RPF - III

(PERFORMA FOR SUBMISSION OF FINAL REPORT OF RESEARCH PROJECTS)

Part- I: General Information

800	Project Code:	
8001	Institute Project Code No.	Gen. I (813)
8002	ICAR Project Code No.	P1-72/4-ICI-F30/2320
801	Name of the Institute and Division	
8011	Name and address of Institute	Indian Institute of Spices Research P.O.Marikunnu, Calicut-12
8012	Name of Division / Section	Crop Improvement and Biotechnology
8013	Location of the Project	Chelavoor/Peruvannamuzhi
802	Project Title	Collection, conservation, cataloguing and evaluation of black pepper germplasm
803	Priority Area	
8031	Research Approach	Applied Res. / Basic Res. / Process / Transfer of Technology. of Tech.Develop. 01 02 03 04
804	Specific Area	Collection and conservation of germplasm of black pepper and related species. Characterization and evaluation of germplasm of black pepper. Development of high yielding varieties of black pepper.
805	Duration of Project	
8051	Date of start	1976
8052	Date of Completion	2008

806 Total cost /Expenditure Incurred : Rs.97.283 lakhs
(Give reasons for variation, if any from original estimated cost)

The original cost proposed was Rs. 60,000/ year (approx.). The Project ran for 33 years with new tech. programmes added. The expenditure incurred was more than the estimated due to the revised pay scale of scientific, technical and supporting staff and also the increase of wages, hike in the cost of chemicals and fertilizers.

807 Executive Summary

During the 33 years of the Project span, results of both practical utility (varieties) and basic knowledge have emanated from the project. The salient achievements are:

- Systematic surveys for collecting genetic resources of black pepper were conducted to most of the pepper growing areas viz. forests and farmers' fields. This includes the forests of Western Ghats –the original habitat of black pepper, north eastern India and the Andaman and Nicobar Islands, where diversity of *Piper* is occurring in wild and for local cultivars farmers' fields of Kerala and Karnataka states were surveyed.

- The collected accessions are maintained *ex-situ* in the field genebank as well as in the black pepper germplasm nursery. At present the germplasm repository of black pepper at IISR holds 2575 accessions besides more than 1400 hybrids and 150 open pollinated progenies.

- Four new taxa were reported. This includes two new species viz. *Piper silentvalleyensis, P. sugandhi* and two varieties viz. *P. nigrum* L. var. *hirtellosum* and *P. sugandhi* var *brevipilis* located from Silent Valley forests of Palaghat district and Sugandhagiri hills of Wayanad district respectively

- Endangered species *Piper barberi* was collected, conserved in the genebank and redescribed

- Populations of *Piper hapnium*- an endangered species- were located from Peruvannamuzhi of Calicut and Manalar region of Achankovil forests and conserved in the germplasm repository.

- A descriptor on 'Black Pepper' was prepared and published it through IPGRI, Rome.

- 1100 cultivar accessions were characterized based on IPGRI descriptor.

- Spicegenes-a database on black pepper consisting passport information and characterization details of germplasm accessions was developed.

- Eight improved varieties were developed. The varieties Sreekara, Subhakara, Panchami, Pournami and PLD-2 IISR-Thevam, (Table-1) were evolved from the black pepper germplasm by selection method where as IISR, Malabar Excel and IISR- Girimunda were developed utilising the germplasm accessions by hybriridization.

- Resolved the genetics of shoot tip colour in black pepper. Shoot tip in black pepper is of 2 types (purple and white) which is a marker trait of pepper cultivars. Genetics of this trait was studied and it is reported that 2 pairs of genes having complementary action control this Mendelian trait.

- Cytological indexing of cultivars of black pepper also resulted in identifying a triploid (2n=78) cultivar 'Vadakkan'.

- Three germplasm accessions (two cultivars and one wild) were registered with NBPGR for their unique characters.

- IC numbers were obtained for the collections made upto 2007 March.

- Compiled the germplasm survey report of Kerala and north eastern India with the help of GIS software to understand the relationship of the species with the climate and environmental parameters.

- For safe guarding the valuable germplasm, the *ex-situ* field genebank of wild germplasm is extended to two alternate centers (CPCRI, Kidu for cultivar germplasm and CRC, appangala for wild types).

Table 1. Improved varieties of black pepper and their salient features

Name	Pedigree	Average yield. Dry (kg/ha)	Oleoresin (%)	Piperine (%)	E. oil (%)	Remarks
Subhakara	Clonal selection from 'Karimunda'	2352.0	12.4	3.4	6.0	Suited to all pepper growing regions
Sreekara	Clonal selection from 'Karimunda'	2677.0	13.0	5.1	7.0	Suited to all pepper growing regions
Panchami	Clonal selection of 'Aimpiriyan'	2828.0	12.5	4.7	3.4	Late maturing type suited to all pepper growing areas
Pournami	Clonal selection of 'Ottaplackal'	2333.0	13.8	4.1	3.4	Tolerant to root knot nematode
PLD-2	Clonal selection from 'Kottanadan'	2475.0	15.5	3.3	3.5	Suited to Trivandrum and Quilon districts of Kerala
IISR Thevam	Selection of 'Thevanmundi'	1787.0	8.15	1.6	3.1	Tolerant to foot rot disease. Suited to high altitudes and planes
IISR Malabar Excel	F_1 of 'Cholamundi' x Panniyur-1	1065.0	13.5	2.96	3.2	Suited to high altitudes and rich in oleoresin
IISR Girimunda	F_1 of 'Narayakodi' x 'Neelamundi'	2112.0	9.65	2.2	3.4	Suited to high altitudes

808 Key word : Black pepper, germplasm, characterization, conservation

Part-II: Investigator Profile

(Please identify clearly changes, if any in Project personnel)

810 Principal Investigator:

8101	Name	: Dr. K. V. Saji
8102	Designation	: Sr. Scientist
8103	Division/Section	: Crop Improvement and Biotechnology
8104	Location	: Chelavoor
8105	Institute Address	: Indian Institute of Spices Research, Marikunnu, PO, Calicut-12

811 Co-investigator:

8111	Name	: Dr. Utpala Parthasarathy
8112	Designation	: Tech. officer
8113	Division/Section	: Crop Production
8114	Location	: Chelavoor
8115	Institute Address	: Indian Institute of Spices Research, Marikunnu, PO, Calicut-12

Name	Status	Designation	Location	Year
M. K. Nair	PI	Joint Director	CPCRI, RS, Calicut.	1976
M. C. Nambiar	Co- PI	PC- (C & S)	CPCRI, Kasaragod	1976
P. M. Kumaran	Co- PI	Scientist- S1	CPCRI, RS, Vittal	1976
Mrs. M. J. Ratnambal	Co- PI	Scientist- S	CPCRI, RS, Calicut.	1976
R. S. N. Pillai	Co- PI	Scientist- S1	CPCRI, RC, Palode	1976
M. K. Nair	PI	Joint Director	CPCRI, RS, Calicut.	1977
P. M. Kumaran	Co- PI	Scientist- S1	CPCRI, RS, Vittal	1977
K. N. Murthy	Co- PI	Scientist- S1	CPCRI, RS, Vittal	1977
M. C. Nambiar	Co-PI	PC- (C & S)	CPCRI, Kasaragod	1977
M. K. Nair	PI	Joint Director	CPCRI, RS, Calicut.	1978
P. M. Kumaran	Co- PI	Scientist- S1	CPCRI, RS, Vittal	1978
K. N. Murthy	Co- PI	Scientist- S1	CPCRI, RS, Vittal	1978
M. C. Nambiar	Co-PI	PC- (C & S)	CPCRI, Kasaragod	1978
P. N. Ravindran	PI	Scientist- S2	CPCRI, RS, Calicut.	1979
M. K. Nair	Co- PI	Joint Director	CPCRI, RS, Calicut.	1979
M. C. Nambiar	Co- PI	PC- (C & S)	CPCRI, Kasaragod	1979
P. M. Kumaran	Co-PI	Scientist- S1	CPCRI, RS, Vittal	1979

P. N. Ravindran	PI	Scientist- S2	CPCRI, RS, Calicut.	1980
M. K. Nair	Co- PI	Joint Director	CPCRI, RS, Calicut.	1980
K. Raju	Co-PI	Scientist- S1	CPCRI, RS, Calicut.	1980
P. N. Ravindran	PI	Scientist- S2	CPCRI, RS, Calicut.	1981
M. K. Nair	Co- PI	Joint Director	CPCRI, RS, Calicut.	1981
K. Raju	Co-PI	Scientist- S1	CPCRI, RS, Calicut.	1981
P. N. Ravindran	PI	Scientist- S2	CPCRI, RS, Calicut.	1982
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M. J. Ratnambal	Co-PI	Scientist- S	CPCRI, RS, Calicut.	1982
Ms. Lila Jacob	Co-PI	Scientist- S1	CPCRI, RS, Calicut.	1982
P. S. Ravindran	PI	Scientist- S1	CPCRI, RS, Calicut	1983
M. K. Nair	Co-PI	Joint Director	CPCRI, RS, Calicut.	1983
P. N. Ravindran	Co-PI	Scientist- S2	CPCRI, RS, Calicut.	1983
M. J. Ratnambal	Co-PI	Scientist- S	CPCRI, RS, Calicut.	1983
K. U. K. Nampoothiri	Co-PI	Scientist- S2	CPCRI, RC, Palode	1983
R. S. N. PIllai	Co-PI	Scientist-S1	CPCRI, RC, Palode	1983
P. S. Ravindran	PI	Scientist-S1	CPCRI, RS, Calicut.	July-84
P. N. Ravindran	PI	Scientist- S2	CPCRI, RS, Calicut.	Aug-84
M. K. Nair	Co-PI	Joint Director	CPCRI, RS, Calicut.	1984
P. N. Ravindran	PI	Scientist- S2	CPCRI, RS, Calicut.	1985
M. K. Nair	Co-PI	Joint Director	CPCRI, RS, Calicut.	1985
A. A. M. Sayed	Co-PI	Scientist- S2	CPCRI- Kannara	1985
P. N. Ravindran	PI	Scientist- S2	CPCRI, RS, Calicut.	1986
M. K. Nair	Co-PI	Joint Director	CPCRI, RS, Calicut.	1986
K. Nirmal Babu	Co- PI	Scientist-S1	CPCRI, RS, Calicut.	1986
A. A. M. Sayed	Co-PI	Scientist- S2	CPCRI- Kannara	1986
P. N. Ravindran	PI	Scientist- S2	NRCS Calicut.	1987
M. K. Nair	Co-PI	Director	CPCRI, Kasaragod	1987
K. Nirmal Babu	Co- PI	Scientist-S1	NRCS, Calicut.	1987
A. A. M. Sayed	Co-PI	Scientist- S2	CPCRI- Kannara	1987
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V. S. Korikanthimath	Co- PI	Scientist-S2	NRCS, Appangala	1988
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B. Krishnamoorthy	Co- PI	Scientist- S2	NRCS Calicut.	1989
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K. Johnson George	PI	Scientist	NRCS, Calicut	1990
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B. Sasikumar	Co- PI	Scientist- SS	NRCS, Calicut	1990
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V. S. Korikanthimath	Co- PI	Scientist-S2	NRCS, Appangala	1993
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P. N. Ravindran	Co- PI	PS	NRCS, Calicut	1994
B. Sasikumar	Co- PI	Scientist- SS	NRCS, Calicut	1994
V. S. Korikanthimath	Co- PI	Scientist-SG	NRCS, Appangala	1994
K. Johnson George	PI	Scientist- SS	NRCS, Calicut	1995
P. N. Ravindran	Co- PI	Principal Scientist	NRCS, Calicut	1995
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K. Johnson George	PI	Scientist- SS	IISR, Calicut	1996
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V. S. Korikanthimath	Co- PI	Scientist-SG	CRC, Appangala	1996
K. V. Saji	PI	Scientist	IISR, Calicut	1997
P. N. Ravindran	Co- PI	Principal Scientist	IISR, Calicut	1997
B. Sasikumar	Co- PI	Scientist- SS	IISR, Calicut	1997
V. S. Korikanthimath	Co- PI	Sr. Scientist	CRC, Appangala	1997
B. Chempakam	Co- PI	Sr. Scientist	IISR, Calicut	1997
K. V. Saji	PI	Scientist	IISR, Calicut	1998
P. N. Ravindran	Co- PI	Principal Scientist	IISR, Calicut	1998
B. Sasikumar	Co- PI	Sr. Scientist	IISR, Calicut	1998
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K. V. Saji	PI	Scientist	IISR, Calicut	2000
B. Sasikumar	Co- PI	Sr. Scientist	IISR, Calicut	2000
K. Johnson George	Co- PI	Scientist- SS	IISR, Calicut	2000
D. Prasath	Co- PI	Scientist	CRC, Appangala	2000
B. Chempakam	Co- PI	Sr. Scientist	IISR, Calicut	2000
K. Nirmal Babu	Co- PI	Sr. Scientist	IISR, Calicut	2000
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B. Chempakam	Co- PI	Sr. Scientist	IISR, Calicut	2001
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D. Prasath	Co- PI	Scientist	CRC, Appangala	2002
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K. V. Saji	PI	Scientist -SG	IISR, Calicut	2004
K. Johnson George	Co- PI	Sr. Scientist	IISR, Calicut	2004
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K. V. Saji	PI	Scientist -SG	IISR, Calicut	2005
K. Johnson George	Co- PI	Sr. Scientist	IISR, Calicut	2005
R. Ramakrishnan Nair	Co- PI	Sr. Scientist	IISR, Calicut	2005
Utpala Parthasarathy	Co- PI	Tech. officer	IISR, Calicut	2005
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Utpala Parthasarathy	Co- PI	Tech. officer	IISR, Calicut	2006
K. V. Saji	PI	Sr. Scientist	IISR, Calicut	2007
Utpala Parthasarathy	Co- PI	Tech. officer	IISR, Calicut	2007
K. V. Saji	PI	Sr. Scientist	IISR, Calicut	2008
Utpala Parthasarathy	Co- PI	Tech. officer	IISR, Calicut	2008

Part-III: Technical Details

820 Introduction and objectives

8201 Project Objectives

1. Establishment of global genebank of black pepper.
2. To collect wild and domesticated diversity of the genus *Piper* so as to make a genebank for various characters.
3. To characterize the germplasm for yield and other desirable characters in cultivated and wild *Piper*.
4. Utilization of primary and secondary genepool of *Piper* for genetic improvement.
5. Conservation of black pepper germplasm in the field genebank.

8202 Background information and importance of the projects

Black pepper known as the 'King of Spices' is the most important and widely used spice in the world. Black pepper of commerce is the dried mature fruits of the tropical perennial climbing plant *Piper nigrum* L., which belongs to the family Piperaceae. Trans- Gangetic region and the south Deccan are considered to be the two independent centers of origin of the genus *Piper* in India. The sub mountainous tracts of the Western Ghats are believed to be the centre of origin of black pepper, *Piper nigrum* L. More than 1000 species are included under this genus of which 117 are of Indian origin.

Piper species occurring in India are perennial, scandent or woody climbers or creepers, shrubs. Branching dimorphic not very conspicuous in the shrubby species as in the climbing ones. Leaves alternate, petiolate, simple, entire often unequal sided. A single lateral prophyll present at flowering nodes, the prophyll often modified to for a cap like structure enclosing the shoot apex and spike. Flowers borne on solitary leaf opposed spikes, morphologically terminal, spikes erect or pendent; usually filiform, rarely cylindrical or globose. Flowers unisexual or bisexual, sessile or stipitate each in the axil of a bract. Perianth absent, stamen 2-4 anthers two celled. Ovary one celled, ovule solitary, placentation basal, style absent, stigma 2-5, fruit drupaceous, small ovoid or globose, one seeded and glabrous.

The depletion of forest area, rampant destruction of the forest growth and under growth and changes in the agro ecological condition all have led to a sharp decline of wild pepper and its related taxa. It is believed that cultivation of black pepper started about 6000 years ago. Today about 100 black pepper cultivars are prevalent in India apart from its wild relatives.

Even though the early movement of the settlers across the length and breadth of Kerala helped the spread of landraces to new areas, the advent of improved varieties of black pepper is becoming a threat to many of the released varieties is becoming a threat to many of the old cultivars. If not collected and conserved, these landraces may be lost for ever. The species of *Piper* that are most affected by deforestation are *P. barberi*, *P. hapnium*, *P. silentvalleyensis*, *P. wightii* and *P. schmidtii*. Many of these taxa are now confined to only a few specific locations and may soon be extinct, if not collected and conserved.

The project was started at IISR; Calicut with an aim to collect and conserve the valuable germplasm of *Piper* from all the pepper growing tracts of India, The project envisaged the maintenance of germplasm in the nursery and field as *ex-situ* genebank. It will be useful in identifying types with high yield and good quality having resistance to diseases and pests. Such types can be incorporated in the breeding programme for evolving high yielding varieties resistant to diseases and pests.

In addition to IISR, Calicut, germplasm accessions are being maintained at All India Coordinated Research Project on Spices at the Pepper Research Station, Panniyur (KAU), Pepper Research Station, Sirsi, University of Agricultural Research, Dharwar, Regional Research Station, Chintapally, Acharya N G Ranga Agricultural University (ANGRAU) and Horticultural Research Station, Yercaud, Tamil Nadu.

Systematic efforts have been made periodically at Indian Institute of Spices Research, Calicut, since inception of this project to collect indigenous germplasm of black pepper and its wild relatives from farmers' field and forest areas. The collected germplasm have been characterized for morphological, yield, biotic, abiotic and quality characters and are conserved *ex- situ* in the black pepper germplasm nursery and field genebank at the experimental farm, Peruvannamuzhi.

821 Project Technical Profile

8211 Technical programme

(Indicate briefly plan of procedure, techniques, instruments and special materials, organisms, special environments etc.)

1. Collection and conservation of variability of black pepper and its wild relatives
2. Preparations of a descriptor for characterizing the germplasm
3. Characterization and evaluation of the germplasm
4. Biometrical studies
5. Evolving high yielding varieties of black pepper having good quality and resistance to pests
6. Molecular characterization
7. Cytological studies.
8. GIS studies

8212 Total man months involvement of component project workers

S. No	Investigator	Total Man months
1	M. K. Nair	30
2	P. N. Ravindran	76
3	M. J. Ratnambal	6
4	R. S. N. Pillai	4
5	M. C. Nambiar	2
6	P. M. Kumaran	2
7	K. Raju	4
8	Lila Jacob	2
9	K. U. K. Nampoothiri	2
10	P. S. Ravindran	7
11	A. Gopalam	3
12	A. A. M. Sayed	9
13	K. Nirmal Babu	20
14	B. Krishnamoorthy	2
15	V. S. Korikanthimath	18
16	Johnson George. K	46
17	B. Sasikumar	28
18	R. R. Nair	10
19	B. Chempakam	12
20	K. V. Saji	66
22	D. Prasath	6
23	Utpala Parthasarathy	6

822 Final Report on the Project

Detailed report containing all relevant data with a summary of results
(Not exceeding 2-5 pages)

8221 Achievements in terms of targets fixed for each activity

1. Collection and conservation of variability of black pepper and its wild relatives

The project has helped to collect and conserve the species and cultivar diversity in *Piper*. At present the *ex situ* genebank of *Piper* maintain 2575 accessions (Table -2). This includes cultivars, wild *Piper nigrum* and related taxa besides exotic collections. The accessions are maintained at the *ex situ* genebank of experimental farm, Peruvannamuzi.

Table 2. List of germplasm accessions maintained at the conservatory

Accessions	No
Cultivars	1300
Exotic collections	9
Related species (wild)	1266
Total	2575

Systematic efforts have been made periodically at Indian Institute of Spices Research, Calicut since 1976 to collect the germplasm of black pepper and its wild relatives. The important areas surveyed are the forests of Western Ghats from Maharashtra to Kerala spreading in Goa, Karnataka and Tamil Nadu, Andaman and Nicobar Islands and North Eastern parts of India besides the major pepper growing tracts of South India (Table-3). The collections include wild relatives (Table-4), cultivated types (Table-5), economically important species (Table-6), exotic species (Table-7) and endangered species (Table-8). The germplasm also includes *Piper* species which are having unique features such as scented spike, proliferated spike, transsexual nature of sex etc. are listed in Table-9.

Table 3. Important locations surveyed for collecting *Piper* germplasm.

Sl.No.	State	District	Places surveyed
1	Karnataka	Coorg Dakshin Kannada Hassan Karwar Kollur Shimoga Uttar Kannada	Akumbe , Anagundi, Bindur, Bhagamandala, Bisle, Chettalli, Gobsitta Gonicopal, Kadra, Kaiga, Kaiga- Ansi road, Kannanki forests, Kidu, Kerakoppa Kerodi, Kollur, Koppa, Kudremugh WLS Makuta & surrounding forest Madikeri, Kumpta,Pollibetta, Sagar, Sekleshpur, Shimoga, Sirsi, Somavarpet, South Kanara Sringeri Subramanya Thalacauvery, Tirtahally, Uduppi, Vachegade, Virajpet
2	Kerala	Calicut Idukki Kannur Kollam Kottayam Palaghat Pathanamthitta Trichur Trivandrum Wayanad	Achankovil, Alakode, Amaravathi, Ampayithode, Amplappara, Anakkampoil Anamalai hills, Anavilasam, Aryankavu Athirapally, Anamughi, Anathode, Aruvikad, Attappadi, Chempanoda Attappalam, Bison Valley, Chakkittapara Chalakkayam, Chalissery, Champakara Champakulam, Chenkulam, Cherupuzha Cheruthoni, Choorathodu, Devikulam Dhoni, Edackal, Edamala, Edamalayar, Elangulam, Elangulam, Elappara, Eravikulam, Jeerakapara, Kadalar, Kakkayam, Kakkoor, Kallar, Kannavam, Kariathumpara, Kattapana, Kayanna, Konginipadavu, Konnathadi, Koodaranji Koovapoil, Kothamangalam, Kottiyur, Kozhipara, Kulathuvayal, Kumly, Kurimala, Kuthupara, Kuttiadi, Kuttikanam Kuttikayam, Malampuzha, Malayattur, Manapadi, Manathavadi, Manippara, Manjalampuzha, Mannavanchola, Marayoor, Meppadi Mundakayam, Muthikulam, Myladumpara Nelliampathy , Mlamala, Moozhiyar, Mukkali, Mundakkayam, Munnar, Muthikulam, Nedungandam, Neeleswaram, Nelliampathy, Neyyar, Nilabur, Ottakandam Parambikulam WLS, Peppera , Padachira, Pakshipathalam, Panthenthodu, Kummattanthodu, Peerimedu Perikkallor, Peringalkuthu, Peruvannamuzhi, Plapally, Poochapara, Poopara, Poovarani, Poovattanmoola, Pothumudi, Pulluvazhi Pulpalli, Punkunnam, Puthupady, Rajamala, Sabarimala, Sekhalmudi, Shaktinagar, Sholayar, Silent Valley, Siruvani Sugandhagiri Suchipara Thalakode, Thaliparamba, Thaliparamba, Thiravampady, Thenmala, Thodupuzha Thusharagiri, Ulliyeri, Vandanmedu, Vazhachal, Vazhaperiyar, Vazhathopu, Vellakayam, Vellathuval, Vellayamkudi, Vellimattom, Vempally , Vythiri, Wagamon, Walakkad

3	Tamil Nadu	Nilgiris Nagarkovil Namackal Coimbatore Thirunelveli	Gudallur Naduvattom, Ooty, Paikara Kodayar KMTR (Kallakkad Mundanthurai Tiger Reserve), Pollachi Puliyarai, Valparai
4	A & N Islands		Nicobar, Sholbay Islands, South, Andamans, Rutland Islands
5	Andhra Pradesh	Srikakulam Visakhapattanam	Arakku Valley, Bagtha GRV Mandal Chintapally, Lambasinghi, Madungula Mandal, Pottangalsa
6	Arunachal Pradesh	Anjaw Lohit Namsai	Dingarm, Hauliang, Lathao, Supliang, Tezu.
7	Assam	Mikir hills	Mikir hills, Cherrapunji
8	Goa	Mollem Ponda Canacona	Canacona, Kotegoa, Jindawada
9	Maharashtra	Ratnagiri	Dapoli
10	Meghalaya	Khasi hills	Khasi hills
11	Sikkim	Karbi hills	Karbi hills
12	West Bengal	New Cooch Behar, New Jalpaiguri	Jaigon, Pundibari, Totopara

Table 4. *Piper* species conserved in the genebank

Species	Origin	Species	Origin
P. arboreum Aubl.	South America	*P. argyrophyllum* Miq.	India
P.attenuatum Ham Ex Miq.	India	*P.bababudani* Rahiman.	India
P. barberi Gamble	India	*P. betle* L.	South-East Asia
P. colubrinum. Link	South America	*P. chaba* Hunter	SE Asia
P. galeatum Miq.	India	*P. hapnium* Ham.	India
P. longum L.	India	*P. mullesua* Ham Ex. D. Don	India
P. magnificum Trel	South America	*Piper nepalense* Miq	Nepal
P. nigrum L.	India	*Piper ornatum.* N. E. Br	
P. pedicellosum Wall. Ex DC.	India (Andamans)	*P. peepuloides* Roxb.	India
P. sermantosum Roxb.	India (Andamans)	*P. silentvalleyensis* Ravindran et Nair	India
P. sugandhi Ravindran, Babu et Naik	India	P. sugandhi. Var. brevipilis	India
P. sylvaticum Roxb.	India	*P. thomsonii* CDC	India
P. trichostachyon (Miq.) CDC.	India		

Table 5. Cultivar diversity collected and conserved *ex - situ.*

Aimpirian	Jeerakapala	Kuttianikodi	Perumkodi
Annarvarayan	Kallubalankotta	Kuzhivelikkodi	Pirimundi
Arakkulam munda	Kalluvally	Malamundi	Poonjaranmunda
Aralumurian	Kaniakadan	Malamundi	Punchakodi
Aranavalan	Kanjirakkodan	Malligesara	Sagar local
Arasinagunda	Kanjiramindi	Manjamundi	Shimogalocal
Arikotta	Kaplangamundi	Maramodiyan	Sullia Local
Arimulaku	Karimallegessara	Marampadathi	Thekkan
Arivally	Karimkodi	Marankodi	Thevanmundi
Balankotta	Karimkotta	Multi-branched type	Thippallikodi
Balankotta	Karimunda	Mundi	Thommankodi
Bilimallegessara	Karimundi	Mundikodi	Thottamundi
Chankupazhuppan	Karivally	Murithottan	Thulamundi
Chengannorkodi	Karivilanchy	Muttayarmundi	Uddagara
Chepakulamundi	Karuthakaniakadan	Nadan	Uthirankotta
Cheradupiriyan	Karuthapirimunda	Narayakodi	Vadakkan
Cheriakaniakadan	Karuvilanchi	Nastigunda	Valiyakaniakadan
Cherukodi	Kotta	Natesankodi	Varkkakodi
Cheruvally	Kottanadan	Nedumchola	Vattamundi
Chettalli local	Kottaram vally	Neelamundi	Vellamundi
Chettan kodi	Kuttiyanikkodi	Neyyatinkaramundi	Vellanamban

Cholamundi	Krishnakodi	Orumaniyan	Velliyarmunda
Chumalakodi	Kumbhacola	Ottaplackal	Veluthakaniakadan
Doddalae	Kumbhakodi	Padappan	Veluthapirimunda
Doddigai	Kurielmundi	Palamulaku	Vokkalgunje
Ghantuvalli	Kurimalai	Palualuta	Vokkalu
Irumaniyan	Kuthiravally	Perambramunda	Wynadan
Jeerakamundi	Kuttianikkodi	Perumkarimunda	Yohannankodi

Table 6. Economically *Piper* species conserved in the genebank

Species	Uses
Piper nigrum L. (True black pepper)	The dried fruits, powdered forms or as a whole and oils and oleoresin extracted form the berries are used all over the world.
P. longum L. (Long pepper)	Used in Ayurvedic and Unani systems of medicine. Long pepper forms an important Ayurvedic preparation such as *Trikadu* (dry ginger-long pepper-black pepper) and panchakolam. Both fruits and dried roots are used for medical preparations.
P. chaba Hunter	Used in Ayurvedic and Unani systems of medicine.
P. hapnium Ham.	Used in Ayurvedic medicines like *P. longum*
P. betle L (The betel vine)	Widely cultivated in India for its leaves for the pan industry. The essential oil from leaves is used in respiratory catarrh and also as an antiseptic. The plant is considered by the tribal as useful in treating madness, strangulation of the intestine, venereal sore etc.
P. magnificum. Trel	Ornamental purpose
P. ornatum N. E. Br.	Ornamental purpose
P. colubrinum Link	Used as rootstock for raising footrot tolerant pepper

Table 7. Exotic species conserved in the genebank

Species	Source
Piper ornatum. N. E. Br	Ambalavayal
P. colubrinum . Link	Pepper Research Station, Panniyur, KAU
P. magnificum Trel.	Royal Bot. Gardens, Kew, through TBGRI, Palode
P. arboreum Aubl.	Royal Bot. Gardens, Kew, through TBGRI, Palode
P. chaba Hunter	Java- SE Asia, through a farmer from Ernakulam
P. nepalense Miq	From Nepal
Three more exotic Piper spp.	From Germany, Kottackal Ayurvedic College and Anand, Gujarat respectively
P. nigrum (Kutching)	A prominent cultivar of Malaysia
P. nigrum (LDK and Jambi)	Indonesia

Table 8. Endangered species collected and conserved in the genebank

Sl. No	Name	Remarks
1	*Piper barberi* Gamble	Located from Agastyavanam forests, established in the genebank and re described the species
2	*P.silentvalleyensis.* Ravindran et Asokan	A rare bisexual species resembling p. mullesua, located at Silentvalley forests
3	*P. hapnium* Ham.	A species resembles *P. longum*, slender comber with long cylindrical spike located at Achankovil forests; Sabari hills and Peruvannamuzhi were collected and conserved.

