STUDIES ON GENETIC RESOURCES OF TARO - *COLOCASIA ESCULENTA* (L.) SCHOTT COMPLEX

Thesis
Submitted to the University of Calicut in part fulfillment of the requirements for the award of degree of
DOCTOR OF PHILOSOPHY IN BOTANY

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C E R T I F I C A T E

This is to certify that the thesis entitled **STUDIES ON GENETIC RESOURCES OF TARO, *COLOCASIA ESCULENTA* (L.) SCHOTT COMPLEX** submitted for the award of degree of Doctor of Philosophy in Botany (Faculty of Science) of University of Calicut, is a record of bona fide research work carried out by **Sri. K. C. Velayudhan**, Principal Scientist, NBPGR Regional Station, Thrissur under my guidance and supervision. I furthr certify that no part of this thesis has been submitted for the award of any other degree or diploma.

University of Calicut **Dr. M. Sivadasan**

DECLARATION

I, **K.C. Velayudhan**, here by declare that the thesis entitled **STUDIES ON GENETIC RESOURCES OF TARO, *COLOCASIA ESCULENTA* (L.) SCHOTT COMPLEX** is a record of original work carried out by me under the guidance of **Dr. M. Sivadasan**, Professor & Head, Department of Botany, University of Calicut, Thenhippalam. I further declare that no part of this thesis has been submitted for the award of any other degree or diploma.

Calicut University
15.07.2008

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K. C. Velayudhan

1. INTRODUCTION

Taro, *Colocasia esculenta* (L.) Schott belongs to the family Araceae that comprises about 105 genera and over 3300 species (Mayo *et al.*, 1997). Species of Araceae are collectively called as Aroids and include few important food and vegetable crops distributed in many countries of the tropics. It is perhaps the fourteenth most consumed vegetable over the world wide (Lebot & Aradhya, 1991). According to the FAO production year book (Anonymous, 1989a), taro is cultivated in one million hectares with an annual production of 5.4 million tones. However Misra and Chowdhury (1997) categorically stated that the exact area and production are not documented probably due to the fact that it is mainly a subsistence crop in most of its centers of diversity. Africa ranks first in its area of crop cultivation and production followed by Asia and Oceania. They are mainly cultivated for their edible corms, cormels, leaves and petioles.

Among aroids, tannia or new cocoyam, taro, elephant-foot yam, *Cyrptosperma* and *Alocasia* are the most important ones in terms of their use as food. Cocoyam is of South American and others are of Asian origin. In South Asia taro is most widely used as a tropical tuber vegetable in countries such as India, Nepal, Bangladesh and Malaysia. It also forms an important secondary staple in Pacific islands. The crop is distributed mainly in tropics and subtropics of Asia, and due to its later introduction to other areas it has spread to West Indies, tropical Americas and Africa. Being a versatile crop, it can be grown under puddled condition, irrigated upland conditions and under rain fed conditions in high rainfall areas. In India, two major varieties of taro, *viz. Colocasia esculenta* var. *esculenta* (Dasheen type) and *Colocasia esculenta* var. *antiquorum* (Eddoe type) are cultivated as elsewhere (Misra & Cowdhury, 1997). Nutritive value of taro as compared to most of the common tubers including potato is also higher. The crop under moderately high input conditions gives a fresh tuber yield of 30 to 50 tons per ha. Local people in certain places also use it as a medicine. In India, the crop is stated to be very ancient and is used in rituals in Puri temple in Orissa. The leaves of taro are rich in protein and minerals (Misra & Chowdhury, 1997). As compared to tropical tuber crops such as Cassava, sweet potato, elephant foot yam and tannia the crop is fast loosing its importance in most of the areas where it used to be under cultivation and use. Apart from this, there is a stiff competition from few of the temperate tubers such as potato, carrot and beetroot mainly due to the fact that these are commercially cultivated in large quantities, more attractive in appearance, easy for transportation and storage as compared to the former. Thus, there is an imminent danger of genetic erosion in the crop in most areas of its primary and secondary centres of diversity. Apart from the aforesaid reasons, perhaps the most important one seems to be the rapid changes that took place in food habit of people in areas where taro was once an important subsistence crop. Kundu (1967) opined that the reason for decline in taro popularity is that they are the food of the poor.

The changes in farming sytems over a wide range of eco-geographical areas following the recent globalization in commerce and agriculture also added to the already very grim situation with respect to perpetuation of genetic diversity in the crop. Thus there is an imminent danger of its genetic erosion in most of the areas in Asia and that was why IPGRI had given considerable importance to this crop in its PGR programme for South East Asia. As a result, considerable work was undertaken on the crop in most of the tropics and is being continued. A crop descriptor for taro was published by IPGRI (Anonymous, 1999a) to help the workers on taro. Further, crop genetic resources activities were initiated in most of the countries in South East Asia and around 5886 accessions of taro and its wild relatives were maintained in various countries in the world as per Root and Tuber crops, Directory of germplasm, published by IBPGR (Anonymous, 1986a). Crop genetic resources activities are confined mainly to survey, collection, identification, characterization, preliminary evaluation, classification, conservation, documentation, and dissemination of germplasm on demand to the user agencies for further improvement of the crop. Thus the subject involves a holistic approach touching various research aspects.

Though there are a number of institutions engaged in research on various aspects of genetic resources of the crop, only two institutions Central Tuber Crops Research Institute, Thiruvananthapuram along with its coordinating centres under All India Coordinated Tuber Crop Improvement Programme and National Bureau of Plant Genetic Resources, New Delhi under Indian Council of Agricultural Research in India are mainly involved. These institutions published three catalogues on the indigenous crop germplasm (Unnikrishnan *et al.*, 1987; Thankamma Pillai & Unnikrishnan, 1993; Velayudhan *et al.*, 1993). Several reports indicated that most of the earlier studies on various aspects both of academic and applied nature on taro in India were carried out in piece meals (Velayudhan *et al.*, 1993). However, a comprehensive study on its exploration, collection, distribution, morphology, taxonomy and other aspects related to problems and prospects of taro genetic resources encompassing diversity of wild and cultivated taro from four regions such as North Eastern, South Western, Eastern and North Western regions of the country which is an important center of its origin and diversity (Kuruvilla & Singh, 1981) has not been undertaken so far. Therefore, the present detailed study on genetic resources of taro was planned in order to: 1) identify the extent of genetic diversity in the crop by collection of samples of both cultivated and wild populations from centres cultivation and from sites of natural occurrence, and by receiving sample from other centres in India, 2) to properly verify the taxonomic identity of the samples in order to remove the taxonomic confusion in cultivated and wild taro that occur in India, 3) to characterise, evaluate and classify the samples morphologically, chemically, organoleptically, pathologically and entomologically into genetically distinct types, and 4) to probe into the possible evolutionary relationships between different types and 5) to identify and to report more productive, less acrid, more tasty and pest and disease resistant types for diverse uses such as tuber and leafy vegetables for further genetic improvement in the crop.

2. REVIEW OF LITERATURE

2.1. Origin and distribution

Taro is considered to be one of the oldest crops domesticated prior to rice cultivation in swamps probably in Mesolithic times (Anonymous, 1986b). The present world distribution of taro (Fig. 1) shows that it is being either cultivated or occurs as wild in Australia, Bangladesh, Brazil, Burkina Faso, Cameroon, China, Columbia, Cook Islands, Costa Rica, Cuba, Egypt, Micronesia, Fiji, Polynesia, Guadeloupe, Guatimala, India, Indonesia, Japan, Malaysia, Nepal, Nigeria, Niue, Panama, Papua New Guinea, Peru, Philippines, Solomon Islands, Sri Lanka, Thailand, Togo, Tuvalu, United States of America, Vanuatu, Vietnam and Western Samoa. Wild populations of taro are now invading the marshy habitats even in subtropics of the US. Chandra (1984), de la Pena (1971) gave an account of edible aroids in general and (Chandra, 1982) that of Fiji. The origin and distribution of edible aroids is a difficult subject (O' Hair and Asokan, 1986). Origin and evolution of tuber crops has been dealt by Leon (1977). Debate and research continue on the centers of origin of taro with Northeast India and Melanesia being considered as separate centers of origin and domestication (Jianchu *et al.*, 2001). However, taro is commonly believed to have originated along the northern edge of Bay of Bengal (Sauer, 1969; Spier, 1951; Massal & Barrau, 1956). It is one of the crops domesticated in China (Chang, 1970; Li, 1969 & 1970). According to Spier (1951) taro has been cultivated for at least 2500 years. Harlan (1971) suggested that Myanmar was the region where taro was first domesticated. Migrating people were believed to have carried taro around Malay Archipelago at least 4000 years ago (Chang, 1958) and around Polynesia at least 3000 years ago (Mason, 1953). Yunan province of China is an important center of ethnobotanic importance (Chang, 1958).

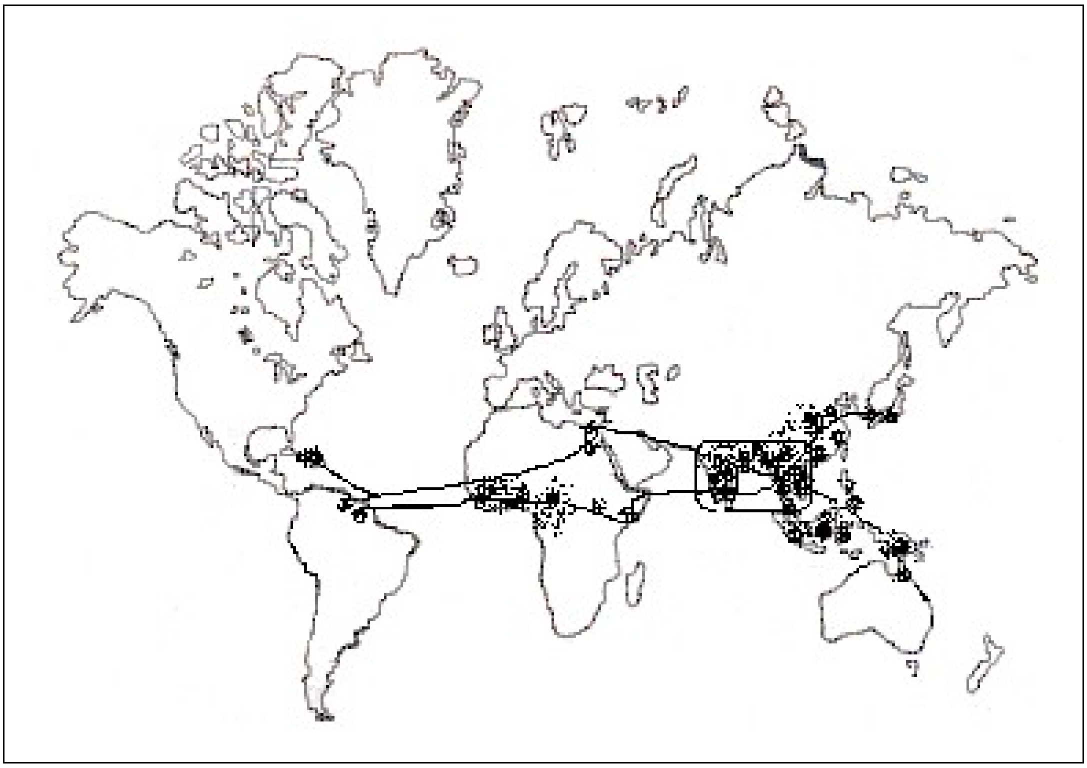


Fig. 1. Origin and distribution of taro

Plucknett (1976) treated two distinct entities of *Colocasia* under two heads such as Dasheen, taro or Cocoyam and Eddoes and stated that

Dasheen, taro or Cocoyam is cultivated throughout the tropics. It has great importance in Pacific islands. It is stated to be the staple food of rain forest dwellers of New Guinea, Solomon Islands and New Hebrides. Literature on origin and distribution of the crop in tropics and sub-tropics of the world is more of a speculative nature on the basis of the present distribution and the scanty historical evidences on spread, distribution, diversity, ethnobotany, anthropology and human migration in the past and lesser on the scientific evidences, and hence probably appears to be inconclusive. According to the concepts on centre of origin and diversity of crops reports on the origin of taro is probably very contradicting and it is legitimate to believe that it has a non-centric origin having wide spread distribution of both wild and cultivated types. Sturtevant (1919) considered that taro originated in South Central Asia perhaps, in India or Malaysia. According to Greenwell (1947) the first inferior taro was taken to Hawaii by traditional discoverers about AD 450 and further, the improved taro was brought by the present Hawaiians from Tahiti about AD 1100 which played an important role in their civilization by growing them in irrigated plots for production of poi. Maoris took them to New Zealand. Dasheen was taken to West Indies in post-Columbian period with the early slave trade. Pliny in AD 23-79 as quoted by Purseglove (1975) recorded it in Egypt. Probably taro has been introduced to Egypt from the West Coast of India as spice trade relationship between these parts was established far back during the Egyptian civilization. It spread along the Mediterranean to Africa and to Guinea coast through the land trade routes that existed in those days. The assumption that Greek word 'quolcas' is derived from the root Malayan word 'thallas', for taro, which is also used in Java, is believed to have derived from the same root (Porteres, 1960). But the etymological relationship of the Malayan word 'Thalla' and the Malayalam word 'Thal' for wild taro, 'thalu' for petiole of taro and a cultivar name in Kerala such as 'Karinthal' for a clone with dark purple coloured petiole is interesting and is undoubtedly connected with the Malayan root word 'thallas' for taro. Further, the historical evidences connected with the Arabic and Chinese trade relationship that existed with the West Coast of India especially with Kerala (Menon, 1995) for spices and the evidences on the role of ancient Kerala sea voyagers in these trades from the time immemorial coupled with the diversity of cultivated and wild varieties noticed in the west coast of India appear to more appropriately fit into the history of the crop involving a very large geographical area and various ethnic groups of Asia and elsewhere. Islam spread to Kerala was as far back as 1200 years (Menon, 1995). Apart from this, the trade relationships between Kerala and Egypt and the near east may have greater antiquity as some of the spices such as black pepper, cardamom, cinnamon and turmeric as a coloring material and later as a condiment occurring in these parts of India have been found to be connected with Egyptian culture and also have been mentioned in Old Testament of bible. These trade relationships might have been through the sea as well as land routes. All these support the Indian and Malayan connection in origin, domestication and spread of cultivated taro in Asia extending towards the western parts and Africa. Ethnobotanic evidences available on the crop made Spier (1951) to consider India as the center of origin of the crop. Mehta (1959) as quoted by Shanmugavelu (1989) suggested its Old World origin and Marigouda and Kachgouda (1952) considered India as the original home for the crop. Harlan (1971, 1975) favoured its Southeast Asian origin and Pacific islands as an original abode of the crop. Further, Plucknett *et al*. (1970) and Plucknett (1976) favoured its Indo-Malayan origin. Onvueme (1978) was of the opinion that it originated in South Central Asia. Similarly, Zeven and Zhukovsky (1975) considered its South East Asian origin with an extensive distribution extending to Indonesian-Indochinese and Japanese centers. The morphological and chemical characterization studies by Kuruvilla and Singh (1981) in Indian taro prompted them to opine about its Indian origin due to wide variability noticed both in wild and cultivated taro. Velayudhan & Muralidharan (1987) and Velayudhan *et al.* (1993) based on their extensive studies on indigenous taro of the country very categorically supported the contention of Kuruvilla and Singh (1981). Arora and Nayar (1984) opined that variability noticed in Indian taro is of very complex nature in such a clonally propagated crop due to its very high polymorphic nature. Matthews (1990) opined that the origin and distribution of natural populations of taro and the cultivated populations that run wild should be distinguished before arriving at a conclusion on the original home of taro and the center of domestication and distribution and spread of the crop and then running wild and establishing secondary and tertiary level populations of taro. He, following Kitamura, (1949), Hotta (1970), Coates *et al.* (1988) also reported the occurrence of *C. esculenta* var. *aquatilis* Hassk. in Australia and in the Pacific islands, Japan and Polynesia and stated it as a possible wild progenitor of taro. In his hypothesis he probably did not mention anything about its original abode in Indo-Malayan region. The interpretation of the natural range of variation is a prerequisite for understanding the selection, propagation and dispersal of taro by humans (Matthews, 1991). He contended that the taro originated somewhere as a natural species and therefore the geographical distribution of the species was never extended before its domestication. The cultivated types might have originated within its geographic distribution. Thus the naturally occurring taro should be clearly distinguished from the cultivated ones in order to clearly classify and the describe both. Several workers like Watt (1985), Chang (1958) and Keleny (1962) opined differently. Keleny (1962) believed that the crop originated in Malaysia and had further spread to many neighbouring centers like Myanmar, China, Indonesia, Melanesia, and Polynesia in the prehistoric times. Quite interestingly, Hay (1996) while commenting on the wild type of taro quoted Matthews (1995) that wild types could eventuate by reversion on escape from cultivation and hence suggested that the wild types of taro might originate polyphyletically both from its wild type ancestor and cultivated forms. Cultivated forms are derived from wild types several times (Coates *et al.*, 1988 & Hotta, 1983). Linnaeus was the first to describe taro in the year 1753 as belonging to the genus *Arum* (Hill, 1939). Later, Schott (1832) established the genus *Colocasia* that has been derived from the word ‘Colcas’, an Egyptian word for taro. The origin of taro now seems to be a highly complicated issue. The debate about taro and the origins of Asian and Pacific agriculture has been reviewed by Spriggs (1982) and has been summarized by Matthews and Terauchi (1994).

The spread and distribution of cultivated taro include either recent or past introductions in Old or New world. Hence Hotta (1983) suggested that there are several separate genealogies of cultivated taro originating among diverse starchy wild types within a natural range limited to mainland of South East Asia. Identification of natural ranges of extreme eastern and southern distribution of the wild *Colocasia esculenta* var. *aquatilis* (probably synonymous to *C. esculenta* var. *stolonifera*) *by* Matthews (1991) to North East India, Australia and Papaua New Guinea may appear to be a bone of contention as similar wild types occur all over the tropics and subtropics having moderate to high rainfall in parts of South East Asia, South Asia and Indo-China. Further, such a report has been made by Velayudhan and Muralidharan (1987) on the variability of wild taro in the extreme southwestern parts of India along the Western Ghats, which is the western most extension of Indo-Malayan region.

Taro is a native of low wetlands of tropical South and South East Asia and is now cultivated in tropical and subtropical parts of Asia, Africa and Americas. As compared to any other country in Asia, India has the widest distribution of the wild and cultivated taro suited to both upland and lowland conditions. It is also found to be associated with sustenance of life of the local primitive people from time immemorial. However, ethnobotanic evidences from the prehistoric times appear to be difficult to assess, as documentary evidences and mention of the plant are very scarce. Detailed information on the diversity of taro in East, North East, North West and Southwestern region of India does not appear much in literature except for the detailed studies by Velayudhan *et al.* (1993). Traceable legendary stories and scanty historical evidences in Indian history are of speculative nature and suggest that the human migration in the prehistoric times might have followed a course not only within sub continental India but between it and other neighbouring countries such as Myanmar, Indonesia, Malaysia, Thailand and Kampuchea during the period of spread of Budhism later on during Hindu renaissance. The process of human migration, cultural and religious integration might have hastened the crop migration from areas of greater diversity to newer areas. Further, through the land-trade routes (the silk route) running across the continent thousands of miles passing through

China, Tibet, Nepal, India, Afganistan, Iraq, Iran touching the central Asia, Africa and the Mediterranean and the sea-routes between India, China, Malaysia, Indonesia, Sri Lanka, Africa and Arabia extending to Mediterranean and European countries vast migration and colonization might have taken place causing migration, spread and association of various peoples, cultures, customs, food habits over to a very vast geographical region. The crops also seem to have taken a similar course, as they are very closely associated in sustenance of life of humans. The early human migrations have been closely associated with their search for food security followed by search for better grazing grounds for their animals, fertile and irrigable lands for cultivation following discovery of agriculture and safer places for their security from natural calamities, animal and human attacks

The basic Malaysian name for taro i.e. ‘tallas’ is stated to be the root of for Polynesian word taro and the Greek word ‘Colocasia’ has its origin from the Arabian word ‘quolqas’. According to Porteres (1960) all these have their root in Malaysian word ‘tallas’. Further Velayudhan *et al.* (1993) provided a detailed account on the etymological connection of the Indian words for taro. The Malaysian word ‘thallas’ or ‘tallas’ happens to be very closely related to Malayalam word ‘talu’ for common wild taro in Kerala. Similarly the Oriya word ‘Saru’ in India is similar to Taro. In certain places in Kerala the black taro is still known as ‘Karinthal’ (‘kari’ means black and ‘thal’ means taro). In this regard, the origin of the name ‘taro’ from ‘Tallas’ was based on the belief that Polynesians took ‘taro’ from Malaysian region (Purseglove, 1975). However further elucidation of the etymological connection with the Indian terms for the crop supported by the historical and prehistorical speculations and legends greatly suggests that the Melanesians were the first to domesticate the crop in coastal regions of India especially Kerala and Orissa and later on the spread of the crop was taken up by the Polynesians to further eastwards. The other Indian words such as Arvi, ‘Guinya’ and ‘Kushu’ for the crop have different etymological roots in Sanskrit language which is an important member of Indo - Aryan linguistic group and hence even in the North -East having greater variation in both wild and cultivated taro the local names used for the crop are the most diverse and contrary to the to the Malaysian and Indonesian names. The important items of trade in Kerala in earlier days were mainly spices and aromatic plants and trade relationships of the West Coast of India with the Arabians also might have helped in the crop dispersal to Egypt from whom Greek obtained the name ‘Colocasia’ a version of the Arabic word ‘Quolquas’ for taro. Further there is a decreasing trend in the diversity noticed in cultivated strains and the wild ones of the crop from the wet tropical and subtropical areas to the drier areas in India. Regarding the crops cultivated in Kerala and southern region during ancient days there is no mention of taro. Whereas, cultivated and wild yams were important for human subsistence. However, the only evidence of great ethnobotanic value and ancient nature of taro is traceable from the information available from

Orissa in India on its use as a sacred offering in famous and ancient Jagannath temple of Puri of Hindus in the present Orissa state or ancient Kalinga kingdom of early Indian history. The Mauryan King, Ashoka, conquered Kalinga and as a part of his mission for spread of Budhism he sent his emissaries to various parts in East Asia and in Sri Lanka. All these historical facts form indirect evidences that point to the possible spread and diversification of some crops like taro in Asia as taro happens to be a primitive subsistence crop having its possible domestication in tropical swamps before rice cultivation in parts of India and Malaysia before 4000-7000 years as opined by Onvueme (1978).

