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ACRONYMS

CIP	:	International Centre for Potato
CIAT	:	International Centre for Tropical Agriculture
IITA	:	International Centre for Tropical Agriculture
AVRDC	:	Asian Vegetable Research and Development Centre
IPGRI	:	International Plant Genetic Resources Institute
NBPGR	:	National Beureau of Plant Genetic Resources
NATP	:	National Agricultural technology Project
MSSRF	:	M.S.Swaminathan Research Foundation
CTCRI	:	Central Tuber Crops Research Institute
BA	:	Benzyl adenine
NAA	:	Naphthalene acetic acid
MS	:	Murashige and Skoog
LN	:	Liquid Nitrogen
DMSO	:	Dimethyl sulfoxide

सत्यमेव जयते

Biodiversity of Tropical Tuber Crops in India

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2006

National Biodiversity Authority
Chennai, TamilNadu, India

NBA Scientific Bulletin Number - 7

Citation : **Edison S., M.Unnikrishnan, B.Vimala, Santha V.Pillai, M.N.Sheela, M.T. Sreekumari and K.Abraham.** 2006. Biodiversity of Tropical Tuber Crops in India. NBA Scientific Bulletin Number - 7, National Biodiversity Authority, Chennai, TamilNadu, India, p60.

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Printed by :

Frontline Offset Printers
26, New Street, Llyods Road,
Triplicane, Chennai - 600 005.
Ph : 28470052

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INTRODUCTION

Root and Tuber Crops are the most important food crops after cereals. They have the highest rate of dry matter production per day and are major calorie contributors. Tuber crops find an important place in the dietary habits of small and marginal farmers especially in the food security of tribal population. Tuber crops not only enrich the diet of the people but also possess medicinal properties to cure many ailments or check their incidence. Many tropical tuber crops are used in the preparation of stimulants, tonics, carminatives and expectorants. The tuber crops are rich in dietary fibre and carotenoids *viz*. â carotene and anthocyanin. India holds a rich genetic diversity of tropical root and tuber crops *viz*. Cassava, Sweet potato, Aroids, Yams and several minor tuber crops. The Indo-Burma region is the centre of origin of taro and Asiatic edible yams. The two hot spots of global biodiversity *viz*. North Eastern Himalayas and Western Ghats are particularly rich in wild relatives of tropical root and tuber crops. Safe conservation and sustainable use of plant biodiversity is essential for meeting the present and future needs of tuber crop improvement in India. The Central Tuber Crops Research Institute, Thiruvananthapuram initiated collection of tuber crops germplasm and wild relatives from all over India from 1963 onwards. The gene bank was subsequently enriched through international exchange of germplasm from CIP,CIAT, IITA, AVRDC etc. The total germplasm holding of tuber crops was about 2000 until 1980's. With the major support of the Jai Vigyan Programme of the National Agricultural Technology Project (NATP) since 1998-99 and the special efforts by the ICAR's ad-hoc schemes, explorations were carried out in several unexplored regions in Chattisgarh, Jharkhand, Madhya Pradhesh, Orissa, Tripura, Mizoram and Andaman & Nicobar islands. Collections were also made several times from the evergreen Western Ghats also. This has resulted in the collection of more than 1000

accessions of different tropical tuber crops. In addition, more than 700 accessions were acquired through International Consultative Group on Agricultural Research (CGIAR) support during 1990's. Several unique collections and indigenous technical knowledge could be gathered.

Among the tuber crops, Cassava is the most important one in the tropics and it ranks fourth, after rice, sugarcane and maize, as a source of calories for human consumption. It is a major carbohydrate food for about 500 m people in the world, and in Africa, it is the most important source of calories in the human diet. Cassava is cultivated in 16 million hectares, spread over the continents of South America, Africa and Asia, producing 158 mt of tubers. The average productivity in the world is 10.88 t $ha^{-1}$and that in India is 27.42 t ha^{-1} from an area of 0.24 m ha. However in sweet potato, average productivity in India is only 8-9 t ha^{-1} as against the world average of 16 t ha^{-1}. Area under cultivation under tuber crops in India is 4 lakh ha under cassava and sweet potato besides approximately 2 lakh ha in elephant foot yam, *Colocasia*, *Xanthosoma* etc.

2.Origin and Distribution of Major Tuber Crops in India

There are five major areas of distribution of root and tuber crops in India. These are (i) South-western hilly and coastal region, (ii) Southern peninsular region, (iii) Eastern coastal region, (iv) North-eastern region and (v) North-western region. The important tuber crops grown in India and the regions of biodiversity are given in Table 1.

The economically and socially important tropical tuber crops are Cassava (*Manihot esculenta*), Sweet potato(*Ipomoea batatas*), Yams (*Dioscorea alata, D.esculenta* and *D.rotundata*), Aroids which include Elephant foot yam, Taro and Tannia ((*Amorphophallus*, *Colocasia* or Taro, *Xanthosoma* or Tannia) and other minor tuber crops namely Chinese potato, Arrow root, Yam bean, *Canna* etc (Table 1.)

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Common Name	Scientific Name	Family	Vernacular Name	Places/Areas Grown
CASSAVA	*Manihot esculenta* Crantz 2n = 36	Euphorbiaceae	Maracheeni kizhangu & Kappa(M) ; Maravalli kizhangu & Ezhalai kizhangu(T) ; Maraganasu(K) ; Karrapendalamu(TE)	Southern region Occasionally in North eastern & western regions
SWEET POTATO	*Ipomoea batatus* (L.)Lam. 2n = 90	Convolvulaceae	Mitha alu & Shakarkand(H); Cheeni kizhangu & Madhura kizhangu(M); Shakkareivalli kizhangu (T); Genasu(K); Chelagada(TE); Ratalu(MR);Lal alu & Ranga alu(B)	Introduced and found all over but mostly concentrated in Eastern U.P, Bihar, West Bengal and Orissa
GREATER YAM	*Dioscorea alata* (L.) 2n = 40, 60, 80	Dioscoreaceae	Pind Aaluk(H); Kachil & Kavithu(M); Peruvalli kizhangu & Vetrilaivalli kizhangu (T)	South & North Eastern region
WHITE YAM	*Dioscorea rotundata* (Poir.) 2n =40	Dioscoreaceae	Safed Aaluk (H); African kachil(M); African valli kizhangu(T)	Introduced to India and spread to South and North Eastern region
LESSER YAM	*Dioscorea esculenta* (Lour.) Burk. 2n =30-100	Dioscoreaceae	Kayu(H) ; Cheruvalli kizhangu, Cherukizhangu , Nana kizhangu, Mukkizhangu(M) ; Siruvalli kizhangu (T)	South, N.E & Eastern region
POTATO YAM	*D. bulbifera var. sativa* 2n = 40,60	Dioscoreaceae	Mekkachil & Erachikachil (M)	Southern, North East and Eastern region
TARO	*Colocasia esculenta* (L.) Schott 2n =28,42	Araceae	Arvi , Kachalu & Ghuiya(H); Kachu(S); Chempu(M); Seppan-kizhangu (T); Kachchi(K); Shamagadde(K); Chamadumpa & Chemagadda(TE); Alu(MR); Kachu(B)	Throughout India with greater diversity in North east, Eastern region and South

Common Name	Scientific Name	Family	Vernacular Name	Places/Areas Grown
TANNIA	*Xanthosoma sagittifolium* 2n =26	Araceae	Palchempu(M)	South and North eastern region
ELEPHANT FOOT YAM	*Amorphophallus paeoniifolius* (Dennst.) Nicolson 2n =28	Araceae	Zamim-kand & Gimmikand(H); Arsaghna & Balukand(S); Chena(M) Karnai-kilangu(T); Suvarna gadde(K); Kanda(TE); Suran(MR); Ol(B)	Southern, North East and Eastern region
CHINESE POTATO	*Solenostemon rotundifolius* (Poir.) J.K. Morton *Plectranthus rotundifolius* 2n = 60	Labiatae	Koorka kizhangu(M); Sim kizhangu(T)	Southern parts of India
YAM BEAN	*Pachyrrhizus erosus* (L.) Urban 2n=26	Leguminosae	Misri Kand (H); Pachi kizhangu (M)	North Eastern region
WINGED BEAN	*Psophocarpus tetragonolobus*(L.) D.C. 2n =26	Leguminosae	Chadhura payar & Goa payar (M)	South & North East
WEST INDIAN ARROW ROOT	*Maranta arundinaceae* L. 2n = 48	Marantaceae	Koova (M)	Adapted to plain areas with high rain fall; shade loving

H – Hindi, S- Sanskrit, M-Malayalam, MR-Marathi, TE-Telugu, T-Tamil, K-Kannada, B-Bengala, NE – North east.

The indigenous technical knowledge held by the tribals and ethnic groups is another valuable resource integrated with biodiversity and this needs to be documented and validated for the fuller exploitation of biodiversity. An integrated approach on biodiversity conservation and sustainable utilization can pave the way for bioprospecting for novel plant products. Search for new life-support species of minor tuber crops from natural habitats of hot spots has to be initiated. India, with its immense wealth of natural biodiversity can take the lead in bioprospecting and new drug discoveries, if a concerted and integrated national approach is adopted.

Concerted effort has to be made by the different agencies like CTCRI, NBPGR, the State Agricultural Universities and NGO's like MSSRF with the support and guidance from the National Biodiversity Authority of India for the preservation and sustainable utilization of this natural wealth. Efforts made in this direction will be of great service to the nation as well as in the protection of the food basket of the tribal people and rural poor.