Table 9. Unique accessions collected and conserved

Sl. No	Species	Unique features
1	*Piper thomsonii*	A bushy species having globose spike collected from the Totopara hills of Indo Bhutan border near Jalpaiguri, WB. Male plant changed to bisexual (Transsexual species)
2	*P. peepuloides*	An economically important species closely related to *P. longum*, collected from the Totopara hills of Indo Bhutan border near Jalpaiguri, WB.
3	*P. sylvaticum*	A collection from Tripura with scented male spikes.
4	*P. bababudani*	*Piper* species having very bold berries resembles *P. galeatum* but with copular bracts located at Bisle, Karnataka and Pakshipathalam, Kerala.
5	*P. sermantosum*	Collected from Andamans. Resembles *P. longum* but lateral branches are erect.
6	*P. nigrum*	An intermediate form with bisexual inflorescence collected from Kuttikkayam areas of Idukki. This transitional stage of *P. nigrum* in wild conditions, points towards the origin of bisexual cultivated types from Western Ghats forests.
7	*P. nigrum*	With extra bold berries collected from Silent Valley forests of Kerala
8	*P. nigrum*	Collected from Nelliampathy with high oleoresin content.
9	*P. nigrum*	A cultivar with multi branched spike

Conservation of germplasm is done by adopting the following strategies:

a. In the nurseries, each accession is trailed in serial order and are under continuous multiplication by using serpentine method
b. In the clonal repository 10 rooted cuttings of each line are maintained
c. In the field genebank the accessions are planted for evaluation
d. In the *in-vitro* genebank, the important accessions are conserved using tissue culture tools.

This four pronged conservation strategy is used because of the threat of disease and pests (eg. *Phytophthora* foot rot and nematodes etc.). In addition to this to safeguard the germplasm two alternate centers were also identified at CPCRI, Seed farm, Kidu and CRC, Appangala, Karnataka for cultivar and wild germplasm respectively. Duplicate set of germplasm will be established in these centers in a phased manner.

Exotic *Piper* species conserved in the germplasm

P. colubrinum

P. arboreum

P. chaba Hunter

P. nepalense Miq

Piper sp.

Piper ornatum. N. E. Br

P. magnificum Trel.

Piper sp.

New species reported

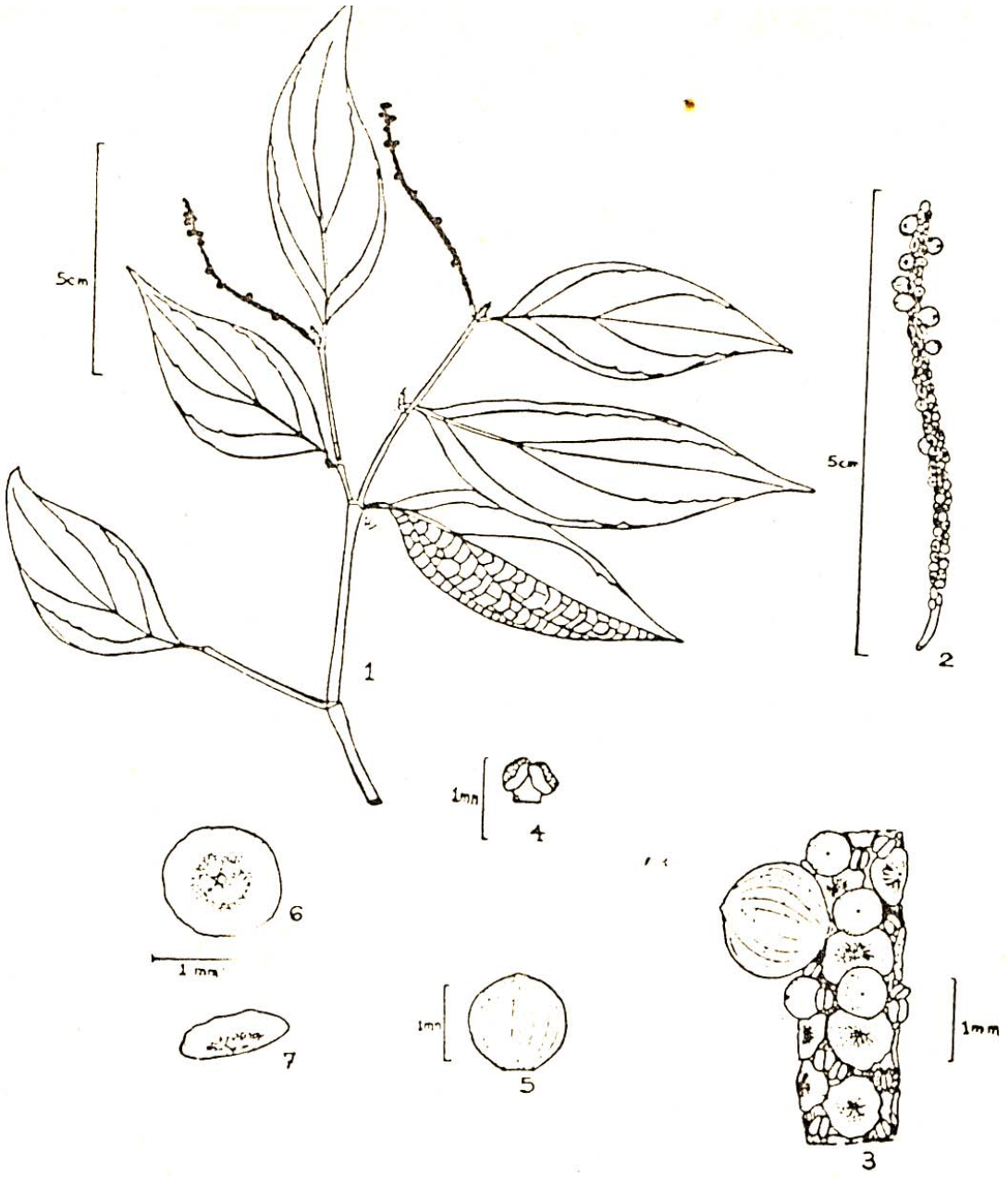
During the course of exploration to Silent valley Wild Life Sanctuary, Palaghat district, Kerala and Sugandhagiri hills, Wayanad district, two new species and two varieties were identified and reported. The new reports are *Piper silentvalleyensis*, *P. nigrum* L. var. *hirtellosum*, *P. sugandhi* and *P. sugandhi*. Var. *brevipils*. Taxonomical description of each species is given below.

***Piper silentvalleyensis* P. N. Ravindran, M. K. Nair and R. Asokan Nair *sp. nova*.**

Allied to *P. mullesua* Buch. Ham ex D. Don (syn. *P. brachystachyum* Wall) but differs from it in the elongated ascending fruiting spikes. 2.5 – 535 cm long, flowers bisexual, leaves sub coriaceous.
HOLOTYPE: PNR: 186 Collected from Silent valley forests, Kerala, India on 8-04-80 and deposited in the herbarium, National Research Center for Spices, Calicut, India and BSI Herbarium (Madras Herbarium) at Coimbatore.

Slender extensively branched climber; stems about 0.5-1 cm thick, swollen at the nodes; branches terrate, entirely glabrous; stipules small; laterally fused to form a lanceate structure of 0.3-0.5 cm long, hirsute and deciduous; leaves alternate, elliptio-lanceolate, somewhat coriaceous; lamina 5-8.5 x 2-3.5 cm glabrous on both sides, base acute, more or less asymmetric, tip caudate acuminate, often bent, lamina prominently ribbed, of two pairs of lateral rib the first arises near the petiole and the other about 0.5 cm above, ribs more pronounced on the dorsal side, petiole very short, 0.3-0.5 long and quite glabrous; spikes 2.5-5.5 cm long, glabrous furrowed when dry never longer than petiole; bracts orbicular, peltate stalked, ± 0.7 cm in diameter; flowers bisexual, stamens two, vary short; anthers two lobed, reniform and attached transversely at the tip of the filament, dehiscing by longitudinal cleft; ovary globoid astylocarpellous, stigma minute and three lobed; fruit a small drupe, mature one ± 0 cm across and slightly longer length-wise, obovate in shape with striations, pungent.

Rare, difficult to distinguish from *Piper mullesua*, unless in fruiting.



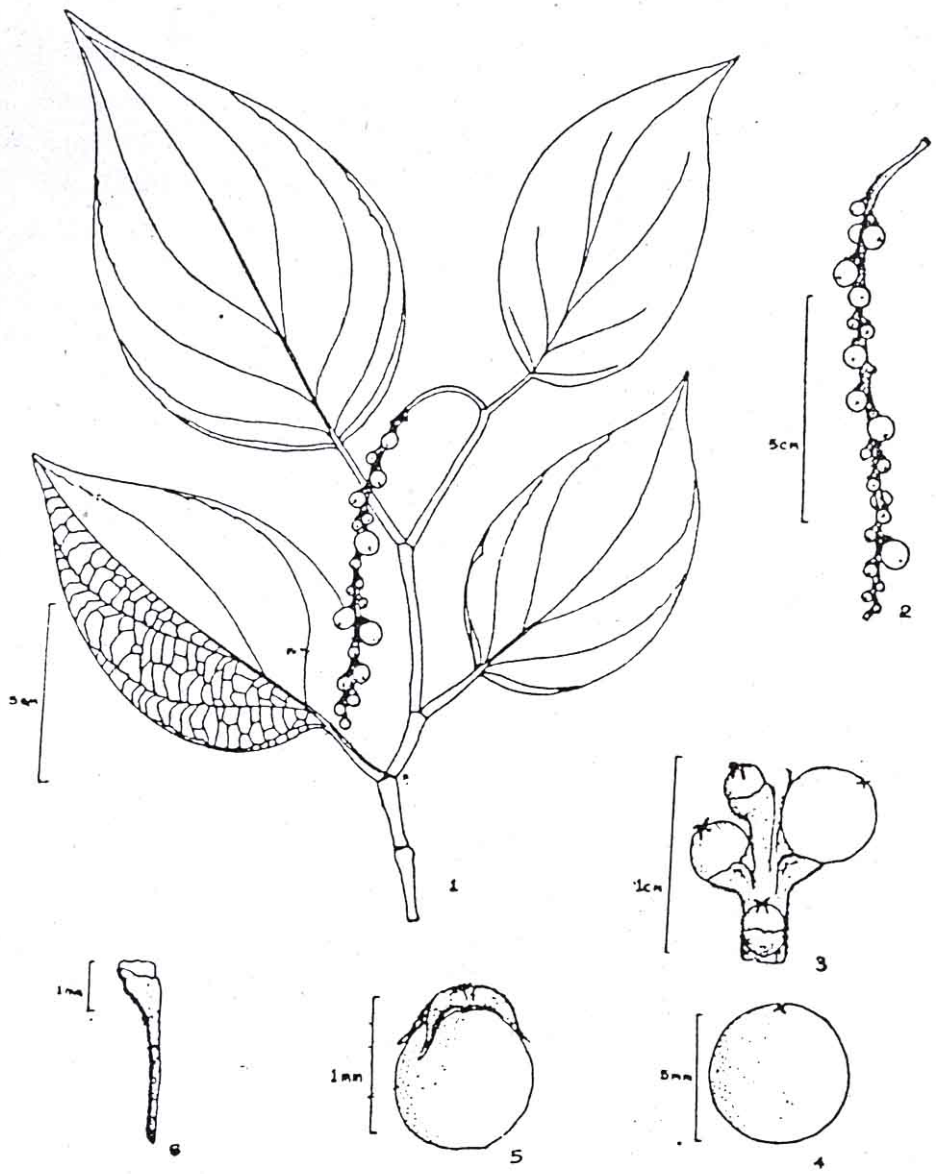
Piper silentvalleyensis P.N. Ravindran, M.K. Nair & R. Asokan Nair
1. A fruiting branch 2. An entire spike 3. A portion of the spike-enlarged 4. Stamen (dehisced). 5. Fruit 6. Bract-surface view 7. Bract - lateral view.

***Piper nigrum* L. var. *hirtellosum* R. Asokan & P.N. Ravindran var. nova**

Allied to *Piper nigrum* L. but distinctly differs from it in having hiretellous bracts. In both young and mature spikes

HOLOTYPE PNR & RAN: 386 collected from Silent Valley Forests, Kerala, India on 24-4-1986, and deposited in the herbarium, National Research Centre for Spices, Calicut, India and in the BSI Herbarium (Madras Herbarium) Coimbatore.

Robust shrubby climber, stems terete entirely glabrous with profuse foliage; leaves alternate, broadly ovate-elliptic, coriaceous and glabrous on both sides; lamina 7.0-18.0 cm long, 3.0-10.0 cm broad, leaf tip acuminate, base almost unequal and oblique, obtuse or cordate sometimes, lamina prominently ribbed, commonly 3 or often 2 pairs of lateral ribs, more conspicuous on the dorsal side, the basal pairs almost opposite and the anterior-most one generally alternate; petiole 1.2-2.5 cm long, glabrous and furrowed; stipules lanceate about 1.5 cm long, glabrous and deciduous; fruiting spikes long, drooping, 5.0-17.0 cm long, peduncle glabrous except for one or two strong hairs; bracts adnate to rachis, upper part cup like, with a decurrent base, hirtellous on the outer side; flowers more or less distantly distributed, having a single spherical ovary, about ±0.2 cm long, astylocarpellous with 3-4 papillalate stigmatic lobes; fruit a drupe, spherical mature on about 0.7 cm in diameter, pungent turns red when ripe; seed single, globose with floury endosperm. Rare, male plant unknown.



Piper nigrum L. var. *hirtellosum* R. Asokan & P.N. Ravindran
1. A fruiting branch 2. Mature female spike 3. A portion of the spike enlarged 4. Mature fruit 5. Pistil 6. Bract-side view

***Piper sugandhi* Ravindran, Babu et Naik sp.nova**

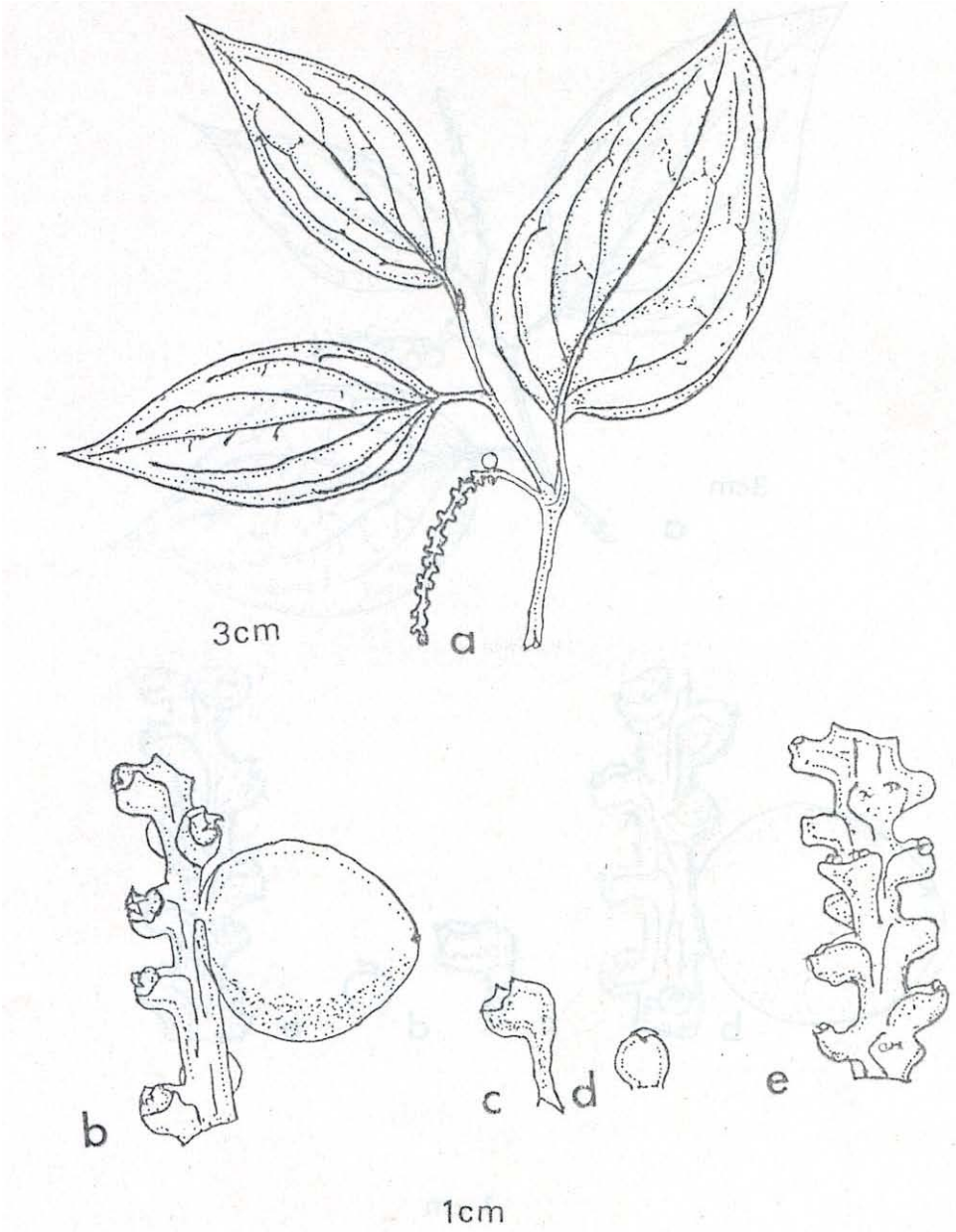
Allied to *P. nigrum* L. (black pepper) but differs from it in having stipitate flowers and deeply copular bract. Allied to *P. galeatum* (Miq.) C. Dc., but differs from it in the nature of bracts and in having pungent fruits as in black pepper allied to *P. trichostachyon* (Miq.) C.DC, but differs from it in having stipitate flowers, nature of bract and in having pungent fruits

Type: India, Western Ghats, Kerala, Wynad District, Vythiri, Sugandhagiri Project area. Ravindran, Babu and Naik 637 (male) and 686 (female). Holotype in herbarium of NRCS Calicut; live specimen in germplasm conservatory of NRCS

A stout woody climber, dioecious and perennial, reaching to a height of 10 m or more; branches terete, swollen at the nodes, glabrous, orthotropic shoot tips purple; leaves alternate, glabrous, coriaceous, ovate to ovate-lanceolate, acuminate, base round to acute and often oblique, margins slightly wavy, more prominent in young leaves; 7-13 cm long and 3-8 cm broad in male vines; 10-18 cm long and 4-11 cm broad in the female, prominently 5-7 ribbed, more conspicuous on the lower side, the basal pair of ribs sub-opposite mothers alternate. Petiole about 2 cm, grooved, margins modified as sheaths, sheaths caduceus.

Male spikes slender, fleshy filiform and pendant or recurved 10-14 cm long; female spikes, 5-10 cm long. Flowers held at right angles to the rachis, stipitate, bracteate, bracts deeply copular with free margins, stamens 2 filaments short and thick, embedded in the cupular bract, anthers projecting out at maturity; dithecous, dehiscing by apical longitudinal slits. Ovary ovoid, monocarpellary, embedded inside the copular bract except for the tip; style 0 stigma 3-lobed, fleshy, and white when young

Fruits oblong, bold, 0.8-1.0 cm diam., pungent as in black pepper, turns yellow and then to red on ripening. Flowering April-May, fruit maturity December-January.



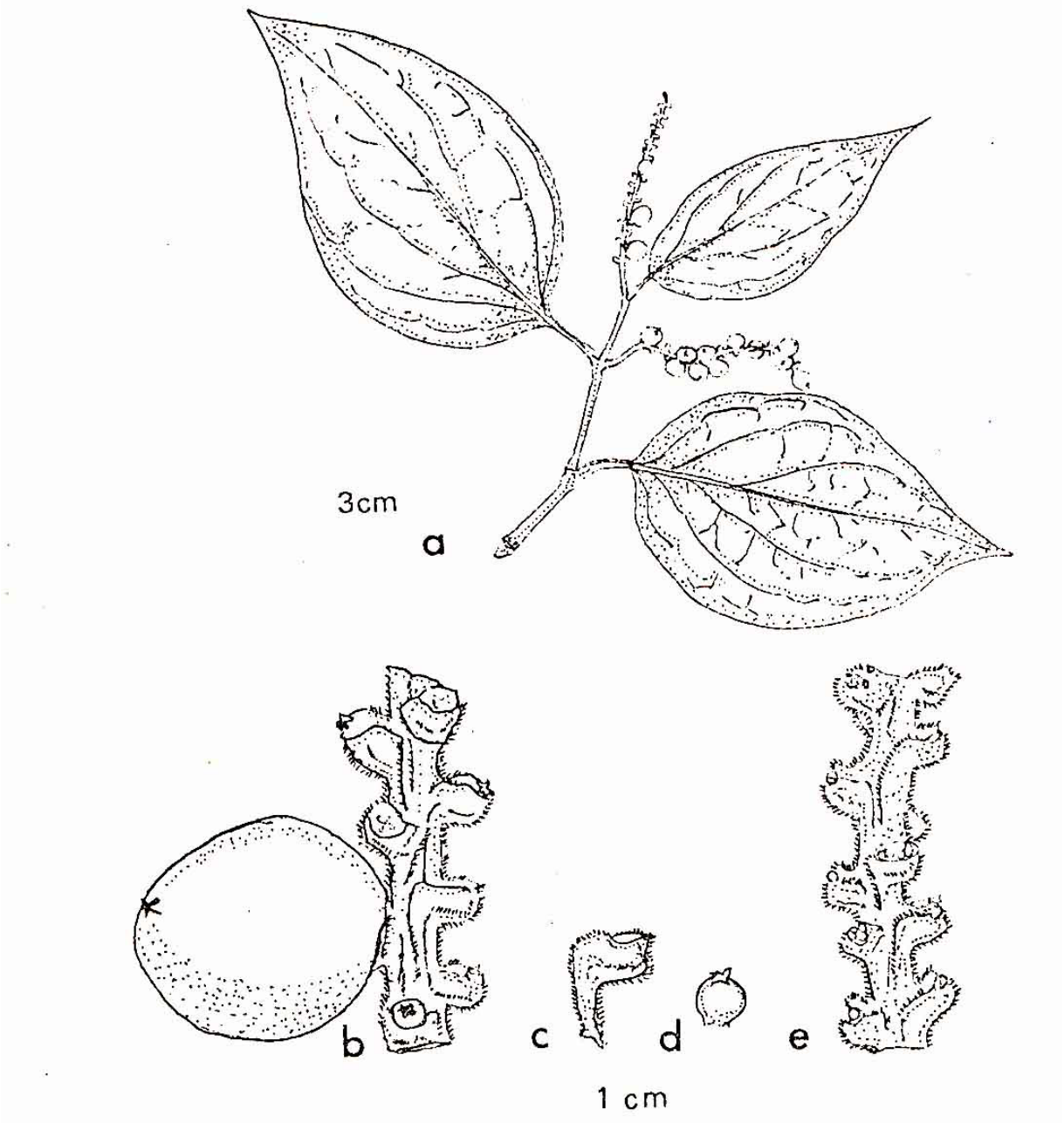
Piper sugandhi

a. a twig b. portion of female spike c. bract d. ovary e.portion of male spike

***Piper sugandhi* var*, brevipilis* Ravindran, Babu et Naik.**

Piper sugandhi simile sed different bractices minute pubescentibus
Very similar to *P.sugandhi* described above but differs from it in having pubescent bracts

Type: India, Western Ghats, Kerala, Wynad district, Vythiri, Sugandhagiri project area. Ravindran, Babu and Naik 678 (male) and 680 (female). Holotype in herbarium of NRCS Calicut: live specimen in NRCS germplasm conservatory.
A study on the morphology of the new taxa showed that they are related to *Piper nigrum, P. trichostachyon and galeatum.* The characters of *P. sugandhi* are intermediate to those of *P. nigrum and galeatum and P. trtrichostachyon* especially in the nature of bracts, which is a major diagnostic character among the South Indian taxa of *Piper. P. nigrum* has shallow cupular bracts and *P. sugandhi* has intermediate type of deeply cupular bracts. It retains the stipitate nature of flowers of *P. galeatum* and also its fruit shape and size. Fruits are pungent as in *P. nigrum*. *Piper sugandhi* var. *brevipilis* is distinct from *P. sugandhi* in the presence of hairs on the bracts. The presence and absence of hairs is an important diagnostic character for classifying South Indian species of *Piper* especially *P. attenuatum, P. argyrophyllum, P. hymenophyllum and P. nigrum* var. *hirtillosum*



Piper sugandhi var. *brevipilis*

a. a twig b. portion of female spike c. bract d. ovary e. portion of male spike

Species redescribed

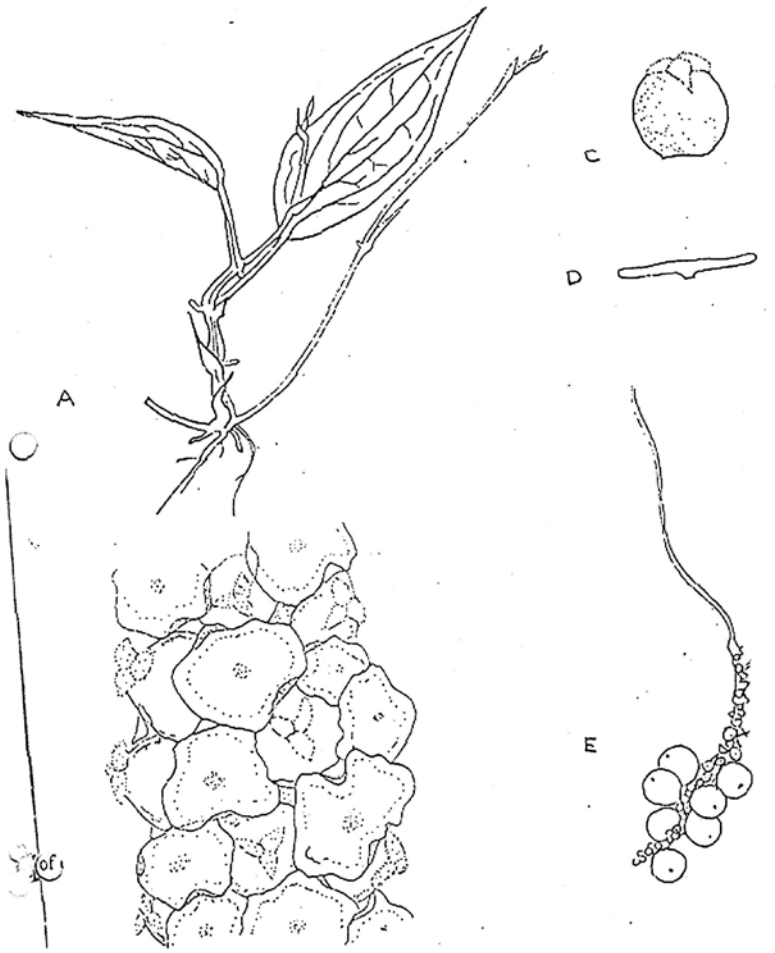
Piper barberi an endangered species listed in the Red Data Book of Botanical Survey of India was first reported by Barber from the Tinnelvelly forests of South India. His collection consist only specimens from the male plant and the description was based on these specimens. However the descriptions were not complete with regard to habit and other morphological details. The species was collected, conserved and redescribed based on the live specimens about its taxonomical and cytological characters.