The opinion of Plucknett (1976) on the origin and spread of the crop from Indo-Malayan region indicated firstly in eastward direction to Far East, Pacific islands, Indo-China and the secondly in westward direction (Fig.1) to Middle East, Egypt and Mediterranean, East Africa and West Africa appears to be very logical.

In the past, during the colonization of these parts by the Europeans such migrations of various crops and useful plants occurred. The spread of some of the crops between the West Coast of Kerala and Malaysia might be a truth as pointed out earlier by Velayudhan *et al.* (1993). Several of the present day crops of Kerala are the introductions by the Portuguese. Aroid tubers such as elephant-foot yam, taro and Tania are very commonly cultivated in areas of high rainfall in India**.** Thus, cultivation of taro in

India appears to be older than or as old as in other regions of Asia. Further its cultivation in the old Wanga or the present Bengal, ancient Kalinga or the present Orissa and the North eastern Parts of the country, no doubt, is more primitive as evident from the present diversity and the subsistence nature of the crop and also decreasing trend in its diversity in those areas in relation to the distant locations of the secondary areas in the north and central parts of the country. Similarly, there is another important pocket of great diversity and of ethnobotanic importance as a primitive subsistence crop and as wild edible plant along the mountainous region in the North Western India with higher amount of rainfall suggesting its ancient base and role in the ethnic life in India. The occurrence of both cultivated and wild strains of *Colocasia esculenta* var. *esculenta* mainly in North - East and Southwestern region again suggests the gradual spread of the crop from the North - East to these areas. However, ethnobotanically wild forms of *C. esculenta* var. *aquatilis* which was proposed to be the progenitor of cultivated taro in Asia (Matthews, 1991) occur in great diversity in tropical Western Ghat region and some strains are being utilized by the locals and tribal people as a famine vegetable. Migration of Aryans from North West of India has not influenced the cultivation of taro but the aborigines or the tribal people who lead nomadic life constantly under the threat of uncertainty of food sources always depended on yams and taro apart from other fruits and grains for meeting their food demands. The localized tribal people in Western Ghats in

Kerala, hills in Chattisgarh and Northeastern region of India still use this wild taro as a vegetable. Thus, tribal people living away from areas of progressive farming and affluence still follow taro and yam based practices. Apart from this, puddle taro cultivation as seen in Pacific islands is also found in hilly tracts of Uttaranchal state (Joseph, 2006) in India. Its original monoculture system of subsistence cultivation of taro in marshes and ditches is still prevalent in North East, where different cultivars are planted after the dry spell in winter during February along the water courses and in ditches where water gets accumulated at the onset of monsoon in April or May and the plants grow fast as the water level rises and the crop is harvested in the month of October-November. The early planting of taro as a subsistence crop is noticed throughout Assam plains. Similarly eastern parts of Bihar and Uttar Pradesh also raises early crop, part of which comes to the markets in North India. The crop is also common in coastal districts of Andhra Pradesh, hills and plains of Orissa and West Bengal. Commercial cultivation of taro is rare indicating its strong subsistence nature except in drier situations where the crop is irrigated as found in parts of Uttar Pradesh, Madhya Pradesh and Tamil Nadu. *Colocasia esculenta* is the first irrigated crop even preceding rice. Magnificent stone walled terraces attest to the cultivation of taro in Asia and Oceania as early as 2000 years ago. Anthropologists concerned with study of migration of peoples have used taro as an indicator in tracing of Polynesian migrations from Indonesia throughout Pacific islands.

2. 2. Ethnobotany

Taro is one of the earliest of crops domesticated in India or in Indo-Malayan region. Handy (1930) as quoted by Purseglove (1975) reported 300 distinct taro varieties in Polynesia. Apart from this it is also an important wild plant of subsistence and famine food in tropics. Under the genus *Colocasia* four species such as *Colocasia esculenta* (L.) Schott, *Colocasia fallax* Scott, *Colocasia gigantea* (Blume) Hook.f. and *Colocasia tonoimo* Nakai are reported to be cultivated (Anonymous, 1986b). *C. fallax* is stated to be cultivated in Chinese gardens for vegetable and fodder, *C. gigantea* for edible corms and as an ornamental, C. *tonoimo* as a vegetable and fodder in Thailand. The taxonomic position of *C. gigantea* was confusing as it has the plant type of the genus *Alocasia* but, Hay (1996) cleared the confusion. Under the genus *Colocasia*, there are two species such as *C. esculenta* L. (Schott) with two varieties and *C. gigantea* that happen to be life supporting one. Of these, *C. esculenta* is mainly cultivated for its mother tubers, (corms), lateral tubers (cormels), leaves and petiole. Both corms and cormels are edible in the case of var. *esculenta* where as, generally cormels are used in the case of var. *antiquorum*. Apart from these, leaves and petioles are also used as a vegetable in parts of India and elsewhere. Corms of var. *esculenta* form almost a staple food in Pacific islands where wet cultivation of taro on terraced and puddled lowlands is a common feature. The leaves and spadices of taro are consumed as a salad in some countries of South-East Asia and Pacific islands. In India, Sri Lanka, Myanmar, Malaysia and Nepal its tubers are used predominantly as a vegetable. Ochse and Backhuizen (1977) describes various preparations made out of tubers, leaves and petiole in different parts of Dutch East Indies i.e., the present Java and Sumatra islands of Indonesia. Taro has a very wide distribution both under wild and cultivation. Its petiole is known as 'thalu' in Kerala and is consumed as a vegetable especially during the famine stricken monsoon period in Kerala (Velayudhan *et al*., 1993). Apart from leaves of taro that of *Remusatia vivipaera* is also consumed by the locals in Hills of Konkan, coastal Karnataka and in Hills of Tamilnadu. In coastal Karnataka and Konkan region of Maharashtra in India many homes have at least a large clone of black taro (var. *esculenta*) the leaves of which are used by the locals like spinach (Yawalkar, 1992). Tender leaves about to unfold are preferred for the purpose. Even now, the stolons of different wild clones of purple petioled taro known as 'kadu karikeshu' in Kudagu district of Karnataka is eaten by the people (Velayudhan *et al.,* 1993). The processing of stolons is a long process in which the long and thick stolones of wild taro are collected during the month of October and are cleaned by removing the outer skin, chopped to small pieces and dried under the sun for few days. The dried starchy pieces are then kept in store and are used as cooked vegetable along with tamerind during the time of scarcity for other vegetables in the rainy season. In Fiji, the locals make use of either boiled or baked breadfruit or tubers of taro as slices along with roasted pig (Muralidharan, 1992). Food value of taro in Hawaii has been given by Miller (1929). Uses of taro in native recipes along with its medicinal uses in treatment of constipation and tuberculosis in Hawaii were given by Kokua (1977). Figueres (1981) gave the ritual based uses of taro in the Pacific. Pressed juice of petiole of taro is highly cystic and is even said to arrest arterial hemorrhage (Drury, 1873). Medicinal value of taro is cited by But *et al.* (1988) in China

Nutritionally, taro is very similar to tannia. Its starch contains 17.5% amylose and the rest amylopectin. Starch grain is very small and the size ranges from 1-4 µ. It is rich in most of the essential amino acids (Rao & Polacchi, 1972) and hence is considered to be a good leafy vegetable. Shanmugavelu (1989) reported that 100 g of taro tuber contains 73.1 g moisture, 3 g protein, 0.1 g fat, 1.7 g minerals, 22.1 g carbohydrates, 0.04 g calcium, 0.14 g phosphorus, 2.1 mg iron, 80 IU Vitamin B and trace of Vitamin C. Lila Jacob (1985) worked out a proximal composition of *Colocasia esculenta* tubers and leaves by calculating averages of various reports available in literature. Protein content is around 7% in tubers and leaf. Nutritional analysis of Pacific taro showed that tuber contained 1.8 g of protein, 0.2 g fat, 24.3 g carbohydrates, 0.8 g fibers, 42 mg calcium, 1.1

mg iron, 88 g phosphate, 0.15 mg thiamine, 0.032 riboflavin, 0.9 Niacin and 5 mg vitamin C whereas leaves contained 31g, 2.4 g, 0.6 g 5.7 g, 1,5 g, 98 mg, 2.0 mg, 49 mg, Vitamin A 1800 R.E. *C. gigantia* (Blume) Hassk. is a giant species of the genus *Colocasia*, the tubers of which are used in the villages mainly to feed pigs in China.

2. 3. Taxonomy

Of the several systems of classification of Araceae, the two earliest ones are by Schott (1832) and by Engler (1879). Schott's system, which is pre Darwinian, is based on striking characters irrespective of their possible relationships. The second system by Engler divided the genus into groups based on their interrelationships. Hooker (1883) followed Schottian system for his treatment on Araceae (Aroideae) in *Genera Plantarum* by incorporating Engler's (1879) reduction in number of genera. Hutchinson (1934) popularized the first system. In Engler's system there are 8 subfamilies. The subtribe Colocasiinae falling under the tribe Colocasieae of the subfamily Colocasioideae included only one genus, i.e. *Colocasia* with long or short sterile appendix on spadix as compared to the genus *Alocasia* under the subtribe Alocasiineae with sterile appendix either absent or if present obconical in shape.

The genus *Colocasia* is usually confused with *Remusatia* and *Alocasia*. In *Colocasia* the sterile appendix of spadix is long or short and in

Alocasia it is obconical or absent. The plants of the subtribe Alocasiinae are different from Colocasiinae in deciduous nature of the limb of the spathe. Nicolson (1960) is of the opinion that Hutchinson's treatments (1959, 1973) are more useful than Engler's (1920). However the use of Engler's system over that of Hutchinson (1934) was found to be more appropriate in a study of survey of pollen types in Araceae.

Taro, *Colocasia esculenta* (L). Schott belonging to the family Aroideae of the Series Nudiflorae of the group Monocotyledons of Bentham and Hooker's system of classification (1862-1883) to the family Araceae of the sixth order Spathiflorae of Monocotyledons of Engler and Prantil's (1887-1915) classification and to the family Araceae of the second order Corolliferae of the second Subphylum Monocotyledons of the Phylum Angiospermae of Hutchinson's (1973) is naturally distributed all over the tropics and subtropics of Asia. O' Hair and Asokan (1986) commented that Aroids remain probably one of the most confused group of plants taxonomically. According to Plucknett (1976) edible aroids are grouped into two subfamilies, viz. Lasioideae and Colocasioideae.

The taxonomic confusion that existed with respect to edible aroids began due to the use of wide spread common names and lack of interest and familiarity with aroids on the part of early historians (Bronson, 1966). Similarly, in the case of taro (*C. esculenta*) some amount of confusion existed as a polymorphic species having extreme levels of morphological variation in cultivated strains. Some recognized only a single species with two botanical varieties viz. *C. esculenta* var. *antiquorum* (Schott) Hubbard and Rehder and var. *esculenta* (syn. *typica* A.F. Hill). Haudricourt (1941) recognized the specific epithet *C. antiquorum* for taro and listed a number of botanical varieties based on vegetative characters and this perhaps appeared to be more useful for infraspecific classification than that based on floral characters as it is difficult due to very shy and erratic flowering at least in cultivated taro. O' Hair and Asokan (1986) stated that confusion existed in taxonomy of aroids.

Yen and Wheeler (1968), Plucknett *et al.* (1970) and Marchant (1971) considered *C. esculenta* var. *globulifera* as Dasheen and *C. esculenta* syn. *C. antiquorum* as taro, 'eddoe', 'old cocoyam', 'keladi', 'arvi' or 'arbi' and 'dasheen' of West Indies. Velayudhan *et al.* (1993) opined that in India, *C. esculenta* var *esculenta* is the type having oblong, fusiform, cylindrical mother rhizomes with few oblong similar looking daughter rhizomes locally called and marketed as 'Kacchaloo' in northern parts of India, 'Suikachu' in the North-East, 'Karikeshu' in Karnataka and 'Karichembu' in the Malabar area of North Kerala and 'Madai' of Goa (Joseph, 2007). This differentiation was done on the basis of the corm and cormel characters. This classification was done on the basis of the mother tuber (corm) and lateral tuber (cormel) characters.

Barrau (1957) recognized two species of cultivated taro viz. *C. esculenta* and *C. antiquorum* on the basis of the length of the sterile appendix in comparison with that of the male part i.e., the sterile appendage shorter than the male part in *C. esculenta,* and longer in *C. antiquorum*. Though this appears to be a legitimate key in differentiating the two species under cultivation in normal course, the extent of continuous variation overlapping each other beyond the line of difference at the specific level both in cultivated and wild taro as indicated by Velayudhan *et al.* (1993) in Indian taro it becomes all the more confusing in delimitation characters as proposed by the former in taro. Its origin as a crop, domestication, diversification and spread probably has a parallelism with that of another vegetatively propagated crop like cultivated banana (*Musa* hybrids). Perhaps the crop with its wild relatives probably is a big complex having very wide distribution. Mathur *et al*. (1966) as quoted by Shanmugavelu (1989) confirmed the *C. esculenta* var. *globulifera* as dasheen. The confusion still continues in the taxonomy of taro as it is a highly polymorphic species and the variation is of very continuous nature. According to Hay (1996) the taxonomy of taro still is under confusion as there is growing evidence for grouping cultivated taro at least under two species. The background information, no doubt, provides ample chance for systematic studies in taro irrespective of the past disclosures with respect to its taxonomy.

The extent of variation noticed in taro is of very complex nature and attempts have been made in the past to identify cultivars and varieties, and Coursey (1969) stated that it has been made on the basis of differences in colour of the lamina, veins, etc. Thus, the 'Caribbean purple' recognized by Gooding and Campbell (1961b), 'Pilo' group in Hawai and 'Mamu' in Fiji are identified cultivars. Almost 1000 cultivars have been described by Plucknett (1976), which seems to be very exaggerating. In India, also several cultivars have been recognized by Maurya (1977), Sarnaik and Peter (1986), Shanmugavelu (1989) and Misra and Chowdhury (1997).

2.3.1. Description of the genus *Colocasia* Schott

Flowers uni sexual and naked, male flowers fertile 3-6 androecium, stamens in synandrium, ob pyramidate, vertically dialated, sub truncate, irregularly polygonus, connate, theca soft, linear, oblong, lower portion suddenly attenuate.

2.3.2. Subgenera categorization of *Colocasia and* the species

Engler and Krause (1920) were the first to classify the family into tribes and subtribes and the genus comes under subtribe Colocasiineae. They divided the genus *Colocasia* into two sections viz. sect. 1. T*uberosae* and sect. 2. *Caulescentes* on the basis of habit of the main underground rhizome. The section *Tuberosae* contained 4 species viz. *C. affinis, C. fallax, C, gracilis* and *C. antiquorum.* The last one was later recognized as revised as

C. esculenta (L.) Schott. The section *Caulescentes* contains species such as *C. virosa*, *C. indica* and *C. manii*. Further, Engler and Krause (1920) also placed 9 varieties viz. var. *typica* Engl., var. *euchlora* (C. Koch) Schott, var. *fontanesii* Schott, var. *illustris* (Bull.) Engl., var. *esculenta* (L.) Schott, var. *nymphaeifolia* (Ventl.) Engl. var. *globulifera* Engl. et Krause, var. *aquatilis* Hassk. and var. *accris* (R. Br.) Schott under the species *C. antiquorum* = *C. esculenta* (L.) Schott. According to Hay (1996), *Colocasia* is a small Asian genus of herbs allied to other Old world, predominantly Asian genera including *Steudnera* K. Koch of Himalayas and Indochina, *Remusatia* Schott and *Gonatanthus* Klotszch (Li Heng & Hay, 1992) of eastern Himalayas/South East Asia/Southern China but distributed to tropical Africa and topical Australia and to *Alocasia* (Schott) G. Don distributed from Indonesia to East Asia and warm temperate Australia. All of this fall under the tribe Colocasieae (*sensu* Grayum, 1990; Hay & Mabberley, 1997). Colocasieae *sensu* Bogner and Nicolson (1991) included only *Alocasia* and *Colocasia* and others placed these genera in allied tribes. The genus *Colocasia* is distinguished from the most commonly confused genus *Alocasia* firstly by the arrangement of the inflorescence (radial to stem in *Colocasia*, paired and each pair being tangential to the stem in *Alocasia*) except in cases where many inflorescences are produced sequentially without interruption by foliage and secondly by large number of ovules with parietal placenta parietal in *Colocasia* in contrast to the few number of ovules axile placentation in *Alocasia.*

The genus *Colocasia* contains 7 species (Matthews, 1991). However, according to Hay (1996) and Long and Liu (2001) the genus contained 8 and 9 species respectively. Thus, in addition to species dealt by Engler and Krause (1920) 4 more species such as *C. heterochroma* (Li & Wei, 1993), *C. oresbia* (Hay, 1996) from Borneo, C. *gaoligongensis* (Li & Long, 1999) from Yunnan in China and *C. lihengiae* (Long & Liu, 2001) from Yunnan in China were described under the genus. Thus, the genus now contains ten species. Hay (1996) considered *C. gracilis* Engler same as wild *C. esculenta* and *C. affinis and C. fallax* as distinct species. Species described under the sect. *Caulescentes* are characterized by thick rigid cylindrical rhizome growing erect and exposed above the soil.

With respect to the various varieties recognized under *C. esculenta,* Nicolson (1979, 1987) considered that it was hopeless to recognize subspecific taxa in such a polymorphic and plastic species. It is logical formally to recognize a single taxon, *C. esculenta* in which cultivars and informal wild types are recognized. Hay (1996) excluded the species and varieties such as *C. devansayana* L. Linden and Rodigas, *C. heterophylla* (Presl.) Kunth, C. *humilis* Hassk., *C. humilis* var. *minor* Hassk., *C. humilis* var. *major* Hassk., *C. indica* (Lour.) Kunth, *C. indica* var. *atroviridis* Hassk., *C. indica* var. *rubra* (Hassk.) Hassk., *C. macrorrhizos* (L.) Schott, *C. neoguineensis* Andre, *C. odorata* Hassk., C. *odora* var. *viridis* Hassk., *C. odora* var. *rubra* Hassk., and *C. pubera* Hassk. previously recognized under the genus from Malaysia and parts of Indonesia. The natural hybridization suspected between *Colocasia* and *Alocasia* has been suggested by Long and Liu (2001) following the reports by Yoshino (1994, 1995, 1998). Thus, there is a genuine possibility of interspecific natural hybrid populations in nature, which are intermediate between *Colocasia* and *Alocasia* as in the case of *C. ihengiae*. The true *Colocasia* species appears to be those with underground tuberiferous stem with tuberiferous cormels in cultivars and with stolons in most of the wild forms. Apart from this, the sterile appendix present in the spadix in members of the sect. *Caulescentes* is either very short or absent. *C. gracilis* from Sumatra is now considered only as a depauperate wild form of *C. esculenta* (Hay, 1996). With respect to *C. manii* from upper Assam and *C. virosa* from Bengal a thorough study of populations of the species is essential to know their proper identity. The better-known species in India are *C. affinis, C. fallax,* and *C. esculenta*. *C. affinis* and *C. fallax* are both found in the wild state in North East India, lower Himalayas in Nepal and mainland of South East Asia. *C. fallax* has been collected during the present study from Meghalaya and *C. affinis* form in North Kerala and Dakshin Kannada district of Karnataka. A large number of cultivars and wild clones of *C. esculenta* could also be collected which formed the base for the present studies. According to Hay (1996) *C. indica* (Lour.) Hassk. as presented in the monographic classification work of Engler and Krause (1920) is a mistake. The second sect. contained those with exposed main rhizome and hence the species can be compared with the species of the genus suspected for the genus *Alocasia* with rhizome exposed above the soil. Thus, *Colocasia gigantia* (Bl.) Hook. f. being synonymous to *C. indica* is now reported to be *Alocasia macrorhizos* (L.) G. Don.

2. 4. Exploration and collection

Exploration and collection is the primary and the most important part of plant genetic resources work. Systematic surveys in centers of crop cultivation and in undisturbed and disturbed natural vegetation zones are indispensable part of it. In taro and its related species though much work has been done in piece-meals in several countries it has been thoroughly carried out in India for the last 30 years in multicrop and crop specific exploration missions (Unnikrishnan *et al.*, 1987; Thankamma Pillai & Unnikrishnan, 1993; Velayudhan *et al.*, 1993, Santha *et al.*, 1999) and considerable variability has been amassed from important taro growing areas in India. Several recent reports on the survey and collection of taro genetic resources are available in literature from Asian, African countries and from Australia. Bao *et al*. (1998) gives a brief history of plant collection in Yunnan in China. This is due to its importance as a subsistence crop in many tropical countries of Asia, as a secondary staple in few countries, and as a vegetable in south Asian countries. Unlike in seed crops and their related species, the technique for sampling vegetatively propagated crops like taro is done after identifying morphologically distinct clones (Hawkes, 1975) in which few corms (mother tubers) or cormels (lateral tubers) of distinct types forming a population is sampled in order to avoid duplication. In taro, attempts on germplasm collection and conservation and classification began much earlier sporadically in various Asian countries followed by African and Caribbean islands. Occurrence, distribution, local cultivar nomenclature and conservation measures are reviewed in *Colocasia* spp. and cultivars by Ghani (1981, 1987) in Malaysia. Plant genetic resources activities in yams, sweet potato, taro etc surveyed and reported from Papua New Guinea by Kambuou (1985).