Advances in agricultural technology could have its greatest impact as an effective instrument against poverty , hunger, malnutrition and environmental degradation. Root and tuber crops have tremendous importance as a means of agricultural development to serve the immediate needs of individuals for food and income. Structuring the genetic diversity is necessary to optimize the use of germplasm by breeders for which molecular level screening is highly warranted.

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/ disappearing species can be done by rehabilitating them in gene banks, in addition to habitat preservation. In the case of tuber crops, it is very necessary to survey, document, collect and conserve the wild relatives / forms of yams and taro that may contain exceptional genes for incorporation into cultivated forms.

Majority of the *ex situ* germplasm collections are land races and breeding materials. The representation of wild and weedy relatives of crop plants in germplasm holdings is minimal. However the wild species can provide novel genes for crop improvement. Hence exploration of the natural / wild habitats for collection is to be strengthened, which needs special projects/ assistance as was granted by NATP- PB project earlier (1998-2005).

The *ex situ* conservation of biodiversity (especially forest collected plants) requires special environments like shade houses and net houses and the field and *in vitro* conservation requires more facilities and resources which is essential in preserving the valuable genes and gene donors for sustainable use in the coming years. The pressure on maintenance of large number of accessions can be considerably reduced by identification and elimination of duplicates among land races and breeding materials.

The national program has to be strengthened by periodical updating of the information on local germplasm collection and incorporation of more accessions from various sources to enhance the genetic variability. Evaluation and documentation of the accessions are to be conducted intensively. Identification of duplicates and formation of core collections will bring down the cost of maintenance of the collections by the National Programme. Facilities are to be strengthened for maintenance of field gene bank as well as *in vitro* conservation. The indigenous technical knowledge has to be validated to get full exploitation of genetic wealth of tuber crops existing in India.

2.1.Cassava

Cassava (*Manihot esculenta* Crantz) belongs to the family Euphorbiaceae and is believed to have originated in South America, most probably Brazil. Wild species of cassava are found in the natural habitat in Brazil. The genus *Manihot* consists of about 98 species but none of the existing wild species can clearly be identified as the ancestor of cassava. Recently genetic variation at microsatellite loci has been used for the investigation on evolutionary and geographical origins of cassava from its wild relatives (Olsen and Schaal, 1999). The evidence from molecular analysis point towards the possible origin of cassava from Brazilian wild species *viz. Manihot tristis* and *M. esculenta* sub sp *flabellifolia*. The studies helped in uncovering the unique genetic diversity in *M. esculenta* subsp. *flabellifolia* and *M. esculenta* subsp. *peruviana* and their genetic similarity to cassava supporting the hypothesis that these two species might be the ancestors of cassava. Genetic erosion of wild *Manihot* species is occurring at a fast rate in Brazil due to deforestation.

2.2.Sweet potato

The cultivated sweet potato (*Ipomoea batatas* L.) and the wild species closely related to it belong to the family Convolvulaceae, genus *Ipomoea,* subgenus Eriospermum, section Eriospermum (formerly Batatas) and series Batatas (Austin and Huaman, 1996). In addition to *I. batatas,* there exists 13 wild species closely related to sweet potato. Sweet potato is an ancient crop, originated in the north western part of South America. Archaeological evidence from Peru shows that domestication of sweet potato dates back to 6000 BC. *I. batatas* is a hexaploid with 2n = 90, while most of the wild species are 2x or 4x, although there are some species like *I. trifida* which has 2x, 3x, 4x and possibly 6x cytotypes. Austin (1988) hypothesized that *I.triloba*

and *I trifida* are the species that contributed the sweet potato genome and that *I.tiliacea* might also have been involved in the origin of sweet potato. Shiotani (1988) reported that sweet potato has the genome structure of an autohexaploid with the B genome that also exists in autotetraploids and diploids of the *I. trifida* complex. However botanical geneology needs further research on wild *Ipomoea* species.

2.3.Yams

Food yams are believed to have originated in the tropical areas of three separate continents, Africa, South East Asia and South America. The Asiatic yam (*Dioscorea alata*), probably originated in Indo Burma region. The putative parents most often mentioned are *D. persimilis* and *D. hamiltonii*, which grow in the wild form in South-East Asia. Wild yams and domesticated cultivars occur throughout the tropical and subtropical world. Yams are grown mostly in Asia, Africa and South America. In India, they are grown in all the States but the major yam producing states are Kerala, West Bengal, Bihar, Orissa, Tamil Nadu, Assam, Rajasthan, Gujarat and Maharashtra. Prain and Burkill (1936) reported the occurrence of about 50 different *Dioscorea* species in India, largely in the west, east and northeast regions. Many of the *Dioscorea* species serve as a 'life saving' plant group for the marginal farming and forest dwelling communities, during periods of food scarcity (Roy *et al.* 1988; Arora and Anjula Pandey, 1996). Henry *et al.*(1989) also reported that the *Dioscorea* sp. are widely distributed in Tamil Nadu. The major wild yams in India and their distribution is given in Table 2.

S. No.	Variety	Maturity Period	Starch (%)	Yield (t/ha)
Taro				
1	Sree Pallavi	7 months	24-25	15-18
2	Sree Rashmi	7 months	15-16	15-20
3	Muktakesi	5-6 months	16-18	20
4	Sree Kiran	7 months	16-18	18
5	Panisaru-1	6-7 months	12-13	16
6	Panisaru-2	6-7 months	16-18	13
Elephant Foot Yam				
1	Sree Padma	8-9 months	12-13	42
Chinese Potato				
1	Sree Dhara	5 months	16-20	25

7. CONCLUSION

India is rich in the floral diversity of root and tuber crops. It harbours two of the richest global biodiversity hot spots in the Western Ghats and the North eastern region, comprising part of the Indo-Burmese hotspot. These hotspots contain a large number of wild relatives of cultivated tuber crops as well as many under-exploited tuber crops known to tribals. The Indo Burmese centre probably contains the ancestral species of cultivated Asiatic yams and taro. It is estimated that these biodiversity hot spots are undergoing exceptional loss of habitat resulting in the erosion or even the loss of precious endemic species. Hence there is an urgent need to check this loss and protect the habitats and document the flora of the hot spots for periodic monitoring. Major portion of the genetic diversity of wild species and land races existing in the tropical forests and remote villages are yet to be explored, collected and conserved. Conservation of the endangered

S. No.	Variety	Maturity Period	Starch (%)	Yield (t/ha)
9	Sankar	120 days	17-18	14
10	Sree Arun	90 days	19-21	20-28
11	Sree Varun	90 days	21-22	20-28
12	Sree Kanaka	75-85 days	14-15	10-15
13	Kalinga	105-110 days	27-29	26-28
14	Goutam	105-110 days	24-26	18-32
15	Sourin	105-110 days	24-26	16-32
16	Kishan	110-120 days	29-30	16-26
Greater Yam				
1	Sree Keerthi	9-10 months	20-22	25-30
2	Sree Roopa	9-10 months	16-18	25-30
3	Sree Shilpa	8 months	17-19	28
4	Sree Karthika	9-10 months	21-23	30
5	Orissa Elite	6 months	20-21	22-25
White Yam				
1	Sree Priya	9-10 months	19-21	35-40
2	Sree Subhra	9-10 months	21-22	35-40
3	Sree Dhanya	9 months	22-24	20
Lesser Yam				
1	Sree Latha	8 months	18-19	25-30
2	Sree Kala	7.5 months	23-25	20

Table 2. Distribution of wild relatives of Yams

Crops	Related Species	Distribution
Greater yam, Potato yam Lesser Yam,	*D. hamiltonii Hook*	All over Western Ghats at lower elevations as a trailing plant.
	D. pentaphylla Linn. *D. oppositifolia* Linn	All over upto 4000 ft. elevation in Western Ghats
	D. bulbifera Linn.	All over from coastal plains to 4000 ft. in Western Ghats
	D. tomentosa Heyne *D. pubera* Blume	At lower elevation (1500') in Western Ghats
	D. spicata Roth	In higher elevations from 3000 ft. and above
	D. wightii Hook	Very rare at lower elevations in Tirunelveli hills , Tamil Nadu
	D. wallichii Hook	All over from plains to 3000 ft.
	D. intermedia Thw.	At lower elevations up to 3000 ft.
	D. hispida Dennst.	All over at lower elevations
	D. belophylla Voight.	At 2000 to 3000 ft.
	D. kalkapershadii Pr. Burk.	At the lower foot hills of Shevarayan hills, Tamil Nadu

Most of the species are ethnically important as a secondary staple and a delicacy for tribal people in the interior areas in Western Ghats. Considerable variability is noticed in edible wild yams (*D.pentaphylla, D.oppositifolia).* The *Dioscorea* species *viz. D. wightii*, *D.spicata* and *D. belophylla* are endemic to these areas. Balakrishnan *et al.,*2003, studied the distribution of wild species and their conservation by Kattunaikka, a predominant tribe in Western ghats. The study revealed that about 21 different types of *Dioscorea* are present

in Wayanad district of Kerala which include a part of the mountain chain of the Nilgiris, Silent Valley and Kodagu region in the Western ghats, a biodiversity hotspot. Among the varieties known to Kattunaikka tribe, Venni kalasu (*D. hamiltonii*) Hekku kalasu (*D. belophylla*), Kavala kalasu (*D. oppositifolia*)L. are predominantly seen in the interior evergreen and moist deciduous forests. Shoddi kalasu (*D. intermedia*?) is seen in dry deciduous forests, and Ere kalasu (*D. wightii*?) in rocky grasslands. Noora kalasu(*D. pentaphylla*), Nara kalasu (*D.wallichii*), Hendhiride kalasu (*D. bulbifera*) on wayside bushes and Boojikkavala kalasu (*D. pubera*) in marshy areas. Among the various species, *D. hamiltonii*, *D. belophylla*, *D. oppositifolia* and *D. pentaphylla* var. *pentaphylla* are the most acceptable ones for culinary purpose, but other than *D.pentaphylla* all are very rare. The tribals collect *Dioscorea* from almost all landscapes, but most frequently from the forests and other such unmanaged habitats