Taxonomical description of *P. barberi* Gamble

P. barberi	:	Holotype 613, Babu and Ravindran.
Type	:	India, Western Ghats, Kerala, Trivandrum district, Breymoor forest area, altitude 700 m MSL.
Holotype	:	NRCS Germplasm conservatory, Peruvannamuzhi, Calicut and at NRCS herbarium, Calicut

P. barberi is a small, slender, glabrous dioecious climber climbing on shrubs and small trees. The plant produces three different types of shoots. The juvenile shoots are leaf less, slender having long internodes, producing persistent scale leaf at every node and a few roots, green in colour except at the nodes where the colour is pale purple. Orthotropic shoots produce small leaves, 5-7 cm long and 2-3 cm broad; lanceolate with 2-3 cm long petiole; base slightly unequal and tip acuminate. Lateral branches arise from the orthotropic shoots which bear normal leaves and spikes. The leaves on fruiting branches are 8-12 cm long and 2-5 cm broad, pinnately reticulate, tip acuminate, base acute, unequal.

Spikes are borne on slender 6-10 cm long dangling stalks (peduncles). The male spikes are slender, about 7-10 cm long, narrow; male flowers are represented by two anthers subtended by an orbicular, peltate bract. The female spikes 4-7 cm long, pale purplish when young, almost green when mature, female flowers represented by a single ovary, sessile stigma, 3 lobed; papillate, fleshy; fruits usually very few' fleshy drupe, 4-7 mm in diameter round when mature, deep red when fully ripe, seed about 2-3 mm diameter, ovoid to round. Seed is slightly pungent.



A. Juvenile branch showing leafless orthotropic shoot.
B. Portion of the female spike enlarged, showing the peltate b
C. Ovary. D. Lateral view of the bract. E. Spike with fruits.

Cytological investigations revealed that *P. barberi* has a somatic chromosome number of 2n=52. The karyomorphological studies of root tip squashes revealed the chromosome complement has 13 metacentric, 10 submetacentric and three acrocentric pairs (Table-10). The chromosome length ranged from 0.74 to 1.85µ.

Table- 10: Karyomorphology of *Piper barberi.*

Chr. No.	Long arm(µ)	Short arm (µ)	Total length (µ)	Arm ratio	Chr. symbol
1	1.11	0.74	1.85	1.50	m
1.	1.11	0.55	1.66	2.01	sm
2.	1.11	0.55	1.66	2.01	sm
3.	1.29	0.37	1.66	3.49	st
4.	1.11	0.55	1.66	2.01	sm
5.	0.92	0.55	1.47	1.67	m
6.	0.92	0.37	1.29	2.49	sm
7.	0.74	0.55	1.29	1.35	m

8.	0.92	0.37	1.29	2.49	sm
9.	0.92	0.37	1.29	2.49	sm
10.	0.74	0.55	1.29	1.35	m
11.	0.74	0.46	1.20	1.61	m
12.	0.74	0.37	1.11	2.00	sm
13.	0.74	0.37	1.11	2.00	sm
14.	0.65	0.46	1.11	1.41	m
15.	0.74	0.37	1.11	2.00	sm
16.	0.74	0.37	1.11	2.00	sm
17.	0.92	0.18	1.10	5.11	st
18.	0.55	0.55	1.10	1.00	m
19.	0.55	0.55	1.10	1.00	m
20.	0.55	0.37	0.92	1.49	m
21.	0.55	0.37	0.92	1.49	m
22.	0.55	0.18	0.92	4.11	st
23.	0.55	0.37	0.92	1.49	m
24.	0.55	0.46	0.92	1.00	m
25.	0.46	0.28	0.74	1.64	m

Population of *P. hapnium*- an endangered species

P. hapnium is an endangered species. Its distribution is very much restricted in the Western Ghats, however, a small population of *P. hapnium* (both male and female) located in the Peruvannamuzhi forests, Calicut, Kerala along with other species of Piper such as *P. nigrum*, *P. attenuatum* etc. The male plants were observed for the first time, which were compared to female plants.

Spikes are erect, long, robust and fused laterally. Young female spikes are light yellow. Male spike is coffee coloured and slightly sickle shaped. Stamens two and dithecus. Bracts peltate orbicular. Ovary is monocarpellary and trilocular. Berries partly projecting out from the rachis. *P. hapnium* (both male and female) has a distinct aroma different from that of *P. longum*. Both male and female plants were characterized for morphological and reproductive traits (Table 11).

Table 11. Morphological characterization of *P. hapnium*

Habit: A slender climbing shrub, runner shoot creep and spread on the ground
Leaves: Petiolate with prominent ribs from the base. Nerves on the lower side of young leaves are pubescent with minute deciduous hairs. Mature leaves glabrous, lanceolate and unequally cordate with incurved auricles at the base, seven nerved and bullate. Leaf tip acuminate

Female plant	Male plant
Fruiting branch leaf length: 8.5 to 8.8 cm Fruiting branch leaf breadth: 4.0 to 4.1 cm Main shoot leaf length: 6.7 – 6.9 cm Main shoot leaf breadth: 4.7 – 5.0 cm Leaf petiole length (main shoot): 6.3–6.5 cm Leaf petiole length (fruiting branch): 2.0–2.2 cm Spike length: 5-5.5 cm Peduncle length: 2.1 – 2.2 cm	Fruiting branch leaf length: 7.7 to 8.0 cm Fruiting branch leaf breadth: 4.3- 4.5 cm Main shoot leaf length: 5.2 to 5.5 cm Main shoot leaf breadth: 4.3 – 4.5 cm Leaf petiole length (main shoot): 6.5 cm Leaf petiole length (lateral branch): 2.0–2.2 cm Spike length: 4.5 – 5.0 cm Peduncle length: 2.0 – 2.2 cm

Germplasm Registered

Registration of germplasm: Registration of valuable and important germplasm will meet the requirement of the intellectual property right and related issues, plant breeder's right, farmer's right etc.

A. Germplasm registered

1. Coll. No. 5455 (IC-370011) Piper nigrum (wild) –a local selection from Nelliampathy, Palaghat district, Kerala is registered for high oleoresin content (28.15%) and bold berries (INGR No 04111).

2. Coll. no 1041 (IC- 316598) from the germplasm was registered with NBPGR for its field tolerance to foot rot disease (INGR No-3091).

3. CLTP 123 (IC- 316588) collected from Ponkunnam, Kottayam has been registered for high caryophyllene percent (INGR- 06026)

B. Germplasm accessions proposed for registration

1. *Piper thomsonii* (Coll. No 5529) - for its transsexual nature from unisexual to bisexual (male to bisexual) and bushy morphotype.
2. *P. nigrum* (Coll. No. 5705) - for Proliferating spikes lead to the increase in yield and novelty in bush pepper

Studies on ecological distribution of *Piper* species of South India

Piper spp. is found distributed extensively in the evergreen, semi evergreen and moist – deciduous forests of Western Ghats and the north eastern regions of India. It grows from almost sea level to an altitude of about 2000 m. Species like *P. schmidtii, P. wightii and P. mullesua* occur only at high elevations, while others like *P. longum* prefer valley and plains. The distribution of *Piper* is denser along footpaths, animal tracts, riversides and towards the periphery of the forests, where there is good light penetration. However, in disturbed forests they occur in good number even in the interior due to the increased light availability. In the genus *Piper* male, female and hermaphrodite vines occur. The cultivated types of *P. nigrum* are hermaphrodite, while the wild species including *P. nigrum* are unisexual. Human selection might have played a major role in the directional hermaphroditism in the present day cultivated types. They are naturally self pollinated which is aided by rain or dew drops and also by the gravitational descending of pollen grains (geitenogamy). The flowers are protogynous, but in the absence of any active pollen transfer mechanism protogyny becomes ineffective in enhancing crossing.

Active and efficient pollen mechanism and seed dispersal mechanisms ensure gene flow within and between population segments leading to the establishment of intergrading populations. The absence any such mechanism in *Piper* thereby establishes effective isolation barriers between individuals and between population units. Within such units variations then could depend upon segregation in the seedling progenies, accumulation of mutations and chances of crossing flowed by segregation. Any such variations arising in the population would get immediately fixed as a result of the prevailing vegetative mode of propagation.

Descriptors for black pepper germplasm

A detailed descriptor of black pepper has been prepared and published by International Plant Genetic Research Institute Rome. The major characters used in the descriptor s given below:

Vegetative

Plant growth habit

1 Climbing (on support)
2 Trailing (on the ground)
3 Erect

Vine column height *(cm)*

Measured from ground to the tip of the vine

Vine column circumference *(m)*

Measured as a means of three different locations of the column each taken from the bottom, middle and upper position of the vine.

Support type

1 Living
2 Non-living

Branching type

1 Dimorphic
2 Polymorphic
3 Other

Young (emerging) orthotropic shoot tip colour

1 Greenish yellow
2 Light purple
3 Dark purple
4 Light red
5 Other

Runner shoot production

0 Absent
3 Few
7 Many

Holding capacity

3 Weak
7 Strong

Adventitious root production

3 Few
7 Many

Absence/ presence of pubescence on stem

0 Absent
1 Present

Lateral branch habit

1 Erect
2 Horizontal
3 Hanging

Lateral branch length *(cm)*

Average length of 50 randomly selected lateral branches

Number of nodes per lateral branch

Average number of 50 lateral branches

Juvenile leaf length

3 Short
5 Intermediate
7 Long

Leaf petiole length (cm)

Average of 50 randomly selected mature leaf petioles from the lateral branches, measured from the base to the insertion with the blade

Leaf length (cm)

Average of 50 randomly selected mature leaves from lateral branches, measured from the base of the midrib to the tip

Leaf width (cm)

Average of 50 randomly selected mature leaves from lateral branches, measured at the maximum width

Leaf lamina shape

Recorded from the lateral branches

1 Ovate
2 Ovate- elliptic
3 Ovate- lanceolate
4 Elliptic- lanceolate
5 Cordate

Leaf base shape

1 Round
2 Cordate
3 Acute
4 Oblique

Leaf margin

1 Even (entire)
2 Wavy (repand)

Types of veining

1 Acrodromous
2 Campylodromous
3 Eucamptodromous

Leaf texture

1 Glabrous coriaceous
2 Glabrous membranous
3 Glabrous sarcous
4 Downy membranous
5 Downy along the veins

Leaf hairiness

0 Absent
1 All over the leaf
2 Mainly along the veins

Presence / absence of leaf scales

0 Absent
1 Present

Presence of pearl(wax) glands

1. Sparse
2. Intermediate
3. Dense

Wax secretion

Recorded on the growing parts during the active growth period

3 Spars
5 Intermediate
7 Profuse

Inflorescence and fruit

Spike orientation

1 Erect
2 Pendant

Spike shape

1 Filiform
2 Cylindrical
3 Globular
4 Conical
5 Other

Spike colour

1 Green
2 Greenish yellow
3 Light yellow
4 Light purple

Spike fragrance

0 Not fragrant
1 Fragrant

Spike length(cm)

Average of 50 randomly selected spikes

Type of hermaphroditism in spikes

1 Staminate flowers only
2 Pistillate flowers only
3 Bisexual flowers only
4 Predominantly male
5 Predominantly female
6 Predominantly bisexual

Peduncle length (cm)

Average of 50 randomly selected spikes

Number of spikes per lateral branch

Average of 50 lateral branches

Number of spikes per vine

Average of 5 vines

Bisexual flowers per spike (%)

Average of 50 spikes

Flower arrangement on spike

1 Free
2 Fused laterally

Number of stamens

1 Two
2 Three
3 Four

Mature anther filament length

Visual observation
3 Short
7 Long

Spike texture

1 Glabrous
2 Hirtellous

Bract type

1 Sessile oblong and adnate to the rachis
2 Peltate orbicular
3 Cupular with decurrent base
4 Fleshy, connate, transformed in to a cup
5 Deeply cupular with decurrent base
6 Other

Flower nature (insertion)

1 Sessile
2 Shortly stipitate
3 Pedicillate

Fruit setting (%)

Average of 50 spikes

Number of fruits per spikes

Average of 50 spikes

Number of berries per 10 spikes

Weight of 100 fruits (gm)

Volume of 100 fruits (cc)

Fruit shape

1 Round
2 Ovate
3 Oblong
4 Other

Weight of fresh fruit per vine (kg)

Weight of 100 dry fruits (gm)

Quality

Essential oil %
Oleoresin %
Piperine %

2. Characterization and evaluation of the germplasm

A. *Cultivar germplasm*

The germplasm collected from different parts of the country were clonally multiplied and established in the field genebank. Characterization of germplasm is done in a phased manner to evaluate the accessions for various quantitative and qualitative characters. The germplasm accessions were characterized based on the IPGRI descriptor for morphological characters. There is considerable variability among the accessions with regard to various morphological as well as floral characters like leaf shape, leaf size, spike length, spiking intensity, composition of male, female and bisexual flowers in the spike, fruit set, shape, weight and volume of the fruit etc., weight and volume of the fruit etc. The extent of variability of important characters are given in Table 12

Table 12. Variability observed in important characters in the accessions

Sl.No.	Characters	Range		Mean	CV (%)
		Minimum	Maximum		
1.	Vine column height (cm)	100	1180	335.9	46.8
2.	Vine column circumference (m)	0.4	11.5	3.26	46.22
3.	Lateral branch length (cm)	9.8	70	36.51	27.66
4.	No. of nodes / lateral branch	2.0	95	15.4	57.75
5.	Leaf petiole length (cm)	0.8	5.0	1.74	28.9
6.	Leaf length (cm)	4.8	23.0	13.29	16.98
7.	Leaf width (cm)	2.1	16.6	8.49	21.52
8.	Spike length (cm)	3.2	17.6	7.5	28.4
9.	Peduncle length (cm)	0.3	5.0	1.2	30.57

10.	No. of spikes / lateral branch	1.0	56	5.97	50.52
11.	No. of spikes / vine	10	720	158	56.6
12.	No. of berries in 10 spikes	10	115	51.4	36.09
13.	Fresh weight of 100 berries (gm)	5	23	12.4	22.01
14.	Volume of 100 berries (ml)	4	22	11.8	21.49
15.	Volatile oil (%)	1	9	3.5	36.8
16.	Oleoresin (%)	5.09	19.8	9.21	20.50
17.	Piperine (%)	0.96	3.95	2.15	26.53

The leaf size varies from 4.8 -23 cm in length and 2.1 to 15.6 breadth. Cultivars like Doddale, Balankotta, Karimkotta etc and the hybrid Panniyur-1 have large leaves while those of Jeerakamundi, Nedumchola, Cholamundi etc have small leaves and Neelamundi, Karimunda, Kottanadan, Arakulammunda etc have medium sized leaves. The varieties with large leaves usually grow into vines with bigger canopy whereas the smaller leaf types have smaller canopy.

Accessions like Panniyur-1, Poonjaranmunda, Balankotta and Thommankodi have long spikes, whereas accessions like Neelamundi, Kalluvally, Arakkulammunda, Aimpiriyan, Kaniakkadan, Mallegessara etc have medium spikes cultivars like Kurialmundi, Jeerakamundi, Nedumchola and Thippalikodi etc have small spikes. Cultivar ‘Vokkalu’ has the smallest spike with 3.2 cm length. The spikes of majority of cultivars are straight, while some cultivars have characteristic curve or twisting of the spike. These include Aimpiriyan, Kalluvally, Kurialmundi, Narayakodi and Kottanadan. The main reason for the twisting is the closeness of flower arrangement and the high setting as a result of which the spikes become twisted or curved.

Table 13. Spike and berry (Fruit) characters of black pepper cultivars

Sl. No	Cultivars	Spike length (cm) (mean)	Peduncle length (cm) (mean)	L.length /S. length	Spike shape	Berry shape	Berry size
1	Aimpiriyan	11.56	1.20	1.2	Curved	Round	Bold
2	Arakkulammunda	11.40	1.31	1.34	Straight	Round	Medium
3	Arimulaku	8.00	1.32	1.20	Straight	Round	Small
4	Balankotta	12.74	1.72	1.55	Straight	Round	Bold
5	Bilimallegessara	10.56	0.86	1.13	Straight	Round	Medium
6	Cheriyakaniakkadan	10.54	0.92	1.13	Straight	Obovate	Small
7	Cheppakulamundi	12.00	1.90	1.24	Straight	Round	Medium
8	Cholamundi	11.13	0.64	1.24	Straight	Round	Small

9	Jeerakamundi	10.36	0.60	1.16	Straight	Round	Small
10	Karimunda	7.80	1.00	1.51	Straight	Round	Medium
11	Kaniakkadan	9.20	0.90	1.38	Straight	Round	Medium
12	Karuvilanchi	10.43	1.00	1.21	Straight	Oblong	Bold
13	Karimkotta	15.63	2.1	0.88	Straight	Round	Bold
14	Kalluvally-1	6.92	1.2	2.05	Curved	Round	Small
15	Kalluvally-2	12.50	1.06	1.90	Straight	Round	Medium
16	Kallubalankotta	13.64	1.05	1.02	Straight	Round	Medium
17	Kottanadan	10.70	1.11	1.20	Curved	Round	Medium
18	Kuching	9.10	9.7	1.51	Curved	Round	Medium
19	Kuriyalmundi	5.32	1.01	2.22	Curved	Round	Small
20	Kuthiravally	17.16	1.05	0.67	Straight	Round	Medium
21	Kurimalai	12.61	1.47	1.03	Straight	Round	Medium
22	Malamundi	9.67	0.79	1.34	Straight	Round	Medium
23	Mundi	8.63	0.91	1.56	Straight	Round	Bold
24	Narayakodi	8.23	0.79	1.25	Curved	Obovate	Small
25	Neelamundi	9.70	0.74	1.60	Straight	Round	Bold
26	Nedumchola	5.17	0.96	1.71	Straight	Obovate	Small
27	Neyyattinkaramundi	7.10	0.70	1.26	Straight	Round	Small
28	Ottaplackal	11.38	1.24	1.03	Straight	Round	Medium
29	Panniyur-1	14.00	1.37	1.02	Straight	Round	Bold
30	Perambramunda	11.90	1.00	1.25	Straight	Oblong	Medium
31	Perumkodi	11.76	1.31	1.30	Straight	Round	Bold
32	Poonjaranmunda	16.39	1.22	0.81	Straight	Round	Bold
33	Sagar local	9.00	1.08	1.70	Straight	Round	Bold
34	Thevanmundi	9.65	0.87	1.46	Straight	Obovate	Medium
35	Thommankodi	12.76	1.55	0.80	Straight	Round	Medium
36	Thuamundi	9.50	1.06	1.30	Straight	Round	Medium
37	Udakkere	12.88	1.16	1.17	Straight	Round	Bold
38	Uthirankotta	10.56	1.26	1.35	Straight	Round	Bold
39	Vadakkan	11.73	1.46	1.41	Straight	Round	Bold
40	Valiyakaniyakkadan	9.75	1.38	1.77	Straight	Obovate	Bold
41	Vattamundi	9.97	1.24	1.14	Straight	Round	Bold
42	Vellanamban	12.24	0.96	0.84	Straight	Round	Bold
43	Velliyaranmunda	10.00	0.85	1.45	Straight	Round	Medium
44	Vokkalu	3.24	0.53	2.12	Straight	Round	Medium

Leaf-spike relationship has shown that in the majority of cultivars the spike length is more or less equal to the leaf length ($x + S.D = 0.99 1.8$). In some of the cultivars the mean spike length is greater than the mean leaf length. These include Karimkotta, Kuthiravally, Poonjaranmunda, Thommankodi and Vellanamban ($x + S.D < 0.99$). There are cases where spike length is shorter than leaf length ($x + S. D. > 1.8$). They include Kuriyalmundi, Vokkalu etc.

Table 14. Sexual composition of flowers of local cultivars and improved varieties

Name	Bisexual flowers (%)	Female flowers (%)	Male flowers (%)
Improved verities			
Panchami	95.50	4.00	0.50
Panniyur-1	99.20	0.07	0.01
Panniyur-2	96.70	3.30	0.00
Panniyur-3	99.90	0.10	0.00
Panniyur-4	96.40	3.60	0.50
Pournami	84.00	15.00	1.00
Subhakara	99.00	0.50	0.50
Sreekara	98.00	1.00	1.00
IISR- Thevam	96.09	2.06	1.03
B. Local Cultivars			
Aimpiriyan	96.39	0.45	3.16
Bilimallegessara	93.69	5.75	0.56
Cheriyakaniyakkadan	1.64	98.36	0.00
Jeerakamundi	86.83	11.76	1.41
Kalluvally	78.56	21.44	0.00
Karimkotta	90.99	2.65	6.36
Karimunda	94.25	0.00	5.75
Kottan	97.35	0.52	2.13
Kottanadan	99.49	0.21	0.30
Kurialmundi	94.00	5.32	0.60
Kuthiravally	88.58	10.65	0.77
Malamundi	86.04	13.61	0.35
Manjamundi	36.00	63.49	0.51
Mundi	21.98	77.66	0.36
Narayakodi	46.65	53.35	0.00
Neelamundi	99.02	0.87	0.11
Perambramunda	19.46	79.66	0.36
Perumkodi	26.89	73.05	0.06
Poonjaranmunda	98.69	0.00	1.31
Thevanmundi	96.14	2.48	1.38
Thommankodi	97.06	2.59	0.35
Thulamundi	94.18	5.35	0.47
Vadakkan	98.49	1.27	0.24
Valiyakaniyakkadan	78.55	21.45	0.00
Vellamunda	97.45	1.78	0.77
Vellanamban	96.00	4.00	0.00

The germplasm accessions were subjected to screening against various biotic and abiotic stresses. The accessions shortlisted for their tolerance against diseases/pest abiotic stresses etc. are listed below. (Table-15)

Table 15. Germplasm accessions shortlisted for different traits

Sl.No	Trait evaluated	Tolerant/ promising lines/ species
1.	Foot rot disease *(Phytophthora capscici)*	Acc. 1041, P.24, C.1095, C.842, 2466, 2471, 2515, 2433, 2459, 2437 Acc. 1311, 1321, 1324, & 1394
2.	*Slow decline* *Meloidogynae incognita*	Pournami, Acc. 4163, 4175, 1090, P.334, HP-1, HP-20, HP-60, HP-305 (Cultivated) Acc. 3219, 3286, 3287 & 3311 (wild)
	Radopholous similis	HP-305 (hybrid), Acc. 3141, 3200, 3283, 3291, 3299 (wild)
3.	'Pollu beetle' *(Longistarsus nigripennis)*	Acc. 816, 841, 925, 1018, 1048, 1084, 1055, 1099, 1114, 1314, 1316 & 1596. (Cultivated). *P.barberi, P.chaba, P.hymenophyllaum, P.longum*, Acc. 2070 (wild *P.nigrum*)
4.	Drought	Panniyur-5, Acc. 828, 892, 926, 1198, 1218, 1251, 1266, 1277, 1315, 1368, 1390, 1585, 4216, 4226, HP-29, HP-328 and OP-Karimunda (shown tolerance during the first round of screening)
5.	High quality Oleoresin, Piperine & Volatile oil	HP-780, HP- 34, HP- 1411, HP- 127, HP-2, (Hybrids) Acc. 5455, Acc.5442, 5441. (wild)

B. Wild germplasm

The morphological and taxonomical characters of South Indian *Piper* species were carried out. Digitized herbaria for each species are prepared and each species is described. The plant species are characterized for 25 qualitative and 8 quantitative characters. Details of the qualitative and quantitative characters observed for wild accessions are given in Tables 16 This gave a better understanding of species inter relationship and a key was prepared for taxonomic identification of South Indian species of *Piper*

Table 16. *Piper* species used morphological study and their discriminatory characters

Species code	Species studied	Discriminating character
1	*P. longum* Linn.	Indian long pepper, creeping habit, erect spike
2	*P. hapnium* Ham.	Morphologically similar to *P. longum*, bold spike, climbing nature, endangered species
3	*P. mullesua* Ham.	Distributed in high elevation areas, female spikes globular and male spikes cylindrical
4	*P. silentvalleyensis* Ravindran & Asokan	Bisexual species, cylindrical to globular spikes, resembles *P. mullesua* morphologically
5	*P. attenuatum* Buch-Ham.	Common wild species occurring in low elevation, very long spikes, leaves seven nerved, glabrous
6	*P. argyrophyllum* Miq.	Resembles *P. attenuatum* but leaves are five nerved and slightly hairy
7	*P. hymenophyllum* Miq.	Occurring on medium to high elevation, leaves and tender stems are pubescent.
8.	*P. bababudani* Rahiman	A hardy vine with fleshy spike and bold berries
9.	*P. wightii* Miq.	Occurs only at high elevations, shoot tip colour is greenish white
10	*P. schmidtii* Hook f.	Hardy vine occurs only at high elevations, thick leaves, purple shoot tip
11	*P. galeatum* (Miq) CDC	Occurs in medium to high elevation, bold berries, bracts large and boat shaped
12	*P. trichostachyon* CDC	Resembles *P. galeatum*, but spikes are slightly hairy
13	*P. sugandhi* Ravindran, Babu et Naik	Resembles *P. nigrum* but berries are bold and shortly stipitate
14	*P. nigrum* Linn.	Occurs at low to high elevations, dioecious, while cultivated forms are monoecious
15	*P. barberi* Gamble	Endangered species, reticulate venation, peduncle very long

Wild

1. *Passport Details*

1.1 Name of the species:	*Piper longum* L.
1.2 Accession number:	0479
1.3 IC number:	318194
1.4 Place of collection:	Dhoni, Palaghat

2. *Morphological descriptors*

2.1 Plant growth habit:	Trailing
2.2 Branching type:	Dimorphic
2.3 Shoot tip colour:	Greenish Yellow
2.4 Runner shoot production:	Many
2.5 Holding capacity:	Strong
2.6 Adventitious root production:	Many
2.7 Lateral branch habit:	Erect
2.8 Lateral branch length:	27.5
2.9 Number of nodes per lateral branch:	15.0
2.10 Leaf petiole length (cm):	0.9
2.11 Leaf length (cm):	11.8
2.12 Leaf width (cm):	5.5
2.13 Leaf lamina shape:	Elliptic- lanceolate
2.14 Leaf base shape:	Oblique
2.15 Leaf margin:	Wavy
2.16 Type of veining:	Campylodromous
2.17 Leaf texture:	Glabrous membranous
2.18 Leaf hairiness:	Absent