Tumana (1987) made a total of 19 collections of taro from Microb district in Papua New Guinea. A novel form of multifaced taro was collected from Nigeria CV Anyamania (Okonkwo, 1988), which resembled Indian cultivar ‘panchmukhi’ or ‘Sahasramukhi’. The review on research and development on taro in Fiji by Chandra (1982) furnished the status of collection, conservation, evaluation and characterization of tuber crops of South Pacific with special reference to improving the descriptors and descriptor- states and tolerance to insect pests and diseases.

2. 5. Characterization

2.5.1. Morphological characterization

Characterization of taro could be based on morphology, production potential, adaptability, palatability, usefulness, chemistry, molecular parameters, resistance, and tolerance to diseases and pests etc. The morphological characterization is the primary need followed by preliminary evaluation. With a view to uniformally characterize and evaluate the world germplasm of taro IBPGR developed descriptors state (Anonymous, 1999a). Following this few institutions in India initiated the characterization and CTCRI, Trivandrum and NBPGR, Thrissur were the foremost among them ((Unnikrishnan *et al.*, 1987; Thankamma Pillai & Unnikrishnan, 1993; Velayudhan *et al*; 1993, Velayudhan *et al*., 1999b). A total of 62 descriptors were present in the characterization data part, which were later modified and used by the workers according to the need. Thus Unnikrishnan *et al*. (1987) used 42 descriptors and Velayudhan *et al*. (1993) used 86 descriptors.

2. 5.2. Chemical and molecular characterization

Chemical and Molecular characterization in taro germplasm by way of isozyme analysis and genetic fingerprinting using RAPD, RFLP and AFLP techniques are essential to classify and reduce the redundancy in large collections maintained in *ex situ* in several Asian countries. Further, these studies may also help in delineating the origin of cultivated taro in each geographical region as proved by Tahara *et al.* (1999). The results can also be used to classify the variant forms and to prove the polygenic relationships in them. Kephart (1990) gave a very detailed account on the use of star electrophoresis of plant isozymes in studying intra specific variability in plants. Tahara *et al*. (1999) investigated the phylogenetic relationships between diploid and triploid taro by analyzing 13 enzyme systems for variations in 59 accessions from Nepal and Yunnan province of China and the results indicated an autoploid origin of triploids. Further distinct geographical groups within diploid and triploid forms were obtained. The use of molecular techniques right from studies on protein banding (Kuruvilla and Singh, 1981; Hirai & Takayanagi, 1989) and Isoenzyme banding pattern (Isshiki *et. al.*, 1995, 1997; Lebot & Aradhya, 1991, 1992; Isshiki *et al*., 1998; Hirai, 1988; Tanimoto & Matsumoto, 1986) to the latest genetic finger printing techniques by RFLP and RAPD have been attempted. Matthews *et al.* (1992), and Isshiki *et al.* (1995) attempted to aid in the study of classification of taro varieties, to understand their interrelationships and to identify the inheritance pattern of few enzymes involving parents and their hybrid lines. Variations based on 17 morphological and peroxidase and esterase Isoenzyme pattern with respect to 38 strains of taro *Colocasia esculenta* and *Colocasia gigantia* showed conformity with cultivar groups shown by Kumazawa *et al.* (1956) based on morphological characters and cultivated taro contained 2 groups of diploid and triploid strains and the giant taro showed diploid strains only (Tanimoto & Matsumoto, 1986). Quite recently, morphological and Isoenzyme variability in taro germplasm from Cuba has also been attempted by Manzano *et al.* (2001) and in those from Unan province of China by Jianchu *et al.* (2001). Tahara *et al*. (1999) attempted on 13 enzyme systems in 59 accessions of taro from Nepal and Unan province of China and the results indicated that isozyme bandings specific to triploids were present only at 5 out of 115 observed and most of the collections were differentiated. The isozyme variations in triploids were derived mostly from the diploids. All the accessions could be differentiated into two geographical groups. Triploid taro derives from cross-fertilization in diploid ones with an unreduced gamete. All These studies proved that better differentiation of triploid and diploid taro are possible against the contention of Lebot and Aradhya, 1991 and Tanimoto and Matsumoto (1986) that this differentiation was not possible using isozyme banding pattern. However, these attempts happened to be on restricted variability in the secondary centers of taro diversity. However, so far no attempt has been made to conduct a comprehensive study on isoenzyme pattern in an indigenous taro germplasm compartmentalized into morphotypes representing wide variability from different agro-ecological regions in India. Recently, Manzano *et al.* (2001) had carried out a detailed morphological and Isoenzyme investigation in forty-two clones including those introduced from Asia, Africa and America including those from Cuba and genetically improved ones to classify the clones into six groups and several subgroups. Esterase enzyme exhibited 27 polymorphic alleles of which 20 were stated to be rare.

2. 6. Preliminary evaluation

Preliminary evaluation of the collections is the part and parcel in any crop genetic resources study. This leads to proper understanding of the genetic potential of the crop collection facilitating its proper utilization in crop improvement programme. Until and unless a collection has been properly evaluated and its attributes in relation to their uses become known to the crop breeders the work has little practical value. In a broad sense, germplasm evaluation in the context of genetic resources studies is aptly the quantitative description of the resources in hand. The preliminary evaluation is based on the measurement of most of the heritable characters that can be measured or quantified and analyzed. These include aboveground and belowground vegetative and reproductive characters. Usually spike, fruit and seed characters in seed crops and underground characters in the case of tuber and rhizomatous crops assume importance. In addition, pest and disease resistance, production potential with respect to other economically useful parts, adaptability to different environments etc are also covered under this. The observable characters such as qualitative can be either nominal based on a standard chart or ordeal by assigning a number to various classes. Thus, IBPGR, Rome with the joint attempt of concerned experts in various aspects of taro had published a descriptor for Taro (Anonymous, 1980, 1999a).

The evaluation may be preliminary one involving a large number of accessions from a wide geographical region and detailed evaluation which is essential for selection of promising lines from less number of lines selected earlier on the basis of preliminary evaluation. Thus, preliminary evaluation is essentially a multidisciplinary approach, as it includes studies on morphology, cytology, taxonomy, genetics, agronomy, entomology, pathology, nematology, chemistry and what not. All the information amassed right from exploration, collection (passport information), characterization and preliminary evaluation and detailed evaluation are used for cataloguing and documenting information on crops. Such studies paves way for proper evaluation as done in the case of potential clones of taro and *Xanthosoma* by Barroah (1987) for proper utilization.

Genetic variability in seed production, between and within seedling populations of varieties 'Yandina' and 'UCI runner' has been reported. Variation in moisture content of corms, anthocyanin content of leaves, alkaloid content of seedlings, coloration of petioles, protein content, chlorophyll content etc were also noticed; the environments considerably affected the anthocyanin content of the corms (Strauss *et al.*, 1980). The leaves, petioles, corms flower and fruits of *Colocasia* and *Xanthosoma* were described by Pardales and Villanueva (1984) in Philippines. Clones belonging to *C. esculenta* var. *esculenta* and *C. esculenta* var. *antiquorum* and suggests that there existed 2 species not two botanical varieties of a species. A review on *Colocasia esculenta* and its potentials in a book on taro production features chapters on the general background of the crop, taxonomy, agronomy, and pests and diseases, utilization, and planning and development are furnished by Wang (1983).

2. 7. Classification

Radford (1986) stated that the classification is the arrangement of groups of plants with particular circumferences by rank and position according to artificial criteria, phenetic similarities or phylogenetic relationships'. In essence, he defined systematics as "the study of phenotypic, genetic and phylogenetic relationship among taxa". This can be either between various taxa or within one taxon or groups of genetically related or otherwise. Usually the extent of infra-specific variation noticed in cultivated plants is above the purview of a taxonomist who does his hierarchical arrangement of taxa up to taxonomic variety level. Due to various reasons of genetic, breeding barriers, mutations both point and structural chromosomal aberrations, selection caused by environment and human pressures, crop plants generally encompass greater variability than the wild species and conventional taxonomy ceases to explain the same in its usual course. Hence, Harlan and de Wet (1971) proposed a new classification in the light of crop species breeding. Taro, *Colocasia esculenta* (L.) Schott mainly being a vegetative propagated species is highly polymorphic (Hill, 1939) and has innumerable types that occur both under cultivation and in nature. Attempts to classify the cultivated ones in South Asian countries and Pacific islands on the basis of morphological features began much earlier. In cultivated taro, two main types such as dasheen and eddoe based on sterile appendix size and nature are distinguished (Purseglove, 1975). They have been further delineated as *Colocasia esculenta* var. *esculenta* similar to dasheen with 2n=2x=28 and Colocasia *esculenta* var. *antiquorum* with 2n=3x=42 chromosomes. The usual practice as in the case of other clonally propagated crops such as banana and yam by the locals as well as by the crop breeders has been to identify them by the existing local names in different languages based on the place of origin, specific traits of plant parts, cultivation practice and uses. Thus, in India having over 15 main languages and over 200 dialects several vernacular names for cultivars and varieties occur as depicted by Velayudhan *et al.* (1993). As it is a very important subsistence crop and due to its greater ethnobotanic importance, any clone known by a specific name in one locality may be known by other names in different localities representing either a small or large geographical area with similar or different linguistic backgrounds. Hence, these names sometimes do not hold much relevance and credibility in identifying different varieties in a large germplasm collection from a large country such as India. Similar situation can be noticed in other vegetative propagated crops also as reported by Velayudhan *et al*. (2003) in cassava. Thus, each variety may or may not hold several local names based on the usual cultivation practice, various qualitative and quantitative traits of the economically important and other plant parts and their uses in relation to the linguistic variations (Velayudhan *et al*., 1993). Rarely, certain cultivars of taro occurring in North Western Region may also occur in Southern region due to human interference on spread of crop and crop evolution. The extent of morphological variability noticed in taro from southwestern high rainfall area of Kerala lying along the western slops of Western Ghats and midlands between the Ghats and the coastal belt is almost next to North Eastern Region in India in the extent of taro variability. Geographically, this small narrow strip of land is considered to be a continuation of the Malaysian Archipelago and ironically there is a commonality in the choreography and vegetation of both these areas and the North-East irrespective of existing latitudinal and longitudinal differences. Exploration and collection of indigenous germplasm with a view to amass the resources that are under the grip of fast genetic erosion has been on in India since 1978 and a considerable amount of germplasm has been amassed, studied and maintained. The difference in sampling strategies and the lack of knowledge on the part of collectors about the exact nature and extent of diversity in any crop in wide geographic area has virtually resulted sometimes in over sampling, redundancy and duplication in *ex situ* field gene banks leading to escalating costs and efforts in maintenance. This can be well avoided by classifying the collections first by morphological characterization followed by preliminary evaluation and molecular characterization. Usually, a systematic classification based on floral characters into the various botanical varieties two major varieties identified in Taro is difficult due to its shy nature in flowering. In the past, different experts based on the morphological features have done classification of cultivated taro. No attempt has ever been made in India in the past in a systematic way except by Velayudhan *et al.* 1993. An attempt in classifying the taro germplasm on the basis of subjective morphology and then to relate them with the local names and specific morphological traits has been first made by Velayudhan *et al*. (1991, 1993). Similar classification has been also done made by Velayudhan *et al.* (1989, 1999, 2003) in few other clonally propagated crops such as greater yam, turmeric and Cassava respectively. Pardales (1985) classified taro into 'Gabi' and 'Yautia' in Philippines. Classification on the basis of morphology has virtually given a new dimension to the concept of classification of crop genetic resources similar to that of core collection concept that is usually applied in seed propagated crops (Brown, 1989) on the basis of Frankel's (1984) suggestion that a collection could be pruned to what he termed a core collection, which would "represent within a minimum of repetitiveness, the genetic diversity of a crop species and its relatives". The only difference between the two concepts is that in the former, an exact replica of the compartmentalized and stable variability trapped in a clone represented by several collections in the germplasm can be selected and the redundancy, duplication and cost of *ex-situ* maintenance can be reduced considerably. In the latter, only the core can represent a major portion of the existing variability in a large germplasm based on breeding behaviour of the crop and its relatives. The core collection representing a very large collection may sometimes lead to loss of certain amount of variability that may be present in a collection by the presence of certain very rare alleles having a frequency < 0.5. More recently Rodríguez *et al.* (2001) used multivariate statistical analysis to study the diversity of *Colocasia esculenta* existing in Cuba. Further they had adopted a multidisciplinary approach of Isoenzyme analysis, PCA and correlation coefficients to classify 42 clones into six major groups and their subgroups in Cuba and suggested that in taro, core collection can be formed using only the proposed 13 descriptors that contributed to the variability, and should be composed of clones representing the three main groups of variability and the eight subgroups within them. Recently, Garcia *et al.* (2003) made an attempt to stratification of 450 accessions of Vanauti taro germplasm on the basis of a simple and practical method of morpho-agronomical traits and validation by AFLP markers to prove the narrow genetic base of taro there. Thus, information on the variability of the accessions collected or maintained *in situ*, as well as of the uncharacterized accessions in the gene bank can be obtained quickly. Later, Sreekumari and Mathew (1990, 1991, 1995) using cytological tools coupled with morphology could describe cytotypes and morphotypes in taro. Isshiki *et al*. (1998) had classified Japanese taro on the basis of Isoenzyme analysis.

Though, it is considered to be mainly a clonally propagated crop in general, possible sexual propagation through self and natural hybridization as opined by Matthews (1991) resulting in extreme levels of variations in morphology due to its highly polymorphic nature (Hill, 1939) leading to existence of innumerable types both under cultivation and in nature cannot be ignored and accordingly classification was made in Nigeria by Onyilagha *et al.* (1987). Using ten inflorescence characters in principal compound analysis and cluster diagram in 34 wild strains collected from Nepal, Thailand, Malaysia, Indonesia, China and Japan Tanimoto *et al.* (1983) could reveal five geographical groups. Kreike *et al.* (2004) grouped 255 accessions of taro from Vietnam, Thailand, Malaysia, Indonesia, Philippines, Papua New Guinea and Vanuatu according to their country of origin, to their ploidy level and to their habitat. From the review it was evident that the geographical distribution did contribute to the genetic diversity in the crop in relation to the habitat and status.

2. 8. Conservation

2. 8.1. Centres of Conservation of Taro Genetic Resources

Plant Genetic Resources (PGR), especially Crop Genetic resources (CGR) comprising the cultivated and wild relatives to prevent genetic erosion, to study them, compartmentalize variations, identify the promising lines for utilization in crop improvement can be practiced in two ways by *in - situ* and *ex - situ* (Khanna & Neeta Singh, 1991). Yongping *et al*. (2003) furnished details of taro biodiversity management and conservation in Yunnan, China. *In - situ* conservation in the case of wild species and crop weed complexes in their own ecological niches and then under *ex - situ* conservation by shifting them from the original abode and cultivating under different or similar situations or by using storage systems are practiced. *Ex - situ* conservation can be possibly by *in-vitro* method, in which, tissue culture and cryo preservation are practiced. In - *vivo* can be by annual regeneration in field condition in the case of annual crops, as arboretums in perennial tree crops or clonally in the case of vegetatively propagated crops. With respect to bulb, corm and tuber bearing species the common method is by cultivation in the field supplemented by *in-vitro* storages. The most ideal storage system is the slow growth storage under low temperatures. *Colocasia esculenta* survived at 9.0º c for 3 - 5 years but only for 2 years under 13.0º C. (Anonymous, 1988). *Colocasia* plants obtained under shoot apex culture grown in field trials during the first year and derived tubers in the second year showed that DMV was present in all the plants in the first year at the time of harvest and only 16% at the time of harvest during the second year. (Monge, *et al*., 1989).

The Global Plan of Action (GPA) for Conservation and sustainable use of Plant Genetic Resources (PGR) has among its high priority activities *ex situ* conservation is included. In addition, the GPA emphasizes the need for studies concerning characterization, evaluation and development of core collections, as these studies are important in the effective classification of the collections and allow the users to accede to this information for needs (Anonymous, 1989a). Anonymous (1986a) reported a total of 5889 accessions of wild and cultivated taro and its relatives were maintained in *ex situ* in different countries viz. Australia (193), Bangladesh (123), Brazil (17), Burkina Faso (1), Cameroon (24), Columbia (36), Cook Islands (57), Costa Rica (23), Cuba (30), Federated States of Micronesia (15), Fiji (75), French Polynesia (30), Guadeloupe (6), Guatemala (36), India (650), Indonesia (432), Japan (65), Malaysia (1352), Nepal (49), Nigeria (247), Niue (51), Panama (3), Papua New Guinea (557), Peru (11), Philippines (380), Solomon Islands (268), Sri Lanka (3), Thailand (68), Togo (1), Tuvalu (14), United Kingdom (50), United States of America (478), Vanuatu (138), Vietnam (5), and Western Samoa (28). Thus the largest germplasm collection of the crop is in Malaysia (22% of the total), Papua-New Guinea (13%), India (11%), USA (8%), Indonesia (7%) and the Philippine Islands (6%) (Anonymous, 1986a). The recent picture in India may be different, as further collections have been made and maintained.

Indian perspective about the role of biotechnology in conservation of plant genetic resources has been furnished by Chandel *et al.*(1988). Ball and Arditi (1977) reported the *in vitro* storage of taro using tissue culture technique. *In vitro* storage of various aroids showed that they could be maintained for several years under *in vitro* with 12 weekly sub culture under 24-28º C. and one clone of taro for 3 years without sub culturing in 90º C. (Zandvoort, 1987). Method of long term storage of *Colocasia esculenta* in darkness at 6º C. of plantlets derived from in vitro cultures of axillary buds one shoot produced about 30 plant lets in two months time. (Staritsky, 1980). *Colocasia* obtained under shoot apex culture grown in field trials during the first year and derived tubers in the second year showed that DMV was present in all the plants in the first year at the time of harvest and only 16% at the time of harvest during the second year. (Monge *et al.*,1989). In India, three species of Aroids could be maintained for 10 moths at 25º C (Mandal, 1999) and among induced slow growth strategy tested in taro, use of a medium with reduced nutrients (½ the strength MS) was found to induce by (Unnikrishnan & Sheela, 2000) in cultures.

2. 9. Varieties and cultivars in taro

The list of common names and vernacular names for taro in different languages used in various countries of the world is summarized and given in table-1. Vernacular names for taro in different languages of India are given in table 2. The common names for different varieties of Colocasia esculenta and other species of the genus are provided in table 3. Cultivars and varieties of taro occurring in India are furnished in table 4. In India, maximum number of local varieties occurs in northeastern and eastern regions followed by the West Coast. Though all the local names could not be obtained, various authors have listed many. Several cultivars are known in the name of places of their origin or common occurrence and many carry numbers indicating clonal selections from their local types. Some of the wild types of taro also have vernacular names such as ‘Thal’, ‘Karinthal’, etc. indicating the key morphological character. The names ‘Kattuchembu’ and ‘Velichembu’ in Kerala, ‘Kadukesu’ in Karnataka, ‘Kattukevu’ in Tamil indicate the common wild types.

Mainly breeding in local taro clones also generated several clones that are either high yielding such as ‘Sreerasmi’, ‘Sreepallavi’ and ‘Sreekiran’ at CTCRI, Thiruvananthapuram and various clones such as ‘Gyano’, ‘Warm’, ‘Selection 3-11’, etc. in other countries. The common names in different languages in India for taro are given in table 2. The list includes around 28 named varieties of Kerala (Velayudhan *et. al.,* 1993). Some of these types were morphologically related and could be included in a separate large group viz. ‘Kannan’. At the same time a name such as ‘Bilathi chembu’ probably indicated an introduced exotic one in the past. More over, ‘Thalu’, ‘Karinthal’, etc. indicated the edible petiole of wild types and are sometimes assigned as names to the wild types by the locals.