2.4.Aroids

Aroids include the tuber bearing plants belonging to the family *Araceae viz*. taro (*Colocasia*), giant taro (*Alocasia*) tannia (*Xanthosoma*), elephant foot yam (*Amorphophallus*), and swamp taro (*Cyrtosperma*). Among these, taro is the most widely cultivated crop occupying 10 lakh hectares around the world and producing 6.61 million tons of tubers. Taro is mostly cultivated in Asia, Africa and Pacific as well as Caribbean Islands. In Pacific Islands it is an important economic crop besides being a staple in countries like Fiji, Papua New Guinea, Western Samoa, Vanuatu etc in the South pacific region. In India, taro is cultivated in almost all the states, right from the foot hills of Himalayas to the coastal areas in the South. Taro is believed to have originated in South East Asia including India (Watt, 1889). From there, it probably spread to Egypt,

Table-8. Tuber crop varieties released from CTCRI.

S. No.	Variety	Maturity Period	Starch (%)	Yield (t/ha)
Cassava				
1	H-97	10 months	27-31	25-35
2	H-165	8-9 months	23-25	33-38
3	H-226	10 months	28-30	30-35
4	Sree Visakham	10 months	25-27	35-38
5	Sree Sahya	10-11 months	29-31	35-40
6	Sree Prakash	7 months	29-31	30-35
7	Sree Harsha	10 months	38-41	35-40
8	Sree Jaya	6-7 months	24-27	26-30
9	Sree Vijaya	6-7 months	27-30	25-28
10	Sree Rekha	8-10 months	28-30	45-48
11	Sree Prabha	8-10 months	26-29	40-45
Sweet Potato				
1	H-41	120 days	14-16	20-25
2	H-42	120 days	16-18	22-25
3	Varsha	120 days	14-16	17-22
4	Sree Nandini	100-105 days	25-26	20-25
5	Sree Vardhini	100-105 days	13-15	20-25
6	Sree Rethna	90-105 days	22-23	20-26
7	Sree Bhadra	90 days	18-20	20-27
8	Gouri	110-120 days	16-17	19

In taro, the triploid varieties released are high yielders and 'Muktakeshi', another germplasm selection, was found to be resistant to the serious taro leaf blight disease caused by *Phytophthora colocasiae*. In taro also, the first hybrid variety was released by hybridization of fertile diploid parents from the germplasm. Flowering inadequacies, occurrence of sterile triploid genetic stocks and protogynous nature of the spadix are the main obstacles for the genetic improvement of taro through hybridization and selection. By effective utilization of taro fertile diploid germplasm accessions, a large number of hybrids were produced in CTCRI. Systematic screening of hybrid progeny resulted in releasing the first hybrid variety of taro in India under the name "Sree Kiran" during 2004 from CTCRI. The higher cormel yield, good cooking quality and larger storability of tubers are the desirable attributes of this hybrid. In elephant foot yam (*Amorphophallus paeoniifolius*) the released variety 'Sree Padma' from CTCRI is the first variety released in this crop from Kerala State is also a superior germplasm selection. *Coleus* being a sterile species, superior germplasm selections like 'Sree Dhara' released as a variety will be of use for popular cultivation.

A total of 45 improved varieties of root and tuber crops have been released from CTCRI of which nearly 50 percent are superior germplasm selections directly released as varieties.. In addition, another equal number of varieties from germplasm selection have also been released from AICRP centres on tuber crops. The tuber crop varieties released from CTCRI are listed in Table: 8.

Arabia and the Pacific. The hypothesis that the North East India is the centre of origin of taro was confirmed by many Indian workers. South America in particular is considered as the centre of origin of tannia. Elephant foot yam is more prevalent in southern and eastern regions.

Table 3. Distribution of wild relatives of Aroids

Crops	Related Species	Distribution
Taro (Colocasia)	*C. esculenta var. antiquorum*	All over as wild
	C. esculenta var esculenta	In hills at about 3000 ft. and North Eastern region
	C. esculenta var. sylvestris	Very rare, a mutant type from common wild taro
	C. esculenta var. aquatilis	Very common in marshes, water courses and under the evergreen forests in Western.Ghats
	C. affinis	North east India and Kerala
	C.fallax Schott	At lower hills in Assam, West Bengal and Meghalaya
Elephant foot yam	*Amorphophallus dubius* Bl.	Very common in Kerala, in laterite soils in plains
	A. hohenackerii Engl.	-do-
	A. commutatus (Schott) Engl.	In lower hills and in plains in Kerala and Coastal Karnataka
	A. smithsonianus	Found In lower hills in southern districts of Kerala
	A. bonoccordensis	-do- (Rare)
	A. bulbifera Bl.	All over in Malabar, Waynad, S. Kanara and Chikmagalur
	A. sylvaticus (Roxb.)Kunth	Karnataka
	A. oncghophyllus	Andaman & Nicobar islands

In *Colocasia*, the richest diversity is noticed in the North-east followed by Kerala and Western region. In elephant foot yam, rich diversity has been reported from Western Ghats. Seven wild species such as *A. hohenackeri*, *A. commutatus, A. paeoniifolius* var. *dubius*, *A. bulbifera*, A. *smithsonianus, A. bonoccordensis* and *A. sylvaticus* were located in the Western Ghats in Kerala and Karnataka. The taro germplasm includes cultivated and stoloniferous wild taro present in Western Ghats. *Moghania tuberosa*, a wild type bearing succulent roots, has been located in coastal Konkan region of Maharashtra. The Western Ghat region is also a store house of several under-utilized edible tuberous species of which *Tacca bipinnatifida*, *Asparagus spp.*, *Aponogeton sp.* and *Ceropegia sp.* which are also used as vegetables.

2.5.Minor tuber Crops

i. *Canna* :

In addition to the major tuber crops, there are many rhizomatous types and tuberising species which are grown and used in different parts of India. The genus *Canna* includes about 25 species of herbs, widely distributed throughout the tropics and sub-tropics. It belongs to the family Cannaceae. *C. edulis* Ker-Gawler originated in the Andean region or Peruvian coast and extended from Venezuela to northern Chile, in South America. It is commercially cultivated in Australia for the production of starch whereas in India, it is grown for the edible, tuberous rhizome. The plant is hardy and has low incidence of pest and diseases. The flowers of ornamental cannas (*Canna indica*) are larger and more beautiful and variable in colour than the edible types (*Canna edulis*).

ii. Arrowroot

The genus *Maranta* which belongs to Marantaceae includes 20 species of perennial herbs. One species, *Maranta arundinacea* L. (West

Fourth priority : Number of storage roots per plant, weight of roots (yield), root dry matter content, consistency, colour, texture and sweetness of boiled storage root flesh.

Evaluation of germplasm resulted in the release of Sree Bhadra, an exotic germplasm with high yield (27 t ha^{-1}) and can be raised as a trap crop in nematode infested soil. S 1221, an early bulking accession (75 days) is now under on farm trials. The germplasm of sweet potato includes about 200 carotene rich accessions. The flesh colour ranged from dark yellow to dark orange. Among the high carotene lines, the CIP accessions viz. S-1230 (CIP 440069), S-1355 (CIP 440056), S-1346 (CIP 187017) and S-1364 (CIP 440060) were found to be promising. Two varieties released from CTCRI *viz*. Gowri and Sree Kanaka also had high carotene content. Sree Kanaka, an early maturing hybrid with dark orange flesh colour was identified from the cross between a local germplasm accession S-187 and a hybrid, H.633. The tubers of Sree Kanaka contain high â-carotene to the tune of 8.8-10.0 mg/100g fresh weight, which is almost equivalent to that of carrot (11.0-12.0 mg/100 g fresh weight).

In greater yam, two superior germplasm selections were released as the first varieties. In this dioecious tuber crop, systematic efforts have helped to isolate fertile male and female germplasm collections leading to hybridization and selection. This has resulted in the development of the world's first recombinant hybrid 'Sree Shilpa' in greater yam (*Dioscorea alata*) released in 1998. The dwarf type of white yam 'Sree Dhanya', which does not require trailing, is a novel germplasm selection from white yam.

these two promising hybrids viz. H-165 and H-226 are popular in Tamil Nadu and Andra Pradesh for industrial use. Interspecific crosses also were effected for imparting mosaic resistance and high protein in roots, drought tolerance etc. to cultivated cassava varieties.

The germplasm of sweet potato was evaluated and categorized based on modified IPGRI descriptors. Seven hundred and sixty four sweet potato accessions were characterized and documented; the computerized data base is maintained (Rajendran *et al*, 1993). Recently 869 accessions were evaluated for important morphological traits for assessing the spectrum of variability and association of characters for traits such as plant type, vine growth rate, petiole length, number of storage roots and tuber yield per plant. (Easwari Amma *et al.,* 1999). Each entry of sweet potato was characterized adopting six passport and 39 morphological descriptors assigned according to the relative importance of each descriptor as given below.