3. *Reproductive characters*

3.1 Spike orientation:	Erect
3.2 Spike shape:	Cylindrical
3.3 Spike colour:	Light Yellow
3.4 Spike length (cm):	2.1
3.5 Type of hermaphroditism:	Pistillate flowers only
3.6 Peduncle length (cm):	1.5
3.7 Number of spikes per lateral branches:	5.0
3.8 Flower arrangement:	Fused laterally
3.9 Spike texture:	Glabrous
3.10 Bract type	Peltate orbicular
3.11 Flower nature:	Sessile
3.12 Fruit shape:	Round
3.13 Fruit taste:	Pungent
3.14 Fruit size:	Very small
3.15 Fruit colour while ripening:	Green to black

Male plant

3.16 Spike length (cm):	3.2
3.17 Number of stamens:	2
3.18 Stamen filament length:	Intermediate

Male spike

1. *Passport Details*

1.1 Name of the species:	*P. hapnium* Buch.-Ham.
1.2 Accession number:	5501
1.3 IC number:	371075
1.4 Place of collection:	Manalar, Achankovil

2. *Morphological descriptors*

2.1 Plant growth habit:	Climbing
2.2 Branching type:	Polymorphic
2.3 Shoot tip colour:	Greenish Yellow
2.4 Runner shoot production:	Many
2.5 Holding capacity:	Weak
2.6 Adventitious root production:	Few
2.7 Lateral branch habit:	Horizontal
2.8 Lateral branch length:	28.1
2.9 Number of nodes per lateral branch:	15.0
2.10 Leaf petiole length (cm):	2.2
2.11 Leaf length (cm):	8.8
2.12 Leaf width (cm):	4.1
2.13 Leaf lamina shape:	Elliptic- lanceolate
2.14 Leaf base shape:	Oblique
2.15 Leaf margin:	Wavy
2.16 Type of veining:	Campylodromous
2.17 Leaf texture:	Downy along the veins
2.18 Leaf hairiness:	Mainly along the veins

3. *Reproductive characters*

3.1 Spike orientation:	Erect
3.2 Spike shape:	Cylindrical
3.3 Spike colour:	Light Yellow
3.4 Spike length (cm):	5.5
3.5 Type of hermaphroditism:	Pistillate flowers only
3.6 Peduncle length (cm):	2.2
3.7 Number of spikes per lateral branches:	3.0
3.8 Flower arrangement:	Fused laterally
3.9 Spike texture:	Glabrous
3.10 Bract type	Peltate orbicular
3.11 Flower nature:	Sessile
3.12 Fruit shape:	Round.
3.13 Fruit taste:	Pungent
3.14 Fruit size:	Very small
3.15 Fruit colour while ripening:	Green to black

Male plant

3.16 Spike length (cm):	3.5
3.17 Number of stamens:	2.0
3.18 Stamen filament length:	Short

Male spike

1. *Passport Details*

1.1 Name of the species:	*Piper mullesua* Buch.-Ham
1.2 Accession number:	5405
1.3 IC number:	Not allotted
1.4 Place of collection:	Naduvattoom, Nilgiris

2. *Morphological descriptors*

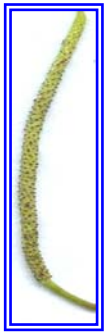
2.1 Plant growth habit:	Climbing
2.2 Branching type:	Dimorphic
2.3 Shoot tip colour:	Light purple
2.4 Runner shoot production:	Many
2.5 Holding capacity:	Weak
2.6 Adventitious root production:	Few
2.7 Lateral branch habit:	Horizontal
2.8 Lateral branch length:	32.0
2.9 Number of nodes per lateral branch:	19.0
2.10 Leaf petiole length (cm):	0.6
2.11 Leaf length (cm):	8.1
2.12 Leaf width (cm):	2.8
2.13 Leaf lamina shape:	Ovate
2.14 Leaf base shape:	Round
2.15 Leaf margin:	Entire
2.16 Type of veining:	Acrodromous
2.17 Leaf texture:	Glabrous membranous
2.18 Leaf hairiness:	No hairs

3. *Reproductive characters*

3.1 Spike orientation:	Erect
3.2 Spike shape:	Globose
3.3 Spike colour:	Green
3.4 Spike length (cm):	1.0 cm
3.5 Type of hermaphroditism:	Pistillate flowers only
3.6 Peduncle length (cm):	2.3
3.7 Number of spikes per lateral branches:	18
3.8 Flower arrangement:	Free
3.9 Spike texture:	Glabrou
3.10 Bract type	Peltate orbicular
3.11 Flower nature:	Sessile
3.12 Fruit shape:	Round
3.13 Fruit taste:	Spicy
3.14 Fruit size:	Very small
3.15 Fruit colour while ripening:	Green to black

Male plant

3.16 Spike length (cm):	4.2
3.17 Number of stamens:	Two
3.18 Stamen filament length:	Intermediate



Male spike

1. *Passport Details*

1.1 Name of the species:	*Piper silentvalleyensis* R.
1.2 Accession number:	5407
1.3 IC number:	Not alloted
1.4 Place of collection:	Paikara Nilgiris

2. *Morphological descriptors*

2.1 Plant growth habit:	Climbing
2.2 Branching type:	Polymorphic
2.3 Shoot tip colour:	Greenish Yellow
2.4 Runner shoot production:	Few
2.5 Holding capacity:	Strong
2.6 Adventitious root production:	Many
2.7 Lateral branch habit:	Horizontal
2.8 Lateral branch length:	32.1
2.9 Number of nodes per lateral branch:	18.0
2.10 Leaf petiole length (cm):	0.6
2.11 Leaf length (cm):	5.18
2.12 Leaf width (cm):	2.1
2.13 Leaf lamina shape:	Ovate
2.14 Leaf base shape:	Round
2.15 Leaf margin:	Entire
2.16 Type of veining:	Acrodromous
2.17 Leaf texture:	Glabrous coriaceous
2.18 Leaf hairiness:	No hairs

3. *Reproductive characters*

3.1 Spike orientation:	Erect
3.2 Spike shape:	Cylindrical
3.3 Spike colour:	Green
3.4 Spike length (cm):	1.83
3.5 Type of hermaphroditism:	Predominantly bisexual
3.6 Peduncle length (cm):	0.4
3.7 Number of spikes per lateral branches:	4.0
3.8 Flower arrangement:	Free
3.9 Spike texture:	Glabrous
3.10 Bract type	Peltate orbicular
3.11 Flower nature:	Sessile
3.12 Fruit shape:	Round
3.13 Fruit taste:	Spicy
3.14 Fruit size:	Very small
3.15 Fruit colour while ripening:	Green to black

Male plant

3.16 Spike length (cm):	1.83
3.17 Number of stamens:	Two
3.18 Stamen filament length:	Intermediate

Male spike

1. *Passport Details*

1.1 Name of the species:	*Piper attenuatum* Buch.-Ham.
1.2 Accession number:	0699
1.3 IC number:	318274
1.4 Place of collection:	Peruvannamuzhi, Calicut

2. *Morphological descriptors*

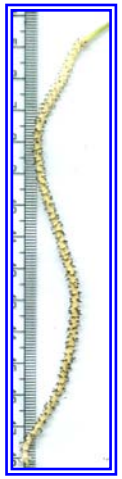
2.1 Plant growth habit:	Climbing
2.2 Branching type:	Dimorphic
2.3 Shoot tip colour:	Greenish Yellow
2.4 Runner shoot production:	Many
2.5 Holding capacity:	Strong
2.6 Adventitious root production:	Many
2.7 Lateral branch habit:	Horizontal
2.8 Lateral branch length:	58.0
2.9 Number of nodes per lateral branch:	20.0
2.10 Leaf petiole length (cm):	1.7
2.11 Leaf length (cm):	10.6
2.12 Leaf width (cm):	5.2
2.13 Leaf lamina shape:	Ovate-elliptic
2.14 Leaf base shape:	Round
2.15 Leaf margin:	Entire
2.16 Type of veining:	Campylodromous
2.17 Leaf texture:	Glabrous membraneous
2.18 Leaf hairiness:	No hairs

3. *Reproductive characters*

3.1 Spike orientation:	Pendent
3.2 Spike shape:	Filiform
3.3 Spike colour:	Green
3.4 Spike length (cm):	21.0
3.5 Type of hermaphroditism:	Pistillate flowers only
3.6 Peduncle length (cm):	1.7
3.7 Number of spikes per lateral branches:	9.0
3.8 Flower arrangement:	Free
3.9 Spike texture:	Glabrous
3.10 Bract type	Sessile, oblong and adnate to rachis
3.11 Flower nature:	Sessile
3.12 Fruit shape:	Ovate
3.13 Fruit taste:	Bitter
3.14 Fruit size:	Small
3.15 Fruit colour while ripening:	Green to black

Male plant

3.16 Spike length (cm):	18.0
3.17 Number of stamens:	4.0
3.18 Stamen filament length:	Long



Male spike

1. *Passport Details*

1.1 Name of the species:	*Piper argyrophyllum* Miq.
1.2 Accession number:	0625
1.3 IC number:	318241
1.4 Place of collection:	Sastanode Thiruvananthapuram

2. *Morphological descriptors*

2.1 Plant growth habit:	Climbing
2.2 Branching type:	Dimorphic
2.3 Shoot tip colour:	Light green
2.4 Runner shoot production:	Many
2.5 Holding capacity:	Strong
2.6 Adventitious root production:	Many
2.7 Lateral branch habit:	Horizontal
2.8 Lateral branch length:	45.0
2.9 Number of nodes per lateral branch:	11
2.10 Leaf petiole length (cm):	1.0
2.11 Leaf length (cm):	9.2
2.12 Leaf width (cm):	3.9
2.13 Leaf lamina shape:	Ovate-elliptic
2.14 Leaf base shape:	Round
2.15 Leaf margin:	Entire
2.16 Type of veining:	Campylodromous
2.17 Leaf texture:	Downy membranous
2.18 Leaf hairiness:	Along with the veins

3. *Reproductive characters*

3.1 Spike orientation:	Pendent
3.2 Spike shape:	Filiform
3.3 Spike colour:	Light green
3.4 Spike length (cm):	11.5
3.5 Type of hermaphroditism:	Pistillate flowers only
3.6 Peduncle length (cm):	1.2
3.7 Number of spikes per lateral branches:	9.0
3.8 Flower arrangement:	Free
3.9 Spike texture:	Glabrous
3.10 Bract type	Sessile, oblong and adnate to rachis
3.11 Flower nature:	Free
3.12 Fruit shape:	Ovate
3.13 Fruit taste:	Bitter
3.14 Fruit size:	Small
3.15 Fruit colour while ripening:	Green to black

Male plant

3.16 Spike length (cm):	12.4
3.17 Number of stamens:	Three
3.18 Stamen filament length:	Intermediate

Male spike

1. *Passport Details*

1.1 Name of the species:	*Piper hymenophyllum*
1.2 Accession number:	5345
1.3 IC number:	285501
1.4 Place of collection:	Thrissur

2. *Morphological descriptors*

2.1 Plant growth habit:	Climbing
2.2 Branching type:	Dimorphic
2.3 Shoot tip colour:	Light green
2.4 Runner shoot production:	Many
2.5 Holding capacity:	Strong
2.6 Adventitious root production:	Many
2.7 Lateral branch habit:	Erect
2.8 Lateral branch length:	48.0
2.9 Number of nodes per lateral branch:	9.0
2.10 Leaf petiole length (cm):	1.8
2.11 Leaf length (cm):	12.0
2.12 Leaf width (cm):	6.2
2.13 Leaf lamina shape:	Ovate- elliptic
2.14 Leaf base shape:	Round
2.15 Leaf margin:	Entire
2.16 Type of veining:	Campylodromous
2.17 Leaf texture:	Glabrous coriaceous
2.18 Leaf hairiness:	All over the leaves

3. *Reproductive characters*

3.1 Spike orientation:	Erect
3.2 Spike shape:	Filiform
3.3 Spike colour:	Green
3.4 Spike length (cm):	12.1
3.5 Type of hermaphroditism:	Pistillate flowers only
3.6 Peduncle length (cm):	2.5
3.7 Number of spikes per lateral branches:	15
3.8 Flower arrangement:	Free
3.9 Spike texture:	Glabrous
3.10 Bract type	Sessile, oblong and adnate to rachis
3.11 Flower nature:	Sessile
3.12 Fruit shape:	Ovate
3.13 Fruit taste:	Bitter
3.14 Fruit size:	Small
3.15 Fruit colour while ripening:	Green to black
Male plant	
3.16 Spike length (cm):	9.5
3.17 Number of stamens:	Two
3.18 Stamen filament length:	Intermediate

Male spike

1. *Passport Details*

1.1 Name of the species:	*Piper bababudani*
1.2 Accession number:	4674
1.3 IC number:	325144
1.4 Place of collection:	Kodagu, Karnataka

2. *Morphological descriptors*

2.1 Plant growth habit:	Climbing
2.2 Branching type:	Polymorphic
2.3 Shoot tip colour:	Dark purple
2.4 Runner shoot production:	Many
2.5 Holding capacity:	Strong
2.6 Adventitious root production:	Many
2.7 Lateral branch habit:	Erect
2.8 Lateral branch length:	42.0
2.9 Number of nodes per lateral branch:	7.0
2.10 Leaf petiole length (cm):	2.1
2.11 Leaf length (cm):	17.8
2.12 Leaf width (cm):	8.2
2.13 Leaf lamina shape:	Ovate
2.14 Leaf base shape:	Round
2.15 Leaf margin:	Entire
2.16 Type of veining:	Acrodromous
2.17 Leaf texture:	Glabrous coriaceous
2.18 Leaf hairiness:	No hairs

3. *Reproductive characters*

3.1 Spike orientation:	Erect
3.2 Spike shape:	Filiform
3.3 Spike colour:	Light Yellow
3.4 Spike length (cm):	10.8
3.5 Type of hermaphroditism:	Pistillate flowers only
3.6 Peduncle length (cm):	2.1
3.7 Number of spikes per lateral branches:	6.0
3.8 Flower arrangement:	Free
3.9 Spike texture:	Glabrous
3.10 Bract type	Deeply copular with decurrent base
3.11 Flower nature:	Sessile
3.12 Fruit shape:	Round
3.13 Fruit taste:	Initially bitter then pungent
3.14 Fruit size:	Large
3.15 Fruit colour while ripening:	Green to Yellow and Orange

Male plant

3.16 Spike length (cm):	12.1
3.17 Number of stamens:	Two
3.18 Stamen filament length:	Short

Male spike

1. *Passport Details*

1.1 Name of the species:	*Piper trichostachyon*
1.2 Accession number:	3340
1.3 IC number:	318491
1.4 Place of collection:	Waynad, Kerala

2. *Morphological descriptors*

2.1 Plant growth habit:	Climbing
2.2 Branching type:	Polymorphic
2.3 Shoot tip colour:	Dark purple
2.4 Runner shoot production:	Few
2.5 Holding capacity:	Strong
2.6 Adventitious root production:	Few
2.7 Lateral branch habit:	Horizontal
2.8 Lateral branch length:	46.0
2.9 Number of nodes per lateral branch:	28.0
2.10 Leaf petiole length (cm):	1.2
2.11 Leaf length (cm):	17.0
2.12 Leaf width (cm):	6.7
2.13 Leaf lamina shape:	Elliptic- lanceolate
2.14 Leaf base shape:	Round
2.15 Leaf margin:	Entire
2.16 Type of veining:	Acrodromous
2.17 Leaf texture:	Glabrous coriaceous
2.18 Leaf hairiness:	No hairs

3. *Reproductive characters*

3.1 Spike orientation:	Erect
3.2 Spike shape:	Filiform
3.3 Spike colour:	Light Yellow
3.4 Spike length (cm):	6.1
3.5 Type of hermaphroditism:	Pistillate flowers only
3.6 Peduncle length (cm):	1.1
3.7 Number of spikes per lateral branches:	4.0
3.8 Flower arrangement:	Free
3.9 Spike texture:	Hirtellous
3.10 Bract type	Fleshy, connate, transformed into a cup
3.11 Flower nature:	Shortly stipitate
3.12 Fruit shape:	Oblong
3.13 Fruit taste:	Bitter
3.14 Fruit size:	Extra bold
3.15 Fruit colour while ripening:	Green to Yellow and Orange

Male plant

3.16 Spike length (cm):	7.5
3.17 Number of stamens:	Two
3.18 Stamen filament length:	Short

Male spike

1. *Passport Details*

1.1 Name of the species:	*Piper galeatum*
1.2 Accession number:	3339
1.3 IC number:	318490
1.4 Place of collection:	Waynad, Kerala

2. *Morphological descriptors*

2.1 Plant growth habit:	Climbing
2.2 Branching type:	Polymorphic
2.3 Shoot tip colour:	Dark purple
2.4 Runner shoot production:	Few
2.5 Holding capacity:	Strong
2.6 Adventitious root production:	Many
2.7 Lateral branch habit:	Horizontal
2.8 Lateral branch length:	46.5
2.9 Number of nodes per lateral branch:	26.0
2.10 Leaf petiole length (cm):	1.9
2.11 Leaf length (cm):	15.8
2.12 Leaf width (cm):	6.6
2.13 Leaf lamina shape:	Elliptic- lanceolate
2.14 Leaf base shape:	Round
2.15 Leaf margin:	Entire
2.16 Type of veining:	Acrodromous
2.17 Leaf texture:	Glabrous coriaceous
2.18 Leaf hairiness:	No hairs

3. *Reproductive characters*

3.1 Spike orientation:	Erect
3.2 Spike shape:	Filiform
3.3 Spike colour:	Greenish Yellow
3.4 Spike length (cm):	4.5
3.5 Type of hermaphroditism:	Pistillate flowers only
3.6 Peduncle length (cm):	1.0
3.7 Number of spikes per lateral branches:	5.0
3.8 Flower arrangement:	Free
3.9 Spike texture:	Glabrous
3.10 Bract type	Fleshy, connate, transformed into a cup
3.11 Flower nature:	Shortly stipitate
3.12 Fruit shape:	Oblong
3.13 Fruit taste:	Bitter
3.14 Fruit size:	Extra bold
3.15 Fruit colour while ripening:	Green to Yellow and Orange

Male plant

3.16 Spike length (cm):	4.2
3.17 Number of stamens:	Two
3.18 Stamen filament length:	Short

Male spike

1. *Passport Details*

1.1 Name of the species:	*Piper sugandhi*
1.2 Accession number:	4660
1.3 IC number:	Not allotted
1.4 Place of collection:	Idukki, Kerala

2. *Morphological descriptors*

2.1 Plant growth habit:	Climbing
2.2 Branching type:	Dimorphic
2.3 Shoot tip colour:	Dark purple
2.4 Runner shoot production:	Many
2.5 Holding capacity:	Strong
2.6 Adventitious root production:	Many
2.7 Lateral branch habit:	Horizontal
2.8 Lateral branch length:	46.0
2.9 Number of nodes per lateral branch:	32.0
2.10 Leaf petiole length (cm):	2.2
2.11 Leaf length (cm):	12.5
2.12 Leaf width (cm):	6.0
2.13 Leaf lamina shape:	Ovate-lanceolate
2.14 Leaf base shape:	Acute
2.15 Leaf margin:	Entire
2.16 Type of veining:	Acrodromous
2.17 Leaf texture:	Glabrous coriaceous
2.18 Leaf hairiness:	No hairs

3. *Reproductive characters*

3.1 Spike orientation:	Pendent
3.2 Spike shape:	Filiform
3.3 Spike colour:	Dark purple
3.4 Spike length (cm):	14.0
3.5 Type of hermaphroditism:	Pistillate flowers only
3.6 Peduncle length (cm):	1.0
3.7 Number of spikes per lateral branches:	8.0
3.8 Flower arrangement:	Free
3.9 Spike texture:	Glabrous
3.10 Bract type	Cupular with decurrent base
3.11 Flower nature:	Shortly stipitate
3.12 Fruit shape:	Round
3.13 Fruit taste:	Pungent
3.14 Fruit size:	Large
3.15 Fruit colour while ripening:	Green to yellow, and red

Male plant

3.16 Spike length (cm):	7.5
3.17 Number of stamens:	2.0
3.18 Stamen filament length:	2.0

Male spike

1. *Passport Details*

1.1 Name of the species:	*Piper wightii*
1.2 Accession number:	5410
1.3 IC number:	Not Allotted
1.4 Place of collection:	Nilgiris, Tamil Nadu

2. *Morphological descriptors*

2.1 Plant growth habit:	Climbing
2.2 Branching type:	Polymorphic
2.3 Shoot tip colour:	Greenish Yellow
2.4 Runner shoot production:	Many
2.5 Holding capacity:	Strong
2.6 Adventitious root production:	Few
2.7 Lateral branch habit:	Horizontal
2.8 Lateral branch length:	42.0
2.9 Number of nodes per lateral branch:	36.0
2.10 Leaf petiole length (cm):	1.9
2.11 Leaf length (cm):	11.86
2.12 Leaf width (cm):	7.43
2.13 Leaf lamina shape:	Ovate
2.14 Leaf base shape:	Round
2.15 Leaf margin:	Entire
2.16 Type of veining:	Acrodromous
2.17 Leaf texture:	Glabrous coriaceous
2.18 Leaf hairiness:	No hairs

3. *Reproductive characters*

3.1 Spike orientation:	Pendent
3.2 Spike shape:	Filiform
3.3 Spike colour:	Green
3.4 Spike length (cm):	8.3
3.5 Type of hermaphroditism:	Pistillate flowers only
3.6 Peduncle length (cm):	1.2
3.7 Number of spikes per lateral branches:	6.0
3.8 Flower arrangement:	Free
3.9 Spike texture:	Glabrous
3.10 Bract type	Peltate-oblong
3.11 Flower nature:	Sessile
3.12 Fruit shape:	Round
3.13 Fruit taste:	Bitter
3.14 Fruit size:	Intermediate
3.15 Fruit colour while ripening:	Green to yellow.

Male plant

3.16 Spike length (cm):	12.5
3.17 Number of stamens:	Two
3.18 Stamen filament length:	Intermediate

Male spike

1. *Passport Details*

1.1 Name of the species:	*Piper schmidtii*
1.2 Accession number:	5403
1.3 IC number:	Not allotted
1.4 Place of collection:	Nilgiris, Tamil Nadu

2. *Morphological descriptors*

2.1 Plant growth habit:	Climbing
2.2 Branching type:	Polymorphic
2.3 Shoot tip colour:	Dark purple
2.4 Runner shoot production:	Few
2.5 Holding capacity:	Strong
2.6 Adventitious root production:	Many
2.7 Lateral branch habit:	Erect
2.8 Lateral branch length:	38.0
2.9 Number of nodes per lateral branch:	28.0
2.10 Leaf petiole length (cm):	1.6
2.11 Leaf length (cm):	8.5
2.12 Leaf width (cm):	4.7
2.13 Leaf lamina shape:	Ovate
2.14 Leaf base shape:	Round
2.15 Leaf margin:	Entire
2.16 Type of veining:	Acrodromous
2.17 Leaf texture:	Glabrous coriaceous
2.18 Leaf hairiness:	No hairs

3. *Reproductive characters*

3.1 Spike orientation:	Pendent
3.2 Spike shape:	Filiform
3.3 Spike colour:	Green
3.4 Spike length (cm):	7.07
3.5 Type of hermaphroditism:	Pistillate flowers only
3.6 Peduncle length (cm):	1.1
3.7 Number of spikes per lateral branches:	8.0
3.8 Flower arrangement:	Free
3.9 Spike texture:	Glabrous
3.10 Bract type	Peltate orbicular
3.11 Flower nature:	Sessile
3.12 Fruit shape:	Ovate
3.13 Fruit taste:	Bitter
3.14 Fruit size:	Intermediate
3.15 Fruit colour while ripening:	Green to yellow, orange and red

Male plant

3.16 Spike length (cm):	13.5
3.17 Number of stamens:	2
3.18 Stamen filament length:	intermediate

Male spike

1. *Passport Details*

1.1 Name of the species:	*Piper nigrum* L
1.2 Accession number:	0269
1.3 IC number:	318102
1.4 Place of collection:	Palaghat Kerala

2. *Morphological descriptors*

2.1 Plant growth habit:	Climbing
2.2 Branching type:	Dimorphic
2.3 Shoot tip colour:	Light purple
2.4 Runner shoot production:	Many
2.5 Holding capacity:	Strong
2.6 Adventitious root production:	Many
2.7 Lateral branch habit:	Horizontal
2.8 Lateral branch length:	32.0
2.9 Number of nodes per lateral branch:	29.0
2.10 Leaf petiole length (cm):	1.6
2.11 Leaf length (cm):	16.4
2.12 Leaf width (cm):	8.4
2.13 Leaf lamina shape:	Ovate
2.14 Leaf base shape:	Cordate
2.15 Leaf margin:	Entire
2.16 Type of veining:	Acrodromous
2.17 Leaf texture:	Glabrous coriaceous
2.18 Leaf hairiness:	

3. *Reproductive characters*

3.1 Spike orientation:	Pendent
3.2 Spike shape:	Filiform
3.3 Spike colour:	Light green
3.4 Spike length (cm):	9.2
3.5 Type of hermaphroditism:	Pistillate flowers only
3.6 Peduncle length (cm):	1.2
3.7 Number of spikes per lateral branches:	16.0
3.8 Flower arrangement:	Free
3.9 Spike texture:	Glabrous
3.10 Bract type	Cupular with decurrent base
3.11 Flower nature:	Sessile
3.12 Fruit shape:	Round
3.13 Fruit taste:	Bitter
3.14 Fruit size:	Intermediate
3.15 Fruit colour while ripening:	Green to yellow, orange and red

Male plant

3.16 Spike length (cm):	7.8
3.17 Number of stamens:	Two
3.18 Stamen filament length:	Short

Male spike

1. *Passport Details*

1.1 Name of the species:	*Piper barberi* Gamble
1.2 Accession number:	0614
1.3 IC number:	318232
1.4 Place of collection:	Kanyakumari, Tamil Nadu

2. *Morphological descriptors*

2.1 Plant growth habit:	Climbing
2.2 Branching type:	Polymorphic
2.3 Shoot tip colour:	Light purple
2.4 Runner shoot production:	Many
2.5 Holding capacity:	Weak
2.6 Adventitious root production:	Few
2.7 Lateral branch habit:	Horizontal
2.8 Lateral branch length:	24.5
2.9 Number of nodes per lateral branch:	22
2.10 Leaf petiole length (cm):	2.1
2.11 Leaf length (cm):	14.5
2.12 Leaf width (cm):	5.1
2.13 Leaf lamina shape:	Elliptic- lanceolate
2.14 Leaf base shape:	Oblique
2.15 Leaf margin:	Entire
2.16 Type of veining:	Eucamptodromous
2.17 Leaf texture:	Glabrous sarcous
2.18 Leaf hairiness:	No hairs

3. *Reproductive characters*

3.1 Spike orientation:	Pendent
3.2 Spike shape:	Cylindrical
3.3 Spike colour:	Green
3.4 Spike length (cm):	7.1
3.5 Type of hermaphroditism:	Pistillate flowers only
3.6 Peduncle length (cm):	10.1
3.7 Number of spikes per lateral branches:	4.0
3.8 Flower arrangement:	Free
3.9 Spike texture:	Glabrous
3.10 Bract type	Peltate orbicular
3.11 Flower nature:	Sessile
3.12 Fruit shape:	Round
3.13 Fruit taste:	Bitter
3.14 Fruit size:	Intermediate
3.15 Fruit colour while ripening:	Green to yellow and red

Male plant

3.16 Spike length (cm):	
3.17 Number of stamens:	
3.18 Stamen filament length:	

Male spike

Morphological characterization of Spike, Flower and Fruit characters

The spikes are either pendulous or erect. Among the South Indian species erect spikes are observed in species like *Piper longum, P. hapnium, P. mullesua* and *P. silentvalleyensis.* Erect spikes seen exotic species like *P. arboreum, P. chaba, P. magnificum* and two more species. The spike shape ranges from filiform, cylindrical and globose. The flowers are either laterally fused or free. Spike length in Piper accessions ranges from 1.0 cm in *P. mullesua* to 21.0 cm as in the case of *P. attenuatum.* The fruits differ in size and shape. The fruits are either free or fused laterally and are minute as in *P. longum, P. hapnium* or bold as in *P. galeatum, P. trochostachyon, P. sugandhi* and some accessions of *P.nigrum.* Variability of spike and fruit characters are given in Table: 17 & 18.