Table 1. Common names for *Colocasia esculenta* in different languages in various countries

Language	Name	Countries
1	2	3
English	Taro	All over the world
West Indian	Eddoe, Dasheen, Coco yam	West Indies
	Nampi	Central America
Polynesian	Taro	Pacific Islands
Malay	Tallas, Daun keladi	Malaysia
Arabic	Colqas	Egypt
South Pacific	Talo	South Pacific
North Pacific	Dalo	North Pacific
Hawaii	Kalo	Hawaii
Greek	Colocasia	Central Americas
French	Nambai, Arouille, Colocase	France
Egyptian	Colcas	Egypt
Japanese	Imo, Sato imo	Japan
Chinese	Yu, Wu, Yudou	China
	Cocoyam	Africa
Italian	Aro d'Egitto	Italy
Spanish	Malanga, Nampi, Bore	Spain
Thai	Phueak, Phuak, Bai bon, Bon, Bon chin dam, Bon nam	Thailand
Korean	Taro, Toran	N. & S. Korea
	Dagmay, Abalong, Lubigan, Pising, Talles	Indonesia
Amazonian	Pituca	Amazonia
	Malanga islena	Cuba
	Tajoba	Brazil
Cambodian	Kachu, Pani, Taro, Kuk, Taro chouk	Cambodia
	Kari, koko, Ya beri	West Africa
German	Kolokasie, Yamsuwurzel	Germany
Vietnamese	Khoaiman, Khoaic nuoc	Vietnam
Zulu	Amadumbe	Africa

Table 2. Common names in different languages in India for taro

Language	Names	State/Place
1	2	3
Assamese	Kuchu, Kachu, Garo kachu	Assam
Malayalam	Chembu, Thalu	Kerala
Tamil	Seppaikilangu	Tamil Nadu
Marathi	Arvi	Maharashtra
Telugu	Shamagadda, Chamalu	Andhra Pradesh
Hindi	Arvi, Guinya	North India
Kannada	Keshu, Shama gadda	Karnataka
Bengali	Kusu, Kachu, Kuchu	West Bengal
Oriya	Saru, Kachu	Orissa
Punjabi	Kachalu	Punjab, Delhi
Assamese	Kachu, Kuchu	Assam

Table 3. Names of varieties of C. esculenta and other species of Colocasia in various languages

C. esculenta* var. *illustris		
Language	Names	Country
1	2	3
English	Black caladium, Green veined black leaved elephants ear, Imperial taro	
C. affinis		
Chinese	Zi ye yu	China
English	Purple leaved taro, Black leaved taro, Black caladium	
C. fallax		
English	Silver leaved taro	
C. esculenta* var. *illustris		
English	Silver leaved taro	
C. gigantea		
English	Giant taro	
Chinese	Yen de yu	Yunnan, China
Japanese	Hasu limo	Japan
Thai	Khun ok dip, Thun	Thailand

(Information collected by the author personally as well as available in literature (Mabberley, 1997; Wang Zongxun *et al.*, 1996; Weirsema & Leon, 1999; Eurodecautou Online tech. Dictionary, European Commission, USDA, ARS, 2002).

Table 4. Cultivars/ varieties of *Colocasia esculenta* in India

Variety/cultivars	Variety/cultivars	Variety/cultivars	Variety/cultivars
Desh banda	Lanka kachu	N.238	Panikorada
Banda	Pipli	N-125	C-149
Faizabad	Nagaland	Muktakeshi	Telia
Bansi	Ahina	Nagaland	Topi
Lathara	Kalasaru	Thamarakannan	Nagakachu
Gyano	Jankiri	Valiyachembu	Kuttichembu
Warm	Alg	Konokachu	Karuthakannan
S-3	Tripura local	Kashi bugga	Kochuchembu
S-11	Hangar local	Bohe	Kottachembu
BL-3	Barmandi	Lampang podhish	Munshikuttiakachu
Aiginia local	Manasaru	Mantri	Podichembu
CL-39	Adakkachembu	Purple	Panthalamchembu
Megh	Appopan chembu	Mumu	Velichembu
Hantia	Arattupuzhakannan	Big Lehna	Vayalchembu
SK-9	Bilathichembu	Api	Karikeshu
CL-6	Chuttichembu	Pikokea	BL-1
Panchmukhi	Cheruchembu	Bunlong	Muktapuri
2-266	Chuvannakannan	Manaopelu	Telibari
BL-2	Karuthachembu	Pipli	Kanthanchembu
C-137	Karichembu	CL-33	Kalichembu
White Gauria	Karinthal	Kattuchembu	Kannan
Malaraman	Mallikkadan	Nanachembu	Pani kachu
Lothi kachu	-	-	-

2. 10. Etymology

Etymology of any crop mostly lends support to crop origin, dispersal and antiquity by providing additional clues to its past history in relation to its ethnic relationships. In the case of taro, often the common vernacular names and local cultivar names add more to the existing confusion regarding the center of origin and center of diversity of the crop.

It is apparent that in almost all places where taro is cultivated, the crop has two distinct types except in the interior areas away from tropical wet areas with lesser amount of rainfall. In India, 'Arvi' with small to medium sized globose corm and oblong round more number of cormels is considered as *Colocasia esculenta* var. *antiquorum* and 'katchalu' or 'Suikachu' with large, oblong and spindle shaped corms and few similar looking cormels as var. *esculenta*. 'Katchalu' types occur everywhere but more in the Northeast and East followed by South. 'Arvi' has maximum variability both in North East and South West as compared to that in East, North West and South. Tuber bearing forms called 'Arvi' in India are mainly used as a vegetable. In Northeastern and Eastern region of the country it is generally known as 'Kachu'. Purseglove (1975) stated that many common names for *Colocasia* esculenta create confusion and if the name 'Dasheen' were confined to var *esculenta* and 'Eddoe' to var. *antiquorum* confusion would cease. It seems that the world-wide confusion with respect to the above mentioned varieties may not be that simple to solve unless we could morphologically differentiate these two both under cultivation and under the wild situations not only with the aid of certain conventional inflorescence and floral parameters but also with certain dependable vegetative characters in the light of various reports as being followed in the present study.

Porteres (1960) considered that the Greek name *Colocasia* was probably derived from Arabic word ‘quolquas’ and that in turn from the Malay name ‘Tallas’ which gave rise to the Polynesian name ‘Taro’. This assumption is based on the belief that the Polynesians took taro from the Malaysian region. Surprisingly, the Oriya name ‘Saru’ in Orissa and the Malayalam name ‘Talu’ in Kerala in the Southwestern corner of India are all related linguistically. Their mother rhizome or the main corm of the taro plant in Malayalam is also known as ‘thalla’, which means mother rhizome. In India, maximum taro cultivars are noticed in the Northeast, East and the South-Western region along with the concentration of several wild types. The Arabians had commercial contacts with the Kerala coast from the time immemorial. Polynesians were great voyagers and were believed to have had contacts with coastal areas of India in the prehistoric times. In the South-East Asia, three major human races are the Mongoloids, the Melanesians and the Polynesians who probably were mainly responsible for spreading the cultivation of taro from India to Malaysia, Indonesia, Indo-

China, Micronesia and Polynesia. The historical evidences are of course speculations and no direct clues regarding these are traceable till now. However, the above account throws some speculative evidences to the origin, spread and cultivation of taro in Asia and other places.

2. 11. Cytogenetics and Breeding

Cytology of taro, *Colocasia esculenta* (L.) Schott has been studied by several workers right from 19312 (Asana & Sudaria, 1931., Maeda, 1932; Banerji, 1934,1937; Nakajima, 1934; Kurakubo, 1940; Ito, 1942; Rao, 1947; Delay, 1951; Rattenbyrry, 1956, 1957; Sharma & Das, 1954; Mookerjea, 1955; Fukushima *et al.*, 1962; Sharma & Sarkar, 1963; Yen & Wheeler, 1968; Vijaya Bai *et al.*, 1971; Kawahara, 1978; Subramanyan, 1979; Kuruvilla & Singh, 1981; Coates *et. al.*, 1988; Sreekumari, 1992; Sreekumari & Mathew, 1989; 1991a, 1991b, 1991c, 1992). Studies in taro by Maeda (1932), Banerji (1934, 1937) and Nakajima (1934) indicated the existence of two major cytotypes with 2n=28 and 42 chromosomes. The two recognized taxonomic varieties of taro, viz. *Colocasia esculenta* var. *esculenta* and var. *antiquorum* have two ploidy levels of 2n=2x=28 and 2n=3x=42 respectively. Darlington and Wylie (1955), Federov (1969) and Mookerjea (1955) have suggested 7 as primary basic number of the family, and numbers higher than 10 were presumed to be of polyploid origin. These diploid and triploid forms occur in both varieties (Yen & Wheeler, 1968; Plucknett *et al.*, 1970; Marchant, 1971; Barrow, 1957; Ramachandran, 1978). Zhang and Zhang (1984) reported that 30 out of 90 cultivars were diploids. Sharma and Sarkar (1963) reported chromosome numbers of 2n = 2x = 22, 26, 28, 38 and 42. Of 199 taro varieties examined in Pacific region, 137 had 2n = 28 and 62 had 2n = 42. Vijaya Bai (1982) reported 2n=42 in collections from Nigeria. Other chromosome counts such as 2n=12, 36 and 42 were by Choudhury and Sharma (1979), Rao (1947) and Delay (1951). Pillai (1972) reported that *C. esculenta* var. *esculenta* and var. *antiquorum* appeared to be two distinct species on the basis of cytological evidences. He contended that the cultivated species has evolved by involving two complex polyploid types during the course of cultivation. Examination of the root tip cells of the non-edible wild types of *C. antiquorum* showed 2n = 22 (Pillai, 1969). The Karyotype was asymmetrical and only V shaped and J shaped chromosomes were present. According to him *C. antiquorum* is the most primitive of the genus as it has an asymmetrical karyotype. In diploids meiosis was almost normal and in triploids many abnormalities were observed resulting in pollen infertility. Krishnan *et al.* (1970) reported desynapsis in the species and Jose and Vijaya Bai (1976) formation of multiple sporocytes in taro. Karyomorphological studies by Sharma and Sarkar (1963), Kuruvilla and Singh (1981), Coates *et al*. (1988) have given clues to minor differences in chromosome morphology. However, Coates *et al.* (1988) reported few cytotypes with diploid and triploid taro collections from a wider geographical region. Similar studies in a large number of representative collections from different agro-ecological situations of India by Sreekumari (1992) gave a detailed information and contented that notable degree of chromosomal structural changes have operated during the course of evolution of this complex species. They also distinguished few karyotypically distinguishable cytotypes. Sreekumari and Mathew (1995) also postulated on the North Eastern origin of taro. Enough meiotic abnormalities in taro have also been reported by Vijaya Bai *et al.* (1971). Ramachandran (1978) reported regular synaptic pairing with normal anaphase in diploids, and abnormal pairing and aberrations in triploids leading to sterility in pollens. Krishnan *et al*. (1970) also reported desynapsis in a cultivar of taro. In a review on the cytogenetics of taro, Sreekumari (1997) pointed out that that variation in somatic chromosome number is characteristic of taro and 2n=28 as the secondary basic number was derived from the possible ancestral somatic number of 2n=14. Thus the possible primary basic number being n = 7, a basic set in the species from which both aneuploid and polyploid variations occurred thus, x = 14. Thus he basic number of being x = 7, a basic set in the species from which both aneuploid and polyploid variations occurred resulting in x = 14 as the basic number of the species and alloploid origin of the species. Allopolyploid origin of triploid ones has been suggested in the species by fertilization of unreduced gametes. Recent studies on karyomorphology in various morphotypes of taro from India by Sreekumari and Mathew (1989, 1991a, b, 1995) revealed occurrence of different cytotypes in them. Their studies also confirmed the findings of Plucknett (1976) that the triploids were mostly ‘*antiquorum*’ types with longer sterile spadix-appendix and the diploid '*esculenta*' types with shorter spadix-appendix. Coates *et al.* (1988) studied chromosomal variations in wild and cultivated taro of the Pacific region and Oceania and postulated two lineages of triploid taro from two distinct diploid forms, which appeared to be very legitimate. The two common forms of taro with diploid and triploid chromosome numbers were differentiated on the basis of morphological features and electrophoretic patterns of corm storage-proteins by Hirai *et al.* (1989), and by the study of ribosomal or mitochondrial DNA variation by Matthews *et al.* (1992). Both ploidy forms are found in Asia, and only diploid forms in Pacific region. Karyo-type studies in other families of plants by Arano (1956, 1957, 1963, 1965) have been found to be useful in taxonomic assessments. Sreekumari and Mathew (1989) in their studies on 6 diploid cultivars of taro noticed intra-chromosomal variation patterns, which are reflected in the morphology. Thus the symmetrical chromosomes probably denoted the more primitive types and the asymmetrical chromosome types indicated the advanced types. The detailed chromosomal studies however has not given any concrete evidence in solving the confusion of origin and evolution of taro at least that in India, probably being a region of its origin and diversification. Carpological data on 107 clonal varieties from the Pacific, India, Sri Lanka, Thailand and Nepal indicated 2 separate lineages within the *C. esculenta* populations thus upholding the putative Indian-South East Asian origin of one form of the species and also a parallel domestication process of another form in the

Western Pacific region (Coates *et al.*, 1988). The available information on the cytology and other related morphological aspects on the species very well reveals that there are basically two distinct major types in both cultivated and wild taro which can be *C. esculenta* var. *esculenta* and var. *antiquorum*.

2. 12. Flowering, fruiting and seed setting in taro

Phenological studies in aroids especially in taro are scarce. Flowering in taro as induced by Colchicine revealed that the difference in flowering phase, pollen grain size etc. varied in 2-3% clones including a tetraploid. *Colocasia* is originally reported as a protogynous and allogamous genus (Miyazaki *et al*., 1987). Flowering is normally initiated during the main growing season. In the wild taro, flowering phase extends for a long period depending on the availability of moisture. Thus flowering in marshy taro can be noticed in all the seasons whenever the suckers mature.

Scattered reports are available regarding seeds and seedlings (Kikuta *et al*., 1937, 1938; Abraham and Ramachandran, 1960; Yen and Wheeler, 1968; Plucknet *et al*., 1970; Shaw, 1975; but the descriptions are general and scanty. However more detailed accounts were provided by Jackson *et al.* (1977), Strauss and Arditti (1979), Strauss *et al.* (1979) Jackson and Pelomo (1979), Wilson (1981), Wilson and Cable (1984), Melin (1981), and Sunell and Arditti (1983). Usually fruit and seed-set are absent in triploid clones having 2n = 42, but occur in cultivated or wild colnes having a diploid number of 2n=28. Sterility in taro has been studied by Maeda (1932) and Banerji (1934, 1937) and had attributed its reasons to meiotic irregularities. Ramachandran, 1969 reported fruit and seed setting in diploid types and expressed his optimism in future use of hybridization in crop improvement. In his later work (Ramachandran, 1978) reported the difficulty in seed-set and germination. Barrau (1959) and Velayudhan *et al*. (1993) reported the flowering and seed setting in few collections of taro. Though seeds germinate very well, damping off and fungal infections are common in taro seedlings (Shaw, 1975). Nyman and Adritti (1985) had succeeded in getting good germination under artificial conditions of taro mature seeds collected from ripened fruits.

The pistillate portion of the inflorescence softens when the seeds ripen (Melin, 1981). Ripe fruits are yellow and have a fruity smell (Strauss *et al*., 1979). Seeds are very small, striated and often loses viability very quickly and are taken out from the fruits by pressing the fruits in water to make a homogenate and strained through a sieve. Though taro is a shy seed-setter, seeds can be produced by hand pollination (Melin, 1981). Miyazaki *et al.* (1986) reported the favorable effect of gibberillic acid on flowering and seed setting in taro. David Gory (1983) dealt post pollination and adaptive changes in plants. The non-induced changes are reported to correspond temporally with cessation of stigma receptivity and pollen viability in plants (Sachaal & Leverich, 1980).

2. 13. Taro cultivation and production

Taro requires a warm humid climate, and for rainfed cultivation it requires a fairly distributed rainfall of about 1200 to 1500 mm. It can be grown from sea level to an altitude of 2000 m. It is cultivated in a variety of agro-ecological situations from swamps to uplands under rainfed and irrigated conditions. Onwueme (1999) had detailed taro cultivation in Asia and pacific. O' Hair and Asokan (1986) stated that most cultural practices for edible aroids are from empirical knowledge accumulated by untold generations of farmers. In India, it is commercially cultivated mainly in uplands away from the high rainfall areas (Bailey, 1925). Survey and collection of taro in the past showed such situations in central India and Tamilnadu (Velayudhan *et al*., 1993). Under subsistence farming it is noticed in swamps, uplands, paddy fields, in terraces on Himalayan Hill slopes at lower elevation, and among tree crops as in Kerala coasts and midlands. There is a tendency to cultivate the crop usually as a subsistence one under high rain fall in Southern, Eastern and in Northeastern situations. Swamp cultivation is very common in Gangetic plains of West Bengal and in Assam (Sethuram *et al*., 2005). It is grown fully under swampy situations in Philippines (Pardales and Villanuea, 1984), in Southern China (Matthews, 2000; Yongping *et al*., 2003), in Bangladesh (Rana & Adhikary, 2005) and in India (Sen *et al*., 1998; Saud & Barua, 2000). In Hawaii and Vietnam, swamp taro is very common. Under upland situations it is cultivated as a rainfed or irrigated crop. Occasionally '*esculenta*' type taro is found to be cultivated as perennial clumps in paddy fields in Karnataka and Konkan region. Taro has been observed to have a production potential of 30-50 tons/ha.

In India, taro is commonly grown in upland under irrigated or rained conditions and also in lowland paddy fallows, and very rarely under puddle conditions on terraced hill slopes in Uttaranchal (Joseph, 2006). Soil pH of 5 - 7.8 is ideal for good crop growth. Yield is reduced at pH 4.2 with aluminum saturations (Vicente - Chandler *et al*., 1983). Abruna Rodriguez *et al.* (1982) were of the opinion that aluminum concentration is more detrimental than soil pH value. Different types of soil like sandy loam, laterite, and alluvial soils are ideal for the crop. Upland planting is done on ridges, mounts or flat on ground. In upland irrigated conditions it is planted flat, and under high rainfall situations it is planted on mounts or ridges.

Cormels weighing 15-20 g or 'hulis' which consists of the upper 1 cm section of the corm or cormel and first 20 to 25 cm of the petiole (Ravindran, 1985) are used as planting material. Often larger propagules give higher yields (Lee *et al*., 1979). Mathur *et al.* (1966) as quoted by Shanmugavelu (1989) reported that 56 g 'seed' size gave the highest yield while 28 g 'seed' size was found to be the most economical. Under flooded culture of taro, planting is done in 2.5 cm of standing water at a depth of 15-

25 cm. Usually a spacing of 60 x 45 cm and a depth of 2.5 to 7.5 cm is given in uplands. It was to provide 30 x 30 cm spacing between plants, and water irrigation facility was considered as a determining factor that decided the optimum spacing in taro. Thus planting density in taro varied considerably from place to place, and situations to situations. Density varied from 26, 900 plats to 100, 000 plants per ha (Plucknett & de la Pena, 1971). Spacing varied from 30 x 60 cm to 30 x 90 cm and 60 x 54 as reported by Mohankumar *et al*. (1974) as quoted by Shanmugavelu (1989). Sethumadhavan (1980) as quoted by Shanmugavelu (1989) recommended 60 x 45 cm as ideal for Kerala. Kurihara (1979), and Joseph and Kunju (1981) have recommended Mulching.

Taro is intercropped with various other crops such as coconut, grain amaranth, elephant-foot yam, turmeric, chillies, ginger, maize, yam, okra, cassava, new coccoyam and rubber *(Velayudhan et al., 1993)*. Taro is a shade tolerant crop (Asokan *et al.* 1987). In subsistence and conventional cropping systems chemical fertilizers are not used (Velayudhan *et al*., 1993). However, reports are available on the use of 560 kg of nitrogen, phosphorus and potassium (NPK) as beneficial to the crop (Plucknett & de la Pena, 1971). Dozes as high as 560 kg of N, phosphorus and Potassium are beneficial to the crop (Plucknett & de la Pena, 1971). Mandal (1971) reported significant yield increase by the application of 120 kg of N and K per ha.

2.14. Pests and diseases

Being a subsistence crop comparatively less attention has been paid by researchers to the pest and disease problem in aroids especially in taro (Velayudhan *et al*., 1993). However, recently the situation has changed. Earlier, the notion was that edible aroids had few pest and disease problems (O' hair & Asokan (1986). Taro is less resistant to pests and diseases than *Cyrptosperma,* another cultivated aroid for food (Mahony, 1960). Jackson (1980) and Shaw *et al.* (1979) have reported various pests such as Aphids (*Aphis gossyppii*), Japanese rose beetle (*Popillia japonica* Newman), mealy bug ((*Dysmococcus brevipes* Cookrel), Taro plant hopper (*Tarophagus proserpina* Kirk ssp. *proserpina*), white fly (*Bemisia tabaci* Genn.), taro beetle (*Papuana* sp.), taro born worm or hark moth (*Miportion celerio* L.), army worm or cluster caterpillar (*Spodoptera litura* Fabricius), and spidermites. Shanmugavelu (1989) has given a detailed account of various pests and diseases of taro. Apart from the leaf eaters (*Monolepta signata*), white-spotted flee, beetle and tobacco caterpillar are important pests in new cocoyam. It is estimated that field loss of crop due to various pests ranges from 14 to 28%. According to the review 25 pests are found to be attacking taro.

Among the pests that attack the edible aroids, Aphids (*Aphis gossypii* G.) belonging to Aphidae: Homoptera, (Anononymous, 1978) are very important and they cause destruction of the crop under more conducive conditions of intermittent rains and sunshine. Detailed study on aphid infection on taro has been conducted by Palaniswami and Pillai (1980). Survey on the occurrence of aphids and spidermites and their predators in important aroid growing areas in South India have been made by Palaniswami and Pillai (1981).

Root-knot nematode (*Melidogyne incognita* Kofoid and White Chit wood can be a problem in taro (Mc Sorley *et al*., 1983). Damage from other nematodes is reported to be of minor significance.

Among fungal and bacterial pathogens, taro leaf blight caused by *Phytopthora colocasiae* Raciborski is the most serious. Among others, *Cladosporium colocasiae* Sawada, *Phyllosticta colocasiophylla* Weedom and *Sclerotium rolfsii* Sacc. (Parris, 1941) are of minor importance. Root, corm and petiole rot of taro in Puerto Rico and Hawaii have been attributed to *Pythium ultimatum* Throw (Alwarez-Garcia & Cortes Monllor, 1971; Plucknett & de la Pena, 1971; Parris, 1941). Several *Pythium* spp. are associated with taro root and corm diseases in Pacific region (Jackson, 1980). *Fusarium solani* (Mart.) Sacc. has been reported from Egypt (Michael and Salem, 1981). Leaf rot caused by *Rhizoctonia bataticola* is also a serious disease. Sanitation and use of Copper fungicides are effective control measures for fungal diseases of *Colocasia* (Jackson, 1980).