First priority : Source of origin, plant type, vine growth rate, vine internode length, vine pigmentation, vine tip pubescence, mature leaf shape, mature leaf size, foliage colour, abaxial leaf vein pigmentation, petiole length and petiole pigmentation.

Second priority : Root shape, root cortex thickness, root skin colour and root flesh colour.

Third priority : Flowering habit, flower colour, flower length and width, shape of limb, sepal length, sepal shape, sepal apex, sepal pubescence, sepal colour, colour of stigma, colour of style, stigma exertion and seeds capsule set.

Indian arrowroot) is cultivated for its edible rhizomes. It is believed to have originated in the North western part of South America and the Lesser Antilles. It has been widely distributed throughout the tropical countries like India, Sri Lanka, Indonesia, the Philippines, Australia and West Indies. In India, it is grown in Uttar Pradesh, Bihar, Orissa, West Bengal, Assam and Kerala.

iii. *Curcuma*

The genus *Curcuma* belongs to the family of Zingiberaceae which contains about 70 species of rhizomatous herbs distributed in India, Cambodia, Malayan Archipelago and North Australia. About 30 species occur in India, of which two species are useful for the production of starch viz. *C.angustifolia* and *C.zedoaria* (Kundu, 1967). In India, the species *C. angustifolia* (East Indian Arrow root) occurs in the hilly tracts of Bengal, Maharashtra, Tamil Nadu and some of the lower Himalayan ranges. The plant grows in the wild in many places and is found in moist and cool habitats up to an altitude of 1,500 ft. *C. zedoaria* Rosc. (zedoary) is widely cultivated in many parts of India, Sri Lanka and China. In India, this species is growing wild in eastern Himalayas and in moist deciduous forests of coastal tracts of Karnataka. It originated in north-east India and has spread throughout the country. The plant grows up to one meter and bears green leaves with brownish-purple veins on either side of the midrib. The rhizomes are large, fleshy, branched, the inner part of which is pale yellowish brown in colour. Several species like *Curcuma aromatica*, *C.harita*, *C.malabarica*, *C.zedoaria* are used for extraction of starch having medicinal applications.

iv. Chinese potato

The genus *Solenostemon* includes about 60 species distributed throughout the tropics. *Solenostemon rotundifolius* **(**Poir)

J.K. Morton , Syn *Plectranthus rotundifolius* (chinese potato) is an important minor tuber crop cultivated in India., Sri Lanka, South-east Asia and parts of Africa and is believed to be a native of Africa. In India, it is grown in most of the homestead gardens of Tamil Nadu and Kerala . Chinese potato is mainly confined to central Kerala and Malabar in laterite soils (@200ha)and sandy coastal soils sometimes extending to Mangalore district of Karnataka. Due to its wide acceptance as an aromatic tuber vegetable in Kerala and Tamil Nadu there is a gradual spread of the crop even to black soils in Tamil Nadu as an irrigated commercial crop and of late it is intensely cultivated in more than 500 ha in South Tamil Nadu. In *Coleus*, four species *viz*, *C. aromaticus*, *C. forskholii, C. zeylanicus* and *C. spicata*,(wild or semicultivated) are present in South India.

v. *Moghania vestita*

Moghania vestita O. Kuntze is a lesser known leguminous root crop of the Khasi hills of Assam. The cultivated Himalayan types are found in the Khasi and Jaintia hills. The present day cultivation is localized to Cheerapunji near Shillong and in Jawai, south of Meghalaya. *Moghania tuberosa* (Dalzell) O. Kuntze is a wild type bearing succulent roots. It occurs in Konkan region of Maharashtra especially in the coastal belts.

vi. Yam bean

Yam bean, *Pachyrrhizus erosus* (L.) Urban is a leguminous, high yielding root crop with good nutritional value. The genus includes 5 species, of which 2 are wild and 3 are cultivated types. *P. erosus* is a native of tropical America and it is widely cultivated in India, Mexico, China, Singapore, Philippines, Hawaii and Indonesia. In India, it is grown in parts of West Bengal, Tripura, Bihar, Orissa and Assam

of *Colocasia*, Elephant foot yam, Cassava, Chinese potato, lesser yam var: Cherukizhangu. Lesser yam var: Nanakizhangu and greater yam are baked and cut into pieces after removing skin. Into this, coconut, powdered pulses and jaggery are mixed to make ettangadi and offered to Gods Ganapathy, Siva and Goddesses Parvathy and Durga.

- **Thiruvathira puzhukku :**Elephant foot yam, *Xanthosoma*, *D.alata*, banana, Chinese potato and Sweet potato are cooked with powdered green gram, coconut, red chillies, curry leaf, salt and turmeric to make this dish on the day of Thiruvathira

- Hindus consume cooked tubers of *D.alata* on the day of festival "**Karthika**"

- **Thalukary** is a preparation made for giving to pilgrims at the Dhanwanthiri temple near Thakazhy in Kuttanadu, Kerala which is believed to have medicinal effect

7. Utilization of Biodiversity

The existing cassava germplasm was evaluated for economic characters and three short duration varieties (Sree Prakash, Sree Jaya Sree Vijaya) were identified for cultivation (1987 and 1998). One mosaic resistant introduction (MNga 1) and a few advanced lines of cassava are being tested in on farm trials in Tamil Nadu prior to release. Elite breeding lines were utilized for intervarietal hybridization, polyploidy breeding and heterosis breeding. Five high yielding diploid hybrids (H 97, H 165,H 226, Sree Sahya, Sree Visakham), one high starch triploid hybrid (Sree Harsha) and two high yielding top cross hybrids (Sree Rekha and Sree Prabha) of cassava were released for cultivation. Of

S. No.	SPECIES	ITK
59.	*Scripus kysoor* L.	Tubers are used against diarrhoea and vomiting
60.	*Scripus lacustris*	Root stock is an astringent and used as diuretic.
61.	*Scripus maritimus*	Roots are astringent and diuretic.
62.	*Scripus tuberosa*	Roots are used as laxative.
63.	*Stephania wightii*	Very big tubers, 6-7 kg, used in treating leprosy.
64.	*Tacca integrifolia*	Tubers used in making tonic and in the treatment of leprosy.
65.	*Tacca leontopetaloides* (L.) Kuntze.	Tubers used in the treatment of piles, rubefacient, diarrhoea and dysentery.
66.	*Theriophonum divaricatum*	Tubers are used against diarrhoea.
67.	*Theriophonum minutum* (Willd.) Baill.	Dried & used after steaming.
68.	*Typhonium roxburghii*	Tubers used in curing skin eruptions.
69.	*Typhonium trilobatum*	Tuber contains a stimulant and is used in the treatment of piles, stomach complaints, haemorrhoids etc.

6.1.Tuber crops in rituals (Kerala)

- **Ettangadi**: A traditional dish associated with Thiruvathira festival. On the previous night of Thiruvathira, the women make "ettangadi" as a part of religious ritual of Hindus. Tubers

vii. Winged bean

The winged bean, *Psophocarpus tetragonolobus* (L.) DC**.** is exceptional among all food plants in that practically all parts of the plant are edible and a usable product is provided at every stage of its life cycle, like leaves, flowers, stem, pods, roots etc.. The genus *Psophocarpus* includes 5 species and they are found throughout the tropics. *Psophocarpus tetragonolobus* is a perennial climber with tuberous roots cultivated in India, Myanmar, tropical Africa, Asia and Madagascar for its edible pods and tuberous roots. The origin of winged bean is uncertain, although it is believed to be a native of either India or Mauritius or African region where all the species of this genus are found in wild. In India, it is cultivated in Maharashtra, Karnataka, Bihar, Orissa, Tripura, West Bengal, Assam, Tamil Nadu and Kerala.

viii. *Vigna*

Vigna vexillata or *Vigna capensis* is another unexploited edible tuber crop (Chandel *et al.*, 1978). It grows wild in western Ghats, Central Peninsular hills, Western Himalayas and Meghalaya.

ix. *Costus speciosus* (Koenig)Sm.

The genus *Costus* belongs to Zingiberaceae which includes about 175 species of perennial herbs. It is a common plant with tuberous rhizome distributed throughout India up to an altitude of 4000ft. It is often cultivated as an ornamental plant and the rhizomes are edible.

Table 4. Distribution of minor tuber crops

Crops	Related Species	Distribution
Coleus sppp	*C. aromaticus* Benth.	All over in plains under dry situation
	C. forskholii Briq.	In hills at about 3000 ft. and cultivated in Tamil Nadu. Himalayan forms are tuberising
	C. zeylanicus Benth.	In pockets of lower foot hills in Western Ghats and cultivated in pockets for its stem
	C. spicata	A wild plant in Hassan district in Karnataka
Starchy *Curcuma* spp	*Curcuma zedoaria* Rosc.	All over plains as wild and sometimes cultivated upto 3000 ft.
	C. malabarica	In coastal areas of Kerala
	C. raktakanta	In coastal areas of Kerala
	C. harita	In coastal areas and midlands of Kerala
	C. aerugenosa Roxb.	West Bengal
	C. caesia Roxb.	West Bengal
	C. ferrugennia	Foot hills of Himalayas in W. Bengal
	C. montana Roxb.	In Central India and Eastern Ghats of Andhra Pradesh
Minor wild	*Tacca pinnatifida*	Konkan region
tubers	*Asparagus*	All over India
Asparagus	*racemosus* Willd	

The Western Ghat region is also a store house of several under-utilized, edible tuberous species of which *Tacca pinnatifida*, *Asparagus spp.*, *Aponogeton sp.* and *Ceropegia sp.* are also used as vegetables.