Table 17. Spike characters of *Piper* spp. occurring in South India

Species	Spike length (cm)	Peduncle length (cm)	Spike shape	Spike orientation	Spike texture	Bract type
P. argyrophyllym	11.50	1.2	Filiform	Pendent	Glabrous	Sessile, oblong and adnate to rachis
P. attenuatum	21.00	1.7	Filiform	Pendent	Galbrous	Sessile, oblong and adnate to rachis
P. barberi	7.10	10.1	Cylindrical	Pendent	Glabrous	Peltate orbicular
P. bababudani	10.80	2.1	Filiform	Pendent	Glabrous	Cupular with decurrent base
P. galeatum	10.50	1.0	Filiform	Pendent	Glabrous	Fleshy, connate, transformed into a cup
P. hapnium	5.50	2.2	Cylindrical	Erect	Glabrous	Peltate orbicular
P. hymenophyllum	12.10	2.5	Filiform	Pendent	Glabrous	Sessile, oblong and adnate to rachis
P. longum	2.10	1.5	Cylindrical	Erect	Glabrous	Peltate orbicular
P. mullesua	1.00	2.3	Globose	Erect	Glabrous	Peltate orbicular
P. nigrum	9.20	1.2	Filiform	Pendent	Glabrous	Cupular with decurrent base
P. silentvalleyensis	1.83	0.4	Filiform	Erect	Glabrous	Peltate orbicular
P. sugandhi	14.00	1.0	Filiform	Pendent	Glabrous	Cupular with decurrent base
P. sugandhi var. brevipilis	6.90	1.4	Filiform	Pendent	Hirtellous	Cupular with decurrent base
P. schmidtii	7.07	1.1	Filiform	Pendent	Glabrous	Peltate orbicular
P. trichostachyon	6.10	1.1	Filiform	Pendent	Hirtellous	Fleshy, connate, transformed into a cup
P. wightii	8.30	1.2	Filiform	Pendent	Glabrous	Peltate orbicular

Table 18. Fruit characters of *Piper* spp. occurring in South India

Species	Fruit nature	Fruit shape	Fruit taste	Colour change while ripening
P. argyrophyllym	Free	Ovate to oblong	Bitter	Green to black
P. attenuatum	Free	Ovate to oblong	Bitter	Green to black
P. barberi	Free	Round	Bitter	Green to red
P. bababudani	Free	Round	Biiter/ pungent	Green to yellow then red
P. galeatum	Free	Ovate to oblong	Bitter	Green to yellow
P. hapnium	Fused	Elliptical	Bitter/ Spicy	Green to black
P. hymenophyllum	Free	Ovate to oblong	Bitter	Green to black
P. longum	Fused	Elliptical	Bitter/ Spicy	Green to black
P. mullesua	Free	Ovate to oblong	Spicy	Green to black
P. nigrum	Free	Round	Bitter/ Pungent	Green toorange then red
P. silentvalleyensis	Free	Ovate to oblong	Bitter/ Spicy	Green to black
P. sugandhi	Free	Round	Bitter/ Pungent	Green to orange then red
P. sugandhi var. brevipilis	Free	Round	Bitter/ Pungent	Green to orange then red
P. schmidtii	Free	Obovate	Bitter	Green to yellow then red
P. trichostachyon	Free	Ovate to oblong	Bitter/ Pungent	Green to yellow
P. wightii	Free	Ovate to oblong	Bitter/ Pungent	Green to yellow

Key for identification of South Indian *Piper* species

Spike

- **Erect**
  - Bract peltate
  - Elliptic lanceolate leaves, spike cylindrical, fruits laterally fused fruit taste-pungent
    - Creeper, leaves glabrous, spike 2-3cm, distribution 40-300 m. → *P. longum*
    - Shy climber, slightly pubescent leaves, ♀spike > 4 cm, distribution 250-360 m. → *P. hapnium*
  - Ovate coriaceous leaves, fruits not fused laterally distribution 600-1740 m taste-spicy → *P. mullesua*
- **Pendant**
  - Venation reticulate, spike cylindrical, very long pedicel, bracts peltate distribution 600-700 m taste-pungent → *P. barberi*
  - Spike cylindrical, hermaphrodite → *P. silentvalleyensis*
  - Leaves ribbed, spike filiform

Leaves membraneous, campylodromous venation, bract fused laterally free margins, ripe fruit black, taste-bitter

- Glabrous leaves, 7 nerved, long spike → *P. attenuatum*
- Downy along the veins 5 nerved → *P. argyrophyllum*
  - Pubescent leaves 7 nerved → *P. hymenophyllum*

Venation acrodromous bracts peltate distribution >1750 m taste-bitter

- Light green shoot tip, membraneous leaf silvery scale beneath → *P. wightii*
- Light purple shoot tip leathery leaves oblong berries → *P. schmidtii*

Bract fleshy, reni form distribution 440-1150m MSL taste-bitter

- Spike glabrous → *P. galeatum*
- Spike minutely hairy → *P. trichostachyon*

Bract cupular taste-bitter/ pungent

- Purple spike, stalked berries → *P. sugandhi*
- Bract deeply cupular, fruit sessile yellow-red → *P. bababudani*
- Fruit sessile, distribution 40-1150 m → *P. nigrum*

Biometrical studies

1. Cluster analysis

The numerical taxonomic study of South Indian species was carried out using 17 Operational Taxonomic Units (OT Us) (Table 19). Observations on 30 characters (Table 20) were recorded and cluster analysis was conducted using 'average linkage' for grouping the characters and 'centroid method' for grouping the taxa. Highly significant correlations were observed between certain characters.

Table 19. *Piper* taxa used for principal component analysis

OTU No	SPECIES
1	*Piper attenuatum*
2	*P. argyrophyllum*
3	*P. galeatum*
4	*P. hymenophyllum*
5	*P. longum*
6	*P. mullesua*
7	*P. schmidtii*
8	*P. silentvalleyensis*
9	*P. trichostachyon*
10	*P. wightii*
11	*P. nigrum* (1) Acc.no.2077
12	*P. nigrum* (2) Acc.no.2071
13	*P. nigrum* (3) Acc.no.2009
14	*P. nigrum* (4) Acc.no.2059
15	*P. nigrum* (5) Acc.no.2060
16	*P. nigrum* (6) Acc.no.2015
17	*P. nigrum* (7) Acc.no.2062

The average linage clustering of characters based on character correlations led to the identification of the following clusters.

1. Leaf length, leaf breadth, leaf size index
2. Fruit taste, presence of gall forming thrips
3. Leaf length/ leaf breadth ratio, number of ribs on the leaf, ecological distribution and growth habit.
4. Spike length, peduncle length, spike orientation and fruit shape
5. Leaf length/ spike length ratio and spike shape
6. Leaf shape and leaf base

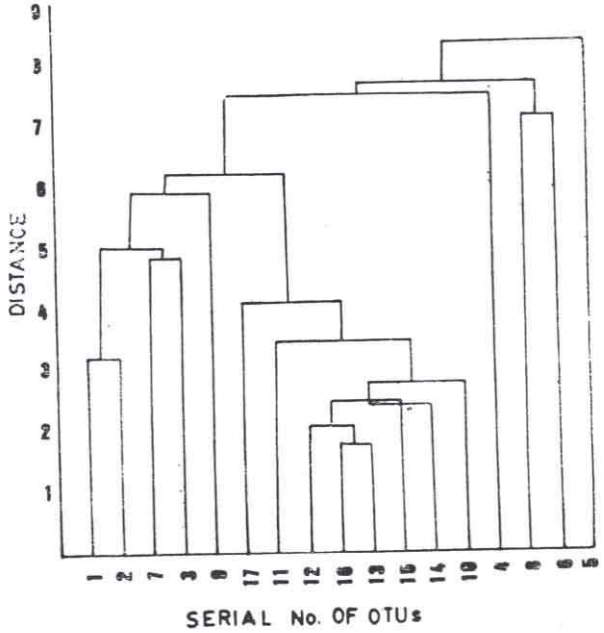
Centroid cluster analysis for grouping the taxa led to the recognition of six clusters as follows:

1. Cluster A: *P. attenuatum, P. argyrophyllum*
2. Cluster B: *P. schmidtii, P. galeatum, P. trichostachyon*
3. Cluster C: *P. nigrum, P. wightii*
4. Cluster D: *P. nigrum, P. wightii*
5. Cluster E: *P. silentvallensis, P. mullesua*
6. Cluster F: *P.longum*

Table 20. Descriptors used for cluster analysis

Code number	Details of character
1.	Leaf length in mm
2.	Leaf breadth in mm
3.	Leaf length/ leaf breadth
4.	Leaf size index
5.	Petiole length in mm
6.	Spike length in mm
7.	Peduncle length in mm
8.	Leaf length/ Spike length
9.	Stomata density per mm^2
10.	Guard cell length in mm
11.	Guard cell breadth in mm
12.	Distance from leaf base to the 2^{nd} pair of ribs
13.	Number of ribs
14.	Leaf shape (1: Ovate to ovate-elliptic; 2: Cordate; 3: Ovate lanceolate; 4: elliptic to elliptic lanceolate
15.	Leaf base (1: round; 2: Cordate; 3: acute to attenuate)
16.	Leaf texture (1: Glabrous; 2: Sparsely hairy mainly on the veins; 3: hirsute)
17.	Leaf nature (1: membranous; 2: coriaceous)
18.	Spike shape (1; filiform; 2; Cylindrical; Globose)
19.	Spike orientation (1: pendulous; 2: erect)
20.	Spike texture (1: Glabrous; 2: hirtellous)
21.	Bract type (1: Sessile, adnate to rachis; 2: Stalked, peltate orbicular; 3: copular with decurrent base; 4: fleshy connate, cup like; 5: oblong, angular and free all around)
22.	Stamen number (1: two; 2: three or four)
23.	Fruit nature (1: free; 2: fused)
24.	Fruit shape (1: ovate-oblong, 2. Spherical; 3: elliptical; 4: obovate
25.	Fruit colour change on ripening (1: Green to orange and red; 2: green to yellow; 3: green to black)

26.	Fruit taste (1: pungent; 2: spicy and mildly pungent; 3: bitter)
27.	Plant type (1: dioecious; 2: monoeceous; 3: predominantly monoecious)
28.	Growth habit (1: shrubby climber; 2: stout woody climber; 3: no climbing habit and trailing on the ground)
29.	Distribution in the natural habitat (1: plains to lower elevations (from 0-500 m); 2: plains to higher elevations (from 0-1500 m) 3: lower elevations to higher elevations (from 500 – 1500 m); 4: found only at high elevations.
30.	Presence of thrips infestation



Clustering of *Piper* spp. by centroid linkage. Dendrogram representing the distances between the taxa studied.

2. Principal component analysis

Bio systematical studies were carried out in *Piper* species using 17 Operational Taxonomic Units (OTUs) comprising 10 species and seven accessions of *Piper nigrum* (Table---)and 30 characters (Table---)to carry out Principal Component Analysis for establishing similarity/ dissimilarity among the taxa.

The analysis involved the following steps:

1. Computation of the correlation matrix for the thirty characters.
2. Computation of Eigen vectors and Eigen roots and estimation of PC loadings. These indicate how far each character is correlated with the principal components.

3. Rotation of PC loadings to obtain a simple interpretation so that each PC can be taken to be representative of a few sets of highly correlated characters and
4. The computation of PC scores. The PC score is a numerical value which expresses the degree to which each case or OUT possesses the property that the PC describes.

The study has resulted identification of seven PC that accounted for almost all the variance observed among the OTUs. The first PC consist of leaf and fruit characters (leaf length, leaf breadth, leaf size index, petiole length, distance from the base to the second pair of ribs, plant type, fruit colour, fruit taste and thrips infestation). The second PC consists of spike length, peduncle length, spike orientation and fruit shape. The fourth PC consists of leaf length/spike length index and spike shape. The sixth PC consists of guard cell length, guard cell breadth and leaf texture. The seventh PC consists of spike texture. Distribution of OTUs between the PCs can give insight in to the nature of divergence among species . *P. attenuatum* and *P. argyrophyllum* get differentiated from other taxa by PC-4, *P. hymenophyllum* gets differentiated by PCs 1& 6. *P. longum* is distinct because of PCs 1 & 3. *P. mullesua* is distinct from all other species due to the PCs 2, 3 & 5. PCs 1, 2, 3, 4, 6 & 7 are important in differentiating *P. schmidtii*. PCs 2, 3 & 5 differentiated *P. silentvalleyensis* from all other taxa. *P. trichostachyon* gets separated from other taxa by virtue of PCs 4 & 7. PC 1 is important in separating *P. nigrum* from other taxa. This study gives an insight into the relationship among the South Indian taxa of *Piper*, especially on the characters that led to the differentiation of the individual species.

Cluster analysis of 44 major cultivars and seven wild collections of *P. nigrum* (51 OTUs) using 22 characters led to the following groupings:

A. Aimpiriyan, Kalluvally (Pulpally)
B. Poonjaranmunda, Thulamundi
C. Karivilanchy, Kallubancotta, Uddaghere, Uthirancotta, Vellanamban, Valiakaniakkadan, Velliyaranmunda
D. Cheriyakaniakkadan, Neyyattinkaramundi,Arimulaku, Kaniakkadan, Thommankodi,Kuching, Mundi, Bilimalligesara, Vattamundi, Malamundi,

Ottaplackal 1, Neelamundi, Perambramunda, Thevanmundi, Sagar Local, Perumkodi, Kalluvally , Kurimalai, Kottanadan, Arakkulam munda, Jeerakamundi, cholamundi, Cheppukulamundi,Karimkota, Wild Coll. 2077, 2062, 2071, 2015

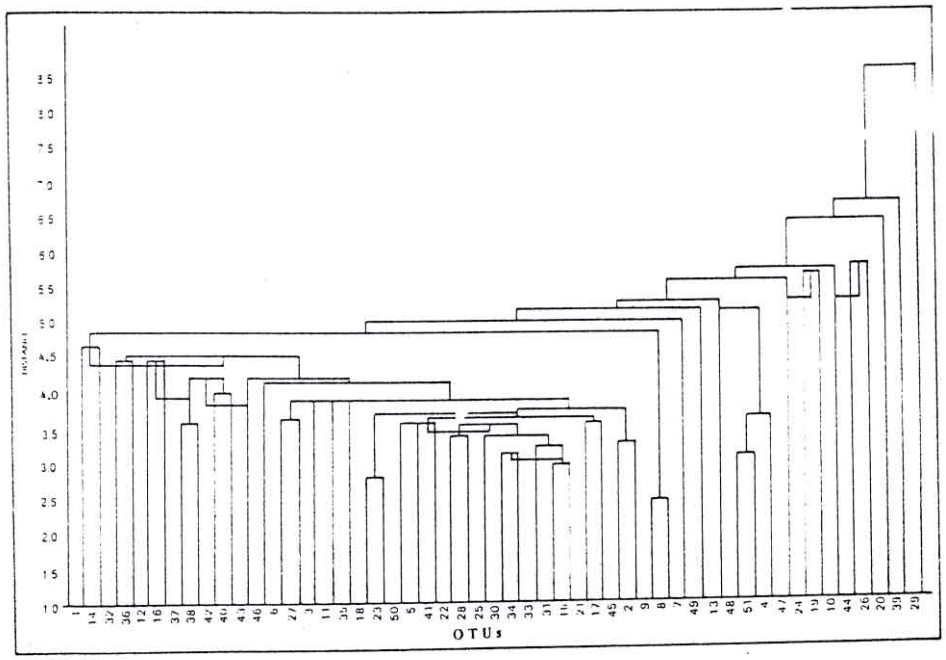
E. Balankotta, Wild coll: 2059, 2062, 2009\
F. Narayakodi, Kuriyalmundi
G. Karimunda'Vokkalu, Nedumchola
H. Kuthiravally
I. Vdakkan
J. Panniyur 1

The pattern of grouping shows that 28 of the 51 cultivars fall in just one group, and four groups have just one cultivar each. Thus Karimunda, Kuthiravally, Vadakkan and Panniyur 1 are in unique groups. Among this Panniyur 1 is a hybrid and Vadakkan a natural triploid. Karimunda, the original home of which is the Kottayam district of Kerala, is the most popular cultivar. Kuthiravally is also a popular cultivar in certain areas. Twenty eight cultivars clustered into a single group (D) and the differences among them for the 22 characters studied are small and they are very difficult to be distinguished when grown together in a field. Computation of intercluster D-values showed that cluster D is closely related to clusters A, B C, indicating that though these cultivars are in ten groups thereby indicating significant morphological divergendce among them. The very distinctive nature of these cultivars probably indicates that domestication of black pepper from the forest grown wild plants could have started at many centeres isolated in space and time.

Inter character correlations among 22 characters studied in black pepper cultivars

	1*	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1*	1.000																					
2	0.542	1.000																				
3	0.437	-0.344	1.000																			
4	0.968	0.879	0.078	1.000																		
5	-0.016	-0.257	0.286	-0.143	1.000																	
6	0.168	-0.143	0.331	0.029	0.701	1.000																
7	0.092	-0.019	0.105	0.038	0.586	0.538	1.000															
8	-0.249	0.096	-0.068	-0.172	0.567	0.149	0.063	1.000														
9	-0.178	-0.037	-0.033	-0.104	1.145	-0.076	-0.120	0.293	1.000													
10	0.277	-0.055	0.375	0.141	0.192	0.191	0.114	-0.083	-0.004	1.000												
11	0.170	0.018	0.383	0.135	-0.006	0.098	0.067	-0.089	0.007	0.571	1.000											
12	0.330	0.260	0.140	0.308	0.027	0.061	0.001	0.030	-0.096	0.076	0.078	1.000										
13	0.384	0.238	-0.172	0.370	-0.024	0.098	0.028	-0.071	-0.186	0.117	0.148	0.509	1.000									
14	0.141	0.080	0.002	0.149	-0.060	0.009	0.029	-0.128	-0.025	-0.002	-0.007	-0.787	0.295	1.000								
15	0.326	0.086	0.195	0.241	-0.245	0.139	-0.103	-0.295	-0.073	0.176	0.171	-0.029	0.045	0.178	1.000							
16	0.181	-0.026	0.196	0.095	-0.163	-0.039	-0.159	-0.071	-0.201	0.184	0.118	0.048	-0.061	0.013	0.634	1.000						
17	-0.036	-0.103	0.027	-0.096	0.060	-0.069	0.108	-0.101	-0.175	-0.016	-0.086	-0.277	-0.115	0.226	-0.243	-0.062	1.000					
18	0.038	0.263	-0.218	0.156	-0.065	0.025	0.050	0.111	-0.045	-0.053	0.054	0.233	0.126	-0.124	-0.162	0.008	-0.159	1.000				
19	-0.222	-0.278	0.024	-0.275	0.078	-0.061	-0.008	0.161	0.022	0.115	-0.019	-0.280	-0.274	0.069	-0.162	-0.075	0.356	-0.225	1.000			
20	-0.319	-0.281	-0.071	-0.360	-0.008	-0.249	-0.099	0.136	-0.034	-0.195	-0.118	-0.364	-0.454	0.144	-0.019	-0.016	0.113	-0.137	0.464	1.000		
21	0.066	0.280	-0.186	0.209	-0.126	-0.144	-0.213	-0.039	0.136	0.074	-0.015	0.187	0.122	-0.130	0.094	0.134	-0.074	0.270	-0.080	-0.041	1.000	
22	-0.109	-0.071	-0.078	-0.111	0.006	0.038	0.058	-0.021	-0.035	-0.126	-0.078	-0.245	-0.045	0.203	-0.135	-0.044	0.202	0.202	0.057	0.289	-0.041	1.000

* 1-22 denote characters studied (Refer Table 1)



Dendrogram based on centroid cluster analysis employing 20 characters in black pepper

BIOCHEMICAL CHARACTERIZATION

The popular cultivars were evaluated for the quality parameters viz. piperine, oleoresin and essential oil. For easy accessibility for the end user they were indexed based on a scale devised and are categorized into high, medium and low quality types based on piperine, oleoresin and essential oil.

Table 21. Grouping of pepper cultivars based on the levels of piperine, oleoresin and essential oil

Constituent	Name of the cultivar	Category of the constituent	
Piperine	Kaniyakadan, Karimunda, Kottanadan, Kumbhakodi, Kuthiravally, Munda, Nilgiris, Perumunda, Thaliparamba local.	High	>5.49
	Arikottanadan, Arakulammunda, Balankotta, Cheryakaniakkadan, Chumala, Doddigaya, Kalluvally, Karimunda, Karuvilanchi, Mundi, Narayakodi, Paullouta, Panniyur-1, Perumkodi, Shimoga local, Sullia local, Uthirankotta, Vally, Sagar local, Kuthiravally, Thommankodi, Kurimalai, Aimpiriyan, Arayanmundi, Padappan, Thirthahally local, Karimallegessara, Kodi,	Medium	5.49-2.59
	Vokkalu, Narayakodi, Udhakare, Doddale, Pulpally local	Low	<2.59
Oleoresin	Kottanadan, Kumbhakodi, Kuthiravally, Nilgiris, Aimpiriyan, Udhakare, Pulpally local.	High	>14.62
	Arikottanadan, Arakulamunda, Balankotta, Cheriyakaniyakadan, Kalluvally, Karimunda, Karuvilanchi, Narayakodi,Panniyur-1, Perumkodi, TMB-II, Uthirankotta, Thirthahally, Kurimalai, Karimallegessara, Thommankodi, Doddale, Kodikottanadan, Arayanmundi, Aimpiriyan, Permbramunda, Vokkalu,Sagar local, Narayakodi, Kuthiravally, Kalluvally, Thommankodi, Udhakare, Kurimalai, Aryanmundi, Padappan	Medium	16.42-8.38

	Doddigaya, Chumala, Munda, Mundi, Palulouta, Perumunda, Shimoga local, Sullia local, Vally	Low	<8.38
Essential oil	Arikottanadan, Arakkulammunda, Balankotta, Kaniakkadan, Kumbhakodi, Kuthiravally	High	4.40
	Munda, Nilgiris, Perabramunda, Kalluvally, Thommankodi, Karimunda,Cheriyakaniyakadan, Doddigaya, Kottanadan, Karuvilanchi, Mundi, Narayakodi, Paullouta, Panniyur-1, Perumkodi, Perumunda, Shimoga local, Sullia local, TMB-II, Uthirankotta, Vally, Kurimalai, Karimallegessara, Thommankodi, Kodikottanadan, Aimpiriyan, Vokkalu, Sagar local, Narayakodi, Arayanmundi, Padappan	Medium	4.40-2.40
	Chumala, Thirthahalli local, Vokkalu, Doddale, Pulpally local	Low	

Seed Protein

Twenty nine black pepper cultivars collected from different parts of the country, including one exotic collection (LKD, were studied with respect to the seed protein profile. Dendrograms were prepared on the basic of average similarity of the cultivars based on the protein profile. A total of 11 clusters could resolved (Table-22). Even though a clear cut genetic differentiation of the cultivars could not be established, preferred/popular cultivars generally clustered together such as Kottanadan-Karimunda (Acc Nos. 1471 and 1418), Neelamundi – Karimunda (Acc. Nos. 2099 & 815), Karimunda – Arakulammunda (Acc. Nos. 1510 & 1087) with reference to the seed protein. These varieties are characterized by medium bold/bold berries with high bulk density and other desired quality features. Seed protein may be an indirect contributing factor for the better preference of the varieties by the farmers, vis-à-vis its high organic value.

Cluster	Sample No.	Accessions	Percentage similarity
I	21 23 24	Neelamundi, Nedungandam Cultivated wild, Puthur Cholamundi, Thotilpalam	68
II	26 27 3	Karimunda, Idukki LDK, Indonesia Karimunda, Peruvannamuzhi	67
III	14 17 18	Vellanamban, Vellathuval Kurimala, Sagar Taluk Neelamundi, Nedungandam	68
IV	2 22	Karimunda, Peruvannamuzhi Arakulammunda, Kallarkutty	58
V	19 20 15	Kottanadan, Palode Kottanadan, Palode Karimunda, Chemperi	81
VI	12 24	Kottanadan, Palode Balankotta, Peruvannamuzhi	73
VII	16 25 13	Narayakodi, Vellathuval Neelamundi, Idukki Kottanadan, Palode	62
VIII	6 7	Arakulammunda, Chemperi Karimunda, Chemperi	55
IX	8 9	Kalluvally, Chemperi Karimunda, Anakkampoil	50
X	5 11	Karimunda, Chemperi Kottanadan, Palode	60
XI	1 4 10	Karimunda, Chemperi Karimunda, Chemperi Kottanadan, Palode	78

Molecular characterization

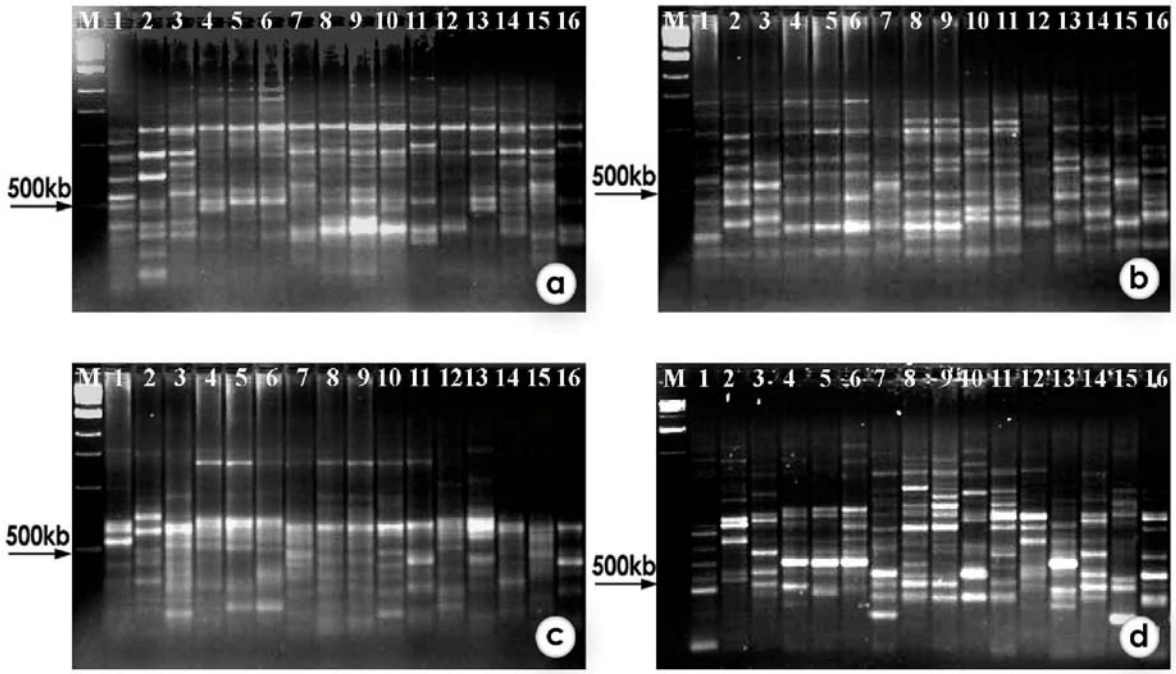
RAPD and ISSR profiling of Piper species

Molecular profiles were developed for 15 wild species along with popular cultivar Karimunda with 20 RAPD 'Operon' primers *viz.* OPA-03, OPA-08, OPA-13, OPA-18, OPB-05, OPB-07, OPB-14, OPB-20, OPC-02, OPC-09, OPC-13, OPC-18, OPC-20, OPD-07, OPD-10, OPD-13, OPD-15, OPE-02, OPF-10 and OPF-15 and 12 ISSR primers *viz.* $(CT)_8GC$, $(CA)_7GT$, $(CA)_7GG$, $(CA)_6CC$, $(CT)_8AC$,$(CT)_8GC$, $(CA)_7AG$, $(GT)_6GG$, $(GT)_6CC$, $(GACA)_3GG$ and $(AGTG)_3TT(TA)_7$.