Taro leaf blight caused by *Phytopthora colocasiae* Racib. Is the major cosmopolitan disease of taro in most of the South East Asian countries extending to other taro producing areas in Asia, Africa and Americas (Trujillo & Aragaki, 1964; Trujillo, 1967 & 1971; Jackson & Fireman, 1984; Misra, 1991). A review on this aspect in India was made by Thankappan (1985). Misra and Chowdhury (1997) gave brief account of the disease. Vasquez (1990) reported 24 to 36% yield reduction in moderately resistant and susceptible varieties of the crop at two to four months after planting. Bergquist (1974) studied control of taro leaf blight by fungicide application and other related aspects of management. Reports by Packard (1975), Gollifer and Brown (1974), Jackson *et al.* (1980), Trujillo and Aragaki (1964), Berquist (1974) and Misra (1993) indicated that the disease adversely affects the crop yield in all taro-growing areas of South East Asia and Pacific islands. Trujillo and Menezes (1995) reported the resistance of Micronesian taros to *Phytopthora* leaf-blight. Patel *et al.* (1984) reported the breeding strategies for controlling diseases in taro in Solomon Islands. Misra and Chowdhury (1997) have conducted detailed investigation on this aspect in India and have prepared a very useful report in which they have listed the countries where blight is a very serious problem. In India, the leaf-blight disease is very serious in Southern, North Eastern and Eastern regions enjoying a higher annual rainfall and humid weather. However, the geographic distribution of the disease is reported to be restricted to South

East Asia and Pacific areas (Holliday, 1980). The past assessment of crop production in the country based on the field experiments indicated about 39-50% crop loss in the case of susceptible varieties and 26.6% in tolerant varieties (Misra & Chowdhury, 1997). Leaf-blight is thus, undoubtedly, the most dreaded disease in taro and in view of its strategic importance as a subsistence crop having its origin, early domestication, spread and diversification in Indo-Malayan region with a maximum diversity in both cultivated and wild varieties and the severe incidence of the taro-blight disease in these parts, a preliminary observation on the incidence of the disease on a large number of Indian collections is indeed very desirable for further advanced screening of symptomless collections. No preliminary screening of taro collections representing a wide variability and encompassing both wild and cultivated taro has ever been carried out earlier except that by Velayudhan *et al.* (1993) in a similar study on 54 morphotypes of taro. Kumar and Dubey (1996) reported screening of *Colocasia* genotypes for the disease. Several varieties of taro such as 'Ahina Poonam Pat', 'Salem V', 'Bhadia Kachu', 'Naga Kachu', 'Pusa Sakin II' and 'Simla' are stated to be resistant to blight. Screening of large number of collections containing distinct genotypes of India has not been reported and an attempt in the present studies has been made to observe the collections for their tolerance to the disease under field epiphytotic conditions.

Among viral diseases, Dasheen Mosaic Virus (DMV) (Zettler *et al.*, 1970), Taro Large Bacilliform Virus (TLBV) and Taro Small Bacilliform Virus (TSBV), have been identified in Papua New Guinea and South Pacific islands (Shaw *et al.* 1979) and resistance has been identified (Patel *et al.*, 1984) and is difficult to add resistance to the high yielding types. DMV was first reported from Florida, USA. In India, DMV was first reported by Malathi and Shantha (1981). The disease is transmittable to taro and other aroid crops.

2.15. Chemistry and Nutritive value of Taro

All parts of the plants are edible. Stalks contain 93.4% water, 3% protein, 0.3% fat, 1-2% minerals, 4.1% carbohydrate, 0.06% calcium, 0.02% phosphorus and 0.5 mg iron per 100 g. The leaves and petioles are stated to be good sources of vitamin A and C. Sarnaik and Peter (1976) reported that corms contain small starch granules and contain 21.1% carbohydrates, 3.0% protein, 1.7% minerals and appreciable quantities of calcium, phosphorus, potassium and vitamins like A and B. The tuber has 3-4% protein and is rich in phosphorus, iron, calcium and 100 g of fresh tubers provides 97K calories of energy. The tubers contain mucilage, which yields on hydrolysis δ – galactose and L-arabinose. Detailed biochemical composition as given by Shanmughavelu (1989) is furnished in table 5. Starch in taro is the smallest in food plants and is easily digestible as compared to that of other tubers. Composition of taro tubers has been reported by Shanmughavelu (1989). Further, Lila Jacob (1985) in an attempt to review chemistry of taro has given a detailed account of its chemical compounds by quoting from various reports. The proximal composition of moisture, energy and nutrients contained in tubers and two different kinds of leaves in taro on the basis of average values available in literature and furnished by Lila Jacob (1985) is given in table 6. Saha and Hussain, 1983 studied the irritating principles in aroids.

Table 5. Composition of taro tubers (Shanmughavelu, 1989)

Water	**Protein**	**Fat**	**Minerals**	**Carbohydrates**
1	**2**	**3**	**4**	**5**
73.1%	3.0%	0.1%	1.7%	22.1%
Calcium	Phosphorus	Iron	Vitamin B	Vitamin C
0.04%	0.14%	2.1 mg./100 g	80IU/1100 g	trace

Table 6. Proximal composition of moisture, energy and nutrients in taro tubers and leaves

Plant parts	**Moisture (g)**	**Energy (K Cal)**	**Carbohydrates (g)**	**Proteins (g)**
1	**2**	**3**	**4**	**5**
Tubers	73.1	97	25	3.0
Leaves green	82.7	56	6.8	3.9
Leaves purple	78.8	77	8.1	6.8

Plant parts	Fat (g)	Minerals (g)	Fibre (g)	Calcium (mg)
1	**6**	**7**	**8**	**9**
Tubers	0.2	1.7	1.0	50.0
Leaves green	1.5	2.2	2.9	227.0
Leaves purple	2.0	2.5	1.8	460.0

Plant parts	Phosphorus (mg)	Iron (mg)	Carotene (mg)	Thiamine (mg)
1	**10**	**11**	**12**	**13**
Tubers	34	0.6	260	0.06
Leaves green	82	10.0	10278	0.22
Leaves purple	125	38.7	12000	0.06

Plant parts	Riboflavin (mg)	Niacin (mg)	Vitamin C (mg)
1	**14**	**15**	**16**
Tubers	0.07	0.7	-
Leaves green	0.26	1.1	12.0
Leaves purple	0.45	1.9	63.0

Variation in acridity has been noticed all aroids (O' Hair & Asokan, 1986) with low acridity in cultivars. It is believed that irritation is caused by the mechanical action of the crystals on tongue. This factor limits the consumption of taro as a food. Acridity in different plant parts varies considerably. Boiling the tubers, frying, drying and adding ingredients like certain condiments in India remove acridity. Naturally several cultivars are devoid of itchiness. Several scientists have studied the source of itchiness in aroid plants. The common belief that the raphides and calcium oxalate crystals occurring in plant parts are responsible for acridity is not fully true. Tang and Sakai (1983) were of the opinion that several other agents are associated with this. Conflicting evidences on this aspect however lead to conclusion that general sources of irritation were 1) Physical irritation and 2 chemical irritation of slower and widespread nature. Several proteins and glucosides have been suggested as the reason for irritation. Saha and Hussain (1983) suggested that acrid factor in taro and *Alocasia* was not mainly due to calcium oxalate crystals, as cooking reduced the itching without substantially changing the structure of raphides. *Colocasia* and *Alocasia* flesh washed in alcohol removed acridity but the alcohol extract caused irritation. Subsequently chromatographic separation and analysis they attributed the cause to a glycoside, 3, 4-diglucosilicbenzaldehide. The exact chemistry of acridity in taro and other Araceae plants is still very confusing as there are conflicting reports on the agents causing such irritation. Suzuki *et al.* (1975) attributed the reason for glucosides and its aglycones.

3. MATERIALS AND METHODS

3.1. Exploration and collection

Exploration and collection of both cultivated and wild taro from different agro-climatic regions of India was carried out by visiting and surveying important centers of cultivation of the crop and also wild and disturbed habitats. In the initial stages random sampling of distinct types of taro at 5 to 10 km distance in South-Western coastal region, North-Eastern region, Eastern region and North-Western region was done. Farmers' fields, backyards, market places and farm stores were covered for cultivars of taro in these regions. Later on, wild types were also collected especially from all the above regions. Since taro is a vegetatively propagated crop the morphotype sampling as suggested by Hawkes (1975) was practiced and one to two healthy corms or cormels per each selected sample was made. The materials collected from the disease-free clones were cleaned well before packing them in aerated muslin cloth bags for transportation to the site of *ex situ* conservation and characterization. Minimum passport-information was also collected giving a collector's number. Later on Indigenous collection numbers (IC Nos.) were assigned at NBPGR, New Delhi. Apart from the above, materials collected by others in the past and deposited with NBPGR regional station at Vellanikkara, Thrissur were also included in the study. The morphotype sampling method of vegetatively propagated crops is practiced in order to avoid collecting bulk quantities impinging problems in transportation of samples and difficulty in conservation in the field gene bank. In some of the past collections source-data were missing. The exploration trips were either crop specific, crop group specific or multicrop. Map of explored areas in India and areas from where samples of germplasm have been collected are presented in fig. 2. The collections from coastal districts and hilly areas in Andhra Pradesh were obtained after the major part of the study and hence these could not be included in the study. The samples were transferred to the Vellanikkara farm of NBPGR Regional station and planted in pots filled with garden soil for initial regeneration. The regenerated plants were harvested at maturity during November to December months and were added to the main collection. As the accessions collected from Andhra Pradesh were obtained after the conduct of major part of the present study, those could not be included. However, when dealing with the general discussion on the crop distribution and cultivation some points were added.

3.2. Maintenance of collections

The collections were transferred to the maintenance plots in the ensuing season. Usually three plants were planted per collection on 1 meter wide raised beds with 30 x 30 cm distance from plant to plant and 1 m between line to line enclosed by a border line on all sides of the long running beds maintained under rain-fed condition in lateritic soil. The plants received about 250 g of dried farm yard-manure placed along with the seed tubers in shallow pits followed by covering the seed tubers/cormels with a thin layer of soil and green or dry-leaf mulch to protect them from the scorching heat and to provide sufficient moisture required for proper regeneration of tubers. One duplicate set of these collections were maintained in poly-bags filled with pot mixture having soil, cowdung and sand at a ratio of 1:1:1 under 25% shade. The balance materials were kept in cloth bags were kept in the chiller cabinet run at 13° C and at 72% RH.

Collections were always maintained under low input condition. However the crop received at least two weedings followed by application of NPK 16:16:16 at the rate of 100 g per three plants in two split dozes followed by earthing up during July and August months. Planting was done during the last week of May every year with the commencement of pre-monsoon showers.

3.3. Materials for study

Materials collected and used for the present study with available passport information are furnished in table 7.

Table 7. Showing materials used for the study

Sl. No.	Collection No.	IC No.	Local name	District	State/region
1	**2**	**3**	**4**	**5**	**6**
1	273-B	86837		Solan	Himachal Pradesh
2	Kerang Along	86838			North-East
3	226 Chatharpur	86864			Madhya Pradesh
4	274-A	86839		Solan	Himachal Pradesh
5	NL-26	86866			North-West
6	Lanachetta	86920		Solan	Himachal Pradesh
7	NL-1	86865			North-West
8	NL-120	86867			North-West
9	221Mouranipur	86840	Arvi	Jhansi	Madhya Pradesh
10	Kaling Pong	86868			North-East
11	Karakkal	86841			Pondichery
12	Solan Market	86842		Solan	Himachal Pradesh
13	Taragaon	86843			North-East
14	NL-56	86869			North-East
15	Sarsona	86844		Samasthipur	Bihar
16	78/155-A	86889			Kerala
17	S-910	86896			Maharashtra
18	Chowrar mohra	86846		Solan	Himachal Pradesh
19	273	86922			Himachal Pradesh
20	78/130-A	86848			Kerala
1	**2**	**3**	**4**	**5**	**6**

21	S 62/1125	86891			Maharashtra
22	286-A Delhi	86850			Delhi
23	229	86851			Uttar Pradesh
24	218/81-28	86976			Kerala
25	253 Solan	86853		Solan	Himachal Pradesh
26	263-B	86923			Himachal Pradesh
27	278 Rahan	86921		Solan	Himachal Pradesh
28	203 Debra	86863		Gwalior	Madhya Pradesh
29	219/81-7	86870			Tamil Nadu
30	290 New Delhi	86855			Delhi
31	260 Simla	86858			Himachal Pradesh
32	S 59/1029	86874			Maharashtra
33	P-381	86895			Maharashtra
34	S 81/1289	86871			Maharashtra
35	S 39/896	86873			Maharashtra
36	S 84/1307	86875			Maharashtra
37	P-392	86876			Maharashtra
38	P-31	86877			Maharashtra
39	P-284	86893			Maharashtra
40	P-814	86878			Maharashtra
41	P-441	86927			Maharashtra
42	P-237	86928			Maharashtra
43	NL	86929			Maharashtra
44	Burdwan	86930			Himachal Pradesh
1	**2**	**3**	**4**	**5**	**6**

45	P-341	86931			Maharashtra
46	212 Alwar	86856			Rajasthan
47	230Baruasagar	86857			Uttar Pradesh
48	91/81-4	86880		Pathanamthitta	Kerala
49	P-187	86881			Maharashtra
50	248 Dharampur	86859			Himachal Pradesh
51	220	86860			Rajasthan
52	294-New Delhi	86861			Delhi
53	S-8/734	86898			Maharashtra
54	S 29/795	86899			Maharashtra
55	S 60/1046	86882			Maharashtra
56	S 50/970	86883			Maharashtra
57	269 shimla	86932			Himachal Pradesh
58	153/81/6	86884		Trivandrum	Kerala
59	204/81-13	86885			Tamil Nadu
60	262	86862			Himachal Pradesh
61	Sarsona	86933			Bihar
62	119/81-25	86934		Kanyakumari	Tamil Nadu
63	31-1	86966		Kollam	Kerala
64	88/81-27	86967	Kannan	Thrissur	Kerala
65	15-2	86951	Cheruchembu	Ernakulam	Kerala
66	80/121	86983		Thrissur	Kerala
67	78-130	86985			Kerala
68	NL-3	87001			Kerala
69	53/81-4	86949	Kannan	Idukki	Kerala
70	Thrissur local	86986	Thamarakkannnan	Thrissur	Kerala
1	**2**	**3**	**4**	**5**	**6**

71	20/81-6	86918		Ernakulam	Kerala
72	95/81-13	136689		Pathanamthitta	Kerala
73	26-3	86942	Cheruchembu	Kollam	Kerala
74	S 735	87006			Maharashtra
75	S 10/736	87002			Maharashtra
76	P 326	87003			Maharashtra
77	P 107	86998			Maharashtra
78	P 364	87005			Maharashtra
79	S 72/1209	86999			Maharashtra
80	S 12/739	87000			Maharashtra
81	54/81-2	86941	Kannan	Idukki	Kerala
82	P 8-42	86978		Thrissur	Kerala
83	99/81-6	136690	Kannan	Kollam	Kerala
84	35/81-11	86936	Kudachembu	Idukki	Kerala
85	54/81-17	86944	Kuzhinirayan	Idukki	Kerala
86	108/81-12	86975		Kottayam	Kerala
87	96/81-5	86935			Kerala
88	67/81-5	86973	Cheruchembu	Alappuzha	Kerala
89	NL 5	86968			Kerala
90	76/81-4	86919		Alappuzha	Kerala
91	73/81-6	86954	Cheruchembu	Pathanamthitta	Kerala
92	81/81-4	86906	Kannan	Pathanamthitta	Kerala
93	112/81-4	86955	Choriyan chembu	Kollam	Kerala
94	83/81-16	86947	Kannan	Pathanamthitta	Kerala
95	73/81-20	86948	Cheruchembu	Idukki	Kerala
96	31/81-5	86979		Idukki	Kerala
97	32/81-17	87024			Karnataka
98	33-5B	87025		Trivandrum	Kerala
99	Gabil	87034			Meghalaya
1	**2**	**3**	**4**	**5**	**6**

100	Gobhallapur	87023			Bihar
101	33-3	87028	Valiyachembu	Trivandrum	Kerala
102	34/81-6	87029		Idukki	Kerala
103	29/81-1	87030		Ernakulam	Kerala
104	34-7	87031	Thamarakannan	Trivandrum	Kerala
105	Hashim	87032		Kamrup	Assam
106	32/81-3	50968		Idukki	Kerala
107	53/81-2	86892		Idukki	Kerala
108	78-156	87049			Kerala
109	78-135	87050			Kerala
110	33-3	136691	Valiyachembu	Trivandrum	Kerala
111	177/81-8	46091A			Tamil Nadu
112	53/81-06	87051		Idukki	Kerala
113	214/81-1	46095			Kerala
114	74/81-4	87052	Cheruchembu	Pathanamthitta	Kerala
115	38/81-4	87053		D.Kannada	Karnataka
116	53/81-6	87055		Idukki	Kerala

117	248/81-6	46099		Trichy	Tamil Nadu
118	53/81-11	87069		Idukki	Kerala
119	NL	406435			Kerala
120	NL-3	87076	Karutha chembu		Kerala
121	78-131	87071	Karutha chembu		Kerala
122	254	86852			Himachal Pradesh
123	53/81-17	87070	Karutha chembu	Idukki	Kerala
124	161/81-8	87105	Thamarakannan	Kanyakumari	Tamil Nadu
125	61/81-9	87107	Thamarakannan		Kerala
126	121/81-4	86957		Kanyakumari	Tamil Nadu
127	33/81-4	136692			Kerala
1	**2**	**3**	**4**	**5**	**6**
128	NL	406434			Kerala
129	128/81-12	136693			Kerala
130	1/82-5	87056		Kasaragod	Kerala
131	4/82-2	70148		Kasaragod	Kerala
132	7/82-3	70155	Kattuchembu	Kasaragod	Kerala
133	12/82-14	70158	Karichembu	Kasaragod	Kerala

134	13/82-7	70160		Kasaragod	Kerala
135	14/82-9	70161		Kasaragod	Kerala
136	18/82-3	70163		Kasaragod	Kerala
137	22-82-3	70166		Kasaragod	Kerala
138	25/82-12	70171		Kasaragod	Kerala
139	27/82-5	70173		Kasaragod	Kerala
140	29/82-6	70175	Karutha chembu	Kasaragod	Kerala
141	36/82-15	70181		Kannur	Kerala
142	40/82-5	70182		Kannur	Kerala
143	41/82-8	70183		Kannur	Kerala
144	43/82-22	70186		Kannur	Kerala
145	43/82-24	70187		Kannur	Kerala
146	43/82-24 *	70188	Karuthakannan	Kannur	Kerala
147	43/82-5	70189	Chuvannakannan	Kannur	Kerala
148	48/82-4	70194		Kannur	Kerala
149	50/82-2	70195		Kannur	Kerala
150	50/82-6	70197	Adukkuchembu	Kannur	Kerala

151	57/82-1	87097	Adukkuchembu	Wayanad	Kerala
152	57/82-4	86958		Wayanad	Kerala
153	59/82-55	70204	Karutha chembu	Wayanad	Kerala
154	60/82-6	70206		Wayanad	Kerala
155	60/82-11	70209		Wayanad	Kerala
156	60/82-12 A	70210		Wayanad	Kerala
1	**2**	**3**	**4**	**5**	**6**
157	61/82-18	70211	Karichembu	Wayanad	Kerala
158	61/82-19	70212		Wayanad	Kerala
159	61/82-24	70213	Karutha chembu	Wayanad	Kerala
160	66/82-1	70218	Cheruchembu	Wayanad	Kerala
161	66/82-4	70219	Cheruchembu	Wayanad	Kerala
162	67/82-28	70221		Wayanad	Kerala
163	68/82-3	70222		Wayanad	Kerala
164	68/82-4	70223		Wayanad	Kerala
165	68/82-14	70227		Wayanad	Kerala
166	69/82-37	70228	Karichembu	Wayanad	Kerala
167	69/82-38 B	70229	Karutha chembu	Wayanad	Kerala

168	69/82-42	70230		Wayanad	Kerala
169	71/82-12	70232	Malaraman	Wayanad	Kerala
170	71/82-13	70233	Karichembu	Wayanad	Kerala
171	71/82-15	70234	Karutha chembu	Wayanad	Kerala
172	71/82-19	70235		Wayanad	Kerala
173	71/82-20	70236	Cheruchembu	Wayanad	Kerala
174	72/82-6	136694	Karichembu	Wayanad	Kerala
175	74/82-1	70241	Malaraman	Wayanad	Kerala
176	74/82-7	70242	Karichembu	Wayanad	Kerala
177	NL	406433			Kerala
178	78/82-24	70250	Cheruchembu	Kozhikkode	Kerala
179	79/82-9	70252		Kozhikkode	Kerala
180	84/82-24	70267		Kozhikkode	Kerala
181	85/82-15	70268		Kozhikkode	Kerala
182	86/82-13	70270		Kozhikkode	Kerala
183	86/82-26	70271		Kozhikkode	Kerala
184	87/82-18	70272		Malappuram	Kerala