The southern part of the Indian sub continent especially the Western Ghats comprising of forests, mountain ranges, the mid lands and coastal areas distributed in the States of Kerala, Tamil Nadu, Karnataka and Maharashtra is the abode of a large bounty of genetic wealth of root and tuber crops (Edison *et al*, 2005). The North-eastern

S. No.	SPECIES	ITK
48.	*Ipomoea batatas*	Tubers are laxative.
49.	*Ipomoea carnea*	Root decoction reduces blood pressure.
50.	*Ipomoea digitata*	Root applied on swelling of joints.
51.	*Ipomoea hispida*	Root used in the treatment of rheumatism, headache, epilepsy, leprosy and ulcers.
52.	*Ipomoea alba.*	Roots are purgative.
53.	*Ipomoea paniculata*	Aromatic. Tubers used for enhancing milking.
54.	*Maranta aurndinacea* L.	Rhizomes contain easily digestible starch, which are used in making face powder and special glues. It is a rubefacient and also applied on wounds and used for the treatment of ulcers.
55.	*Nelumbo nucifera* Gaertn.	Rhizome used as tonic and in the treatment of diarrhoea, dysentery, dyspepsia and skin diseases.
56.	*Pueraria tuberosa* (Roxb.)D.C.	Roots are demulcent, used as refrigerant in fevers, reduce swellings of joints and a lactagogue.
57.	*Sagittaria sagittifolia*	Roots used in treatment of skin diseases, leaves used as an antidote to snake bite and insect bite and relieve itching.
58.	*Scripus grossus* L.	Tubers are astringent, laxative, cooling and have diuretic properties. Used for arresting vomiting and diarrhoea. It is also used as a tonic.

S. No.	SPECIES	ITK
38.	*Dioscorea hispida* Dennst.	Tuber is used as an antidote in arrow poison.
39.	*Dioscorea oppositifolia* Thumb.	Kavalakizhangu is believed to be an excellent food tonic by tribals. Tubers are used in the treatment of swellings, scorpion and snake bites.
40.	*Dioscorea tomentosa* Koenig.	Edible tubers eaten after boiling.
41.	*Dioscorea wallichii* Hook.	Cooked tubers could be chewed & juice consumed for treatment of jaundice.
42.	*Drosera peltata*	Highly medicinal having red coloured tubers of 1-2 gm. Seen around KMTR area during February. Used for the preparation of Thangabhasmam, a life drug.
43.	*Gloriosa superba* L.	Bears tubers. Red flowers. Seeds used for treatment of heart ailments. Also called as Kalappa kizhangu, Kanmanippoovu. It is also used to kill intestinal parasites
44.	*Hedychium spicatum* Buch. Ham.	Rhizome is stomachic, carminative, stimulative and used as tonic and for the treatment of dyspepsia.
45.	*Hedychium coronarium* J.Koenig	Stem juice used against swelling. Rhizome is an antirheumatic and is used as tonic and excitant.
46.	*Helianthus tubersosus* L.	Rhizome is a commercial source of levulose – sweetening agent for diabetic patients.
47.	*Ipomoea aquatica*	Root is a purgative.

hill region of India, abundant with tropical forests is another site of genetic diversity of taro and yams. Introduced crops like cassava and sweet potato also have developed several morphotypes, land races and farmers' varieties due to natural hybridisation and conscientious selection by the farmers who cultivate these crops traditionally.

3. Biodiversity Conservation and Utilization

The conservation of germplasm is the basic requirement for crop improvement and its utilization. Except yam bean (*Pachyrrhizus erosus*) which can be conserved through true seeds, all other tuber crops germplasm is conserved vegetatively through field gene banks by continuous cycles of replanting after harvest.. Most of these crops are characterized by peculiarities like shy flowering, non-synchronous flowering of male and female plants, protogyny, incompatibility and sterility, all leading to lack of seed set. In spite of these seed (set) propagation related problems, most of the root and tuber crops are hardy that can survive under marginal conditions and fit in different types of cropping systems and there is heavy demand for their planting material. Concerted efforts made to improve the situation of on farm conservation of tuber crops have resulted in the advancement of sustainable methodologies to reduce the costly inputs for conservation.

3.1. *In situ* conservation:

Conservation of root and tuber crops germplasm in their original habitat hasn't received much attention, even though it is being practised consciously or otherwise in the case of the wild species especially of yams and aroids in the protected forests of Western Ghats. On farm conservation of germplasm exists in root and tuber crops because these are cultivated by tribals and poor farmers, whose preference for specific local cultivars varies depending upon various factors like size, shape and number of tubers, medicinal value,

commercial use, taste etc. Tribals play an important role in the *in situ* conservation of wild species of tuber crops. Even though they consume wild tubers, they mostly leave a piece of tuber in the cavity from which the collection is made, to ensure its availability for the next season.

3.2.*Ex situ* conservation:

Ex situ conservation of germplasm of root and tuber crops requires special attention due to the fact that they are stored and propagated as vegetative propagules. *Ex-situ* conservation of these species is generally carried out through field gene banks. The field genebanks have certain advantages namely cost effectiveness particularly in tropical countries and require very less technical expertise as compared to biotechnological methods. However, in field gene banks the germplasm is exposed to natural vagaries.

The field gene bank of root and tuber crops is maintained by annual replanting except in the case of sweet potato, which is to be replanted every quarter. The maintenance of field gene bank is extremely difficult due to the possible loss of accessions, chances of mixing up and requirement of heavy inputs (labour intensive) particularly in sweet potato.

Conservation of wild species, especially the collections from tropical forests fail to survive in open field because of their specific adaptation and requirements. Shade net houses with 50 to 75% shade has been found effective in growing wild species of *Dioscorea, Amorphophallus, Colocasia* and sweet potato collections, *Coleus* species and other medicinal tuberous plants. (Unnikrishnan *et al* 2005).

At the Central Tuber Crops Research Institute(HQ), 4840 accessions of different tuber crops germplasm are maintained as field gene bank (Table 5) besides 598 accessions at the Regional Centre, Orissa.

S. No.	SPECIES	ITK
27.	*Curcuma zedoaria* Rosc.	Rhizome is a stimulant, carminative, demulcent& expectorant. Also applied on bruises, sprains, pains, dyspepsia, cold, cough and bronchitis. Oil is used as an antiirritant.
28.	*Curcuma amada*	Rhizome is a carminative, and also used for stomach ache.
29.	*Curcuma malabarica* Vel *C.zedoaria* Rose	Collected from forests by tribals (Kadar-*Sholayar forest) sold in market for starch as* well as for making cheap paints. It contains easily digestible starch which has antifungal and antibacterial properties.
30.	*Cyanotis tuberosa*	99% watery. Used to prevent thirst.
31.	*Cyperus rotundus* medicinal use.	Staple food for wild folk. Broad spectrum of
32.	*Dioscorea deltoidea*	For production of diosgenin.
33.	*Dioscorea floribunda*	For production of diosgenin.
34.	*Dioscorea kumaonensis*	Tubers used in the treatment of arthritis and rheumatism.
35.	*Dioscorea pentaphylla* Linn.	Tuber are applied on swelling of joints and also used as a tonic to improve body immunity.
36.	*Dioscorea esculenta* (Lour.) Burk.	Tubers used for treatment of chest pain, nervous disorders and swellings.
37.	*Dioscorea hamiltonii* Hook.f.	Treatment of stomach ache

S. No.	SPECIES	ITK
19.	*Coleus forskohlii* (Willd.)Briq.	Root contains Forskolin which is a bronchodilator, and used as a cardio tonic in the treatment of congestive heart failure, glaucoma therapy, anti-hypertensive, remedy for metastatic condition and thrombosis.
20.	*Coleus amboinicus* Lour.	Juice of the leaves which contain an aromatic carminative are used in treatment of urinary disease, dyspepsia, chronic coughs, asthma, cuts and wounds.
21.	*Colocasia esculenta* (L.) Schott	Juice of the petiole is used as a stimulant and rubefacient. The corm juice is used against scorpion stings. *Colocasia* starch is used to prepare weaning baby food and cosmetics.
22.	*Corollocarpus epigens*	Used as medicine to cure skin disease.
23.	*Costus speciosus* (Koenig) Sm.	Roots used as antidote for snake bite and wounds, the rhizomes contain depurative and anthelmintic and purgative properties and is used as tonic. Root powder is used in the treatment of urinary diseases, body pain, fever and snake bites.
24.	*Curculigo orchioides*	The tubers used for imparting strength.
25.	*Curcuma aromatica*	Rhizome is used as a tonic, carminative and also for treatment of bruises and sprains.
26.	*Curcuma caesia*	Rhizome is used as a stimulant and carminative and also in the treatment of asthma, bruises and sprains.