Good polymorphism was observed between species for most of the primers used. RAPD primers OPB-20, OPA-9 and the ISSR primers $(GA)_6CC$ followed by the primer $(CT)_8AC$.

A total number of 475 bands (loci) were scored and the paired affinity indices were calculated based on similarity indices and presented in Table 19. Dendrograms were drawn based on NTSYS Version 2.01 software to study the interrelationships.

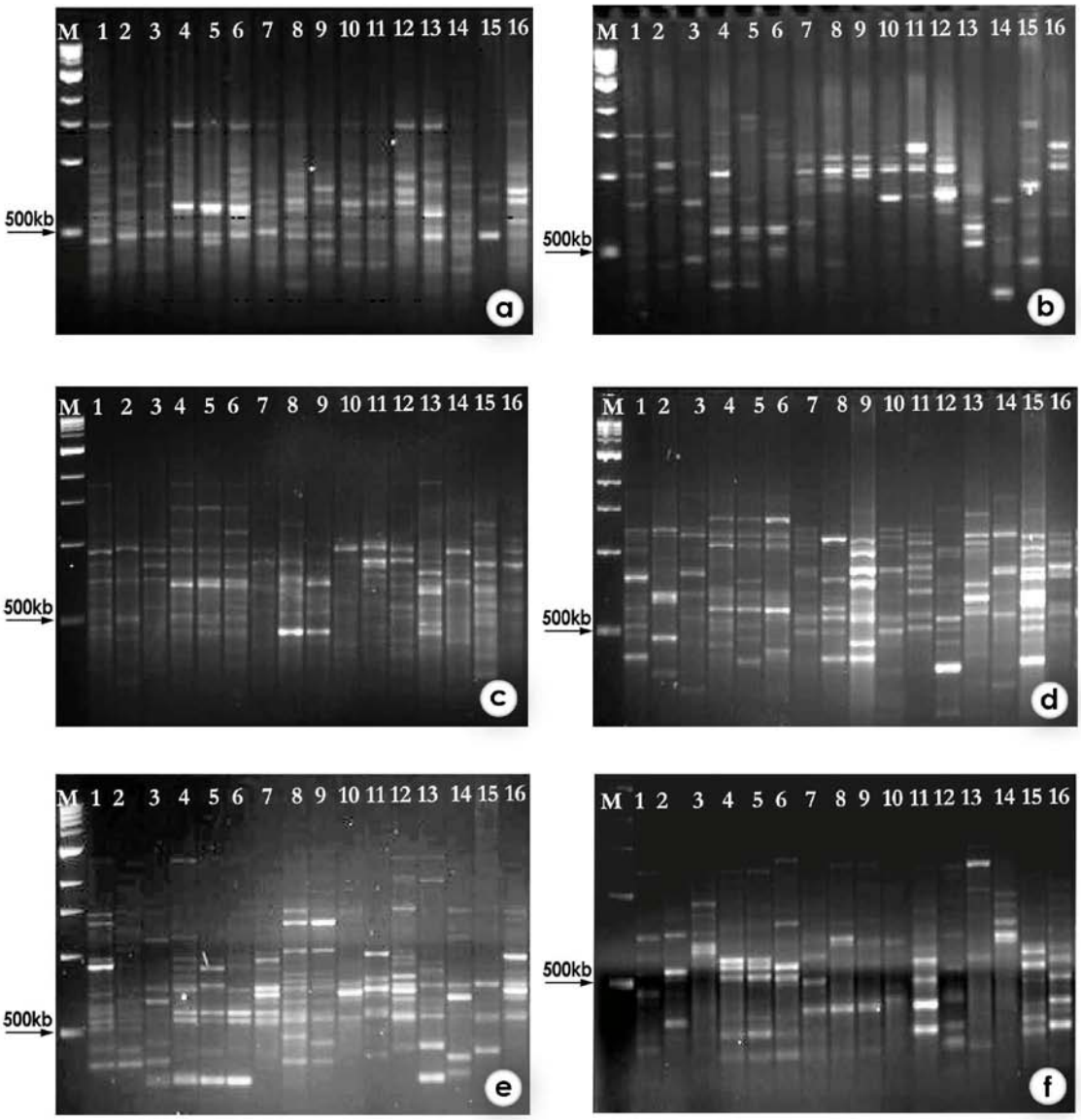
The values of similarity based on Jaccard's coefficient for all fifteen accessions ranged from 0.65 to 0.86 reflecting a broad level of genetic variability within the species.



ISSR profile of 15 *Piper* species.

Primers a. (CT)8GC, b. (CA)7GT, c. (CA)7GG, d.(GA)6CC

Lane M. 1 kb Marker, 1 *P. longum,* 2 *P. hapnium,* 3 *P. mullesua,* 4 *P. attenuatum,* 5 *P. argyrophyllum,* 6 *P. hymenophyllum,* 7 *P. bababudani,* 8 *P. trichostachyon,* 9 *P. galeatum,* 10 *P. sugandhi,* 11 *P. nigrum,* 12 *P. schmidtii,* 13 *P. wightii,* 14 *P. silentvalleyensis,* 15 *P. barberi* and 16 Karimunda (control).



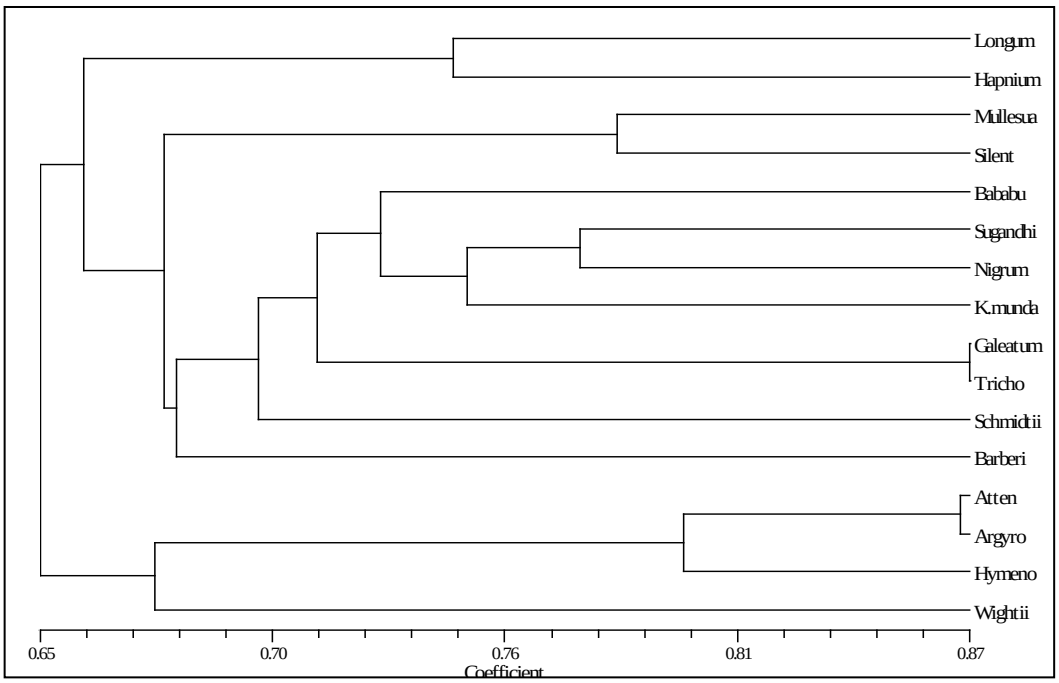
RAPD profile of 15 *Piper* species

Primers (a) OPA-03, (b))OPA-09 (c) OPA-13, (d)OPA-18, (e) OPB-05, (f) OPB-07

Lane M. 1 kb Marker, 1 *P. longum,* 2 *P. hapnium,* 3 *P. mullesua,* 4 *P. attenuatum*, 5 *P. argyrophyllum*, 6 *P. hymenophyllum,* 7 *P. bababudani*, 8 *P. trichostachyon*, 9 *P. galeatum*, 10 *P. sugandhi*, 11 *P. nigrum,* 12 *P. schmidtii*, 13 *P. wightii,* 14 *P. silentvalleyensis*, 15 P. *barberi* and 16 Karimunda (control)

Table 23. Paired Affinity Indices of 15 South Indian *Piper* based on RAPD and IISR polymorphism.

Species	*P.longum*	*P.hapnium*	*P.mullesua*	*P.silent.*	*P.atten.*	*P. argyro.*	*P. hymeno.*	*P. babubu.*	*P.wightii*	*P.schmidti*	*P. galeat.*	*P. tricho.*	*P. sugand.*	*P.nigrum*	*P. barberi*	Karimunda
P. longum	1.0000000															
P. hapnium	0.7468085	1.0000000														
P. mullesua	0.6851064	0.7382979	1.0000000													
P. silent.	0.6234043	0.6510638	0.7851064	1.0000000												
P. atten.	0.6404255	0.6340426	0.6489362	0.6425532	1.0000000											
P.argyro	0.6382979	0.6404255	0.6723404	0.6574468	0.8659574	1.0000000										
P.hymeno.	0.6425532	0.6489362	0.6680851	0.6574468	0.7765957	0.8255319	1.0000000									
P.baba..	0.6638298	0.6744681	0.6936710	0.6702128	0.6617021	0.6936170	0.6765957	1.0000000								
P. wightii	0.6276596	0.6340426	0.6744681	0.6808511	0.6468085	0.6787234	0.7042553	0.6489362	1.0000000							
P.schmidtii	0.6191489	0.6382979	0.6659574	0.6638298	0.6170213	0.6234043	0.6446809	0.7000000	0.6638298	1.0000000						
P.galeatum	0.6234043	0.6851064	0.7000000	0.6723404	0.6127660	0.6404255	0.6531915	0.6829787	0.6638298	0.7063830	1.0000000					
P.tricho.	0.6191489	0.6468085	0.7000000	0.6382979	0.6042553	0.6361702	0.6531915	0.6914894	0.6510638	0.6936170	0.8680851	1.0000000				
P.sugandhi	0.6638298	0.7127660	0.7063830	0.7000000	0.6276596	0.6765957	0.6936170	0.7489362	0.6914894	72978720.	0.7468085	0.7510638	1.0000000			
P.nigrum	0.6446809	0.6765957	0.6702128	0.6510638	0.6170213	0.6531915	0.6702128	0.7212766	0.6297872	0.6936170	0.7191489	0.7234043	0.7765957	1.0000000		
P.barberi	0.6574468	0.6638298	0.6957447	0.6510638	0.5957447	0.6361702	0.6446809	0.661702	0.6765957	0.6680851	0.6893617	0.6765957	0.7042553	0.6638298	1.0000000	
Karimunda	0.6446809	0.6638298	0.6872340	0.6893617	0.6255319	0.6617021	0.6617021	0.7212766	0.6680851	0.6808511	0.7063830	0.6936170	0.7382979	0.7617021	0.7063830	1.0000000



Dendrogram of divergence in 15 South Indian *Piper* based on RAPD and ISSR polymorphism.

Molecular profiling have resulted the formation of five major clusters at 0.79 similarity coefficient levels. The major clusters formed are

Cluster-I - *P. longum* and *P. hapnium*

Cluster-II - *P. mullesua* and *P. silentvalleyensis*

Cluster-III - *P. bababudani, P. sugandhi, P. nigrum,* Karimunda, *P. galeatum, P. trichostachyon, P. schmidtii and P. barberi*

Cluster-IV - *P. attenuatum, P. argyrophyllum* and *P. hymenophyllum*

Cluster-V - *P. wightii*

The clustering pattern was similar to the morphological characterization except for cluster III and cluster-V.

The cluster three can be separated in to five groups. *P. bababudani*, *P. schmidtii* and *P. barberi* formed independent clusters while *P. sugandhi, P. nigrum* and Karimunda with 76% similarity formed one group and *P. trichostachyon* and *P. galeatum* formed other group. This study also failed to distinguish between *P. galeatum* and *P. trichostachyon.*

Molecular characterization, which reflects more of genetic similarities have separated *P. schmidtii* and *P. wightii*, which were grouped together in morphological

(phenotype) characterization. *P. schmidtii* is included in the III major cluster along with *P. sugandhi, P. nigrum,* Karimunda, *P. trichostachyon* and *P. galeatum* as mentioned above, while *P. wightii* is unique and is placed in cluster V but distantly grouped with IV major cluster involving *P. attenuatum*, *P. argyrophyllum* and *P. hymenophyllum.*

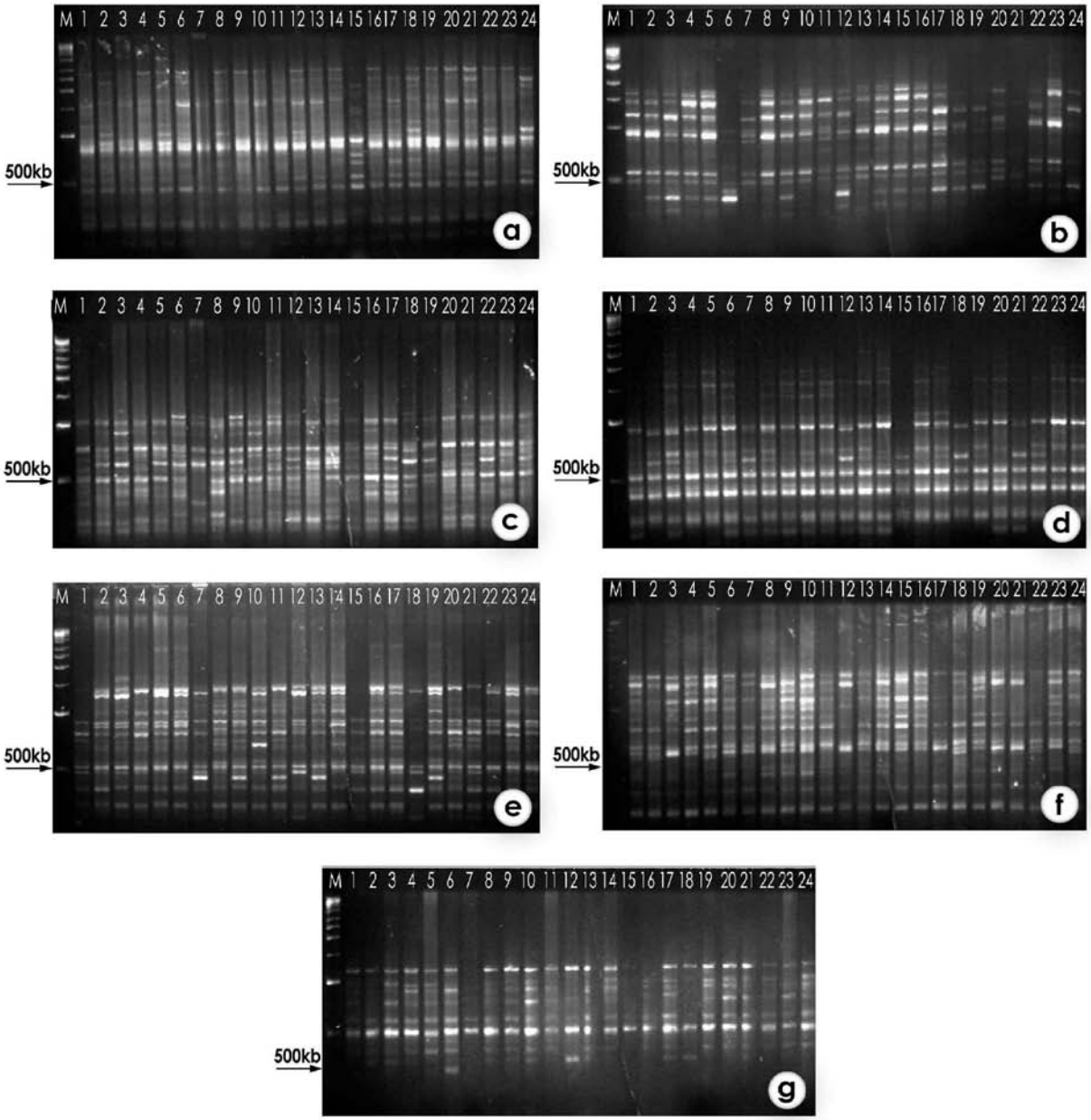
Important cultivars and varieties

The 24 important cultivars were characterized using thirteen RAPD and seven ISSR primers. The operon primers used for RAPD analysis are OPA-09, OPA-15, OPB-20, OPC-07, OPC-09, OPC-13, OPD-03, OPD-15, OPE-02, OPE-11, OPF-09, OPF-10 and OPF-15, where as primers $(CT)_8$ AC, $(CT)_8$ GC, $(CA)_7$ GT, $(CA)_7$ AG, $(CA)_7$ GG, $(GA)_6$ GG and $(CAC)_3$ GC were used for ISSR profiling. A total number of 171 markers were formed out of which 73 were polymorphic. Similarity indices were calculated using Jaccard's coefficients, using this molecular data and dendrograms were drawn using NTSYs software

The paired affinity indices ranged from 76% to 96% between cultivars. The resultant dendrogram grouped into two major clusters. Cultivars Kottanadan, Kuthiravally, Valiyakaniyakadan, Narayakodi, Poonjaranmunda and Panniyur- 3 were grouped in one cluster where as all the remaining 16 were grouped in another major cluster.

The first major cluster has further resulted 5 sub clusters. The second major cluster sub divided into two sub clusters. The clustering pattern was as follows.

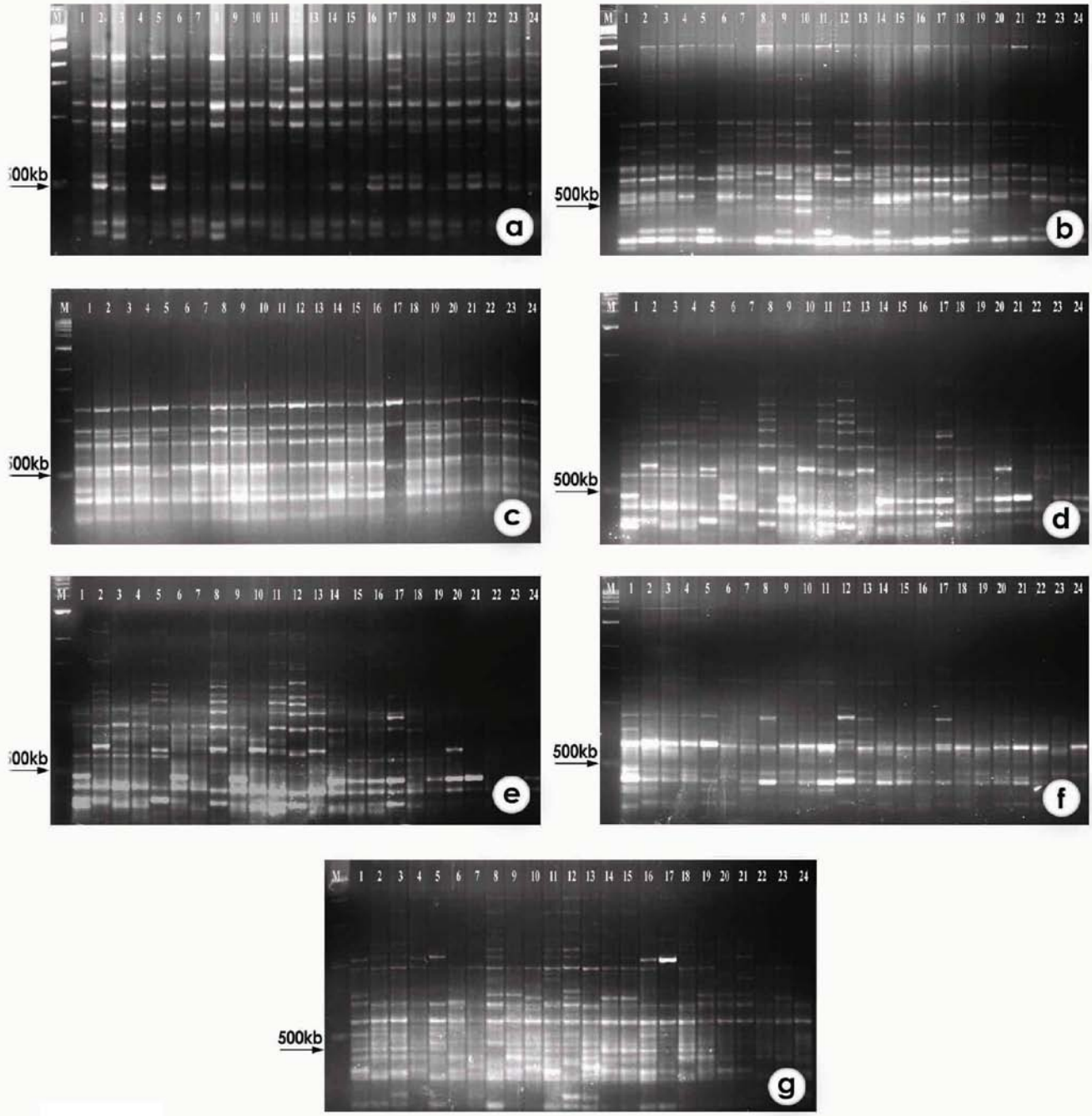
	Sub cluster-1	: Karimunda, Vellamunda and Balankotta
	Sub cluster-2	: Balankotta, Thommankodi
Cluster -I	Sub cluster-3	: Kalluvally, Sreekara, Panniyur-2, Subhakara
	Sub cluster-4	: Panniyur-4, Panchami, Pournami, PLD-2
	Sub cluster-5	: Arakulammunda, Cheriyakanniakadan
Cluster -II	Sub cluster-1	: Kottanadan, Kuthiravally, Valiyakaniyakadan, Poonjaranmunda
	Sub cluster- 2	: Panniyur-3



RAPD profiles of 24 cultivars of black pepper

Primers (a) OPD-03, (b) OPD-15 (c) OPE-02 (d) OPE-11 (e) OPF-09 (f) OPF-10 (g) OPF-15

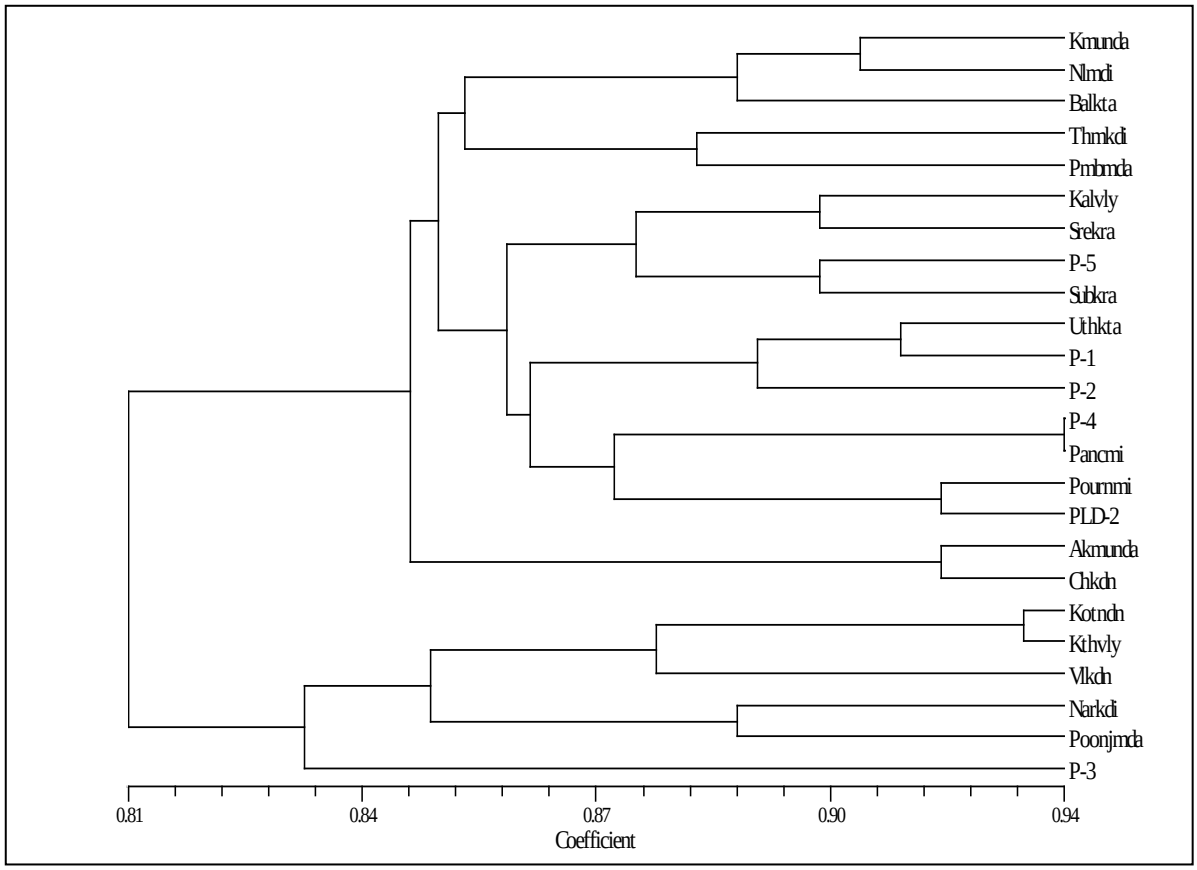
Lane M. 1Kb ladder, 1 Karimunda, 2 Kottanadan, 3 Balankotta, 4 Neelamundi, 5 Kuthiravaly, 6 Kalluvally, 7 Arakkulam munda, 8 Narayakodi, 9 Thommankodi, 10 Perambramundi, 11 Poonjaranmunda, 12 Valiyakaniakadan, 13 Cheriyakaniyakadan, 14 Uthirankotta, 15 Panniyur-1, 16 Panniyur-2, 17 Panniyur-3, 18 Panniyur-4, 19 Panniyur-5, 20 Sreekara, 21 Subhakara, 22. Panchami, 23 Pournami and 24 Palode-2.



ISSR profiles of 24 cultivars of black pepper.

Primers (a) (CT)8 AC (b) (CT)8GC (c) (CA)7GT (d) (CA)7AG (e) (CA)7GG (f) (GA)6GG (g)(CAC)3GC.

Lane. M. 1Kb ladder, 1 Karimunda, 2 Kottanadan, 3 Balankotta, 4 Neelamundi, 5 Kuthiravaly,.6 Kalluvally, 7 Arakkulam munda, 8 Narayakodi, 9 Thommankodi, 10 Perambramundi, 11 Poonjaranmunda, 12 Valiyakaniakadan, 13 Cheriyakaniyakadan, 14 Uthirankotta, 15. Panniyur-1, 16 Panniyur-2, 17 Panniyur-3, 13 Panniyur-4, 19 Panniyur-5, 20 Sreekara, 21 Subhakara 22 Panchami, 23 Pournami and 24 Palode-2.



Dendrogram showing the genetic relationships among 24 accessions important local cultivars and improved varieties based on RAPD and ISSR markers derived from Jaccard coefficient of similarity

In cluster-I, the members of the first sub cluster, 90% similarity coefficient was shown between cvs. Karimunda and Neelamundi. They have shared 85% similarity with Balankotta. The members in the second sub cluster showed 83% similarity. In the third sub cluster the Kalluvally, Sreekara, P-5 and Subhakara showed 92% similarity each other. However, the common similarities between these two groups were 87%. The improved variety Panniyur-1 expressed 94% similarity with one of its parents Uthirankotta and this group shared 87% similarity with Panniyur-2. Members in the 4th sub cluster *viz.* P4 and Panchami showed 95% similarity where as Pournami and PLD-2 had 91% similarity coefficient.

The fifth sub cluster Arakulam munda and Cheriyakanniakadan showed 93% similarity each other, however this sub cluster have out-grouped from the other sub clusters of the first major cluster.