185	87/82-19	70273		Malappuram	Kerala
1	**2**	**3**	**4**	**5**	**6**
186	88/82-2	70274	Cheruchembu	Malappuram	Kerala
187	88/82-6	70275		Malappuram	Kerala
188	88/82-8	70276		Malappuram	Kerala
189	92/82-22	136696		Malappuram	Kerala
190	92/82-25	70278	Karichembu	Malappuram	Kerala
191	96/82-31	70283		Malappuram	Kerala
192	100/82-20	70292		Malappuram	Kerala
193	103/82-57	70297	Karuthachembu	Thrissur	Kerala
194	109/82-39	70299	Cheruchembu	Palakkad	Kerala
195	127/82-24	70305	Cheruchembu	Palakkad	Kerala
196	128/82-26	70306	Cheruchembu	Malappuram	Kerala
197	128/82-31	70307	Cheruchembu	Malappuram	Kerala
198	128/82-33	70308	Cheruchembu	Malappuram	Kerala
199	129/82-33	136697	Cheruchembu	Malappuram	Kerala
200	129/82-44	70313	Cheruchembu	Malappuram	Kerala
201	132/82-17	70316	Karichembu	Palakkad	Kerala

202	7/83-46	86988	Cheruchembu	Ernakulam	Kerala
203	11/83-35	86959		Ernakulam	Kerala
204	11/83-39	87090	Karichembu	Ernakulam	Kerala
205	12/83-44	86990		Ernakulam	Kerala
206	22/83-2	87114		Ernakulam	Kerala
207	26/83-1	87058	Malaraman	Ernakulam	Kerala
208	32/83-4	87060	Nanachembu	Idukki	Kerala
209	38/83-12	86938	Arattupuzhakannan	Kottayam	Kerala
210	38/83-22	86939	Kannan	Kottayam	Kerala
211	39/83-20	86961	Cheruchembu	Kottayam	Kerala
212	41/83-18	86962	Appooppan chembu	Kottayam	Kerala
213	41/83-18-B	136698		Kottayam	Kerala
1	**2**	**3**	**4**	**5**	**6**
214	43/83-2	86940	Cheruchembu	Kottayam	Kerala
215	44/83-15	87033	Thamarakannan	Ernakulam	Kerala
216	46/83-31	86964	Veluthachembu	Ernakulam	Kerala
217	Kovvur	86900	Kovvwi	Trivandrum	Kerala
218	C 140	86888		Trivandrum	Kerala

219	C 149	86894		Trivandrum	Kerala
220	C 266	86890		Trivandrum	Kerala
221	35/81-11	87061	Kudachembu	Idukki	Kerala
222	43/82-30	87007		Idukki	Kerala
223	123/81-25	87115			Kerala
224	35/81-12	87062		Idukki	Kerala
225	T 66/83-14	86913	Siruchembu	N.Kattabomman	Tamil Nadu
226	T 82/83-12	86905		Madurai	Tamil Nadu
227	P6/84-4	86904		Palakkad	Kerala
228	P7/84-30	87075	Karichembu	Palakkad	Kerala
229	P 9/84-3	86903		Palakkad	Kerala
230	N 1/84-6	87118		Malappuram	Kerala
231	1/84-101	136699			Kerala
232	V 788	87065	Bilathichembu	Wayanad	Kerala
233	V 807	87101		Wayanad	Kerala
234	V 822	86972		Wayanad	Kerala
235	V 892	86956	Kuttichembu	Wayanad	Kerala

236	V 915	86909	Karinthal	Wayanad	Kerala
237	V 950	87012		Wayanad	Kerala
238	V 962	86995	Vayalchembu	Wayanad	Kerala
239	V 974	86912		N.Kattabomman	Tamil Nadu
240	V 1008	87124		N.Kattabomman	Tamil Nadu
241	V 1035	87123		N.Kattabomman	Tamil Nadu
242	V 1073	87066	Malariyanchembu	Kollam	Kerala
1	**2**	**3**	**4**	**5**	**6**
243	V 1074	86911	Cheruchembu	Kollam	Kerala
244	V 1086	87064	Malaraman	Trivandrum	Kerala
245	V 1096	87067	Kottachembu	Kollam	Kerala
246	V 1226	87120		S.Arcot	Tamil Nadu
247	V 2115	136702	Karichembu	Nilgiris	Tamil Nadu
248	V 2206	87077	Karichembu	Nilgiris	Tamil Nadu
249	V 2207	87125		Nilgiris	Tamil Nadu
250	M-34	87112	Kombillachembu	Palakkad	Kerala
251	M-156	86996		Kannur	Kerala
252	DKH-49	87127		Karbi	Assam

253	BD 7/114	87129		Hamren	Assam
254	DKH-40	87139		Karbi	Assam
255	NH 6/2	87037		Phek	Nagaland
256	NH 6/4	87141		Phek	Nagaland
257	BDJ 6/1	86950			Assam
258	DKH 48	87038			Assam
259	BD 85	87168			Meghalaya
260	NH 6/8	87131		Dimapur	Nagaland
261	BDS 82	87044			Meghalaya
262	MMH 6/2	87008			Maharashtra
263	BD 7/115	87161			Assam
264	NH 6/11	87167		Mokokchung	Nagaland
265	DKH 34	87150			Assam
266	DKH 44 A	87154		Karbi Anglung	Assam
267	NH 6/6	87135		Phek	Nagaland
268	BD 7/112	87151			Nagaland
269	DKH 51	87152		Karbi Anglung	Assam

270	BD 21	87153			Nagaland
271	BDJ 6/3	87146		Silo Sagar	Assam
1	**2**	**3**	**4**	**5**	**6**
272	BDJ 6/3	86914			Assam
273	DKH 56	87165			Northeast
274	DKH 56 A	87045			Northeast
275	BD 7/116	87157		Karbi Anglung	Assam
276	NH 6/16	87138		Lumhebota	Nagaland
277	V 2383	87172		Coorg	Karnataka
278	V2907	87173		Coorg	Karnataka
279	V 2378	87174		Coorg	Karnataka
280	V 2913	86916		Coorg	Karnataka
281	Karn.NL	87175		Coorg	Karnataka
282	V 3248	86997		D.Kannda	Karnataka
283	V 3297	86901		Kannur	Kerala
284	P2(V 3437)	87180		Coorg	Karnataka
285	P.28	87083	Karichembu	Palakkad	Kerala
286	BDJ-2060	87193		Dehra Dun	Uttar Pradesh

287	TCR No. 669	87195			Unknown
288	TCR No. 674				Unknown
289	BDJ 2306	136703		Sirmur	Himachal Pradesh
290	NAF/89/27	87200			Uttar Pradesh
291	NAF/89/29	87202			Uttar Pradesh
292	NAF/89/31	87204			Uttar Pradesh
293	NAF/89/33	87206			Uttar Pradesh
294	NAF/89/35	87208			Nagaland
295	NAF/89/39	87212			Nagaland
1	**2**	**3**	**4**	**5**	**6**
296	MR/29	87217			Arunachal Pradesh
297	MR/30	87218			Arunachal Pradesh
298	MR/31	87219			Arunachal Pradesh
299	MR/32	87220			Arunachal Pradesh
300	MR/33	87221			Arunachal Pradesh
301	MR/35	87223			Tripura
302	MR/37	87224			Tripura
303	MR/39	87225			Assam

304	MR/40	87226			Arunachal Pradesh
305	MR/41	87227			Assam
306	MR/44	266619			Northeast
307	MR/45	87230			Arunachal Pradesh
308	MR/56 A	87234			Arunachal Pradesh
309	BDJ 89/176	87237		Kulu	Himachal Pradesh
310	M 54	136704			Unknown
311	BDJ 89/1006	136705	Gogati	Sirmur	Himachal Pradesh
312	BDJ 89/1012	136706	Gogati	Sirmur	Himachal Pradesh
313	BDJ 89/1017	136707	Katchalu	Sirmur	Himachal Pradesh
314	BDJ 89/1029	136708	Katchalu	Sirmur	Himachal Pradesh

1	2	3	4	5	6
315	BDJ 89/1031	136709	Gogati	Sirmur	Himachal Pradesh
316	BDJ 89/1036	136710	Gogati	Sirmur	Himachal Pradesh
317	BDJ 89/1041	136711	Gogati	Sirmur	Himachal Pradesh
318	BDJ 89/1053B	136712	Gogati	Sirmur	Himachal Pradesh
319	46/83-30	86963		Dehra Dun	Uttar Pradesh
320	BDJ 89/1014	136714	Ghindiyalu	Sirmur	Himachal Pradesh
321	BDJ 89/1018	136715			Himachal Pradesh
322	BDJ 89/1093	136717		Sirmur	Himachal Pradesh
323	BDJ 89/1096	136718	Goati	Sirmur	Himachal Pradesh
324	BDJ 89/1099	136719	Soleyalu	Simla	Himachal Pradesh
325	BDJ 89/1114	136720	Goati	Sirmur	Himachal Pradesh
326	BDJ 89/1117	136721	Goati	Sirmur	Himachal Pradesh
327	BDJ 89/1137	136724	Gagati	Sirmur	Himachal Pradesh
328	BDJ 89/1150	136725	Gagati	Sirmur	Himachal Pradesh
329	BDJ 89/1158	136726			Himachal Pradesh
330	BDJ 89/1161	136727	Gagati	Sirmur	Himachal Pradesh

1	2	3	4	5	6
331	BDJ 89/1164	136728	Gagati	Sirmur	Himachal Pradesh
332	BDJ 89/1175	136731			Unknown
333	BDJ 89/1178	136732			Unknown
334	BDJ 89/1190	136735			Unknown
335	BDJ 89/1200	136737			Unknown
336	BDJ 89/1204	136738			Unknown
337	BDJ 89/1210	136740			Unknown
338	BDJ 89/1217	136742			Unknown
339	BDJ 89/1222	136743			Unknown
340	BDJ 89/1223	136744			Unknown
341	BDJ 89/1229	136746			Unknown
342	BDJ 89/1236	136748			Unknown
343	BDJ 89/1285	136749			Unknown
344	BDJ 89/1251	136750			Unknown
345	BDJ 89/1252	136751			Unknown
346	BDJ 89/1255	136752			Unknown
347	BDJ 89/1263	136753			Unknown

348	NL	313056			Unknown
349	BDJ 89/1270	136754			Unknown
350	BDJ 89/1273	136755			Unknown
351	BDJ 89/1277	136756			Unknown
352	BDJ 89/NL 6	136759			Unknown
353	BDJ 89/NL-8	136760			Unknown
354	BDJ 89/NL-10	136761			Unknown
355	V 4526	136763			Unknown
356	V4561	136764			Unknown
357	V 4676	136769			Unknown
1	**2**	**3**	**4**	**5**	**6**
358	89/0-49-B	136772			Unknown
359	V 92/T-12	266629			Unknown
360	V 92/T-48	266622			Unknown
361	V 92/T-77	266637			Unknown
362	V 92/T-81	266624			Unknown
363	V 92/T-98	266628			Unknown
364	V 92/T-99	266631			Unknown

365	V 92/T-110	266623			Unknown
366	V 92/T-112	266630			Unknown
367	V 92/T-122	266621			Unknown
368	V 92/T-128	266633			Unknown
369	NL-2	313060			Unknown
370	VS.95-4	NIC23433	Kuchu	Kamrup	Assam
371	VS.95-16	313061	Guatiyakusu	Goalpara	Assam
372	VS.95-20	313062	Bankusu	Goalpara	Assam
373	VS.95-22	NIC23453	Garokusu	Goalpara	Assam
374	VS.95-30	NIC23461	Narkilia kusu	Goalpara	Assam
375	VS.95-31	NIC23462		Goalpara	Assam
376	VS.95-37	NIC23468	Garokusu	Bongaigaon	Assam
377	VS.95-41	NIC23472	Bankusu	Bongaigaon	Assam
378	VS.95-82	NIC23513		Gangtok	Sikkim
379	VS.95-91	266618	Bankusu	Gangtok	Sikkim
380	VS.95-93	266616		Gangtok	Sikkim
381	VS.95-114	NIC23545		Kokrajhar	Assam

382	VS.95-116	266617	Panchmukhi	Kokrajhar	Assam
383	VS 95-23	NIC23454	Dhudhkusu	Goalpara	Assam
384	ANL-1	266627			North East
385	ANL-3	266636			North East
386	N-96-C-8	313065		Cuttack	Orissa
1	**2**	**3**	**4**	**5**	**6**
387	N96-C-10	266625		Cuttack	Orissa
388	N96-C-9	313066		Cuttack	Orissa
389	N96-C-5	313068		Cuttack	Orissa
390	N96-C-7	313067		Cuttack	Orissa
391	N96-C-6	313069		Cuttack	Orissa
392	VU/97-14	266626			Kerala
393	VU/97-38	210373			Kerala
394	VU/97-39	210374	Karichembu	Ernakulam	Kerala
395	VU/97-64	210400	Karuthachembu	Idukki	Kerala
396	VU/97-88	210427		Idukki	Kerala
397	NL-1	266634			Kerala
398	19/49-2	313070			Kerala

399	VJ/98-204	248312		Sindurg	Maharashtra
400	PLP/D 99-480	259989		Koraput	Orissa
401	PLP/D 99-488	259997	Berhampuri	Koraput	Orissa
402	AM/99-35	349868		Trivandrum	Kerala
403	AM/99-66	349893		Trivandrum	Kerala
404	AM/99-67	349894		Trivandrum	Kerala
405	VB/99-113	313073		Uduppi	Karnataka
406	V/2000-11	406436		Thrissur	Kerala
407	R/P-RR-37	283349	Saru	Puri	Orissa
408	221Mouranipur	86840A			Madhya Pradesh
409	Karakkal-A	86917			Pondicherry
410	Taragaon	86843-1			North East
411	S-910-A	87011			Maharashtra
412	283 Badaben-A	86854			Himachal Pradesh
413	283 Badaben-B	86924			Himachal Pradesh
1	**2**	**3**	**4**	**5**	**6**
414	S 9/735	136688			Maharashtra
415	P-108 A	86872			Maharashtra

416	269 Shimla-A	086932A			Himachal Pradesh
417	Karakkal-B	86970			Pondicherry
418	85/81-16	86971A	Cheruchembu	Kollam	Kerala
419	85/81-16	86971B		Kollam	Kerala
420	85/81-16	86971C		Kollam	Kerala
421	69/81-7 A	86937A		Alappuzha	Kerala
422	NL-24	87010			Kerala
423	4/82-4	70150		Kasaragod	Kerala
424	18/82-5 A	70164A		Kasaragod	Kerala
425	18/82-5 B	70164B		Kasaragod	Kerala
426	27/82-4-B	70172B	Karutha chembu	Kasaragod	Kerala
427	41/82-8-A	70183A		Kannur	Kerala
428	218/81-28A	86976A			Kerala
429	81/82-12-A	70253A		Kozhikkode	Kerala
430	81/82-12-B	70253B	Karichembu	Kozhikkode	Kerala
431	86/82-10-A	70269A	Cheruchembu	Kozhikkode	Kerala
432	98-82-8B	70284B	Karichembu	Malappuram	Kerala

433	125/82-49 A	70303A		Palakkad	Kerala
434	125/82-49 B	70303B		Palakkad	Kerala
435	125/82-49 C	70303C		Palakkad	Kerala
436	134/82-37	70318A		Thrissur	Kerala
437	134/82-37	70318B		Thrissur	Kerala
438	1/83-26 A	87110	Podichembu	Thrissur	Kerala
439	1/83-26 B	86987	Podichembu	Thrissur	Kerala
440	11/83-33 A	86989	veluthachembu	Ernakulam	Kerala
441	17/83-67 A	86991		Ernakulam	Kerala
1	**2**	**3**	**4**	**5**	**6**
442	22/83-2	0087114A		Ernakulam	Kerala
443	38/83-22	0086939A	Cheruchembu	Kottayam	Kerala
444	Kovvur	86900	Kovvwi	Trivandrum	Kerala
445	V 833 A	136701A		Wayanad	Kerala
446	V 833 B	136701B		Wayanad	Kerala
447	V 888	86993		Wayanad	Kerala
448	V 2163 B	87095B		Nilgiris	Tamil Nadu
449	V 2174 A	87036	Cheruchembu	Nilgiris	Tamil Nadu

450	V 2174 B	87078	Cheruchembu	Nilgiris	Tamil Nadu
451	V 2209 B	87063		Nilgiris	Tamil Nadu
452	M-142-A	87096A	Karichembu	Kozhikkode	Kerala
453	M-142-B	87119B		Kozhikkode	Kerala
454	M-142-C	87119C		Kozhikkode	Kerala
455		87142		Phek	Nagaland
456	NH 6/1-A	87112			Assam
457	NH 6/1-B	87039			Assam
458	BD 47A	87041A			Meghalaya
459	BD 47B	87041B			Meghalaya
460	BD 7/13-A	87043			Assam
461	BD 7/13-B	87144			Assam
462	NH 6/8 A	87188		Dimapur	Nagaland
463	NH 6/114	87163			Nagaland
464	NH 6/12 B	87158B		Ugma	Nagaland
465	NH 6/9 A	87160		Tuensang	Nagaland
466	DKH 59	87009			Maharashtra

467	BD 6	87046			Assam
468	BDJ 2164	87197		Sirmur	Himachal Pradesh

1	2	3	4	5	6
469	BDJ 89/1053A	136712A	Gogati	Sirmur	Himachal Pradesh
470	KKV-CE-AN-5	136729	Gagati	Ratnagiri	Maharashtra
471	KKV-CE-AN-5	136729B	Wakkawali local	Ratnagiri	Maharashtra
472	BDJ 89/NL-4 A	136758	Delhi Market		New Delhi
473		136758B	Delhi Market		New Delhi
474	V 92/T-107	266632B			Tamil Nadu
475	NLSK	313057			Kerala
476		313057			Kerala
477	1/84-108				Kerala
478	PLP/D 99-485	259994A	Berhampuri local	Koraput	Orissa
479	V2907 A	87173 A		Coorg	Karnataka
480	N96-C-6 A	313069A		Cuttack	Orissa
481	VJ/98-115	248219		Uttar Kannada	Karnataka

3. 4. Characterization

Complete characterization is the third important step in PGR conservation, and involves study of morphological parameters of the collections before these are subjected to preliminary evaluation for quantitative characters and also to tolerance to common diseases and pests. In the present study, a total of 481 accessions (Table 7) were characterized for 58 qualitative and quantitative characters as listed in Table 8 based on the descriptors prepared for the crop by Anonymous, (1980 & 1999a)) with slight modifications wherever needed based on the experience of the researcher and were used for various studies in the present treatise.

Table 8. List of Descriptors and descriptor states studied

Aboveground qualitative		
#	Descriptors	Descriptor states
1	Plant type	Subjective grouping of aerial plant parts on the basis of appearance into 1-9 types
2	Leaf type	Subjective grouping of shape and appearance of leaves into 1-16 types as per the fug. 3)
3	Sheath types	Subjective grouping of shape and appearance of leaf sheath margin into 1-4 types as per fig. 4)
4	Morphotypes	Subjective grouping of the taro accessions on the basis of aerial plant types, leaf types, sheath types and tuber types and as per the photos given in plate 2
5	Lamina orientation	1- Drooping, 2- Horizontal, 3- Cup-shaped, 4- Erect-apex up, 5- Erect–apex down, 6-Semi erect
6	Lamina margin undulation	1- Less wavy, 2- Medium wavy, 3- Highly wavy
7	Lamina margin colour	1 - Light green, 2 - Green, 3 - Light purple, 4 - Purple, 5 - Dark purple, 6 - Light purple brown, 7 - Brown, 8 - Purple brown, 9 - Dark brown.
8	Lamina colour	1- Light green, 2- Green, 3- Dark green, 4- Bluish green, 5- Green with purple blotches
9	Lamina petiole joint colour	1- Light green, 2- Green, 3- Light purple, 4- Purple, 5- Whitish green, 6- Purplish violet, 7- Dark

		purplish violet, 8 – Purplish brown, 9- Brown
10	Petiole tip colour	1- Light green, 2- Green, 3- Light purple, 4- Purple, 5- Dark purple, 6 – Light purplish brown, 7- Purplish brown, 8- Whitish green, 9- Purplish green, 10- Greenish purple.
11	Petiole middle colour	1 - Light green, 2- Green, 3- Light purple, 4- Purple, 5- Dark purple, 6 – Light purplish brown, 7- Purplish brown, 8- Wightish green, 9- Purplish green
12	Petiole base colour	1- Light green, 2- Green, 3- Light purple, 4- Purple, 5- Dark purple, 6- Light purplish brown, 7- Purple brown, 8- Whitish green, 9- Dark purplish brown, 10- Greenish purple
13	Petiole sheath margin nature	1-Closed, 2- Medium wide, 3- Wide open, 4- One side overlapping the other as depicted in fig.4.
14	Petiole sheath margin colour	1- Light green, 2- Green, 3- Light purple, 4- Purple, 5- Dark purple, 6- Whitish green, Dark Purplish green, 8- Dark green, 9- Light purplish brown
15	Ligule colour	1- Light green, 2- Green, 3- Light purple, 4- Purple, 5- Green, 6- Purple brown, 7- Purple violet, 8- Dark Purple violet, 9- Dark purple, 10- Greenish purple
16	Lamina thickness	1-Thin, 2- medium thick, 3- Thick
17	Symmetry of leaf	1- Symmetric, 2- Asymmetric
18	Petiole acridity	1-Low, 2- Moderate, 3- High
19	Leaf acridity	1-Low, 2- Moderate, 3- High
Belowground qualitative characters		
1	Tuber types	21 subjective types on the basis of shape and size as depicted in fig. 5 & plate II
2	Presence of stolon	1- Present, 2-Absent
3	Flesh colour	1- White/cream, 2- light pink
4	Taste of tuber	1-Low, 2-Moderate, 3-Good based organoleptically
5	Acridity of tuber	0-Absent, 1- Low, 2- Moderate, 3- High

Floral characters		
1	Inflorescence per axil	Numbers
2	Peduncle length	-cm
3	Spathe length	-cm
4	Tube length	-cm
5	Female part length	-cm
6	Neutral part length	-cm
7	Male part length	-cm
8	Sterile part length	-cm.
9	Sterile part thickness	-cm
10	Flowering time	In days from planting date
11	Female anthesis	In days from planting date
12	Maleanthesis	In days from planting date
Aerial quantitative characters		
1	Plant height	-cm
2	Petiole length	-cm
3	Sheath length	-cm
4	Sheath depth	-cm
5	Leaf length	-cm
5	Leaf width	-cm
6	Sinus width	-cm
7	Sinus depth	-cm
8	Leaf number	-cm
9	Leaf width/length ratio	-cm
10	Time taken for regeneration	Days

Underground quantitative characters		
1	Mother corm length	-cm
2	Mother corm thickness	-cm
3	Cormel number	-cm
4	Cormel length	-cm
5	Cormel thickness	-cm
6	Corm fresh weight/plant	-g
7	Cormel fresh weight/plant	-g
8	Corm thickness/length ratio	Numerical ratio
Pests and diseases screening		
1	Leaf-blight incidence	1- Low, 2-Medium, 3 High
2	Aphid infestation	1- Low, 2-Medium, 3 High
Isoenzyme characters		
1	Esterase	
2	Super Oxide Dismutase (SOD)	

3.5. Preliminary evaluation

Preliminary evaluation of collections was done separately for 427 accessions during the main seasons of 1999-2000 and for 459 accessions during 2000-2001. Collections were planted in augmented design (Agrawal & Sapra, 1995) in lateritic soil with two controls, and every year new accessions were added. Each year the crop was planted in the month of May after the commencement of pre-monsoon showers. The field was prepared by ploughing with disc plough twice, followed by cultivating twice. Pits were made at a distance of 30 x 30 cm distance in lines at a distance of 1 x 1 m on raised beds. Seed tubers weighing 100 gm per pit were planted filled with 250 gm cowdung per pit. Thin layer of soil followed by mulching with green manure covered the planted tubers.