Table 5. Current status of germplasm of tuber crops in India

Crop	CTCRI HQ	CTCRI RC	NBPGR Thrissur	NBPGR New Delhi	Centres of AICRPTC	Total
Cassava	1693	33	184	-	569	**2479**
Manihot sp	27	-	-	-	-	**27**
Sweet potato	927	243	-	260	1858	**3288**
Ipomoea sp	6	78	-	-	-	**84**
Greater Yam	318	44	195		211	**768**
White Yam	258	-	-		-	**258**
Lesser Yam	125	-	68		-	**193**
Dioscorea spp	82	-	184	44	-	**310**
Taro	1043	120	487	49	834	**2533**
Colocasia (wild)	7	-	-	-	-	**7**
Tannia	49	-	-	3	58	**110**
Elephant foot yam	85	32	56	-	120	**293**
Amorphophallus sp	5		95	-	-	**100**
Chinese potato	88	1	50	1	-	**140**
Coleus sp	8	-	-	-	-	**8**
Costus	2	-	-	-	-	**2**
Curcuma spp	11	-	-	-	-	**11**
Canna	5	1	7	-	-	**13**
Arrow root	7	1	5	-	-	**13**
Yam bean	63	45	-	-	-	**108**
Alocasia	1	0	3	1	-	**5**
Other tuberizing sp	27	-	-	-	-	**27**
Typhonium spp	3	-	-	-	-	**3**
TOTAL	**4840**	**598**	**1334**	**358**	**3650**	**10780**

In addition to field gene bank comprising of 1726 cassava accessions at CTCRI , 184 landraces of are conserved at NBPGR, Thrissur (Edison, *et al*. 2005) and 569 cassava accessions in different State Agricultural Universities under the All India Co-ordinated Research Project (AICRP) on tuber crops. Out of the 98 *Manihot* species reported so far, 79 species are available in Brazil while India is maintaining 27 accessions of eight species.

In Sweet potato, in addition to 927 accessions conserved at CTCRI, the AICRP centres are also involved in conservation by maintaining 1858 accessions in field gene bank.

In greater yam, 362 accessions are conserved as field gene bank besides the rich collection of wild *Dioscorea* species (82).

3.3.On farm Conservation

The genetic diversity of traditional varieties of crops is the most economically valuable part of global biodiversity and is of paramount importance for future world crop production. Increasing genetic diversification, combined with farmers' experimental abilities, and underpinned by the formal system, will ensure greater on-farm conservation of more useful genetic resources. On-farm conservation of agrobiodiversity in tuber crops, which is based on traditional/ indigenous knowledge, innovations and practices should focus on local people's needs, constraints and priorities besides achieving the overall objectives of the conservation approach. Key to the success of on-farm conservation is the active community involvement in the diagnosis of local problems, in the formulation of a set of actions, actual implementation of action plans at farm level, and sharing of benefits resulting from the plan of action. This concern should be worked out

S. No.	SPECIES	ITK
10.	*Asparagus racemosus* Willd	Roots are used as a refrigerant, demulcent, diuretic, aphrodisiac, galactogogue, anti-dysenteric and for dyspepsia. Medicated oil is recommended for rheumatic complaints. *Asparagus racemosus* is also used as an appetizer, treatment of impotence and for enhancing milking.
11.	*Asparagus sarmentosus* Linn.	Roots are aphrodisiac and hence taken as a nourishing drink.
12.	*Asparagus officinalis* Linn.	Roots have demulcent, diuretic, laxative, cardiac sedative, tonic and aphrodisiac qualities. Also used in the treatment of jaundice. It contains the essential oil – asparagine and tyrosine which are used in commercial purpose.
13.	*Asparagus adscendens* Roxb.	Tubers are used as vegetable as it possessed cooling and demulcent properties.
14.	*Asparagus gonocladus* Baker	Roots are aphrodisiac. It is boiled with oil & applied in cutaneous disease and treatment against gonorrhoea.
15.	*Canna orientalis*	The tuber has diaphoretic, demulcent and diuretic properties. It is also a stimulant and hence used during fever and dropsy.
16.	*Canna edulis* Ker-Gawler.	Easily digestible starch similar to arrowroot starch.
17.	*Ceropegia tuberosa*	Big tubers toxic to rats.
18.	*Chlorophytum borivilianum*	Root is a vitalizer. Hence used as a health tonic, curative for pre and post natal problems, alternative to Viagra and for immunity improvement.

Table 7.Indigenous Technical Knowledge on Tuber Crops

S. No.	SPECIES	ITK
1.	*Alocasia macrorrhiza* (L.)Donn.	Stem juice is believed to relieve scorpion and nettle sting, leaves are used as rubefacient for joint pains.
2.	*Alocasia indica* (Roxb.) Schott.	Has easily digestible starch, leaf juice is an astringent, rhizome acts as mild laxative and diuretic.
3.	*Alpinia galangal* Sw.	Rhizome used for curing catarrhal affections, fever and rheumatism.
4.	*Amorphophallus dubius* Blume	Tubers cooked in butter milk and fried in ghee and used for treating dysentery. It is also used as a carminative, expectorant, and in the treatment of piles, rheumatism and haemorrhoids. Fermented juice of petiole is used for diarrhoea.
5.	*Amorphophallus sylvaticus*	Fruits and seeds are crushed into a paste and used in the treatment against toothache, bruises, and glandular enlargements.
6.	*Amorphophalus paeoniifolius*	It is used as a tonic and has restorative and carminative properties. Also used in the treatment of piles, dysentery and rheumatism.
7.	*Anaphyllum wightti*	Small tubers of 1gm size. Rare plant. Maximum tuber yield 5-10gm. Used for the treatment of piles.
8.	*Arisaema pulchrum*	Used for treatment of piles.
9.	*Asparagus felicious*	Roots posses astringent properties

and materialized in the coming years. Therefore, it is vitally important to identify the pathways along which people and community themselves will behave in making the traditional systems become more efficient and sustainable. Protection of forests and its biodiversity is an important aspect in the *in situ* conservation of tuber crops.

3.4. *In vitro* conservation

Healthy propagules of convenient size, form and a good storage (shelf) are essential for conservation of germplasm for a prolonged period and for their safe exchange. Such requirements have led to the utilization of *in vitro* conservation and microtuberization in many root and tuber crops that are being stored in major gene banks all over the world. During the past two decades, *in vitro* techniques have been extensively used for conservation of vegetatively propagated plants involving all the above components (Withers, 1993; Ashmore, 1997). *In vitro* technology can be utilized at various stages in conservation and utilization of tropical tuber crops. These stages include efficient collection, disease elimination, fast multiplication, exchange and storage. Establishment and exchange of disease-free material is of paramount importance in genetic resource conservation programs. *In vitro* culture methods are used for both medium-and long-term *ex situ* conservation of plants (Engelmann, 1991). In the slow-growth method meant for medium term conservation (up to a 5 years), cultures are maintained under conditions that can reduce the rate of growth, thus leading to extension of subculture interval. This is achieved by modifying the culture medium and culture maintenance conditions. Addition of growth retardants and osmotic regulators and reduction of nutrient content are some of the ways of modifying the growth medium. However, in order to reduce the frequency of somaclonal variations,

the protocols involving addition of osmotic and growth retardants in the media are usually avoided. Cryopreservation, for long-term conservation, involves the storage of propagules at ultra-low temperature (-150ºC to –196ºC) using liquid nitrogen (LN). Since all cell metabolic processes stop at these temperatures, the live material can be stored without variation for unlimited periods.

Cassava

Cassava cultures are amenable to *in vitro* conservation under normal conditions as well as reduced growth rates. *In vitro* gene banks have been set up in cassava using slow-growth cultures at various cassava genetic resource centers in Africa, South America and Asia. The various conservation methods viz. low temperature incubation, use of low light intensity, use of osmotically active agents or growth retardants, manipulations in the concentration of the growth hormones, macro and micro-nutrients and sucrose have been used individually or in combination for the medium term storage of the cassava germplasm. Experiments with minimal and mannitol enriched media indicated that combination of both media was usually effective to induce slow growth. Osmotic retardants like mannito l(3%) or sorbitol (3%) along with sucrose (3%) in the medium was found effective in extending the subculture period from 3 to 12 months. Sorbitol was found better in imparting slow and healthy growth than mannitol (Unnikrishnan and Sheela, 2000). Silver nitrate (1mM) and activated charcoal (1g/l) in MS medium with sucrose (3%) and growth regulators (0.05 μM NAA, 0.1μM BA and 0.3μM GA3) was found to help in maintaining the cultures up to 18 months. Addenda like silver nitrate and activated charcoal was found effective in reducing leaf chlorosis and preventing leaf shedding, thereby contributing to culture life and regeneration capacity.

the advancement of modern technologies. Literature on indigenous technical knowledge on tuber crops is too little as compared to other crops. A harmonious blend of indigenous knowledge with modern science is essential to promote sustainable development and utilization of tuber crops.

Under the National Agricultural Technology Project on Plant Biodiversity, conscious efforts have been undertaken to collect ITK on different crops during 1998-2005. Alsou under the project on Technology Assessment and Refinement through the Institution Village Linkage Programme (IVLP), ITK was collected but, it is rather localized pertaining to certain villages alone. Since tuber crops are mainly concentrated in southern and north eastern states of India, collection of ITK on tuber crops needs to be specifically intensified in these regions.

