

Date of completion : 16. 04. 2009

8. Total cost of the project.

Revised

Releases made:

I instalment Rs.3,40,000

II instalment	Rs.1,65,000
III instalment	Rs.1,54,000
IVinstalment	Rs.1,39,000
V instalment	Rs.2,05,000
Total Rs.10,03,000	

4.	23/28/2005-RE Establishment of in vitro gene banks of Nothapodytes foetida (Wt.) Sleumer-A thereatened species of Western Ghats.	Prof. D.H. Tejavathi, Department of Botany, Bangalore University, Bangalore-560056.

1. Title of the project : Establishment of *in vitro* gene banks of *Nothapodytes foetida* (Wt.) Sleumer-A threatened species of Western Ghats.

2. Key words : Seed germination, Micropropagation, Somatic embryogenesis, In vitro Gene Banks, *Nothapodytes foetida*

3. Name and Address of Principal Investigator : Prof. D.H.Tejavathi, Department of Botany, Bangalore University, Bangalore-560 056.

4. Executive Summary of the results vis-à-vis objective envisaged originally:

Nothapodytes foetida, a member of Icacinaceae, is one of the important medicinal plants having the potential to cure several types of cancers and also found to be effective in the treatment of HIV. Mature seeds were collected from four different regions all along the Western Ghats. ***In vitro*** techniques were employed to establish ***in vitro*** gene banks of this threatened taxon of the Western Ghats. In addition to ***in vitro*** techniques, seed germination studies were also carried out by subjecting the recalcitrant seeds to mechanical, acid and hormone treatments. Among all the treatments tried, germinating the seeds aseptically on paper bridges in test tubes and incubation in the desiccators on wet filter paper proved to be best for maximum percent of germination. However, GA_3 treatments were effective in reducing the time taken for the initiation of germination. Seeds from Ooty accessions showed higher percent of germination compared to Mahabaleshwar, Bisle ghat and B.R.Hills. Estimation of phenolics in the seeds of all four accessions substantiates this result by showing low phenols contents in the seeds of Ooty accessions.. Several explants like mature embryos, leaf, seed and hypocotyl segments were used to raise the cultures. Embryos were responded better in the culture conditions in respect of number of multiple shoots produced. The explants were inoculated onto Murashige and Skoog's, Phillips and Collins leguminous and Modified Murashige and Skoog's media supplemented with various growth regulators. Three different types of ***in vitro*** propagule multiplications such as proliferation of multiple shoots from the shoot apical meristem, differentiation of shoots from callus cultures and induction of

somatic embryos from the cultures were obtained. Among all the growth regulators, the presence of Thidiazuron (TDZ) promoted both proliferation of shoots from the shoot apical region of the young seedling and also differentiation of shoots from the callus which was induced at the transition zone of hypocotyl and primary root. The best hormone combination for shoot proliferation and differentiation of shoots from callus were found to be L_2 + TDZ and L_2 + TDZ + BAP + L-glutamine respectively. While somatic embryos were differentiated when the embryo derived callus on MS + 2.4-D + Kin transfer to L_2 + TDZ + BAP + L-glutamine. Thus obtained shoots were transferred to MS/MMS + IBA for rooting and elongation. Rooted plantlets were transferred to small plastic cups containing soil rite for acclimatization and covered with perforated plastic bags to maintain humidity. They were then transferred to pots containing soil: sand: manure mixture in 1:1:1 ratio. Embryos and shoot apices from the young seedlings were encapsulated in sodium alginate and were stored at varying temperatures ranges from 5°C to -20°C. Their viability was tested at different intervals.

5. Results and Conclusions:

Highlights of the Results achieved in the project:

a) Effective protocol is developed for shoot proliferation from the embryo culture.

b) Effective reproducible protocol is developed for organogenesis through callus cultures for the **First time**.

c) Somatic embryogenesis from callus cultures is standardized.

d) Production of synseeds of embryos and shoot apices is optimized for the **First time**

e) Best treatments for maximum percent of seed germination are identified and causes for seed coat imposing dormancy are analyzed for the **First time.**

f) Camptothecin contents of cultures and seeds were qualitatively and quantitatively analyzed by HPLC.

Conclusion

The main aim of the project was to conserve the natural resources of *Nothapodytes foetida* which is categorized as threatened species through conventional as well as *in vitro* techniques. It is estimated that over the last decade there has been a 20% decline of the natural populations of this species in the Western Ghats. Though there are a few reports on the contents of CPT in various parts of the plants, *in vitro* studies are negligible. During the past few decades, efficient and reproducible micropropagation protocols have developed for especially herbaceous taxa. Still many tree species remain to be exploited through *in vitro* techniques since most of the tree species are recalcitrant for culture conditions. In the present study, both direct and indirect regeneration of the shoots (**First time report**) along with somatic embryogenesis from the embryo cultures was possible and *in vitro* gene banks are successfully established.

6. Recommendation including usefulness of the findings and their application:

Nothapodytes foetida is a good source of the anticancer drug Camptothecin. The germination studies that were carried out in the present studies can be adopted by the organizations both NGO and Government including Forest Department to raise the healthy seedlings from these recalcitrant seeds. The *in vitro* studies that were standardized in the present investigations can be employed to multiply the elite accessions. Establishment of effective in vitro protocols for mass multiplication is one of the alternate sources for researchers, farmers and forest

department who wish to domesticate or raise plantations of this taxon. These studies can be exploited further for extraction of camptothecin from callus cultures. Embryos of these elite accessions can be stored for long time as synseeds or artificial seeds as a means of conservation.

7. Records of dissemination of project findings to stakeholders (Publication in peer-reviewed journals/presented in workshop, conference etc. :

Publications

1. Induction of multiple shoots from the embryo cultures of *Nothapodytes foetida* (Wt.)Sleumer. The Journal of Swamy Botanical Club (in press).
2. Organogenesis from the cultures of Nothapodytes foetida (wt.) Sleumer raised on TDZ supplemented media. Indian Journal of Biotechnology (in press).
3. Evaluation of different treatments to improve the seed germination among the populations of *Nothapodytes foetida*. Communicated to Indian Journal of Plant Physiology.

Workshops attended

Conferences/Seminars

1. *In vitro* morphogenetic studies in *Nothapodytes foetida* (Wt.) sleumer .IV Global Summit, 1st - 5th Dec 2009, Kuching, Sarawak, Malaysia. **Best Poster Award**.
2. *In vitro* conservation strategies for *Notahpodytes foetida* (Wt.) Sleumer .32nd All India Botanical Conference and International symposium on "Diversity of plants and microbes: Present Scenario" 28-30 Dec, 2009. Kuvempu University, Shankaraghatta.
3. Micropropagation of *Nothapodytes foetida* (Wt.) Sleumer-A Threatened medicinal plant. National conference on Developmental Biology-NACON D BIO 2010, 15 to 17 Sept.2010, Bangalore. Paper presented, **Best Paper Presentation Award**.

8. Total cost of the Project and releases made (In Rs.):

Funds Received: **Rs. 8,58,017**

Funds yet to receive: **Rs. 3,07,538**

Total: **Rs. 11,65,555**

5.	23/36/2005-ERS/RE Biodiversity of mites associated with insects in Western Ghats	Dr. K. Ramaraju, Professor of Entomology, Department of Agricultural Entomology, Tamilnadu Agricultural University, Coimbatore-641003. E-mail: kunchiramaraju@yahoo.com

1. Title of the Project

"Biodiversity of mites associated with insects in Western Ghats"

2. Keywords

Western Ghats, Insect mites, biodiversity, biodiversity indices

3. Names and Address of the Project Investigator

Dr. K. Ramaraju
Professor of Entomology,
Department of Agricultural Entomology,
Tamil Nadu Agricultural University,
Coimbatore - 641003.

4. Executive Summary of the results vis-à-vis objective envisaged originally

A. Introduction

Biodiversity has become an increasingly important topic within ecology. It is indisputable that levels of biological diversity are decreasing worldwide due to human activities, although it is difficult to quantify this trend by simply making lists of species that have become extinct. Lack of knowledge of pre existing diversity hampers our ability to record such trends numerically. Many claim that more diverse ecosystems are more productive. Mites occupy varied habits and habitats. In forests they greatly outnumber all other arthropods. Their association with other animals includes phoresy and commensalisms to active parasitism. At present, it is known that over 1000 mite species are carried over by 1400 hosts. Species of prostigmatid mite's *viz.,* Erythraeids, Trombidids, Tarsonemids, Podapolipids, Iolinids, Acarids and Ascids are parasitic on insects. The predatory group includes Macrochelidae, Parasitidae, Cheyletidae, Pyemotidae and Hemisarcoptidae families. A few species are endoparasitic on grasshoppers, cockroaches and bees etc,. Biodiversity and taxonomic work on insect mites is very meagre in India. Hence, it is necessary to study the diversity of mites associated with insects. Considering our rich fauna, (widely unexploited) there is a vast scope for the study of insect associated mites in Western Ghats. With this view, the present project was undertaken with the following objectives.

B. Objectives

- To survey, collect and study the mites that are associated with the insects in Western Ghats region.
- To identify, describe and fix the taxonomic position of the collected mites.
- To study the Biodiversity indices of a few major group of mites

C. Work done

The study was conducted in 19 different locations *viz.* Anaikatti, Attakatti, Coonoor, Maruthamalai, Mettupalayam, Mudumalai, Ooty, Sirumugai, Siruvani and Valparai in Tamil Nadu region; Agali, Bodi Mettu, Kumuli, Pampadumpara, Mulli, Munnar and Myladumpara and Thekkadi in Kerala region and Dimbam in Karnataka border of Western Ghats. The live insects collected from various collection methods were anaesthetized and stored in glass vials and insect collection store boxes with all collection details. Initially, all the insect specimens were examined for the presence of mites under a stereozoom binocular microscope. The point of attachment of mites to various body parts of insect specimens *viz*., wing bases, legs, leg joints, acarinarium, elytra, abdominal cavities and head regions were observed. Hoyer's medium was used and permanent slides were prepared for detailed taxonomic study. Photographs were taken using image analyzer and camera for easy identification up to family level. In case of new mite species, the dorsum, ventrum, legs, gnathosoma and other striking characters were drawn using a drawing tube for new species. Then, the measurements of the important taxonomic structures of mite specimens were made with the help of a calibrated ocular micrometer and expressed in microns. Identification and fixing of the systematic position was undertaken with the help of all the available literatures and the descriptions. All the measurements made in this study have been reported in microns. In some cases, taxonomic specialists were also consulted for identification. The Bio-diversity Indices *viz.,* Richness index, Diversity indices (Shannon-Weiner index, Simpson-Yule index, Renyi diversity ordering) Species evenness or Equitability and Similarity index were worked out to assess and compare the diversity of Acari-Insect association.

D. Results/findings

a. Acari-insect association revealed that phoretic association was the most predominant one with 67 per cent *i.e*., 24 mite genera/species, followed by parasitic and predatory with 30 (9) and 3 per cent (1), respectively.

b. Thirty-four mite genera belonging to 16 families under 3 suborders of acari were recorded. Maximum numbers of mites (1277) were collected from Mettupalayam forest area followed by Siruvani (1274), Maruthamalai (1060) and Mudumalai (742).

c. Among 34 species, *Leptus* spp. was the most abundant (1456) than others, which was followed by *Macrocheles muscadomesticae* (810), *Neocypholaelaps indica* (762), *Sennertia carpenteri* (552), *Blattisocius* sp. (548) , *Neocypholaelaps* stridulans (469) and *Fuscuropoda* sp. (412), *Grandiella batocerae* (365), *Podapolipoides nitidulae* (328) and *Charletonia* sp. (317).

d. Maximum number of genera (18) were recorded in the suborder Mesostigmata followed by Prostigmata (9) and Astigmata (7).
e. Maximum species richness was observed in Siruvani with 26 genera (3.4965), followed by Mettupalayam (24) and minimum in Annaikatti (7) with a richness index of 1.1007 as per the Margalef index. In Kerala region, Munnar (1.9354) and Mulli (1.9212) recorded maximum species richness.
f. Renyi diversity ordering showed maximum diversity in Siruvani and minimum in Myladumpara.
g. Maximum mite evenness was observed in Mettupalayam followed by Siruvani and minimum evenness in Annaikatti. Similarly, evenness was high in Mulli and Myladumpara in Kerala region.

h. The dendrogram separated 19 locations into four major clusters at 0.60 similarity level. The similarity coefficient values of the localities ranged from 0.32 to 0.91. The mites associated with insects collected from Anaikatti and Agali showed the highest similarity index of 0.91. Next major cluster included Valparai and Mulli locations with the similarity coefficient of 0.82.

i. Maximum number of mites was observed from Coleoptera (3700) and Hymenoptera (3593). The species richness, diversity and evenness were high in Coleoptera, followed by Hymenoptera and low in Odonata.

j. Among the insect families Apidae (2932) (Hymenoptera), Cerambycidae (1522) (Coleoptera), Acrididae (1473) (Orthoptera), Scarabaeidae (926) (Coleoptera) harbours more mites.

k. Curculionidae recorded only 11 genera, with higher richness, diversity and evenness when compared to more number of genera recorded in Cerambycidae (13). This may be due to the abundance nature of mites associated with Curculionidae.

l. Among the three suborders, Mesostigmata recorded to be associated with more number of mites (5625) followed by Prostigmata (3025) and Astigmata (1454). Renyi diversity ordering was followed, which showed maximum diversity in Mesostigmata and minimum in Prostigmata.

m. Maximum species richness was recorded in all bees except rock bee. The diversity and Evenness was high in the most commonly domesticated Indian honeybee, *Apis cerana indica.*

n. Two genera *viz*., *Fuscuropoda* and *Blattisocius* species were found associated with the stingless bees.

o. Heavy mite loads have been observed on most of the honeybees (549) and coleopteran beetles (542).

p. Analysis of species richness (Margalef index) was maximum in Kerala (13) with a index of 1.6872 and minimum in Mettupalayam (1.0831). Shannon-Wiener index revealed higher mite diversity in Kerala (1.8538). Maximum mite evenness was observed in Kerala (0.6543) and minimum evenness in Mettupalayam (0.4803) (Table 18).

q. Seven insect associated mites have been identified as new to science viz. *Macrocheles distipilochaetae, Uroobovella passalaephorae*, *Uroobovella basilianae*, *Sejus rufomaculata*, *Imparipes bengalensis, Melisia mysorensis* and *Melisia passalae.*

r. Larval morphology of *Arrenurus* (Acari: Hydrachnidia) on *Trithimes* sp. (Odonata) was described for the first time.

s. The extent of natural mite parasitism ranged from 25 to 66.6 per cent in different insects, but parasitic mites are not capable of causing any significant mortality of the hosts.

5. Results and Conclusions

A. Survey

The survey was conducted in 19 places, which includes 10 in Tamil Nadu, eight in Kerala and one in Karnataka regions. A total of 6988 insects were collected from different areas during the past three years. The pooled data is given in Table 1. The collected insects belong to seven orders and 16 families. The collected insect orders include Coleoptera, Orthoptera, Odonata, Hymenoptera, Dermaptera, Hemiptera and Diptera. Among the orders maximum numbers of insects have been collected from Coleoptera.

The Acari-insect association was presented in Table 2. The phoretic association was the most predominant one with 67 per cent i.e., 24 mite genera/species, followed by parasitic and predatory with 30 (9) and 3 per cent (1), respectively (Plate 1-3).

B. Biodiversity of mites associated with insects

B.1. Occurrence of mite species in different locations of Western Ghats

Thirty-four mite genera belonging to 16 families under 3 suborders were recorded from different locations of Western Ghats. Maximum numbers of mites (1277) were collected

from Mettupalayam forest area followed by Siruvani (1274), Maruthamalai (1060) and Mudumalai (742). Among 34 species, *Leptus* spp. was the most abundant (1456) than others, which was followed by *Macrocheles muscadomesticae* (810), *Neocypholaelaps indi*ca (762), *Sennertia carpenter* (552), *Blattisocius* sp. (548), *Neocypholaelaps stridulan*s (469) and *Fuscuropoda* sp. (412), *Grandiella batocerae* (365), *Podapolipoides nitidu*lae (328) and *Charletonia* sp. (317). Maximum number of genera (18) were recorded in the suborder Mesostigmata followed by Prostigmata (9) and Astigmata (7) (Table3). The suborders were represented by eight, six and two families, respectively. *Leptus* spp. and *Macrocheles* spp. were present almost in all locations. *Sennertia carpenteri* was recorded from a maximum of 14 locations followed by *Grandiella batocerae* from 13 places. *Dinogamasus* sp. (12), *Diagamasellus* (11), *Poecilochirus* (11) and *Centrouropoda* (10), *Alliphis* and *Neocypholaelaps stridulans* from 8 places were next in order of diversity (Table 3). In Tamil Nadu region, more mites have been isolated from insects collected from Mettupalyam, Siruvani and Maruthamalai forest areas.

Among the areas surveyed in Kerala, more number of mites were collected from Mulli (516) followed by Agali (372), Kumuli (295), Munnar (294) and Bodi Mettu (262). *Leptus* spp. and *Macrocheles muscadomesticae* were present in all the locations surveyed. *Sejus rufomaculatae, Cheletophyes* sp., *Podapolipus hopperae, Calvolia* sp. were recorded in Bodi Mettu, Thekadi, Pampadumpara and Munnar, respectively. More than 500 mites were not identified even up to family level and hence, they were grouped under unidentified category. This may be due to damaged body parts, poor preparation of slides, lack of literatures etc. (Table 3).

C. Diversity of mite species in different locations of Western Ghats

Biodiversity indices were worked out for 150 insects selected in each insect group.

C.1. Species richness

Maximum species richness was observed in Siruvani with 26 genera (3.4965), followed by Mettupalayam (24) and minimum in Annaikatti (7) with a richness index of 1.1007 as per the Margalef index (Table 4). In Kerala region, Munnar (1.9354) and Mulli (1.9212) recorded maximum species richness.

C.2. Species diversity

Shannon-Wiener and Simpson-Yule indices revealed that higher mite diversity in Mettupalayam followed by Siruvani and lower in Annaikatti. The Shannon-Wiener diversity was maximum in Mettupalayam (2.8944) followed by Siruvani (2.8364), Maruthamalai (2.6774) as against the lowest in Annaikatti (1.8604). The respective Simpson – Yule diversity values of the above localities were 14.6300, 12.6290, 10.8150 and 6.1066, respectively. Similarly, the diversity indices were high in Mulli, Valparai, Bodi Mettu and Myladumpara (Table 4). Since, the above diversity indices differed in ranking, Renyi diversity ordering was followed, which showed maximum diversity in Siruvani and minimum in Myladumpara (Fig. 1).

C.3. Evenness

Maximum mite evenness was observed in Mettupalayam, followed by Siruvani and minimum evenness in Annaikatti. Similarly, evenness was high in Mulli and Myladumpara in Kerala region (Table 4).

C.4. Similarity index

Diversity analysis for mites associated with insects collected from different localities was calculated based on Jaccard's similarity coefficient matrices. A dendrogram was constructed based on the Jaccard's coefficient (Fig. 2). The dendrogram separated 19 locations into four major clusters at 0.60 similarity level. The similarity coefficient values of

the localities ranged from 0.32 to 0.91 (Table 5). The mites associated with insects collected from Anaikatti and Agali showed the highest similarity index of 0.91. Next major cluster included Valparai and Mulli locations with the similarity coefficient of 0.82. Insects collected from Coonoor and Ooty also showed an average of 80.4 and 75 per cent similarity with Anaikatti and Agali locations. Insects collected from Mudumalai were distinctly varied from other localities showing the lowest similarity index of 0.32. In the present study, it was observed that insect and mite association was high in localities like Anaikatti, Agali, Valparai and Coonoor which showed more than 80 per cent similarity index.

D. Occurrence of mite species in different Insect Orders

Acari-insect associations were recorded from different insect orders viz., Coleoptera, Orthoptera, Odonata, Hymenoptera, Hemiptera and Diptera. Maximum numbers of mites were observed from Coleoptera (3700) and Hymenoptera (3593), Orthoptera (2452), Odonata (179) were next in order. More number of genera/species was recorded in Coleoptera (20) followed by Hymenoptera (10). Hemiptera and Dermaptera were confined to one each i.e., *Cheletophyes* sp. and *Imparipes* sp. among the association. Two mite species, *Dinogamasus* spp. and *Macrocheles muscadomesticae* were observed from Diptera, Arrenurus sp. and *Leptus* sp. from Odonata. The other insect orders were recorded multiple mite genera from Western Ghats regions with less numbers (Table 6). Maximum species richness, diversity and evenness were observed in Coleoptera, followed by Hymenoptera and low in Odonata (Table 7).

E. Occurrence of mite species in different insect families

Thirty-four genera/species of mites were recorded from sixteen families of class Insecta. Maximum number of individuals were recorded from Apidae (2932) (Hymenoptera), Cerambycidae (1522) (Coleoptera), Acrididae (1473) (Orthoptera), Scarabaeidae (926) (Coleoptera) and Tettigoniidae (892) (Orthoptera) were next in order. In other families it ranged from 28 to 575. The population of *Neocypholaelaps indica* and *Blattisocius* sp. was 762 and 548, respectively in Apidae. The insect families viz., Carabidae, Gryllidae, Forficulidae and Reduviidae registered single mite genera viz., *Eviphis spatulaesetae, Hypoaspis* sp., *Imparipes* sp. *and Cheletophyes* sp., respectively (Table 8).

F. Diversity of mite species in different insect families

Diversity of mite species in different insect families were worked out and given in Table 9. Scarabaeidae registered maximum mite species richness, diversity indices viz., Shannon Weiner and Simpson Yule, evenness which was followed by Cerambycidae and Curculionidae and minimum in Reduviidae, Forficulidae, Vespidae, Gryllidae and Carabidae. Even though Curculionidae recorded 11 genera, the richness, diversity and evenness were high, when compared to more number of genera recorded in Cerambycidae (13). This may be due to the abundance nature of mites associated with Curculionidae.

G. Similarity index

Diversity analysis was performed based on Jaccard's similarity matrices calculated from 16 insect families to construct a dendrogram (Fig. 3). The dendrogram grouped the families into two major clusters at the similarity index of 0.85.The similarity coefficient values ranged from 0.39 to 0.93 (Table 10). In the first group cerambycidae and curculionidae has showed high similarity index value of 0.82. In the second cluster, mites collected from Muscidae and Vespidae families showed the highest similarity index of 0.93 per cent followed by Passalidae, Gryllidae, Forficulidae, Reduviidae, Vespidae and carabidae families pair with the similarity value of 0.87. The mites associated with Acrididae and Tettigonidae also recorded high similarity index of 0.84. Mites collected from Apidae showed distinct variability with all other families and recoded a low similarity coefficient value of 0.39. From the analysis it was observed that mites associated with major insect families were

Muscidae, Vespidae, Passalidae, Gryllidae, Forficulidae, Reduviidae and carabidae which showed more than 80 per cent similarity.

H. Occurrence of mite species in different mite suborders

Among the three suborders, Mesostigmata recorded to be associated with more number of mites (5625) followed by Prostigmata (3025) and Astigmata (1454) (Table 11).Maximum species richness, diversity and evenness were observed in Mesostigmata followed by Prostigmata i.e, richness and diversity (Shannon weiner) and evenness. Whereas, the Simpson-Yule index was maximum in Astigmata and low in Prostigmata. Shannon-Wiener and Simpson-Yule indices revealed higher mite diversity in Prostigmata and lower in Astigmata. Since, the above diversity indices differed in ranking, Renyi diversity ordering was followed, which showed maximum diversity in Mesostigmata and minimum in Prostigmata (Table 12) (Fig. 4).

H.1. Diversity of mite species in Mesostigmata

Maximum species richness, diversity and evenness were observed in Coleoptera, which recorded 11 species followed by Hymenoptera (7) and Diptera (2). The diversity indices was zero in Orthoptera, since, only one genus was recorded (Table 13a). The results clearly indicated that the orthopterans lack mesostigmatic mite association.

H.2. Diversity of mite species in Prostigmata

Maximum species richness, diversity and evenness were observed in Orthoptera (4), followed by Coleoptera (3), Odonata (2) and minimum in Hymenoptera, Hemiptera and Dermaptera (1 each) (Table 13b). In contrast to Mesostigmata, prostigmatic mites were more abundant with orthopteran insects with a high richness index (0.3875). In Hymenoptera and Dermaptera, the diversity was zero.

H.3. Diversity of mite species in Astigmata

Maximum species richness (0.7451), diversity (1.4136, 3.2867) and evenness (0.7265) were observed in Coleoptera, followed by Hymenoptera and zero in Orthoptera (Table 13c).

I. Diversity of mite species in Honeybees

Six mite species have been collected and identified from four different species of honeybees viz., *Apis cerana indica, Apis flora, Apis dorsata* and *Trigona irridipennis* from four different places of Western Ghats. *Apis cerana indica* recorded highest mite population (4157), followed by *Trigona irridipennis* (1375), *Apis flora* (1110), and *Apis dorsata* (159). *Blattisocius* sp. was the predominant mite genus associated with *T. irridipennis* in Siruvani areas only. In other locations this mite species was not noticed. *Neocypholaelaps indica* was recorded only in the hilly areas like Ooty and Coonoor in *Apis cerana indica* (Plate 4). *Fuscuropoda* sp. was specific to *Trigona irridipennis* recorded in the lower elevations (Mettupalayam and Siruvani) of Western Ghats. The parasitic bee mites *Varroa* and *Tropilaelaps* are very common in all places (Table 14).

Maximum species richness was recorded in all bees except rock bee. The diversity and Evenness was high in the most commonly domesticated Indian honeybee, *Apis cerana indica* (Table 15).

J. Diversity of mites associated with stingless bee

The nests of social insects harbour a variety of arthropods, the most numerous and also least studied of which are the acari. An extensive survey was conducted and mites were collected from three stingless bee colonies and identified. The presence of mites was identified from the stingless bee colonies, brood and sealed brood using a hand lens (10x). Two genera viz., *Fuscuropoda* and *Blattisocius* species were found associated with the stingless bees. A total of 0 and 1310; 85.6 and 2227.8; 60.6 and 3144.8 of *Fuscuropoda* and *Blattisocius* mite species were collected from sealed brood, floor and above the brood, respectively (Table 16). Among the two genera *Blattisocius* was the most predominant one.

Fuscuropoda species were orange coloured found associated with the stingless bee broods and floor of the hive colony. Mites were not found in the sealed broods. The mite population was very low when compared to *Blattisocius.* The exact relationship is not known. It is presumed that the mites may feed on the debris found in the colony. Hence, further studies are required to know the exact association between host insect and mite. The *Blattisocius* were white coloured mites and found in large numbers in the stingless bee colonies (Plate 4). Mites were collected from the stingless bee nests, floor and sealed broods of the colony. More number of mites was observed on the surface of the brood followed by floor and sealed brood. These mites were very active and move very fastly on the surface of the broods. No mite was observed on the body of the stingless bee. When the seal of the each cell was opened, the emergence of mites from the sealed broods was observed under microscope. The exact nature of relationship between these two organisms is not known clearly. Based on our preliminary observation, it is presumed that these mites feed upon the debris of the colony. But in depth studies are needed to confirm the exact nature of association.

Since, these mites were observed from the sealed broods, broods and floor, it is clearly evident that these mites definitely affect the behaviour and reproductive development of the colony. Hence, it is concluded that intensive survey and in-depth studies on biology and feeding behaviour of the mites are required to unearth the possible association between the two organisms. Only by studying the above aspects we can develop suitable control strategies for the management of mites.

K. Relative abundance of Mesostigmatid mites associated with insects in forest localities of Tamil Nadu

A total of 1355, 1232 and 644 mites were collected from Coimbatore Western Ghats regions (Sirumugai, Maruthamalai, Siruvani, Mulli, Annaikatti and Agali), Kerala Western Ghats regions (Kumuli, Bodi Mettu, Thekadi, Myladumpara, Pampadumpara and Munnar) and Mettupalayam Western Ghats regions (Mettupalayam, Ooty and Coonoor), respectively (Table 17). Ten mite genera/species were associated with coleoptera, three mites from hymenoptera, two from Orthoptera and one from Diptera. Most of the mites are collected from coleopteran family, because of hard elytra provides easy portection from enemies. *Anolina prolineata, Blattisocius* sp. and *Sejus rufomaculata* were unique to Coimbatore forest locations; *Alliphis serrochaetae, Eviphis ramosae, Eviphis spatulaesetae, Poecilochirus coleophorae* and *Poecilochirus rutellae* were confined to Kerala forest locations. *Digamasellus* sp., *Dinogamasus* sp., *Macrocheles* sp., *Tropilaelaps clareae, Uroobovella* sp. and *Varroa jacobsoni (*Oud.) were collected from all the three localities. *Fuscuropoda* sp. was identified from Coimbatore and Mettupalayam, whereas *Gamasellous* sp. was collected from Coimbatore and Kerala. The mite genera/species were collected from *Catharsius capucinus* Fab., *Oxya* sp., *Trigona irridipennis* (Smith), *Rhynchophorus ferrugineu*s (Olivier), *Onthophagus ramosus* (Wiedman), *Onitis philemon* Fab., *Phyllognathus dionysius* Fab., *Anomala dorsalis* Fab., *Batocera rufomaculata* (DeGeer), *Apis florae* Fab. and *Apis cerana indica* Fab. Heavy mite loads have been observed on most of the honeybees (549) and coleopteran beetles (542).

K.1. Diversity of Mesostigmatid mite species

Analysis of species richness (Margalef index) was maximum in Kerala (13) with a index of 1.6872 and minimum in Mettupalayam (1.0831). Shannon-Wiener index revealed higher mite diversity in Kerala (1.8538). Maximum mite evenness was observed in Kerala (0.6543) and minimum evenness in Mettupalayam (0.4803) (Table 18).

K.2. Similarity index

Diversity analysis for mites associated with insects collected from three different forest localities was calculated based on Jaccard's similarity coefficient matrices. The similarity coefficient values ranged from 0.47 to 0.76. The diversity index showed 76 per cent similarity between Coimbatore and Mettupalayam, whereas 59 per cent between Madurai and Mettupalayam (Table 19).

L. Taxonomic Description of new mite species

Seven insect associated mites have identified as new to science and the same were described below. Larval morphology of *Arrenurus (*Acari: Hydrachnidia) on *Trithimes* sp. (Odonata) was desribed for the first time.

1. *Macrocheles distipilochaetae* sp. nov. (Figs. 5-8)

Female Dorsum: Length of idiosoma 998 long and 683 wide; hysterosomal shield with a strong reticulate pattern; with 28 pairs of setae; of which j5, j6, z1, z5, z6, r4 and Z3 smooth, simple, acicular, others distally pectinate or pilose; the pilosity varying from slight to distinct. Setae j1 closely placed and directed anteriorly; dorsum with 14 pairs of pores; anterior and marginal setae longer than medial setae; dorsal integumental setae smooth and simple.

Venter: Sternal shield 220 long and 179 wide; with three pairs of setae and two pairs of pores; shields with reticulate punctuations. A pair of medially converging ridges form the anterior linea angulata (l. ang.); a pair of short deeply punctuate 1.arc. present posterior to 1. ang. A strongly well developed ridge 1.m.t. joins sternal shield setae 2. The depressed area posterior to 1.m.t. bordered laterally by the l.o.p. which includes sternal pores 2; a.pf. and a.p.p. punctuate. The ramus of l.o.p. running to sternal setae 3. The distance between st1 - st2 135 and st2 - st3 108. The epigynial shield 158 long and 26 wide, with fine ornamentation and a pair of simple setae and pores. Metasternal shield elongate bearing simple setae. Ventrianal shield 336 long and 378 wide, ornamented with deeply dimpled rectangular cells, with 3 pairs of simple preanal setae which are longer than para and postanal setae. Opisthogastric setae smooth and simple; Cribrum normal, small metapodal shield present; peritremes each extending anteriorly beyond coxae I.

Gnathosoma: Well sclerotized, four pairs of hypostomal setae; chelicerae with brush - like arthrodial process; the palpal apotele with three tines. Epistome tripartite and forked, hypostome with 6 rows of denticles, tritosternum typical for the genus.

Legs: Well sclerotized; Leg I 735; Leg II 788; Leg III 714 and Leg IV 1208 long. Genu IV with seven setae. Chaetotaxy of legs I-IV as follows - I: 3-4-10-10-10-32; II: 1-4-9-8-7-16; III: 0-3-4-7-8-16 and IV: 0-4-4-7-7-15.

Type data: A holotype female marked on slide, Valparai, Tamil Nadu, India 23.X.2007. ex. *Onitis distinctus* (Scarabaeidae: Coleoptera); K. Ramaraju Coll. No.37-1-15; five paratype slides all with females, collection data same as that of holotype. Holotypes and paratypes deposited in the Acarology Collection of the Department of Agricultural Entomology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, India.

Diagnosis: This new species belongs to the 'limue' complex of the glaber group of the genus Macrocheles. This new species has 3 setae on coxa 1 which is unique in the sub order Mesostigmata. Further, by the presence of three setae, it is clearly differentiated from all other Macrocheles species. It also differs from *M. limue* and *M. caelatus* by the presence of a greater number of distally pectinate or pilose dorsal setae, poorly ornamented sternal shield, coarsely punctuate reticulate verti-anal shield and genu IV with seven setae. Even though this new species shares the genu IV character by having 7 setae (1,2/1,2/0,1) as in *M. aestives*, it can be differentiated by the presence of distally pilose j2, J2, s4, s6, Zl and S1 and the shape of the epistome. It can also be differentiated from *M. witcoskyanus* Walter and Krantz, 1986 by the poorly ornamented sternal shield and epigynial shield patterns, procurved 1.arc. distally pilose j1, J5 and genu IV with 7 setae. The new species can also be distinguished

from all other macrochelid complexes viz., friggi, capensis, kraepelini and glaber by their dorsal shield setal chaetotaxy, sternal shield size and leg chaetotaxy.

Relationship to the host: Dark brown coloured mites numbering more than 50 were found adhered in groups on the ventral side of body and legs. They were attached to body hairs with the help of their chelicerae and hence, the relationship is simple phoresy.

2. *Uroobovella passalaephorae* sp. nov. (Figs. 9 - 12)

Deutonymph Dorsum: Dorsal shield oval, with vertex 305 long and 210 wide (Total size 420 x 315); most dorsal setae short (27 long), serrate or pilose particularly marginal setae which are long, one pair of setae at anterior margin and three pairs on posterior opisthosomal part of hysterosomal shield and are deeply pilose, measuring 43 long; vertex simple, smooth with some irregular markings or lines. Dorsum with 59 pairs of setae, out of which 46 located on dorsal shield; shield surface with oval patterns; oval patterns in a narrow band on lateral margin and in middle portion of shield. A small half oval area present between middle and lateral oval patterns. Posterior opisthosomal margin of shield with two tubercles, each with a small round opening.

Venter: Sternum narrow, ending posteriorly between coxae IV; anteriorly much wider than posterior and with small teeth like projections. Sternum measures 189 long and 68 wide. Posterior margin tongue-like, with small, simple ventral setae V1, V2, V3, V4, V5, V6 and with oval irregular pattern all over. Ventrianal shield round, smooth, surrounded with a broad anterior margin bearing oval pattern and a narrow posteriolateral area with a pair of V2, V3, V4, V5, V6 and a single 'U' setae. Setae V5 long and measures 19. A small anus on posterior part surrounded with a half oval chitin bows and two pairs of simple, short inanal setae (Ia).

Ia1 and Ia2 almost equal in their size. Sternum, exo-metapodal shields, outer and lateral portions of ventrianal shields with oval patterns. Fossulae tarsale in legs III (Fovae pedales) bow-like and paw-like in legs IV. Peritremes slightly hooked or curved anteriorly and extending to level of posterior coxae I.

Gnathosoma: Chelicera with fixed digit, with a long pointed process. Length of movable digit and hyaline process not same. Lacinia of tritosternum serrate and divided into three branches. On palptrochanter setae IV simple, long and slender than setae V.

Legs: Terminate in well developed claws. The length of legs I-IV; 149, 167, 208, 216 long, respectively. Leg chaetotaxy I-IV: Femora, 5-4-3-3; genua, 6-7-2-3; tibiae, 6-6-3-4 and tarsi, 21-15-8-10.

Adults, protonymph and larvae not known.

Types: Holotype marked on slide and two paratype slides with 2 deutonymphs in each, India; Tamil Nadu; Ooty. The Nilgris, 23.IV.2007. ex. *Basilianus indicus* Stol. (Passalidae: Coleoptera); K. Ramaraju coll. (No.77/2).

Diagnosis: This new species closely resembles *Uroobovella californiana* (Wisniewski and Hirschmann, 1992) belongs to the Vitzthumi group and *U. zairensis Hirschmann* (1981) from Zaire and it could be differentiated from them by the following characters.

(1). *U. passalaephorae* sp. nov. sternum has oval patterns throughout its length; anterior part of peritreme slightly hooked and dorsal shield with oval pattern in contrast to *U. zairensis*.

(2). It also differs from *U. californiana* by having six pairs of ventral setae on the sternum, long in anal and ventrianal setae and pilose or serrate setae on the dorsal shield.

Relationship to the host: The small brown coloured phoretic mites were found attached to the ventrum of the body by means of their anal pedicel.

3. *Uroobovella basilianae* sp. nov. (Figs. 13-15)

Deutonymph Dorsum: Dorsal shield 567 long and 452 wide; oval, sclerotized with vertex; shield surface with small oval patterns and the vertex region smooth. Shield with 50-55 pairs of long setae deeply serrate on one side; hyaline marginal area with small thick setae distally serrate.

Venter: Sternum broader in the middle portion with five pairs of simple small setae v1, v2, v3, v4, v5 (25) and oval irregular patterns. Ventrianal shield almost triangular in shape, much wider anteriorly (173) than longer (130) with 5 pairs of setae. Setae V4 are small; V2, V6 and V8 long (46) and serrate on one side; V7 arising on the integument are serrate but smaller than ventrianal shield setae. Anus on posterior end of ventrianal shield with two pairs of simple inanal setae, 1a2 = 2 x 1a1. Fossulae tarsale IV well developed and curved posteriorly. Stigmata located anterior to coxae III and anterior end of peritreme hook-like.

Gnathosoma: Cheliceral fixed digit with long pointed hyaline process, corniculi horn like; setae C1 simple, long and C2, C3 and C4 serrate and medium sized. On palptrochanter setae iv and v simple. Lacinia of tritosternum sparsely serrate, divided into three branches.

Legs: All legs broad basally and ending in a pair of claws. Leg chaetotaxy (I-IV); Coxae, 2-0-1-1; trochanters, 0-0-2-4; femora, 1-4-3-6; genua, 3-6-5-4' tibiae, 5-6-6-2; tarsi, 23-10-11-12.

Types: A holotype deutonymph marked on the slide along with five paratype slides with deutonymphs, Dodabetta, Ooty, Tamil Nadu, India, 02.III.2007. ex. 4 hosts, *Basilianus neelgeriensis* Guer. (Passalidae: Coleoptera) K. Ramaraju (Col. 76/6). The holotype and paratype slides are deposited in the Acarology collections of the Department of Agricultural Entomology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, India.

Diagnosis: *Uroobovella basilianae* sp. nov. is closely related to *U. texana.* Wisniewski and Hirschmann (1992) and *U. plaumanni* Sellnick (1962). Chelicerae of these species bear a long pointed hyaline process. However, in *U. basilianae* the dorsal and ventrianal setae are long and deeply serrated; also the sternal shield lacks Vx group setae as seen in *U. texana.*

Relationship to the host: These uropodid mites can attach their bodies on host by using their anal papillae and this character helps to distinguish uropodids from canistrinid mites. This nature of attachment suggests that the relationship is a simple phoresy.

4. *Sejus rufomaculata* Ram. (Figs. 16-21)

Deutonymph Dorsum: Dorsal shield oval, flat; body orange red, with fine reticulate ornamentation. Idiosoma 494 long and 389 wide, with 76-80 pairs of pectinate setae. Dorsum divided into propodosomal and hysterosomal shields. Propodosomal shield almost triangular and larger (263) than hysterosomal shield (179), with 29 pairs of setae arranged into three rows. Hysterosomal shield with 20 pairs of setae similar to those of propodosomal shield. The opisthogastric integument laterad of the dorsal plate, bear 30 pairs of setae, each arising from a small plate. Vertical setae widely spaced and located anterior to propodosomal shield, measuring 46, those on the shield 35 long and the other marginal and median setae 40 long. Two pairs of unequal tuber–like projections extending from the posterior edge of the idiosoma, terminating in long pectinate setae (81 and 140 long).

Venter: Sternum small, narrow, 122 long, with three pairs of setae; setae st1 longer (40) than others. Ten pairs of small setae present between sternal and anal shields. Anal shield well developed large, with 3 pairs of setae and 2 pairs of pores. On either side, a pair of well developed large reticulate metapodal plates present and each with 8 pairs of setae.

Gnathosoma: 294 long and 136 wide; chelicerae well sclerotized, with toothed chela; corniculi horn-like. Hypostomal setae C3 longer (48) than C2 and C4 (27); setae C3 serrate; the palpal apotele two-tined, Setae c1 not evident. Laciniae of tritosternum forked medially.

Legs: Well sclerotized, provided with simple and pectinate setae. Legs I-IV measure 472, 347, 420 and 494, respectively. Chaetotaxy of legs I-IV Coxae, 2-5-3-6; trochanters, 5-3-1-2; femora, 14-11-7-7; genua, 12-12-11-11; tibiae, 12-11-10-12 and tarsi, 23-15-16-19.

Types: A holotype deutonymph marked on slide along with 2 nymphs, Mettupalayam, Tamil Nadu, India 15.VIII.2007. ex. *Batocera rufomaculata* (Cerambycidae:Coleoptera). Coll. K. Ramaraju (No.52/5), 10 paratype slides each with deutonymphs, collection data same as that

of holotype. The holotype and paratype slides are deposited in the Acarology Collections of the Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore, India.

Diagnosis: The new species differs from *Sejus indicus* (Bhattacharyya, 1977), *S. venezuelanus* (Hirschmann and Wisniewski, 1994), *S. longipes* (Kaluz, 1993) and *S. novaezealandiae* (Fain and Galloway, 1993) and other known *Sejus* spp. in having more pectinate dorsal setae; the form and arrangement of the dorsal setae and the leg chaetotaxy. The new species can also be differentiated from other *Sejus* spp. in having only three pairs of hypostomal setae and the absence of C1.

Relationship to the host: These orange-red mites were collected from a *Bactocera* beetle. The mites were found firmly attached to the host in the ventral neck region by their leg setae in groups. Since only deutonymphs were extracted from the host the nature of association may be a simple phoresy

5. *Imparipes bengalensis* sp. nov. (Figs. 22 - 26)

Body dimension: Idiosoma length 186 and width 155 measured from the widest part of the plate. Entire surface of body with tiny pores, cupulae ia and ih round. Free margin of tergite C broad; insertion points of c1 and d surrounded by a ring consisting of numerous tiny pores.

Body setation: Length of some dorsal setae slightly variable. Dorsal setal pattern is entirely different from the ventral setae i.e., barbed setae and simple setae, respectively.

Female dorsum: Insertion point of c1with a ring of tiny pores and it measures 65 and c2 (53) with long alveolar canal; Setae d=65; f=53, e=60, h1=100, h2=65; hi>c1=d=h2>e>c2=f.

Venter: Apodeme 1, 2 and 3 well developed, ap 4 and ap5 reduced. All the ventral setae simple, with exception of posterior setae ps1 and ps3 very sparsely barbed. Length of setae 1a, 1b, 2a, 2b, 3a, 3b, 3c, 4a and 4b are 35, 32, 31, 37, 39, 51, 41, 43 and 51, respectively. 4b=3b>4a>3c>3a>2b>1a>1b>2a. Posterior setae ps1, ps2 and ps3 are 43, 16 and 45, respectively. Setae 3b and 4b are longer among the ventral setae and Ps2 is tiny. ps3>ps1>ps2.

Posterior genital sclerite (pGe): Ventral surface smooth and slightly sclerotised. Its anterior margin (b) runs without any transition in to the anterior margin of segments PS; Measurements of pGe: b > s1and s2; I < b; β > α1 and α2.

Trichobothrium: Club shaped, thin stemed, with fine scales, outer setae v1 relatively short, longer than v2.

Gnathosoma: Gnathosoma 28 long and 25 wide. Palp with four pairs of setae and one pair of ventral setae; one pair of solenidia visible, 5 long.

Legs: Relative length: Leg I< Leg II< Leg III< Leg IV. Leg I: Setal formula: Fe 3, Ge 4, TiTa 16 (4 sol); Relative length of sol: ω2<ω1>φ2<φ1

TiTa with well developed claw, tip of claw elongated. Leg I measures 78 long.

Leg II: Setal formula: Fe 3, Ge 3, Ti 4 (sol φ), Ta 6 (2 sol ω); sol ω > φ; ω- finger shaped, free; φ - partly embedded. Ta with 2 claw and empodium. Leg II measures 138 long.

Leg III: Setal formula: Fe 2, Ge 2, Ti 4 (sol φ), Ta 5; Ta with 2 claw and empodium. Leg III measures 158 long.

Leg IV: Setal formula: Co 1, Fe 2, Ge 1, Ti 3 (sol φ), Ta 4; relative length of tibial/tarsal setae: tc'>pv'>tc''>dTi=I,Ti>pv''>u'; u' tiny. PrTa with 2 tiny claw and empodium. Leg IV measures 213 long.

Male and Larva: Unknown.

Types: A holotype female marked on slide INDIA: Tamil Nadu, Mettupalayam, 31.X.2006. Eg: *Labidura bengalensis* Dohrn (Forficulidae: Dermaptera), Coll: V. Radhakrishnan, (No: 2006-179/1). Two paratype slides with female, collection data same as type.

Etymology: The species "bengalensis" refers to the insect host species.

Type locality: Mettupalayam, Tamil Nadu, India.
Relationship to the host: The orange coloured mites found attached to the forewing of the earwig. It is presumed to be phoretic in nature.
Diagnosis: This new species *Imparipes bengalensis* sp. nov. is closely related to *Imparipes (Imparipes) louisianae* and *Imparipes haeseleri* in most of the character, but can be differentiated by the absence of coxal setae in I - III legs and trochanter setae in all the legs as against one trochanter setae is *in Imparipes (Imparipes) louisianae* (Ebermann and Moser, 2008) and *Imparipes haeseleri* (Ebermann and Hall, 2003) in all the legs.