Observation on 22 important quantitative characters of aerial parts and underground parts was made each year at the time of good crop growth stage during August-September and at the time of harvest during November–December respectively.

3.6. Classification

Classification of the collections was done on the basis of the subjective method proposed by Mathews (1962). The morphotypes were grouped and the collections falling under each type were listed and the qualitative and quantitative data collected were tabulated. Along with the morphotype-wise grouping, classification of plant types (481 accessions), leaf types (474), and tuber types (474) were also carried out subjectively. Final morphotypic grouping is given only for 474 accessions. Grouping of plant types, leaf types and sheath types was done during the main cropping season and that of the tuber types was done at the time of harvest during November-December. Morphotype-wise list of collections and characters, photographs of morphotypes, sheath and tuber types are made and presented. Diagrammatic representation of tuber types, leaf types and sheath types are also presented. Distribution map of morphotypes in India is also presented.

3.7. Floral characters in taro

Out of 481 accessions of taro maintained in the field 474 out of which 293 accessions belonging to 55 morphotypes flowered. Twelve spadix/inflorescence and floral characters were observed and type-wise range, mean, SD and CV% are furnished. The results obtained have been discussed in the light of taxonomy of taro. Collections have been observed for flowering in four consecutive years from 1999 to 2002. Twelve spike and floral characters were observed and type wise range, mean, SD and CV% are furnished along with number of accessions flowered in table. The results have been discussed in the light of taxonomy of taro.

3.8. Taxonomic grouping of Indian taro

Finally 55 morphotypes flowered were first subjected for taxonomic grouping on the basis of leaf breadth/length ratio and leaf shape, mother tuber thickness/length ratio (Shape of the mother tuber) and finally on the basis of male part/sterile appendix ratio. Morphotypes were divided into *C. esculenta* var. *esculenta* (e), *C. esculenta* var. *antiquorum* (a) and intermediates (e/a and a/e) based on the two main ratios such as sterile appendix/male part ratio of the spadix, and mother corm thickness/length ratio along with subjective corrections. An attempt was also made to verify the genetic distance between them by conducting numerical taxonomic studies.

3.9. Numerical Taxonomic Analysis in taro

A total of 55 morphotypes, which flowered and 54 which yielded complete set of data were subjected to numerical analysis studies with a view to find out the inter-group relationship within the species. A total of 41distinct qualitative and quantitative characters of aerial, underground and floral parts were pooled in an Excel format and was first linearly transformed for sequential agglomerative, hierarchical and nested clustering through similarity or dissimilarity indices (Sneath & Sokal, 1962) using NTSYS 2.0 package.

3.10. Isoenzyme studies

Samples representing one each of the morphotypes were obtained from the NBPGR Regional Station, Vellanikkara, Thrissur and were grown in pots filled with garden soil (sand: farm yard manure: soil in 1:1:1 ratio) in a grow house at NBPGR, New Delhi. Temperature varied between 31-35 ^{o} C and RH between 65-70% during growing season. Out of the total samples, 49 accessions representing one each of 48 morphotypes of *Colocasia esculenta* and one of *C. affinis* Schott considered as a garden escape in north Malabar were analyzed in the present study. Others could not be used due to their failure in growing at New Delhi.

In the case of Esterase enzyme analysis, though 48 samples of *Colocasia esculenta* and one sample of *C. affinis* were used, samples with respect to morphotypes such as M2, M35, M71 and M76 were duplicated. With respect to the analysis for Super Oxide Dismutase (SOD), 47 morphotypes of *Colocasia esculenta* and one sample of *C. affinis* were used. However for the genetic analysis and for clustering only 40 morphotypes of *Colocasia esculenta* and one of *C. affinis* which were subjected to the above two analyses were used.

About 2-3 cm long piece of fresh young leaf from each accession were collected over moist filter paper and transferred to the laboratory in an icebox. The tissue was ground to a fine powder after freezing in liquid nitrogen. About 1:5 (w/v) proportion of the extraction buffer (0.1M triscl pH 7.4) was added to each sample and tissue was homogenized. The homogenates were transferred to pre-cooled 15 ml centrifuge tubes and were subjected to centrifugation at 20,000 x g in rotor maintained at 4^0 C. The supernatant was transferred to base 1.5 ml tubes. About 30% sucrose was added to the extracts to increase the viscosity of samples and the tracking dye bromophenol blue was added to a final concentration of 0.002%.

Poly-achrylamide gel electrophoresis (PAGE) was used to separate the enzyme fractions in a 7.5% gel following the methodology of Bhat *et al.* (1992). About 60 µl of each sample was loaded on vertical gels of size 20 x 20 cm. Each gel was subjected to enzyme activity staining following the procedure of Vellejos (1983). The enzyme pattern was scored across the sample lanes, treating each band produced as a character state since no genetic study could be conducted. The combined data matrices of both the enzyme systems were used to calculate the Jaccard's similarity coefficients (Jaccard, 1908). This similarity matrix was used for cluster analysis following UPGMA procedure, and a combined dendrogram is prepared. The statistical analysis was performed using the NTSYS-pc, version 1.80 package (Extra Software, New York, USA).

3. 11. Correlation studies in taro morphotypes

One accessions each of the representatives of 72 morphotypic groups were planted on 1.2 m wide raised beds with 4 plants per line at a distance of 1m from line to line and 30 cm from plant to plant. The trial was laid out in augmented block design (Agrawal & Sapra, 1995) with three checks such as M1, M2 and M3 being the three promising morphotypes identified in the collection. Every 10 entries were followed by the three checks to constitute one block. The experiment was carried out in the year 1999 at the NBPGR farm in Vellanikkara situated at 76^0 2 E longitude and $10^0$5 N latitude. The soil was lateritic and the average annual rainfall was 3631mm. Observation was recorded on two middle plants per collection and the mean values per plant for 12 characters were used for Path Coefficient Analysis following the method suggested by Dewey and Lu (1959) for partitioning the correlation coefficient into direct and indirect effects.

3. 12. Analysis of variance

During the main growing season of the year 2000, a total of 427 accessions and that of 2001, 459 accessions were grown in lateritic soil at Vellanikkara in augmented design with two controls (M1 & M3). The planting was done during the month of May. Three central plants were treated as experimental plants. Collections were planted in rows at 1 m distance and plant to plant at 30 cm distance on raised beds. During both the years the experimental plots were weeded twice and fertilized twice once in July and the other in August, and were applied with 20 kg of Nitrogen 20 kg of Phosphorous, and 30 kg of Potash in two split doses. The plants also received Ekaulex 0.04% and 1% Bordeaux mixture spray twice one in July and the other in August to control aphids and armyworm in the first case and leaf blight in the second case. The crop was harvested at senescence during last week of November to first week of December. The experimental plants were covered on all sides by one row of border plants. Two plants per accession were subjected to observation of 11 important characters (4 aboveground and 7 belowground traits) and these were subjected to analysis of variance by using Augmen1 package (Agrawal and Sapra, 1995) during both the years. Range mean, standard deviation and CV% for these characters were also worked out and presented. ANOVA tables for 11 characters are also presented. However no pooled analysis for two years could be done due to difference in number of collections grown in two years.

3.13. Principal Component Analysis

A total of 472 collections comprising 83 morphotypes representing wild, weedy and cultivated entities of taro were grown in augmented design during 2001-2002 at the station's farm at Vellanikkara.

A total of 20 aboveground and belowground vegetative characters (8 qualitative and 12 quantitative) were observed in two plants per accession and the mean values of each group with respect to 8 quantitative characters for all the 83 morphotypes were computed. In the case of qualitative characters as no variation at the infra-group level was noticed, the codes for the descriptor states under each of the 8 qualitative descriptors were also used for computation. The morphotypes-wise quantitative and codified qualitative characters were used for principal component analysis (Johnson & Wichern, 1988). The analysis was carried out using Spar1 Statistical Package.

Characters that were maximum responsible for contributing to the differences in these morphotypes were determined on the basis of original variables with greater influence on the components. For the purpose, the mean values from the highest and the lowest Eigen Vectors were determined by totaling the values against each variable distributed under various components and these were summed up for finding the mean value. This value was considered to be the threshold for selection of the most contributing variable in each component (Fundora *et al*., 1992). A Scatter diagram was prepared using the first two principal components on the X and Y axes respectively in order find out association of various morphotypes.

3.14. Aphid infestation

A total of 477 accessions of taro including 475 accessions falling under 81 morphotypic groups based on subjective morphology (Anonymous, 1999b) and 2 in ungrouped category were planted on May 20th, 1999 on 1 m wide raised beds at 75 cm distance with three plants per accession at 30 cm distance in the field gene bank in the NBPGR Regional Station's farm situated at Vellanikkara. A basal application of FYM @ 250 g per plant was done following a mulching on the bed. Fertilizer application at the rate of 100 g of NPK per line following weeding was carried out twice during the crop growth. During 1999 cropping season, there was an extreme situation of uniform aphid infestation on taro germplasm (Plate VI) in these. The Experts of the Entomology Department, Horticultural College, Kerala Agricultural

University, Vellanikkara identified the pest. Observation on incidence of the aphid infestation was made subjectively by assessing the intensity of damage caused using the scale 0-9 assessing all the three plants. Morphotype wise data for the whole collection were computed into mean, range and SD. Aphid-tolerant lines were identified and their geographic origin was traced. The infestation occurred during the third week of August, immediately after the cessation or decrease in the intensity of rains and severe by the first week of September all the leaves wilted except in a very few lines.

3.15. Taro leaf blight disease

Growth of plants belonging to 477 accessions was satisfactory in the early stages. Symptoms of the incidence of blight appeared during the first week of July during the heavy monsoon showers with the sky overcast with clouds, and the expression progressed after July third week during sunny days immediately after the cessation of rains. The observation on parameters such as total number of functional leaves per plant, number of infected leaves, number of spots per leaf, leaf length, leaf width, and the size (diameter) of the brown spots and lesions developed, and each random spot area was calculated by using the mathematical formula πr^2**.** Two plants per collection were observed and the data were converted into percentage of mean leaf area infected in each collection. Total leaf area per plant was computed as per formula 1 (Birader *et al.,* 978) and the percentage of leaf area as per formula 2.

1. Total leaf area per plant per collection = Mean leaf length X Mean width X Total number of functional leaves x 0.978.

2. Mean infected leaf area per plant per collection / Mean total leaf area pr plant/ per collection x100

Subjective scoring of the incidence of blight was also done in three classes such as a low (0.01- 5% infected leaf area), medium (5.1 – 10%) and high (10% or above of infected leaf area). Further, morphotype-wise mean and SD for the infected leaf-area was also worked out and presented. Frequency-class distribution of the accessions with respect to the percentage of infected leaf area was determined and the curve was drawn using the Microsoft Excel package. Correlation between percentage leaf-area infected and the fresh tuber yield was also computed.

3.16. Regeneration in taro

Taro is a clonally propagated crop and as such time taken for regeneration of planted tuber is an important factor that favours or affects the early crop vigour and good yield. A total of 475 accessions belonging to 82 morphotypes were observed for the number of days taken for regeneration of the planted cormel/tuber from the date of planting. The date of regeneration was marked on the day the buds were observed above soil level.

3.17. Senescence in taro

A total of 456 accessions of taro belonging to 82 morphotypes could be observed for the number of days taken for senescence of aerial plant parts from the date of planting to the date of senescence indicating the crop duration and maturity of the tubers. Three plants per collection were observed for the purpose. The data were recorded collection-wise and morpohotype-wise range, mean, SD and CV% were calculated.

3.18. Organoleptic studies in taro

3.18.1. Tuber taste and acridity

A total of 409 accessions belonging to 69 morphotypes and 426 accessions belonging to 57 morphotypes were subjected to observation for tuber-taste and acridity respectively. For recording tuber taste and acridity, tubers were cleaned immediately after the harvest and about 25 gm of sliced tuber pieces were cooked for 15 minutes in boiling water and tasted by three persons and the taste and acridity were recorded jointly by three persons and the mean per collection was recorded on 1-3 and 0-3 scales respectively. Frequency class distribution was worked out for the above-mentioned parameters. All the morphotypes could not be observed due to decay of the underground parts at the time of harvest in some cases.

3.18.2. Leaf lamina and petiole acridity

With respect to leaf (lamina) and petiole acridity, leaves and petiole of 450 accessions belonging to 76 morphotypes and petiole of 472 accessions belonging to 76 morphotypes were subjected to observation. Leaves and petioles at tender stage were selected from the field and 10 gm of each were cooked in boiling water for ten minutes and tasted and acridity was recorded on a 0-3 scale. Frequency class distribution was worked out and presented.

3. 19.Taro chemistry

3.19.1. Oxalic acid content of tubers

Tubers representing one each of 35 morphotypes were subjected to analysis of for oxalic cid Oxalic acid content as per the method by Anonymous (1984) at Central Tuber Crops Research Institute, Thiruvananthapuram.

3.19.2. Sugar content of tubers

A total of 56 collections each one representing a morphotype have been subjected to analysis for total soluble sugar following the method by Nelson (1944).

3.19.3. Protein content of tubers

Tubers of 53 accessions, each one representing a morphotype have been subjected to analysis for protein content using COAC Official methods of Analysis (Anonymous, 1960).

3.20. Cost of *ex situ* maintenance of taro

Being clonally propagated, maintenance of taro germplasm in *ex situ* field condition involves huge expenditure and it has been calculated on the basis of the material costs such as cost of farm yard manure, fertilizers, pesticides, fungicides and the wages for manual field operations including planting, harvesting, cleaning and storing and field preparation by tractor and is presented as per the rates that existed during 1993 coupled with chiller cabinet running costs (Electricity charges, labour charges and cost of muslin cloth bags etc.).

4. RESULTS

4.1. Exploration

Though a total of 993 accessions of taro were collected in 28 exploration and collection trips conducted in different parts of India and on transfer of collected germplasm from different parts, only 481 accessions were subjected to classification, characterization, evaluation and other studies as listed in Table 7. Collections from coastal areas of Andhra Pradesh obtained after the completion of major part of the study could not be included.

4.1.1. Areas covered

Southern, southwestern, eastern, northwestern, northeastern and western regions. The latitude of areas of taro cultivation varied from 8°. 85 N in the extreme south to 35° 0 in Himachal Pradesh of North-Western region and in all longitudes of India except in extreme desert conditions in Rajasthan. The areas covered as presented in the fig. 2. Included states of Kerala, Tamil Nadu, Karnataka, Karnataka, Goa and parts of Maharashtra, parts of Rajasthan, parts of Andhra Pradesh, Orissa, West Bengal, Sikkim, Uttar Pradesh, Madhya Pradesh, Tripura, Nagaland, Assam and Mizoram.

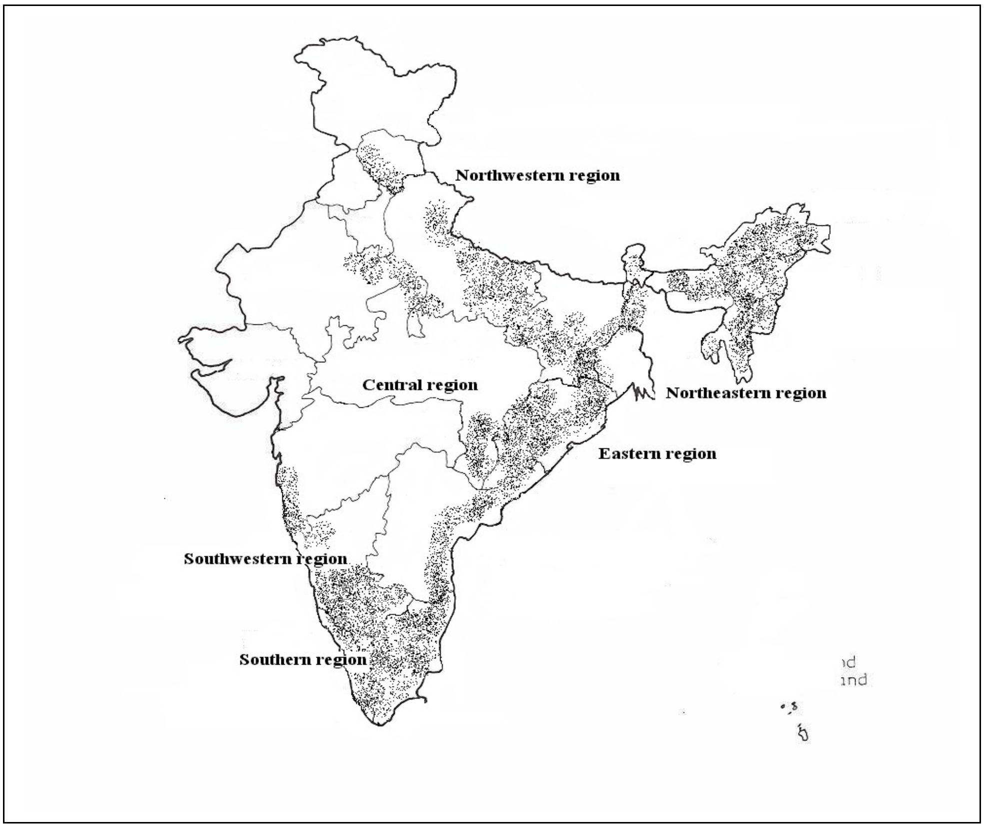


Fig.2. Areas explored and surveyed in India

4.1.2. Ecology of taro

The naturally occurring taro was observed in areas with moderate to very high rainfall, especially in southern, northern and eastern regions. None of the species other than taro (*C. esculenta*) was seen cultivated in India during the survey. It was found to be adapted to a wide variety of soils right from tropical lateritic soils in coastal Kerala to Maharastra, sandy soils in West Coast, alluvial soils along the river banks, forest alluvium in the North-East, East and the South. Natural taro grows in almost everywhere in marshy areas irrespective of rainfall pattern. Under cultivation, taro is seen in ditches especially in plains of Assam and West Bengal, in up lands and in low land paddies in Kerala and uplands in Tamil Nadu Uttar Pradesh, Kerala, Andhra Pradesh and Uttar Pradesh. No puddle taro parallel to that reported from Fiji could be noticed anywhere in India during the collection trips by the author. However, 'Kariekshu' in Karnataka and in Konkan is noticed in lowland conditions along the fringes of paddy lands below the hills. 'Karichembu' or 'Karutha chembu' (M26) in Kerala is found to be cultivated rarely on raised beds in paddy lands and also in uplands. It was once an important crop that was intercropped with other tuber crops likes cassava, greater yam, elephant-foot Yam and fruits like banana in Kerala. Pure cropping of commercial nature was noticed mainly in Tamil Nadu along the river alluvium in South Arcot, Dindugal and in Kanyakumari districts. In Himachal Pradesh, it was seen as a subsistence crop on terraces around homesteads on terraces. In Konkan ('Badai'), in Uttar Kannada region of Karnataka (Karikeshu) and in Kerala ('Karichembu') cultivated in standing water near the homesteads for their leaf appeared to be a perennial type. Its leaves and petiole are edible. Taro growing naturally in several places in tropical evergreen forests and along the streams is used by tribal people as a vegetable in Kerala and hilly areas in Karnataka. In marshes taro grows perennially. The crop grows well from MSL to elevations as high as 1200 m. in Western Ghats. In Andhra Pradesh, Northeastern parts and in Orissa the crop is predominantly grown in distant places in hilly tracks and valleys. In North-East, especially in Assam

Plate I. Natural and man made habitats of taro

I-1. Wild taro along the rivulets, I-2. Wild *C. esculenta* var. *sculenta* along the road sides, I-3 Wild taro in highly shaded tropical undisturbed forests in Western Ghats, I-4. *C. esculentta* var. *antiquorum* (M 14) in disturbed road sides in Kerala, I-5. Wild *C. esculenta* var. e*sculenta* in coastal sandy soils, I-6. *C. affinis* run wild in coastal areas and midlands of northern Kerala and Coastal Karnataka, I-7. Wild purple *C. esculenta* var. *esculenta* in roadside ditch , I-8. *C. esculenta* var. *antiquorum* in disturbed forests in Chattisgarh, I-9. *C. esculenta* var. *illustris*, I-10. *C. fallax* among disturbed road side vegetation in Meghalaya, I-11. Subsistence cultivation of taro in uplands of Kerala, I-12. Island model of invasion of wild taro in abandoned paddy fields taro is planted in the form of ‘hulis’ (Main rhizome/ corm tops) plant mother tops as reported in Hawaii by O’ Hair and Asokan (1986) during October-November in moist ditches along the roadsides, and the crop grows luxuriantly during the summer and monsoon periods. In Malappuram, Kerala intercropping of almost 7-8 different crops were found and taro is cultivated on raised beds in Paddies, with major crop being banana. Taro belonging to ‘Kannan’ group (M7 to M10 and ‘Karutha Kannan’ or ‘Karutha chembu’ (M26) is cultivated along with yams, turmeric, ginger and some Cucurbitaceous vegetables in sloppy hills after felling the trees of old rubber plantations. This kind of cropping system continues in the inter-row spaces of rubber for 3-4 years. Wild taro (Plate I) grows in very interior forest areas in tropical evergreen forests, which is more or less similar to the common var. *aquatilis*, which is reported to be the progenitor of cultivated taro (Matthews, 1991). Taro cultivation along with turmeric, chillies, ginger, turmeric, new cocoyam and vegetables like okra are commonly seen in sandy soils in coastal areas of Kannur district, Kerala. In parts of Uttar Pradesh and Central India taro (Plate III-2) namely ‘Arvi’ (M2) is grown as a commercial crop in plains along the riverbanks in sandy loam and alluvial soils under irrigation. Wild taro of various types belonging to both var. *esculenta* and var. *antiqiorum* (Plate I) occurs from coastal sandy belt to areas with elevations as high as 1500 m in Western Ghats and surrounding areas. However, its luxuriant growth is noticed from plains to elevations as high as 1000 m. In marshy habitats in plains and in hills, various forms of var. *esculenta* occur in groups or patches (Plate I) and gradually cover acres together. It is a very successful invader of partially inundated areas, muddy areas and along sewage canals around urban areas and irrigation canals in villages. It appears that taro has a great potential of withstanding the highly polluted marshes around cities formed by drainages. The plants can be used for gradual reclamation of such areas.