Tuber crops are associated with several rituals and beliefs. Except in the industrial belt like Salem district of Tamil Nadu and East Godavari district of Andhra Pradesh, the tuber crops are cultivated and utilized by using indigenous technologies. Planting of tuber crops in Kerala coincides with festivals (Sivarathri.) in February/March. The tuber crops are consumed as a part of religious rituals like Thiruvathira & Karthika. Tribals eat yams for maintaining their physical health and also for medicinal purpose(Viswanathan,2004). Consumption of wild yams rich in steroids is believed to help in the natural birth control among the tribal population. The brief summary on Indigenous technical knowledge on tuber crops collected by scientists of CTCRI is outlined below (Table 7.):

the germplasm collections to 5520 with the receipt of tuber crop accessions from other collecting centres of NBPGR Regional Station at Cuttack (Orissa), Bhowali (Utharanchal) and also from the Indira Gandhi Agricultural University, (Chhattisgarh).Work is in progress for the complete characterization and evaluation of the collected germplasm which are being documented and recorded in the National data bank at CTCRI and at NBPGR. Potential collections are already being subjected to direct utilization as well as in genetic improvement programmes of the respective tuber crops.

6. Indigenous Technical Knowledge (ITK) on Tuber Crops in India

ITK is knowledge unique to the society or culture. Indigenous knowledge is holistic in nature and has been integrated into the lives of people and used by people from time immemorial. For a long time, indigenous knowledge was ignored by modern science and it was said to be primitive, superstitious, or unscientific. A proper documentation can enable its validation, quantification and spread of this valuable knowledge. Recently, modern science has rediscovered the wisdom of indigenous knowledge, and found that it has a great deal to offer and it is right time for the scientists and farmers to work together to improve the indigenous practices and to derive maximum advantages and improve health.

Tuber crops are cultivated by tribals and resource poor farmers from time immemorial that led to the development of several indigenous cultivation, plant protection and processing technologies. Even though several useful technologies have been recorded, they can prove their wide applicability only if they are made known and can be validated. The erosion of indigenous knowledge is taking place due to

Throughout the storage period, the cultures continued to produce axillary buds, indicating the viability of the cultures.

Initially, Bajaj (1987) reported cryopreservation technique for long-term conservation of cassava using shoot tips. He found that isolated meristems precultured on a medium containing DMSO and treated with a mixture of DMSO, sucrose and glycerol, could be frozen in liquid nitrogen using rapid freezing as well as slow-freezing techniques. By adopting the method of preculture followed by slow freezing using the programmable freezer, the protocol for cryopreservation, using shoot-tips has been developed and tested for 15 genotypes of cassava at CIAT and in some cases, regeneration up to 70 % has been achieved.

Sweet potato

In vitro methods in sweet potato were used earlier at several international centers like Centro International de la Papa, (CIP), Peru, the International Institute of Tropical Agriculture (IITA), Nigeria and AVRDC, Taiwan for conservation of sweet potato germplasm. Besides, several national programmes in USA, Costa Rica and India have been maintaining a large number of *in vitro* collections of sweet potato over the last 10 years. Meristem cultures in conjunction with thermotherapy along with the use of antiviral drugs have been found effective in virus elimination in sweet potato (Ashmore, 1997). Meristem culture technique coupled with indexing by ELISA and grafting on indicator plants was used to establish healthy cultures, at NBPGR (Mandal and Chandel, 1996). *In vitro* propagation technique has been refined at NBPGR, so as to develop a single medium capable of eliciting desirable response from all varieties and related species. MS medium

supplemented with 4 % sucrose, 0.2 mg l^{-1} kinetin and 0.1 mg l^{-1} IAA has been successfully used to establish cultures of 260 sweet potato accessions maintained at NBPGR. For the medium term storage of sweet potato, various methods have been used successfully. These include incubation at low temperature (16-20ºC) (Ng and Hahn, 1985), addition of mannitol to the medium coupled with reduction in incubation temperature and use of sucrose (3 %) with 3 % mannitol (Dodds and Roberts, 1985). Though low temperature incubation (18°C) is effective in reducing growth rate, maintenance of large collections at this temperature during the summers months when the ambient temperature exceeds 40°C is expensive and risky in view of frequent power breakdowns or sometimes an equipment failure. Among the several modifications tested, supplementation of the medium with 1-2 % mannitol was found to be the very effective (Mandal and Chandel, 1991). Using this method, 260 accessions have been maintained at CTCRI culture room temperature of 25±2°C for ten years with an annual subculture. While genotypic variation in response to mannitol does exist, the concentration of 1-2 % was suitable for most of the accessions.

Application of cryopreservation technology for sweet potato conservation has not been satisfactory. The use of somatic embryos or embryogenic tissues seems to hold more promise since recent studies (Bhatti, *et al.* 1997; Blackesley *et al.* 1997) have demonstrated the recovery of complete plantlets from Liquid Nitrogen exposed embryogenic tissues.

Yams

Being a vegetatively propagated crop, yam is seriously affected by an accumulation of pathogens. To overcome the problems of field

kg tuber yield per plant. This is a regular flowering clone and it is being utilized in the transfer of the dwarfing gene to other cultivars. A total of 77 germplasm accessions were collected from the interior plains.

4.4. The Andaman and Nicobar Islands:

One exploration programme was conducted in this remote group of Islands in the Bay of Bengal having vegetation similar to the Indian mainland flora but more related to the Indo- Malayan flora. The 19 day long exploration was jointly conducted by different crop based Institutes like CPCRI, Kasaragod, IISR, Kozhikode, SBI Coimbatore, CTCRI, Trivandrum and NPBGR, Regional Station Thrissur in March, 2003. Tuber crops, especially, sweet potato, yams, and taro are important to the islanders, particularly in Nicobar District. A total of 39 germplasm accessions were collected. The collections of *Dioscorea alata* locally called 'Achin' and Paltu' and *Dioscorea esculenta* called 'Tumik' and two sweet potato accessions were important. These collections were from the Nicobari villagers of Carnicobar, the Island which was later devastated by the Tsunami of December, 2004 and therefore can be provided back to the Islanders for restoring the lost genetic wealth. Besides, "Achin" is a fertile female accession with 12 to 14 kg per plant yield having anthocyanin rich purple fleshed tubers. It has been used in inter varietal breeding programme for transferring the novel characters to other lines. Two wild species of *Dioscorea viz. D. vexans* and *D. glabra* endemic to Andamans were also collected during this exploration.

5. National Regeneration Centre for Root and Tuber Crops:

CTCRI has been assigned with the duty of an active regeneration centre for tropical tuber crops by the NBPGR. This has further enhanced

Pachamalai were surveyed. Thirty four collections were made which included different species of *Dioscorea.* The *D.stemona*, a tuber bearing species closely related to *Dioscorea* spp were collected from Kolli hills. Two species having tubers of medicinal value were also collected. One was *Stephania glabra*, with large tubers used in treating bovine dysentery. The other was an epiphytic fern (tree fern) *Dryneria* with tuberous rhyzoid which was used for making decoctions for treating body pain, indigestion and fatigue by the tribal people in Kolli Hills. It is locally known as 'Attukal Mandu' as the tuber is having the shape of goat's leg. *Dioscorea oppositifolia* was found to be the most widely preferred wild tuber by the tribals in all the areas surveyed in Western & Eastern Ghats. The tubers were used by the tribals in a raw or cooked form. In Kolli hills and Pachamalai, it was observed that extensive areas were cultivated with cassava, replacing the traditional dry land crops of upland rice, jowar, minor millets like ragi, bajra and other pulses. Cassava is cultivated as industrial raw material for starch extraction in the factories in neighbouring Namakkal and Salem districts. The farmers prefer to cultivate this tuber crop because of the steady price and assured market, besides its hardy nature to yield in marginal conditions of soil fertility and moisture.

4.3. The interior plains :

Several places in the States of Kerala, Karnataka and Tamil Nadu were explored. Different cultivars of *Dioscorea alata*, *D. esculenta*, related wild species of cassava and *Colocasia* were collected. One dwarf variety of cassava locally called "Lakshmi Vella" was collected from Chithirakodu, of Kanniyakumari district (Tamil Nadu). This was found to be popular in the locality suitable for closer planting, giving 2 ½ to 3

maintenance, IITA, and IPGRI have recommended the use of *in vitro* techniques for yam conservation (Hanson, 1986). In yams, two kinds of *in vitro* germplasm preservation were considered : slow growth condition for medium term conservation and cryopreservation using the encapsulation/dehydration technique for long term conservation.

Many species of yams have been successfully established under *in vitro* conditions. Axillary buds and nodal cultures have been found to be used most frequently. In India, the work related to the micropropagation of yams has been carried out mainly at CTCRI and NBPGR (Mandal and Chandel, 1996; Nair and Chandrababu, 1996).

Using nodal cuttings as explants, *in vitro* tuber development has been recorded in several species (Ng and Ng, 1997; Mandal, 1999). Nodal segments with one or two axillary buds have been cultured on MS medium alone or supplemented with kinetin or NAA @ 0.25 mg l^{-1} each. However, for routine sub culturing, a single medium *i.e.* MS supplemented with 0.15 mg l^{-1}NAA, is applicable to all the accessions maintained in the repository.

Incubation temperatures play a significant role in the growth rate of yam plantlets. Plantlets storage period could be extended to 1-2 years by incubating them at 18-20°C. Use of mannitol and high level of sucrose, either alone or in combination, has significant effect on plantlet growth rate of the culture at room temperature (26±2°C). Addition of mannitol to the medium can prolong storage at normal culture room temperature of 25-30°C for a period up to 12 months with high recovery rates (80%). Use of BA (2.0-mg l^{-1}) or kinetin (2.0-mg l^{-1}) helped in maintaining cultures of *D.alata* for two years. Induction of micro tubers increased the shelf life by an additional 3-6 months. At

CTCRI, *D. alata, D. rotundata* and *D. esculenta* nodal cultures could be conserved up to 12 months without subculture on MS basal medium containing 3 % mannitol and with out growth regulators.