All the ventral setae are simple except ps1 and ps3 (sparsely barbed) in the new species, but it is differs with *I. louisianae* by the presence of sparsely barbed setae, except 2b and ps2. Presence of 5 setae in Ta in Leg III in the new species as against 6 *in I. louisianae* and *I. haeseleri.*

6. *Melisia mysorensis* sp. nov. (Figs. 27-30)

Diagnosis: This new species resembles most of the *Melisis* spp., but can be differentiated by many characters. It differs from *M. mariettae, M. ariadnae, M. salomeae, M. irenae, M. gabrielae* and *M. melaniae* by having completely ornamented idiosoma, barbed vi, ci setae very long and the absence of L4. Further, idiosoma not suboval and post anal fossa are not deeply impressed on opisthosoma when compared to *M. mariettae* and *M. ariadn*ae. Setae Ci longer than ce.
Female dorsum: Idiosoma ovoid, or suboval in outline 504 long and 315 wide between humeral setae, slightly tapering to a round opisthosoma. Dorsum coarsely reticulate (hexagonal to octogonal) except posterior of opisthosoma. Vertical setae (vi) finely serrate, pectinate, 97 long. Idiosoma bears nine pairs of dorsal setae, of them four pairs viz., Sci, he, d1 and d2 are profusely barbed. External scapular setae (Sce) very long (432) acicular with very minute spines; internal scapular setae (Sci) broadly barbed (194); humeral setae (he) finely pectinate, 257 long; d1 260; lumber setae (laterals) L1 ultra long with faintly minute spikelets and L2 fairly long, pectinate measuring 270 and 243, respectively. Hi, d2 and d3 smooth, simple, minute caudal setae (ce) 392 long and csi thin extreme long (459) placed widely. A thin smooth pad or wing like expansion on both side of dorsum between Leg II and III (Fig. 27).
Venter: Ventrum with weak or poor reticulation, not uniform. Coxal apodemata finely defined. Venter with five pairs of simple acicular setae, coxal setae CX1 and CX3 and CX4 measures 54 each.; d1 and d2 small, minute, genital shield small 95 long with three pairs of paranal and one pair of postanal setae (Fig 28).
Gnathosoma: Gnathosoma 198 long with a prominent setae arising from the subcapitulam. Chelicera with fixed digits and palpal podomere bear a blunt denticle (Fig. 29).
Legs: Legs elongate and thin. L1: 275; L2: 275; L3: 329; L4: 351 long. Leg chaetotaxy: Femora, 1-1-0-0; Genua, 2-3-0-0; Tibiae, 1-1-1-1 and Tarsi, 4-6-3-4. Pretarsi ending with a small stalked apotele and sucker like plates. Dosal setae near the tip of tarsi I long, II and IV short; dorsal setae on tibia I, II, III. Ti I very long, exceeds 200, Ii II 200, Ti IV 50. Ta 100; TaII 100; apical setae Ta1 83 long (Fig. 30).
Types: The holotype female marked on slide, India, Tamil Nadu, Mudumalai. 15. III.2007. ex: *Basilianus nelgeriensis* Guer. (Passalidae: Coleoptera). Two paratype slides with male, collection data same as holotype (No. 2007-73/2).
Relationship to the host: Groups of large and medium sized pale coloured mites were found on the venter of head, thorax, inner side of elytra and leg joints of passalid beetle. They are attached to the host body by means of their strong claws and the nature of attachment suggested that the relationship is a simple phoresy.

7. *Melisia passalae* sp. nov. (Figs. 31-34)

Diagnosis: This new species is very closely related to *Melisis occidii* and *M. superba*. From the first species, it can be separated by longer ci, barbed Sci, ce, ci. From the second one by Sce, L1 and ce. It is also separable from *M. melinae* and *M. glabrielae* by the ornamental setae, shorter Sce, L1, ce and vi. Ta1, II, IV and apical setae of Ti 1, II and IV. Further in the new species the idiosoma is suboval in shape. Setae L1, ce, ci has prominent spikelets each near midlength and lacks minute barbs throughout its length as against *M. melinae.*

Female dorsum: Idiosoma suboval, 473 long; widest (315) at middle and slightly tapering posteriorly; dorsal integument wrinkled. Idiosoma with 10 pairs of dorsal setae, vertical setae simple, acicular, 70 long; external scapular setae (Sce) slender, ultra long (473) with faint spines along the length. Sci short, finely barbed, 200 long; humeral setae (he) barbed, 216 long; dorsal setae (d1) very long, slender, barbaed (443); 3 pairs of lumber setae, L1 slender, ultra long and LII pectinate 346 and 302 long; IV short and broadly barbed, 117 long; Setae Sce, cse and csi are ultra long each with two prominent spikelets near mid length; d1 and d2 simple, minute, two pairs of caudal setae cse (465) and csi (221) long. Five thin wing/pad like expansions are present between leg I and leg III posterior opisthosoma.

Venter: With fine reticulation; venter with 5 pairs of simple setae with genitoanal wrinkles, genital shield 184 long; anal shield 59 long with simple paranal setae. Postanal fossa deeply impressed.

Gnathosoma: Typical for the genus.

Legs: Leg I and II short, thick and broader than leg III and IV which are elongate. Leg I 251;L II 197; L III 302 and L IV 338. Leg setation in trochanter, femora, genua, tibiae and tarsi are L1; 0-1-3-1-4; L II, 1-1-3-1-4; L III, 1-0-1-1-1 and L IV 0-0-0-1-2. Tarsus I 50, II 82, IV 118; apical setae Ti I 200, Ti II 110, Ti III very long and Ti IV 27.

Types: The holotype female marked on slide, India, Tamil Nadu, Mudumalai. 15. III. 2007. ex: *Basilianus nelgeriensis* Guer. (Passalidae: Coleoptera). Two paratype slides with male, collection data same as holotype (No2007- 70/3).

Relationship to the host: A simple phoresy was noticed.

8. *Arrenurus* (Acari: Hydrachnidia) Description of Larval Morphology (Fig. 1-5)

The larvae were found only on females and were attached to the ventral side of the body of adult dragonflies. The preferred areas were the mesosternum and metasternum. The larvae attached to the *Trithemis pallidinervis* have not been described as species until now. Therefore we add a short morphological description after assigning the larvae to proper species of the *Arrenurus* genus.

Morphological description

The dorsal plate is egg-shaped, with a bending in the anterior lateral sides with rounded posterior margin. The antero-lateral indents are relatively deep. The dorsal plate setae viz., Mp1, Mp2, Lp1, Lp2, Mh1 and Mh2 are thin, long and smooth. Dorsal plate length and width, CpI medial margin length and CpII medial margin length were shorter than *A. maculator* and A. *cuspidator.* CpIII medial margin length, the range of Mp1-Mp1, Lp1-Lp1 and Lp2-Lp2 were longer than *A. cuspidator*. The C1, C2, C3 and C4 setae bear secondary setae on both sides. Brush of hairs on its base of C1 seat is not present. The distance between the C4 seta and the median CpIII edge is longer that the distance between the C1 seta and the CpI margin. The distance between C1 and C2 setae is longer than the distance between the C4 seta and the median CpIII edge and the distance between the C1 seta and the CpI margin.

The dorsal and coxal plate features a microrelief in the form of a regular porous reticulum. The excretory pore plate width and length are almost equal, the plate surface bearing two pairs of short setae. The palps have a pronounced tooth and three setae on segment IV. Segment V bears 8 setae. One seta (PV1) is a solenidion, another one (PV6) is

relatively short, stout one and PV7 is characteristically bent and bears secondary setae on one side and seta PV8 is very long (113.8) and bears secondary setae on both sides; the remaining setae (PV2, PV3, PV4 and PV5) are smooth. Segment III bears two smooth setae of which one is larger than the other one. Segment II has a single smooth seta. Each leg has five segments, the last segment bearing three claws.

Material Examined

Five larval slides, INDIA: Tamil Nadu, Idikarai, 12.VIII.2006. Eg: *Trithemis pallidinervis* (Libellulidae: Odonata), Coll. V. Radhakrishnan, (No: 260/5).

The larva of *Arrenurus* sp. is easily recognized from *A. agrionicolus* Uchida and *A. mitoensis* Imamura described from Japan (IMAMURA & Mitchell, 1967) by the shape of Expp and the locality of Exp (below E2 setae) and the number of setae on tarsus III.

Natural observations on parasitic mite parasitism

The extent of natural mite parasitism was observed on six different insects collected from different places. In all cases the field collected insects placed in a container and maintained in the laboratory for further observation of 15 days and the infestation level was recorded. The parasites preferred distinct body regions like wings, wing bases, abdomen and legs for their attachment. A quantitative analysis revealed that the parasitisation (infestation) rates ranged from 25 to 66.6 per cent. Our observations revealed that severely infested insects showed sharp decline in vigour. Eventhough the occurrence of these mites are numerous and parasitic on grass hoppers and bees, they can not capable of causing any significant mortality of the insects. But, definitely they can hamper the free movement and vigour of these insects. The possibility of using these mites as a promising biocontrol agent against various insects can be explored. But so far, there is no report or study about their infestation on phytophagous pests except grasshoppers and some beetles in India. Hence, there is a need to study in detail about their biology, development, per cent parasitisation, host specificity, field survival and infestation level, etc., on different hosts before they can be put into use.

Table 1. Total number of insects collected from Western Ghats regions (Pooled data 2007 - 2009)

Months/Insect order	Coleoptera	Orthoptera	Odonata	Hymenoptera	Dermaptera	Hemiptera	Diptera	Total
January	192	82	57	162	11	73	28	**605**
February	111	43	93	39	12	28	140	**466**
March	212	108	44	51	0	79	37	**531**
April	68	59	29	26	2	46	32	**262**
May	104	90	64	40	1	19	6	**324**
June	132	76	51	82	7	187	31	**566**
July	69	48	32	119	19	173	69	**529**
August	196	68	87	94	12	59	3	**519**
September	205	27	68	216	17	107	55	**695**
October	251	71	124	101	29	166	92	**834**
November	286	110	50	157	39	102	34	**778**
December	174	143	36	173	26	180	147	**879**
Total	**2000**	**925**	**735**	**1260**	**175**	**1219**	**674**	**6988**

Table 2. Acari - Insect association

S. No.	Mite genera/species	Association
1.	*Tropilaelaps clareae*	Parasite
2.	*Blattisocius* sp.	Phoresy
3.	*Dinogamasus* spp.	Phoresy
4.	*Gamasellus* sp.	Phoresy
5.	*Rhyzolaelaps* sp.	Phoresy
6.	*Hypoaspis* sp.	Phoresy
7.	*Digamasellus* spp.	Phoresy
8.	*Poecilochirus rutellae* Ram. & Moh.	Phoresy
9.	*Macrocheles muscadomesticae*	Phoresy
10.	*Neocypholaelaps indica*	Parasite
11.	*Neocypholaelaps stridulans*	Phoresy
12.	*Eviphis spatulaesetae* Ram. & Moh.	Phoresy
13.	*Alliphis trichiensis* Ram. & Moh.	Phoresy
14.	*Fuscuropoda* sp.	Phoresy
15.	*Sejus rufomaculatae* Ram.	Phoresy
16.	*Uroobovella* spp.	Phoresy
17.	*Centrouropoda* sp.	Phoresy
18.	*Varroa jacobsoni*	Parasite
19.	*Cheletophyes* sp.	Predator
20.	*Imparipes* sp.	Phoresy
21.	*Allothrombium sureshi* Ram.& Moh.	Parasite
22.	*Arrenurus* sp.	Phoresy
23.	*Leptus* spp.	Parasite
24.	*Charletonia* spp.	Parasite
25.	*Podapolipus hopperae* Ram.& Moh.	Parasite
26.	*Tarsopolipus* sp.	Parasite
27.	*Podapolipoides nitidulae* Ram.&Moh.	Parasite
28.	*Grandiella batocerae* Vis. and Moh.	Phoresy
29.	*Bircericola* sp.	Phoresy
30.	*Melisia* spp.	Phoresy
31.	*Sennertia carpenteri* Ram. and Moh.	Phoresy
32.	*Acarus* sp.	Phoresy
33.	*Caloglyphus* sp.	Phoresy
34.	*Calvolia* sp.	Phoresy

Phoresy = 24, Parasite= 9, Predatory= 1 Nos.

Table 3. Distribution of mite species collected from different locations of Western Ghats (Nos.) (Pooled data 2007- 2009)

	Locality																			
Mite genera/species	**Siruvani**	**Maruthamalai**	**Sirumugai**	**Mulli**	**Annaikatti**	**Agali**	**Mettupalayam**	**Ooty**	**Coonoor**	**Mudumalai**	**Attakatti**	**Valparai**	**Kumuli**	**Bodi mettu**	**Thekadi**	**Myladumpara**	**Pampadumpara**	**Munnar**	**Dimbam**	**Total**
Mesostigmata																				
Tropilaelaps clareae	25	34	0	0	0	0	52	0	0	0	156	0	0	0	0	0	0	0	0	**267**
Blattisocius sp.	132	153	0	0	0	0	202	0	0	0	61	0	0	0	0	0	0	0	0	**548**
Dinogamasus spp.	54	12	8	11	0	0	49	0	0	0	46	31	10	16	7	0	0	15	13	**272**
Gamasellus sp.	17	25	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	**56**
Rhyzolaelaps sp.	5	12	0	0	33	0	11	0	0	0	0	0	0	18	0	21	0	0	0	**100**
Hypoaspis sp.	0	0	26	0	0	0	0	5	10	8	0	17	0	0	0	0	17	0	0	**83**
Digamasellus spp.	19	29	0	0	12	25	0	14	0	51	47	0	0	0	0	22	17	31	57	**324**
Poecilochirus rutellae	2	17	0	27	0	31	39	15	31	0	0	0	11	0	24	0	0	9	3	**209**
Macrocheles muscadomesticae	15	28	19	91	40	26	54	84	52	31	27	37	72	40	85	33	58	0	18	**810**
Neocypholaelaps indica	48	0	0	0	0	0	125	212	195	182	0	0	0	0	0	0	0	0	0	**762**
Neocypholaelaps stridulans	0	85	59	0	29	73	85	61	37	40	0	0	0	0	0	0	0	0	0	**469**
Eviphis spatulaesetae	71	53	0	0	0	0	0	0	0	0	6	0	0	39	0	0	43	0	27	**239**
Alliphis trichiensis	24	0	19	42	0	0	15	0	0	0	0	0	0	0	26	14	0	11	22	**173**
Fuscuropoda sp.	213	199	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**412**
Sejus rufomaculatae	0	29	0	0	0	0	48	0	0	37	0	0	0	4	0	0	0	0	0	**118**
Uroobovella spp.	27	47	10	0	0	0	0	0	13	0	0	37	31	0	0	0	0	49	62	**276**
Centrouropoda sp.	0	0	0	12	0	0	11	21	0	0	22	59	47	7	0	6	11	8	0	**204**
Varroa jacobsoni	44	25	0	45	31	60	52	19	27	0	0	0	0	0	0	0	0	0	0	**303**
Prostigmata																				

Cheletophyes sp.	27	0	12	0	0	0	46	0	0	0	0	0	0	0	8	0	0	0	0	**93**
Imparipes sp.	0	0	0	0	0	0	0	7	0	21	0	0	0	0	0	0	0	0	0	**28**
Allothrombium sureshi	20	11	0	34	0	0	11	8	0	0	0	0	27	46	51	39	0	0	0	**247**
Arrenurus sp.	19	17	54	0	0	0	0	0	0	0	27	0	0	0	20	0	0	0	0	**137**
Leptus spp.	172	134	34	49	61	109	52	86	143	77	50	61	47	26	39	70	55	108	83	**1456**
Charletonia spp.	37	0	0	41	0	0	29	0	33	0	0	91	0	0	49	0	0	0	37	**317**
Podapolipus hopperae	13	0	68	0	0	0	94	0	0	62	0	0	0	0	0	0	35	0	0	**272**
Tarsopolipus sp.	0	43	0	0	0	0	0	32	0	28	0	0	0	19	0	8	0	17	0	**147**
Podapolipoides nitidulae	52	0	73	0	0	0	52	0	0	113	0	0	21	0	0	0	0	15	2	**328**
Astigmata																				
Grandiella batocerae	27	44	73	11	27	18	64	0	9	23	0	18	29	0	0	8	0	0	14	**365**
Bircericola sp.	11	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	8	**29**
Melisia spp.	27	0	14	76	0	0	47	0	0	0	0	33	0	47	0	0	2	0	0	**246**
Sennertia carpenteri	89	34	29	48	0	30	99	52	31	41	20	22	0	0	0	23	18	16	0	**552**
Acarus sp.	0	0	8	0	0	0	0	0	0	28	0	0	0	0	0	14	0	8	0	**58**
Caloglyphus sp.	84	0	16	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	**117**
Calvolia sp.	0	29	0	29	0	0	13	0	0	0	0	9	0	0	0	0	0	7	0	**87**
Total	**1274**	**1060**	**522**	**516**	**233**	**372**	**1277**	**616**	**581**	**742**	**476**	**415**	**295**	**262**	**309**	**258**	**256**	**294**	**346**	**10104**
																	Unidentified mites			**598**

Table 4. Measures of diversity of mite species for different localities of Western Ghats

Locality	No. of species/genera recorded	Richness index	Diversity indices		Evenness
		Margalef	Shannon-Wiener	Simpson-Yule	Equitability J
Siruvani	26	3.4965	2.8364	12.6290	0.8043
Maruthamalai	21	2.8711	2.6774	10.8150	0.7593
Sirumugai	16	2.3971	2.5203	10.7170	0.7147
Mulli	13	1.9212	2.3977	9.9053	0.6799
Annaikatti	7	1.1007	1.8604	6.1066	0.5276
Agali	8	1.1827	1.8976	5.7688	0.5381
Mettupalayam	24	3.2158	2.8944	14.6300	0.8208
Ooty	13	1.8682	2.0503	5.6050	0.5814
Coonoor	11	1.5712	1.9406	5.1014	0.5503
Mudumalai	14	1.9669	2.3622	8.3638	0.6699
Attakatti	11	1.622	2.0797	6.1141	0.5898
Valparai	11	1.6588	2.2238	8.1682	0.6306
Kumuli	9	1.4067	2.0386	6.9384	0.5781
Bodi Mettu	10	1.6163	2.1190	7.7128	0.6009
Thekadi	9	1.3953	1.9700	6.2597	0.5586
Myladumpara	11	1.8008	2.1513	7.1589	0.6101
Pampadumpara	9	1.4427	1.9585	6.3787	0.5554
Munnar	12	1.9354	2.0454	5.3484	0.5800
Dimbam	12	1.8815	2.1258	7.0284	0.6028

Table 5. Values of similarities recorded between different localities using Jaccard's similarity coefficient

Insect Family/Locality	Siruvani	Maruthamalai	Sirumugai	Mulli	Annaikatti	Agali	Mettupalayam	Bodi Mettu	Thekadi	Myladumpara	Pampadumpara	Dimbam	Munnar	Ooty	Coonoor	Kumuli	Mudumalai	Attakatti	Valparai
Siruvani	1.000																		
Maruthamalai	0.559	1.000																	
Sirumugai	0.500	0.412	1.000																
Mulli	0.471	0.559	0.559	1.000															
Annaikatti	0.412	0.559	0/559	0.647	1.000														
Agali	0.441	0.647	0.588	0.735	0.912	1.000													
Mettupalayam	0.676	0.471	0.529	0.676	0.441	0.471	1.000												
Bodi Mettu	0.324	0.529	0.471	0.676	0.676	0.588	0.471	1.000											
Thekadi	0.471	0.500	0.618	0.765	0.647	0.676	0.500	0.676	1.000										
Myladumpara	0.411	0.500	0.559	0.706	0.765	0.735	0.441	0.736	0.647	1.000									
Pampadumpara	0.412	0.441	0.618	0.647	0.706	0.735	0.382	0.735	0.588	0.706	1.000								
Dimbam	0.559	0.529	0.588	0.676	0.676	0.706	0.471	0.588	0.735	0.618	0.618	1.000							
Munnar	0.324	0.529	0.588	0.676	0.559	0.647	0.412	0.588	0.618	0.735	0.618	0.706	1.000						
Ooty	0.353	0.559	0.441	0.647	0.706	0.794	0.441	0.618	0.588	0.706	0.706	0.500	0.618	1.000					
Coonoor	0.471	0.559	0.618	0.706	0.765	0.853	0.500	0.500	0.647	0.588	0.647	0.676	0.559	0.765	1.000				
Kumuli	0.471	0.618	0.618	0.647	0.647	0.676	0.559	0.559	0.589	0.589	0.471	0.618	0.618	0.588	0.647	1.000			
Mudumalai	0.324	0.471	0.647	0.441	0.676	0.706	0.412	0.529	0.441	0.676	0.676	0.529	0.588	0.735	0.676	0.500	1.000		
Attakatti	0.471	0.676	0.500	0.588	0.647	0.676	0.382	0.676	0.647	0.647	0.765	0.618	0.618	0.588	0.529	0.529	0.500	1.000	
Valparai	0.353	0.500	0.676	0.824	0.647	0.676	0.500	0.676	0.647	0.647	0.765	0.676	0.676	0.588	0.765	0.588	0.559	0.765	1.000

Table 6. Distribution of mite species in different Insect Orders (Nos.) (Pooled data 2007& 2009)

Mite genera/species	Coleoptera	Orthoptera	Odonata	Hymenoptera	Dermaptera	Hemiptera	Diptera	Total
Mesostigmata								
Tropilaelaps clareae	0	0	0	267	0	0	0	**267**
Blattisocius sp.	0	0	0	548	0	0	0	**548**
Dinogamasus spp.	43	0	0	175	0	0	54	**272**
Gamasellus sp.	56	0	0	0	0	0	0	**56**
Rhyzolaelaps sp.	100	0	0	0	0	0	0	**100**
Hypoaspis sp.	0	83	0	0	0	0	0	**83**
Digamasellus spp.	324	0	0	0	0	0	0	**324**
Poecilochirus rutellae Ram. & Moh.	209	0	0	0	0	0	0	**209**
Macrocheles muscadomesticae	717	0	0	0	0	0	93	**810**
Neocypholaelaps indica	0	0	0	762	0	0	0	**762**
Neocypholaelaps stridulans	0	0	0	469	0	0	0	**469**
Eviphis spatulaesetae Ram. & Moh.	239	0	0	0	0	0	0	**239**
Alliphis trichiensis Ram. & Moh.	173	0	0	0	0	0	0	**173**
Fuscuropoda sp.	0	0	0	412	0	0	0	**412**
Sejus rufomaculatae Ram.	118	0	0	0	0	0	0	**118**
Uroobovella spp.	276	0	0	0	0	0	0	**276**
Centrouropoda sp.	204	0	0	0	0	0	0	**204**
Varroa jacobsoni	0	0	0	303	0	0	0	**303**
Prostigmata								
Cheletophyes sp.	0	0	0	88	0	5	0	**93**
Imparipes sp.	0	0	0	0	28	0	0	**28**
Allothrombium sureshi Ram.& Moh.	247	0	0	0	0	0	0	**247**
Arrenurus sp.	0	0	137	0	0	0	0	**137**
Leptus spp.	0	1414	42	0	0	0	0	**1456**
Charletonia spp.	0	317	0	0	0	0	0	**317**
Podapolipus hopperae Ram.& Moh.	26	246	0	0	0	0	0	**272**
Tarsopolipus sp.	147	0	0	0	0	0	0	**147**
Podapolipoides nitidulae Ram.&Moh.	0	328	0	0	0	0	0	**328**
Astigmata								
Grandiella batocerae Vis. and Moh.	365	0	0	0	0	0	0	**365**
Bircericola sp.	29	0	0	0	0	0	0	**29**
Melisia spp.	246	0	0	0	0	0	0	**246**
Sennertia carpenteri Ram. and Moh.	70	0	0	482	0	0	0	**552**
Acarus sp.	58	0	0	0	0	0	0	**58**
Caloglyphus sp.	53	64	0	0	0	0	0	**117**
Calvolia sp.	0	0	0	87	0	0	0	**87**
Total	**3700**	**2452**	**179**	**3593**	**28**	**5**	**147**	**10104**

Table 7. Measures of diversity of mite species in different insect orders of Western Ghats

Insect Order	No. of species/ genera recorded	Richness index	Diversity indices		Evenness
		Margalef	Shannon-Wiener	Simpson-Yule	Equitability J
Coleoptera	20	2.3125	2.6813	11.5810	0.7605
Orthoptera	6	0.6406	1.2915	2.6399	0.3662
Odonata	2	0.1928	0.5448	1.5654	0.1545
Hymenoptera	10	1.1005	2.1299	7.5525	0.6040
Dermaptera	1	0	0	1	0
Hemiptera	1	0	0	1	0
Diptera	2	0.20004	0.6573	1.8797	0.1865

Table 8. Distribution of mite species collected from different insect families of Western Ghats (Nos.) (Pooled data 2007- 2009)

	Insect Family																
Mite genera/species	Cerambycidae	Carabidae	Scarabaeidae	Curculionidae	Elateridae	Passalidae	Acrididae	Tettigoniidae	Gryllidae	Libellulidae	Vespidae	Xylocopidae	Apidae	Forficulidae	Reduviidae	Muscidae	**Total**
Mesostigmata																	
Tropilaelaps clareae	0	0	0	0	0	0	0	0	0	0	0	0	267	0	0	0	**267**
Blattisocius sp.	0	0	0	0	0	0	0	0	0	0	0	0	548	0	0	0	**548**
Dinogamasus spp.	0	0	41	0	2	0	0	0	0	0	0	175	0	0	0	54	**272**
Gamasellus sp.	0	0	56	0	0	0	0	0	0	0	0	0	0	0	0	0	**56**
Rhyzolaelaps sp.	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**100**
Hypoaspis sp.	0	0	0	0	0	0	0	0	83	0	0	0	0	0	0	0	**83**
Digamasellus spp.	65	0	104	99	56	0	0	0	0	0	0	0	0	0	0	0	**324**
Poecilochirus rutellae	79	0	78	0	0	52	0	0	0	0	0	0	0	0	0	0	**209**
Macrocheles muscadomesticae	499	0	213	0	0	0	0	0	0	0	0	0	0	0	0	98	**810**
Neocypholaelaps indica	0	0	0	0	0	0	0	0	0	0	0	0	762	0	0	0	**762**
Neocypholaelaps stridulans	0	0	0	0	0	0	0	0	0	0	0	0	469	0	0	0	**469**
Eviphis spatulaesetae	73	108	12	12	34	0	0	0	0	0	0	0	0	0	0	0	**239**
Alliphis trichiensis	0	0	146	0	27	0	0	0	0	0	0	0	0	0	0	0	**173**
Fuscuropoda sp.	0	0	0	0	0	0	0	0	0	0	0	0	412	0	0	0	**412**
Sejus rufomaculatae	79	0	21	13	5	0	0	0	0	0	0	0	0	0	0	0	**118**
Uroobovella spp.	109	0	0	0	0	167	0	0	0	0	0	0	0	0	0	0	**276**
Centrouropoda sp.	141	0	0	63	0	0	0	0	0	0	0	0	0	0	0	0	**204**
Varroa jacobsoni	0	0	0	0	0	0	0	0	0	0	0	0	303	0	0	0	**303**
Prostigmata																	
Cheletophyes sp.	0	0	0	0	0	0	0	0	0	0	0	88	0	0	5	0	**93**
Imparipes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	**28**
Allothrombium sureshi	21	0	14	11	201	0	0	0	0	0	0	0	0	0	0	0	**247**
Arrenurus sp.	0	0	0	0	0	0	0	0	0	137	0	0	0	0	0	0	**137**

Leptus spp.	0	0	0	0	0	0	582	828	0	46	0	0	0	0	0	0	**1456**
Charletonia spp.	0	0	0	0	0	0	317	0	0	0	0	0	0	0	0	0	**317**
Podapolipus hopperae	0	0	0	26	0	0	246	0	0	0	0	0	0	0	0	0	**272**
Tarsopolipus sp.	0	0	147	0	0	0	0	0	0	0	0	0	0	0	0	0	**147**
Podapolipoides nitidulae	0	0	0	0	0	0	328	0	0	0	0	0	0	0	0	0	**328**
Astigmata																	
Grandiella batocerae	308	0	15	42	0	0	0	0	0	0	0	0	0	0	0	0	**365**
Bircericola sp.	18	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	**29**
Melisia spp.	0	0	0	0	0	246	0	0	0	0	0	0	0	0	0	0	**246**
Sennertia carpenteri	0	0	60	14	0	0	0	0	0	0	0	307	171	0	0	0	**552**
Acarus sp.	22	0	18	10	8	0	0	0	0	0	0	0	0	0	0	0	**58**
Caloglyphus sp.	8	0	1	42	2	0	0	64	0	0	0	0	0	0	0	0	**117**
Calvolia sp.	0	0	0	0	0	0	0	0	0	0	87	0	0	0	0	0	**87**
Total	1522	108	926	343	335	465	1473	892	83	183	87	575	2932	28	0	152	**10104**

Table 9. Measures of diversity of mite species for different insect families of Western Ghats

Insect Family	No. of species/genera recorded	Richness index	Diversity indices		Evenness
		Margalef	Shannon-Wiener	Simpson-Yule	Equitability J
Cerambycidae	13	1.6376	2.0649	5.6815	0.5856
Carabidae	1	0	0	1	0
Scarabaeidae	14	1.9043	2.2144	7.4779	0.6279
Curculionidae	11	1.7130	2.0753	6.347	0.5885
Elateridae	8	1.2040	1.2538	2.4763	0.3555
Passalidae	3	0.3256	0.9496	2.3803	0.2693
Acrididae	4	0.41124	1.3308	3.5789	0.3774
Tettigoniidae	2	0.1472	0.2581	1.1539	0.0732
Gryllidae	1	0	0	1	0
Libellulidae	2	0.1920	0.5638	1.6088	0.1599
Vespidae	1	0	0	1	0
Xylocopidae	3	0.3148	0.9817	2.4451	0.2784
Apidae	7	0.7516	1.8511	5.8858	0.5249
Forficulidae	1	0	0	1	0
Reduviidae	1	0	0	1	0
Muscidae	2	0.1991	0.6506	1.8558	0.1845

Table 10. Values of similarities recorded between different insect families using Jaccard's similarity coefficient

Insect Family	Cerambycidae	Carabidae	Scarabaeidae	Curculionidae	Elateridae	Passalidae	Acrididae	Tettigoniidae	Gryllidae	Libellulidae	Vespidae	Xylocopidae	Apidae	Forficulidae	Reduviidae	Muscidae
Cerambycidae	1.0000															
Carabidae	0.6364	1.0000														
Scarabaeidae	0.7273	0.5455	1.0000													
Curculionidae	0.8182	0.6970	0.6667	1.0000												
Elateridae	0.7273	0.7879	0.7576	0.7879	1.0000											
Passalidae	0.6364	0.8788	0.5455	0.5758	0.6667	1.0000										
Acrididae	0.5152	0.8182	0.4242	0.6364	0.6667	0.7576	1.0000									
Tettigoniidae	0.6667	0.8485	0.4546	0.7273	0.6970	0.7879	0.8485	1.0000								
Gryllidae	0.5758	0.8788	0.4849	0.6364	0.7273	0.8182	0.8182	0.8485	1.0000							
Libellulidae	0.5455	0.8485	0.4546	0.6061	0.6970	0.7879	0.7879	0.8182	0.8485	1.0000						
Vespidae	0.5758	0.8788	0.4849	0.5758	0.6667	0.8182	0.8182	0.8485	0.8182	0.8485	1.0000					
Xylocopidae	0.5152	0.8181	0.5455	0.6364	0.7273	0.7576	0.6970	0.7273	0.7576	0.7273	0.7576	1.0000				
Apidae	0.3940	0.7576	0.4242	0.5152	0.5455	0.6970	0.6970	0.7273	0.6970	0.7273	0.7576	0.7576	1.0000			
Forficulidae	0.5152	0.8788	0.4849	0.6364	0.6667	0.8182	0.7576	0.7879	0.9394	0.8485	0.8182	0.8182	0.7576	1.0000		
Reduviidae	0.5758	0.8788	0.4849	0.6364	0.6667	0.8182	0.7576	0.7879	0.8182	0.7879	0.8182	0.8182	0.7576	0.8182	1.0000	
Muscidae	0.5758	0.8788	0.5455	0.5758	0.7273	0.8182	0.8182	0.8485	0.8182	0.8485	0.9394	0.8182	0.7576	0.8182	0.8182	1.0000

Table 11. Distribution of mite species in different mite suborders (Nos.) (Pooled data 2007& 2009)

Mite genera/species	Mesostigmata	Prostigmata	Astigmata
Tropilaelaps clareae	**267**	0	0
Blattisocius sp.	**548**	0	0
Dinogamasus spp.	**272**	0	0
Gamasellus sp.	**56**	0	0
Rhyzolaelaps sp.	**100**	0	0
Hypoaspis sp.	**83**	0	0
Digamasellus spp.	**324**	0	0
Poecilochirus rutellae Ram. & Moh.	**209**	0	0
Macrocheles muscadomesticae	**810**	0	0
Neocypholaelaps indica	**762**	0	0
Neocypholaelaps stridulans	**469**	0	0
Eviphis spatulaesetae Ram. & Moh.	**239**	0	0
Alliphis trichiensis Ram. & Moh.	**173**	0	0
Fuscuropoda sp.	**412**	0	0
Sejus rufomaculatae Ram.	**118**	0	0
Uroobovella spp.	**276**	0	0
Centrouropoda sp.	**204**	0	0
Varroa jacobsoni	**303**	0	0
Cheletophyes sp.	0	**93**	0
Imparipes sp.	0	**28**	0
Allothrombium sureshi Ram.& Moh.	0	**247**	0
Arrenurus sp.	0	**137**	0
Leptus spp.	0	**1456**	0
Charletonia spp.	0	**317**	0
Podapolipus hopperae Ram.& Moh.	0	**272**	0
Tarsopolipus sp.	0	**147**	0
Podapolipoides nitidulae Ram.&Moh.	0	**328**	0
Grandiella batocerae Vis. and Moh.	0	0	**365**
Bircericola sp.	0	0	**29**
Melisia spp.	0	0	**246**
Sennertia carpenteri Ram. and Moh.	0	0	**552**
Acarus sp.	0	0	**58**
Caloglyphus sp.	0	0	**117**
Calvolia sp.	0	0	**87**
Total	**5625**	**3025**	**1424**

Table 12. Measures of diversity of different mites in various suborders of subclass Acari

Mite suborders	No. of species/genera recorded	Richness index	Diversity indices		Evenness
		Margalef	Shannon-Wiener	Simpson-Yule	Equitability J
Mesostigmata	18	1.9687	2.6809	12.427	0.7602
Prostigmata	9	0.9982	1.6879	3.6448	0.4787
Astigmata	7	0.8239	1.5931	4.0437	0.4518

Table 13a. Measures of diversity of different mites under suborder - Mesostigmata

Insect Order	No. of species/genera recorded	Richness index	Diversity indices		Evenness
		Margalef	Shannon-Wiener	Simpson-Yule	Equitability J
Coleoptera	11	1.2808	2.1341	6.7606	0.7383
Orthoptera	1	0	0	1	0
Hymenoptera	7	0.7514	1.8524	5.8963	0.6409
Diptera	2	0.2004	0.6575	1.8524	0.2275

Table 13b. Measures of diversity of different mites under suborder - Prostigmata

Insect Order	No. of species/genera recorded	Richness index	Diversity indices		Evenness
		Margalef	Shannon-Wiener	Simpson-Yule	Equitability J
Coleoptera	3	0.3311	0.8519	2.1235	0.3877
Orthoptera	4	0.3875	1.0889	2.344	0.4956
Odonata	2	0.1928	0.5448	1.5654	0.2480
Hymenoptera	1	0	0	1	0
Dermaptera	1	0	0	1	0
Hemiptera	1	0	0	1	0

Table 13c. Measures of diversity of different mites under suborder - Astigmata

Insect Order	No. of species/genera recorded	Richness index	Diversity indices		Evenness
		Margalef	Shannon-Wiener	Simpson-Yule	Equitability J
Coleoptera	6	0.7451	1.4136	3.2867	0.7265
Orthoptera	1	0	0	1	0
Hymenoptera	2	0.1590	0.442	1.3722	0.2271

Table 14. Distribution of mite species in different Localities and on honey bee species

Mite genera/Species	Bee Species (Nos.)				
	Apis cerana indica	***Apis dorsata***	***Apis flora***	***Trigona irridipennis***	**Total**
Ooty					
Macrocheles muscadomesticae	0	67	47	0	**114**
Blattisocius sp.	0	0	0	0	**0**
Neocypholaelaps indica	923	0	0	0	**923**
Tropilaelaps clareae	0	0	283	0	**283**
Fuscuropoda sp.	0	0	0	0	**0**
Varroa jacobsoni	254	0	0	0	**254**
Coonoor					
Macrocheles muscadomesticae	0	43	20	0	**63**
Blattisocius sp.	0	0	0	0	**0**
Neocypholaelaps indica	1508	0	0	0	**1508**
Tropilaelaps clareae	0	0	119	0	**119**
Fuscuropoda sp.	0	0	0	0	**0**
Varroa jacobsoni	235	0	0	0	**235**
Mettupalayam					
Macrocheles muscadomesticae	0	19	10	0	**29**
Blattisocius sp.	0	0	0	0	**0**
Neocypholaelaps indica	0	0	0	0	**0**
Tropilaelaps clareae	0	0	0	0	**0**
Fuscuropoda sp.	0	0	0	99	**99**
Varroa jacobsoni	493	0	0	0	**493**
Siruvani					
Macrocheles muscadomesticae	0	30	21	0	**51**
Blattisocius sp.	0	0	0	772	**772**
Neocypholaelaps indica	0	0	0	0	**0**
Tropilaelaps clareae	0	0	610	0	**610**
Fuscuropoda sp.	0	0	0	504	**504**
Varroa jacobsoni	744	0	0	0	**744**
Total	**4157**	**159**	**1110**	**1375**	**6801**

Table 15. Measures of diversity of different mite of present in honeybees

Honeybee	No. of species/genera recorded	Richness index	Diversity indices		Evenness
		Margalef	Shannon-Wiener	Simpson-Yule	Equitability J
Apis cerana indica	2	0.1200	0.6787	1.9445	0.3788
Apis dorsata	1	0	0	1	0
Apis flora	2	0.1426	0.2986	1.1921	0.1666
Trigona irridipennis	2	0.1384	0.6856	1.9716	0.3826

Table 16. Abundance of mite species present in stingless bee colonies collected from three different forest locations

Forest Locations	Total number of mites* (15x20 cm area)					
	Sealed brood		Floor		Brood	
	Fuscuropoda sp.	*Blattisocius* sp.	*Fuscuropoda* sp.	*Blattisocius* sp.	*Fuscuropoda* sp.	*Blattisocius* sp.
Coimbatore	0	481.2±23.31	27.4±2.14	689.6±27.67	18.2±2.69	1087.4±33.72
Siruvani	0	397.8±63.96	33.4±3.72	753.8±19.31	13±1.30	1113.8±29.17
Mettupalayam	0	431±70.26	24.8±2.69	784.4±28.40	29.4±2.42	943.6±19.25
TOTAL	**0**	**1310**	**85.6**	**2227.8**	**60.6**	**3144.8**

* Mean of 5 observations with Standard Error

Table 17. Relative abundance of mesostigmatid mite associated with insects (Nos.)

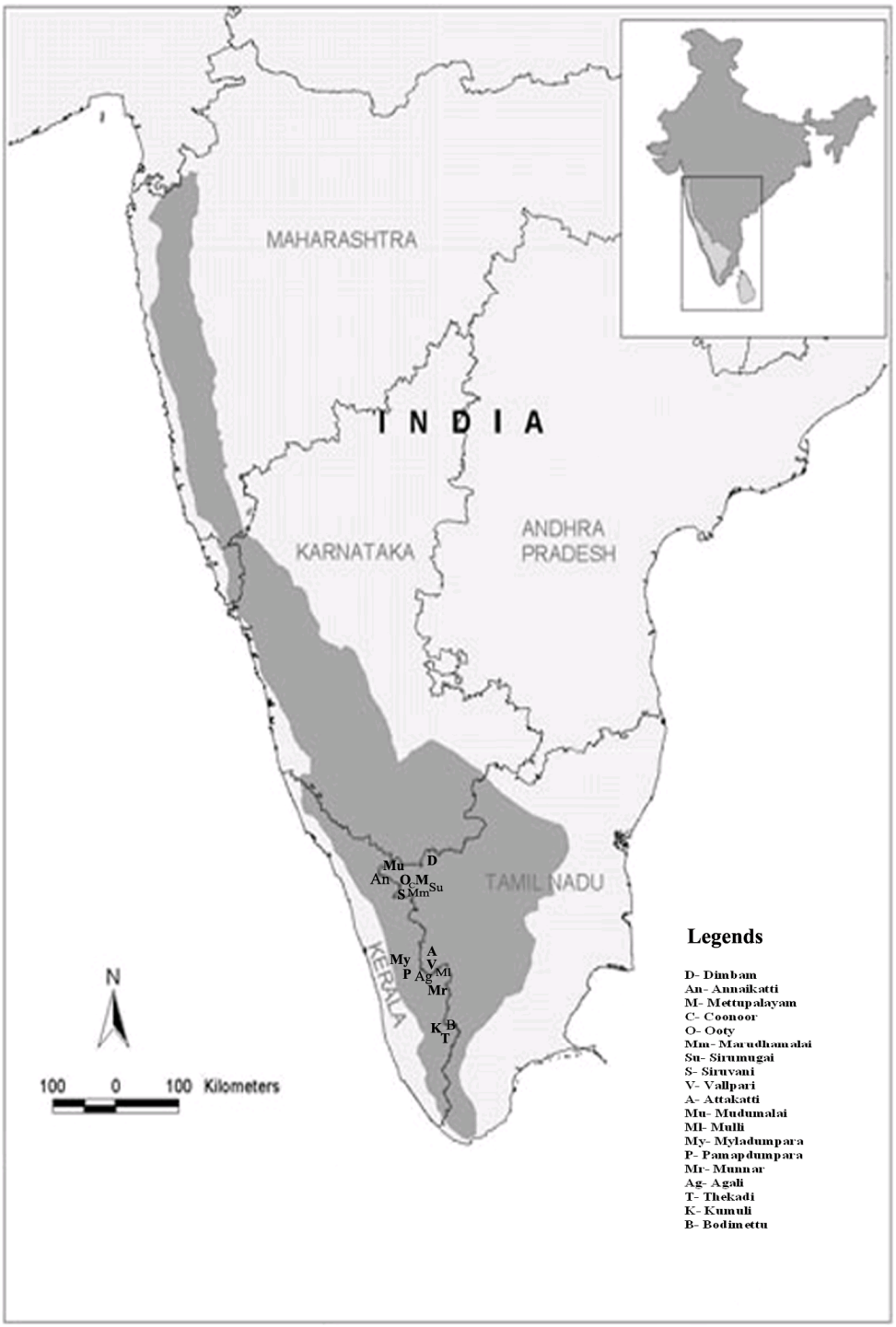
Mite genera/species	Insect genera/species	Coimbatore Western Ghats regions	Kerala Western Ghats regions	Mettupalayam Western Ghats regions
Alliphis serrochaetae Ram. and Mohana.	*Catharsius capucinus*	0	23±0.7	0
Anolina prolineata Ram. and Mohana.	*Oxya* sp.	16.4±0.6	0	0
Blattisocius sp.	*Trigona irridipennis*	548.8±15.6	0	0
Digamasellus sp.	*Rhynchophorus ferrugineus*	23±0.7	16.2±0.6	42.2±1.7
Dinogamasus sp.	Dipteran fly	14.6±1.2	33.2±1.7	8.8±1.2
Eviphis ramosae Ram. and Mohana.	*Onthophagus ramosus*	0	43.6±1.4	0
Eviphis spatulaesetae Ram. and Mohana.	*C. capucinus*	0	30.8±0.9	0
Fuscuropoda sp.	*T. irridipennis*	128.6±1.7	0	19.6±1.5
Gamasellous sp.	*Onitis philemon*	9.6±1.6	12.6±1.2	0
Macrocheles sp.	*O. philemon*	295±3.2	215.2±3.9	381±6.7
Poecilochirus coleophorae Ram. and Mohana.	*Phyllognathus dionysius*	0	542±2.6	0
Poecilochirus rutellae Ram. and Mohana.	*Anomala dorsalis* Fab.	0	54.8±1.4	0
Rhyzolaelaps sp.	*Batocera rufomaculata*	21.6±1.3	5.6±0.7	12.6±0.9
Sejus rufomaculata Ramaraju	*B. rufomaculata*	33.4±1.6	0	0
Tropilaelaps clareae Delfinado and Baker	*Apis florea*	86.4±1.6	91.2±3.5	64±1.7
Uroobovella sp.	*Trilophidia turpis*	80.8±1.2	108.4±1.7	86.2±3.6
Varroa jacobsoni (Oud.)	*Apis cerana indica*	74.8±1.4	55.2±2.8	29.6±1.5

Table 18. Measures of diversity of Mesostigmatid mite species in three forest areas of Tamil Nadu

Locality	No. of species recorded	Richness index	Diversity index	Evenness
		Margalef	Shannon-Wiener	Equitability J
Coimbatore Western Ghats regions	12	1.5298	1.7956	0.6338
Kerala Western Ghats regions	13	1.6872	1.8538	0.6543
Mettupalayam Western Ghats regions	8	1.0831	1.3609	0.4803

Table 19. Values of similarities recorded between mites associated with insects collected from different forest localities using Jaccard's similarity coefficient

Localities	Coimbatore	Madurai	Mettupalayam
Coimbatore Western Ghats regions	1.0000		
Kerala Western Ghats regions	0.4706	1.0000	
Mettupalayam Western Ghats regions	0.7647	0.5882	1.0000



Map showing areas from where insects were collected

Fig. 1. Ranking of insect associated mite species recorded from different locations of

Western Ghats based on Renyi ordering

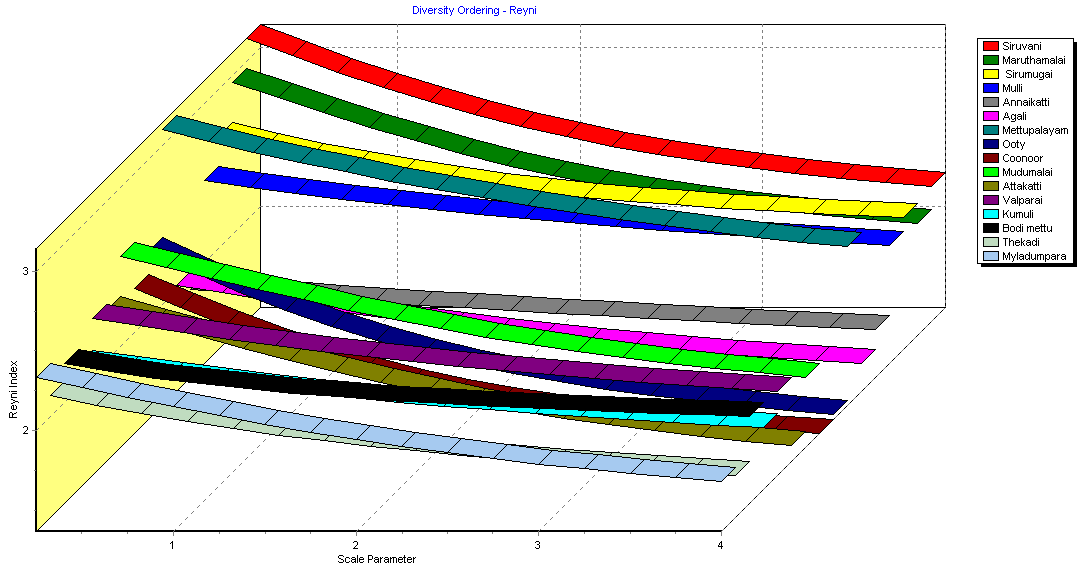


Fig. 4. Ranking of insect associated mite species recorded from different mite suborders based on Renyi ordering