The members in the second major cluster formed two sub clusters. The members of the first sub cluster in this group *viz.* Kottanadan and Kuthiravally had a close similarity coefficient of 93% and they shared 88% similarity with Valiyakaniyakadan. Narayakodi and Poonjaranmunda showed 88.5% similarity and the common affinity in the sub groups in the sub clusters were 87%. The improved variety P-3 out-grouped in the second major cluster.

Bootstrap analysis of the molecular data divided 24 cultivars into four major clusters. Among the clusters there were four sub clusters with significant P value above 70% *viz.* Arakulam munda and Cheriyakanniakadan; Panchami and Panniyur-4, PLD-2 and Pournami and Kottanadan and Kuthiravally.

EVOLVING HIGH YIELDING VARIETIES OF BLACK PEPPER HAVING GOOD QUALITY AND RESISTANCE TO PESTS

Characterization, evaluation and improvement of *Piper* germplasm resulted evolving of improved varieties. A total of eight varieties/hybrids are evolved through the project as detailed below:

VARIETY : SUBHAKARA

YEAR OF RELEASE : 1990

PEDIGREE : Clonal selection from the Karimunda (KS-27).

AREAS OF ADAPTATION : All pepper growing tracts of Kerala and Southern Karnataka

MATURITY GROUP : Medium

AVERAGE YIELD : 2352 kg (dry)/ha

QUALITY CHARACTERS

Piperine(%) : 3.4

Oleoresin (%) : 12.4

Essential oil (%) : 6.0

PLANT CHARACTERS

Leaf length/ breadth (cm) :12.3/6.5

Leaf shape : Ovate

Spike length (cm) : 7.7

Spike composition

- Bisexual (%) : 99.0
- Female (%) : 0.5
- Male (%) : 0.5

Fruit set (%) : 68.0

No. of fruits per spike : 63.0

100 fruit volume (cc) : 10.0

100 fruit wt. (gm) : 10.3

Yield per vine (kg) : 4.2 (green)

Dry recovery (%) : 32.5

VARIETY : SREEKARA

YEAR OF RELEASE : 1990

PEDIGREE : Clonal selection from the Karimunda (KS-14).

AREAS OF ADAPTATION : All pepper growing tracts of Kerala and Southern Karnataka

MATURITY GROUP : Medium

AVERAGE YIELD : 2677 kg (dry)/ha

QUALITY CHARACTERS

Piperine(%) : 5.1

Oleoresin (%) : 13.0

Essential oil (%) : 7.0

PLANT CHARACTERS

Leaf length/ breadth (cm) :11.6/6.2

Leaf shape : Ovate

Spike length (cm) : 8.6

Spike composition

- Bisexual (%) : 98.0
- Female (%) : 1.0
- Male (%) : 1.0

Fruit set (%) : 63.4

No. of fruits per spike : 61.0

100 fruit volume (cc) : 10.6

100 fruit wt. (gm) : 10.8

Yield per vine (kg) : 4.8 (green)

Dry recovery (%) : 35.0

VARIETY : PANCHAMI

YEAR OF RELEASE : 1991

PEDIGREE : Clonal selection from Aimpiriyan (coll. 856)

AREAS OF ADAPTATION : All pepper growing tracts of Kerala and Karnataka

MATURITY GROUP : Late

AVERAGE YIELD : 2828 kg (dry)/ ha

QUALITY CHARACTERS

Piperine(%) : 4.7

Oleoresin (%) : 12.5

Essential oil (%) : 3.4

PLANT CHARACTERS

Leaf length/ breadth (cm) : 14.5/8.5

Leaf shape : Ovate

Spike length (cm) : 11.2

Spike composition

- Bisexual (%) : 95.5
- Female (%) : 4.0
- Male (%) : 0.5

Fruit set (%) : 82.0

No. of fruits per spike : 84.0

100 fruit volume (cc) : 10.8

100 fruit wt. (gm) : 10.7

Yield per vine (kg) : 5.2 (green)

Dry recovery (%) : 34.0

Special Characters: A high yielding variety with excellent fruit set. Spike twisted in appearance due to high fruit set. Oleoresin content is high.

VARIETY : POURNAMI

YEAR OF RELEASE : 1991

PEDIGREE : Clonal selection from germplasm(coll. 812)

AREAS OF ADAPTATION : All pepper growing tracts of Kerala and Karnataka

MATURITY GROUP : Medium

AVERAGE YIELD : 2828 kg (dry)/ ha

QUALITY CHARACTERS

Piperine(%) : 4.1

Oleoresin (%) : 13.8

Essential oil (%) : 3.4

PLANT CHARACTERS

Leaf length/ breadth (cm) : 15.6/8.5

Leaf shape : Ovate - lanceolate

Spike length (cm) : 12.0

Spike composition

- Bisexual (%) : 84.0
- Female (%) : 15.0
- Male (%) : 1.0

Fruit set (%) : 68.0

No. of fruits per spike : 79.0

100 fruit volume (cc) : 13.0

100 fruit wt. (gm) : 12.8

Yield per vine (kg) : 4.7 (green)

Dry recovery (%) : 31

Special Characters: Tolerant t root knot nematode . A moderately high yielding variety with high oleoresin content.

VARIETY : PLD-2

YEAR OF RELEASE : 1996

PEDIGREE : Clonal selection from cultivar Kottanadan (2559)

AREAS OF ADAPTATION : Trivandrum and Quilon districts of Kerala

MATURITY GROUP : Late

AVERAGE YIELD : 2475kg (dry)/ ha

QUALITY CHARACTERS

Piperine(%) : 3.0

Oleoresin (%) : 15.45

Essential oil (%) : 4.8

PLANT CHARACTERS

Leaf length/ breadth (cm) : 15.5/8.4

Leaf shape : Ovate

Spike length (cm) : 8.33

Spike composition

- Bisexual (%) : 94.1
- Female (%) : 4.3
- Male (%) : 0.6

Fruit set (%) : 87.7

100 fruit volume (cc) : 12.27

100 fruit wt. (gm) : 12.23

Yield per vine (kg) : 4.97 (green)

Dry recovery (%) : 31.13

Special Characters: A variety with high quality and suitable to all pepper growing areas. Oleoresin content is high.

VARIETY : IISR THEVAM

YEAR OF RELEASE : 2004

PEDIGREE : Clonal selection from the cultivar ‘Thevan mundi’.

AREAS OF ADAPTATION : All pepper growing tracts of south India including high altitudes

MATURITY GROUP : Medium

AVERAGE YIELD : 5 Kg per vine, fresh

QUALITY CHARACTERS

Piperine (%) : 1.6

Oleoresin (%) : 8.15

Essential oil (%) : 3.1

PLANT CHARACTERS

Leaf length/ breadth (cm) :14.2/7

Leaf shape : Ovate elliptic

Spike length (cm) : 8.2

Spike composition

- Bisexual (%) : 96.9
- Female (%) : 2.06
- Male (%) : 1.03

Fruit set (%) : 80

No. of fruits per spike : 39.1

100 fruit volume (cc) : 12

100 fruit wt. (gm) : 15.5

Yield per vine (kg) : 5

Dry recovery (%) : 32.5

RESISTANCE TO MAJOR PESTS AND DISEASES

Phytophthora foot rot

(*Phytophthora capsici*) : Durable resistance (field resistance) to *Phytophthora* foot rot. Registered as a unique germplasm collection with INGR No. 03091.

VARIETY : IISR GIRIMUNDA

YEAR OF RELEASE : 2004

PEDIGREE : Hybrid (Narayakodi X Neelamundi)

AREAS OF ADAPTATION : All pepper growing tracts of south India including high altitudes

MATURITY GROUP : Medium

AVERAGE YIELD : 6 Kg per vine, fresh

QUALITY CHARACTERS

Piperine(%) : 2.2

Oleoresin (%) : 9.65

Essential oil (%) : 3.4

PLANT CHARACTERS

Leaf length/ breadth (cm) :15/9.5

Leaf shape : Ovate elliptic

Spike length (cm) : 10.81

Spike composition

- Bisexual (%) : 94.3
- Female (%) : 3.27
- Male (%) : 3.38

Fruit set (%) : 80

No. of fruits per spike : 50.9

100 fruit volume (cc) : 12

100 fruit wt. (gm) : 15.5

Yield per vine (kg) : 6

Dry recovery (%) : 32

Suited to high altitude areas (3000 ft)

VARIETY : IISR Malabar Excel

YEAR OF RELEASE : 2004

PEDIGREE : Hybrid (Cholamundi X Panniyur 1)

AREAS OF ADAPTATION : High elevations and plains

MATURITY GROUP : Medium

AVERAGE YIELD : 3 Kg per vine, fresh

QUALITY CHARACTERS

Piperine (%) : 2.95

Oleoresin (%) : 13.5

Essential oil (%) : 3.2

PLANT CHARACTERS

Leaf length/ breadth (cm) :17/8

Leaf shape : Elliptic- lanceolate

Spike length (cm) : 8.8

Spike composition

- Bisexual (%) : 96.8
- Female (%) : 2.48
- Male (%) : 0.62

Fruit set (%) : 80

No. of fruits per spike : 40.3

100 fruit volume (cc) : 10

100 fruit wt. (gm) : 10.3

Yield per vine (kg) : 3

Dry recovery (%) : 32.3

SPECIAL CHARACTERISISTICS

High oleoresin (13 %) and high bulk density (540g)

Improved Varieties

Sreekara

Subhakara

Panchami

PLD-2

Improved Varieties

Thevam

Girimunda

Pournamy

Malabar Excel

Genetics of shoot tip colour in black pepper

Shoot tips of black pepper are in two colours viz., purple and white. Not many studies on the genetics of this marker character have been attempted in this crop, mainly due to its perennial nature though from a preliminary study of selfed progenies of six cultivars, complimentary type of gene action involving two pairs genes was reported.

First generation (F_1) progenies of twelve crosses (Table 24) were scored for shoot tip colour. The observed and expected frequency of progenies segregating for shoot tip colour is presented in Table 25. In most of the crosses the expected frequency confirmed the observed pattern of segregation, even though the number of individuals was few in two cases, as revealed by the x^2 test of goodness of fit.

Table 24. Segregation for shoot tip colour in progenies of pepper crosses

Cross	No. of progenies observed	Observed frequency		Excepted frequency		Expected segregation ratio	X^2-value (P=0.05)
		Purple	White	Purple	White		
Panniyur-1 (White) x Karimunda (Purple)	43	15	28	16.12	26.8	3:5	0.14
Perumkodi (Purple)x Karimunda(Purple)	20	20	0	All Purple		___	
Cholamundi (Purple) x Karimunda (Purple)	68	68	0	All Purple		___	
Narayakodi (Purple) x Karimunda (Purple)	11	11	0	All Purple		___	

Valiyakanikadan (Purple) x Karimunda (Purple)	12	10	2	9	3	3:1	0.44
Thommankodi (Purple) x Karimunda (Purple)	12	12	0	All Purple		___	
Cheriakaniakadan (Purple) x Panniyur-1 (White)	9	9	0	2	2	1:1	___
Narayakodi (Purple) x Neelamundi (Purple)	21	21	0	All Purple		___	
Valiyakaniakadan (Purple) x Aimpirian (Purple)	5	5	0	All Purple		___	
Cholamundi (Purple) x Panniyur-1 (White)	86	86	0	All Purple		___	
Irumanian (Purple) x Panniyur-1 (white)	6	6	0	All Purple		___	
Panniyur-1 (White) x Cheriyakaniakadan (Purple)	4	2	2	2	2	1:1	

A genotype heterozygous at two loci is represented as A_1 a_1 A_2 a_2. Assuming complimentary type of gene action, in the presence of genes A1 and A2 purple coloured shoot tip will be produced. In the absence of either of the complimentary genes shoot tips will be white.

Further, with no linkage, a genotype heterozygous at two loci will produce 4 types of gametes in equal proportion and a genotype heterozygous at any one locus will produce 2 types of gametes. By crossing the various selected genotypes, off springs will be produced at ratios as given in Table 24. Thus an expected segregation ratio of 3:5, 3:1 or 1:1 can be arrived at by crossing the selected genotypes.

Based on the segregation pattern observed and assuming complimentary gene action without linkage the genotypes of the parents used in the study are proposed in Table 26 Thus, Panniyur-1, which is a cross between 'Cheriakaniakadan' and 'Uthirankotta', both purple coloured varieties may be represented as A_1a_1 a_2 a_2 or A_1A_1 a_2a_2. This genotype is white as expected. Further, selfing such a genotype will produce only white tipped shoots.Panniyur-1 produces white shoot tip coloured seedlings on selfing.

Table 26. Proposed genotypes of pepper cultivar utilized in the cross

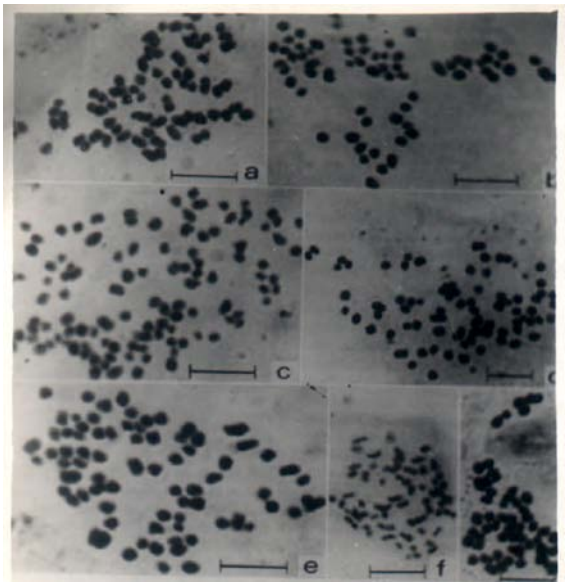
Cultivar	**Genotype**	**Phenotype**
Panniyur-1	A_1a_1 a_2a_2 A_1 A_1 a_2a_2	White
Karimunda	A_1a1 A_2 a_2	Purple
Cheriakaniakadan	A_1a1 A_2 a_2	Purple
Valiyakaniakadan	A_1 A_1 A_2 A_2	Purple
Cholamundi	A_1 A_1 A_2 A_2	Purple
Neelamundi	A_1 A_1 A_2 A_2	Purple
Narayakodi	A_1 A_1 A_2 A_2	Purple
Thommankodi	A_1 A_1 A_2 A_2	Purple
Irumanian	A_1 A_1 A_2 A_2	Purple
Aimpirian	A_1a1 A_2 A_2 A_1 A_1 A_2 A_2	Purple
Perumkodi	A_1 A_1 A_2 A_2	Purple

CYTOLOGY

Cytological investigations revealed that black pepper has a predominanant chromosome number 2n=52. However, the germplasm accessions shown variability in chromosome number are listed below

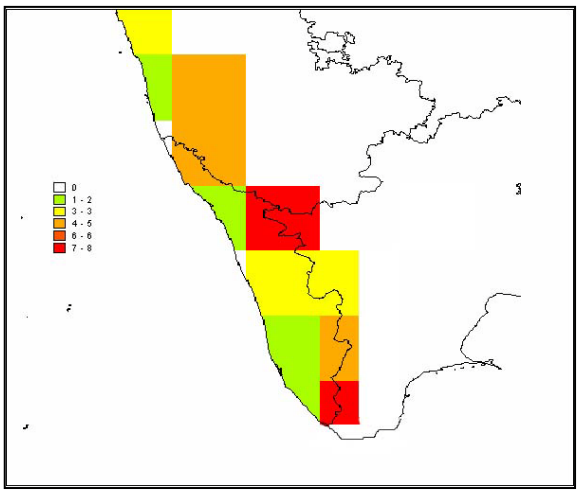
Name	**Chr. number**
P. attenuatum (Acc. 396)	104
P. magnificum	26, 24
P. arboreum	26
P. colubrinum	26
Vadakkan (Acc. 1344)	78

Cytological indexing of cultivars of black pepper also resulted in identifying a triploid (2n=78) cultivar (Vadakkan). Cytological analysis of the progenies of this triploid revealed a whole lot of cytotypes.

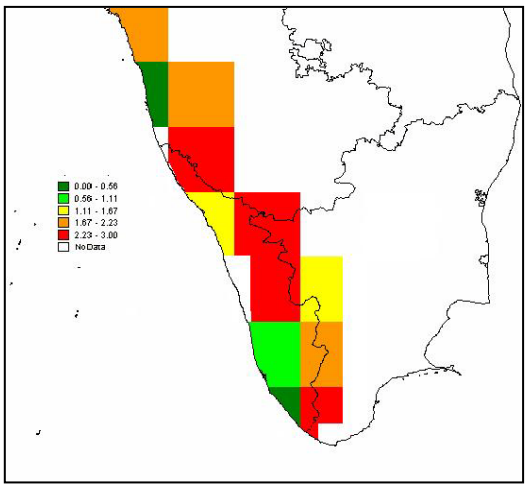


GIS studies in black pepper

Fifteen qualitative morphological characters of 16 wild species were studied and plotted the hierarchal cluster, using SPSS software. The cluster groups were compared using BIOCLIM (Bio- climatic analysis and prediction system) model of DIVA-GIS to identify the areas or 'niches' where *Piper* species occur predominantly. A grid of 50x 50km cells and a circular neighborhood with a radius of 50km to assign points to grid cells was used to map species richness and species diversity. The highest richness grid was found to have 15-16 species while the highest diversity value found is 1.8 to 3.



Diversity indices of distribution of *Piper* species



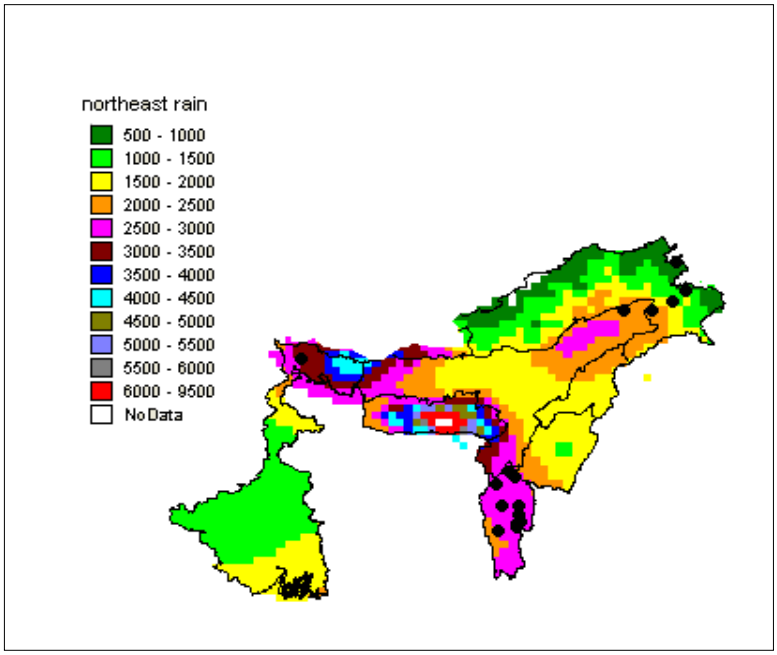
Species richness of *Piper* species in Western Ghats

Distribution of *Piper* species in North East

Geographic Information System (GIS) is used to understand the pattern of genetic diversity and distribution of *Piper* spp. in North East India (Mizoram, Arunachal and Jalpaiguri district of West Bengal).

The collection sites were plotted on map with the help of DIVA –GIS and longitude and latitude recorded at the time of collection with GPS. Rain fall and altitude maps were made accordingly. It gives a clear idea that 2000mm-3000mm rainfall is the rainfall of all most all the collection sites, and the optimum rainfall for pepper is between 2200 to 2700 mm. In case of altitude it shows that upto 1000m is the altitude of almost all the collection sites and optimum altitude for the pepper is between 100-1000 m MSL. So form the maps it can be predicted that western part of Meghalaya and Assam there exist a

chance of availability of *Piper*. Northern part of Nagaland also shows having conducive precipitation and altitude for *Piper* distribution.



Distribution of *Piper* species based on rain fall in north east region

8222 Questions- Answered

What is the status of germplasm at IISR, Calicut?

The germplasm repository of IISR Calicut is having more than 2500 accessions. This includes local cultivars, improved varieties and wild relatives besides exotic collections.

What are all the major centers of distribution of *Piper* in India?

In India two hotspots for *Piper* are identified. The Western Ghats of South India and the North Eastern India are the two major areas besides Andaman and Nicobar islands. It is found occurring in the evergreen and semi evergreen forests. However, the economically important species *Piper nigrum* is distributed only in the Western Ghats region in its wild form

Whether any new species is reported during the survey?

Four new taxa were reported. This includes two new species viz. *Piper silentvalleyensis*, *P. sugandhi* and two varieties viz. *P. nigrum* L. var. *hirtellosum* and *P. sugandhi* var *brevipilis* located from Silent valley forests of Palaghat district and Sugandhagiri hills of Wayanad district respectively

Whether wild *Piper* is available in dry deciduous forests?

Generally *Piper* species are reported from the evergreen and semi ever green forests of Western Ghats. However, *Piper* nigrum and *P. attenuatum* could be located and collected from the forests of Karwar district.

Are there any red listed species in the germplasm conservatory?

Three species viz. *P. hapnium*, *P. barberi* and *P. silentvalleyensis* are listed as endangered in the Red Data book Published by the Bot. Survey of India. These species were located, collected and conserved in the germplasm.

Is there any source of resistance in the germplasm accessions collected and conserved?

The germplasm accessions were screened for various pest and diseases. The exotic species *Piper colubrinum* is resistant to *Phytophthora* foot rot and nematodes. This species is utilizing in the crop improvement programme as a root stock. The released variety IISR, Thevam is field tolerant to foot rot disease. Another variety 'Pournamy' – a selection from the germplasm is resistant to nematode infection.

What is the extent of variability in spike shape?

Three types of spike shape noticed in *Piper* species. It may be cylindrical (*P. longum, P. hapnim*), filiform (*P. nigrum, P. attenuatum*) or globose (*P. mullesua, P. thomsonii*). Species like P. nigrum and P. attenuatum the spikes are pendent where as it is erect in P. *longum, P. mullesua* etc.

What is the basic mode of pollination in cultivated *black* pepper?

Black pepper is naturally self pollinated which is aided by rain or dew drops and also by the gravitational descending of pollen grains (geitenogamy). The flowers are protogynous, but in the absence of any active pollen transfer mechanism protogyny becomes ineffective in enhancing crossing.

What is the basic chromosome number of black pepper?

Black pepper has a predominanant chromosome number 2n=52. Cytological indexing of cultivars of black pepper resulted in identifying a triploid (2n=78) cultivar ('Vadakkan'). Cytological analysis of the progenies of this triploid revealed a whole lot of cytotypes

8223 Process/ Product/ Technology/ Developed

1. Developed eight high yielding varieties. The improved varieties 'Pournamy' is nematode tolerant and "IISR Thevam' is having field tolerance to foot rot disease respectively.

2. *Ex situ* Conservatory of *Piper* established which conserves almost all land races, primitive types and some exotic lines. Based on MTA, accessions are given to researchers in the country.

3. *Germplasm Registered:*

   a. Coll. No. 5455 (IC-370011) Piper nigrum (wild) (INGR No 04111).– for high oleoresin content (28.15%) and bold berries .

   b. Coll. no 1041 (IC- 316598) (INGR No-3091) for field tolerance to foot rot disease .

   c. CLTP 123 (IC- 316588) (INGR- 06026) for high caryophyllene percent

8224 Practical Utility

Systematic efforts have been made at IISR, Calicut since inception of this project led to the assemblage of more than 2500 accessions from different parts of the country viz. forests and farmers' field. The germplasm repository serves as a source bank of accessions to the researchers in SAUs and other Institutes in the country.

The high yielding varieties evolved will help to bridge the yield gap, if sufficient planting material of good quality are produced and distributed. The foot rot tolerant variety, IISR Thevam with its adult plant tolerance to the disease will be an ideal choice for the disease affected areas. Pournami, the root knot tolerant cultivar can be deployed in soils infested with nematodes. PLD-2 and IISR Malabar Excel with their high oleoresin and high yield will be useful for the value added industry and farmers alike. IISR Thevam, IISR Girimunda and IISR Malabar Excel are suited to high altitudes and plains. Hence these genotypes can be successfully grown in tea/coffee estates, in the existing shade trees.

Successful transfer of genes for *pollu* beetle resistance from related species to cultivated black pepper may lead to development of black pepper varieties with resistance to *pollu* insect thereby eliminating the risk of pesticide residue. This aspect is very relevant from the Sanitary and Phytosanitory aspects of the WTO agreement.

Molecular and morphological characteristaion of the elite lines of black pepper is important for protecting the biowealth/to prevent biopiracy in the present context of globalization.

8225 Constraints, if any

823 Publications and Material Development

8231 Research papers

1. Gopalam A, Zachariah T. J, Nirmal Babu K., Sadanandan AK and Ramadasan A 1991. Chemical quality of black and white pepper. *Spice India*, 4(4): 8-10.
2. Gopalam A, Zachariah TJ, Nirmal Babu K and Ramadasan A (1990) Effect of different methods of white pepper preparation on the chemical and aroma quality in selected cultivars of *Piper nigrum* L. *Indian Perfumer*, 34 (2): 152-156.
3. Gopalam A, Zachariah TJ, Nirmal Babu K., Sadanandan AK and Ramadasan A (1991) Chemical quality of black and white pepper. *Spice India*, 4(4): 8-10.
4. Gopalam, A. and Ravindran, P. N. 1987. Indexing quality parameters in black pepper cultivars. *Indian Spices* 22/23, 8-11.
5. John Zachariah, T. 1996. Essential oil and its major constitute in selected black pepper accessions. Pl. Physiol and Biochem. 25:213-214.
6. Krishnamurthy, K. S, Ankegowda S. J. and Saji, K. V. 2000. Water stress effects on membrane damage and activities of catalase, peroxidase and superoxide dismutase enzymes in black pepper (*Piper nigrum* L.), *J. plant Biol.* Vol. 27 (1) 39-42.
7. Krishnamuthy, K. S. and Saji, K. V. Response of *Piper* species to water stress. *Ind. J. Hort* 63 (4). Pp. 433-438.

8. Nair, R.R, Sasikumar, B and Ravindran, P.N 1993. Polyploidy in a cultivar of black pepper and its open pollinated progenies. Cytologia, 58: 27-31.
9. Nirmal Babu K, Naik G and Ravindran PN (1993) Two new taxa of *Piper*(Piperaceae) from Kerala,with a note on their origin and interrelationships *Spices&AromaticCrops*,2(1&2):26-33
10. Nirmal Babu K, Nair RR, Johnson George K and Ravindran PN 1992. *Piper barberi* Gamble - A re-description of the species with a note on its karyotype. *J. Spices &Aromatic Crops*,1(1): 88-93.
11. Nirmal Babu, K and Ravindran, P. N. 1992. Improved varieties of black pepper and cardamom In: Black pepper and Cardamom –problems and prospects (Ed.).
12. Rahiman, B. A., Murthy, K. N, Nair M. K. and Nayar, N. M.1979. Distribution, morphology and ecology of Piper species Karnataka. *J Plantation Crops*, 7 (2): 93-100.
13. Ratnambal MJ, Ravindran PN, Nair MK and Nirmal Babu K. 1990. Two high yielding selections of Karimunda. *Spice India* 3 (11): 9-11.
14. Ravindran PN, Asokan Nair T, Nirmal Babu K, Chandran K and Nair MK 1990. Ecological and morphological notes on *Piper* spp. from the Silent Valley forests, Kerala. *J. Bombay Natural Hist. Society*, 87 (3): 412-426.
15. Ravindran PN and Nirmal Babu K (1996) Numerical taxonomy of South Indian *Piper* L. II Principal component analysis of the major taxa. *Rheedea*. 6 (2): 75-86.
16. Ravindran PN, Balakrishnan R and Nirmal Babu K (1992) Numerical taxonomy of South Indian *Piper* L. (Piperaceae) 1. Cluster Analysis. *Rheedea* 2 (1): 55-61.
17. Ravindran PN, Balakrishnan R and Nirmal Babu K (1997) Morphometrical studies on black pepper II. Principal component analysis of black pepper cultivars. *J. Spices and Aromatic Crops*. 6(1): 21-29.
18. Ravindran PN, Balakrishnan R. and Nirmal Babu K (1997) Morphometrical studies on black pepper 1. Cluster analysis of black pepper cultivars. *J. Spices and Aromatic Crops*. 6 (1) : 9-20.
19. Ravindran PN, Nair MK and Nirmal Babu K (1992) Panchami-A high yielding selection of black pepper. *Spice India* 5 (6): 11-13.
20. Ravindran, P. N. Ramana, K. V., Nair, M. K and Nirmal Babu, K. and Mohandas, C. 1992. Pournami –a high yielding selection of black pepper tolerant to root knot nematode (*Meloidogyne incognita*) . J Spices and Aromatic Crops 1: 136-141.