Cryopreservation of yam shoot tips of two cultivated edible species (*Dioscorea alata, D. bulbifera*), a medicinal yam (*D. floribunda*) and one wild edible type (*D.wallichii*) were successfully carried out using the technique of encapsulation-dehydration (Mandal and Chandel 1996). Though survival and growth initiation from cryopreserved shoot-tips was recorded at a frequency of 28-71 %, regeneration of complete plantlets were recorded at a frequency of 21-37 % in *D. alata* and *D. wallichii* (Mandal *et al.* 1996). Malaurie *et al.* (1998) reported successful cryopreservation of shoot tips *of D. alata* and *D. bulbifera* using the technique of encapsulation - dehydration. Very recently, success of cryopreservation of shoot-tips/somatic embryos of several edible and medicinal yams using both vitrification and encapsulation-dehydration has been registered. These include, vitrification of shoot-tips of *D. rotundata* (Ahuja *et al.,* 2000;), *D. floribunda* (Mandal, 2000), and *D. pentaphylla* (Ahuja *et al.* 2000), *D. deltoidea* (Mandal and Dixit, 2000) and somatic embryos of *D.bulbifera* (Dixit *et al.* 2000). The regenerated plants obtained from cryopreserved shoot-tips/somatic embryos were transferred to field with 90-100 % establishment. The field grown plants obtained from cryopreserved explants were morphologically similar to those of their mother stocks maintained *in vitro* conditions and transferred to the field.

Aroids

In vitro technology in aroids is well developed and is being routinely used in national and international centers for conservation of these crops (Staritsky *et al.* 1986; Bessembinder *et al.* 1993). There

Table 6. Exploration sites of Western Ghats (1999-2004)

Regions explored	No. of Collections
Peppara	3
Senkottai, Manimuttar, Kodayar, Gundar, Sivagiri, Puliyankudi (KMTR)	24
Karayar, Papanasam, Manjolai(KMTR)	4
Karayar,Papanasam, Servilar, Kudamadi, Kalakkad, Mundanthurai (KMTR)	37
Mundanthurai, Karayar, Papanasam, Veerapandyapuram(KMTR)	13
Anamalai, Malakkapara	3
Vazhachal Division, Vettilappara, Sholayar forest	35
Kulathurpuzha range, Onthupacha, Devagiri, Mahendragiri	12
Dakshin Kannad,Uttar Kannad, Udupi districts	16
Kudremukh	33
Pechippara	10
Wayanad	4
Total	194

4.2. The Eastern Ghats :

The Eastern Ghats surveyed were generally dry areas which receive less than 900 mm rainfall, distributed in Salem, Tiruchirappalli, Namakkal, Perambalur and Vellore districts of TamilNadu. hills like Yelagiri , Javvadu hills, Yercaud, Kolli hills, Shervarayan hills and

Under the Jai Vigyan Programme of the National Agricultural Technology Project (NATP) on Plant Biodiversity, efforts were taken to create awareness among farmers, tribals etc for the collection and conservation of genetic resources of tuber crops. In the Western Ghats, biodiversity "hot Spots" like the Kalakkad Mundanthurai Tiger Reserve (KMTR) were repeatedly explored (4 explorations). Areas like Wayanad Wild life Sanctuary, forest ranges of Chalakudy, Sholayar, Kulathuppuzha, (Kerala), Kollur and Kudremukh (Karnataka) also were subjected to exploration (Unnikrishnan *et al*. 2005). A series of interactive workshops were organized to plan the exploration activities in which scientists and forest officials interacted to prepare the route map and programme of exploration activities in KMTR. Twelve explorations were conducted during the period and 194 collections were made (Table 6.). Different Species of *Dioscorea* were collected from all along the Western Ghats. The *Dioscorea* species were found to be an important source for food and medicine to the tribal peoples like Kadar, Paniyar, Kattunaickar, Mala Pandaram and so on. *D. oppositifolia, D. pubera, D. bulbifera D. hamiltonii, D. pentaphylla, D. tomentosa , D. kalkapreshadii, D. wightii, D. wallichi, D.hispida* and *D. spicata* were some of the important species collections. Two under utilized tuber crop species *viz. Tacca pinnatifida* and *Theriophonum minutum* were important new collections because of their local food value and the the starch is used for making confectionary items. The highest number of collections were made from the Western Ghats which receives the maximum annual rainfall (1500 to 3000 mm) in South India.

have been several reports on production of virus-free taro. Shoot tips (meristem) dome plus one or two-leaf primordial) 0.2 to 0.3 mm in size were cultured on MS medium with 0.1 mg l^{-1} NAA at 25°C under 12 h day length (Morishita and Yamada, 1978). These meristems regenerated to shoots and produced roots after four months of culture. Successful cormel tip culture of *Colocasia esculenta* leading to the elimination of Dasheen mosaic virus has been done at CTCRI. In *Xanthosoma sagittifolium*, addition of spermine, arginine and ornithine was found to enhance plant regeneration from shoot tip cultures (Sabapathy and Nair, 1995). In India work on medium term *in vitro* conservation has been carried out at CTCRI and NBPGR. Taro cultures could be stored upto ten months under light (3000 lux) on MS basal medium containing sucrose and mannitol (3 %) without vitamins or growth regulators. Half strength basal medium was also found to induce slow growth (Unnikrishnan and Sheela, 2000). *Colocasia* and *Alocasia* cultures could be conserved at normal culture room temperature of 25°C±2°C upto 10 months without subculturing (Mandal, 1999). For long–term conservation, slow freezing of embryogenic callus prior to cryopreservation resulted in 70 % survival, without loss of regenerability (Takagi *et al.* 1997). Vitrification of axillary buds, which initially met with only partial success, was modified for cryopreservatioon of *in vitro* shoot tips resulting in almost 80 % shoot recovery (Takagi *et al.,* 1997; Thinh *et al.*, 2000).

In Chinese potato (*Solenostemon rotundiifolius*), standardized protocols for *in vitro* conservation and micropropagation are available. Direct regeneration was obtained from lamina explants and internodal cuttings at higher levels of BA(1 to 10mM). Higher levels of NAA (1 to 10mM) produced callus and indirect regeneration.

As already mentioned, propagules developed through micropropagation like *in vitro* slow growth cultures, encapsulated somatic embryos and nodal explants as well as microtubers have been used for international exchange of germplasm safely over long distances. The live cultures or other propagules are properly packed in tight containers and sent by air along with phyto sanitary certificate ascertaining freedom from. infections At the receiving end, the package is opened and cultures stored in light (3,000 Lux) in a sterile room for a week at 25°C to remove any effect of continuous darkness. They are then checked for contamination. Contaminated cultures are destroyed in an incinerator to prevent chance introduction of any pathogen. Plantlets are then either micropropagated and multiplied or subjected to hardening in soil inside green house or mist house and later transferred to field. The international advisory body on crop germplasm (IPGRI) recommends micropropagated material to be safe for exchange of germplasm of root and tuber crops across national borders.

4. Hot spots of Biodiversity of Tuber Crops in India

Exploration and Collection

During the last decade, there has been an overwhelming concern about the loss of tropical forest biological diversity, and hence an emphasis was laid on the identification of biodiversity hot spots in an attempt to optimise conservation strategies. Furthermore, the concept of sites of high diversity, or hotspots, has attracted the attention of conservationists as a tool for conservation priority settings.

The Central Tuber Crops Research Institute, Thiruvananthapuram holds the largest collection of root and tuber crops germplasm in India and most of these collections are cultivated

accessions (indigenous & exotic) of different tuber crops like Cassava, Sweet potato, Yams, Aroids and a few under utilized tubers. Germplasm has been collected from almost all the states in India. Special explorations were also conducted in the North-eastern hill region, Andaman & Nicobar islands, Western Ghats and Bastar region (MP) for the collection of wild relatives. Yam germplasm has been collected from different states/regions of India particularly Kerala, Tamil Nadu, Karnataka, parts of Western Ghats, Bihar, Orissa, North-eastern hill region and Chattisgarh. Efforts were made during the past six years (1998-2004) under the NATP funded National Agro-biodiversity Project (net work with NBPGR, New Delhi) to strengthen this collection by exploring potential areas like Kalakkad Mundanthurai Tiger Reserve(KMTR) and collecting the wild species as well as cultivars having novel characters for their direct utilization.

4.1. The Western Ghats

Flora of Western Ghats comprise about 12,000 species ranging from unicellular cyanobacteria to angiosperms. The tropical climate complemented by heavy precipitation from southwest monsoon and favourable edaphic factors create an ideal condition for the luxuriant growth of plant life, which can be seen only in few parts of the world. One thousand seven hundred and twenty (> one third) species are endemic to this region and are found nowhere else in the world. Many of these species are traditional sources of medicines. It is the Centre of Origin/diversification of several tuber crops like *Dioscorea, Alocasia, Colocasia, Amorphophallus etc.* in addition to wild relatives of different tuber crops especially *Dioscorea*s and medicinal tubers. The CTCRI organised exploration trips in the Kalakkad Mundanthurai Tiger Reserve (KMTR) in Tamil Nadu for the collection of wild relatives of tuber crops.