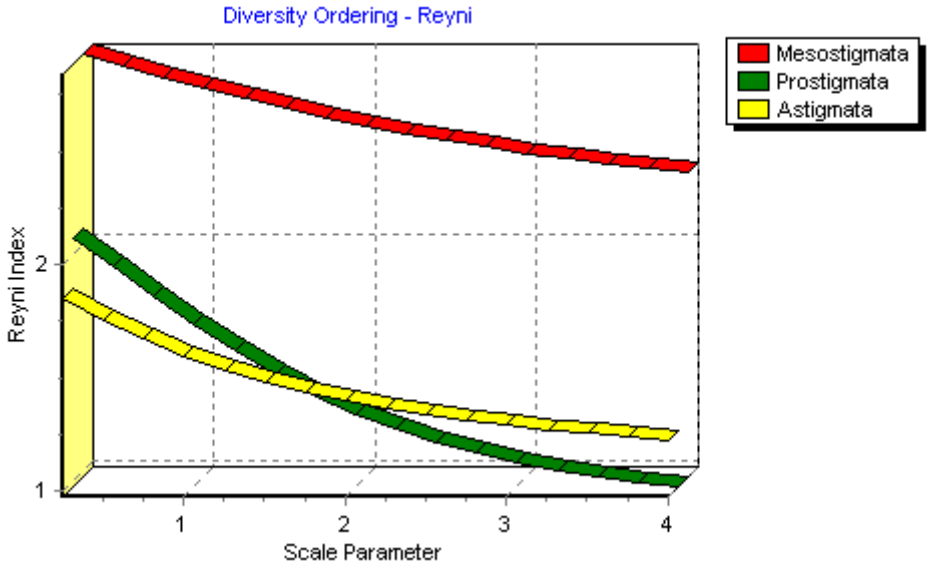


Fig. 2. Dendrogram showing the similarity of different mite species associated with different localities based on Jaccard's similarity co-efficient

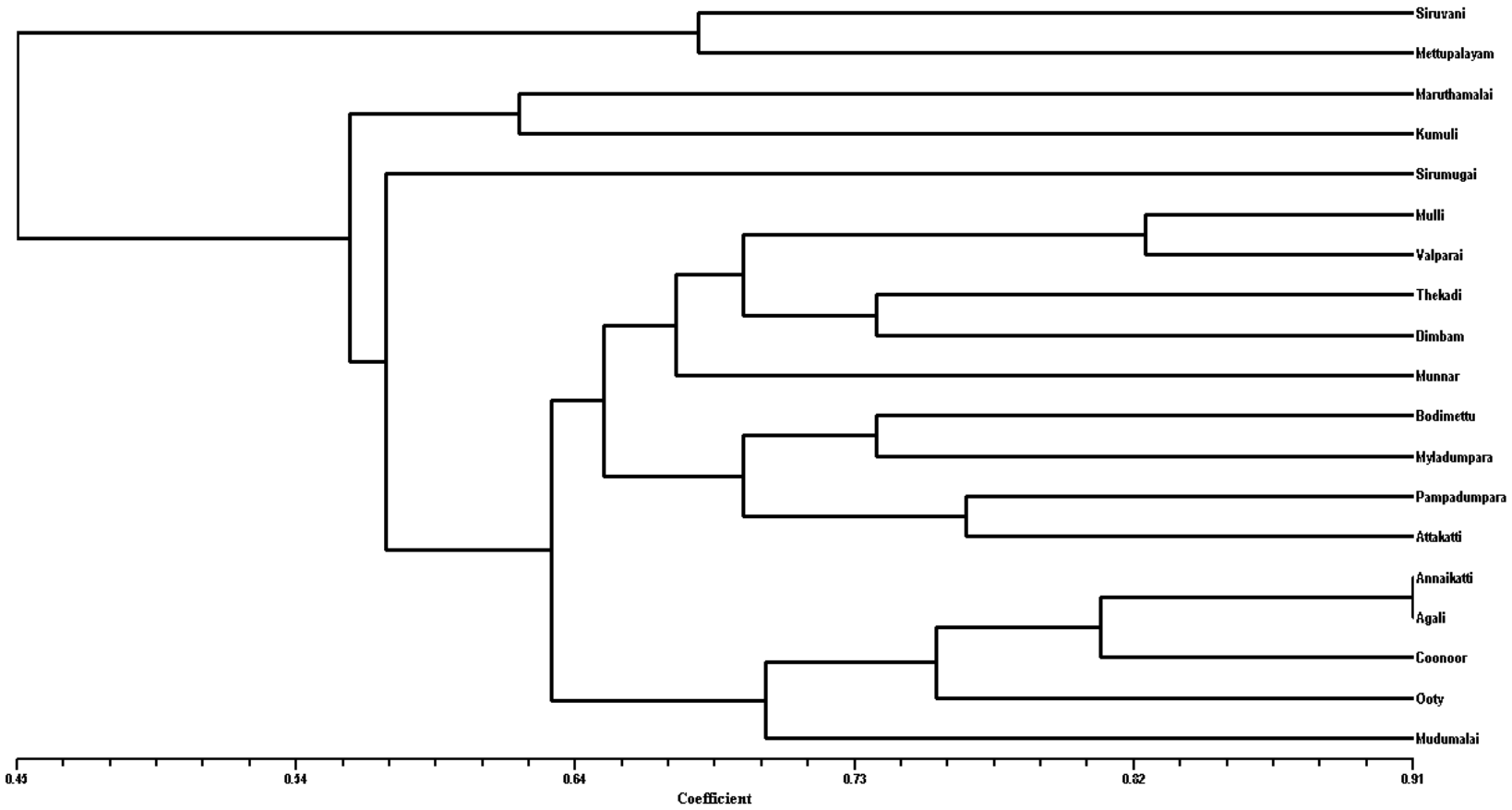
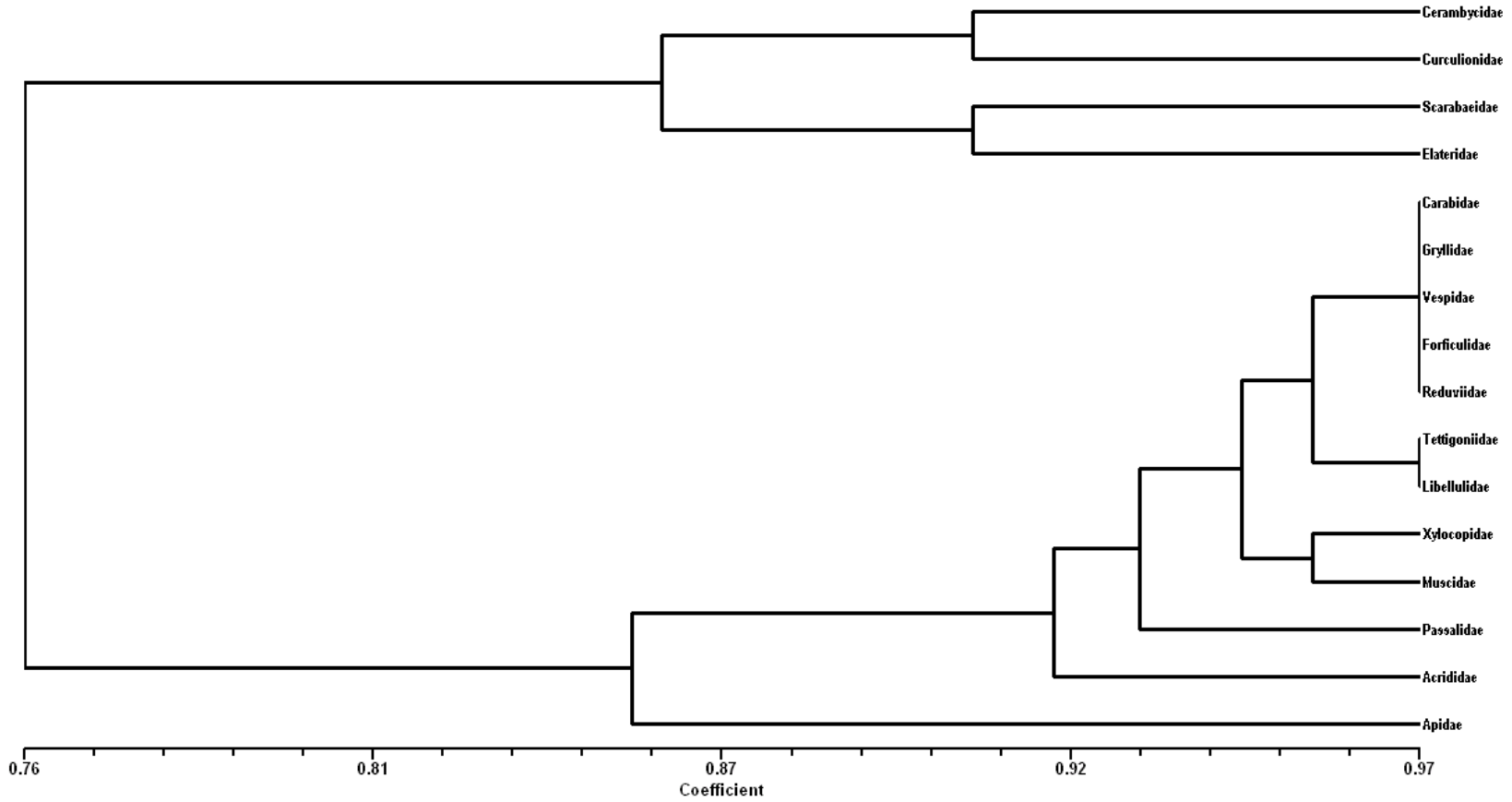


Fig. 3. Dendrogram showing the similarity of different mite species associated with insect families based on Jaccard's similarity co-efficient