21. Ravindran, P. N., Nair, M. K. and Muneer, V. M. 1985. Seed germination studies in black pepper. *J. Plantation Crops* 13 (2)132-134.
22. Ravindran, P. N., Nair, M. K. and Nair, R. A. 1987. New taxa of *Piper* (Piperaceae) from Silent Valley Forests, Kerala. *J. Eco. Tax. Bot*., 10: 167-169.
23. Ravindran, P. N., Ratnambal, M. J and Munir, V. M. 1986. Differential radio sensitivity in black pepper (*P. nigrum* L.) cultivars. Planter, 62:515-518.
24. Ravindran, P. N., Sasikumar, B and Nirmal Babu, K. 1992. Genetics of shoot tip colour in black pepper. J Plantation Crops, 20: 76-78.
25. Saji K.V., Sasikumar B. Johnson George K and S.Biju. 2001. *Piper hapnium*- a rare *Piper* species from Peruvannamuzhi, Kerala- a new report. *J.of Spices and Aromatic Crops* (10): 1 pp. 63-64
26. Saji, K.V., Sasikumar, B., Johnson George, K and Parthasarathy, V. A. 2005. Sex change in *Piper thomsoni* Hook. (Piperaceae). *J. of Spices and Aromatic Crops*. 14 (1): 39-41.
27. Saji. K. V. Johnson George, K., Sasikumar, B., John Zacharia, T. and V. A. Parthasarathy. 2005. Coll. No. 5455 (INGR 04111, IC- 370011) Black pepper (*Piper nigrum* L.) germplasm with high oleoresin content and bold berries. *Indian J. Plant Genet. Resources***.** 18 (3) 297-98.
28. Sasikumar, B. and Johnson K. George 1993. Direct single node propagation of black pepper *J. Plantation Crops*. 20: 165-167.
29. Sasikumar, B., Krishnamurthy, B., Saji, K. V., Johnson George, K., Peter, K. V. and Ravindran, P. N. 1999. Spices diversity and conservation of plants that yield major spices in India. *Plant Genetic Resources Newsletter*, No. 118: 19-26.
30. Sasikumar, B., Haridas, P., Johnson. K. George., Saji, K. V., John Zachariah, T. and Parthasarathy, V. A. 2004. 'IISR Thevam' 'IISR Malabar Excel' and 'IISR Girimunda'- three new black pepper clones (*P. nigrum* L). *J Spices and Aromatic Crops*, 13: 1-5.
31. Sasikumar, B, John Zacharia, T, Saji. K. V. Johnson George, K. and Ravindran. P. N. 2006. CLTP 123. (IC-547018, INGR 06026) a high caryophyllene black pepper germplasm. *Indian J. Plant Genet. Resources*. 19 (2) 305.
32. Susheela Bhai, R., Anandaraj, M., Sarma Y. R., Veena, S. S and **Saji. K. V.** 2007. Screening of black pepper germplasm (*Piper nigrum* L.) for resistance to foot rot

disease caused by *Phytophthora capsici* Leonian. *J. Spices and Aromatic Crops*. Vol. 16 (2): 115-117.

33. Utpala Parthasarathy, Johnson George, K., Saji. K. V. Srinivasan. V. Madan, M. S., Mathur, P. N. and Parthasarathy, V. A. 2006. Spatial Analysis for *Piper* species distribution in India. *Pl. Gen. News letter*. No. 147. pp. 1-5.

34. Utpala Parthasarathy, K. V. Saji, K. Jayarajan and V. A. Parthasarathy. Biodiversity of *Piper* in South India - application of GIS and cluster analysis. *Current Science* Vol, 91 (5) 952-658.

8232 Popular articles

1. Raju, K., Ravindran, P. N and Nair, M. K. 1983. Quality evaluation of black pepper cultivars. *Indian Spices* 20(1): 3-5.
2. Ravindran, P.N., and Nair, M. K. 1984. Pepper varieties. Indian Cocoa, *Arecanut and Spices. J.* 7(3):67-69.
3. Ravindran, P.N. and Nirmal Babu, K. 1988. Black pepper cultivars suitable for various regions. Indian Cocoa, *Arecanut and Spices J. 11*: 110-113.
4. Sasikumar, B.1996. The green and glory of the golden berry. *Indian Spices*, 32: 2-6.
5. Sasikumar, B.1996. Bush pepper. Yojana (Mal). March-April, 1996, p. 28.
6. Ravindran, P. N. and Nirmal Babu, K. 1997. Cultivating black pepper in homestead gardens *Indian Horticulture* 41(4): 28-29.
7. John Zachariah. T. 1997. Piperine is the bite principle in pepper. *Spices India* (Mal) 10:8.
8. Sasikumar, B.1997. Black pepper cultivars and varieties. Decade Celebration Committee Souvenir Regional Coffee Research Station (Coffee Board) Thandigudi. Tamil Nadu.
9. Sasikumar B. 1997. Drying of black pepper the scientific way. Karshakashree (Mal.) 8: 30-32.
10. Sasikumar B. 1999 Black pepper cultivars. *Spice India* 12(9): 2-4.
11. Sasikumar B. 1999. Black pepper. *Science Express*, October 5, 1999.
12. Sasikumar B. 1999 Bush pepper a slip of Mangattachan. *Indian Spices* 36:1.
13. Sasikumar B. 2000 Bush pepper. *Science Express*, March 14, 2000.

14. Sasikumar B. 2000 Pollination in black pepper- Myth and truth. *Science Express*, Sept 9, 2000
15. Sarma, Y.R and Sasikumar,B.2001.Status of blackpepper industry in India.*International Pepper News Bulletin*.Oct-2000-March 2001,29-36.
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17. Sarma, Y. R. and Sasikumar, B. V. 2001. Aspects and prospects of spices in the post WTO scenario. *Proc. Nat. Agri. Fair, Hyderabad*, pp. 66-68.
18. Sasikumar, B. and Sarma, Y. R. 2002 New black pepper varieties from IISR-I. *ICAR News* 8(2): 12-13.
19. Sasikumar, B. and Sarma, Y.R. 2002. New black pepper varieties from IISR-II. *ICAR News* 8(1): 16.
20. Sasikumar, B. 2002 Geographical Indication for spices and other agricultural produces. *Mathrubhoomi* (News Paper) 13 Dec. 2002.
21. Sasikumar, B.2003. The epic history of black pepper. *Kerala Karshakan (Mal)* 48(10): 25-28.
22. Sasikumar, B.2004. The legendry spices fame of Kerala. *Karshakan (Mal)* 50(1): 18-21.
23. Sasikumar, B., Saji, K. V., Johnson K. George and Haridas, P. 2004. Three new black pepper clones from IISR, Kozhikode. *Spice India* 17(7): 2.
24. Sasikumar, B. 2004 Black pepper cultivars and new varieties. *Green Tech*. 5: 18-2
25. B. Sasikumar, K. V. Saji and Johnson George, K. 2005. Sex change in *Piper thomsoni*. *Kerala Karshakan (Malayalam)* 51 (6): 19.

8233 Seminars, conferences and workshops (relevant to the project) in which the Scientists have participated.

Dr. M. K. Nair

1. All India Co-ordinated Research Project on Coconut, Arecanut, Spices and Cashewnut, Panaji, Goa, 18-20 Sept 1978.
2. First Annual Symposium on Plantation Crops (PLACRSYM -I) Rubber Research Institute of India, Kottayam, March 20-23, 1978.
3. International Cashew Symposium, Cochin. 12-15 March, 1979.

4. Second Annual Symposium and Plantation Crops (PLACROSYM II) Ootacamund, 26-29, June 1979.
5. Workshop on Management Practices, NAARM, Hyderabad Jan 17-19, 1980.
6. Annual Workshop on All India Co-ordinated ICAR scheme on Harvest and Post harvest technology, Kasaragod, 13-16 Feb 1980.
7. National Seminar on Water Management, Calicut, 11-12 Oct 1980.
8. Workshop on Processing pepper and pepper products. Mysore 23-24 May, 1981.
9. The Vth Workshop of AICSCIP and AICCAIP, Vellanikkara, Thrissur, Oct 31 Nov. 3, 1981.
10. Eighth Plant Tissue Culture Conference, Kasaragod, 2-4 March, 1981.
11. IV All India Botanical conference, Calicut, Dec. 28-30. 1981.
12. PLACROSYM – IV (Plant breeding & Genetics). Mysore, Dec 2-4, 1981.
13. XV International Congress on Genetics, New Delhi, 2-21 Dec. 1981.
14. Sixth Workshop of the All India Co-ordinated Spices and Cashew nut Improvement Project, Calicut, Sept 10-13, 1983.
15. PLACROSYM-VI, Kottayam Dec. 16-20, 1984.
16. Workshop for the Development of a Minimum Competencies based curriculam in Plantation Crops 1985.
17. Workshop of All India Co-ordinated Research project on Medicinal and Aromatic Plants, Bangalore, 1985.
18. Seventh Workshop of All India Co ordinated Research Project on Palms, Spices and Cashew, 1986
19. Eleventh Technical meeting of the International Pepper Community-Rotterdam, The Netherlands, May19-25, 1986.
20. Workshop on Impact of drought on Plantation Crops Kasaragod, 26-27 May 1986.
21. Ninth NARP-KAEP (North Zonal) Workshop, Pilicode, 7 Aug, 1986
22. Workshop on beneficial microbes on tree crop management. Kasaragod 8-9, Dec 1986.
23. National Science Seminar, New Delhi October 1 1986
24. PLACROSYM-VII, Coonoor ,Oct.16-19, 1986.
25. Eighth workshop of All India Coordinated Research Project on Spices. Lam, Guntur 30 Jan Feb 1 1987
26. National Symposium on Plant Genetic Resources, New Delhi, 3-6 March 1987.

27. National Seminar of Spices Industries - Present Scenario. Problems & Prospects 9-10, April, 1987, New Delhi.
28. Twelth Pepper Tech Meeting of the International Pepper Community 4-11 May, 1987, FR Germany.

Dr. P. N. Ravindran

1. International Cashew Symposium, Cochin. 12-15 March, 1979.
2. The Vth Workshop of AICSCIP and AICCAIP, Vellanikkara, Thrissur, Oct 31 Nov. 3, 1981.
3. Sixth Workshop of the All India Co-ordinated Spices and Cashewnut Improvement Project Calicut, Sept 10-13, 1983.
4. Seventh Workshop of All India Co ordinated Research Project on Palms, Spices and Cashew, 1986.
5. Tenth Workshop of AICRP(S), Coimbatore 22-24 Aug 1989.
6. Pepper Seminar, Coorg, 30 Jan, 1990.
7. International Symposium Genetic Engineering and Tissue Culture for Crop Pest and Disease Management Coimbatore, June 13-15, 1990.
8. International Symposia on New Frontiers in Horticulture, Bangalore, 24-28 Nov 1990.
9. XI Workshop of AICRP (Spices), Trivandrum 26-28 July, 1991.
10. National Seminar on Pepper and Cardamom, Calicut, 17-18 March, 1992.
11. National Seminar on Post harvest technology of Spices, Trivandrum, 13 -14 May, 1993.
12. Second Asia Pacefic Conference on Agricultural Biotechnology, Chennai, 6-10 March, 1993.
13. National Seminar on Diseases of Spices, Calicut, 7-8April, 1994.
14. International Symposia on Plantation Crops (PLACROSYM-XI), Calicut, Nov 29-Dec 3 1994.
15. Seminar 'Crop breeding in Kerala' Kerala University, Trivandrum 25 Jan 1996.
16. National Seminar a Biotechnology of Spices, Medicinal and Aromatical Plants Calicut, 24-25 April, 1996.
17. Interface with farmers –exporters – Scientists Calicut, Oct 11-12, 1996.
18. National symposium on Horticultural Biotechnology, 28-30 October 1996, Bangalore.

19. XIV Workshop of Research Workers of AICRP (Spices), Bangalore 8-10 July 1997.
20. National Seminar on Water and Nutrient Management for sustainable production and quality of spices, Coorg, 5-6 Oct 1997.
21. Meeting on Preparing a Compendium on all major spices cultivated in India Kochi 9 March 1998.
22. Golden Jubilee National Symposium on Spices, Medicinal and Aromatic Plants- Biodiversity Conservation and Utilization , Calicut 10-12 Aug, 1998
23. PLACROSYM – XIII, Coimbatore 16-18 Dec, 1998
24. XV Workshop of AICRP (Spices) Calicut 18-21 Nov 1999
25. Brain storming session on Biotechnology Calicut, Jan 17-18, 2000
26. Centennial Conference an Spices Medicinal and Aromatical Plants, Calicut 20-23 Sept, 2000.
27. Eleventh workshop/Group meeting of Research workers of AICRP (Spices) July 26-28, 1991 Trivandrum.
28. PLACROSYM – IV (Plant breeding & Genetics). Mysore, Dec 2-4, 1981.
29. IV All India Botanical conference Calicut, Dec. 28-30. 1981.

Dr. K. Nirmal Babu

1. X^{th} workshop on AICRP on Spices, 22-24 August, 1989 Tamil Nadu Agricultural University, Coimbatore, India.
2. Group meeting of AICRP on Spices, 26-28 July 1991, Kanakakunnu Palace, Trivandrum, India.
3. Group meeting of AICRP on spices, 8-10 July 1997, University of Agricultural Sciences, Bangalore.
4. National Seminar on Black pepper and Cardamom 17-18 May 1992, National Research Center for Spices Calicut, Kerala, India.
5. National Seminar on Post-Harvest Technology of Spices, 13-14 May 1993, Regional Research Laboratory, Trivandrum, India.
6. National Seminar on Diseases of Spices, 7-8 April, 1994, National Research Center for Spices Calicut, Kerala, India.
7. International Symposium on Plantation Crops (PLACROSYM-XI), 30 November- 3 December 1994, National Research Center for Spices, Calicut, Kerala, India.

8. National Seminar on Biotechnology of Spices and Aromatic Plants (BIOSAAP), 24-25 April 1996, Indian Institute of Spices Research, Calicut, Kerala, India.
9. National Symposium on Horticultural Biotechnology 28-30 Oct, 1996 Indian Institute of Horticultural Research, Bangalore.
10. Plantation Crops Symposium (PLACROSYM-XII), 27-29 Nov, 1996, Rubber Research Institute of India, Kerala, India.
11. Centennial Conference on Spices & Aromatic Plants, Indian Society for Spices, September 20 –23, 2000, Calicut, Kerala, India.
12. Seminar on Biotechnological interventions in Medicinal Plants of Kerala, 7th Nov.2000; Kerala Agricultural University, Trivandrum, Kerala –695 522.
13. Seminar on Recent Advances in Biology, 28Feb.2001, Regional Science Center, Calicut, Kerala, India.
14. 6th International workshop on Plant Growth Promoting Rhizobacteria, 5-10th October, 2003, Calicut, India
15. 16th Kerala Science Congress, (Co-Chairman for Session on Biotechnology) Kerala State Council for Science, Technology and Environment, Centre for Water Resources Development and Management, Calicut, January 2004.
16. AICRPS Workshop on Spices, 3-5th February, 2004, IISR, Calicut.
17. Commercialization of Spices, Medicinal and Aromatic Crops, Indian Society for Spices, Nov. 1-2, 2004, Calicut, Kerala, India.
18. Diagnestics and Molecular Characterization of Pathogens of Horticultural Crops and their Bio control Organisams, ICAR Winter school, 1-21 December, 2006, Indian Institute of Spices Research, Calicut, Kerala.
19. Basic Concepts in Molecular Biology and Gene Trasfer in Plants, DBT sponsored Popular Lecture Series in Biotechnology, 19Sept, 2007, Unity Women's College, Manjeri, Kerala.
20. National Seminar on Organic Spices and Aromatic crops, Feb 1-2, 2007. DASD,MOA, GOI, Calicut
21. National Symposium on "From Chromosomes to Genomes- Challenges and Prospects", 26-28 March, 2008 Kerala University, Trivandrum- 695581, India.
22. National Workshop on Spices Statistics, 23-24 May, 2008, DASD, Calicut.

Dr. B. Sasikumar

1. National Seminar on Pepper and Cardamom, Calicut, 17-18 May 1992.
2. DBT National Associate ship, MKU, Madurai, April 92 –Jan 93.
3. National Seminar on Post harvest Technology of Spices, Trivandrum, 13-14 May, 1993.
4. XII Workshop of AICRP (Spices), Thrissur, July 26-29, 1993.
5. National Seminar on Diseases of Spices, Calicut, 7-8April, 1994.
6. International Symposium on Plantation Crops (PLACROSYM-XI), Calicut, Nov 29-Dec 3, 1994.
7. National Group Meeting of Workers of AICRP (S) Jaipur, 23-25 July, 1996.
8. Interface with Farmers – Exporters – Scientists Calicut, Oct 11-12, 1996.
9. National Seminar on Water and Nutrient Management for Sustainable Production and Quality of Spices, Coorg, 5-6 Oct 1997.
10. Golden Jubilee National Symposium on Spices, Medicinal and Aromatic Plants-Biodiversity Conservation and Utilization, Calicut 10-12 Aug, 1998.
11. PLACROSYM – XIII Coimbatore 16-18 Dec, 1998.
12. XV Workshop of AICRP (Spices) Calicut 18-21 Nov 1999.
13. Centennial Conference on Spices, Medicinal and Aromatical Plants, Calicut 20-23 Sept, 2000.
14. Pepper Technology Mission review sheet, Thrissur, 2 Oct 2000.
15. National Biodiversity Strategy and Action Plan, Regional Workshop Thrissur, 4 Nov 2000.
16. Fifth Meeting Kerala Biodiversity Committee, Trivandrum Dec 1 2000.
17. Diamond Jubilee Symposium on 100 years of Post Mendelion Genetics and Plant breeding - Retrospect's and Prospectus, New Delhi, 6-9, Nov 2006.
18. Brain storming on IPR with Particular reference to Plantation Crops, Kasaragod, Jan 9 2001.
19. National seminar. WTO and its Impact ion India Agriculture, Hyderabad, 11-12 October 2001.
20. Policy Makers Workshop on Farmers Right From Legislation to Action and Kerala Bioresources Conservation, Kalpetta Nov 24, 2001
21. International conference on biodiversity and conservation, Calicut, 24 Jan 2001

22. Implementation of Farmers Right for Conservation and Utilization of Plant Genetic Resources in Asia - Pacefic Region From Legislation to Action – Chennai, January 21-23, 2002.
23. South Zone Meeting of Indian Phytopathological Society, Calicut, Dec 10-12 2001.
24. Workshop on Codification of Crop Resources, Calicut, 5-6 Feb 2002
25. Patent Awareness Workshop, Thrissur, 21 March 2003
26. Seminar on Investment Opportunities on Herbal Spices, Coimbatore, May 22, 2003.
27. Workshop on National Biodiversity, Strategy Action Plan for Kerala, Thrissur, 23-24 Sept 2002.
28. Farmers Seminars, Calicut 15 march 2003.
29. Geographical Indication of spices - WTO Task force subcommittee Meeting 14 November 2002 Calicut.
30. 22nd State Seed sub committee Meet, Thiruvananthapuram 18 September 2002.
31. Research - Extention workers - Farmers interface meet, Ambalavayal, 5 Aug, 2002.
32. National Seminar on Strategy for Increasing Production and export of spices Calicut 24-26 Dec 2002.
33. Farmers-Scientist interaction workshop on Development of Homestead farming, 28 Aug, 2003, Calicut.
34. Research – extension workers interface 27 Oct 2003 Calicut.
35. National Seminar on Biotechnology - A tool for sustainable production, 5-6 Jan, 2004, Gujarat.
36. Farmers Seminar, 13 Feb 2004, Calicut.
37. Workshop on Agricultural Bioinformatics, 29-30 Oct 2003, Calicut.
38. National Seminar on new Perspectives in Spices, Medicinal and Aromatic Plants 27-29 Nov 2003, Goa.
39. XVII National Group meeting of Research workers of AICRP (Spices) 3-5 Feb 2004, Calicut.
40. ICAR-IPA Conference on IPR and Management of Agricultural Research New Delhi, Aug 27-29, 2005
41. XVII Workshop/ National group meeting of Research works of AICRP (Spices) Feb 3-4 2004, Calicut.

Dr. Johnson. K. George

1. National Seminar on Pepper and Cardamom Calicut, 17-18 May 1992.
2. Workshop on DNA Techniques, Madurai, Oct 16-22, 1992
3. Application of Laboratory Techniques in Biotechnology, Madurai, March 8-16, 1990
4. National Seminar on Post harvest Technology of Spices, Trivandrum, 13-14 May, 1993.
5. National Seminar on Diseases of Spices, Calicut, 7-8April, 1994.
6. International Symposium on Plantation Crops (PLACROSYM-XI), Calicut, Nov 29-Dec 3 1994.
7. Seminar 'Crop breeding in Kerala' Kerala University, Trivandrum 25 Jan 1996.
8. National Seminar a Biotechnology of Spices, Medicinal and Aromatical Plants Calicut, 24-25 April, 1996.
9. National Seminar on Water and Nutrient Management for Sustainable Production and Quality of Spices, Coorg, 5-6 Oct 1997.
10. Golden Jubilee National Symposium on Spices, Medicinal and Aromatic Plants-Biodiversity Conservation and Utilization , Calicut 10-12 Aug, 1998
11. XV Workshop of AICRP (Spices) Calicut 18-21 Nov 1999.
12. National Seminar on Strategy for increasing production and export of spices Calicut 24-26 Dec 2002.
13. Workshop on Codification of Crop resources Calicut, 5-6 Feb 2002

Dr. K. V. Saji

1. National Biodiversity Strategy & Action Plan - Regional Workshops, Thrissur, 4 Nov. 2000.
2. National Group meeting of Research workers of AICRP (Spice) Thrissur Nov 1-3, 2001.
3. South Zone Meeting of Indian Phytopathological Society, Calicut, Dec 10 -12, 2001
4. Workshop on Codification of Crop resources Calicut, Feb 5-6, 2002.
5. National Seminar on Strategy for Increasing Production and Export of Spices Calicut 24-26 Dec 2002.
6. National workshop on NATP-PB, organized by NBPGR, New Delhi from23rd to 24th 2001 at NBPGR, New Delhi.

7. XVI Workshop of All India Co-ordinated Research project on Spices, held at KAU from 1st to 3rd November 2001.
8. 4th Indian Agricultural Scientists and farmers congress organized by CCS University, Meerut and Bioved Research and Communication Center, Allahabad at CCS Universiy, Meerut on 16-17 Feb 2002.
9. III Zonal workshop of NATP (PB) held at CPCRI, Kasaragod from 6 to 7th of March 2002.
10. National Seminar on 'Bioinformatics & Biodiversity Data Management' from 15 to 17 May 2003. Organized by Bioinformatics centre, Tropical Botanic Gardens & Research Institute, Palode, Thiruvananthapuram.
11. Zonal workshop of National Agricultural Technology Project on Plant biodiversity from 5-6 August 2003 at CTCRI, Trivandrum. Organized by NBPGR, Trichur.
12. Workshop on Agricultural Bioinformatics. Organized by Bioinformatics centre, IISR, Kozhikode from 29-30 October 2003 at IISR, Kozhikode.
13. National Seminar on 'New Perspectives in Spices, Medicinal and Aromatic Plants'. Organized by Indian Society of Spices, IISR, Kozhikode and ICAR Research Complex, Goa. At ICAR Research Complex, Goa from 27 to 29 November 2003.
14. National workshop of 'All India Coordinated Research Project on Spices' from 3 to 5 February 2004 at IISR, Kozhikode. Organized by IISR, Kozhikode.
15. SYMSAC-1 Symposium on Spices and Aromatic Plants) – Commercialization of Spices, Medicinal and Aromatic Crops at IISR, Calicut from 1-2 November, 2004.
16. Wild relatives of crop plants and post collection care of germplasm" at NBPGR, Thrissur. Training for CCPI's of Zone II a d X of NATP (PB) at NBPGR, Regional Station, Thrissur, on 6-10-04. – As a resource person.
17. Workshop on "AgriInformatics" organized by bioinformatics center, IISR Calicut from 15-16, October, 2004.

Dr.R. R. Nair

1. National Seminar on Pepper and Cardamom Calicut, 17-18 May 1992.
2. National Seminar or Post harvest technology of Spices Trivandrum 13-14 May, 1993

Dr. Utpala Parthsarathy

1. National consultation workshop on " Agrobiodiversity hotspots and access and benefit sharing" organized by National Biodiversity Authority, Chennai, PPV & FRA, New Delhi and Faculty of Agriculture, Annamalai University . 19-20 th July.
2. SYMSAC IV- 'Threats and solutions to Spices and Aromatic Crops Industry' at OUAT, Orrissa from 25-26, Nov. 2007.

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3. Varieties of Spices Developed at IISR. 2001. K.Nirmal Babu, K.V Saji, B.Krisnamoorthy and Y.R. Sarma
4. Saji. K. V., Johnson George, K., Utpala Parthasarathy & Parthasarathy, V. A. 2007. Biodiversity of *Piper* in India. NBA scientific bulletin No. 16, National Biodiversity Authority, Chennai, Tamil Nadu. India. Pp-91

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2. Ravindran, P. N., Sasikumar, B. and Peter K. V. 1997 Black pepper, ginger and turmeric In: natural Resources of Kerala (Ed) Thambi, K. B., Nayar, N. M. and Nair, C. S. WWF for Nature India pp. 296-309.
3. V. A. Parthasarathy, K.V.Saji & B. Sasikumar. 2005. Achievements in Spice crops and future strategies. In: Crop Improvement and Production Technology of Agricultural Crops. Vol.1. Proc. The first Indian Hort. Congress, 6-9-Nov. 2004. (Ed.) K.L. Chadha et al. Indian Soc. Hort., New Delhi, pp 105-132.

4. K.V. Saji, B. Sasikumar, Johnson George, K and Sarma. Y.R. 2005.Biodiversity in black pepper and its conservation. (ed) Annon. In. State Biodiversity Strategy and Action Plan (SBSAP) for Kerala, KFRI, Trissur, pp.194-199.
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6. Parthasarathy & Saji. K. V. 2007. Improvement of Spices. In" Breeding for resistance to diseases and insect pests in plantation crops". (Eds). R. V. Nair, V. Krishnakumar, Regi. J. Thomas, K. Muralidharan & George. V. Thomas. CPCRI, Kasaragod. pp 70-89.

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2. Sarma, Y. R., Nambiar, K. K. N. and Nair, M. K. 1982 Screening of black pepper (*P. nigrum*) and *Piper* spp. against *Phytophthora palmivora* In: Nambiar KKN (ed.)Proc workshop on *Phytophthora* diseases of tropical cultivated plants. 19-23 Dec 1980.PP 242-247.
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4. Peter, K.V. and Ravindran, P. N. 1996. Genetics and breeding of black pepper. Second international Crop Science, 19-24 Nov 1996, New Delhi.
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824 Infrastructural facilities developed

1. Green house-1
2. Crossing block-1
3. Multiplication nursery shed-12
4. Herbarium facility

8245 Comments/ Suggestions of Project Leader regarding possible future line of workthat may be taken up arising out of this Project.