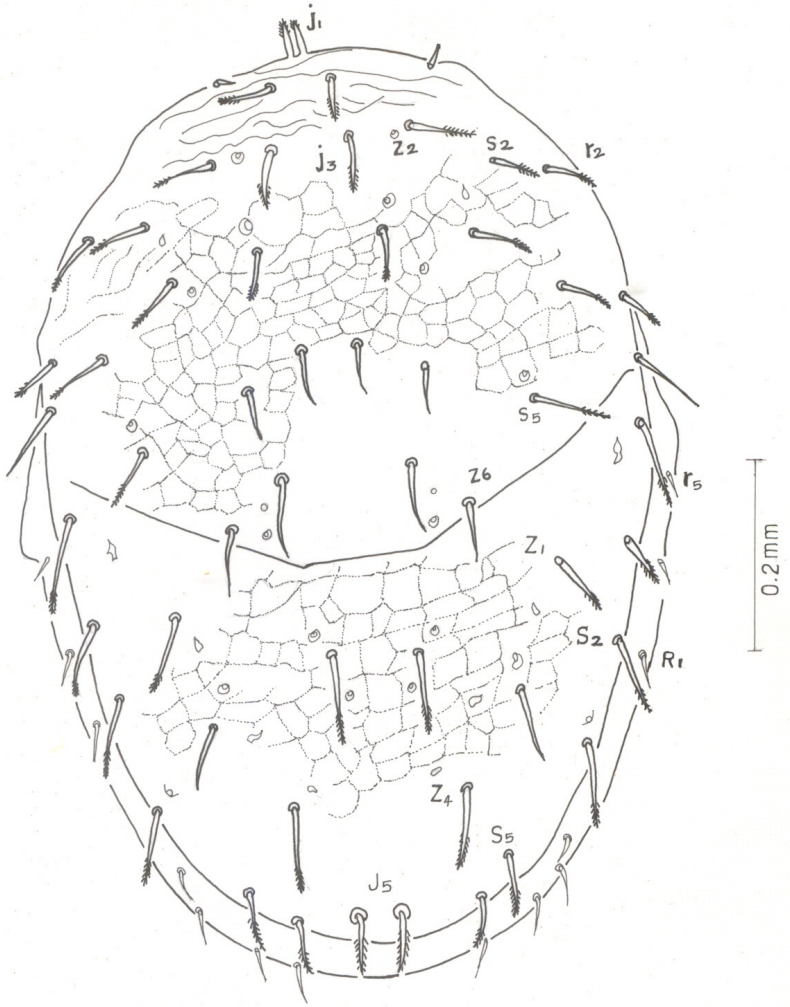


Fig. 5. ***Macrocheles distipilochaetae sp.nov.*** **– Dorsal View**

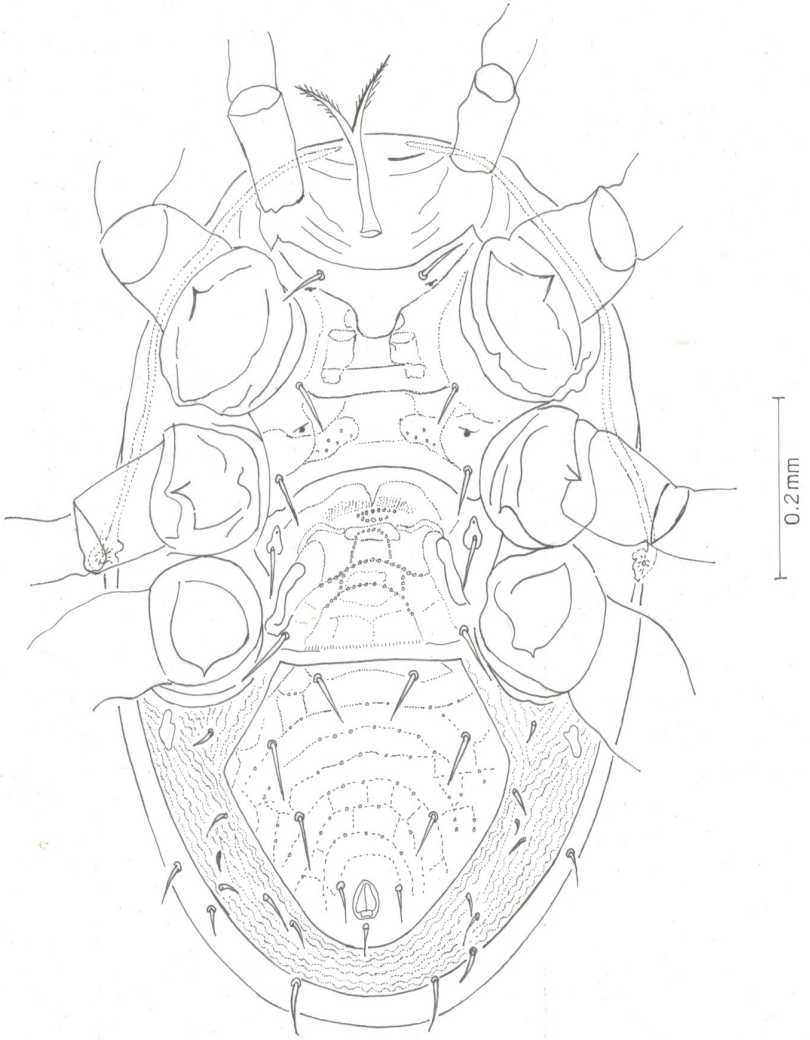


Fig. 6. ***Macrocheles distipilochaetae sp.nov.*** **– Ventral View**

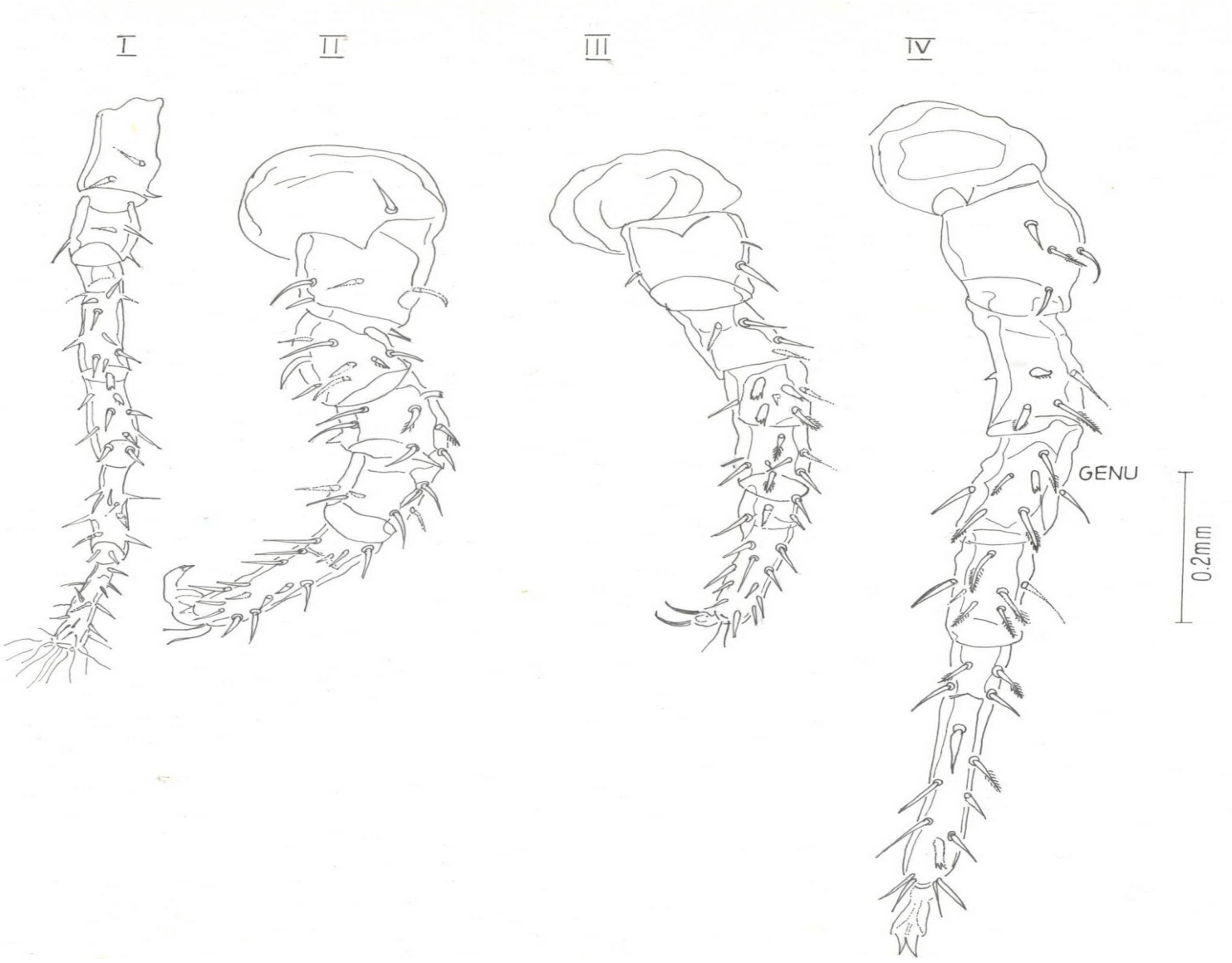


Fig. 7. ***Macrocheles distipilochaetae sp.nov.*** **– Legs I – IV**

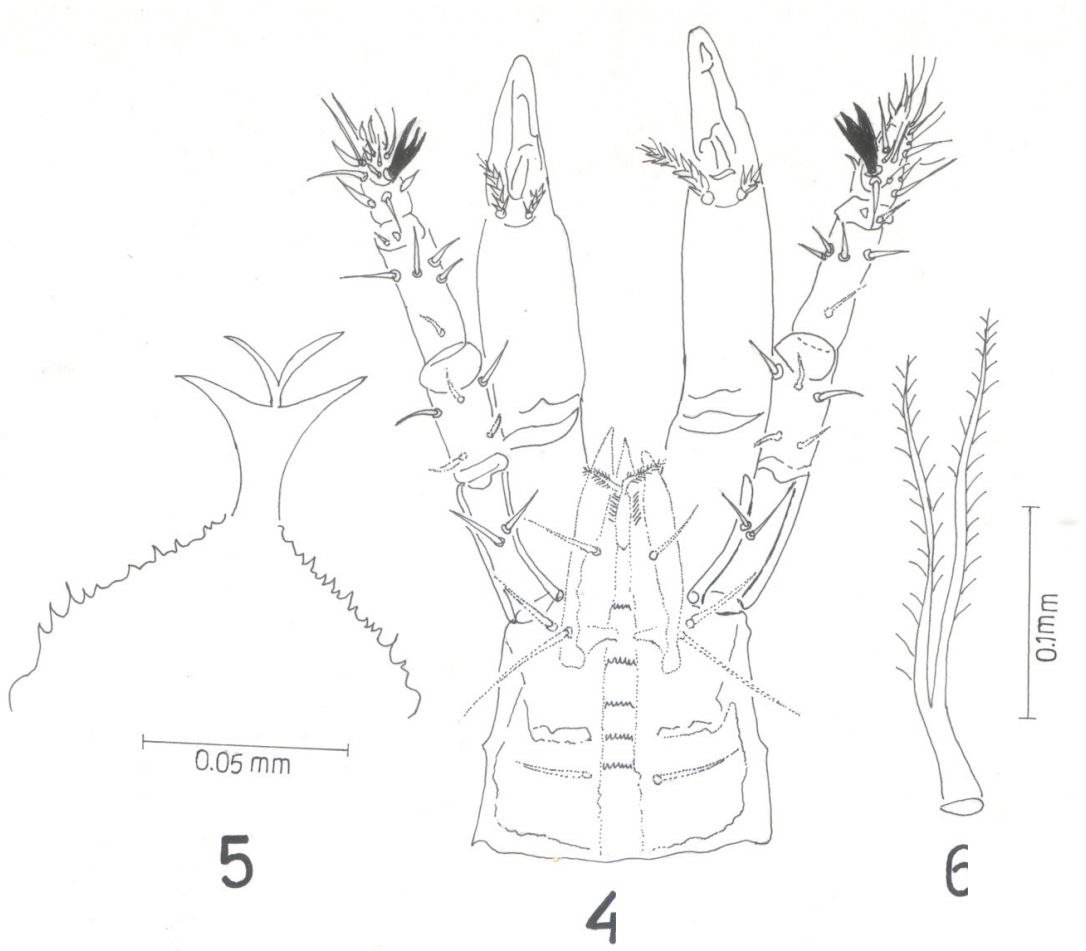


Fig. 8. ***Macrocheles distipilochaetae sp.nov.*** **– Gnathosoma**

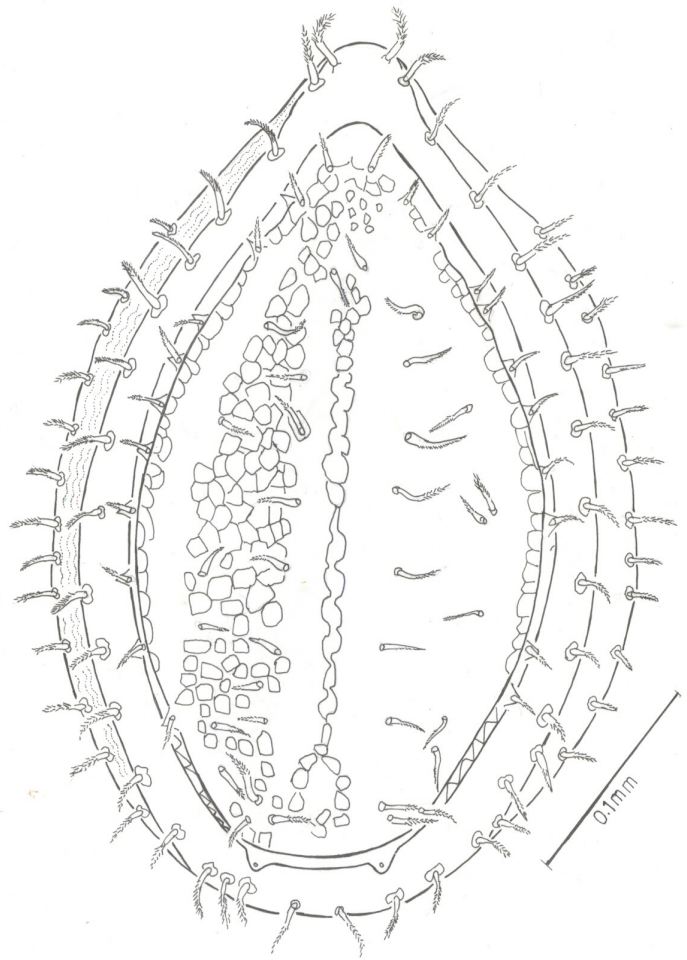


Fig. 9. *Uroobovella passalaephorae* sp. nov. – Dorsum

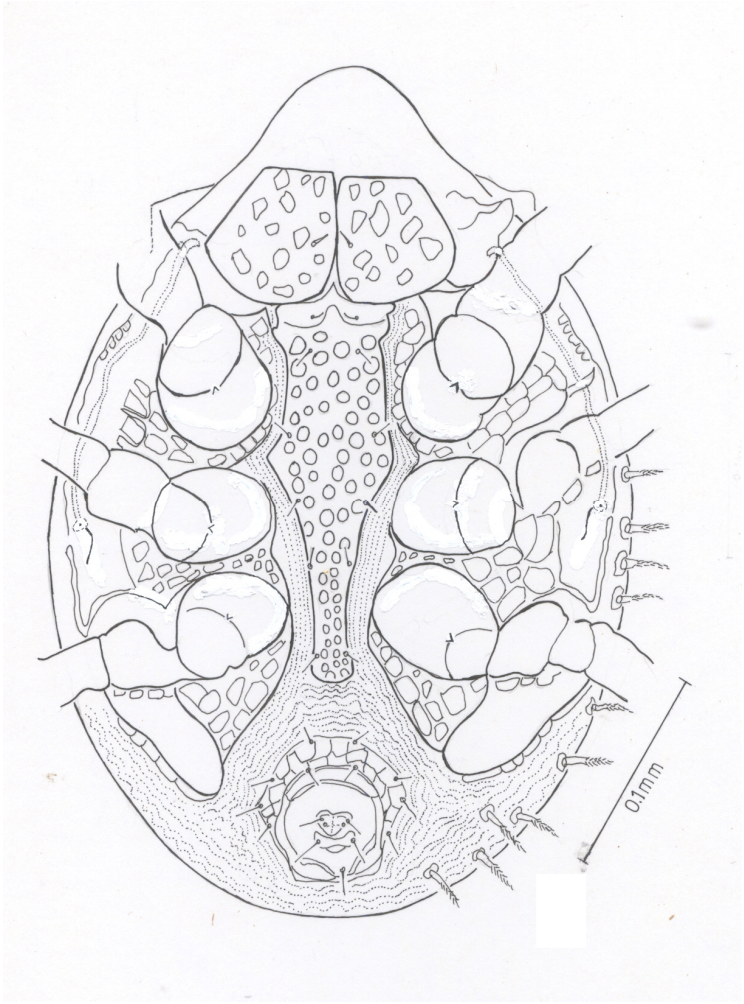


Fig. 10. *Uroobovella passalaephorae* sp. nov. – Ventrum

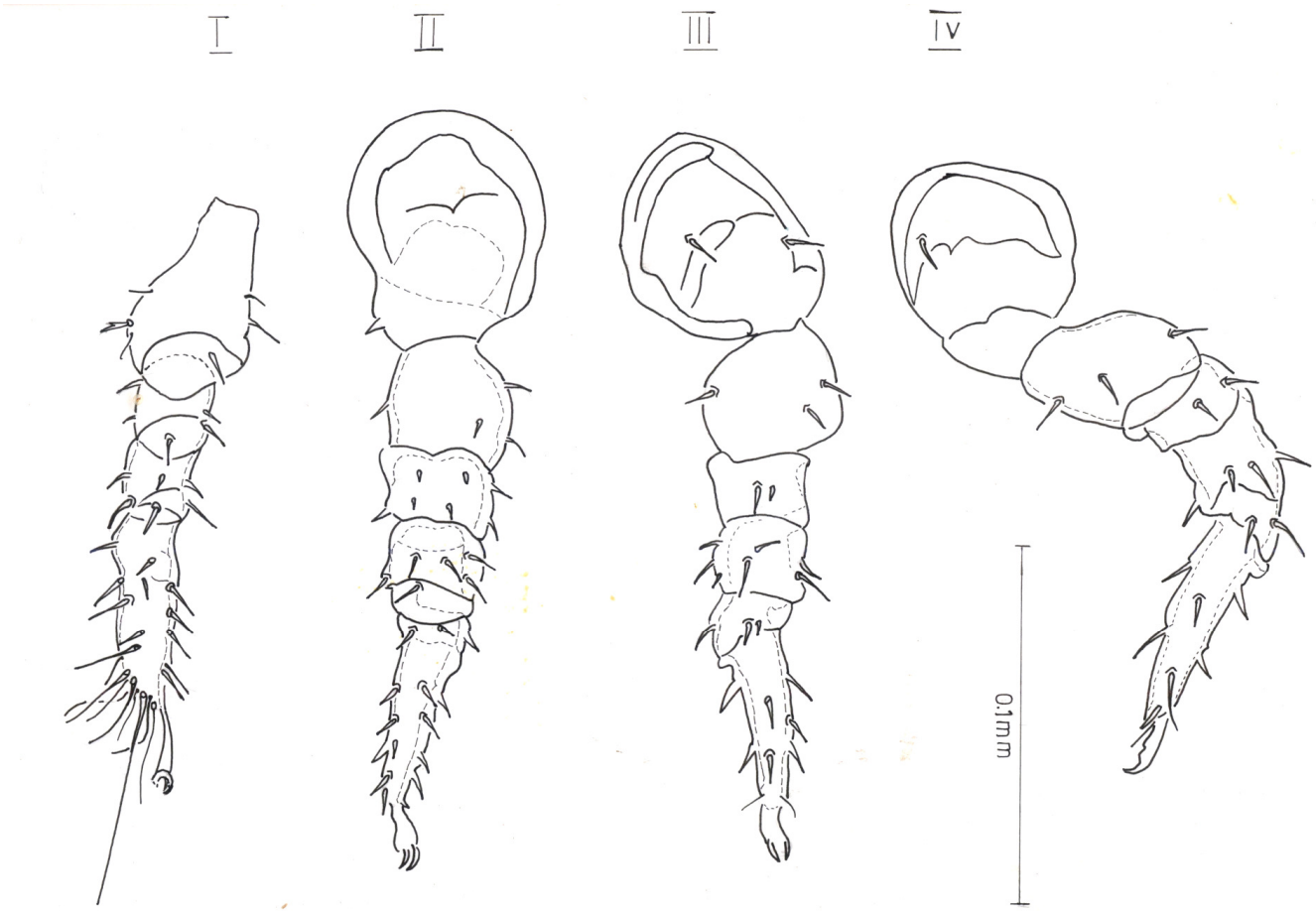


Fig. 11. ***Uroobovella passalaephorae*** **sp. nov. – Leg I-IV**

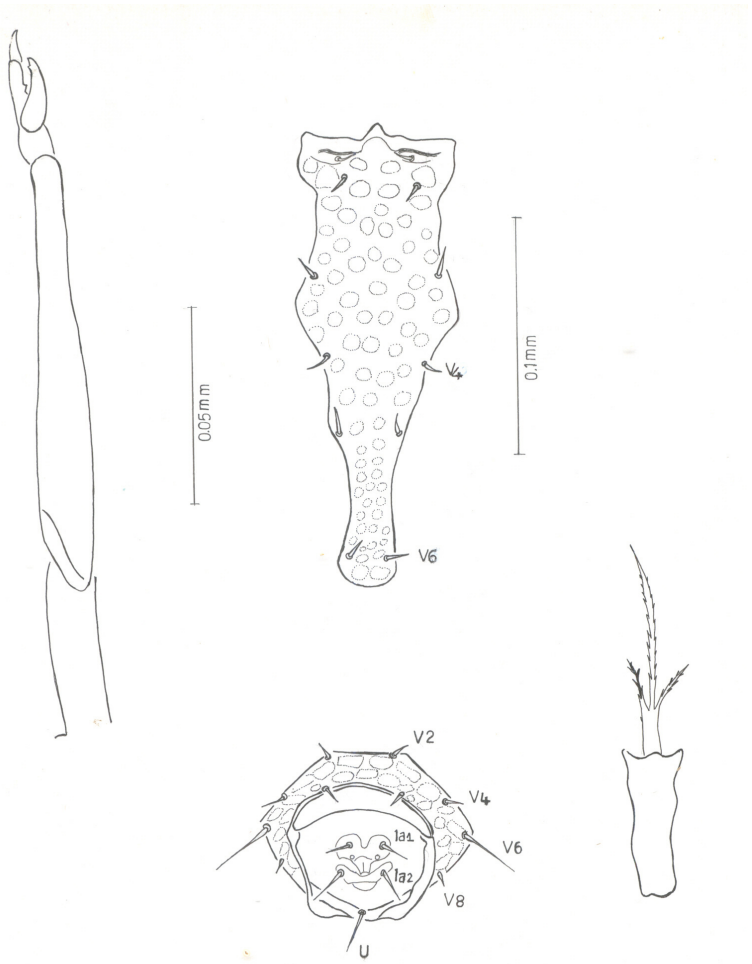


Fig. 12. ***Uroobovella passalaephorae*** **sp. nov. – Gnathosoma**

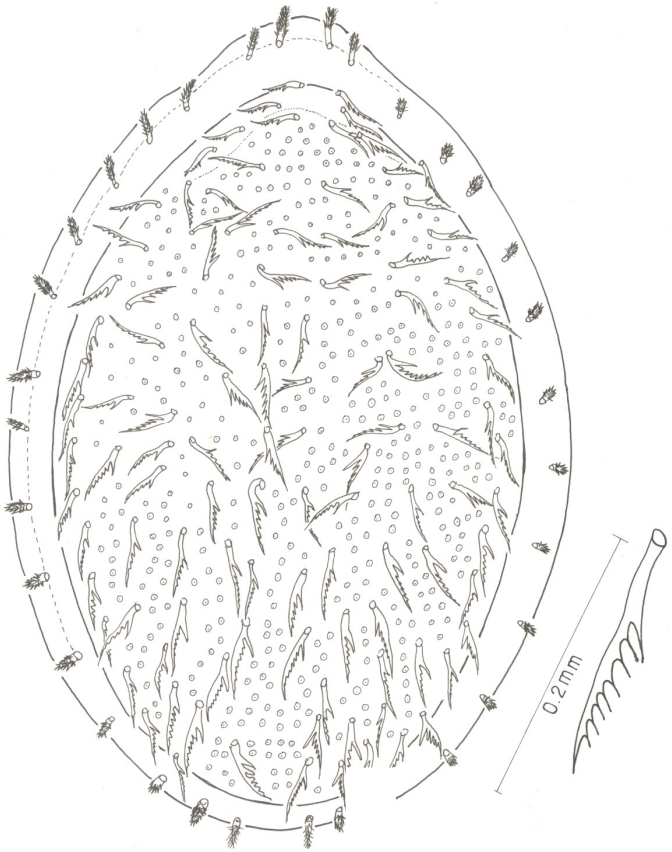


Fig. 13. ***Uroobovella basilianae*****sp. nov. – Dorsum**

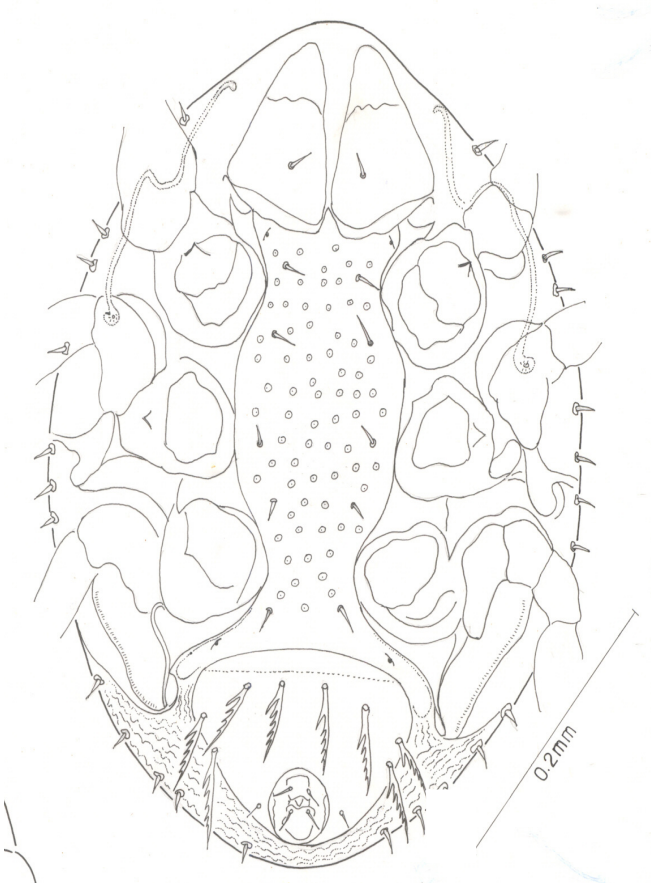


Fig. 14. ***Uroobovella basilianae*** **sp. nov. – Ventrum**

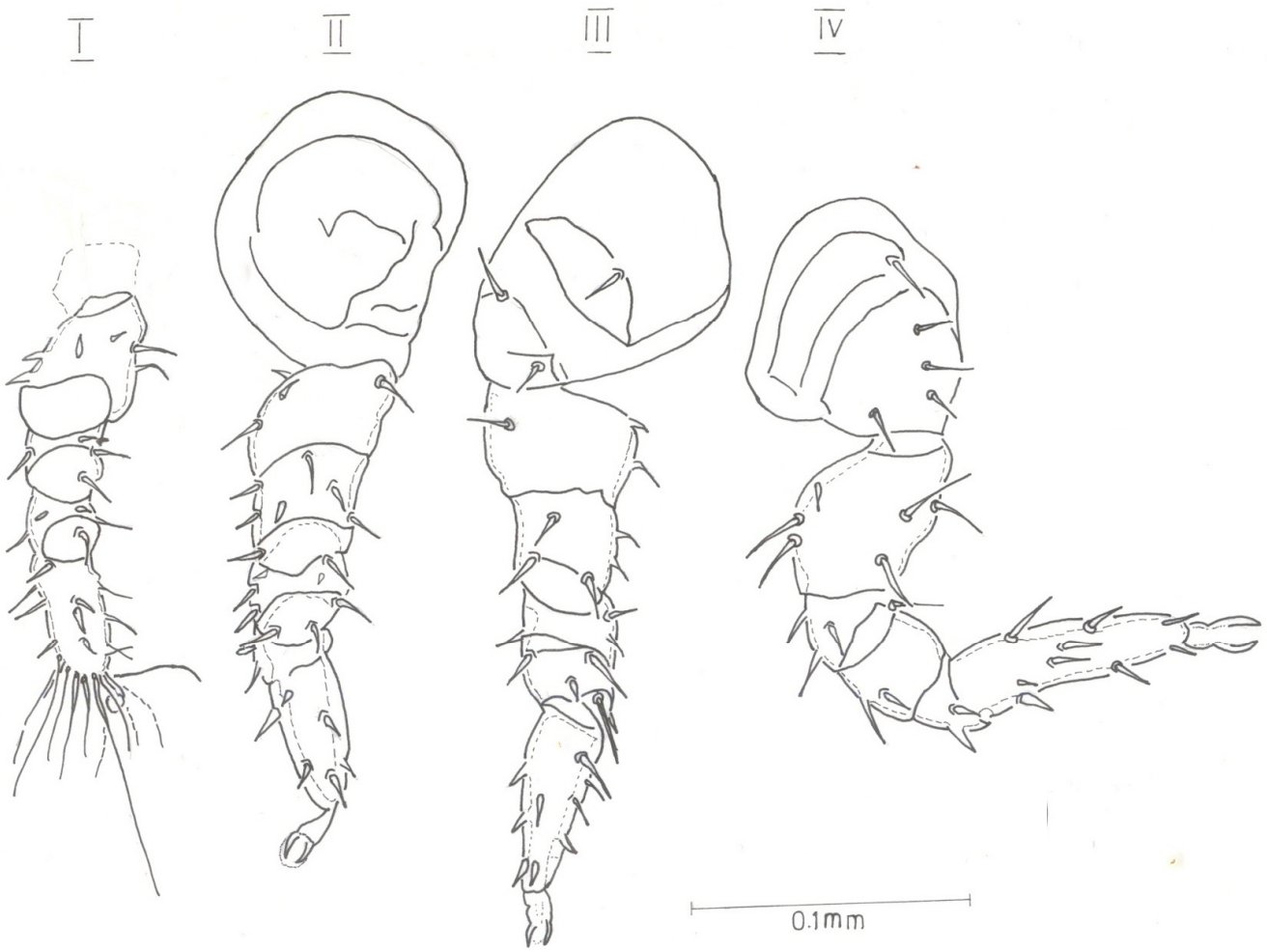


Fig. 15. *Uroobovella basilianae* sp. nov. – Leg I-IV

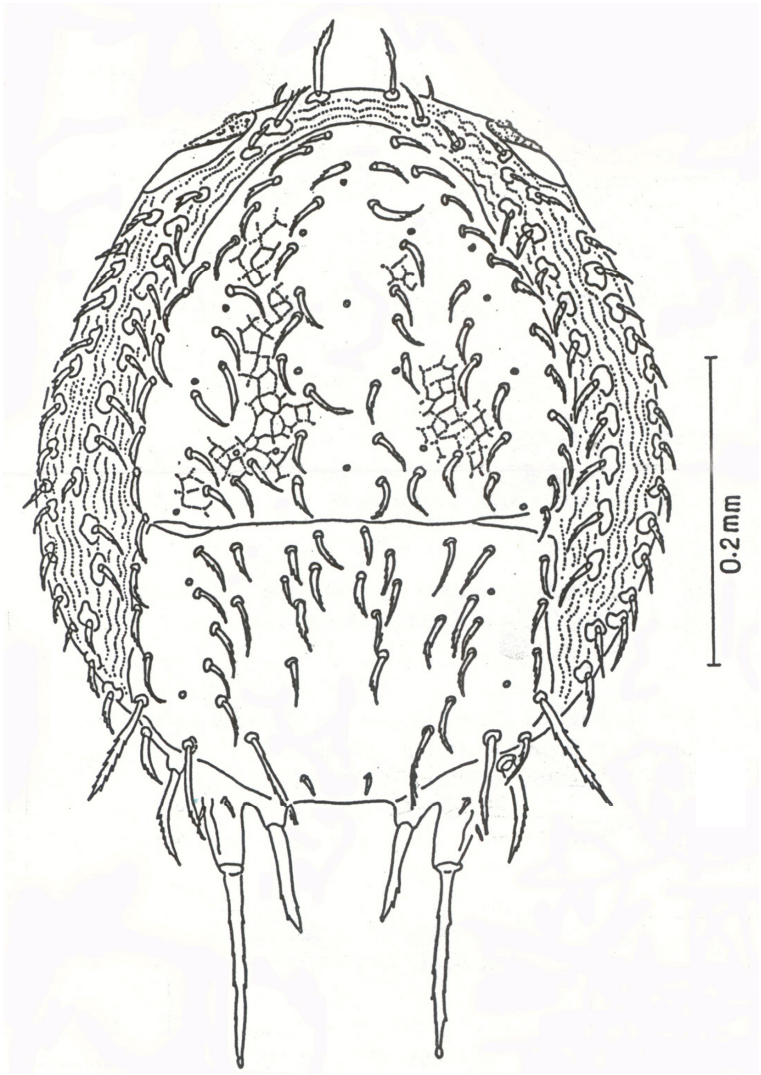


Fig. 16. ***Sejus rufomaculata*** **sp. nov. (Deutonymph) - Dorsum**

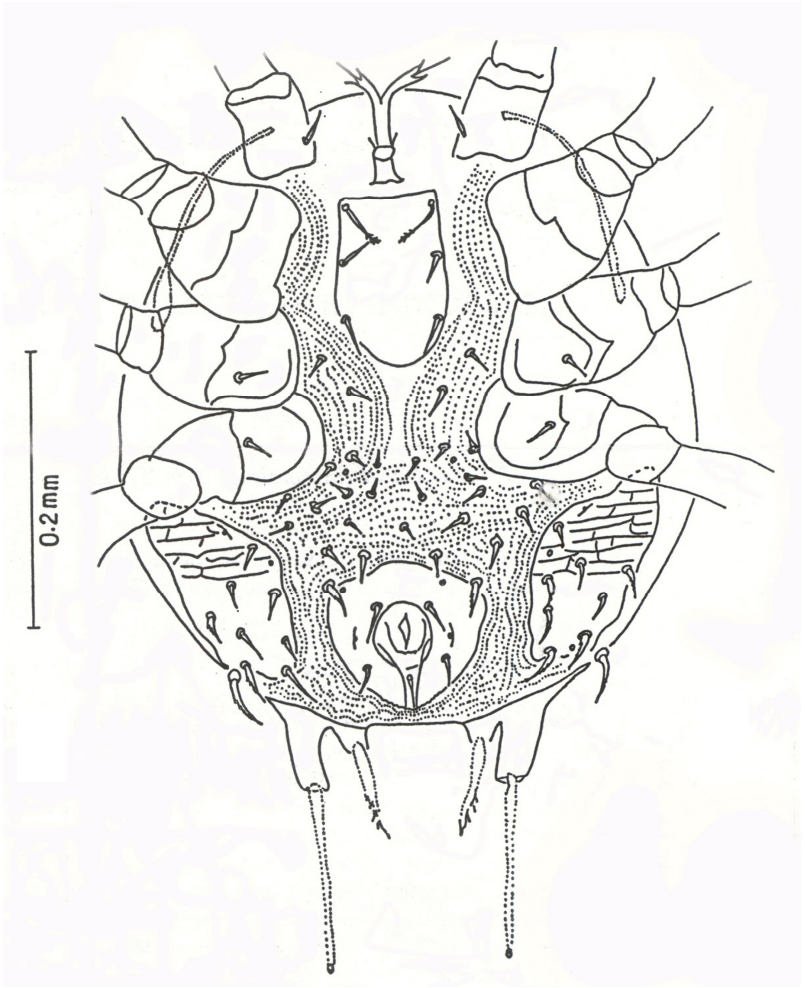


Fig. 17. ***Sejus rufomaculata*** **sp. nov. - Ventrum**

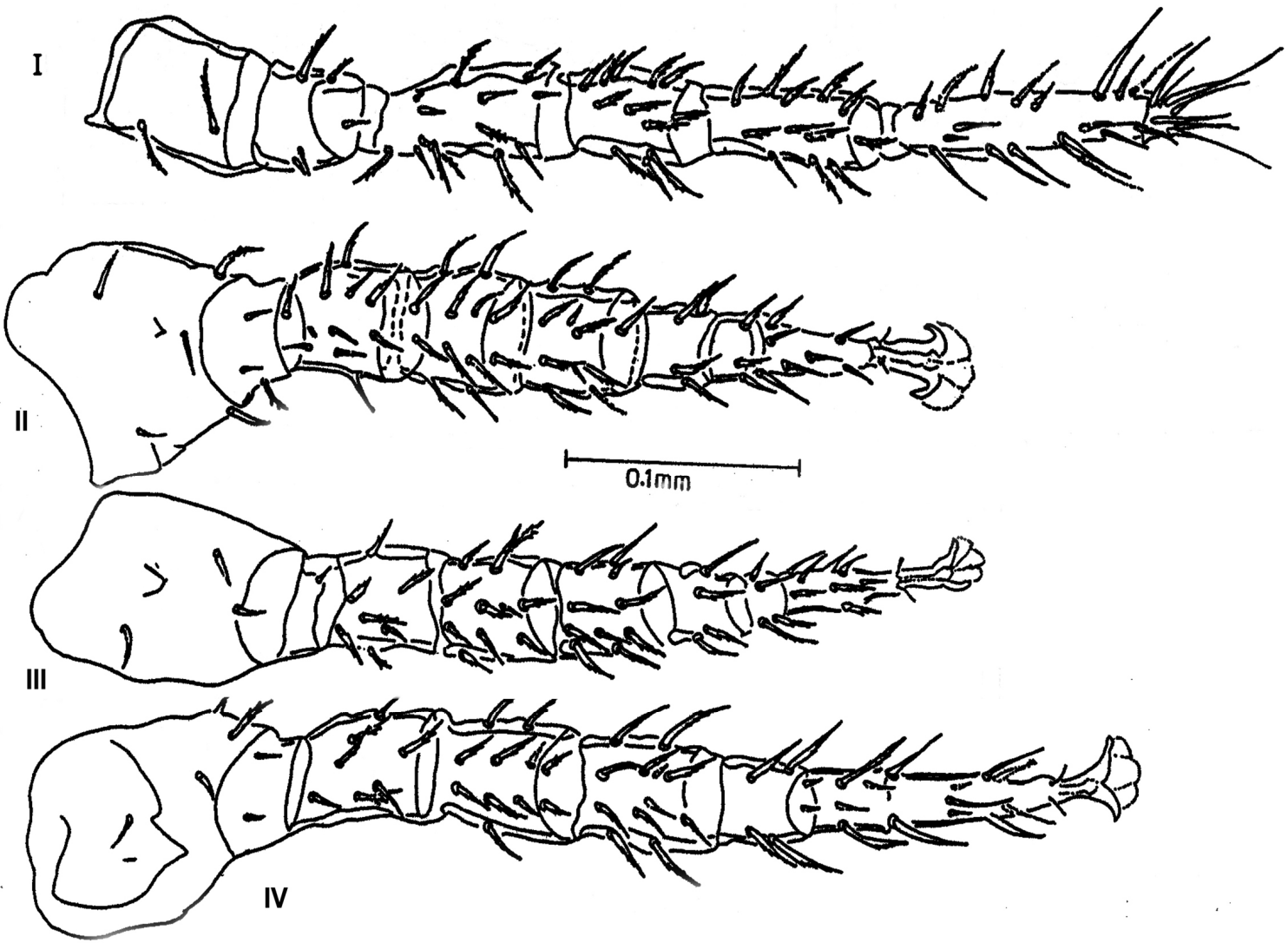


Fig. 18. ***Sejus rufomaculata*** **sp. nov. (Deutonymph) – Leg I-IV**

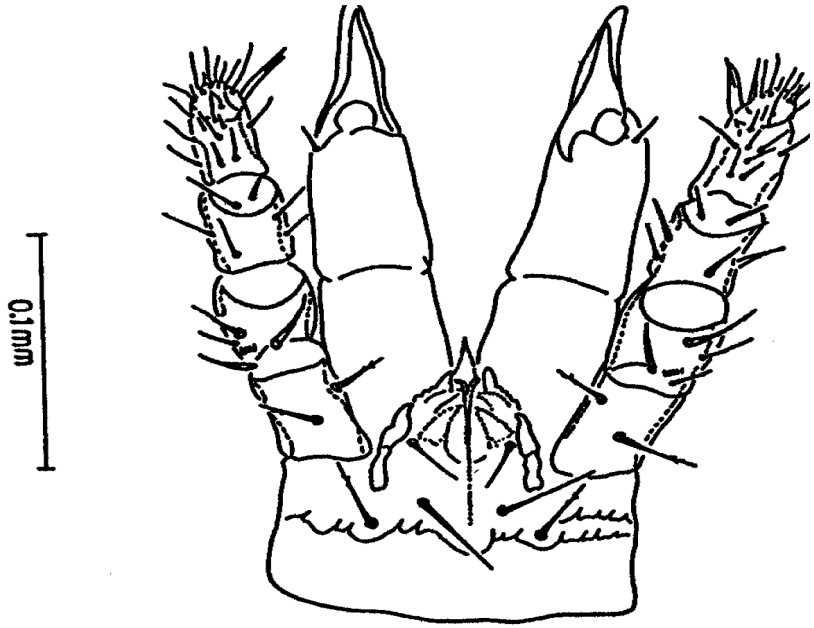


Fig. 19. Gnathosoma

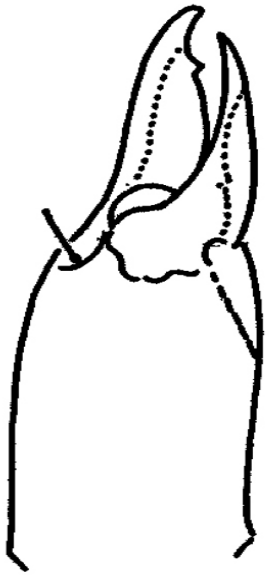


Fig. 20. Chelicera enlarged

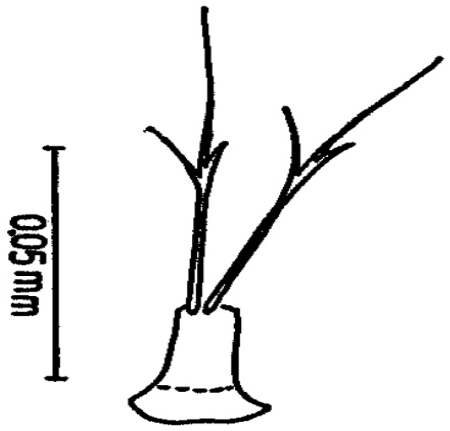


Fig. 21. Tritosternum

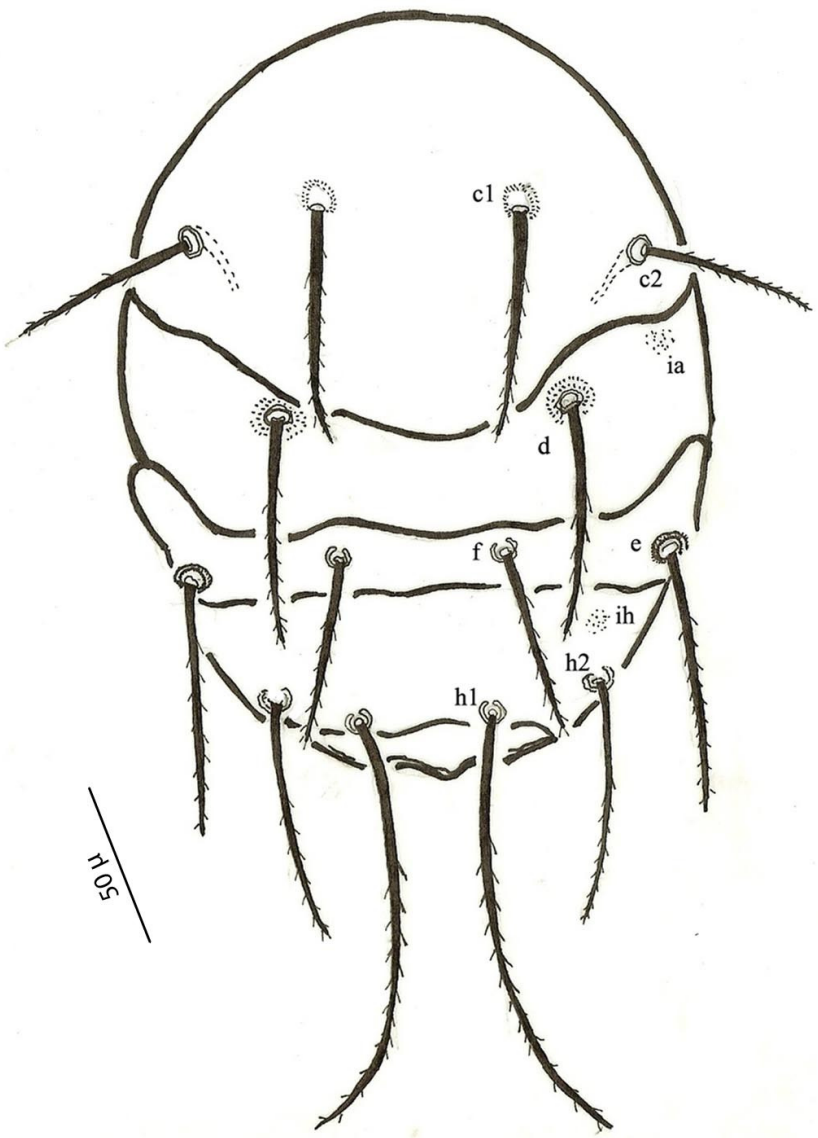


Fig. 22. ***Imparipes bengalensis*** **sp. nov. – Dorsal View**

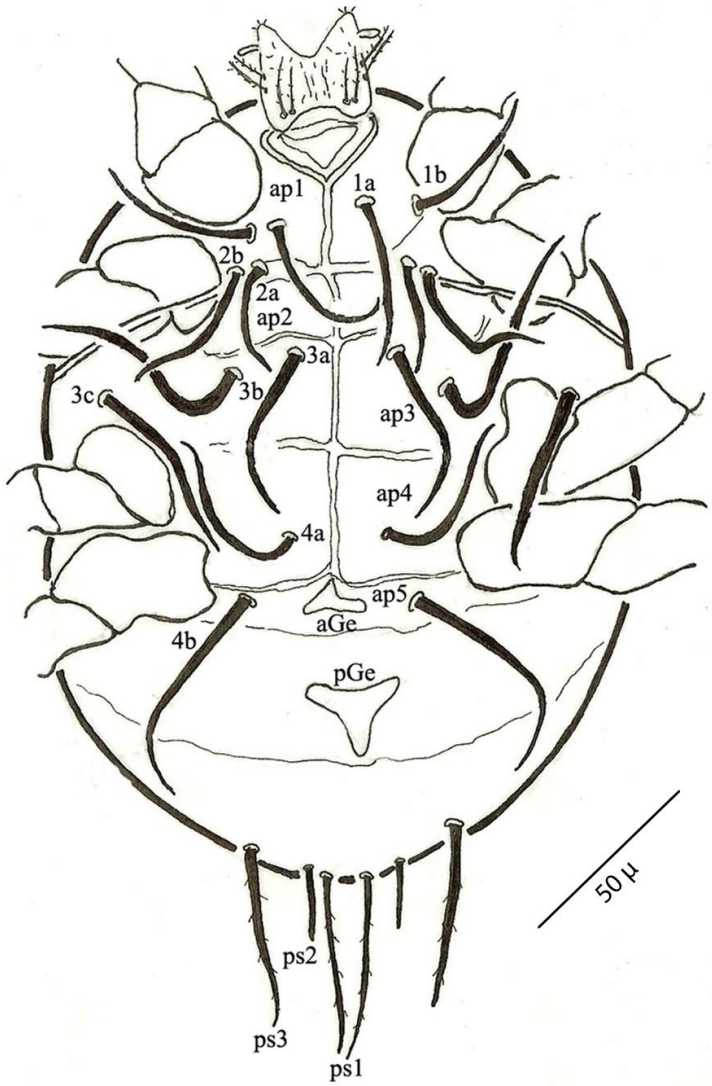


Fig. 23. ***Imparipes bengalensis*** **sp. nov. – Ventral View**

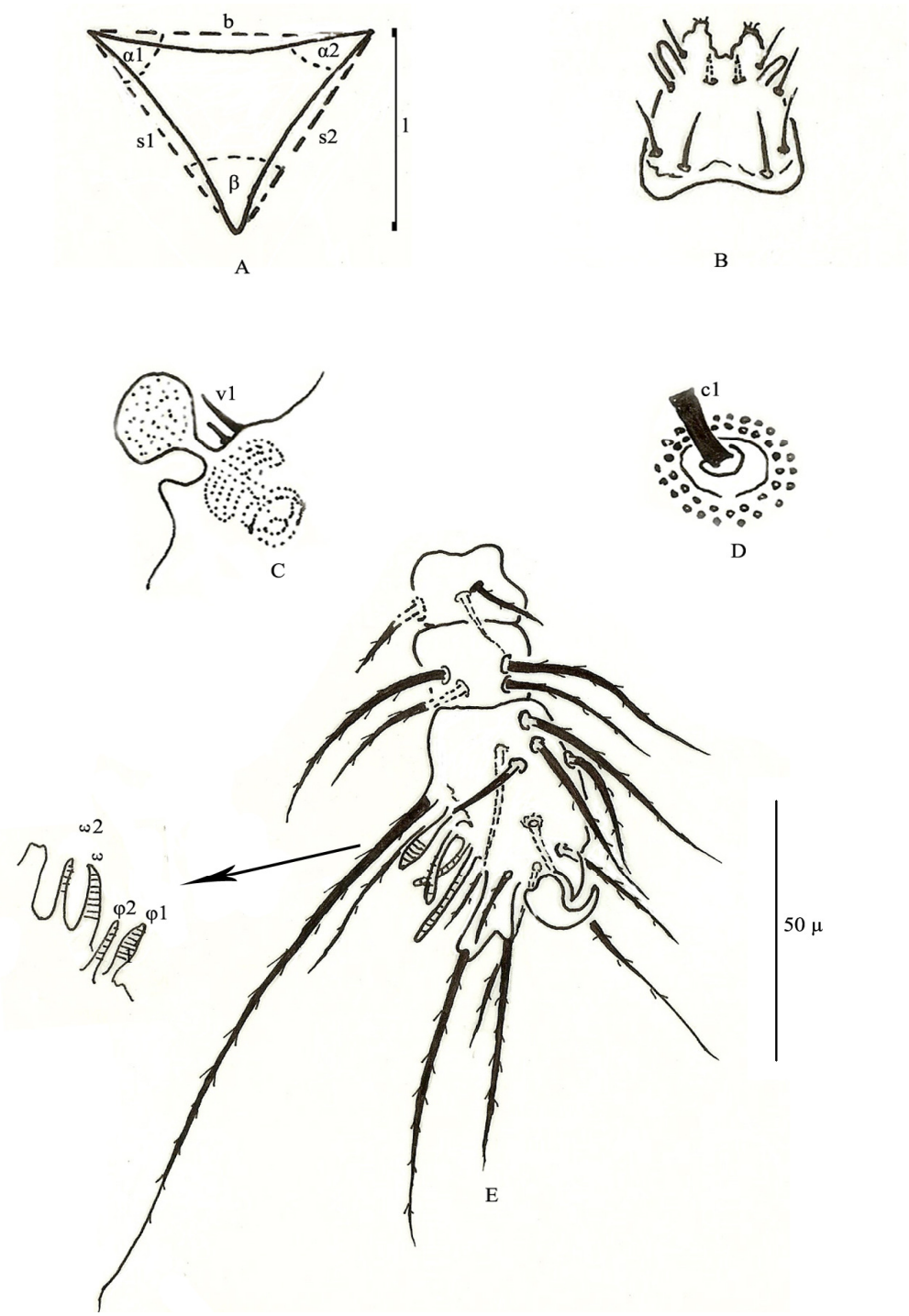


Fig. 24. ***Imparipes bengalensis*** **sp. nov. Female. A – Measurement of the posterior genital sclerites; B – Gnathosoma; C – Trichobothrium; D – Insertion point of C1; E – Leg.**

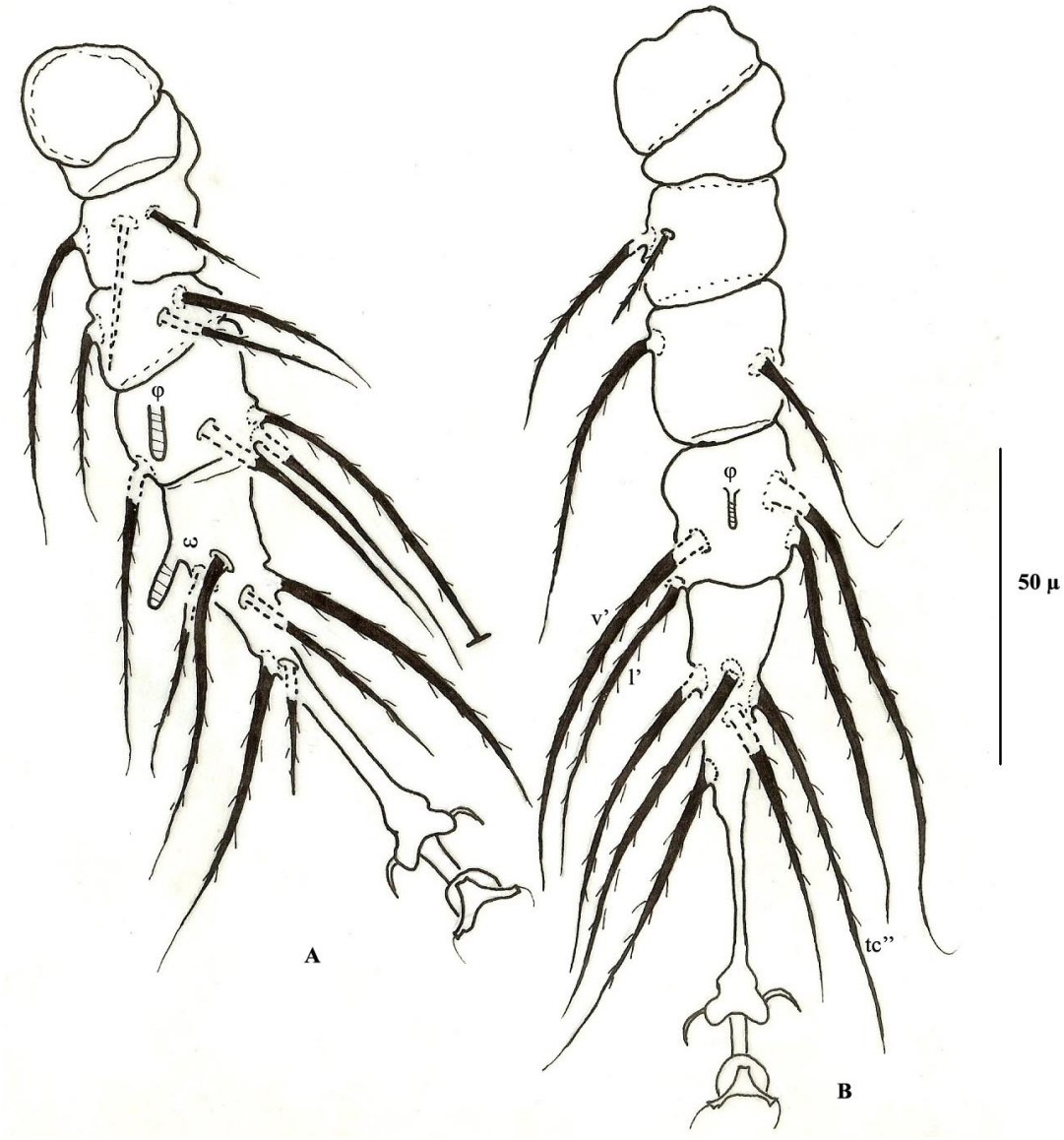


Fig. 25. ***Imparipes bengalensis*** **sp. nov. Female. A –Leg II; B – Leg II.**

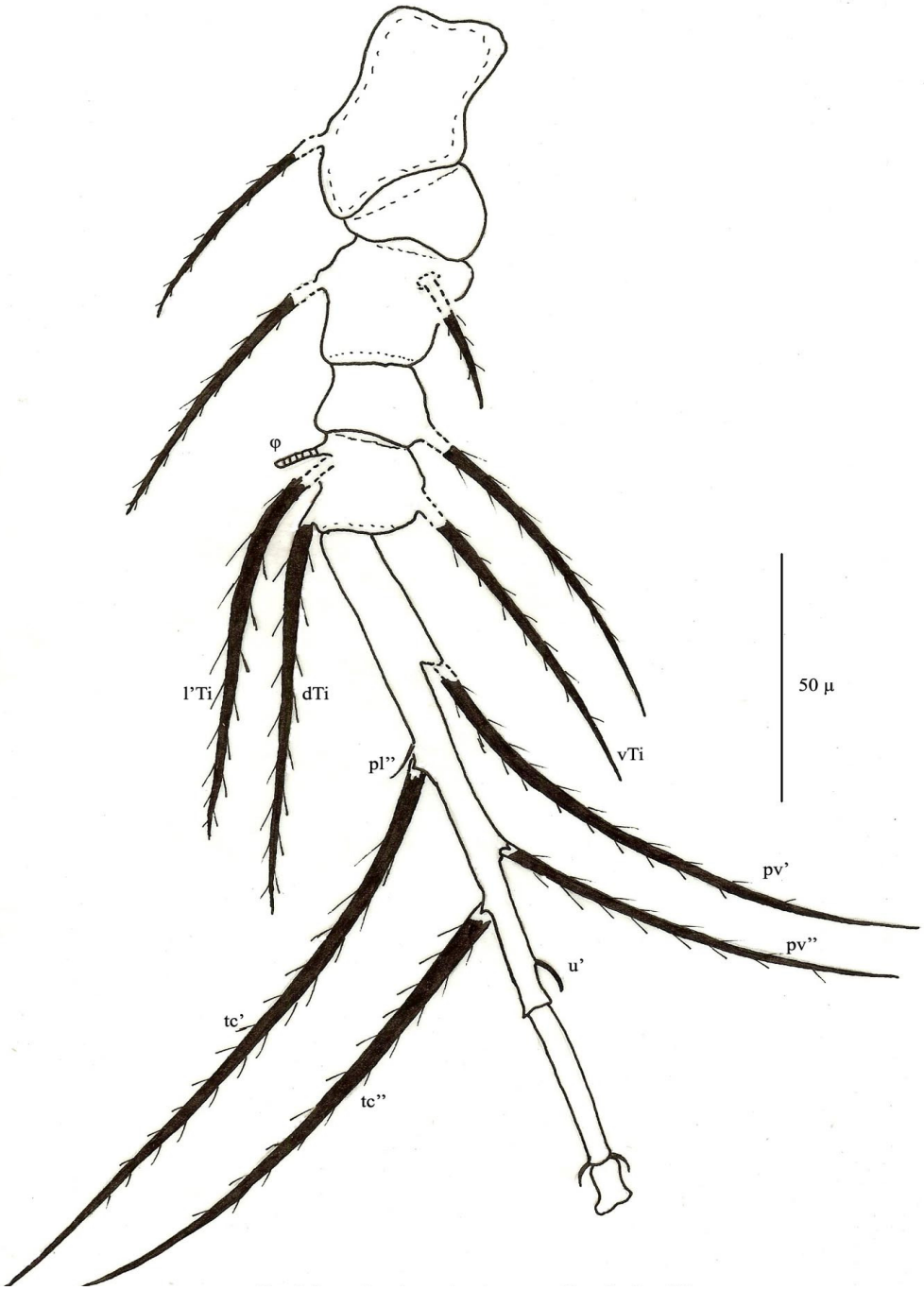
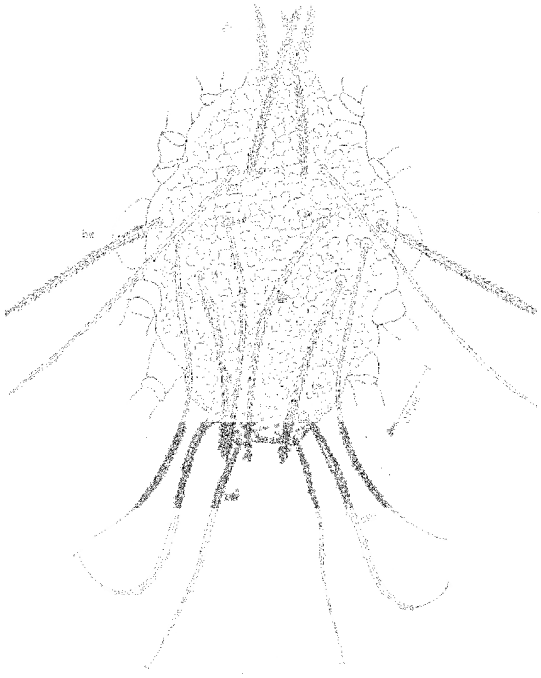


Fig. 26. *Imparipes bengalensis* sp. nov. Female. A –Leg IV.



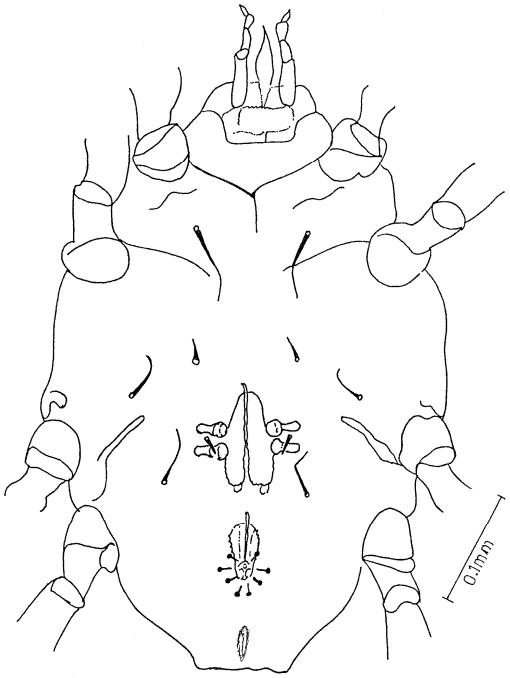
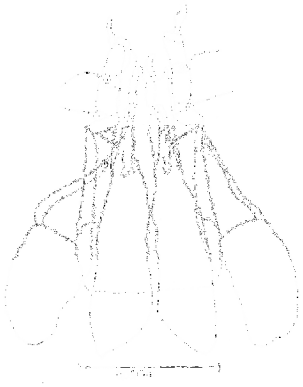
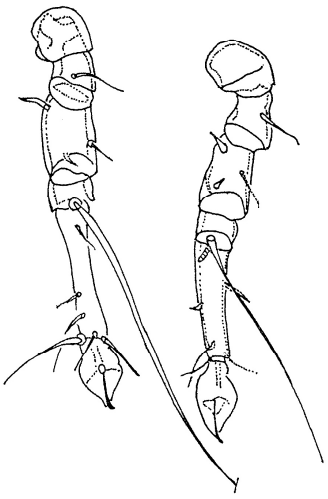


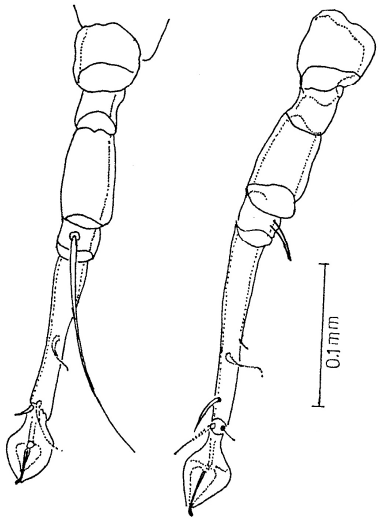
Fig. 27. *Melisia mysorensis* sp. nov. - Dorsum

Fig. 28 . Venter





L I **L II**



L III **L IV**

Fig. 29. Gnathosoma

Fig. 30. Leg I - IV

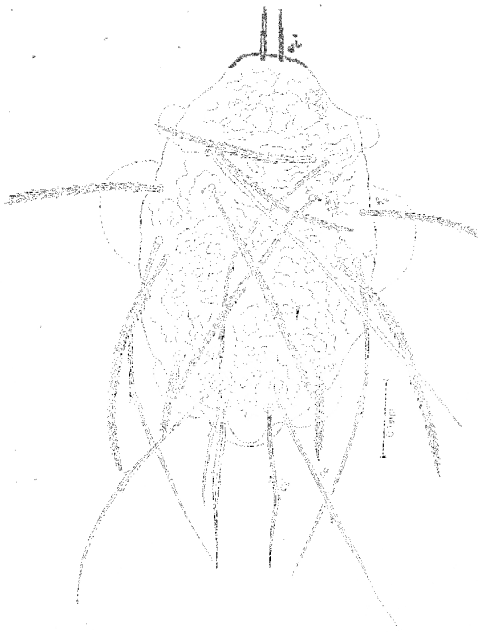


Fig. 31. ***Melisia passalae*** **sp. nov. - Dorsum**

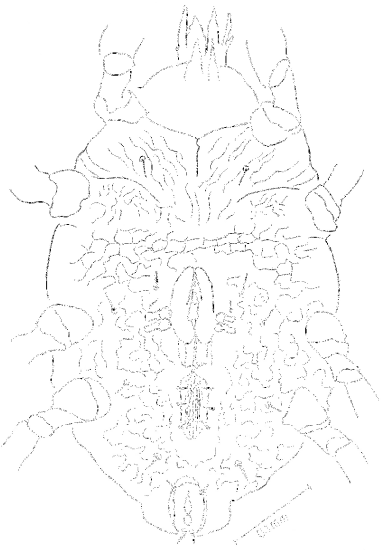


Fig. 32 . Venter

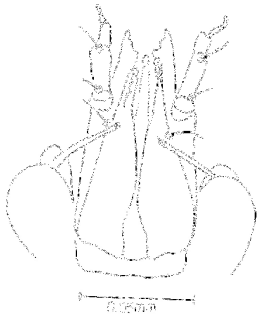
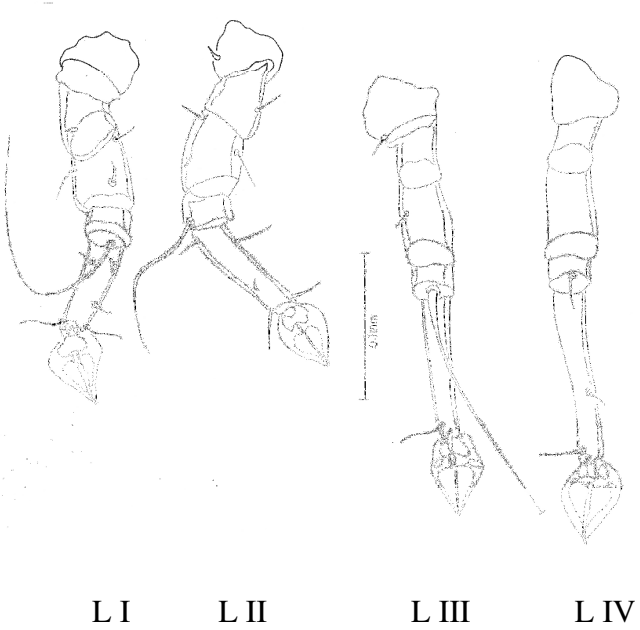


Fig. 33. Gnathosoma



L I L II L III L IV

Fig. 34. Leg I - IV

Conclusion

Agriculture including forestry and human settlements occupy as much as 95 per cent of the terrestrial environment, a large portion of the worlds biological diversity coexists in these ecosystems. Therefore more emphasis should be given to conserve the existing natural environment which ultimately sustains the existing fauna and flora. More awareness programmes should be conducted to educate the people about the importance of forest ecosystem and their benefits. Conservation programmes are aimed to preserve the biological diversity. An abundance of biomass, diversity of plant species, diversity of habitats, abundant soil nutrients, ecofriendly pest management programmes will help the ecosystem and eventually preserve the species diversity. Millions of species live and carry out vital functions in the biosphere and are essential to the society. Biological diversity in Agriculture/plantation/forestry systems can be best conserved by maintaining abundant biomass/energy plant and habitat diversity, conserving soil, water and biomass resources and reducing the use of pesticides and similar toxic chemicals in agriculture and forestry. Maintaining this biological diversity is essential for sustainable agriculture and forestry. A holistic approach is needed for the management of the earth's natural resources as the whole. To conclude, the present study revealed the abundance of acari insect association existing in the Western Ghats ecosystem. A variety of associations have been recorded and there is a chance to unearth more in future. The variety exhibited in the acari insect dversity may indicate the richness of the healthy ecosystem. Even though more phoretic mite associations were recorded, no promising biocontrol agents were identified in the present study, there is every possibility to identify more mites and a few promising biocontrol agents in future. Risch (1981) reported that structural diversity could be achieved by adding different plant species by intercropping and allowing weed growth within the crop to enhance insect diversity.

The various cultivation activities viz., deforestation and conversion of forest land to cultivable area, human intervention like cultivation of plantation crops, destruction of forest covers, weeds, use of xenobiotics like pesticides, fertilizers and other synthetic chemicals in excess, certainly alter the natural occurrence and biotic balance of insects which ultimately affect the acarines. In natural undisturbed area the abundance and diversity of mite fauna is more and the population dynamics of mites is almost around the equilibrium position. This is attributed to the reasons that forest flora support of a minimum population of insect and mites. There should be a statutory body to monitor these activities and suitably advice the local/state/central government on what sort of conservation measures should be adopted. The people and planters should be sensitized about the ill effects of pesticides on the biodiversity of organisms. A catalogue of mites associated with insects has to be prepared and this will serve as a taxonomic key for identification of insect mites. This will serve as a permanent record for identification of mite fauna in future.

6. Recommendation including usefulness of the findings and their application

The entire range of Western ghat is a treasure of diversified flora and fauna which include not only higher vertebrates, but also the micro arthropods like insects and mites. The acari –insect association was studied for the first time in a few localities of Western Ghats. By undertaking this systematic faunistic survey, on the rich diversity of insect- mite association was unearthed. The hitherto unexplored microscopic organisms were exposed which will be of immense useful to assess acarine richness and diversity which are endemic to this hill range of Western ghats. From the faunistic study, 34 species of mites have been recorded which include 6 species of new taxa described for the first time from India. Some mites associated with insects as parasites and phoretic has been discovered. A few insects for eg. Passalid beetles, which are very common in Ooty forest areas have not been collected in this study. This may be due the absence of host plants or more deforestation. Since, this insect harbors more mites than other bJJeetles. Further the investigation on the diversity of insect- Acarina revealed that deforestation, excessive use of pesticides in plantations and urbanization adversely influenced the insects, leading to extermination of naturally occurring

insect population. In addition, misuse of pesticides which often lead to the outbreak of pest mites and insects. These two are the key factors which reduce the diversity of insects and mites in general on cultivated area compared to the undisturbed forest area. In order to conserve the insect diversity the over dependence on pesticide use is to be reduced and resort to ecofriendly management tactics. Awareness should be created among people on the importance of Biodiversity and conservation aspects of various fauna and flora. A handful of soil contains more species of mites which serve as a very good bioindicators. Hence, it is highly imperative to conserve the fauna and flora of Western Ghats.

Acari-insect association has been studied in a few selected Western Ghats regions. Different species (34) of mites associated with insects has been documented. The species index recorded in the present study will certainly help the taxonomists working on mites in identification. The catalogue and the information can be used by all zoologists and acarologists as a reference material for identification of new taxa. These findings will also be made use of by the International agencies like CAB – London where, the acarologists from all over the world can refer the technical reports and diagrams /photographs/ etc., to identify the species, which has become too costlier now a days. The findings are immensely useful to the Ministry of Environment and Forestry to initiate suitable measures to conserve the rich acarine faunal diversity in the natural environment sensitizing different people. The results are useful to the students, university staff and scientists, who work in acari biodiversity to update their knowledge on Acari-insect relationship.

7. Records of dissemination of the project findings to stakeholders (publication in peer-reviewed journal/presented in workshop conference etc.)

Ramaraju, K. 2007. A new species of *Sejus* (Acar: Sejidae) from Tamil Nadu. *Journal of Acarology*. **16**(1&2): 5-7.

Radhakrishnan, V. and K. Ramaraju. 2010. Relative abundance of mesostigmatid mites associated with insects in forest localities of Tamil Nadu.*Madras. Agric. J.,* **97** (1-3): 75-77.

Radhakrishnan, V. and K. Ramaraju. 2008. Mites associated with insects in Tamil Nadu. **In**: National symposium on Integrated pest and disease management in Arid and Semi Arid areas, Arid Forest Research Institute, Jodhpur, from March 12 &13. p 46.

Radhakrishnan, V. and K. Ramaraju. 2009. Biodiversity of mites associated with insects in and around Coimbatore. **In**: International Congress of Global Warming on Biodiversity of Insects: Management and Conservation (GW-BIMC, 2009), Bharathiar University, Coimbatore, February, 9-12. p 38.

Ramaraju, K. and V. Radhakrishnan. 2010. Biodiversity of mites associated with insects in Western Ghats region. *Madras Agric.J.,* (sent for publication).

Ramaraju, K. 2010. Two new species of *Melisia* (Acari: Canestriniidae) from Western Ghats. *Entomon (sent for publication).*

Ramaraju,K. 2010. Two new species of *Uroobovella* (Acari: Uropodina) from Western Ghats regions of Tamil Nadu. (Sent for publication)

8. Total cost of the project and releases made (In Rs.) Rs.6,15,689 /-

Environment Research Scheme (ERS)

6.	14/40/2002-ERS/RE Status, ecology and conservation of striped hyena (Hyaena hyaena) in Gir National Park and Sanctuary	Prof. Jamal A. Khan, Secretary, Wildlife Society of India, Department of Wildlife Sciences, AMU, Aligarh-202002, Uttar

1.Title of the project: Status, ecology and conservation of striped hyena (*Hyaena hyaena*) in Gir National Park and Sanctuary

2.Key words: Hyena (*Hyaena hyaena*), Gir National Park, Conservation, density, food habits, denning

3.Name and address of project investigator: Prof. Jamal A. Khan, Secretary, Wildlife Society of India, Department of Wildlife Sciences, AMU, Aligarh-202 002, Uttar Pradesh. e-mail:secretarywsi@gmail.com, +91-571-2701205 (Telefax)/2905234(direct), 7895931767 (M)

4.Executive summary of the results vis.-a-vis objectives envisaged originally:

The research project titled "Status, Ecology and Conservation of Striped Hyena (*Hyaena hyaena*) in Gir National Park and Sanctuary, Gujarat, India" funded by Ministry of Environment and Forest (Government of India) was started in joint collaboration of Wildlife Society of India, Aligarh and Gujarat Forest Department in April 2006. The overall goal of the project was to generate information on population status and ecology of striped hyena in Gir National Park and Sanctuary (here after Gir PA) for the formulation of a suitable management strategy for long term conservation of the target species. Although striped hyena is big carnivore, but we still know very few about the animal ecology, social organization, and behavior etc. Very little studies have been done, and only few study publications from Africa (Kruuk 1976, Leakey et.al 1999), Israel (Macdonald 1978, Bouskil 1984, Ilani 1975, Kerbis-Peterhans and Horwitz 1992, Skinner and Ilani 1979), India (Davidar 1990), and in captivity by Rieger 1978, 1979a, & 1979b. However, most of data are based on anecdotal information and were brief and relatively informal. Only systematic study was conducted by Wagner 2006, on behavioral ecology of striped hyena in Laikipia District, Kenya. The ecology of the striped hyena (*Hyaena hyaena*) is little understood and has only marginally been investigated. This study was originally designed, to fill the 'gap' in our understanding the ecology of this species.

Objectives:

1. To investigate the current status, distribution and abundance of hyena in different management units and habitats of Gir PA.
2. To investigate the seasonal habitat use, movement and ranging pattern of hyena in Gir PA.

3. To investigate the social organization, breeding and feeding ecology of hyena in Gir PA with special reference to role of hyena in the function of Gir ecosystem.
4. To prepare conservation strategy for hyena in Gir PA using the data generated under this research program.

Methodology

Several sets of methodology were used to fulfill these objectives.

Status and population estimation

A questionnaire survey was conducted inside the Gir PA and the adjoining villages around the PA. Gir forest department staff, Maldhari and villagers close to PA were interviewed. Nesses, settlements inside the PA were surveyed in all over the Gir PA, including western, central, and eastern Gir PA. To obtain information pertaining to presence and distribution of the animals their footprints and scats were randomly searched for on the sanctuary roads and forest trails all over the Gir PA. Photographic capture-recapture sampling technique for estimating abundance of striped hyenas. A grid of 2.5 x 2.5 km² overlaid on the Gir PA, and 15 grids in four areas (zone) east, central, national park, and west were selected systematically to cover all the habitat types and management units for the capture-recapture sampling. The program CAPTURE was used to analyze the capture and recaptured photograph data of striped hyena. Density estimates were generated by dividing striped hyena number by the effectively sampled area, minimum convex polygon with buffer from half mean maximum distance moved (HMMDM).

Food and feeding habits

Scat analysis method was used to determine the food habits of striped hyena in Gir PA. Scats were collected in poly-bags, food remains near the den were noted and regurgitated hairballs found near the dens were also collected and tagged with information like place and date of collection. The scats were collected randomly from October 2006 to June2009. Seasonal and annual variation was also observed. To observe the hyena food habit in different management unit of Gir PA, scats collected were separated in to three zones as West Gir, Central Gir and East Gir, analyzed and represented accordingly. Also, to find any difference in striped hyena diet between different zones, chi square test was performed. Biomass of prey ingested was calculated by estimating the weight of prey eaten per scat sample (Y) for each prey type using the equation: $Y=0.38+0.02X$, where X is the mean adult weight of a given prey type.

Habitat utilization

Habitat use of striped hyena was examined by determining proportion of location on the basis of direct and indirect evidences (foot print, resting sites, dens and scats) of striped hyena from all over the Gir PA. Data on habitat use of lion (*Panthera leo persica*) and leopard (*Panthera pardus*) were also collected and recorded same as described for striped hyena, to see the variation of habitat use between these three big carnivores of Gir PA. The analysis of vegetation was done in Gir PA. The study area was divided into four zones on the basis of vegetation and management unit namely west zone, east zone, Central zone and NP zone. Vegetation sampling was carried out on three transects of 3 km length each sampled zone, with total 12 transects (36 km) in all over the Gir. Sampling of

vegetation was done in 10m radius circular plots at each transect at an interval of 100m, with a total 31 plots on each transect, 93 plots at each sampling zone and 372 plots in total from all the four sampled zone. Seasonal habitat use were calculated and chi square test was computed to test seasonal variation in habitat use of striped hyena and variation in habitat use between lion, leopard, and hyena in Gir PA was also observed by calculating chi square test. Habitat availability and utilization by striped hyena in Gir PA was assessed (Neu et al. 1974). For the available habitat we followed the Q. Qureshi and N. Shah (2004). To understand the habitat use by striped hyena, data were subjected to Principal Component Analysis (PCA).

Denning and behavior

Dens and resting sites were selected for the sampling and data pertaining to vegetation characteristics and den parameters were collected on well planed data sheet. Number of tree in ten meter with species name, habitat type, Number of shrub and ground cover were recorded from five meter plot within ten meter plot. Den opening parameter and slop of terrain and direction of opening or hill slop were also recorded. GPS location and elevation was recorded using GPS receiver. All the possible measurements of den and resting sites were taken for the analysis. Active dens were monitored regularly at dawn and dusk from a hide from an appropriate distance, which varied from place to place depending on terrain (moderate hilly to steep slope) and vegetation, using binocular and spot scope avoiding disturbance to animals. Wherever possible, behavioral activities were documented using a camera (Canon EOS 350D).

Results

Status and population estimation

Altogether, 149 people were interviewed in and around the Gir PA during April 2006 to June 2008. About 78% people considered, as the population of striped hyena as good as sighting were frequent in earlier time but now they are declining in number as encounter rate has declined. A total of 150 trap-nights of sampling effort was expended at each phase and with total of 600 trap-nights from all four zones over six months from December 2007 to May 2008, and as a result 34 usable striped hyena photographs were obtained with an average trapping effort of 17.6 trap-nights per hyena photograph. The effectively sampled area of capture-recapture sampling was calculated for central as 132.37 km², for east 145.44 km², for NP 159.03 km², and for west 132.29 km². The estimated adult striped hyena density for central was 3.78 striped hyena/100 km², for east 11.69 /100 km², for NP 7.55/100 km², and for west was 2.27/100 km². The mean density of striped hyena for the Gir PA was calculated as 6.50 striped hyena/100 km².

Food and feeding habits

Analysis of 699 striped hyena scats from Gir PA showed that 12.92% scats were found to have single mammalian prey item, while only 0.43% scats were found with five prey items. The minimum number of mammalian hair to be examined per scat to detect all mammalian prey species in a particular striped hyena scat in Gir PA with 95% certainty was found as 21 hairs. The 'Observation area-curve' shows that the all striped hyena prey species could be detected by analyzing 40 scats. A variety of food items were identified in the diet of striped hyena in Gir PA, including large mammals to small rodents, birds, insects and even fruits. Total 12

mammalian prey species were detected. Chital was found to be the most common prey item in the diet of striped hyena. Seasonal variation in the diet was observed in the mammalian as well as non mammalian prey items. Significant differences were observed in diet composition in different zones of Gir PA. On average 50.91% of total relative consumed biomass was contributed by the wild prey while livestock contribution was found as 49.08%.

Habitat utilization

Striped hyena was found around all the habitat type with preference of Mixed forest (40.46 ± 5.97 SE) and others as Moist mixed forest (8.09 ± 1.13 SE), Teak-Acacia-Zizyphus (30.64 ± 4.5 SE), Acacia-Teak/Anogeissus (1.16 ± 0.06 SE), Acacia-Lannea-Boswelia (8.67 ± 1.22 SE), Acacia-Zizyphus ((8.67 ± 1.22 SE), Scrubland (1.73 ± 0.17 SE), and Open area (0.58 ± 00 SE) and no difference was observed in the seasonal habitat use pattern. Significant difference between two habitats that is Mixed forest and Acacia-Lannea-Boswelia in lion, leopard and striped hyena habitat utilization in Gir PA. Mixed forest is most preferred habitat type by striped hyena in Gir PA. Habitat types like Moist mixed forest, Teak-Acasia-Zizyphus, Acasia-Lennia-Boswelia, Thorn forst, Scrub lands and open area were utilized in proportion to its availability, while Acasia-Teak/Anogeissus, savanna and wetlands were avoided. Tree density was found as negative and grass was found as positive correlation with the hyena density in Gir PA.

Denning and behavior

A total 28 dens and 30 resting sites at six locations were searched from different parts of Gir PA. All were found in hilly terrain and most of them in middle of the hill slope and some of them on top of the hill. Out of 28 dens 23 dens were sandy and only 5 were rocky, while out of 30 resting sites 24 were sandy and only 6 dens were rocky. The striped hyena uses three types of structures for the resting and pup rearing, resting sites, resting den and rendezvous site in Gir PA. The mean litter size was found 3 ± 0.24 SE, ranges from 2-4 pups. The newly born pups were observed in winter from January – March (n=9) and age was estimated from body size. Striped hyena was found solitary at all the active times but clans (a group of hyena) was observed at den site. Mean number of individuals in clan was estimates with confidence interval as 3.74 ± 0.05 SE. The largest clan was of 8 individual and smallest of 3 individuals in Gir PA. Mother usually stayed with pups in the same den, seldom moves out of den but remains in close proximity when pups are very young (1-3 month), and mothers were observed resting at far place around 50m to 150m (n=5), in day time when pups became little old. The mean duration of lactation with 95% confidence interval was 12.94 ± 1.09 SE minutes that vary from 5-25. The striped hyena was found very calm animal that rarely uttered any sound.

5.Results and conclusions:

Striped hyena is present in all over the Gir PA.

Mean density of striped hyena was estimated as 6.5 adult individual/100 km².

Availability of favorable resources could be the factor for having this population. Although a quantitative density estimate is needed from an unprotected or degraded forest habitat of India of this species.

Eastern Sanctuary has higher density of striped hyena (11.69 individual/100 km² while western sanctuary has lowest density 2.27 individual/100 km² and central part as 3.78 individual/100 km².

The vegetation composition and density, shrub and grass cover for hide, availability of food, and safe denning sites could be the reasons for this variation of striped hyena population in different zones of Gir PA.

Striped hyena was found as extremely nocturnal with rare sighting in Gir PA.

Photographic capture-recapture sampling technique was found appropriate to estimate population in Gir PA for rare and nocturnal species with natural markings.

Minimum number of hairs to be examined per scats was found as 21 hairs to detect all possible mammalian prey items with 95% confidence limit in striped hyena scats.

Minimum number of scats to be analyzed was found as 40 scats for striped hyena of Gir PA.

Striped hyena was found as omnivorous that feed on variety of food items from big mammals (buffalo, bluebull, sambar) to small mammals (rodents) that is supplement by seasonal fruits.

Chital and hare were found as most common mammalian species eaten by striped hyena in Gir PA.

Zizyphus spp. and *Diospyros melanoxylon* was found as most common fruits eaten by striped hyena in Gir PA in their respective seasons, thus variation was found in the diet between winter and summer.

Total mammalian biomass consumed by striped hyena was around 3668.58 kg, from April 2006 to July 2009.

Both wild as well as domesticated prey contributes around equal biomass in the striped hyena diet in Gir PA.

The decline in domestic biomass contribution and increase in wild prey biomass contribution was observed from data 2006 to 2009 in striped hyena diet in Gir PA.

In western and eastern Gir PA contribution of domestic biomass was found higher than wild prey biomass, while in central Gir PA wild prey biomass contribution was higher than domestic biomass in the diet of striped hyena.

Mixed forest was found as most utilized habitat type by hyena followed by *Teak – Acasia- Zizyphus.*

Acasia – Lannea – Boswelia (hill forest) vegetation type was utilized mainly for denning and resting by hyena in Gir PA.

There was no difference in the habitat use by striped hyena was observed between summer and winter in Gir PA.

Moist mixed forest type is least utilized and *Acasia – Lannea – Boswelia* (hill forest) more utilized by striped hyena in compare to lion and leopard.

Tree density was found as negative correlated while grass cover was found as positive correlated with hyena population.

Tree density was low in east zone compare to other three zones.

Higher striped hyena density in eastern Gir PA could be due to availability of suitable refuge in the form of ridges, high predator density and human habitation compare to western Gir PA.

Striped hyena was identified as solitary animal but they can live in communal denning system.
Sandy dens are more preferred for denning as they can be constructed according to requirement, that provide more protection to pups from natural enemies.
Total three type of structures utilized by hyena in Gir for resting and pup rearing process.
Newly born pups were only found in between January and March season suggesting that striped hyena gave birth to pups in winter season.
The mean litter size was found 3 ± 0.44 SE, while minimum litter size was found as 2 and maximum was 4 pups in a single litter.

Striped hyenas were found solitary in all the active time but clan (a group of hyena) can be observed at den site. Largest clan was recorded of 8 individual and smallest of 3 individuals in Gir PA.
Striped hyena was found as very calm animal produce any sound very occasionally.

6.Recommendation including usefulness of the findings and their application: The main recommendations of the project findings have been incorporated in the management plan of the Gir National Park which being revised currently by the CCF and DCF Wildlife Sasan Gir.

7.Records of dissemination of project findings to stakeholders:
Final technical report of the project has been made available to the managers for implementation. A paper on mark-recapture techniques for density estimation of striped hyena has been submitted to the International Journal "Oryx". More research papers are being prepared for submission. The data on habitat use is being analysed at the Indian Remote Sensing Institute, Dehradun in collaboration with Prof. S.P.S. Kushwaha on habitat modeling of the striped hyena.

8.Total cost of the project and releases made in Rs: 25,31,600

7.	14/75/2003-ERS/RE Restoration of Certain Mining Sites of Gujarat by Application of VAM Fungi	Prof. Arun Arya, P.I and Head, Department of Botany Faculty of Science, The Maharaja Sayajirao University of Baroda.

1. Title of The Project : **Restoration of Certain Mining Sites of Gujarat by Application of VAM Fungi**

2. Key Word: **Mining area, VAM Fungi, Reclamation, Gujarat**

3. Name of Project Investigator : **Prof. Arun Arya**
Principal Investigator and
Head, Department of Botany
Faculty of Science,
The Maharaja Sayajirao University of Baroda

3A. Number and date of Sanction latter: No 14/75/2003- ERS/RE dated 30-10-2006
3B Duration of the Project 6/12/2006 to 5/12/2009
3C. Date of start of Project 6th Dec 2006
3D. Date of completion of Project 5/12/2009

4. Executive Summary and Objectives

Restoration aims to return the degraded system of any area to same form of cover which is protective, productive, aesthetically pleasing or valuable in the sense of conservation. Plantation is the oldest technology available for the restoration of lands degraded by human activity.

In a study done for restoration of damaged coal mine areas in India, Singh *et al.*, (1996) reported that as compared to native non leguminous species, native leguminous species show greater improvement in soil fertility parameters. Leguminous plants can benefit from the symbiotic association with *Rhizobium* as well as AM fungi. On this basis three leguminous tree species viz. *Pongamia pinnata* (L.) Pierre*., Tamarindus indica* L. and *Leucaena leucocephal*a (Lam.) Dewit. were selected for restoration of minig land. Efforts have been made to survey different mining sites of Gujarat like Shivrajpur, Bapotia, Ghamodi, Kadipani, Gayanawada and Sorna and efforts have been made to find out the association of AM fungi in roots and rhizospheric soil of various plants.

AM fungus *G. fasciculatum* was selected to be multiplied *in vivo* and then three tree species were inoculated with different concentration of AM spores and *Rhizobium*. Pot experiments were carried out with different treatments of AM fungi along with control and growth rate of saplings/ plants was observed by taking biomass at every 15 day interval till 6 months. Plants showing better performance were planted in mining sites. A significant increase in biomass was obtained in AMF associated plants planted at Kadipani and Sorna. (AM inoculated tree species showed 80 % survival rate after 3 months of plantation). This technique will be extremely helpful in better reclamation of mining soil.

Objectives

1. To identify and study the population of AM fungi in the rhizospheric soil of herbs and shrubs growing in the active mining sites and dump areas of Vadodara, Kheda and Panchamahal districts of Gujarat.
2. To isolate *Rhizobium* from leguminous plants growing in the mined areas.
3. To study the physicochemical characteristics of soils of active mining sites.
4. To select the dominant AM fungi and study their effect on the establishment and growth of *Pongamia pinnata, Tamarindus indicus* and *Leucaena leucocephala* plants in glasshouse trials, singly and in combination with selected *Rhizobium* isolates.

5. To identify and select best treatment combinations(s) for field application.
6. To evaluate the field performance of seedlings after best treatments.
7. To recommend the best treatments(s) for rehabilitation of mined sites.

5. Results and Conclusions:

The rhizospheric soil of mining areas showed the dominance of *Glomus fasciculatum* (Thaxt.) Gerd. & Trappe, *G. aggregatum* Scheneck & Smi., *G. macrocarpum* Tul. & Tul., and *G. mossae* Nicol. & Gerd. The rhizospheric soil of thirty five plants of Kadipani showed dominance of *Glomus fasciculatum, G. aggregatum G. intaradius* and *G. mosseae.* Plate III shows some of these AM fungi. The population of spores was increased by pot culture method. Successes inoculation of AM spores was further obtained by Funnel method The pH of soil ranged from 7.2 - 8.5 and electric conductivity ranged from 1 – 3.

AM fungus *G. fasciculatum* was selected to be multiplied *in vivo* and then three tree species were inoculated with different concentration of AM spores and *Rhizobium*. Pot experiments were carried out with different treatments of AM fungi along with control and growth rate of saplings/ plants was observed by taking biomass at every 15 day interval till 6 months. Plants showing better performance were planted in mining sites. A significant increase in biomass was obtained in AMF associated plants planted at Kadipani and Sorna. (AM inoculated tree species showed 80 % survival rate after 3 months of plantation). This technique will be extremely helpful in better reclamation of mining soil.

Biomass studies were undertaken in *T. indica,* AM inoculated plants, showed maximum 1.79g dry wt of shoot after 75 days while in control it was 0.83 g. After 75 days root length was 40.6 cm as compared to 33.3 cm in control plants. An increase in biomass of plants with AM inoculated tree species was recorded than control. These AM plants showed better performance when planted in mining site. No toxic effect of minerals was seen on leaves. The plants were healthy. Thus degraded area of mining site can be reclaimed with use of AM fungi.

6. Recommendations:

1. There is a need to study the physico-chemical properties of mining soil, this will help to suggest type of trees to be planted.
2. Methods should be adopted to increase the VAM population in mining soil.
3. Of the three different types of tree saplings tried on mining waste land the performance of *Pongamia* and Tamarind tree was better and plantation of these two trees is recommended,

7. Publications:

1. Occurrence of Arbuscular Mycorrhizal Fungi in rhizosphere of certain weeds and revegetation strategies in Fluorspar mines of Kadipani (Gujarat), India
Arun Arya, Shirali K. Choksi and Hiral Buch
Paper presented in 1st International Congress on Mycorrhizal Symbiosis: Ecosystems & Environment of Mediterranean area from11th – 13th October, 2010, Marrakesh, Morocco.

2. Reclamation of fluorspar mining areas of Kadipani by AMF inoculated tree species
Shirali K. Choksi and Arun Arya

Presented in National Seminar on Emerging areas in Plant Sciences 22nd February, 2009, Department of Botany, M.S. University of Baroda

3. **Reclamation of mining land by application of AM inoculated tree species**
Shirali K. Choksi and Arun Arya

Presented in National Seminar on Air Pollution Management I Changing global environmental scenario 7th February, 2010, Department of Botany, M.S. University of Baroda

5. Total Cost of the Project **Rs. 8,72,880=00**
Amount received **Rs. 3,70,000 + Rs. 2,85,000=00**

(Rs. 78,662=00 to be recovered from Funding Agency)

Prof. Arun Arya
Principal Investigator

8.	14/40/2003-ERS/RE Regeneration and Tree Diversity Status along the Disturbance Gradient on Natural Oak (Quercus leucotrichophora A.Camus) Forests in Garhwal Himalaya.	Dr. D.S. Chauhan, Department of Forestry & Natural Resource, Post box-59, HNB Garhwal University, Srinagar Garhwal, Uttarakhand.

1. Title of the Project:

Regeneration and Tree Diversity Status along the Disturbance Gradient on Natural Oak (*Quercus leucotrichophora A.Camus*) Forests in Garhwal Himalaya.
(No. 14/40/2003-ERS/RE)

2. Keywords:

Undisturbed, moderately disturbed, highly disturbed, density, diversity, seedling, regeneration, *Quercus leucotrichophora, altitudes.*

3. Names and Address of the Project Investigator:

Dr. D.S.Chauhan, Department of Forestry & Natural Resource, Post box – 59, HNB Garhwal University, Srinagar Garhwal, Uttarakhand.

4. Executive Summary of the results vis-à-vis objectives envisaged originally:

Objectives:

- ✓ Inventorization of tree diversity in different levels of disturbances along (1100-2100m) altitudinal gradient on Oak (*Q. leucotrichophora*) forests.
- ✓ Determine the regeneration status of Oak (*Q. leucotrichophora*) forests along different levels of disturbances.
- ✓ Measure and monitor tree diversity and regeneration pattern through permanent plots in Oak (*Q. leucotrichophora*) forests.
- ✓ To determine the population dynamics of few permanent plot both control and open to anthropogenic pressure.

Objectives achieved:

- ➢ Total 19 sites along 1500 – 2500 m asl altitudes, which have 125 altitudinal sites of Oak forest stands were explored covering 6 districts viz: Chamoli, Dehradun, Pauri, Rudraprayag Tehri, and Uttarkashi. Out of which 83 altitudinal sites were found in north facing aspect and 42 altitudinal sites were found in south facing aspect. Maximum occurrence of Oak forest was observed at 1800 m in north facing aspect.
- ➢ A database of plants has been documented, total of 134 species, 107 genera belonging to 63 families across all explored sites. Among nineteen Oak stands, there were 31 tree species under 26 genus and 17 families. Further forty-seven shrub species belonging to 35 genus and 22 families and fifty-six herb species representing 46 genus and 24 families were found. As a whole Rosaceae and Asteraceae were the dominant families.
- ➢ Highest stand density for tree species (1388 trees ha^{-1}) was recorded in Diwalikhal, whereas the highest density (906 trees ha^{-1}) for *Q. leucotrichophora* was recorded in same site. Basal area of *Q. leucotrichophora* was found maximum (158.4 m^2 ha^{-1}) in Radi. While maximum Importance Value (IVI) showed (184.5) for *Q. leucotrichophora* in Tripalisain.
- ➢ The population structure of tree species in terms of proportion of seedlings, saplings and adults among nineteen oak forests stands varied greatly. However, maximum proportion (46.7%) of adults was recorded in Khirsoo and minimum proportion (31.3%) in Tirpalisain and tree density of *Quercus leucotrichophora* was found more than the sapling and seedling density.

- The regeneration status of studied Oak stands was recorded higher in north aspect as compared to south aspect. It might be due to sufficient availability of soil moisture and other favorable conditions for the seedling survival.
- Across the explored sites 30 were found undisturbed, 70 moderately disturbed and 25 were under highly disturbed sites. Out of three disturbance categories, the moderately disturbed sites showed maximum species richness.
- At the upper most vegetation layer, the tree density varied with the magnitude of different disturbance categories. However, maximum tree density (1480 trees/ha) was observed in undisturbed site at Khirsoo, followed by 1160 trees/ha in moderately disturbed site at Nauti. Highest basal area (4.42 m^2/ ha) was found in moderately disturbed site at Mussoorie.
- Concerning diversity indices in all disturbance regimes, the Simpson index, Berger-Parker and Evenness index were found maximum in the moderately disturbed sites while, Shannon diversity was maximum in undisturbed sites and the Margalef index was found highest in the highly disturbed site.
- The regeneration status varied in the different disturbance regimes, however, seedling and sapling density was recorded maximum in undisturbed sites.
- Physiochemical properties included Nitrogen, phosphorus, potassium, organic carbon, organic matter, water holding capacity, moisture and soil pH showed that all the soil content was highest at moderately disturbed sites.
- For the long term monitoring of Oak regeneration, three permanent plots (1ha plot each site) were established. Among these at Diwalikhal in Chamoli district was observed favorable Oak province for seedling survival.
- Most of the sites showed <70% seedling survival of *Quercus leucotrichophora* during the study period. Some co-dominant species also showed good survival percentage such as *Rhododendron arboreum, Lyonia ovalifolia, Myrica esculenta, Pyrus phasia* and *Benthamidia capitata*.
- Most of the sites showed <20% seedling recruitment of *Q. leucotrichophora* during the study period. Maximum mortality in seedlings was found during winter season, may be due to dense fog, frost, hailstorms, chilling temperature and local grazing & browsing pressure.
- Rate of litter accumulation was observed maximum in the winter season when most of tree species admixed with *Quercus leucotrichophora* shed their leaves. However, highest (90.87 gm/ m^2) litter accumulation was recorded at 2100 m in Khirsoo.
- Seedling development of different species showed a successive growth in diameter but fluctuations occurred in the height growth and leaf numbers might be grazing and browsing pressure, seasonal variation and human interference.
- The forests that were situated close to human habitation had high disturbance frequency and forests that were far from the human habitation had low disturbance. Disturbances may changing the species richness and diversity, which influence the soil and environmental conditions.
- Thus, the disturbances play an important role in change, loss or establishment of plant diversity of a region. These disturbances not only influence the soil, nutrient and water conditions, but also influence climatic conditions. The conservation and management of biodiversity of these forests will be important for the sustainability and improvement of soil nutrient and water conditions of the region. Therefore, the conservation and management of these forests will be important for the sustainability of human and land in the region.

5. Results and Conclusions:

The Inventorization of Oak forest biodiversity, vegetation analysis and regeneration status of dominant species occurring in these forests provide the background information for applying appropriate conservation measures. With the major focus on anthropogenic disturbance, plant diversity, regeneration status and community structure was studied in nineteen Oak forest stands were explored for the purpose covering six districts viz: Chamoli, Dehradun, Pauri, Rudraprayag Tehri, and Uttarkashi. All nineteen sites at altitudinal range of 1500-2500 m asl was situated at either north or south -facing aspects.

Further, based on the disturbance index these sites were categorized in to three disturbance classes viz; undisturbed, moderately disturbed and highly disturbed.

Altitudinal distribution of Oak stands in study area:

A total of 125 altitudinal ranges of Oak forest were surveyed in Garhwal Himalaya, out of which 83 altitudinal ranges were found in north facing aspect and 42 altitudinal ranges were found in south facing aspect. In north facing aspect, 1800 m. altitudinal range was found with 15 Oak stands in different sites, which showed maximum distribution of Oak species at this range. Only one stand at Chaurangikhal in 2500 m. altitude range showed minimum occurrence of Oak. While in south facing aspect among 42 altitudinal ranges, the maximum (9) stands were situated at 1800 m. altitude in different sites and minimum (2) stands were found at 1600 m. and 2500 m. altitudinal ranges in Chaurangikhal and Naugonkhal Oak sites respectively.

Plant diversity, population structure and regeneration status:

In all nineteen Oak forests in Garhwal Himalaya, a total of 134 species representing 107 genus under 63 families were recorded. Across the nineteen Oak stands, there were 31 tree species under 26 genus and 17 families. Further forty-seven shrub species belonging to 35 genus and 22 families and fifty-six herb species representing 46 genus and 24 families were found across the all studied sites. As a whole maximum number of species were found in the family Rosaceae (17) followed by Asteraceae (15). With regards to tree species, Rosaceae and Lauraceae were the dominant families followed by Fagaceae and Pinaceae. In shrub category, Rosaceae was again found the dominant family, while in herb layer Asteraceae (9) was found dominant family.

Concerning the composition observed in all studied Oak forests, the dominant species occurred in the upper vegetational layer were; *Quercus leucotrichophora, Q. semecarpifolia Rhododendron arboreum, Lyonia ovalifolia, Myrica esculenta, Benthamidia capitata, Cedrus deodara, Pyrus pashia, Symplocus paniculata* and *Pinus roxburghii.* In the middle layer the dominant shrub species were; *Eupatorium adenophorum, Berberis aristata, Myrisine africana, Rosa macrophylla, Rubus ellipticus, Colebrookia oppositifolia, Cotoneaster bacillaris,Desmodium elegans, Daphne papyracea* and *Desmodium elegans.* In ground vegetational layer the major dominant species were; *Andropogon munroi, Boenninghausenia albiflora, Cynadon dactylon, Fragaria nubicola, Herteropogon contortus, Micromaria biflora, Valeriana jatamansii* and *Viola canescens.*

Among nineteen studied sites, highest stand density for tree species (1388 trees ha^{-1}) was recorded in Diwalikhal and minimum density (615 trees ha^{-1}) was found in Koti Oak forest stand. Whereas the highest density (906 trees ha^{-1}) for *Q. leucotrichophora* was recorded again in Diwalikhal Oak forest followed by Khirsoo (798.2 trees ha^{-1}) and Pipalkoti (733 trees ha^{-1}) for the same species. Basal area of tree species was recorded highest (256.9 m^2 ha^{-1}) in Radi followed by Chaurangikhal (245 m^2 ha^{-1}) while its lowest value was recorded in Bhawan Oak forest stand (38.6 m^2 ha^{-1}). Basal area of *Q. leucotrichophora* was found maximum (158.4 m^2 ha^{-1}) in Radi Oak forest stand. Importance Value Index (IVI) showed its maximum value (184.5) for *Q. leucotrichophora* in Tripalisain and minimum (0.6) for *Taxus baccata* in Chaurangikhal Oak forest stand.

Species density for shrub ranged from 7.42 individuals/10m^2 at Nauti to 28.62 individuals/10m^2 in Mussoorie Oak forest stand. IVI value for shrub species was recorded maximum for *Eupatorium adenophorum* (56.25) in Chandrabadani forest and minimum (0.30) for *Eisholtzia flava* in Khirsoo Oak stand. Herb density was maximum (25.71 individuals/m^2) recorded in Tripalisain while it was minimum (13.15 individuals/m^2) in Chandrabadani. IVI for herb species was recorded highest (58.4) for *Cynadon dactylon* in Chandrabadani and its lowest value (0.6) was found for *Cyperus niveus* in Chaurangikhal and *Perilla frutescens* in Ghuttu Oak forest stand.

The population structure of tree species in terms of proportion of seedlings, saplings and adults in nineteen oak forests varied greatly. The relative proportion of seedlings ranged from 17.8 % in Chaurangikhal Oak forest to 37.5% in Tirpalisain Oak forest. Whereas maximum proportion (46.7 %) of adults was recorded in Khirsoo Oak forest and minimum proportion (31.3 %) was in Tirpalisain Oak forest. In all explored oak sites, tree density of *Quercus leucotrichophora* was found more than the sapling and seedling density except at four sites (Chaurangikhal, Diwalikhal, Joshimath and Lansdown) where seedling density was less than tree density but more than the sapling density.

The regeneration status of studied Oak stands was recorded higher in north aspect as compared to south aspect. On north aspect maximum (4.4 individuals/m^2) seedling density was recorded in Pipalkoti Oak stand while minimum (0.4 individuals/m^2) in Dagar Oak forest stand. The sapling density was highest (9.0 plants/10 m^2) in Khirsoo Oak stand and lowest (1.0 plants/ 10 m^2) in Mussoorie Oak stand.

Diversity, density and regeneration status in different disturbed (Undisturbed, moderately disturbed and highly disturbed) sites:

Out of three disturbance categories, the moderately disturbed sites showed maximum species richness among all studied oak forests. A total of 28 tree, 45 shrub and 55 herb species were found in the moderately disturbed sites. In undisturbed

sites 25 tree, 39 shrub and 43 herb species were recorded while, 19 trees, 41 shrub and 42 herb species were recorded in highly disturbed sites.

At the upper most vegetation layer, the tree density varied with the magnitude of different disturbance categories. Maximum tree density (1480 trees/ha) was observed in undisturbed site at Khirsoo Oak stand, while in moderately disturbed and highly disturbed sites at Nauti and Naugonkhal oak forest the tree density was found 1160 trees/ha and 780 trees/ ha respectively. Highest basal area (4.42 m^2/ ha) was found in moderately disturbed site at Mussoorie Oak forest followed by 4.26 m^2 /ha in undisturbed site at Chaurangikhal Oak forest and 2.18 m^2/ ha in highly disturbed site at Naugonkhal Oak forest.

Concerning diversity indices in all disturbance regimes, the Shannon diversity was found maximum (1.00) in undisturbed site at Chaurangikhal Oak forest followed by 0.954 at moderately disturbed site in Radi and 0.845 at highly disturbed site of Mussoorie Oak forest. While Simpson diversity was found highest (0.836) at moderately disturbed site of Diwalikhal Oak forest. In rest of two sites, the Simpson values were recorded 0.53 and 0.58 in undisturbed and highly disturbed sites respectively. Berger parker index of dominance was found highest (0.915) at moderately disturbed site in Diwalikhal Oak forest. However, in undisturbed and highly disturbed sites the values were recorded 0.774 and 0.710 respectively. In context of evenness index of Shannon the maximum evenness (0.918) was found at moderately disturbed site in Ghuttu oak forest. However, Mackintosh evenness index showed highest evenness (1.196) at highly disturbed site in Bhawan Oak stand followed by 1.189 also at Bhawan Oak forest of moderately disturbed site and 1.179 in undisturbed site of Chaurangikhal Oak forest. Margalef index was found decreasing trend with the disturbance categories i.e. UD>MD>HD.

In the middle vegetational layer of the studied Oak forests, the maximum shrub density (57.33 plants/10m^2) was observed in moderately disturbed site of Mussoorie Oak stand followed by 31.67 plants/10m^2 at undisturbed site of Khirsoo Oak forest and 28.33 (plants/10m^2) at highly disturbed site of Dagar Oak forest. The Shannon diversity was found in increasing pattern with the disturbance intensities. The maximum (1.301) diversity was found in highly disturbed site at Dagar oak stand. However, Simpson diversity Index was highest (0.41) in undisturbed site and moderately disturbed sites at Ghuttu and Dagar oak forests respectively. Shannon evenness was also maximum (0.980) in moderately disturbed site of Ghuttu Oak forest. While Mackintosh evenness showed, its maximum value (1.165) at Bhawan oak forest in the highly disturbed site and Margalef index was also found maximum (4.132) in highly disturbed site at Dagar oak forest.

At the ground vegetation layer, among all studied oak forests, the maximum (27.5 individuals/ m^2) herb density was recorded in highly disturbed site of Chakisain oak forest. There was a little difference between the recorded densities in undisturbed and moderately disturbed sites. The herb density in both the undisturbed and moderately disturbed sites was recorded 27.2 individuals/ m^2 and 27.0 individuals/ m^2 in Khirsoo and Tirpalisain oak forests respectively. Concerning Shannon diversity of herb layer in all disturbance regimes, the highest diversity (1.663) was recorded in highly disturbed site of Bhawan Oak forest. Maximum Simpson diversity (0.276) was found in moderately disturbed site at Chandrabadani oak forest. Moderately disturbed site of Chandrabadani Oak forest also showed highest Berger-parker value (0.45). Evenness index of Shannon and Mackintosh showed higher values (0.954 and 1.153) respectively in undisturbed sites of Bhawan oak forest. Margalef index showed decreasing pattern with increasing magnitudes of disturbance. The highest Margalef value (2.480) was recorded in moderately disturbed site and 2.167 in highly disturbed site.

Regeneration status of all Oak stands revealed higher seedling density in North-facing aspect as compared to South-facing aspect. It might be due to sufficient availability of soil moisture and other favorable conditions for the seedling survival. The regeneration status varied in the different disturbance regimes in the studied Oak forests. The maximum seedling density (4.4 individual/ m^2) was recorded in undisturbed site of Pipalkoti Oak forest followed by 4.0 individual/ m^2 in moderately disturbed site and 2.8 individual/ m^2 in highly disturbed site. While the sapling density was highest (9.0 individual/ m^2) in moderately disturbed site of Khirsoo Oak forest followed by 7.0 individual/ m^2 in highly disturbed site and 6.8 individual/ m^2 in undisturbed site.

Seedlings Recruitment and Survival in Permanent Plots:

Among three permanent Oak plots in Garhwal Himalaya, the Diwalikhal Oak stand in Chamoli district was observed favorable Oak province for seedling survival. Maximum (100%) survival was found in undisturbed site and minimum (71.4%) was found in moderately disturbed site in Diwalikhal Oak forest. In this Oak stand most of sites in different disturbance categories (UD, MD and HD) showed <70% seedling survival during the study period which was more than the rest of two permanent sites in Khirsoo and Chandrabadani. In Khirsoo Oak, forest 100% survival of *Quercus leucotrichophora* was found only in undisturbed sites. In Chandrabadani Oak, stand maximum (93.3%) survival was recorded for *Quercus leucotrichophora* in undisturbed site. The minimum (50%) survival was found at moderately disturbed and highly disturbed sites of Khirsoo and Chandrabadani Oak stands. Some co-dominant species also showed good survival percentage such as *Rhododendron arboreum, Lyonia ovalifolia, Myrica esculenta, Pyrus phasia* and

Benthamidia capitata in all three permanent sites of Oak stands. Maximum mortality in seedlings was found during winter season, may be due to the combination of dense fog, frost, hailstorms and high wind velocity.

In North-facing aspect showed good survival of seedlings in the middle elevation range (1800 m), where 90% and 88.9% survival was recorded in control and restricted plots respectively for the *Quercus leucotrichophora*. Some species i.e. *Pyrus phasia*, *Rhododendron arboreum, Lyonia ovalifolia* and *Benthamidia capitata* also showed 100% survival. *Quercus leucotrichophora* showed minimum (50%) survival at lower elevational range (1600 m) which was nearest to the habitation. In south-facing aspect, *Quercus leucotrichophora* showed 100% survival in the restricted plot of lower altitude (1700 m) and had 11.1% seedling recruitment. Here minimum (50%) survival for *Quercus leucotrichophora* was recorded in the upper altitude (2100 m) after 12 months observations.

Seedling development of different species in permanent plots showed a successive growth in diameter but fluctuations occurred in the height and leaf numbers. Grazing and browsing pressure, changing season and human interference might be the main factor for checking the growth and reduced the leaf number of seedlings. Low moisture percentage and litter accumulation around the seedlings might be the cause of poor development of the seedlings in South-facing aspect.

Soil analysis and litter accumulation in permanent plots:

Soil moisture percentage was found reducing with increasing depth of the soil. Soil moisture percentage, water holding capacity, nitrogen percentage, phosphorus and potassium was recorded highest in middle and lower altitude. While soil pH and organic carbon percentage was recorded highest in upper altitude in both aspect. Rate of litter accumulation was observed maximum in the winter season when most of tree species adjoining with *Quercus leucotrichophora* shed their leaves such as *Benthamedia capitata*, *Symplocus paniculata, Lyonia ovalifolia, Pyrus phasia* etc. In Khirsoo Oak forest highest (90.87 gm/ m^2)litter accumulation was recorded at upper altitudinal range (2100 m) while it was observed lowest (24.25gm/ m^2) in the lower altitudinal range (1600 m) in the spring season. At Chandrabadani Oak forest the maximum (90.49gm/ m^2) litter was recorded also at upper altitude (2100 m) and minimum (28.83gm/ m^2) in spring season at upper altitude (2100 m). In the Diwalikhal Oak forest the highest (67.90 gm/ m^2) litter accumulation was found at upper altitude (2100 m) and lowest (27.10 gm/ m^2) was found at the lower elevational range (1500 m). Maximum accumulation of litter were found in the upper elevational ranges it might be due to the limited collection of litter at these altitudes as most of the habitations were situated near the lower elevational ranges.

6. Recommendation including usefulness of the findings and their application:

- Forest inventory, floristic diversity, population structure, soil properties and anthropogenic disturbances data of oak forests may utilized by Forest Department for sustainable management and conservation of oak forests in Himalayan region. This may also helpful in application of suitable management and silvicultural practices of Oak species/forests in Garhwal Himalayan region.
- Concerning the increasing anthropogenic pressure on Oak forests, the management and conservation of these forests can be effective by the help of local people with their own traditional knowledge about the managing forest at sustainable way.
- The data obtained by present study may be useful for the formulation of strategies and action plans for the conservation of Oak forests by the Government, NGO's and Van Panchayats. Long-term regenerative inventories in the permanent plots will also help to the Forest Department for oak species conservation in Garhwal Himalayan region.
- The study points out an urgent need for the conservation of biodiversity of the banj oak forests of Garhwal Himalaya. Strict protection and regulatory measures are required for its conservation; however, such measures will fail unless fuel and fodder requirements of the local inhabitants are met.
- Non Government Organizations, those are working for the Biodiversity and Conservation in Himalayan region also benefited by our recommendations and findings for their project implementation.
- Considering the slow growing nature of Oak species, regeneration data did not visualize any concrete conclusion so it is necessary to acquire long-term regeneration inventories in permanent plots.
- The study points out an urgent need for the conservation of biodiversity of the banj Oak forests of Garhwal Himalaya. Strict protection and regulatory measures are required for its conservation; however, such measures will fail unless fuel and fodder requirements of the local inhabitants met by these forests.
- For conservation point of view, proper planning for implementing the developmental activities in forest areas. To prepare grass-root level conservation plan with the cooperation of the local communities.

- Promote Oak regeneration by Gaps creation for improving the adequate microclimatic condition for seedling recruitment and survival.
- Promote moderately disturbance conditions (thinning/pruning/litter collection) for improvement of seedling and sapling growth.
- On the basis of above study, we can say that oak tree to be lopped about 3 to 4 years or after seed maturation for proper regeneration.
- Efforts should be taken at government level to conserve forest by law. Protect the Oak forests from the seed feeding insect (*Calandra sculpturata*) and tent caterpillar (*Malacosoma indica*).
- Promote the agencies for right collection period of *Quercus* seed for seedling nursery to avoid insect attack and lost viability. Promote energy plantation to minimize dependency upon Oak species. For local communities, there should be provision of alternatives sources of fuelwood such as LPG, Solar heaters, room heaters, coke etc.
- Alternative species like *Alnus nepalensis*, which is a fast growing and N_2 fixer, can be introduced to reduce the pressure on Quercus forest. JFM, Social forestry, village forest community etc. should be focused on conservation of Quercus.

Name of the user agencies:

1. State Forest Department
2. Non Government Organizations
2. Village Forest Communities (Van Panchayats)
3. Mahila Mangal Dal

7. Records of dissemination of the project findings to stakeholders (publication in peer-reviewed journal/presented in workshop conference etc.):

Research papers/published/accepted/communicated in the research work done under the scheme.

Research Paper published:

1. B. S. Negi, D.S. Chauhan and N.P. Todaria (2008). Inventory of species richeness of Panchayat forests and adjoining reserve forests in three districts of Garhwal Himalaya, India. ***Tropical Ecology*** 49 (2): 121-129.

2. Baledev S. Negi, D.S. Chauhan and N.P. Todaria (2008). Comparative plant diversity between Panchayat and adjoining reserve forests in Garhwal Himalaya. ***Indian Journal of Forestry*** 31 (4): 585-593.

3. Chauhan, D.S., Negi, A.K., Chamola, B.P. and Todaria, N.P. (2011). Van Panchayats: Community Conserved Areas in Uttarakhand. In *Community – based Biodiversity Conservation in the Himalayas* (ed. Y.Gokhale and A.K. Negi). Published by Tata Energy and Resource Institute (TERI) press, New Delhi, pp. 21-31

4. N. P. Todaria, D.S. Chauhan and B.S. Negi (2010). Plant biodiversity in Panchayat forests of three districts of Garhwal Himalaya, Uttarakhand. Paper presented in International Conference on "Mountain biodiversity: Conservation and Sustainable Utilization" held at Doon University, Dehradun, during 13-15 March 2010.

Research Paper communicated:

1. Sunil Bhatt, Vikaspal Singh, D.S. Chauhan, and N.P. Todaria. Community composition, Tree population structure in a Temperate Broad-leaved Evergreen Oak Forest along a disturbance gradient in Garhwal Himalaya, Uttarakhand, India (Communicated in Journal of Forestry Research).
2. Chauhan, D.S. Vikaspal Singh, Sunil Bhatt and N.P. Todaria. Altitudinal gradients in Banj Oak (*Quercus leucotrichophora* A. Camus) forest composition, species richness and diversity in Garhwal Himalaya, Uttarakhand, India. (Communicated).

Ph.D registered students:

1. Sunil Bhatt – Title of Thesis - Population structure and Regeneration status in relation to different disturbance level along altitudinal gradient in natural Oak forest of Garhwal Himalaya.

2. Vikaspal Singh Rawat – Title of Thesis – Effect of stand structure and microenvironment on regeneration of oak (*Quercus leucotrichophora* a. camus) forests along anthropogenic disturbance.

8. Total cost of the project and releases made (in Rs.): 14, 69,475=00

9.	14/26/2004-RE Diversity and Ecology of Mites Infesting Medicinal Plants of West Bengal.	Prof. Goutam Kumar Saha, Professor, Department of Zoology, University of Calcutta.

1. **Title of the Project:** DIVERSITY AND ECOLOGY OF MITES INFESTING MEDICINAL PLANTS OF WEST BENGAL
2. **Keywords:** Mites, Medicinal plant, New species, Diversity, Ecology.
3. **Name of members of Research Team and their designation:**

(a) Principal Investigator: Prof. Goutam Kumar Saha
Professor, Department of Zoology
University of Calcutta

(b) Co- Principal Investigator: Dr. S. K. Gupta
Former Joint Director &
Emeritus Scientist, Zoological Survey of India, Kolkata

(c) Research Fellow: Dr. Indranil Roy
University of Calcutta

4. **Executive Summary of the results vis-avis objective envisaged originally**

Mites are pest of different crops, cereals, vegetables and ornamental and medicinal plants, and are thus being studied for management and control. In this context, an assessment of the taxonomy, biology and control of mites infesting medicinal plants was carried out for a period of three years viz., from October 2006 to December 2009, to highlight the diversity, spatiotemporal variations in relation to the selected medicinal plants. An initial systematic survey of thirteen districts in West Bengal revealed the presence of 99 different mite species including 8 new species (belonging to 36 genera, 17 families and 3 orders) in almost all varieties of medicinal plants.

Based on the abundance the life cycle of four mite species, *Tetranychus ludeni, Petrobia harti, Tydeus justicia* and *Pronematus sextoni* was studied under laboratory conditions, which reflected species specific variations in the life history parameters like duration of instar stages, longevity, and fecundity.

To deduce the variation in the mite species assemblage, monthly sampling was made on four selected medicinal plants *Withania somnifera, Abutilon indicum, Ocimum gratissimum, Murraya koenigi* in a medicinal plant garden in Ramakrishna Mission Ashram, Narendrapur, South 24 Parganas district, West Bengal. The number of species associated with the plants varied in relative and absolute numbers per sampling unit between the months and tree species, revealed through 3-way ANOVA. The phytophagous: predator mite density varied with the season, but no significant correlations were noted between the environmental variables and the mite species abundance. The species association varied between the phytophagous and predatory mite species. However, significant association between the mite pairs - *Amblyseius largoensis* (predatory) and *Tetranychus neocalidonicus* (Phytophagous) in *W. somnifera*; *A. multidentatus* and *T. ludeni* in *A. indicum*; *Cunaxa* sp. and *T. neocalidonicus* in *O. grattisimum* and *A. suknaensis* and *Schizotetranychus hindustanicus* in *M. koenigii* – was noted.

The data on the relative abundance of mite species in these plants was subjected to multivariate analyses like PCA and Cluster analysis that revealed significant difference in the orientation of mite

species in these plants indicating difference in the prey predator interactions between predatory and phytophagous mite species.

Laboratory studies on the population regulation of mites using extracts of three plants *Eupatorium triplinerve, Cassia alata, Ocimum tenuiflorum* revealed that the methanolic extracts were significantly effective in reduction of the mite species compared to the aqueous extracts and the commercial available miticides (fungi, and neem oil). An exposure for 72h with a fixed dose of the methanolic extract of these plants was effective to reduce the population of mites by 70 – 90%. A study on the prey predator interaction using the predatory mite *Amblyseius multidentatus* and the phytophagous mite *Tetranychus neocaledonicus* showed that biological control of phytophagous pest mites is possible. The predator, *A. multidentatus* consumed on an average 12 to 15 *T. neocaledonicus* per day that varied significantly with the prey and predator densities.

The concentration of total carbohydrate, lipid and protein and phenolics between the infested and non-infested leaves was made that reveal no significant variations (G-tests) due to mite infestation. This might possibly due to the fact that the analysis did not include temporal variations.

The results of the present study confirms the pest nature of phytophagous mites on the medicinal plants and the diversity of mites including the variations in predatory and phytophagous mites offers the use of biological control strategies to regulate them. Further, the strategy for control can be made using the spatiotemporal variation in the mite populations in different medicinal plants as noted here.

5.Results and Conclusion:

Results

A. Diversity:

All total 99 mite species belonging to 36 genera and 17 families under 3 orders were observed during the study period (Table 1). Among these 33 phytophagous mite species belonging to 12 genera and 4 families, whereas 66 predatory mite species belonging to 24 genera and 13 families were found to occur in different districts of West Bengal infesting 68 species of medicinal plants. The present study includes new reports of 25 species of phytophagous mites from their respective host plants and 27 species of predatory mites for the first time from their respective habitat.

Description of new species

During this study period a total of **8 species were identified as new to science**. During identification of the collected mite species on medicinal plants, species could be discovered as new to science, full descriptions and illustrations have also been prepared, of which descriptions of four have been published in the journal ENTOMON and the descriptions and illustrations of the remaining two species have been published in the JOURNAL OF ASIA-PACIFIC ENTOMOLOGY. The description and illustration of another two species, along with biology of one new species have already been published in PROCEEDINGS OF ZOOLOGICAL SOCIETY, KOLKATA and JOURNAL OF THE BOMBAY NATURAL HISTORY SOCIETY, respectively.

Table 1. List of total species recorded during the course of study from different host Plants at different Districts of West Bengal

A

Phytophagous Mite species	Host plant/ habitat	District	Remarks
Order I. PROSTIGMATA			
Family 1. TETRANYCHIDAE Donnadieu			
Genus 1. *Petrobia* Murray			
1. *Petrobia* (*Tetranychina*) *harti* (Ewing)	*Oxalis corniculata* Linn.	Kolkata & 24-Parganas (South)	
Genus 2. *Eutetranychus* Banks			
2. *Eutetranychus caricae* Nassar & Ghai	*Ficus carica* L.	Kolkata & 24-Parganas (South)	
3. *E. orientalis* (Klein)	*Aegle marmelos* Corr.exRoxb, *Carica papaya* L. *Withania somnifera*Dunal, *Datura metel* Linn.	Kolkata & 24-Parganas (South), Bardhamann	New record on *Datura metel*
Genus 3. *Eotetranychus* Oudemans			
4. *Eotetranychus* sp.	*Murraya koenigii* (Linn.)	Kolkata & 24-Parganas (South)	
Genus 4. *Oligonychus* Berlese			
5. *Oligonychus biharensis* (Hirst)	*Datura metel* Linn.	Hoogly	New record on this host
6. *O. indicus* (Hirst)	*Musa paradisica* L. *Cocos nucifera*L. *Saccharum officinarum* L.	Howrah, Kolkata & 24-Parganas (South)	New record on *Cocos nucifera*
7. *O. oryzae* (Hirst)	*Cymbopogon winterianus* Jawitt	Kolkata & 24-Parganas (South)	
Genus 5. *Panonychus* Yokoyama			
8. *Panonychus citri* (McGregor)	*Crataeva nurvala* Buch.-Ham, *Carica papaya* L.	Kolkata & 24-Parganas (South)	New record on *Crataeva nurvala*
Genus 6. *Schizotetranychus* Trägardh			
9. *Schizotetranychus baltazari* Rimando	*Murraya koenigii* (Linn.), *Curcuma zedoaria* Rosc.	Kolkata & 24-Parganas (South)	New record on *Curcuma zedoaria*
10. *S. cajani* Gupta	*Murraya koenigii* (Linn.), *Indigofera tinctoria* Linn. *Cymbopogon martini* Roxb) Wats. *Phyllanthus fraternus* Webster	Kolkata & 24-Parganas (South)	New record on *Murraya koenigii* and *Phyllanthus fraternus*
11. *S. hindustanicus* (Hirst)	*Murraya koenigii* (Linn.)	Kolkata & 24-Parganas (South)	
Genus 7. *Tetranychus* Dufour			
12. *Tetranychus cinnabarinus* (Boisd.)	*Datura metel* Linn.	Darjeeling	New record on this host

13. *T. fijiensis* Hirst	*Pongamia pinnata* (L.) Pierre	Kolkata & 24-Parganas (South)	New record on this host
14. *T. hydrangeae* Pritchard & Baker	*Datura innoxia Mill.*	Hoogly	New record on this host
15. *T. ludeni* Zacher	*Abutilon indicum* (Linn.) Sweet, *Tinospora cordifolia* (Willd.) Miers.ex Hook.f.& Thoms., *Datura metel* Linn.	Kolkata & 24-Parganas (South); Midnapur (West)	New record on *Abutilon indicum* and *Tinospora cordifolia* .
16 *T. macfarlanei* Baker & Pritchard	*Withania somnifera* (Linn.)Dunal	Jalpaiguri	
17. *T. neocaledonicus* André	*Withania somnifera* (Linn.)Dunal, *Abelmoschus moschatus* Medic. *Leucas plukenetii* (Roth.) spreng.	Kolkata & 24-Parganas (South), Midnapur	New record on *Withania somnifera* and *Leucas plukenetii*
18. *T. urticae* Koch	*Aristolochia indica*Linn. *Withania somnifera* Dunal, *Justicia adhatoda* Linn., *Datura metel* Linn., *Murraya koenigii* (Linn.) *Ocimum sanctum* Linn., *Sida rhombifolia* Linn.	Darjeeling, Kolkata & 24-Parganas (South) Hoogly	New record on *Sida rhombifolia*
19. *Tetranychus* sp.	*Hibiscus vitifolius* Linn.	Hoogly	Species identification not possible for want of male species.
Family 2. TENUIPALPIDAE Berlese			
Genus 8*. Brevipalpus* Donnadieu			

20. Brevipalpus californicus *(Banks)*	*Alstonia scholaris* R. Br. *Cassia alata* Linn, *Murraya koenigii*(Linn.)	Kolkata & 24-Parganas (South)	New record on these hosts
21. B. chilensis *Baker*	*Azadirachta indica* A. Juss.	Purulia	New record on this host
22. B. cucurbitae *Mohansundaram*	*Ricinus communis* Linn. *Murraya koenigii* (Linn.)	Coochbihar 24- Parganas (south)	New record on this host
23. B. deleoni *Pritchard & Baker*	*mum gratssimum* Linn.	Kolkata & 24-Parganas (South)	New record on this hosts
24. B. essigi *Baker*	*mum grattisimum* Linn.	Kolkata & 24-Parganas (South)	New record on this host
25. B. euphorbiae *Mohansundaram*	*minalia chebula* Retz.	Jalpaiguri	New record on this host
26. B. karachiensis *Chaudhri, Akbar & Rasool*	*Ocimum sanctum* Linn. *mum basilicum* Linn.	Kolkata & 24-Parganas (South), Midnapur (West).	
27. B. obovatus *Donnadieu*	*rodendrum indicum* n.) O. Kuntz, *Desmodium gangeticum* DC.	Kolkata & 24-Parganas (South), Midnapur	New record on *Clerodendrum indicum*.
28. B. phoenicis *(Geij)*	*Acacia catechu* (L.f.)Willd *Ocimum grattisimum* Linn.	Howrah Kolkata & 24-Parganas (South)	New record on this host
29. B. rugulosus *Chaudhri, Akbar & Rasool*	*Justicia adhatoda* Linn.	Jalpaiguri	New record on these hosts
Family 3. ERIOPHYIDAE Nalepa			
Genus 9. *Aceria* Keifer			
30. *Aceria clerodendronis* Farkas	*Clerodendrum viscosum* Vent.	Howrah	
Genus 10. *Calepitrimerus* Keifer			
31. *Calepitrimerus azadirachtae* ChannaBasavanna	*Azadirachta indica* A. Juss	Midnapur	
Genus 11. *Paratetra* ChannaBasavanna			
32. *Paratetra murrayae* ChannaBasavanna	*Murraya koenigii* (Linn.)	Kolkata & 24-Parganas (South)	
Family 4. TARSONEMIDAE Kramer			
Genus 12. *Polyphagotarsonemus* Beer & Nucifora			
*33.*Polyphagotarsonemus latus *(Banks)*	Withania somnifera (Linn.)*Dunal* *Ocimum sanctum* Linn.	Kolkata & 24-Parganas (South)	

B

Predatory Mite species	Host plant/ habitat	District	Remarks
Order I. PROSTIGMATA			
Family 5. ANYSTIDAE Oudemans			
Genus 13. *Anystis* von Heyden			
34. *Anystis baccarum* (Linnaeus)	*Cinchona officinalis* Linn.	Darjeeling	
Family 6. BDELLIDAE Duges			

Genus 14. *Bdellodes* Oudemans			
35.*Bdellodes manipurensis* Gupta	*Andrographis paniculata* (Burn. f.)	Kolkata & 24-Parganas (South)	New record on this habitat
36. *Bdellodes* sp. nov.	*Ambroma augusta* (L.) L.f.	Kolkata & 24-Parganas (South)	Already sent for publication.
Family 7. CHEYLETIDAE Leach			
Genus 15. *Chelacaropsis* Baker			
37.*Chelacaropsis moorei* Baker	*Nyctanthes arbortristis* Linn.	Kolkata & 24-Parganas (South)	New record on this habitat
Family 8. CUNAXIDAE Thor			
Genus 16. *Cunaxa* von Heyden			
38. *Cunaxa mangiferae* Gupta	*Carica papaya* L.	Kolkata & 24-Parganas (South)	
39. *C. myabunderensis* Gupta and Ghosh	*Zingiber* sp.	Darjeeling	
40. *C. setirostris* (Hermann)	*Ficus glomerata* Roxb., *Ocimum grattisimum* L. *Withania somnifera* Dunal	Kolkata & 24-Parganas (South)	New record on *Ocimum grattisimum* and *Withania somnifera*.
41. *C. womersleyi* Baker & Hoffmann	*Datura metel* Linn., *Bauhinia acuminate* Linn. *Ocimum sanctum* Linn.	Kolkata & 24-Parganas (South), Howrah, Darjeeling	
Genus 17. *Neocunaxoides* Smiley			
42. *Neocunaxoides* sp.	*Clerodendrum viscosum* Vent	Howrah	
Family 9. ERYTHRAEIDAE Robineau-Desvoidy			
Genus 18. *Erythraeus* Latreille			
43. *Erythraeus cinchoni* Roy, Gupta & Saha	*Cinchona officinalis* Linn	Darjeeling	New species already published out of this work.
Family 10. RAPHIGNATHIDAE Kramer			
Genus 19. *Exothorhis* Summers			
44. *Exothorhis justicia* Roy, Gupta & Saha	*Justicia adhatoda* Linn.	Kolkata & 24-Parganas (South)	New species already published out of this work.
Family 11. EUPODIDAE Koch			
Genus 20. *Eupodes* Koch			
45.*Eupodes sigmoidensis* Strandtmann and Goff	*Acacia* sp.	Kolkata & 24-Parganas (South)	
Family 12. STIGMAEIDAE Oudemans			
Genus 21. *Agistemus* Summers			
46. *Agistemus edulis* Gupta	*Mangifera indica* Linn.	Kolkata & 24-Parganas (South)	
47. *A. fleschneri* Summers	*Desmodium gangeticum* (Linn.)DC, *Gymnema sylvestre* (Retz) R. Br. Ex Schult, *Justicia adhatoda* Linn.	Midnapore, Hoogly, Kolkata & 24-Parganas (South);	New record from these habitats.

48. *A. lobata* Roy, Gupta & Saha	*Urena lobata* Linn.	Kolkata & 24-Parganas (South)	New species already published out of this work.
49. *A. simplex* Gonzalez-Rodriguez	*Zingiber* sp.	Darjeeling	
50. *A. terminalis* (Quayle)	*Dioscorea* sp	Jalpaiguri	
51. *A. unguiparvus* Gonzalez Rodriguez	*Aristolochia indica* Linn.	Darjeeling	
52. *Agistemus* sp.	*Dioscorea* sp. *Aristolochia indica* Linn.	Midnapore	New record on this habitat
Family 13. TYDEIDAE Kramer			
Genus 22. *Lorryia* Oudemans			
53. *Lorryia* sp.	*Terminalia myriocarpa* Hewick and Muell	Darjeeling	
Genus 23. *Parapronematus* Baker			
54. *Parapronematus murshidabadensis* Gupta	*Crataeva nurvala* Buch.-Ham,	Midnapur	New record on this habitat
Genus 24. *Pronematus* Canestrini			
55. *Pronematus fleschneri* Baker	*Pterrocarpus santalinus* Linn.f.,	Kolkata & 24-Parganas (South)	New record on this habitat
56. *P. sextoni* Baker	*Bauhinia acuminata* Linn.	Howrah	
Genus 25. *Tydeus* Koch			
57.*Tydeus cumini* Gupta	*Thevetia nerifolia* Juss. Ex Steud, *Ficus carica* L.	Howrah, Purulia	New record on this habitat
58. *Tydeus* sp. nov.	*Justicia adhatoda* Linn.	Kolkata & 24-Parganas (South)	(New species, already accepted for publication)
59. *Tydeus* sp.	*Bauhinia acuminata* Linn.	Midnapore	Appear to be new species
Order II. ASTIGMATA Canestrini			
Family 14. ACARIDAE Ewing & Nesbitt			
Genus 26. *Acarus* Linnaeus			
60. *Acarus farris Oudemans*	*Datura metel* Linn.	Kolkata & 24-Parganas (South)	New record on this habitat.
Genus 27. *Caloglyphus*			
61.*Caloglyphus rhizoglyphoides* (Zachvatkin)	*Gossypium herbaceum* Linn.	Kolkata & 24-Parganas (South)	New record on this habitat.
Genus 28. *Tyrophagus* Oudemans			
62. *Tyrophagus putrescentiae* (Schrank)	*Solanum nigrum* Linn., *Justicia adhatoda* Linn.	Kolkata & 24-Parganas (South)	New record on these habitats.
Family 15. AMEROSEIIDAE			
Genus 29. *Kleemannia* Oudemans			
63. *Kleemannia plumigera* Oudemans	*Alstonia scholaris* R. Br.	Kolkata & 24-Parganas (South)	New record on this habitat.
Order III. MESOSTIGMATA			
Family 16. ASCIDAE Voigts & Oudemans			
Genus 30. *Lasioseius* Berlese			
64. *Lasioseius phytoseioides* Chant	*Alstonia scholaris* R. Br.	24-Parganas (North)	New record on this habitat

65. *L. quadrisetosus* Chant	*Nyctanthes arbortristis* Linn.	24-Parganas (North)	New record on this habitat
66. *L. terrestris* Menon & Ghai	*Boerhavia diffusa* Linn., *Datura metel* Linn.	Kolkata & 24-Parganas (South), Nadia	New record on this habitat
67. *Lasioseius* sp.	*Alstonia scholaris* (Linn.) R Br.	Kolkata & 24-Parganas (South)	New record on this habitat
Family 17. PHYTOSEIIDAE Berlese			
Genus 31. *Amblyseius* Berlese			
68. *Amblyseius (Amblyseius) aerialis* (Muma)	*Clerodendron siphonanthus* R. Br.	Darjeeling	
69. *A.* (*A.*) *channabasavannai* Gupta	*Ambroma augusta* (Linn.) L.f	Kolkata & 24-Parganas (South)' Midnapur (West)	
70. *A. (A.) cucurbitae* Rather	*Nyctanthes arbortristis* Linn.	24-Parganas (North)	New record on this habitat
71. *A.* (*A.*) *herbicolus* (Chant)	*Cinchona officinalis* Linn., *Coccinea indica* W. A.	Darjeeling, Kolkata & 24-Parganas (South)	
72. *A.* (*A.*) *kulini* Gupta	*Murraya koenigii* (Linn.)	Kolkata & 24-Parganas (South)	
73. *A.* (*A.*) *largoensis* (Muma)	*Aristolochia indica* *Gymnema sylvestre* (Retz) R. Br. ex Schult, *Aegle marmelos* Corr.ex Roxb. *Alstonia scholaris* R. Br. *Azadirachta indica* A. Juss. *Boerhavia diffusa* Linn. *Carica papaya* L. *Curcuma zedoaria* Rosc. *Justicia adhatoda* Linn.	Darjeeling Hoogly, Coochbihar Jalpaiguri, Purulia, Nadia Kolkata & 24-Parganas (South)	New habitat records on *Aegle marmelos*, *Alstonia scholaris, Curcuma zedoaria*
74. *A. (A.) paraaerialis* Muma	*Acacia catechu* (L.f.) Willd. *Carica papaya* L.	Kolkata & 24-Parganas (South)	New record from habitat (*Acacia catechu*)
75. *A. (Euseius*) *alstonae* Gupta	*Aegle marmelos* Corr.ex Roxb., *Alstonia scholaris* R. Br. *Cassia alata* Linn.	Hoogly, Kolkata & 24-Parganas (South)	
76. *A.* (*E.*) *coccineae* Gupta	Morus alba *Linn.*	Darjeeling	
77. *A.* (*E.*) *coccosocius* Ghai & Menon	*Desmodium motorium* (Houtt.) Merril	Darjeeling	
78. *A. (E.) eucalypti* Ghai & Menon	*Coccinia grandis* (Linn.) Voigt.	24-Parganas (North)	New record from habitat
79. *A.* (*E.*) *finlandicus* (Oudemans)	*Quercus incana* Roxb., *Justicia adhatoda* Linn.	Darjeeling, Kolkata & 24-Parganas (South)	
80. *A. (Euseius) macrospatulatus* Gupta	*Tinospora sinensis* (Lour.) Merrill	Nadia	New record from habitat

81. *A. (Euseius) ovalis* (Evans)	*Aegle marmelos* Corr.ex Roxb.	Kolkata & 24-Parganas (South)	
82. *A.* (*E.*) *pruni* Gupta	Clematis buchananian *DC*	Darjeeling	
83. *A.* (*Neoseiulus*) *longispinosus* (Evans)	Oroxylum indicum *Vent,* *Datura metel* Linn., *Carica papaya* L.	Purulia, Kolkata & 24-Parganas (South)	New habitat record from *Oroxylum indicum*
84. *A. (Paraphytoseius) multidentatus* (Swirski and Shechter)	*Ambroma augusta* (Linn.) L.f. *Ocimum sanctum* Linn., *Ficus carica* L.	Midnapore, Kolkata & 24-Parganas (South)	
85. *A.* (*Proprioseiopsis*) *peltatus* Van der Merwe	*Nyctanthes arbortristis* Linn.	Kolkata & 24-Parganas (South)	New record from habitat
86. *A. (Typhlodromips) suknaensis* Gupta	Barleria lupulina *Lindl.,* *Datura metel* Linn., *Murraya koenigii* (Linn.)	Kolkata & 24-Parganas (South)	*New habitat record from* Barleria lupulina
87. *A.* (*Typhlodromips*) *syzygii* Gupta	Abelmoschus moschatus *Medic.* *Asteracantha longifolia* (L. Nees)	Midnapur, Kolkata & 24-Parganas (South)	New record on Asteracantha longifolia.
Genus 32. *Indoseiulus* Ehara			
88. *Indoseiulus eharai* Gupta			
89. *Indoseiulus* sp	*Aristolochia indica* Linn.	Darjeeling	
Genus 33. *Iphiseius* Berlese			
90. *Iphiseius* (*Trochoseius*) *augusta* Roy, Gupta and Saha	*Ambroma augusta* L.f.	Kolkata & 24-Parganas (South)	New species already published out of this work.
Genus 34. *Phytoseius* Ribaga			
91.*Phytoseius* (*Pennaseius*) *kapuri* Gupta	*Ficus* sp	Howrah	New record from habitat
92.*P. (Phytoseius) intermedius* Evans & Macfarlane	*Clerodendrum viscosum* Vent.	Howrah	New record from habitat
93. *P. (Phytoseius) maldahensis* Gupta	*Zingiber* sp	Darjeeling	
94. *P. (Phytoseius) mizoramensis* Gupta & Chatterjee	*Clerodendrum viscosum* Vent.	Howrah	
95. *P. (Phytoseius) neocorniger* Gupta	*Abelmoschus moschatus* Medic.	Howrah	
96. *P. (P.)* sp. nov.	*Clerodendrum viscosum* Vent	Howrah	New species sent for publication out of this work
Genus 35. *Typhlodromus* Scheuten			
97. *Typhlodromus (Amblydromella) himalayensis* Gupta	*Clematis buchananian* DC	Darjeeling	
98. *T. (A.) homalii* Gupta	*Aegle marmelos* Corr.ex Roxb.	Kolkata & 24-Parganas (South)	

99.*Typhlodromus (Anthoseius) majumderi* Gupta	*Ficus glomerata* Roxb.	Kolkata & 24-Parganas (South)	New record from habitat

B. Life Cycle:

The different developmental stages included egg, one larval stage, two nymphal stages and adult. The fecundity and the duration of individual stages are presented in Table 2.

Table 2: Fecundity and Duration of different developmental stages of two phytophagous and two predatory mites under laboratory condition

Stage	*Tetranychus ludeni* Zacher Duration ± SE (in days)	*Petrbia harti* Ewing Duration ± SE (in days)	**Tydeus justicia* Roy *et al* Duration ± SE (in days)	*Pronematus sextoni* Baker Duration ± SE (in days)
Egg	1.57±0.22	2.8 ± 0.77	1.33 ± 0.14	1.2±0.34
Larva	2.38±0.14	1.5 ± 0.51	2.33 ± 0.28	2.3±0.31
Protonymph	3.8±0.20	2.15 ± 1.04	1.83 ± 0.17	2.5±0.32
Deutonymph	6.8±0.37	3.64± 1.23	2.17 ± 0.17	_
Egg to Adult	14.4±1.34	10.1 ± 1.48	7.67 ± 0.47	6±0.25
Adult longevity (female)	9.8±1.39	6.1±2.19	16.5±3.20	18.16±0.48
Fecundity/day /Female	16.65±1.20	6.75 ± 0.37 eggs	7.75 ± 0.69 eggs	9.15 ± 0.32 eggs

**Published in the *Journal of The Bombay Natural History Society*

A reference to the table 2 indicates the duration of different life stages of phytophagous mites and appears that the mean duration of egg to adult period was 14.4±1.34 days in *Tetranychus ludeni* and in case of *Petrobia harti*, it appears that the life cycle took (egg-adult) 10.1 ± 1.48 days. In case of predatory mites the life cycle took 7.67 ± 0.47 in *Tydeus justicia* and 6±0.25 in *Pronematus sextoni*. Female longevity was 9.8±1.39 and 6.1±2.19 days in *Tetranychus ludeni* and *Petrobia harti*, respectively. Fecundity of female was 16.65±1.20 and 6.75±0.37 eggs in *Tetranychus ludeni* and *Petrobia harti*, respectively. On the other hand, adult longevity of female predatory mites was found to be 16.5±3.20 days in *Tydeus justicia* and 18.16 ±0.48 days in *Pronematus sextoni*. The fecundity was found to be 7.75 ± 0.69 eggs in *Tydeus justicia* and 9.15 ± 0.32 eggs in *Pronematus sextoni*.

C. Seasonal Occurrence:

The variations in relative abundance of different mite species in the four medicinal plants are presented in Figure **1.**

On *Withania somnifera* (Ashwagandha) a total of seven species of mites were collected, of which 3 are phytophagous and 4 predacious species. Among phytophagous mites *Tetranychus neocaledonicus* and *Polyphagotarsonemus latus* are dominant in terms of their abundance whereas occurrence of *Brevipalpus cucurbitae* was negligible. *Tetranychus neocaledonicus* was found during January to August whereas *Polyphagotarsonemus latus* infest quite seriously during March-July. The predatory mites *Amblyseius* (*N.*) *longispinosus*

are dominant in terms of their occurrence. Occurrence of other predatory mites *Amblyseius multidentatus, Amblyseius suknaensis* and *Cunaxa setiriostris* on *Withania somnifera* was noted.

On *Ocimum grattisimum* (Ramtulsi) equal number of predatory mites was noted and 2 phytophagous species was found. *Brevipalpus essigi*, phytophagous mite, was recorded throughout the season except October whereas *Tetranychus ludeni* was found March, July and August Among predatory mites, relative numbers of *Amblyseius suknaensis* were highest. Relative numbers of *Amblyseius multidentatus* and *Pronematus* were moderate. Abundance of *Cunaxa* was recorded minimal.

On *Abutilon indicum* (Atibala), 2 each of predatory and phytophagous mites were noted. *Tetranychus ludeni* was found throughout the season but, the occurrence of other phytophagous mite *Brevipalpus essigi* might be accidental. Abundance of predatory mites *Amblyseius multidentatus* and *Amblyseius suknaensis* were also recorded.

On *Murraya koenigii* (Karipata) 4 phytophagous and 1 predatory mite species were noted. Among phytophagous *Schizotetranychus hidustanicus* was dominant throughout the season. Other phytophagous mites *Eutetranychus* sp., *Brevipalpus* and *Tetranychus* were recorded low in number. Occurrence of predatory mite *Amblyseius suknaensis* was accidental.

Figure 1 : The seasonal variation in the relative abundance of phytophagous and predatory mites in the medicinal plants and the environmental parameters. **A.** *Withania somnifera* **B.** *Ocimum grattisimum* **C.** *Abutilon indicum* **D.** *Murraya koenigii*.

From the results it is evident that the mite species assemblage varied with the months in a year in all the medicinal plants considered in the study. The relative density of phytophagous and predatory

mites varied with the months and the medicinal plant species, as revealed through univariate three-way and two-way factorial ANOVA. The relative and absolute abundance of the mite species were not significantly correlated with the environmental variables. The factor loadings clearly demonstrate the relative abundance of the predatory mites is dependent on the phytophagous mites. This is substantiated in the ordination pattern based on the mite densities and the cluster analysis. This is also substantiated through the coefficient of species association (Table 3), in all the medicinal plants.

D. Studies of Control of mites –

I - Plant Extract and Pathogens:

As indicated in table 4, after 24 hours of treatment, highest mortality (36±0.74%) was observed in case of methanolic extract of *Ocimum tenuiflorum*, while lowest mortality (3.3±0.16%) was recorded in water extract of *Eupatorium triplinerve*. In other cases mortality ranged from 5.5± 0.017 in aqueous extract of *Eupatorium triplinerve* to 34±.021 in neem oil. After 48 hours of treatment, same trend was found i.e. methanolic extract of *Ocimum tenuiflorum* had given highest mortality (64±1.14%), whereas water extract of *Eupatorium triplinerve* had given lowest mortality (14.4±0.17%). It is interesting that after 72 hours of treatment, highest mortality was recorded in case of commercially available *Paecilomyces fumosoroseus* than by plant extracts. Among the plant extracts, the highest mortality (75±1.08%) was recorded in case of methanolic extracts of *Ocimum tenuiflorum* followed by methanolic extracts of *Cassia alata* (72±0.86%). Water extract of *Cassia alata* and water extract of *Ocimum tenuiflorum* recorded 42±0.86% and 41±1.04%, respectively. Minimum mortality (25±0.24%) was recorded in case of water extract of *Eupatorium triplinerve*.

Table 4: Evaluation of plant extracts/Neem oil (Azadirachtin 0.03% EC)/Entomopathogenic fungus (*Paecilomyces fumosoroseus*) on *Tetranychus neocaledonicus* infesting Aswagandha after different intervals.

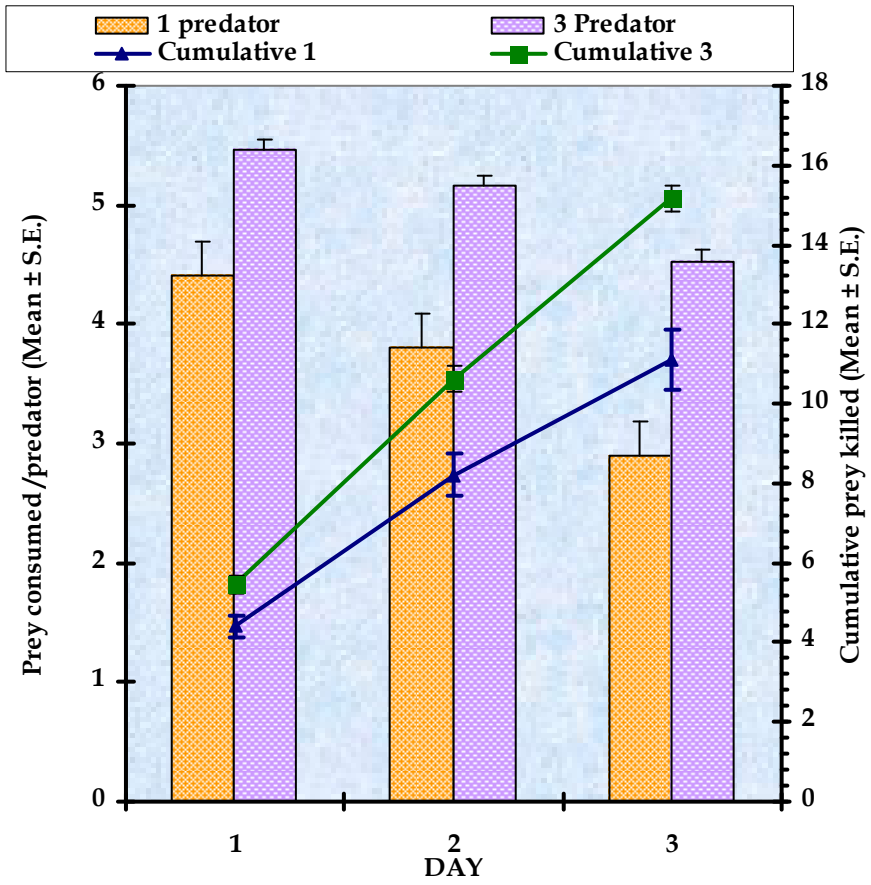
Treatments	Percentage mortality after different intervals		
Bio pesticides / Plant extracts	24 hrs. (Mean±SE)	48hrs. (Mean±SE)	72hrs. (Mean±SE)
F/PATHO (1.15% WP)	15±0.14	43±0.28	**87±0.21(H)**
N/OIL(.03%EC)	34±0.21	46±0.21	83±0.16
DA (1.5%)	4.4±0.17	18±0.38	42±0.86
DM (1.5%)	35±0.64	55±0.86	72±0.86
KA (1.5%)	13±0.33	25±0.59	41±1.04
KM (1.5%)	**36±0.74(H)**	**64±1.14(H)**	75±1.08
AA (1.5%)	**3.3±0.16(L)**	**14.4±0.17(L)**	**25±0.24(L)**
AM (1.5%)	5.5±0.17	20±0.16	30±0.16

(H)=Highest; (L) =Lowest; [F/PATHO=Fungal pathogen (*Paecilomyces fumosoroseus*), N/OIL=Neem oil (Azadirachtin 0.03% EC), DA=Dadmari aquas, DM= Dadmari methanolic, KA=Krishnatulsi aquas, KM= Krishnatulsi methanolic, AA=Ayapan aqueous, AM=Ayapan methanolic,]

II- Studies of Control of mites-predators

The predatory mite *Paraphytoseius multidentatus* killed on an average 2.9 to 4.4 numbers of *T. neocaledonicus* per day depending on the predator density and days (Fig 2). The consumption pattern varied between the predator densities significantly (P, 0.001). The ANOVA results indicate significant variations between the days and the predator densities.

Figure 2 : Prey consumption per day per individual of adult *Amblysieus multidentatus* on adult *Tetranychus neocalidonicus* (n = 30 replicate per prey: predator ratio) for three consecutive days. The paired two-tailed t-test revealed significant difference in predation rate between one and three predators (t = 30.31, f = 58, P<0.001). Results of one-way ANOVA justifying the observed variation in predation.



For Three predators

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Days	1.514	2	0.757	3.678	0.029	3.10
Error	17.9	87	0.206			
Total	19.414	89				

For One predator

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Days	36.52	2	18.26	7.16	0.001	3.094
Error	237.31	93	2.55			
Total	273.83	95				

E. Studies of effect of mite feeding on biochemical components of *Abutilon indicum*

Difference in phytochemicals

In *Abutilon indicum*, leaves infested with mites did not differ significantly in the composition of the biochemicals, though the non-infested leaves exhibited higher levels of carbohydrates (Table 5).

Table 5: Composition of different phytochemicals in the plants *Abutilon indicum* – with and without mite infestations.

Phytochemicals	Amount (mg/g) Infested	Amount (mg/g) Non-infested
Carbohydrate	5.78±0.03	7.75±0.05
Protein	8.42 ±0.10	5.30 ±0.60
Lipid	282.50± 0.79	256.95± 0.95
Phenolics	0.30± 0.01	0.35± 0.01
Starch	16.75± 0.08	16.05± 0.21

Conclusion

Diversity

The present research documents the presence of 99 different mite species belonging to 36 genera, 17 families under 3 orders in different medicinal plants and 8 new species were identified and described. It is a pioneer effort in that the study covered all the biogeographic zones of West Bengal and more than eighty different medicinal plants were assessed for estimation of mite infestations. **The results are expected to supplement the existing information on the pest status of mites in different medicinal plants apart from elaborating mite species diversity.**

Life cycle of selected mite species associated with medicinal plants

During the course of study the life cycle of 4 species was estimated, based on the abundance. Life cycle of ***Tetranychus ludeni, Petrobia harti, Tydeus justicia*** **and** ***Pronematus sextoni*** was studied under laboratory conditions, which reflected species specific variations in the life history parameters like duration of instar stages, longevity,

and fecundity. **These information will help to understand and compare the biology of these mites to predict possible abundance pattern in nature.**

Mite abundance at spatial and temporal scale

The study explored the spatiotemporal variation in mite species richness and abundance in four selected medicinal plants, *W. somnifera*, *A. indicum*, *O. grattisimum*, and *M. koenigii*, for the first time. The species ensembles in the four medicinal plants with emphasis on the trophic status as phytophagous (prey) and predatory mites, was studied. **Inter-specific association of different mite were established, that would be helpful in predicting the characteristic mite ensemble in medicinal plants.** Considering the economic importance of the medicinal plants these estimates will be helpful in understanding the dynamics of the relative abundance of different mite species and formulating strategies for control of phytophagous mites.

Control of mites – pesticide / pathogen/predator

Extracts of selected plants *C. alata*, *O. tenuiflorum* and *E. triplinerve* showed positive results in regulating the mite population, thereby providing an alternative way to control target mite population. Predation pattern of the mite *Paraphytoseius multidentatus* was also evaluated as a basis for biological control of phytophagous mites. **The association of the predatory mites is significant in highlighting the possibilities of using them as biological resource against phytophagous mites.**

As proposed in the aims and objective of the proposal control of mites with the help of bacterial pathogen *Bacillus thuringiensis* were tried, however no mortality was observed during experimentation.

Difference in phytochemicals

However, a preliminary study was done to evaluate the effect of mite feeding on biochemical components like carbohydrate, protein, lipid, phenolics and starch. No significant result was noted between the infested and non-infested leaves. But considering the nature of damage of the phytophagous mites, further studies are required for understanding the population dynamics and the changes in the chemical composition of the leaves and other plant parts affected.

Recommendation including usefulness of the findings and their application

The present report includes the findings accumulated during last three-year study period on the diversity, distribution and various ecological requirements of mites infesting medicinal plants from different bio-geographical regions of West Bengal with a note their bio control management. The compilation provides for the first time a comprehensive document on the diversity of both phytophagous and predatory mites occurring on medicinal plants and also represent the data on various bio-ecological aspects including life history parameters, seasonal population structure, and damage potential of some economically important pest species. At the same time the study represents the data on the control potentiality of some important predatory mite species as well as other biocides as bio-control agents to suppress pest population. This aspects of the present study has much relevance in the present day scenario because of the fact that use of chemical pesticides on medicinal plants, in particular has far reaching effect due to obvious reasons. On the basis of present finding it is recommended that use of potential predatory mites and bio-control agents may act as effective alternative to overcome the hazardous effects of use of chemical pesticides.

Result of this study will be useful to the state and central Medicinal Plant Board, Ayurvedic colleges, Pharmaceutical Companies and Agriculture Universities, Department of Health, Govt. of India. Since the various Government Agencies like, ICAR, ICMR, Dept. of Ayush, Ministry of Health Govt. of India, as per advise of the planning commission are encouraging cultivation, conservation and popularisation of indigenously available medicinal plants in India, the present study will augment our knowledge regarding our mite pest scenario of those crops and suggest method to combat those. Needless to mention that, this knowledge is a prerequisite before undertaking conservation and propagation strategy of the crops proposed in this project.

7. Records of dissemination of project findings to stakeholders (pulication in peer-reviewed journal/presented in workshop conference etc)

LIST OF PUBLICATIONS

1. Roy, I., Gupta, S. K. and Saha, G. K. (2006) Two new species of Prostigmatid mites infesting medicinal plants in West Bengal, India. *Entomon*.**31 (4):** 307-313.
2. Roy, I., Gupta, S. K. and Saha G. K. (2008) A new species and a new record of phytoseiid mites infesting medicinal plants of West Bengal, India. *Proceedings of zoological society, Kolkata* **61(1&2):** 1-4.
3. Roy, I., Gupta, S. K. and Saha G. K. (2008) New reports of predatory mites (Acari: Prostigmata, Mesostigmata) from medicinal plants of Darjeeling district, West Bengal, India with description of a new species. *Entomon* **33 (2):** 119-128.
4. Roy, I., Gupta, S. K. and Saha G. K. (2008) Notes on the occurrence of mites infesting medicinal plants of Darjeeling Himalayas. *Insect Environment* **14(3):**130-132.
5. Roy, I., Gupta, S. K. and Saha G. K. (2009) Description of a new species of *Tydeus* Koch (Prostigmata: Tydeidae) infesting medicinal plant *Justicia adhatoda* L.Nees with a note on its biology. *Journal of The Bombay Natural History Society* **106(1):** 83-85.
6. Roy, I. Gupta, S. K. and Saha G.K. (2010) Predatory mites of the genus *Agistemus* (Acari: Stigmaeidae) from medicinal plants of West Bengal, India, with description of a new species. *Entomon* **34(3):** 175-180.
7. Roy, I. and Saha G. K. (2010) Two new predatory mites (Acari: Bdellidae, Phytoseiidae) collected from medicinal plants in West Bengal, India. *Journal of Asia Pacific Entomology* **13:**121-126.

ABSTRACTS

1. Roy, I**.**, Gupta, S. K. and Saha, G. K. (2007) Species composition and interaction of mites of selected medicinal plants. In: National seminar on Dimensions in Zoological research in human welfare (Sponsored by National Biodiversity Authority W.B. Biodiversity Board). The zoological Society, Kolkata; Department of Zoology, University of Calcutta and Zoological Survey of India. Pp 183. (Poster Presentation)
2. Roy, I., Gupta, S. K. and Saha, G. K. (2008) An inventory of mites infesting medicinal plants of Darjeeling and its foot hills. In: National seminar on Recent trends in exploration, exploitation and conservation of biodiversity (Sponsored by UGC). Post graduate department of Zoology, Darjeeling Govt. College, Darjeeling. Pp 20. (Oral Presentation)
3. Roy, I. and Saha, G. K. (2010) Mite species assemblage on *Withania somnifera* – A medicinal plant. In: Golden Jubilee International Seminar on Researches in Zoology

– Basic and Applied. Department of Zoology, The University of Burdwan. Pp 102-103. (Oral Presentation)

ACCEPTED FOR PUBLICATION

Roy, I., Aditya, G. and Saha, G. K. () Life-history features of the mite *Petrobia harti* (Acari: Tetranychidae) associated with *Oxalis corniculata* L.(oxalidaceae)**. Accepted for publication in *International Journal of Acarology.***

8. Total cost of the project and releases

Total outlay of the project: Rs. 1145646.00

Released: Rs. 897500.00

9. Man power Produced: Mr. Indranil Roy, Research Fellow has been awarded his Ph. D. from the University of Calcutta on 21.03.2011

10.	14/17/2005-RE Diversity and Distribution of Asterinaceous Fungi in India	Dr. V.B. Hosagoudar, Senior Scientist, Tropical Botanic Garden And Research Institute, Palode, Thiruvanathapuram-695562, Kerala.

1. Title of the Project: "Diversity and Distribution of Asterinaceous Fungi in India"

2. Keywords: Black mildews, Asterinales, India

3. Name and Address of the principal investigator : Dr. V.B. Hosagoudar
Scientist E1
Microfungi &Lichen Unit
Tropical Botanic Garden and
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Palode – 695 562
Thiruvananthapuram
Kerala

4. Executive Summary of the results vis-à-vis objective envisaged originally

a) Summary of the objective

(As suggested in the first review committee meeting, Nov. 28-29, 2007)

I. Collection, identification and documentation of Asterinaceous fungi in India

II. To study the geographical distributional pattern of these fungi

III. Categorization of the infected plants based on their economic importance.

Asterinaceous fungi are ectophytic, obligate biotrophs infecting wide range of flowering plants ranging from herbs to trees, weeds to economically important cultivated plants, etc. These fungi produce thin to dense black colonies on the surface of the leaves. Structurally brown superficial mycelium produces appressoria which in turn produce haustoria or nutritive hyphae into the epidermal cells of the host plants for the nourishment.
The fruiting body is flattened with radiating cells known as thyriothecium, which splits radially like a star (aster), hence they are known as Asterinaceous fungi. The family Asterinaceae was raised to an order Asterinales. Asterinaceous fungi can be clearly distinguished from Microthyriaceae which dehisce stellately at the center and have oval to globose asci while, the Microthyriaceae have ostiolate thyriothecia with cylindrical asci.

Infected plant parts were noticed carefully in the field, field notes were made regarding their pathogenicity, nature of colonies, nature of infection, locality, altitude, etc. For each collection, a separate field number was given. In the field, each infected plant was collected separately in polythene bags along with the host twig (preferably with the reproductive parts to facilitate the identity of the corresponding host). These infected plant parts were pressed neatly and dried in between blotting papers. After ensuring their dryness, they were kept in the manifold or butter paper folders. Later, these folders were placed in thick paper envelope of convenient size with the name of

the host, locality, date of collection, place of collection and name of the collector along with the field number written on the top corner. These envelopes were serially arranged in a rack based on their collection number. Such materials were used for the microscopic study.

2.
For microscopic study, scrapes were taken directly from the infected host and mounted in 10% KOH solution. After 30 minutes, KOH was replaced by Lactophenol. Both the ountants worked well as clearing agents and made the septa visible for taking measurements. Nail Polish technique used to mount the fungal colonies in situ.

After the study of each collection, part of the material was retained in the regional herbarium, Tropical Botanic Garden, Thiruvananthapuram (TBGT) and part of it were deposited in the Herbarium Cryptogamae Indiae Orientalis (HCIO), IARI, New Delhi.

This work mainly concentrated in Kerala state and a collection trip was made to Shillong and examined the materials deposited from HCIO New Delhi and Agerarkhar Mycological Herbarium, Pune.

5. Result and Conclutions

The present work gives an account of 17 genera and 253 species including 3 infraspecific taxa. Of these, Asterinaceae represents 200 taxa belonging to 8 teleomorphic genera viz. Asterina (180), Asterolibertia (4), Ishwaramyces (1), Meliolaster (1), Prillieuxina (11), Symphaster (1), Trichasterina (1) and Vishnumyces (1); 3 anamorphic genera: Asterostomella (27), Bramhamyces (1) and Mahanteshamyces (1). Lembosiaceae represents 23 taxa belonging to 6 genera, namely, Cirsosia (2), Echidnodella (5), Echidnodes (1), Eupelte (1), Lembosia (14) and Maheshwaramyces (1).

NOVELTIES FROM THE PRESENT WORK

NEW FAMILY

Lembosiaceae

NEW GENERA

1.Bramhamyces Hosag.
2.Maheshwaramyces Hosag.
3. Vishnumyces Hosag. & Harish
4.Ishwaramyces Hosag.

NEW SPECIES

1. Asterina acronychiae Hosag. & Goos
2. Asterina acrotremae Hosag. & Chandra.
3. Asterina adeniicola Hosag. & Kamar.
4. Asterina aglaiae Hosag.
5. Asterina anamirtae Hosag.
6. Asterina ardisiicola Hosag. & Chandra.
7. Asterina arecacearum Hosag. et al.

3.

8. Asterina aristolochiae Hosag.
9. Asterina asclepiadis Hosag. & Goos
10. Asterina atalantiae Hosag. & Agarwal
11. Asterina averrhoae Hosag. et al.
12. Asterina balakrishnanii Hosag.
13. Asterina betonicae Hosag. & Goos
14. Asterina cannonii Hosag. & C. K. Biju.
15. Asterina canthiigena Hosag.
16. Asterina canthii-dicocci Hosag.
17. Asterina caesariicola Hosag. & Goos
18. Asterina chukrasiae Hosag. et al.
19. Asterina cryptocariicola Hosag. et al.
20. Asterina cynanchi Hosag. & Shiburaj
21. Asterina diospyri Hosag. & C. K. Pradeep
22. Asterina elatostematis Hosag. & Goos
23. Asterina emciciana Hosag. et al.
24. Asterina enicostemmatis Hosag.
25. Asterina erythropalicola Hosag. & Goos
26. Asterina euonymi Hosag. & Goos
27. Asterina euryae Hosag. & C. K. Biju
28. Asterina flacourtiacearum Hosag. et al.
29. Asterina gamsii Hosag. & C. K. Biju
30. Asterina girardiniae Hosag. et al.
31. Asterina glycosmidis Hosag. & Rajkumar
32. Asterina glyptopetali Hosag. & C. K. Biju
33. Asterina gomphandrae Hosag. & C. K. Biju
34. Asterina Goosii Hosag. & Balakr.
35. Asterina granulosa (Hansf.) Hosag., Balakr. & Goos
36. Asterina hibisci (Doidge) Hosag.
37. Asterina hopeae Hosag. & Kamar.
38. Asterina hopiicola Hosag. & Abraham
39. Asterina hydnocarpi Hosag. & Abraham
40. Asterina hydrocotyles Hosag. &C. K. Biju
41. Asterina hyptidicola Hosag. et al.
42. Asterina knemae-attenuatae Hosag. et al.
43. Asterina lanneae Hosag. & Manoj.
44. Asterina lepianthedis Hosag.et al.
45. Asterina ligustricola Hosag. & Kamar.
46. Asterina litseae-ligustrinae Hosag., Balakr. & Goos
47. Asterina lobeliacearum Hosag. et al.
48. Asterina loeseneriellae Hosag. & Goos
49. Asterina loranthigena Hosag. et al.
50. Asterina lycianthedis Hosag. & Abraham.
51. Asterina madikeriensis Hosag.
52. Asterina malloticola Hosag.
53. Asterina melicopecola Hosag. & Abraham
54. Asterina meliosmae-simplicifoliae Hosag., C. K. Biju & Abraham
55. Asterina micheliicola Hosag. & Riju
56. Asterina micheliigena Hosag. & Riju
57. Asterina microtropidicola Hosag. & C. K. Biju

58. Asterina microtropidis Hosag., Balakr. & Goos
59. Asterina miliusae Hosag. & C. K. Biju
60. Asterina millettiae Hosag. et al.
61. Asterina mimusopsidicola Hosag. et al.
62. Asterina morellae Hosag. et al.
63. Asterina naraveliae Hosag., C. K. Biju & Agarwal
64. Asterina neolitsiicola Hosag., C. K. Biju & Abraham
65. Asterina oreocnidecola Hosag.,Balakr. & Goos
66. Asterina oreocnidegena Hosag.
67. Asterina palaquii Hosag. & Goos
68. Asterina parsonsiae Hosag.
69. Asterina phyllanthi-beddomei Hosag. & Jacob
70. Asterina phyllanthigena Hosag.
71. Asterina plectranthi Hosag. et al.
72. Asterina pongalaparensis Hosag., C. K. Biju & Abraham
73. Asterina psychotriicola Hosag., & Archana
74. Asterina rhodomyrti Hosag., H. Biju & Manoj.
75. Asterina sabiacearum Hosag. & Goos
76. Asterina samaderae Hosag. & Manoj.
77. Asterina saracae Hosag., Abraham & Crane
78. Asterina sarcandrae Hosag. & Kamar.
79. Asterina schimae Hosag., Jacob Thomas & Robin.
80. Asterina scleropyri Hosag. & Chandra.
81. Asterina suttonii Hosag., C. K. Biju & Abraham.
82. Asterina talacauveriana Hosag.
83. Asterina theacearum Hosag., Abraham, C. K. Biju&Shiburaj
84. Asterina thotteae Hosag. &Hanlin
85. Asterina toddaliicola Hosag., Agarwal, H. Biju & Archana
86. Asterina toxocarpi Hosag. & C. K. Biju
87. Asterina tylophorae-indicae Hosag., H. Biju & Manoj.
88. Asterina xanthophylli Hosag., Abraham & C. K. Biju
89. Asterina wingfieldii Hosag., Balakr. & Goos
90. Asterolibertia hydnocarpi Hosag. & Abraham
91. Asterolibertia nothopegiae Hosag. & Abraham
92. Asterolibertia vateriae Hosag.
93. Ishwaramyces flacourtiae Hosag., Kamar. & Sabu
94. Meliolaster aporusae Hosag., Harish & Archana
95. Prillieuxina aquifoliacearum, Hosag. et al.
96. Prillieuxina argyreiae Hosag., Balakr. & Goos
97. Prillieuxina diospyri Hosag. & Chandra
98. Prillieuxina elaegni Hosag. &C. K. Biju
99. Prillieuxina garciniae Hosag.
100.Prillieuxina ixorigena Hosag. & Chandra.
101.Prillieuxina jasmini Hosag. & Abraham
102.Prillieuxina polyalthiae Hosag. & Abraham
103.Prillieuxina pterigotae Hosag. & Abraham
104.Symphaster mimusopsidis Hosag., Sabeena & Agarwal

105.Trichasterina goniothalami Hosag. & Goos
106.Vishnumyces otonepheli Hosag. & Harish
107.Cirsosia arecacearum Hosag. & Pillai

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108.Cirsosia hopeae Hosag. & Jacob
109.Echidnodella hopeae Hosag., Balakr. & Goos
110.Echidnodella manilkarae Hosag. & T. Sabu
111.Echidnodella memecyli Hosag. & Abraham
112.Echidnodella polyalthiae Hosag.
113.Echidnodella vateriae Hosag. & Kamar.
114.Echidnoides pandanicola Hosag. & Hanlin.
115.Lembosia araliacearum Hosag. & Kamar.
116.Lembosia humboldtiae Hosag. & Abraham
117.Lembosia humboldtiigena Hosag. Jacob & Sabeena
118.Lembosia humboldtiicola Hosag. Jacobe & Sabeena.
119.Lembosia lagerstroemiae Hosag. & Abraham
120.Lembosia linocierae Hosag.
121.Lembosia malabarensis (Sydow & Sydow) Hosag. & Goos
122.Lembosia memecylicola Hosag.
123.Lembosia salaciae Hosag. & Archana
124.Lembosia terminaliae-chebulae Hosag., Abraham & Crane.
125.Maheshwaramyces pachygones Hosag. Archana & Dan.
126.Asterostomella alangii Hosag. & Mohanan
127.Asterostomella baliospermi Hosag., Arachana & Agarwal
128.Asterostomella boehmeriae Hosag.
129.Asterostomella ceropegiae Hosag., H. Biju & Manoj.
130.Asterostomella daphniphylli Hosag. & Ravikumar.
131.Asterostomella dilleniacearum Hosag., Abraham & C. K. Biju
132.Asterostomella elaeocarpi-serrati Hosag.
133.Asterostomella excoecariicola Hosag. & Goos
134.Asterostomella helicteridis Hosag., Balakr. & Goos
135.Asterostomella isonadrae Hosag. & Goos
136.Asterostomella ligustri Hosag., Balakr. & Goos
137.Asterostomella lepianthedis Hosag., Balakr. & Goos
138.Asterostomella micheliae Hosag. & Goos
139.Asterostomella otonepheli Hosag., Agarwal, H. Biju & Archana
140.Asterostomella radermacherae Hosag., Balakr. & Goos
141.Asterostomella scolopiae-crenatae Hosag. & Abraham.
142.Asterostomella strombosiae Hosag. Archana, andAgarwal
143.Asterostomella terminaliae Hosag., Balakr. &Goos
144.Bramhamyces ilecis Hosag. & Chandraprabha.
145.Mahanteshamyces agrostachydis Hosag. & C. K. Biju

NEW VARIETY

1.Asterina cansjericola Hansf. & Thirum.var. indica Hosag., Balakr. & Goos
2.Asterina erysiphoides Kalch. & Cooke var. indica Hosag., Balakr. & Goos
3.Asterina jasmine Hansf.var. indica Hosag.

4.Asterina lobulifera Sydow var. indica Hosag. & Chandra.
5.Asterina thunbergiicola Hansf. var. indica Hosag. & Jacob.
6. Recommenendation including usefulness of the findings and their application:

1. This is the first of its kind for this group in India.

2. This forms the base for the identification of Asterinaceous fungi in India;

3. This gives an account of host- parasite relation.

4. This work emphasized the occurrence of these fungi in abundance and rarity in different

regions of India.

Records of dissemination of project findings to stakeholders (publication in peer- reviewed journal/ presented in workshop conference etc: Reprints attached

8. Total cost of the project: 17, 69,000/- and release made: 12, 65,000/-

Environment Research Programme (ERP):

11.	19-6/2002-RE Recovery of value added products from shrimp processing waste.	Sachindra N.M, Scientist, Department of Meat, Fish & Poultry Technology, Central Food Technological Research Institute, Mysore-570020.

1. Title of the project:

*Recovery of value added products from shrimp processing waste (*No. 19-6/2002-RE dated 20.01. 2005)

2. Keywords

Shrimp waste, carotenoid, fermentation, enzyme hydrolysis, flavour compounds

3. Names and address of the Project Investigator

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4. Executive summary of the results vis-à-vis objective envisaged originally

Objectives of the project

a. Preservation and stabilization of pigments in shrimp waste by fermentation ensiling

b. Development of process for separation of carotenoids from carotenoprotein complex

c. Standardization of process for separation of carotenoids from carotenoprotein complex

d. Assessment of suitability of recovered carotenoids as pigments in fish/shrimp feed and as colorants in fish products

e. Characterization of flavor components in shrimp waste

f. Development of process for flavor concentrate from shrimp waste and its application in fish products

g. Preparation of chitin/chitosan from shrimp waste after recovery of carotenoids and flavor compounds

Results of Academic Importance

a. Evaluation of different lactic acid bacteria (LAB) cultures for their ability to ferment shrimp biowaste.

b. Optimization of conditions for fermentation of shrimp biowaste as well as conditions for acid ensiling.

c. Assessment of aminoacid composition of shrimp biowaste and fermentation liquor obtained after shrimp biowaste fermentation

d. Evaluation of antioxidant properties of liquor obtained through shrimp biowaste fermentation

e. Evaluation of shrimp waste carotenoids as feed colorants

f. Comparison of demineralization and deproteination efficiency of fermentation v/s classical method of chitin preparation

g. Assessment of non-volatile flavor compounds associated with shrimp biowaste

Results of Practical Importance

a. The fermentation process developed gives an integrated approach to recover and utilize different biomolecules associated with shrimp biowaste

b. Feed formulation developed using shrimp waste carotenoids has practical application in aquaculture feed industry

c. Antioxidative property coupled with superior amino acid composition and carotenoid content of lyophilized fermentation liquor has potential for application in animal feed industry both as a probiotic as well as nutritious ingredient with balanced amino acid composition

d. The fermentation process can be an eco-friendly alternative to the chemical method of preparation of chitin

5. Results and Conclusion

Fermentation ensiling using Lactobacillus plantarum B4496 and comparison with acid ensilaging

Fermentation of shrimp waste using starter cultures and various carbohydrates has been attempted in some earlier studies. However, the level of starter culture and fermentable substrate and time required to achieve a desired pH depends on the initial raw material. Hence, these factors were optimized by using a statistically designed experiment. The analysis of observed values by ANOVA indicated that all the three variables and the interaction between the three variables had a significant effect on pH, while the TTA was not affected by the interaction of 3 factors. The time of fermentation and level of sugar has a profound effect of pH and TTA compared to level of starter culture.

The optimized levels of factors were determined using the profiles for predicted values for pH and desirability function. The optimized levels of factors for obtaining the lowest pH of 4.1 was 20.5% of sugar, 19.5% of starter culture and fermentation time of 70 hrs. The predictability of the model was assessed by comparisons of observed and predicted values for the two independent variables pH and TTA. The regression coefficients for pH and TTA were 0.9951 and 0.9353, indicating the usefulness of the model for prediction.

The usefulness of the model was further validated using different random combinations (other than used for optimization) of three factors and comparing the observed and predicted values. The regression coefficient and the slope of the regression equation for pH was 0.9639 and 0.9283 and that for TTA was 0.9381 and 0.757. These high values (close to 1.0) indicate the validity of the prediction model.

Standardization of acid ensilaging conditions

The solvent extraction yield of carotenoids (μg/g waste) from fresh waste was 76.46±1.78. The acidification process led to the considerable decrease of carotenoid pigments in all the treatments compared to the original content in the untreated material. The carotenoid yields were not significantly different ($P \geq 0.05$) between T1 (12%Sulpuric acid + 6% Phosphoric acid + 1% Propionic acid) & T5, T2 (15% of Formic acid) & T3 and T3 & T4. However, the reduction in carotenoid content (% of the original content) was 43.24, 49.53, 51.80, 54.71 and 43.37

respectively in the case of T1, T2, T3, T4 and T5. It can be said that the loss of carotenoid pigments is mainly dependent on the type of acid rather than its strength.

Oil extraction yield of carotenoids from fresh waste was 40.11±5.12 µg/g waste. The reduction in oil extraction yield of carotenoids was significantly different between T5 and all other treatments ($p \leq 0.01$) at the end of the storage. However, the reduction was not significantly different between treatments T2, T3 and T4 ($p \leq 0.01$). The reduction (% of original content) in oil extractable carotenoid content was about 50, 59, 63, 64 and 29 respectively in the case of treatments T1, T2, T3, T4 and T5 by the end of the storage.

The carotenoid content (µg/g) reduced from an initial level (raw waste) of 76.5 to between 29.8 and 42.3 during storage for 90 days depending on treatment. Highest reduction (54.7%) was observed in ensilage using combination of formic acid and sulphuric acid (T4) and lowest (43.4%) when propionic acid alone (T5) was used for ensilaging. Vegetable oil extractability of carotenoids reduced immediately after acidification from an initial level of 40.1 µg/g to values ranging between 22.3 to 33.3 µg/g depending on acid combination used. However, the extractability of carotenoids increased during storage upto 45 days in all treatments (26.2 to 40.1 µg/g), but decreased during further storage. Among all the acid ensilages analysed, acid ensilage prepared using 15% propionic acid (v/w) was found to be superior to the other combinations in respect of stability of carotenoids. The treatment with propionic acid alone gave a better solvent extraction yield of carotenoids apart from good recovery with oil as extractant as well.

Comparison of effect of acid and fermentation ensiling on the recovery of carotenoids

A significant difference in the pH ($p \leq 0.05$) was found between the two types of silage as the pH reduction in fermented silage is always gradual compared to the acid ensilaging. In fermented silage the pH reduced drastically from an initial level of 7.95±0.06 to 4.77±0.04 in 3 days and remained constant, while in the acid silage the pH did not change and was constant in the range of 4.50 during the storage period. The lowest pH observed in the optimization experiment was 4.13 with a sugar level of 15% and culture level of 20×10^4cells/g. The higher pH observed in this experiment might be due to the higher initial pH and difference in the batches of shrimp waste used.

The yield of carotenoids (µg/g waste) by solvent extraction from fresh waste was 47.86±2.18. Immediately after the addition of ingredients to waste during the preparation of fermented silage, the yield was reduced to 32.20±1.85 µg/g, but increased during storage to reach 41.85±1.02 µg/g on 75th day. In contrast, after acidification of waste with 15% propionic acid, the carotenoid yield was 43.09+2.84 µg/g, but reduced gradually during storage to 26.76±1.16 µg/g by 75 days of storage. There was a significant difference ($p \leq 0.05$) in the carotenoid yield between the two types of silage. The initial low yield in fermented silage may be due to the interference of added ingredients like glucose on the extractability of carotenoids, as it was observed that the mass becomes a thick paste and firmly bound while extracting with solvents. As the fermentation progressed, the yield increased to a level close to that of fresh waste and the mass was in the form of free granules during extraction. The reduction in carotenoid yield in acid ensilage is suggestive of a possible degradative effect of propionic acid on the carotenoid and its stability.

The yield of carotenoids from fresh waste by oil extraction was 34.05±2.42 µg/g. In both type of silage the initial extraction yield was lower than that from fresh waste. However, during storage the extraction yield increased significantly ($p \leq 0.001$). In fermented silage the yield (µg/g) reached a level of 31.03±1.34 by the end of 75 days of storage from an initial level of 22.60±1.48. In acid silage the extraction yield increased from an initial level of 19.03±3.66 to

29.27±1.16µg/g after 45 days of storage, always being higher than the yield from fermented silage from day 3, but decreased later to 26.18±3.32 by 75 days of storage. The increase in the extraction yield may be attributed to release of carotenoids from the carotenopeotein complex by the hydrolysis at acidic condition, which resulted in increased uptake of pigments by the extraction medium. In acid silage the yield reduced with storage, due to the degradative effect of acids.

It is observed that the yield of carotenoids from ensiled waste is lower than the fresh waste. Fermentation was found to be superior to acid ensilaging with respect to stability and extractability of carotenoids from the shrimp waste.

Preservation of shrimp waste by fermentation ensiling – screening of different lactic acid bacteria (LAB) cultures

The original shrimp biowaste was found to harbor a LAB count of 3.35±0.5 log cfu g^{-1}. The results of screening experiments and information on LAB load per gram of shrimp biowaste after addition of inoculum and during fermentation are presented in table 9. As can be seen from the table, *P. acidolactici* CFR2182 was found to be the best culture for obtaining a pH of around 4.30 and was significantly different ($P \leq 0.05$) from all the other cultures in terms of cell mass per gram of shrimp biowaste. Also, the pH obtained after 72 hours using *P. acidolactici* was significantly different ($P \leq 0.05$) from all other cultures except the mixed culture ($P \geq 0.05$). Hence *P. acidolactici* was chosen for standardization of fermentation conditions and further studies. No difference was observed in pH reduction with or without agitation.

Preservation of shrimp waste by fermentation ensiling – Optimization of fermentation conditions for Pediococcus acidolactici CFR 2182 (selected LAB culture)

The selection of *Pediococcus acidolactic* CFR 2182 as the starter culture was based on the results of screening experiments. The shrimp biowaste used in the optimization experiments had a LAB load of 3.19±0.09 log cfu g^{-1}.The influence of inoculum level (X1; % v/w), glucose level (X2; % w/w) and incubation time (X3; hours) on the fermentation of shrimp biowaste was determined using Box-Behneken design. Among the independent variables, glucose and fermentation time had higher significant effect ($P \leq 0.01$) as compared to the inoculum level ($P \leq 0.05$). The interactions between different factors also influenced the pH of fermented sample significantly ($P \leq 0.05$).

The pH decreases as glucose increases up to 15% (w/w) beyond which level it increases. This could probably be due to the product inhibition caused by excess amount of substrate. Similarly, pH decreases with time to about 4.3 around 72 hours before leveling off. The pH also decreases with an increase in inoculum level. However, the decrease is not considerable at inoculum levels above 5% (v/w).

To determine the optimum levels of variables (X1, X2 and X3), the response variable (pH) was assigned a desirability of 1.0 for the lowest observed value for response variable (pH of 4.27) and a desirability of 0 for the highest observed value of the response variable (pH of 5.08), to get the overall desirability. The desirability function to get optimum carotenoid yield was fitted by the least square method. The level of variable giving highest desirability (1.0) was selected as optimum level. The optimized levels of variables (X1, X2 and X3) were determined using the profiles for predicted values for pH and desirability function. The optimized factors for obtaining the lowest pH of 4.3 were 15% (w/w) of glucose, 5% inoculum (containing 8.28 log cfu ml^{-1} of *P. acidolactici* i.e. $>10^8$ cfu ml^{-1}) and incubation time of 72 hrs.The predictability of the model was assessed by comparing observed and predicted values of pH. The regression coefficient for pH observed in the experimental runs was 0.9364, indicating the usefulness of the model for prediction.

The model was validated using random combinations (other than used for optimization) of the independent variables. The regression coefficient and slope of regression equation for observed v/s predicted values of pH was 0.9651 and 1.0091 respectively. These high values confirm the validity of the prediction model.

Preservation of shrimp waste by fermentation ensiling – Effect on recovery of chitin and carotenoids

The results clearly indicated the significant ($P \leq 0.05$) reduction in pH as a result of acids produced by the lactic culture and the same is indicated by the increasing TTA (≤ 0.05) values during fermentation. Fermentation resulted in more than 72% demineralization and 97.9% of deproteination at the end of 72 hours of fermentation. DM was significantly different ($P \leq 0.05$) during the course of fermentation except that DM at 48 hours was not significantly different ($P \geq 0.05$) from that observed at the end of 72 hours. Similarly DP was significantly different ($P \leq 0.05$) during the course of fermentation. This clearly indicates the usefulness of fermentation as a tool to produce chitin biologically instead of the conventional chemical methods that employ strong mineral acids for demineralization and strong alkali for deproteination.

The recovery of carotenoids was more than 72% at the end of fermentation period of 72 hours. It can be noticed that total carotenoids recovered was significantly different between 0, 24 and 48 hours ($P \leq 0.05$); while, it was not significantly different between 48 and 72 hours of fermentation ($P \geq 0.05$).

Yield and composition of different fractions obtained after shrimp biowaste fermentation

Fermentation resulted in >79% of fermentation liquor and >20% of chitinous residue. The chitinous residue was found to be deproteinated to a level of close to 92% and demineralized to a tune of 78%. The fermentation liquor upon lyophilization resulted in 14.66% (w/v) yield. The lyophilized liquor had a carotenoid content of >218 µg per gram (Table 17) with a fat content of close to 46%. The tristimulus hunter color lab indicated the lyophilized powder to be more towards whiteness mixed with tinge of orange thereby giving an appealing color. Fermentation resulted in the recovery of >70% of carotenoids present in wet shrimp waste.

Amino acid and fatty acid composition of different fractions

When compared to standard reference proteins, methionine was found to be most limiting in both original shrimp waste as well as fermented liquor. Barring methionine, the fermented liquor retained all the amino acids present in original shrimp waste, indicating the fact that fermentation had not adversely affected the amino acid composition. The lyophilized fermentation liquor has a composition that is recommended for common carp juveniles as well as that of the reference protein recommended by FAO/WHO (1985). This clearly indicates the value of this material as a nutritional ingredient in juvenile fish diets.

The fatty acid composition of lyophilized fermentation liquor indicated that this product is rich in saturated fatty acids. However, the product also possesses considerable quantities of mono unsaturated and poly unsaturated fatty acids, both of which account for >34% (w/w) of total fatty acids.

In-vitro antioxidant activity of liquor from fermented shrimp biowaste

All the radical scavenging activities were significantly ($p < 0.001$) affected by the concentration of the sample. DPPH radical scavenging activity is most commonly used to evaluate the antioxidative activity, which is based on the formation of nonradical form DPPH-H by the reduction of alocoholic DPPH in the presence of hydrogen donating antioxidant. DPPH radical scavenging activity of the buffer extract of the lyophilized powder showed a dose dependency with 40% scavenging at a concentration of 1 mg/ml. The effective concentration for

50% percent scavenging (EC_{50}) determined using the regression equation indicated that for 50% scavenging of DPPH radical a sample concentration of 1.26 mg/ml is required. The ABTS radical scavenging activity of the lyophilized powder was stronger than DPPH radical scavenging activity with 95% scavenging even at 0.5 mg/ml concentration and the EC50 value for ABTS radical scavenging activity was as low as 0.2 mg/ml.

Hydroxyl radical scavenging activity as measured by chemiluminescence technique indicated the very high scavenging activity of the sample towards the radical. Even at a very low concentration of 0.05 mg/ml a scavenging activity of 49.34 $\pm$ 6.08% was observed. For determination of peroxyl radical scavenging activity AAPH was used as peroxyl radical generator and pyrogallol red as target molecule. Reduction in absorbance at 540 nm in presence and absence of the buffer extract of the lyophilized powder was measured to calculate the scavenging activity. Peroxyl radical scavenging activity also showed does dependency with an EC50 value of 0.75 mg/ml. Thus the high scavenging activity of the lyophilized liquor from the fermented shrimp waste is an important criterion in considering it as a strong antioxidant.

To assess the singlet oxygen quenching ability of the lyophilized powder from fermented liquor, the oxidation of 1,3-Diphenyl-siobenzofuran (DPIBF) by the singlet oxygen generated chemically was monitored at 420 nm in presence and absence of the sample. The reduction in absorbance of DPIBF due to oxidation was faster in absence of the sample and the absorbance was reduced by 82% in 5 mins, while the reduction in absorbance in presence of 1.0 mg of sample per ml of the reaction mixture was only 26%. The quenching percentage determined from the absorbance reduction indicated that the activity was significantly ($p < 0.001$) influenced by the sample concentration and 68% quenching was observed at a sample concentration of 1.0 mg/ml with an EC_{50} value of 0.53 mg/ml.

Flavor Compounds Associated with Raw Shrimp (Metapenaeus Monoceros) Waste

The typical GC-MS spectra of typical methanolic extract and mass spectra of some of the peaks are presented indicated a total of 11 different major compounds were identified. Water soluble weak (WSW) and aqueous basic strong (ASS) constitute the major non-volatile flavor fractions followed by water soluble compounds (WSC), ether soluble (EL), aqueous phase (AP), organic basic (OB), organic weak (OW) and organic basic strong (OSS), in raw waste of *M monoceros*. 1, 2, benzenedicarboxylicacid dioundecylester occurred in all the fractions except OW fraction.

Recovery of chitin from flavor extracted residue of shrimp (*Metapenaeus monoceros*) waste

Flavor extraction resulted in a DP of >44% and also resulted in reduction in ash content as evidenced by DM close to 30%. Treatment with strong mineral acids for demineralization resulted in a DM close 100% at room temperature itself. However, when mineral acid (Hydrochloric acid at 5% level in this case) alone was used the deproteination was little above 51% but it increased to about 85% when alkali in combination with acid was used for deproteination and demineralization respectively. Acetic acid (at low concentrations of 2%) in combination with alkali at 55°C resulted in a DP close to 90% and DM of >73%. This clearly indicates that weak acids like acetic acid can be good replacements for much stronger and hazardous mineral acids

Effect of in-situ and commercial proteases on the recovery of carotenoids from shrimp biowaste

The raw shrimp waste had a considerable amount of proteolytic acitivity in the neutral and alkaline range. The recovery of carotenoids was better when a crude protease extract prepared from the fish waste (*Catla catla* visceral waste that has been shown to have two protease fractions active in the alkaline range). The recovery was equal in the case of both the residue and filtrate. The carotenoid that is entering the filtrate will be obviously in the protein form and hence

stands a better utility in the form of hydolysate. Further, as can be noticed from the results, the recovery was better when 0.9% NaCl alone was present in the medium than in combination with EDTA, indicating the fact that proteases used were being inhibited by the presence of EDTA..

Feeding experiments with diet containing shrimp waste carotenoids

The three diets used (C, T1 and T2) had a protein content of 34.6%, 36.4% and 34.8% and carotenoid content (μg/g) of 0.82, 5.11 and 24.15 respectively. The weight of fishes fed with diets containing carotenoids was slightly higher that those fed with control diet. The inclusion of shrimp waste carotenoids enhanced the skin coloration of the ornamental fish, koi carp. The carotenoid content in fishes fed with carotenoid containing diet was 3.3 μg/g (T1: 5 ppm diet) and 4.3 μg/g (T2: 25 ppm diet) and showed a significant difference ($p \leq 0.001$) between fishes fed with 3 diets. Hunter L ($p \leq 0.01$), a* ($p \leq 0.001$) and b* values ($p \leq 0.05$) were significantly different between 3 groups of fishes fed with different diets. Even though carotenoid content and L values differed between fishes fed with two diets containing 5 ppm and 25 ppm carotenoid, the difference in a* and b* values between two were marginal ($p \geq 0.05$). In the present study the improved skin coloration was also reflected in increased total carotenoid content and Hunter L, a*, b* values, indicating that carotenoid extracts from shrimp waste can be successfully used as a source of pigments in ornamental fish diets.

Process economics of recovery of carotenoids and chitin through shrimp biowaste fermentation

1000 Kg wet shrimp waste (including head and body carapace) after fermentation will yield 180 kg protein & carotenoid rich lyophilized powder and 25 kg crude chitin. The plant would be economical mainly because of high value product like astaxanthin rich lyophilized powder which can also serve as probiotic ingredient in aquaculture formulations. The chitin recovered from this process would be better in functionality mainly due to less severity of acids produced during fermentation.

6. Recommendation including usefulness of the findings and their application

Indian shrimp processing industry produces >100,000 tonnes as industrial wastes that makes it the single largest industrial fish waste in the country. Shrimp biowaste being alkaline (pH 7.5 – 8.0) in its characteristic supports the growth of undesirable putrefying microflora resulting in spoilage. Although shrimp biowaste is usually dried on the beaches it encourages not only environmental pollution but also reduces the recoverable components in these biowastes. For instance, fresh shrimp biowaste allows better pigment retention while its dried counterpart loses majority of its pigmentation due to the strong affinity of the constituent pigments for oxygen thus making drying unsuitable for a complete recovery of the components present in such biowastes. Any process that eliminates the drying stage prevents degradation of some proteins, allowing the full potential of protein recovery to be realized. Conversion of shrimp waste into ensilage advantageously upgrades the biowaste with this approach being eco-friendly, safe, technologically flexible and economically viable. Against this background, the major objective of the project was to develop an integrated process that is eco-friendly so as to recover most of the biomolecules from shrimp waste and effectively utilize them.

Work was carried out to compare fermentation and acid ensiling to evaluate their effect on recovery of carotenoids and proteins. Fermentation was found to be superior to acid ensilaging with respect to stability and extractability of carotenoids from the shrimp waste. Fermentation also allowed recovery of carotenoids to a considerable extent (>75%). The protein rich fermentation liquor containing carotenoids could be effectively utilized by concentrating it or co-drying with other feed ingredients.

The lyophilized powder from fermented shrimp waste has both hydrogen-donating (scavenging of DPPH, ABTS radicals) and chain breaking (scavenging of peroxyl radical) antioxidant property. This result indicates that the sample has the ability to prevent lipid oxidation via chain breaking reaction. The water-soluble peptides and proteins are responsible for this antioxidant activity. In addition to the peptides and amino acids, the lyophilized powder also contains carotenoids. Carotenoids possess various biological functions including antioxidant activity. The role of carotenoids as a source of pigment and in immune defense system of cultures aquatic species has been established. Thus the protein and carotenoid rich lyophilized powder obtained from fermented shrimp waste would find immense potential in aquaculture nutrition. In addition, it can also be used as a source of coloring and flavoring agent in fish and shrimp analogs.

The work carried out under this project clearly indicates an improvement of skin coloration in fish fed with carotenoid from shrimp waste. This was also reflected in increased total carotenoid content and instrumental color values, indicating that carotenoid extracts from shrimp waste can be successfully used as a source of pigments in ornamental fish diets.

The shrimp waste was found to have various non-volatile flavor fractions which can be utilized for enhancing the flavor of fish and fish products or shellfish analogs. The residue obtained from both flavor extraction and fermentation has crude chitin which is largely deproteinized and demineralized. Since, the residue from fermentation is obtained from a milder process, chitin prepared from such material may have better physico-cheimical quality characteristics as compared to chitin prepared by conventional chemical methods.

The plant economics calculated for a plant operational at 1 tonne capcity clearly indicates the economic feasibility mainly because of high value product like astaxanthin rich lyophilized powder which can also serve as probiotic ingredient in aquaculture formulations. The chitin recovered from this process would be better in functionality mainly due to less severity of acids produced during fermentation. The chitin from such eco-friendly process would fetch better price and might yield good quality chitosan.

7. Records of dissemination of project findings to stakeholders (publication in peer-reviewed journal/presented in workshop, conference etc.)

Research papers published

a. Sachindra, N.M., Bhaskar, N., Siddegowda, G.S., Sathisha, A.D. and Suresh, P.V. 2007. Recovery of carotenoids from ensilaged shrimp waste. *Bioresource Technology*, 98, 1642-1646**.**

b. Bhaskar, N., Suresh, P.V., Sakhare, P.Z. and Sachindra, N.M. 2007. Shrimp biowaste fermentation with *Pediococcus acidolactici* CFR2182 : Optimization of fermentation conditions by response surface methodology and effect of optimized conditions on deproteination/demineralization and carotenoid recovery. *Enzyme and Microbial Technology*, 40, 1427 – 1434.

c. Sachindra NM and Bhaskar N. 2008. In-vitro antioxidant activity of liquor from fermented shrimp biowaste. *Bioresource Technol*, 99, 9013-9016

d. Bhaskar N, Suresh PV, Sakhare PZ, Lalitha R Gowda and Sachindra NM. 2010. Yield and chemical composition of fractions obtained from fermented shrimp biowaste. *Waste Management Res*, 28, 64-70.

Poster papers presented in organized symposia

Following papers were presented at 18th ICFoST held at Hyderabad, November 2006

a. Bhaskar, N., Sachindra, N.M., Siddegowda, G.S. and Sathisha, A.D. 2006. Effect of acid ensilaging on the stability of carotenoids from shrimp biowaste.
b. Sakhare, P.Z., Bhaskar, N., Suresh, P.V. and Sachindra, N.M. 2006. Optimization of fermentation conditions for shrimp biowaste fermentation with Pediococcus acidolactici CFR2182.
c. Rashmi, H.N., Renjini, V.N., Suresh, P.V. and Bhaskar, N. 2006. Effect of the fermentation on the chitinaceous material and carotenoid recovery from the shrimp biowaste.
d. Bhaskar, N., Dhanya, S.R., Lulu, N., Shivaswamy, S. and Sachindra, N.M. 2006. Flavor compounds associated with raw shrimp (*Metapenaeus monoceros*).

8. Total cost of the project and releases made (In `)

Total cost: `8,16,000/=

Amount released: `6,01,000/=

12.	19-26/2003-RE Effect of Coastal Water Quality on the Corrosion and Biofouling Characteristics of Marine Engineering Alloys	Dr. G. Subramanian, Scientist-in-Charge, Offshore Platform & Marine Electrochemistry Centre, CECRI Unit, New Harbour Area, V.O. Chidambaranar Port, Tuticorin-628004, Tamilnadu.

1. Title of the Project : Effect of Coastal Water Quality on the Corrosion and Biofouling Characteristics of Marine Engineering Alloys

2. Key words : Corrosion, biofouling, seawater, mild steel, structural steel, HSLA steel, commercial copper, naval brass, copper/nickel - 90/10 & copper/nickel - 70/30, heavy metal pollution, oil pollution, cathodic protection

3. Name and address of the project investigators :

Dr.G.Subramanian, Scientist - in – Charge
Dr.S.Palanichamy , Scientist (Co. PI)
Dr.M.Eashwar, Scientist (Co. PI)
Dr.A.Rajendran, Retired Scientist (Co. PI)

Offshore Platform & Marine Electrochemistry Centre, CECRI Unit, New Harbour Area, V.O.Chidambaranar Port, Tuticorin – 628 004, Tamilnadu

4. Executive summary of the results & objectives :

Annexure

In this project the corrosion behaviour and biofouling characteristics of seven marine engineering alloys have been studied at three different locations, namely Tuticorin open sea, Tuticorin Harbour (break water) and Mandapam Coastal water, over a period of 24 months. The characterization of biofouling and corrosion of the seven engineering alloys has been done at the interval periods of 3, 6, 9, 12, 18 & 24 months. The physico-chemical characteristics of seawater at the three locations were monitored. The metal coupons after each removal were photographed for documentation. The loss in mechanical strength of the ferrous alloys after exposure to seawater for 12 & 24 months were studied. The performance of cathodic protection of engineering alloys using different anode materials

has been studied at three different locations, namely Tuticorin open sea, Tuticorin Harbour (break water) and Mandapam Coastal water, for a period of 6 months. The effectiveness of the foul release coatings were periodically evaluated in Tuticorin open sea for 100 days. Apart from the field studies laboratory studies were also conducted on the heavy metal and oil pollution on the freely corroded and cathodically protected marine engineering alloys.

Objectives :

- **Optimization of the basis for selection of engineering alloys in marine applications both in polluted and unpolluted natural seawater.**
- **Performance of cathodic protection of engineering alloys using different anode materials in natural seawater**
- **Evaluation of effect of non-toxic, non organo-tin antifouling compounds on the environment under lab and field conditions, and their performance on the various marine engineering materials.**
- Impact of oil pollution on the corrosion behaviour of engineering alloys under lab conditions.
- Effect of heavy metal concentration on the corrosion behaviour of engineering alloys under lab conditions.
- **Understanding the effects of various industrial pollutants on the electrochemical mechanisms of corrosion and change in mechanical properties of the engineering alloys.**
- Characterization of bio-fouling on engineering alloys with respect to water quality.

Results / findings :

The data on the performance of engineering materials in polluted waters is rather limited, and they nevertheless strongly suggest that corrosion data from open ocean environments are unlikely to be relevant for service of the alloys in coastal seawater locations that receive significant amounts of pollutants. Unfortunately, data on materials performance in Indian waters are mainly limited to open ocean conditions. In order to obtain realistic corrosion data these effects should be taken into account. Hence the results of the present investigation on the performance of engineering alloys in coastal environments of varying water quality project will be a guiding tool to the marine engineers in selection of suitable materials for use in marine engineering industries to have enhanced service life.

The seawater quality data indicated that Mandapam water is relatively less polluted when compared to other two locations. Among the three test locations, mild steel & structural steel and copper alloys experienced higher corrosion at Mandapam than Tuticorin waters. The fouling load on both ferrous & copper alloys was higher at Tuticorin waters when compared to Mandapam. Among the ferrous materials studied, the HSLA steel experienced severe crevice corrosion (to the maximum of see through holes) beneath the hard foulers at all the three study locations. Hence this material is not suitable for marine applications.

In general as many as 40 algal species were recorded on ferrous materials over the period of 2 years. In all the three materials the occurrence of algal species increases with time at all three stations. Among the three ferrous materials, HSLA steel registered maximum of 36 algal species, whilst mild steel & structural steel registered 34 algal species at Mandapam. In general the algal species diversity was more at Mandapam than Tuticorin. On contrary to the ferrous materials, the copper alloys were devoid of algal species at Mandapam. Likewise, at Tuticorin Open sea the copper alloys were free from algal fouling, excepting naval brass. However at Turicoirn Harbour as many as 5 algal species were recorded on copper alloys such as naval brass, copper/nickel - 70/30 & copper/nickel - 90/10.

The occurrence of other fouling groups such as., Bryozoan, *Molluscs, Polychaete worms, Barnacles, Tunicates &* Sponge were evident in all the three stations on ferrous materials. In general, the characterization of fouling groups, reveals more species diversity at Tuticorin than at Mandapam. The Bryozoan & *Molluscs* fouling were found to be poor at Mandapam. At all the three stations, the *Polychaete worms* species diversity was found to be more during 12 & 24 months exposure period. *Barnacles* fouling was recorded throughout the study period at all the three stations. In general on copper alloys, the macro fouling could be seen after 12 months period, excepting *Barnacles* which were recorded from 3 months onward (naval brass & copper/nickel - 90/10). Though among the three stations, *Barnacles* (2 species) fouling was found to be common on commercial copper, naval brass & copper/nickel - 90/10, *Molluscs* fouling on copper alloys was absent at Mandapam and recorded poorly at Tuticorin stations. Of the fouling groups, *Polychaete*

worms fouling was found to be predominant especially on commercial copper at Mandapam on 24 months exposure.

Of the two anode materials; zinc and aluminium studied, it is observed that zinc anode performed better than aluminium anode for ferrous materials, and for copper & its alloys, the performance of mild steel anode was found to be better than aluminium anode. The freely corroded aluminium experienced mild etchings beneath hard foulers, whereas the galvanically coupled aluminium with ferrous & copper alloys experienced severe crevice corrosion. The severity of the corrosion was high on aluminium coupled with copper alloys. Unlike aluminium, the freely corroded zinc & galvanically coupled zinc with ferrous materials experienced uniform corrosion

The addition of heavy metals such as, Mn, Cu, S^{-2} & mixture, accelerated the corrosion of ferrous alloys, while addition of Zn inhibited the corrosion. Among the pollutant studied the acceleration of corrosion was maximum with S^{-2} and the efficiency of cathodic protection was decreased by addition S^{-2} & mixture, for both ferrous & copper alloys.

The addition of diesel (WSF) decreased the corrosion of all the materials studied. The CP efficiency increased at lower concentration, while it decreased at higher concentration.

The evaluation of foul release coatings (SPGC 14 & 18) at Tuticorin Coastal water over a period of 100 days revealed that effective removal of organisms could be done only up to 28 days and thereafter only slime, scum & algal fouling could be removed.

5. Results and conclusions : Pl. refer item No. 4 for details

6. Recommendations :

- Enhanced nutrient levels encourage biofouling.
- The detrimental effect of crevice corrosion beneath the hard foulers on ferrous materials can be overcome by adopting cahodic protection technique.
- The detrimental effect of biofouling on ferrous materials can be overcome by applying antifouling coating (e.g. self polishing copolymer)

- In order to extend the service life of the materials in the marine environment, it is suggested that the installations must be protected using anticorrosive & antifouling coatings along with cathodic protection.
- The HSLA steel used in this study is not suitable for marine installations, in view of its susceptibility to crevice corrosion.
- For cathodic protection system, zinc anode can be used for better performance of ferrous materials in marine environment.
- For cathodic protection system mild steel can be used as an anode for better performance of copper alloys in marine environment.
- Corrosion of engineering alloys would be accelerated in the marine environment where the sulphide concentration is more than 2 ppm.
- The sulphide pollution menace can be minimized by adopting anticorrosive & antifouling coatings along with cathodic protection

The results of project will be a guiding tool to the marine engineers in selection of suitable materials for use in marine engineering industries (Navy, Ship Building, Port Authorities, ONGC, Thermal & Nuclear Power Plants, Ocean Thermal Energy Conversion Plants & Ocean Tidal/Wave Energy Conversion Plants, etc.,) to have enhanced service life.

7.Records of dissemination of project findings **:**

Corrosion behaviour and biofouling characteristics of mild steel in the coastal waters of Gulf of Mannar, India (2011)

Corrosion Science (under review)

10 papers are under preparation for publication in peer reviewed journals.

8.Total cost of the project and releases made (in Rs.) **:** (a) cost Rs.7.32 lakhs
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Annexure

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3. Name and address of the project investigators	:	Dr.G.Subramanian, Scientist - in – Charge Dr.S.Palanichamy , Scientist (Co. PI) Dr.M.Eashwar, Scientist (Co. PI) Dr.A.Rajendran, Retired Scientist (Co. PI) Offshore Platform & Marine Electrochemistry Centre, CECRI Unit, New Harbour Area, V.O.Chidambaranar Port, Tuticorin – 628 004, Tamilnadu
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- The detrimental effect of biofouling on ferrous materials can be overcome by applying antifouling coating (e.g. self polishing copolymer)
- In order to extend the service life of the materials in the marine environment, it is suggested that the installations must be protected using anticorrosive & antifouling coatings along with cathodic protection.
- The HSLA steel used in this study is not suitable for marine installations, in view of its susceptibility to crevice corrosion.
- For cathodic protection system, zinc anode can be used for better performance of ferrous materials in marine environment.
- For cathodic protection system mild steel can be used as an anode for better performance of copper alloys in marine environment.

- Corrosion of engineering alloys would be accelerated in the marine environment where the sulphide concentration is more than 2 ppm.
- The sulphide pollution menace can be minimized by adopting anticorrosive & antifouling coatings along with cathodic protection

The results of project will be a guiding tool to the marine engineers in selection of suitable materials for use in marine engineering industries (Navy, Ship Building, Port Authorities, ONGC, Thermal & Nuclear Power Plants, Ocean Thermal Energy Conversion Plants & Ocean Tidal/Wave Energy Conversion Plants, etc.,) to have enhanced service life.

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13.	19-3/2004-RE Phyto-removal of heavy metals from industrial effluents.	Dr. Padma S. Vankar, Principal Research Scientist, Facility for Ecological and Analytical Testing, Indian Institute of Technology, Kanpur.

1. **Title of the project: Phyto-removal of heavy metals from industrial effluents"**

2. **Keywords: Phyto remediation, Industrial effluents**

3. **Name and Address of the project Investigator**

   Dr Padma S. Vankar, Principal Research Scientist, Facility for Ecological and Analytical Testing, Indian Institute of Technology, Kanpur.

4. **Executive Summary of the results vis-a-vis objective envisaged originally**

   (i) To investigate the effectiveness of *Canna indica* flower, *Portulaca oleracea* flower and stem, *Hibiscus rosa sinensis* flower and *Trapa natans* fruit skin (exocarp) in the removal of various heavy metals from simulated wastewater under varying experimental conditions;

   (ii) To investigate the effectiveness of different fungal species such as *Trichoderma* and *Agaricus* for removal of Cr (VI) ions from tannery effluents

   (iii) To establish the optimum conditions for maximum sorption by studying the effect of various operating variables;

   (iv) To examine the applicability of known adsorption kinetics models; and

   (v) To examine the applicability of various adsorption isotherms.

In order to help understand the metal binding mechanism, laboratory batch experiments were performed to determine optimal binding pH, time dependency of binding, and binding capacity for Zn, Cd, Pb, Cu and Cr(III) metals ions with different biosorbents used. The effect of contact time on the adsorption for a fixed initial concentration of 100 mg/l and adsorbent dose of 10 g/l at 20^0C temperature and 250 rpm of metal ions on biosorbents shows asymptotic nature. Adsorption curves are smooth and continuous leading to saturation, suggesting the possible monolayer coverage of metal ions on the surface of the adsorbent. For most adsorption processes, the uptake varies almost proportionately with $t^{1/2}$ rather than with contact time, t. Plot of metals adsorbed, C_t versus $t^{1/2}$, have some general features: initial curved portion followed by linear portion and a plateau.

The results of studies on variable adsorbent sizes reveal that for a fixed adsorbent dose, the adsorption of zinc is higher for smaller adsorbent size. Further, it is observed that the percentage adsorption decreases with increasing adsorbent size. This is because, adsorption being a surface phenomenon, the smaller particle sizes offered comparatively larger surface area and hence higher adsorption occurs at equilibrium. Similar trend with adsorbent dose and size was also reported by other workers for the uptake of metal ions on various adsorbents.

Biosorption studies were carried out only with *Trapa natans*, which showed the maximum adsorption of Cr(VI) in batch studies. Increasing the flow rate decreased the removal of Cr(VI) and after a certain period removal was nil. The increase in flow rate decreases the contact time between the adsorbent and the adsorbate, but increases the volume contacting the adsorbent. When the

available adsorption sites have all been used, metal removal ends. The rate of adsorption decreases as time was increased. Experiments were also carried out to desorb the metal Cr (VI) from the metal loaded *Trapa* as a function of HCl concentration namely 0.1 M and 1M. After two elutions, over 98% of Cr (VI) was recovered using 1M HCl.
Trichoderma sp. showed decreasing trend in all the concentration as the reduction was 75.13, 83.72, 80.35 and 75.54% in 4, 6, 8, 10 ppm in one hour's time. The biosorption capacity of *Agaricus* was also evaluated in the dry form. In this experiment dried thallus was kept overnight in 100 ml and 200 ml volumes of 10 ppm solution. Then reduction in Chromium (VI) concentration was 94.84% and 96.63%, respectively for 100 ml and 200 ml solution which was very encouraging as well.

5. Results and Conclusions

The study of biosorption showed significant difference of chromium uptake by *Trichoderma* filamentous fungi and *Agaricus* fruiting thallus Natural dye waste of Canna, portulaca, hibiscus and trapa have been used for the first time. The results of studies on variable adsorbent derived from different bio mass showed that powder sizes for a fixed adsorbent for different metals such as Cu, Cd, Cr, Zn and Pb showed efficient metal biosorption from solution, predominantly due to physico/chemical interactions between the biomass and metal in solution, This would help to develop cost effective potential biosorbent for removing chromium and other hazardous metals from industrial effluents.

1. **For the first time biosorbent from plants waste have been demonstrated for efficient phyto- removal of heavy metals-Cd, Cr, Cu, Pb, Zn of which Trapa fruit skin showed excellent results for metal binding capacity.**
2. **Fungal species were used for efficient removal of Cr(VI) from tannery effluents.**

6. Recommendations including usefulness of the findings and their application

A particle size analysis of the *Trapa natans* exocarp showed a d_{50} size corresponding to 148.49 um and a surface area of 0.68 m^2/g; while the second best adsorbent *Hibiscus* flowers showed d_{50} size 76.95 um and surface area of 0.78 m^2/g. It has been reported that fine sized materials with a required reactive surface facilitate metal removal and pH neutralization

The remnant biomass of these plant parts after the extraction of natural dye were evaluated as sorbents for Cr (VI) and other heavy metals removal in dried and semi- wet forms. Boiled *Trapa natans* fruits are shown in the figure 1. Exocarp of this fruit was used as potential biosorbent. Further investigations were carried out with sieved powders of all the plant materials as sorbents. Due to high sorptive capacity (as shown in Figure 2 A & B), *Trapa* fruit skin (exocarp) dried and sieved powder was chosen for detailed sorption studies with hexavalent chromium while Hibiscus Dye waste for remediation of other heavy metals.

7. Records of dissemination of project findings to stakeholders(publication in peer reviewed journal/presented in workshops conference etc)

Biosorption of aqueous chromium(VI) by Trapa natans exocarp: Remediation potential of some waste bio-materials, **Padma S. Vankar** and Rishabh Saraswat, First International Conference on Environmental Management, Engineering, Planning and Economics (CEMEPE), Skiathos island, Greece, June 24 to 28, 2007(Oral presentation).
Phyto-removal of chrome-VI from tannery effluents by Trichoderma species. **Padma S. Vankar** and Dhara Bajpai, Proceedings of *"Desalination and the Environment"*, April 22-25; Sani Resort, Halkidiki, Greece.
Phyto-removal of chrome-VI from tannery effluents by *Trichoderma* species, **Padma S. Vankar** and Dhara Bajpai, Desalination, 222, 255-262, (2008).

Hibiscus rosa sinensis flower waste as Biosorbent: Lead(II) and Cadmium(II) removal **Padma S. Vankar** and Rishabh Sarswat accepted to Environmental progress and Sustainable energy, 29 (4), 421-427, (2010).

Biosorption of Zinc ions from Aqueous solutions onto Natural Dye waste of Hibiscus rosa sinensis: Thermodynamic and Kinetic Studies, **Padma S. Vankar**, Rishabh Sarswat and Ramashanker Sahu, Environmental Progress & Sustainable Energy, accepted (2011).

An Assessment and Characterization study for Biosorption efficiency of Natural Dye waste, by **Padma S. Vankar**, Ashish Dwivedi, Rishabh Sarswat and Ramashanker Sahu,submitted toJournal of Cleaner Production Special Issue (2011).

8. Total cost of the project and releases made (In Rs) Rs 8,22,000

Policy Research Project:-

14.	24/6/2005-RE Formulation of a sui generis Regime for Traditional Knowledge (Ethnobiology)	Prof. Dr. P. Pushpangadan, director General, Amity Institute for Herbal and Biotech Products Development, 3-Ravi Nagar, Peroorkada P.P, Thiruvananthapuram-695005.

1. **Title of the Project:** 'Formulation of a sui generis Regime for Traditional Knowledge (Ethnobiology)
2. **Key words:** Biodiversity, Traditional Knowledge, Traditional Medicine, IPR protection, sui-generis
3. **Names and Address of Project Investigator:** Prof. Dr. P. Pushpangadan, Director General, Amity Institute for Herbal and Biotech Products Development, 3-Ravi Nagar, Peroorkada P.O, Thiruvananthapuram – 695 005
4. **Executive summary of the results vis-à-vis objectives envisaged originally**

The traditional knowledge (TK) of traditional/indigenous/local communities has been an easily accessible treasure and thus has been open to misappropriation. The third world countries in the south like India, China and other tropical and subtropical countries in Asia, Africa, S. America are rich in both biodiversity and associated TK. TK was nourished, nurtured and shared freely by the traditional communities among themselves and also shared freely with even outsiders. The traditional communities have never attached any monetary value or IPR to such TK. But this was not the case with the North countries. Value added products based on the TK leads of the North countries, the biodiversity poor but technologically advanced countries of the North were making products with monopolistic marketing rights/IPR that enabled the colonial powers of the North countries to become rich and powerful during 19th and 20th centuries. 20th century witnessed the liberation of the south countries from the colonial powers. This was followed by the liberation of global trade policies and other economic reforms towards the end of 20th century. End of 20th century also witnessed the emergence of the UN- Convention on Biological Diversity (UN-CBD) and the global trade reforms brought under the World Trade Organization (WTO) and also a scenario of fast developing S&T break throughs.

There is no denying the fact that the Wealth of Traditional Knowledge available in most developing countries are very valuable assets capable of being converted into value added products and hence they deserve to be effectively protected not only to derive economic benefits to the holders of such knowledge, but also to ensure that they will be conserved and used equitably. For example, established traditional practices and products used in Agriculture, the main stay of many developing countries have contributed enormously to the food security and sustainability in the communities where they are derived have been providing healthcare to the majority of world's population over the last several centuries. The benefits that accrue from their equitable use will benefit not only the owners of TK, but also the whole of humanity.

Apart from Patents, other legislations legitimized under the TRIPS Agreement such as the Plant Varieties Protection Act, Trade Secrets Act, the Biodiversity Act, Competition Law and a variety of *Sui Generis* laws have been proposed and some of them used, however in a limited

manner by many countries particularly by the developing countries, notably India, Peru, Phillipines, Brazil, Ecuador, Costa Rica, China, Malaysia and many others.

It is therefore suggested that a S*ui generis* legislations are more effective for the protection of TK and related cultural expressions. Though the process of employing TK in the prior art examinations process has gained currency in the world, the larger task of protecting TK in an affirmative sense is yet to be accomplished. This is partly due to the fact that the process of integrating TK concerns within existing laws have not succeeded in many countries due to the inability of many countries to recognize TK as falling within the meaning of novel innovations. While Geographical Indications and Biodiversity Legislations offer scope for TK protection, they are restricted in scope.

The complex and vast area of Traditional Knowledge in India, with millions of uses for biodiversity requires a mammoth effort to streamline. The effort is an attempt in this direction. The Amity Institute for Herbal and Biotech Products Development (AIHBPD) team lead by the PI of this project has played important roles in the National and global debates in promoting Traditional Knowledge, IPR and benefit sharing with back up of technology. Traditional Knowledge and modern technology has to be interlinked optimum returns. However, the legal and operational areas are to be strengthened. With this objective in view a National Conference entitled "Dhishana – 2008 Streamlining India's Traditional Knowledge towards formulating a *Sui generis* Regime" was organized from 23-25th May, 2008 at Rajiv Gandhi Centre for Biotechnology, Thiruvananthapuram. The recommendation of the conference in the form of Thiruvananthapuram Declaration was issued by a group of eminent scientists, traditional knowledge stakeholders, academicians and activists which is incorporated in the recommendations.

5. Results and Conclusion

Govt. of India has enacted necessary statutes and established several national bodies as in the case of Biodiversity Act (2002), Biodiversity Rules (2004), National Biodiversity Authority and Biodiversity Boards, Protection of Plant Varieties and Farmers Rights Act (2001) and Protection of Plant Varieties and Farmers Rights Rules (2003) etc. Since Traditional Knowledge is the core strength of India, unlike technology lead innovations in developed countries, a Sui generis Regime for Traditional Knowledge is felt essential for the country, on a case to case basis and with due care taken on benefit sharing with indigenous communities.

A sui generis legislation that views TK as a composite resource, having both economic and cultural features has a better prospect of ensuring protection of TK, through improved valuation and benefit sharing. If national measures for Sui generis protection are backed by international regulations that harmonize protection measures, TK protection with national boundaries would be fortified by 'reciprocity' guaranteed by international compacts.

6. Recommendation including usefulness of the findings and their application

The recommendations made by the expert group of the Committee met on May, 2008 are the following.

1. That the Government of India establish a statutory Authority for Traditional Knowledge, with central, state and district level systems, to regulate it and efforts be made to stop its further erosion and support promotion through appropriate funding and other measures.
2. There has to be collective efforts to promote fair and equitable sharing of benefits arising from the use of biodiversity, traditional knowledge and its components and any attempt to

pilfer it without consent and benefit sharing be punished by international laws formed with mutual consent.

3. That the Government of India accord a special status to Tribal Healing, after due processes of screening the healers, and accord legal status, and allow them legitimate access to forest and other resources.
4. We demand that equal importance be given to the native streams of healing and other vocations, as now given to predominant systems like modern medicine, and these be made part of the health care apparatus of each country, that is in India Ayurveda and native healing techniques be made primary systems with due honor to the practitioners.
5. That tribal traditional healers and qualified traditional healers be paid a monthly honorarium with immediate effect and a national directory listed, with the best tribal healers and successful healing practices published for the use of all others. That awards be established to honour them in each area.
6. That a separate ministry for traditional forest communities be constituted and a new participative and eco-sensitive development paradigm evolved for the sector, taking in to account the felt needs of the people and resources available.
7. That the tribal areas be given sufficient budgetary support and a series of eco-friendly and locale specific microenterprises, say for collection and processing of wild edibles, be started to augment the quality of life in these areas.
8. That a National Tribal Development Corporation be set up with the mandate of revalidating traditional knowledge and promoting these for augmenting the incomes and well being of the tribal communities.
9. That the Indian owned and India based public and private sector units be given priority in promoting the native TK and the Indian companies given subsidies to promote TK based products for meeting national and international needs.
10. That concrete efforts be made to revitalize traditional cultures, tribal languages and traditional knowledge. That training centres, educational institutions and universities be set up to promote these holistic models of TK among new generations.
11. That the tribal community be given adequate representation in the management of forests at the central, state and local unit levels as they have been the owners and conservators of forests for millenniums.
12. We desire that there be a global order in the new millennium which is not dictated by the motives of trade, what the WTO is, a new order modeled after the symbiotic cultures of the world and not dictated by trade interests and the WTO be made answerable to the United Nations.
13. biodiversity rich Nations of the world for protecting TK associated with biodiversity with a view to build a common platform of TK holders, providers, related scientists, social workers and lawyers specialized in IPR related issues to exchange their views and concerns for safe guarding the TK of their respective Nations by adopting common/specific remedial measures.
14. That a multi-pronged capacity building programme be evolved at grass root level exclusively for TK holders/ providers of biodiversity rich Nations, for implementing various awareness programmes. This will enable them to take appropriate measures to check bio-piracy of bio-resources and associated traditional knowledge.
15. We desire that the product patents on traditional knowledge, in case granted, be made perpetual where this is owned by communities, and not for 20 years as statutorily available now.
16. There has to be new approaches in the new millennium which give due place to the values and modes of livelihood of the non-western people instead of the present western paradigm being imposed on all others.

17. That the principle of *sui generis*, case to case approach, be made universal instead of the present blanket western laws that govern the global transactions. That any utilization of TK and biodiversity for commercial purposes be under the principles of equitable sharing of rewards.
18. We are concerned about· the propagation on native communities of alien and environmentally damaging values and beliefs, through propaganda, economic compulsions, advertisement and use of media which these communities are unable to counter.
19. Ecosystem sensitive local cultures have a strategic value and this has to be honoured and promoted. The importance of the relationship between cultural diversity and biological diversity in human survival has to be acknowledged.
20. That the Government of India establish a National Negotiation Mechanism, with participation of stake holders and experts, for dealing with international treaties as the present arrangement is found inadequate.
21. That the present practice of coupling Scheduled Castes and Scheduled Tribes by the government be decoupled as the problems and prospects of both are fundamentally different.
22. That the government and media accept the forest dwelling tribals as the core culture of India, as the first people, and give them due honour as it is this culture that has helped conserve the primary survival systems, the forests.

These recommendations were sent to various Central and State agencies to implement appropriately.

7. Records of dissemination of project findings to stakeholders (publication in peer-reviewed journal /presented in workshop conference etc.

1. Pushpangadan, P and Pradeep PRJ. A Glimpse at Tribal India -An Ethnobiological Enquiry (2008) Published by Amity Institute for Herbal and Biotech Products Development, Thiruvananthapuram and The Ministry of Environment and Forests, Govt. of India.
2. Thiruvananthapuram Declaration on Traditional Knowledge adopted on May 25, 2008 published by Amity Institute for Herbal and Biotech Products Development, Thiruvananthapuram
3. Pushpangadan, P., George, V., Pradeep, PRJ and Syam B Nair. National Conference Dhishana 2008 Streamlining India's Traditional Knowledge Towards formulating a Sui generis Regime, May 23-25, 2008, Thiruvananthapuram. Book of Abstracts. Published by Amity Institute for Herbal and Biotech Products Development, Thiruvananthapuram
4. Pushpangadam, P (2008) Traditional Medicine and Intellectual Property Rights (IPR) Regime in 21st Century. Ethnopharmacology Recent Advances, Eds. P. Pushpangadan, V. George and K.K Janardhanan, Daya Publishing House, Delhi – 110035, pp 214-230.
5. Pushpangadan, P. and George, V. (2009) Biotechnological Approaches in Herbal Drug Production – Secondary Metabolites through Metabolic Engineering. A Textbook of Molecular Biotechnology Eds. Ashok K Chauhan and Ajith Varma, I.K International Publishing House Pvt. Ltd. Delhi pp. 763-773
6. Pushpangadan, P. and Varughese George (2009) Factors Influencing Secondary Metabolism and Therapeutic Efficacy of Medicinal Plants. In Traditional and Alternative Medicine – Research and Policy Perspectives Eds. De Silva, Bahorum, Sahu and Huong.

Centre for Science and Technology of the Non-aligned and other Developing Countries (NAM S&T Centre), Daya Publishing House, Delhi pp.17-24

7. Pushpangadan, P and Varughese George (2009) Medicinal Plants/ Traditional Medicine and IPR Protection. In Traditional and Alternative Medicine – Research and Policy Perspectives Eds. De Silva, Bahorum, Sahu and Huong. Centre for Science and Technology of the Non-aligned and other Developing Countries (NAM S&T Centre), Daya Publishing House, Delhi pp. 25-34

8. Total cost of the project and releases made (in Rs.)

Total Revised cost of the project Rs. 20,13,840/-

Total releases made Rs. 20,02,426/-

15.	24/8/2005-RE Valuation of Ecological Services of Wetlands in India	Er. Krishna Mazumdar, Professor, Economic Research Unit, Indian Statistical Institute, 203, B.T. Road, Calcutta 700108.

1.Title of the Project : Valuation of Ecological Services of Wetlands in India

2. Keywords : Wetlands, Ecological services, Chilika, Sundarbans, Kolleru, Contingent valuation

3. Name and Address of Project Investigator : Dr. Krishna Mazumdar,
Professor, Economic Research Unit,
Indian Statistical Institute,
203, B.T. Road, Calcutta 700108.

4. Executive Summary of the results vis-à-vis objective envisaged originally : Separate sheets attached.

5. Results and Conclusions : Separate sheets attached.

6. Recommendations including usefulness of the findings and their application : Separate sheets attached.

7. Records of dissemination of project findings to stakeholders :
At the meeting held at the MOEF (in 2007), I placed my Final report (during my presentation, I also reported verbally my experience of visiting and working at KOLLERU in March 2007 and told in detail how myself and my team was threatened while working at Kolleru), I was scolded vehemently by your ONE OF YOUR EXPERT, for presenting my findings on KOLLERU and my recommendations for KOLLERU as well as my experiences of working at Kolleru. The above mentioned expert told that at the end of the day, what should Dr. Bhatia report the Minister about the findings and recommendations of the Project – **"COULD DR. BHATIA TELL THE MINISTER THAT THE KOLLERU LAKE IS NO MORE A LAKE? HOW COULD HE SAY THIS TO HIM?"** I had to heard insulting words for telling and writing the truth. **HOW SHOULD I DARE TO PUBLISH ALL THESE OR CONVEY ALL THESE TO ANY BODY (Including the STAKEHOLDERS)** by publishing in journals, presenting in seminars or workshops

8. Total cost of the project and releases made (In Rs.) :

Total financial assistance sanctioned	: Rs. 12,39,700.00
Financial assistance released during 2005-2006	: Rs. 7,02,650.00
Financial assistance released during 2006-2007	: Rs. 4,00,000.00
Total assistance released during 2005-2007	: Rs. 11,02,650.00

16.	24/7/2005-RE Policy, institutional, and legal barriers to economic utilization of fly-ash	Shri S.K. Chand/Prima Madan (ex-TERI employee), TERI, IHC complex, Lodhi Road, New Delhi-110003.

1. **Title of the Project:** Policy, institutional, and legal barriers to economic utilization of fly-ash

2. **Key words:** Government policy, acts, rules, and guidelines

3. **Names and Address of Project Investigator**:
Prima Madan (ex-TERI employee)

Co-Principal Investigator: SK Chand
The Energy and Resource Institute (TERI)
IHC complex, Lodhi Road, New Delhi-110003
Phone no: (011) 24682100. Extension no: 2320
Fax: 24682100 or 24682145

4. **Executive summary vis-à-vis objectives envisaged originally**:

Objective: The project funded by the MoEF, seeks to analyse the factors that influence the economic utilisation of fly ash in cement and in bricks as well as backfill of mines. The objective is to arrive at policy, institutional and legal measures required to promote the economic utilisation of fly ash.

Executive summary:

With over 50% of India's electricity generation being coal-based and coal supplies to power sector contain 40% ash on an average; an estimated 108 million tonnes (Mt) of fly ash was generated in the year 2006-07. It is further estimated that only about 51% of the ash generated found gainful utilisation (CEA, 2006-07).

The increased quantum of ash generated and likely to be generated in the future, have given rise to growing concerns for maximising its gainful utilisation. The concerns related to low levels of ash utilisation are also linked to the environmental and other costs associated with ash disposal.

In the wake of the above, the Ministry of Environment and Forests (MoEF), Government of India, commissioned TERI to study and report the *"Policy, institutional and legal barriers to economic utilization of fly ash in India".*

The study examines the reasons for the comparatively low level of ash utilisation in the country; investigating if 100% ash utilisation can possibly be achieved given the magnitude of ash generated.

Fly ash can be gainfully utilised in various ways: in cement and ready-mix concrete (RMC), which may be considered as high value and high volume applications, in bricks as a medium value low volume use. Other applications such as for backfill in mines and as landfill are low value applications, but have a potential to take up very large volumes. At another end of the spectrum are technology-intensive applications, which utilise special

characteristics of fly ash. These include, for treatment of wasteland, acidic soils and as soil stabiliser for embankments, which have low value, and can take up very limited amount of fly ash. The potential areas of ash utilisation that this study focuses on are *cement, bricks and as backfill in mines*. Another very high value very low volume application is the collection of cenospheres (also known as floaters) from ash ponds by skimming the surface though its availability is getting reduced due to reduced dumping of ash in the ponds.

Fly ash use in cement is mainly for the production of Pozzolana Portland Cement (PPC), and its use in RMC as cement replacement. The use of fly ash in bricks and blocks vary depending on the type of brick/ block. Some of the noted types of fly ash based bricks/ blocks are: Clay-fly ash bricks, Fly ash-Lime- Gypsum (FaL-G) bricks; Cellular Lightweight Blocks; Autoclaved Aerated Concrete (AAC) Blocks; Fly ash-Lime-Sand Autoclaved Bricks etc.

Almost 90% of coal in India is produced from opencast mines and large capacities for power generation using coal are located in or around coalfields. Clusters of power generation capacities exist as pithead power plants in Singrauli, Korba, Talcher, Ib, Chandrapur and Ramagundem; all serviced by open cast mines. Using fly ash/ pond ash to backfill these open pits would be an ideal situation. Similarly, lignite-fired power generation is all pithead based and the ash generated can be sent back to the mine if no other utilisation avenues are available.

Methodology

The methodology adopted in the study included a combination of literature surveys, interaction with experts and discussions with various stakeholders and visit to ash generation and consumption units. This involved:

- Reviewing the policy context in terms of the current and new draft notifications associated with fly ash utilization to address the regulatory and policy aspects, in light of varying perspectives and possibly conflicting interests of various stakeholders.
- A detailed literature review on issues associated with fly ash utilization in India and other countries.
- Data sourced from Central Electricity Authority has been analysed to assess the current trends in fly ash generation and its utilization in various sectors
- Detailed discussions with stakeholders from power sector, cement sector, brick manufacturers in the context of the study. The discussions aimed at strengthening the findings of the literature review, understanding the ground realities in terms of associated costs and benefits accruing to the users of fly ash.
- Based on consultations and inputs received from the stakeholders a cost benefit analysis was conducted for the sectors of cement and bricks to distil the perceived and real barriers to gainful utilisation of fly ash and how these barriers may be addressed.
- An Analytical Hierarchical Process (AHP) model was developed to rank the barriers identified in order to assess the most important barrier from each sector perspective. AHP is a decision analysis tool, used to compare alternatives. It relies on the decision makers' ability to compare the importance of different attributes.

The data on fly ash generation and utilization for last few years brings out some useful insights (CEA, 2006-07). In the current scenario the most promising sector for fly ash utilization seems to be the cement sector and

with India's increasing economic growth, the utilization of fly ash by the cement sector can be expected to grow further. Based on Cement Manufacturers' Association (CMA) data, projections made by TERI indicate that fly ash utilization by the cement sector would increase to 64 Mt by end of the 11th Five Year Plan. It would become the single most important user of fly ash in the future.

Fly ash demand from uses such as for mine backfilling promise much for the future but till now has not materialized to a substantial extent. Similarly, the use of fly ash for brick manufacturing are promising for the future though have a potential to take up only a limited quantity of ash. It is however expected with right kind of facilitating environment through policy interventions and amendments, the trends of ash utilization in sectors of cement, bricks and back fill in mines will pick up.

In India, fly ash has traditionally been viewed as an industrial waste. But internationally, fly ash has been categorized as a very valuable "by-product" (in some countries referred to as CCB - Coal Combustion By-product) and it has been gainfully utilized to a large extent.

The international experience in fly ash utilization is mixed and provides useful lessons for India, particularly from the policy perspective. The experiences of other countries also point to the presence of policy and regulatory barriers to the utilization of fly ash, which have to be dealt with in creative ways. It needs to be realized that the mandate of achieving 100% ash utilization in India, is often quoted based on experiences of countries like Netherlands where 100% utilization of fly ash (largely in cement and concrete) has been possible through cooperation between various stakeholders. However, the quantum of ash generated in Netherlands is only one million tonnes, which is far lower than in India. On the contrary, large volumes of ash are generated in USA where the utilisation is less than 50%. In case of China where the generation of ash is very high and growth rate of economy is consistently very high signifying larger demand of ash in the infrastructure sector, the utilisation rates are low. It needs to be noted that while learning from other country experiences, we need to keep in mind the quantum of ash generated in India vis-à-vis other countries.

Fly ash management

Fly Ash management has two inter-related aspects –

- Limiting fly ash generation by reducing the ash content of coal used in power generation; and
- Enhancing fly ash utilization by policy intervention

In India, while initiatives towards fly ash management in the policy and institutional context were under way in small pockets, it was only in the late 1990s that policy activity was initiated on these issues at the national level. The government policies in India have essentially followed a twin pronged strategy, with the efforts being devoted towards limiting fly ash generation on one hand and increasing fly ash utilization on the other hand. The earlier notifications of 1997 and amendments in 1998 stressed on reducing ash generation by type of coal used by certain categories of Thermal Power Stations (TPS), while the 1999, 2003 and draft 2007 notifications sought to enhance utilization of generated ash.

While the existing mandate under the 1999 notification is to provide free fly ash to its users, the draft notification of 2007 is different since it proposes a bidding process for fly ash from various plants. This marks a break from the

earlier notifications in the sense that it acknowledges the existence of plant-specific characteristics that determine the level of ash utilization and the need for discovery of its market price. However, the policy continues – like the earlier notifications – to emphasise on mandating rather than incentivizing the use of fly ash. Progress towards economic use of fly ash may be further hampered by the provision that indicates that fly ash may even get a negative price in some cases.

Full economics associated with fly ash use needs to account for the costs associated with ash disposal. Analysis of ash disposal costs in this study provides us with some useful insights.

Ash disposal costs

All coal fired thermal plants in India have lean slurry system of disposal of ash except for one plant in Dadri which is based on dry ash collection and a few plants where dense phase slurry system has been in use since some years. In the slurry system of disposal of ash, the fly ash and bottom ash is mixed with water, generally in the ratio of 1:10 and transported to artificially created ponds in a slurry form.

The wet process requires large tracts of land for disposal ponds and huge quantities of water which acts as carrier during the process of disposal. Also this process of wetting ash lowers its 'lime reactivity', an important property for the fly ash to be used in cement manufacture and as cement replacement. Estimates for a Gujarat State Electricity Corporation Limited (GSECL) power plant reveal that the ash disposal costs for 2007-08 for one of its plant was Rs. 150 per tonne of ash disposed. It must be noted that the total cost of ash disposal would vary in the future and likely to decrease, mainly on account of greater ash in dry form is being dispatched for utilization and thereby a decrease in the ash sent to ash ponds could be expected.

Sector analysis

Bricks

Brick manufacturing has often been deemed as a high potential user sector for fly ash. In fact, the first MOEF notification was forced by a PIL, which advocated that brick was the panacea. It may be noted here that the fly ash generating points in the whole country are limited to about 50. The fly ash brick manufactured in the close vicinity to the TPS would need to be consumed in and around the area and transporting it to long distances would make its use uneconomical and would thus get rejected. On the other hand, clay bricks are manufactured at a large number of locations in the country and thus red bricks have an edge over the fly ash based bricks, in terms of associated transportation costs. However, the total potential for utilisation of fly ash in brick making may be small but would lead to conservation of topsoil, which is very important.

Case studies considered under this study provide a comparative analysis of traditional clay brick manufacturing with fly ash based brick making. The analysis shows that initial investment, fixed costs and raw materials costs are always higher in all types of fly ash based bricks considered, when compared with conventional clay bricks.

The benefits from the manufacture and use of fly ash bricks result in reduced energy use, cost savings on account of lesser mortar requirements in construction, conservation of topsoil and even qualifying under Clean

Development Mechanism etc. But in spite of these benefits, barriers on account of high costs associated with initial investment, fixed costs, high raw material costs, lack of level playing field, mindsets of users, lack of awareness, broad brushed policies etc pose significant barriers in tapping the potential of brick making as a gainful use of fly ash.

Cement sector

Cement industry would continue to remain the most important user of fly ash in the future. This study estimates that, based on certain assumptions, cement plants reap a benefit of a minimum of Rs. 535-724 per tonne of cement. In other words the gain to cement plant is in the range of Rs 1782 to Rs 2412 per tonne of fly ash utilised to produce PPC, depending on assumptions of distance and cost of sourcing of ash. This does not include other benefits such as increased life of limestone mine etc. Thus, the major driving forces for increased utilization of fly ash by this sector would remain to be the economics of fly ash procurement and the resultant margins of profit. This utilization can be encouraged further by certain steps being taken by the power plants like grading of ash, taking appropriate initiatives for reducing the unburnt carbon content in fly ash, etc.

Mine backfilling

The total utilisation of fly ash in mine backfilling during the year 2006-07 has been estimated at only 6.5 Mt or 6% of the total ash generated during the year. This is indicative of very low penetration of this mode of ash utilisation. Within this 6%, there are some non-pithead power plants also who have shown mine backfilling and enquiries reveal that to make space in the dyke, pond ash was evacuated and dumped in to adjacent abandoned stone quarries. In case of pithead power stations the mine backfilling has generally been taking place in case of mine operators who are also the owner of the power stations. After much ado and negotiations, Coal India has finally allowed NTPC and DVC for mine backfilling in a few cases. The case of NTPC Singrauli TPS requesting for backfilling of Gorbi mine in Singrauli coalfields is still hanging fire.

It should be realized, that if utilization levels of fly ash has to increase, backfilling of mines is the only solution in the case of pithead power stations. The associated costs of sending ash to the mine are comparable if the plants would have invested in building ash dyke for ash disposal.

In case of captive mining by the power operator, this should be made mandatory to accommodate ash in the mine backfill if no better utilisation opportunity for the ash exists.

Some of the barriers faced in this sector include, absence of mandatory requirement to fill up abandoned coal mines, mismatch of life spans of TPS and mines, high transportation costs of ash and unwillingness of National Coal Companies to allow use of ash in mine backfilling.

Key findings of the study

A holistic review of the policy framework and a cost benefit analysis of economic use of fly ash in the sectors of cement, bricks and mine back filling,

undertaken in the present study, point out some key barriers faced both by the suppliers i.e. the power producers and various users of fly ash. Some of these barriers are cross cutting across and some specific and limited to the sector in particular.

Barriers to ash utilization: User Sectors Perspective (Cement, Bricks and Mine backfilling)

Policy and legal barriers

a. **Lack of level playing field/need to incentivise**: clay bricks are a unorganized/informal and a seasonal industry and thus are exempt from various taxes. No such exemptions are available to fly ash based bricks and blocks and those exemptions, which were provided in the past, have now been withdrawn. Such a scenario on the policy front discourages many new players to move to a comparatively new technique of brick making, and those already in it are feeling the pinch. High /enhanced duties and taxes that have been made applicable on the ash based products and on machinery and consumables needed for their production are some of the barriers that were identified. If the use of fly ash is to be encouraged in the sector, there is a need to incentivise the use of fly ash based products by at least withdrawing duties /taxes /levies.

b. **Broad brushing:** in the policy context, several instances of broad brushing in the notifications issued for fly ash management has been pointed out. For example, the mixing of 25% of fly ash in all clay fly ash bricks, irrespective of the type of soil available has been mandated by MOEF notification. Apart from difficulty posed by high cost of transportation of fly ash, the making of clay bricks is 'soil-type' and location specific. Another example being pointed out is the mandating 100% utilisation of all ash produced by 100% TPS within a given timeframe.

c. **Mandate of free fly ash:** the mandatory requirement by power plants to issue free fly ash, though preferred by the users of fly ash, acts as a barrier from power plants' perspective. Such a policy provides no incentive to power plants to invest in improving the capacity of dry ash collection or quality of ash. This in turn acts as a hindrance in ash utilization in wake of lack of availability of right quality ash, important for uses such as in cement manufacturing. A market determination of price of ash would provide an incentive for the power producers to invest, improve and make available the right quality of ash to its users.

d. **No mandatory requirement for closure of mines:** the mineral sector has a policy of proper closure of mines but coal sector is yet to formulate such a policy, though such a provision exists in the approved mine plan. The use of fly ash for backfill in mines has the potential to take up large quantities of ash. This is most feasible in case of pithead power station. Since there is no compulsion there is a general slackness and lack of interest on part of the mine owners to use ash for mine backfilling.

Economic barriers

a. **High initial investment, fixed costs and cost of raw material:** for bricks, the case studies reveal that compared with conventional clay bricks, fly ash based brick making needs higher

initial investment. This is mainly because the process of traditional brick making is largely manual whereas in fly ash based bricks the processes have to be mechanized and in many cases involve specific/imported machinery. Applying and getting electrical connection is a must. On account of high investment requirement the associated fixed costs are also high. In addition, it has been observed that the cost of raw materials associated with manufacture of fly ash brick is significantly higher than the clay bricks. These contribute to the extent of 65-85% of variable costs; in spite of fly ash being mandated free the associated transportation costs are high. Therefore, high costs involved pose a huge barrier to fly ash based brick manufacturing.

b. **Transportation costs:** one of the most important financial barriers that emerge from the study is the associated transportation costs of fly ash, cutting across cement, bricks and mine backfilling. These costs have restricted the use of fly ash in spite of policy mandating its free dispatch by the power plants. The economics involved in use of fly ash in the cement sector are in favour of cement provided the transportation costs are not too high, this is because the cement industry having large scale operations and high product price, the costs involved even if high, generates sufficient surplus to the producer. However, fly ash bricks, being in the informal/unorganized sector having small-scale operations, facing competition from availability of already established cheaper substitute like clay bricks, high transportation costs of fly ash greatly discourage many from entering the market. Similarly the cost of using fly ash for mine backfilling is a direct function of cost of transportation, increasing with the distance between the power plant and the abandoned mine.

c. **Cost of handling and storing fly ash:** investment involved in proper handling, storage and mixing of fly ash often pose a hindrance, as expressed by many cement and brick manufacturers.

d. **Subsidy on sand for mine stowing:** the cost of sand stowing in underground mine to prevent subsidence of the surface is fully reimbursed to the mine operator. No such relief is available in case of use of fly ash for stowing of underground mines, thus making it unacceptable to the mine operator. However, this can be easily sorted out by an order from the Ministry of Coal, Government of India.

Technical barriers

a. **Quality of fly ash:** according to survey undertaken as part of this study, the quality of ash in terms of its fineness (measured in mesh and blain) and presence of un-burnt carbon particles is important for its greater utilization in cement/RMC sector and to an extent in fly ash bricks. To deliver fly ash with desired fineness and low un-burnt carbon needs investment and extra care for which the officials of TPS are generally reluctant as there is no incentive to them for doing so.

b. **Varying soil characteristics:** though the brick making in India is in an unorganised sector and runs mostly with help of contract labour, the science of clay firing to make bricks is

universal. The compressive strength of clay bricks depends not only on the firing and attained temperature, but also on the quality of soil and the forming process used. The percentage of sand, silt and clay in the mix decides the quality of final product. The soil characteristics vary widely from black cotton soil to loamy soil to sandy soil and so on. The silt brought and deposited by floods in the rivers in Indo Gangetic plains has its own quality. Mandating a mix of 25% fly ash uniformly in all types of soil would never work. For example, in parts of Maharastra and Gujarat where black cotton soil is found in abundance, fly ash up to even 40-50% is a requirement to make good bricks. Brick makers in these areas use fly ash without any mandate but in areas where the soil is sandy, adding fly ash would not help. Thus varying soil quality acts as a barrier in utilization of 25% ash in clay bricks in certain areas / regions. Also, the particle size of clay, silt and sand and their percentages also plays a very important role.

c. **Need for more supervision:** for making good fly ash based bricks, good mixing of raw material in right proportions is crucial and determines the final strength. The lightweight blocks of various types need special machines and chemicals with proper trained workers to produce good, consistent and acceptable results. It is in this regard essential to educate the workers or supervise them while undertaking the brick manufacturing process. In absence of such a support the right quality and strength of a fly ash brick may not be achieved.

d. **Increased water and power requirements**: the water requirement for fly ash based brick is high, especially where water and autoclaving based curing is adopted. Given that in peri-urban regions, water is made accessible by boring wells and extracting ground-water using motors, the power available is often insufficient, irregular and unreliable, thereby causing a hurdle in increased utilization.

Institutional barriers

a. **Lack of know-how and R&D Dissemination:** it was observed that there is a general lack of technical know-how on part of brick manufacturers. There is little common knowledge about different brick making techniques, what raw materials are needed and used in what proportions, what machinery is involved and how it is to be used. In addition there are no agencies or government support even if a prospective entrepreneur would want to learn about these techniques. Thereby most of these units operate on a hit and trial method due to the absence of a support system fly ash based product manufacturing being a relatively new area of operation it needs free government support for demonstration projects and learning centres for the entrepreneurs. Provision of initial supervision /education of the entrepreneurs is a must for the spread of the new techniques. In India, the use of fly ash bricks has caught on in Andhra Pradesh because an NGO is providing handholding help during the initial period to the new entrepreneurs.

b. **Lack of monitoring institutions / mechanism for implementation of policy:**

there is a growing concern among various sections, for a need for government agencies or committees to act as monitoring institutions for implementation of policy for increasing fly ash utilization. It is essential to have a mechanism in place to ensure its implementation at the ground level. Such committees should have representation from concerned government ministries, public works departments, State pollution control boards, NGOs etc in order to monitor implementation of policy from all perspectives.

c. **Sourcing of clay bricks:** most of the builders/ contractors / government agencies engaged in construction work have their fixed suppliers of clay bricks. Also, because of small pecuniary gains many officials show strong resistance to change, especially in case of government projects, thus discouraging utilization of fly ash based products including bricks.

d. **Little or no credit facilities:** the clay brick manufacturers being in an unorganised sector have serious problem in getting loans from financial institutions, involving cumbersome process, thereby making it difficult for the manufacturer to move to new techniques involving high initial investments in comparison to conventional clay bricks.

Environmental barriers

a. **Pollution from brick kilns in open areas:** the clay brick kilns are mostly in open areas, thus raising concerns for fly ash to spread to near by areas to agricultural fields, thus damaging the crops and affecting the environment. Such a perception often hinders the clay brick manufacturer to move to use fly ash as it entails proper handling and storage of ash.

Other barriers

a. Mindsets: one of the most important barriers faced in fly utilization across all user sectors is the attitude, resistance to change and general public acceptance of fly ash based products.

b. Lack of awareness: there is general lack of awareness in producers, users and consumers of fly ash based products. There is a need to educate the producers, where fly ash is generally perceived to be a waste product.

c. Mismatch between life of TPS and life of mines: National Coal Companies point out that there is a mismatch between the life cycle of a power plant and life of the opencast mines which often pose as a barrier for mine backfilling on a continuous basis and an abandoned mine may not be available at the requisite time and location.

Barriers to ash utilization: Ash Generator Perspective (power sector)

a. The Concept of "One size fits all"- there is a need to re-visit the policy of achieving 100% utilization by all power plants in a given timeframe. It needs to be realized that even if there were a sound legal and regulatory structure in place in India, 100% utilization of ash would never be achieved by **ALL** thermal power plants, big or small. This mandate has forced some TPS to over-report utilisation. It has led to corrupt practice of pond evacuation to qualify for ash utilisation etc.

b. Free disbursal of fly ash: the mandatory requirement for power plants to issue free fly ash, often acts as a barrier in its utilization. Such a policy provides no incentive to the power plants to invest in improving the quality of ash or to get proactively involved in enhancement of dispatches. Instead of command and control system, the market determination of price would be able to better allocate ash among its users and even provide an incentive for the power producers to invest, improve and make available the right quality of ash to its users. Today, whatever investment the power plants are making in building dry ash collection systems (DACS) are being done with reluctance and as if under duress. Value added ash would attract better price for the TPS which may eventually result in lowering of electricity tariff to the advantage of all consumers.

c. Onus of utilization: the responsibility of increasing the utilisation has been put on the TPS (quoting the principle of "polluter pays") while the user of ash are persons, groups, industry and departments other than TPS and on whom the TPS has absolutely no control.

Analytical Hierarchical Process (AHP)

Following the identification of the barriers, an Analytical Hierarchical Process (AHP), model was developed to gauge the level of urgency associated with each barrier. AHP is a decision analysis tool used to compare discrete alternatives based on multiple attributes. It uses human interactions quite heavily and relies on the decision makers' ability to compare the importance of different attributes. The process involves a scoping exercise to develop a hierarchy for evaluation. For the present study, the overall definition of the model is premised on the overriding goal of increasing fly ash utilization in India. The achievement of this goal is evaluated from the point of user sectors of cement, bricks and mine filling and producers of ash, i.e. power sector, to give the ranking of the barriers in the order of importance.

The table below provides the comprehensive ranking of barriers in order of importance based on responses received from various stakeholders. It clearly reveals that the lack of level playing field in the fly ash brick sector was seen to be the most important barrier amongst all. It also shows that the economic barriers faced by the user sectors were very important with respect to ash utilization. It should be noted that from the policy perspective, the arbitrary fixation of 25% ash in bricks, no mandate for compulsory mine filling and onus of utilization on TPS were all perceived to be very important barriers to the utilization of fly ash.

Comprehensive ranking of individual barriers

Barriers		Rank	Sectors
Lack of level playing field	0.144	1	Bricks
Transportation cost of ash	0.119	2	Cement
Investment costs for ash handling and storage	0.085	3	Cement
Transportation cost of ash	0.066	4	Bricks
Arbitrary fixation of 25% ash in clay bricks	0.064	5	Bricks
No mandate for compulsory mine filling	0.064	6	Mine backfilling
Investment and manufacturing (fixed and raw material) costs	0.064	7	Bricks
Onus of utilization	0.062	8	Thermal Power Plants
100% ash utilization mandate	0.059	9	Thermal Power Plants
Quality of ash from power producer	0.059	10	Cement/ bricks
Lack of awareness/confidence amongst consumers of ash based products	0.053	11	Bricks
Need for greater supervision	0.047	12	Bricks
Free fly ash	0.040	13	Thermal Power Stations
Subsidization for sand stowing	0.033	14	Stowing in UG mines
Lack of awareness/confidence amongst consumers of PPC	0.032	15	Cement
Pollution from brick kilns in open areas	0.029	16	Bricks
Mismatch between the life of thermal power stations and mines	0.028	17	Mine backfilling
Varying soil characteristics	0.023	18	Bricks
Lack of implementation / monitoring	0.015	19	Cement/ bricks/ mine backfilling
Lack of know-how and R&D dissemination	0.012	20	Bricks

5. Results and Conclusions:

It became clear from the study that there are barriers of varied nature to economic utilization of fly ash India. However, there exists immense potential to putting fly ash to its gainful uses. The need of the hour is in recognition of this potential in all sections of stakeholders. And the policy and legal framework should create a facilitating environment in order to tap this potential. However, it also needs to be realized that achieving 100% utilization may not be possible given certain associated issues as outlined by this study and the actual utilization figures would always be lower.

6. Recommendations

Some of the key recommendations of the study are:

- **Pricing of clay and withdrawal of duties and taxes:** one of the key concerns for fly ash brick industry is the need for a level playing. Topsoil, which is exhaustible natural resource, needs to be properly priced for encouraging the use of substitute material such as fly ash. Besides this, it is important to withdraw duties and taxes applicable to fly ash based products.

- **Reconsidering the arbitrary fixation of mixing 25% fly ash in clay brick manufacturing:** the polices need to be based on greater, micro level studies revealing the true needs and requirements, based on soil/location and specific characteristics.

- **Market determination of price:** there is a urgent need to discard the command and control system built in to the policy and let the market forces determine the price of fly ash; such a mechanism

would be able to better allocate ash among its users and even provide an incentive for the power producers to invest, improve and make available the right quality of ash to its users.

- **Need for investment by TPS:** it is suggested that some investment by power plants for improving the quality of ash supplied would greatly increase its dispatch.

- **Mandating use of fly ash as back fill in mines:** use of fly ash, as back fill in mines has to be encouraged for the utilization levels to increase. As there is no compulsion, there is a general slack and lack of interest by the mine owners to use ash for mine backfilling. A policy mandating this will increase the utilization of ash as backfill in mines.

- **Transportation by rail:** one of the greatest hindrances posed to users of fly ash is the high transportation cost of ash. In this regard, it is increasingly being suggested to transport fly ash by rail. There is an urgent need for railways to proactively facilitate transportation of fly ash in order to address both the associated costs as well as environmental issues due to road transportation.

- **Dissemination of know-how:** it is extremely important for the government to come forward and facilitate the spread of fly ash based techniques of brick making. Lack of demonstration projects restricts the spread of fly ash brick making. In addition there are no agencies or government support even if a entrepreneur would want to learn about these techniques. Also, there is a need to generate awareness and educate the users and customers at the grass root level, especially relevant for brick industry. A proactive stance by power producers to spread awareness for increasing the use of fly ash is needed.

- **Greening the ash pond:** the potential use of land under ash ponds needs to be explored further in terms of greening the pond. In this regard, many filled-in ponds have been covered by soil and plantation has been done on it in order to utilize the landmass. Bio-diesel plantation, joint forestry etc should be taken as gainful utilization, and to be encouraged by policy.

7. Records of dissemination of project finding to stakeholder

TERI plans to bring out a book on fly-ash where report will find a prominent place

8. Total cost of the project: Rs. 12, 02, 300.00

National Natural Resources Management System Scheme :

17.	13/3/97-EI/RE Evaluation of Natural Resources and Environment of the Koli Hills, Tamil Nadu using Remote Sensing and GIS	Dr. S. John Britto SJ, St. Joseph's College (Autonomous), Tiruchirappalli-620002, Tamilnadu.

1. Title of the Project : **Evaluation of Natural Resources and Environment of the Kolli Hills, Tamil Nadu using Remote Sensing and GIS**

2. Keywords : Natural resources, rocks/ minerals, soil, water, flora of the Kollis, socio-demographic data, GIS, environmental hazards, land use / land cover

3. Names and Address of Project Investigator

: PI: **Dr. S John Britto SJ**
Co-PI: **Dr. D.I. Arockiasamy**
St. Joseph's College (*Autonomous*),
Tiruchirappalli 620 002
Tamilnadu

4. Executive Summary of the results vis-à-vis objective envisaged originally

An R & D project entitled "Evaluation of Natural Resources and Environment of the Kolli Hills, Tamil Nadu using Remote sensing and GIS" was proposed with the aims of taking stock of the resources, analyzing their status, potential and preparing an area specific treatment package for sustainable utilization, conservation and development.

Kolli Hills, the study area is a hilly terrain covering an area of about 503 sq, km situated above river Cauvery having diverse vegetation and land use. The annual mean rainfall is 1318 mm. Kolli hills receives maximum rain fall in Southwest monsoon (719 mm) The mean maximum and mean minimum temperature is 37° and 18°C respectively.

Forest in kolli hills occupies comparatively more area (271 sq km) than the non-forest area (232 sq km). Evergreen, Semievergreen, Deciduous, Thorn and Scrub are the major forest types present. Major portion of the forest area is occupied by the Thorn and Scrub forests (203 sq km). In the non-forest area most of the area comes under wasteland (50%). Single crop and double crop cultivation is practiced. Tapiaco is the major cash crop. There is no industry in kolli hills.

Total population of kolli hills according to 1991 census is 33, 888. Among them 95% belong to tribals. The literacy rate is very poor (27%). The economic status of the population is also not satisfactory. They have very poor awareness on environment and family planning The economy of the people mainly depends on agriculture and livestock rearing.

Primary and secondary data collected on various resources from field and various Government agencies and departments are utilized to generate spatial and non-spatial data.

Resource status, potential and changes through time is analyzed with data base prepared. Charges occurred in land use / land cover and in forest is also analyzed. The results are centainly alarming and warrant serious efforts to conserve the existing resources and recover the lost.

Finally, conservation and developmental packages for sustainable utilization and management on various resources have been given for the entire area. The developmental packages are prepared with data derived from 50,000 scale. Therefore, for micro level implementation, it is suggested to go for further detailed mapping on large scale data.

5a. Results

List of Thematic maps produced by using Remote Sensing and GIS

A: Soil and Land Resources

1) Soil types of Kolli hills
2) Soil texture
3) Land capability
4) Land irrigability

B: Water Resources

1) Kolli hills Isohyete
2) Drainage network
3) Drainage Density
4) Kolli hills watershed
5) Kolli hills subwatershed
6) Kolli hills mini water shed
7) Kolli hills micro watershed

C: Forest

1) Kolli hills Forest cover types
2) Forest cover Density
3) 19 Maps for Forest Type ranger

D: Geology, structure and Minerals

1) Geology, structure and Minerals
2) Lineements

E: Geomorphology and Physiography

1) Kolli hills geomorphology
2) Physiography

F: Land use / hand cover of Kolli hills

1) Land use and cover 1997
2) Land use and cover 1980

G: Modeling

1) Land suitability classification for afforestation
2) Site suitability classification for forest nursery
3) for fodder crop cultivation
4) for local crop based industry
5) for meteorological station
6) forest area sensitive to degradation
7) Fire Risk areas
8) Erosion prone areas

H: Additional Data

1) Socio – economic details
2) Detailed soil taxonomy
3) Ground water Assessment on revised norms rainfall recharge methods
4) Well Inventory Data
5) Consolidates species list of various forest types

5b. Conclusions

a. Investigation of geologic; geomorphic and climatic conditions of the area so as to understand the natural resources is completed.

b. A detailed assessment on the natural resources like rocks / minerals, soil, water, flora of the study area to understand the present status of the natural resources of the area is available.
c. The socio-demographic data and the developmental activities of the area in order to know the intensity of human activities has been analysed.
d. By Analysising through Geographical information System (GIS) of the above data the status of the natural resources has been brought out.
e. Listing of the environmental hazards of the area and analysis of their effects has been done.
f. Comparison of the multi-dated forest and land use / land cover details has been completed to outline the changes it has undergone especially in the last three decades – the reasons for the changes and their effects on the area.
g. Based on the results of the investigations made above, an area specific prescription and treatment package for the conservation and management plans are provided.
h. For the first time modern tool such as Remote Sensing and GIS has been used and more than fifty thematic maps on various resources and related parameters have been executed.
i. Three maps have been digitized and modeling has been for Land, forest and soil parameters.
j. In fine as a result of this project, environmental hazards, developmental packages and ecosystem restoration have been evolved. The Tami Nadu State forest Department is fully using the data produced.

6. Recommendation including usefulness of the findings and their application

Gaps strive to bring out the potential zones with high species richness as a community rather than specificity to particular species. The habitat conservation plays the role of richer diversity areas fit to be protected with extra reinforcements.

Gaps are one of the representations of diversified vegetation structure which in normal terms act as remnants of past vegetation along with the lush characteristics.

Gaps supportingly segregate places of high diversity from other vegetation and pave a better management policy by the forest department planners and frequent monitoring strategies.

Gap analysis and other conservation evaluations represent a first step for any comprehensive land conservation programme for any region. They provide base-line knowledge of the amount and distribution of several components of biological diversity and of the relationship of the components to one another in the landscape. This knowledge will be of little value if it is not applied to the land-use.

Private organizations and public agencies with an interest in maintaining biodiversity management areas can be encouraged or at other end change management prescriptions to emphasize the maintenance of biodiversity. In view of the value of the biological support services to our society and the social and economic costs of endangered species recovery and by avoiding the creation of rare/ endangered species by maintaining biodiversity in natural reserves (*in-situ*) gap analysis will serve both the conservation and development of vegetation communities.

7. Records of dissemination of project findings to stakeholders (publication in peer-reviewed journal/presented in workshop conference etc.

1. John Britto, S., Jayakumar, S., D.I. Arockiasamy 2000. Estimates of current status of forest types in Kolli hills using Remote Sensing. Indian Society of Remote Sensing 28 (2 & 3): 141-151.
2. John Britto, S., Jayakumar, S., D.I. Arockiasamy 2002. Conserving forests in the Eastern Ghats through Remote Sensing and GIS – *A case study in Kolli Hills*. Current Science 82 (10): 1259-1267.
3. John Britto, S., Jayakumar, S., D.I. Arockiasamy 2002. Similarity analysis in two tropical dey evergreen forests in the *Eastern Ghats of Tamil Nadu.* Journal of Hill Research. **15** (1): 4-11.
4. Jayakumar, S., D.I. Arockiasamy and S. John Britto 2002. Forest mapping and vegetation analysis in part of Kolli hills, *Eastern Ghats of Tamil Nadu. Tropical Ecology* **43** (2): 345-494.

8. Total cost of the project and releases made (in `.) `. 14,09,131

18.	13-20/2004-EI/RE Techniques of Survey and Planning for Conservation and Sustainable Use of Biodiversity in Mizoram, North Eastern Region	Dr. K.D. Singh, Ashoka Trust for Research in Ecology and Environment (ATREE), 1, K Block Commercial Complex, 2nd Floor, Birbal Road, Jangapura Extension, New Delhi-110014.

A research project on 'Techniques of Survey and Planning for Conservation and Sustainable Use of Biodiversity in Mizoram, North Eastern Region' has been completed by Ashoka Trust for Research in Ecology and Environment (ATREE). The project's overall objectives were to promote conservation and sustainable use of biological diversity in Mizoram and to develop the following:

(i) A cost-effective methodology for forest sector strategic planning at the district level; and

(ii) Techniques of micro-planning at the village level.

A Stratified Random Sampling was conducted in the Kolasib district as an example using Census 2001 Village Directory as the basis. 40 villages of the district were stratified into three accessibility classes taking into account distance of a village from the nearest town and frequency of bus transport. Studies on the natural resources and the livelihood pattern at the household level for current year as well as 10 years back were undertaken in 12 randomly selected villages, four in each stratum. The sample survey analysis has brought to light many interesting on-going developments and trends, which are as under:

(i) Shifting agriculture has significantly decreased both in stratum 1 and 2 (viz. very accessible and medium accessible villages). However, it has increased in inaccessible villages. A reason could be the lack of development in inaccessible villages.

(ii) Plantations of commercial species have significantly increased across strata. Arecanut, having locally available market, is a common choice; whereas, red palm oil and other horticultural species like oranges and pine apple are more pronounced in accessible villages. This could be attributed to joint venture schemes promoted by the Horticultural Dept in partnership with the private companies.

(iii) Teak and bamboo plantations (the latter is localized) have significantly increased in the last 10 years in accessible area. There are many other species introduced, though in small areal extent. One obvious conclusion is the need for extension services to community in the choice of plantation crops, keeping in view species suitability and marketing prospects.

(iv) The forest cover has increased slightly in accessible villages, but declined significantly in inaccessible villages. Forests seem to be under pressure, both from population increase as well as rising aspirations for economic development. Dense forests and traditionally managed safety/supply reserves have both decreased in all strata in a significant manner with maximum change in inaccessible villages. The overall increase of forests in accessible and moderately accessible villages is perhaps, an indication that economic development might slow down deforestation.

(v) The change in livelihood pattern in various strata during the last decade is perhaps the most important indicator of development. In accessible villages, significant part of population has moved away from shifting agriculture to permanent agriculture. In moderately accessible villages, people have moved from shifting agriculture to forest products as well as permanent agriculture. However, in inaccessible villages, more people seem to be involved in shifting agriculture. One fact is also obvious that overall (un-stratified) figures at a district level hide fine movements. Therefore, there is need for problem oriented survey design and analysis.