4.1.3. Ethnobotany

During the survey few instances of special use of various parts of taro in explored areas were noticed. In the past, its mother rhizome called ‘thalla’ in Kerala was usually not preferred as a vegetable due to its added acridity as compared to the cormels of most of the local varieties, but at times of great scarcity for vegetables people used to consume them after proper processing to remove the acridity by adding sufficient tamarind or buttermilk in another preparation called ‘Kalan’ or ‘Morukootan’. These were some of the delicacies of people of Kerala in the past and the same was found to be retained by locals in certain interior places even now. A similar dish namely ‘Kadi’ is prepared in north India, which is eaten either with rice or with ‘chapatti’. Conventionally in mountainous and tropical forest areas there is always a scarcity of vegetables due to its geographical distance and inaccessibility from plains. As such, the tribal people belonging to

‘Malapulayar’ residing in Chinnar Wild Life Sanctuary in Idukki district of Kerala were found to depend largely on the leaves of a specific wild taro growing in marshes around their dwellings at about 4000 ft elevation as a vegetable.

The tender leaves of certain types of cultivated taro called ‘Kari chembu’ in north Kerala, ‘Karikesu’ in coastal Karnataka and ‘Kala saru’ of Konkan in the western coastal Maharashtra and Goa belonging to var. *esculenta* are used for preparation of very delicious steamed dish. For the purpose, a paste made out of rice and pulse flour in water and mixed with salt and some spices like fenugreek, asafoetida and cumin are spread on tender leaves and are made into rolls and tied with banana sheath fiber are steamed to prepare a very delicious dish. All over India, the tuberous corms and cormels depending upon the varieties are used mainly as a vegetable. There is a flooding of taro tubers in markets from the month of September onwards in North India, which comes from eastern Uttar Pradesh, Bihar and also from pockets of commercial cultivation in inlands. Commercial cultivation of taro was noticed in semi-arid areas of Vindhyan region in central India along the rivers with an assured irrigation. The long/cylindrical thick mother tubers (corms) of var. *esculenta* could be noticed in Delhi market. These come from the eastern parts of Uttar Pradesh and Bihar. The fresh tubers cut and chopped are used for preparation of light refreshments such as ‘Bhajia’ and ‘Pakora’ in North India and chips elsewhere in India. The ‘Sukha subji’ prepared out of

‘Arvi’ or ‘Guinya’ belonging to *Colocasia esculenta* var. *antiquorum* in north and central India is a very good combination with local wheat bread called ‘rotti’ or ‘chapatti’. In South India it is used as dried vegetable called ‘kondattam’, and is added as mixed vegetable along with others in a delicious curry known as ‘Sambar’, or made into a side dish called ‘poriyal’ in Tamil Nadu and used along with rice. Fresh tuber is starchy and mealy and possesses a delicious flavour when cooked. *Colocasia esculenta* tubers, probably belonging to var. *esculenta* may be roasted, baked, boiled, deep-fried, grated and mixed with coconut milk or meat and boiled in leaf wrappings. Cooked taro can be smashed and kneaded and then wrapped in leaves and cooked.

4.1.4. Named local cultivars and wild types collected

During the exploration and collection of taro germplasm from different areas a total of 58 local names could be listed in the passport data (Table 9). From the passport information it was evident that most of the accessions collected did not bear local names either due to the absence of such specific names or due to the inability of the farmers to identify and give names. Further local names include some common names that are related to wild types of taro. ‘Kadukesu’ in Kannada, ‘Kattuchembu’, ‘Velichembu’, ‘Marambu chembu’ or ‘Marambu’, etc. in Malayalam, ‘Jungli saru’ in Oriya, ‘Kattuseppai kilangu’ in Tamil are in use for wild types of taro in different places. One distinct cultivar name at different places may be connected to morphologically different types like the name ‘Kannan’ in Kerala to various closely related types by error in the exact identity of these types by the farmers due to continuous variation in characters. The cultivar names for similar types may be distinct in distant places as well. The list also includes names of three important released types from CTCRI, Thiruvananthapuram. The names denoted mostly specific morphological features of the cultivars like ‘Panchamukhi’ with multiple faced mother tubers, ‘Suikachu’ meaning long thin pointed and cylindrical mother tuber, ‘Karichembu’ or ‘Karutha chembu’ related to dark purple petiole, ‘Kudachembu’ with very large umbrella like leaves, ‘Choriyan chembu’ with itching tuber flesh, ‘Cheruchembu’ with small mother and lateral tubers, ‘Kannan chembu’ with light purple or purplish violet spot on the middle of lamina, ‘Karutha kannan’ with purple petiole and purple spot in the centre of the leaf and with purple petiole, ‘Chuvanna kannan’ with red spot on the center of lamina, ‘Thamarakkannan’ meaning the type with lotus like leaves with a purple spot in the centre of lamina, ‘Adukkachembu, with very compact tubers, ‘Podichembu’ with small tubers, ‘Kottachembu’ with compact large underground tubers like basket, ‘Appooppan chembu’ with more roots and persistent leaf sheaths on tuber parts, and ‘Duddh kusu’ with good tuber with the taste of milk. Names sometimes also denoted the situation and places of taro cultivation or occurrence, like ‘Nanachembu’ meaning irrigated taro and

‘Malaraman’ or ‘Malaariyan’ meaning type cultivated in mountainous or hilly situations. Names also denoted the place of origin of the type like ‘Kovvur local’, ‘Berhampuri local’ and ‘Walkawali local’. All the names with the ‘Kannan’ suffix are from Kerala and these are morphologically closer types falling under a major group with a common origin in Kerala as discussed in taxonomic classification part.

Table 9. Names of cultivars and other wild types of taro collected

Sl. No.	Names of cultivars	States	Sl. No.	Names of cultivars	States
1	**2**	**3**	**1**	**2**	**3**
1	Adukkachembu	Kerala	30	Kudachembu	Kerala
2	Appooppan	Kerala	31	Kuttichembu	Kerala
3	Arattupuzhakanna	Kerala	32	Kuzhinirayan	Kerala
4	Bankusu	Assam,	33	Malaraman	Kerala
5	Berhampuri	Orissa	34	Malaariyan	Kerala
6	Bilathichembu	Kerala	35	Nanachembu	Kerala
7	Cheruchembu	Kerala	36	Narkila kusu	Assam
8	Choriyan chembu	Kerala	37	Panchamukhi	Assam
9	Chuvannakannan	Kerala	38	Podichembu	Kerala
10	Dudhkusu	Assam	39	Saru	Orissa
11	Gagati kusu	Himachal	40	Siruchembu	Tamil
12	Gogoti kusus	Assam	41	Solivalu	Himac
13	Goti kusu	Himachal	42	Thamarakkann	Kerala
14	Garokusu	Assam	43	Kalichembu	Kerala
15	Ghindiyalu	Himachal	44	Valiya	Kerala
16	Guatiya kusu	Assam	45	Vayal chembu	Kerala
17	Jayti kusu	Chathisgarh	46	Velichembu	Kerala

1	2	3	1	2	3
18	Karichembu	Kerala,	47	Velutha	Kerala
19	Karinthal	Kerala	48	Wakkavali	Mahar
20	Karutha chembu	Kerala	49	Sreerasmi	Releas
21	Karutha kannan	Kerala	50	Sreekiran	Releas ed
22	Katchalu	Delhi,	51	Sreepallavi	Releas
23	Kattuchembu	Kerala	52	Suchikusu	Assam
24	Kattuseppaikilang	Tami Nadu	53	Pind Alu	Sikkim
25	Koombilla chembu	Kerala	54	Bakse kusu	W.
26	Kottachembu	Kerala	55	Lohardhaga	Jharkh
27	Kovvur	Andhra	56	Karikeshu	Karnta
28	Kutchi	Assam	58	Marambu	Kerala
29	Kala saru	Maharashtr	59	Badai	Goa,

4.2. Maintenance of taro

Taro collection is mainly maintained in *ex-situ* field condition, which is comparatively a difficult and costly affair. Further, loss of germplasm is caused due to various factors such as extreme situations of leaf blight infection, aphids, and armyworm infestation and rot of stored tubers (planting materials) during summer. Seasonal planting of the main collection in the open upland field under rain-fed condition at Vellanikkara followed by keeping duplicates as potted plants under 25% shaded condition with protective irrigation during summer could solve the problem to certain extent. Though 481 accessions could be subjected at certain stage of the study as in the case of observation on plant types, at the time of final evaluation only 475 accessions could be maintained by these methods. Use of chiller cabinets at

13° C and 71% RH was also made for storing harvested and cleaned tubers after dipping in 0.3% Dithane M45 solution for 5 minutes and drying in shade for two days during the summer. This solved the problems of summer storage of seed tubers of germplasm collection to greater extent. This method enhanced the storage for more than one year. Thus the taro germplasm subjected to the present study was maintained in all the above three conditions. However, some of the collections belonging to distinct morphotypes were lost during the last year of the study leadig to inability to take photographs and to observe certain parameters of few morphotypes. These types were from distant geographical areas. A total of 481 accessions (Table 5) were maintained in taro till the end of studies.

4.3. Classification of taro germplasm

4.3.1. Morphotypic classification

A total of 474 accessions of 481 wild and cultivated taro, *Colocasia esculenta* (L.) Schott from different agro-ecological and physiognomic zones of India as depicted in Table 5 have been subjected to final morphotypic classification. Grouping accessions was done step by step subjectively from plant types to leaf types, sheath margin types and tuber types as discussed in the ensuing parts. Final grouping of 475 collections was done on the basis of comparison of live plants repeatedly over the years.

4.3.2. Plant types in taro

With respect to plant types a total of 9 groups (Table 10) have been identified in 481 collections on the basis of subjective assessment of the plant stature, appearance, colour etc. of the aboveground parts under *ex situ* condition at Vellanikkara, Thrissur. Mainly petioles, leaf-sheaths, and leaves representing the aerial parts, and stolons and exposed rhizome parts representing underground parts of various accessions collectively decided the subjective appearance of the plant types. This could be easily distinguished by comparing live plants in the field during the main growing season. The plants, either erect or semi erect combined with the leaf disposition pattern and suckering habits, pigmentation on various plant parts decided the plant types. The plant types belong to various morphotypes and different taxonomic groups as given in Table 18 along with the key morphological characters.

Table 10. Plant-types in taro

Plant types Nos.	Morphotypes Nos.	Number of M. types	Number of collections.	Characters
1	1, 2, 3, 4, 5, 18, 19, 20, 21, 22, 23, 24, 25, 35, 36, 37, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 54, 55, 56, 60, 62, 63, 67, 71, 72, 76, 77	38	262	Plants Short or Medium tall to tall, 37-102.5 cm, petiole 30.0-93.5 cm long, more suckering broadly sagitate leaves with medium wavy margin mostly cultivars belonging to *C. esculenta* var.*antiquorum.* Include collections from all over India

1	2	3	4	5
2	6, 7, 8, 9, 10, 11, 12, 16, 32, 79	10	117	Plants 53.0-94.41 cm tall, with erect to semi erect petiole 44.0-80.47 cm long, oblong sagitate leaves, leaves with very wavy margin and belong to commonly cultivated “Kannan" and its related wild types.
3	15, 17, 61, 66, 73, 74	06	16	Plants medium, 55.0-90.0 cm tall, erect to semi-erect petioles, 49.5-79.0 cm long conical, oblong sagitate leaves with less wavy margin and less vigorous
4	13, 14, 78	03	14	Dwarf to medium plants, 75.5-93.3 cm tall, semi erect petioles, 62.5-75.83 cm long, suborbicular sagitate leaves with very wavy margin either semi wild or wild; appears to be very distinct type having no parallel lines among cultivars. This plant type is related to wild type-6.
5	26, 27, 28, 29, 30, 31, 33, 34, 38, 39,64, 65, 69, 70, 75, 81, 83	17	58	Plants medium tall to very tall, 42.0-97.72 cm, erect to semi-erect petioles, 31.0-85.93 cm long, wild and cultivated mostly having purple pigmentation on petiole, leaves oblong sagitate with slightly in curved and medium to highly wavy margins, mostly esculenta type mother or stolons in the case of wild ones. This is related to common wild types with purple petiole and its variants occur in southern region.

1	2	3	4	5
6	51, 52,53	03	5	Plants 78.0-116.0 cm tall, petiole 65.0- 93.0 cm with large sub orbicular, sagitate, thick leaves with moderately wavy margin, plant parts green and cormels sometimes club shaped and long club shaped tubers exposed above soil. This plant type may be related to M14 and also wild and semi wild forms under M18, 19, 20, 21, 22.
7	57, 58, 59	03	5	Very vigorous large plant type, 94.0-107.5 cm tall, with purple shades on semi erect-petiole, 77.0-93.5 cm long, very large suborbicular sagitate leaves with moderately wavy margin, leaf sheath-margin of one side overlapping the other, typical cultivated *esculenta* of north east.
8	68	01	1	Plants over 90 cm tall, with dark green petiole, 75.0 cm long, dark green suborbicular sagitate leaves, lamina thick and corrugated leaves with oblong, cylindrical corm and cormel; originally from north east.
9	80, 82	02	3	Plants mostly dwarf, 24.0-44.0 cm tall, petioles green, semi erect to procumbent, 20.0-36.0 cm long very orbicular thin smooth leaves margin less wavy young leaves plate like orbicular leaf sheath wild form from Western Ghats and appear to be distinct species
		83	481	

6.3.3. Leaf types in taro

Similarly, 481 collections were differentiated into 16 leaf types (Fig. 3) based on appearance in relation to lamina size, shape, disposition, colour, lamina margin undulation, lamina basal sinus undulation, and presence of pigmentation in the center of the leaf as detailed in the Table 11 with major characteristic features.

Table 11. Leaf types in taro

Leaf types	**Morphotypes**	**Number of moroho-types**	**Number of Collns.**	**Status**	**Characters**
1	**2**	**3**	**4**	**5**	**6**
1	1, 2, 3, 6, 34, 35, 36, 37, 41, 48, 49, 50, 51, 52, 55, 56, 60, 62, 67,	19	162	Cult.	Lamina semi-drooping, medium to large sized, broadly sagittate, 30.75-69.5 cm long, 28.0-50.0 wide; sinus 11.5-26.0 cm wide,, and 8.5-16.5 cm deep with medium wavy margin with light green centre
2	4, 5	2	13	Cult.	Leaf lamina medium to large size, semi drooping to drooping, broadly 122gitate, 64.38-72.94 cm long, 35.0-42.5 cm wide, sinus 32.94- 39.25 cm wide and 12.94-13.13 cm deep with medium wavy margin and light green n centre

1	2	3	4	5	6
3	7, 8, 9,10,11,16, 43, 44, 61, 76	10	94	Cult. & Wild	Horizontal to semi-erect lamina 27.25- 34.5 cm long, 19.5-30.5 cm wide; sinus 9.0-13.75 cm wide, 7.66-9.0 cm deep with a tendency to form cup or plate with purple or fading purple spot at the centre
4	23, 24, 25	3	46	Cult. & Wild	Lamina very large, drooping, almost flat leaves, 51.52-55.94 cm long, 41.5-45.94 cm wide; sinus 13.5-13.97 cm wide, 11.67-12.0 cm deep, margin low to medium wavy with light purple fading f spot in the centre
5	13,14, 46, 47, 63, 64, 70, 71. 72, 77,79,81,	11	19	Cult. & Wild	Lamina drooping, medium to large sized, 23.5-49.5 cm long, 18.25-40.0 wide; sinus 10.0-19.0 cm wide and 6.5-12.0 cm deep, with highly wavy margin and light green centre
6	15,17, 54	3	13	Wild	Leaves small to medium, less wavy or no wavy margin, long sagittate, light green centre, 29.64-30.5 cm long, 21.27-21.5 cm wide, sinus 7.23-8.0 cm long, 4.5-5.0 cm deep
7	18,19, 20, 21, 22,	5	34	Cult. & Wild	Lamina medium to large, semi erect to drooping, thick, 35.25-46.25 cm long, 29.0-39.25 cm wide; sinus 10.0-12.58 cm wide, 8.75-10.59 cm deep with wavy margin and light yellowish green centre

1	2	3	4	5	6
8	26	1	21	Cult.	Lamina medium, symmetric, dark green, 33.96 cm long, 25.83 cm wide; sinus 11.83 cm wide, 8.58 cm deep with highly wavy margin and with purple centre
9	29 (Thamarakkannan)	1	2	Cult.	Lamina oval, suborbicular, sagittate, dark green, 30.75 cm long, 25.0 cm wide; sinus 9.25 cm wide and 7.88 cm deep with less wavy margin and sinus margin, lotus like hence the name 'Thamarakkannnan'
10	31,	1	2	Cult.	Leaves symmetric, small, less wavy margin, bluish dark green leaves, 27.25 cm long, 21.75 cm wide, sinus 9.63 cm wide, 7.25 cm deep
11	27,28,38,42,83	5	21	Wild	Lamina cup shaped horizontal to semi drooping, 24.0-38.39 cm long, 21.0-30.05 cm wide; sinus 13.0-13.5 cm wide, 9.3-11.5 cm deep, medium to highly wavy margin with purple to light green centre
12	30, 32, 65, 66, 69, 73, 74, 75, 78	9	19	Cult. &. Wild	Lamina small to medium, asymmetric, bluish green to purple violet wash and marks on leaves spreading to the lower surface, 21.0-31.42 cm long, 15.0-25.5 cm wide; sinus 9.5-16.0 cm wide, 6.5-11.46 cm deep with medium wavy margin,

1	2	3	4	5	6
13	33,39,40	3	4	Cult.	Lamina oblong sagitate, semi drooping, 23.0-38.5 cm long, 18.0-31.5 cm wide; sinus 13.5-15.0 cm wide, 10.0-11.75 cm deep with less wavy margin and green leaf centre
14	58,59.68,	3	5	Cult.	Lamina large drooping, 43.5-45.5 cm long, 33.0-37.0 cm wide; sinus 12.0-16.5 cm wide and 8.0-9.0 cm deep with low to medium wavy lamina and sinus margin, purple margin, and purple centre
15	12,43,45,53,57	5	24	Cult.	Lamina Long, sagitate, semi-erect, symmetric to asymmetric, small to medium sized, 21.0-42.5 cm long, 24.75-33.5 cm wide; sinus 10.0-13.84 cm wide and 7.5-11.02 cm deep with medium to highly wavy margin and fading purple brown centre
16	80,82	2	2	Cult.	Lamina medium, suborbicular, round horizontal to semi-erect, glossy, 15.0-27.5 cm long, 13.5-25.5 cm wide, sinus very less deep and wide with less wavy margin and light green centre
Total		83	481		

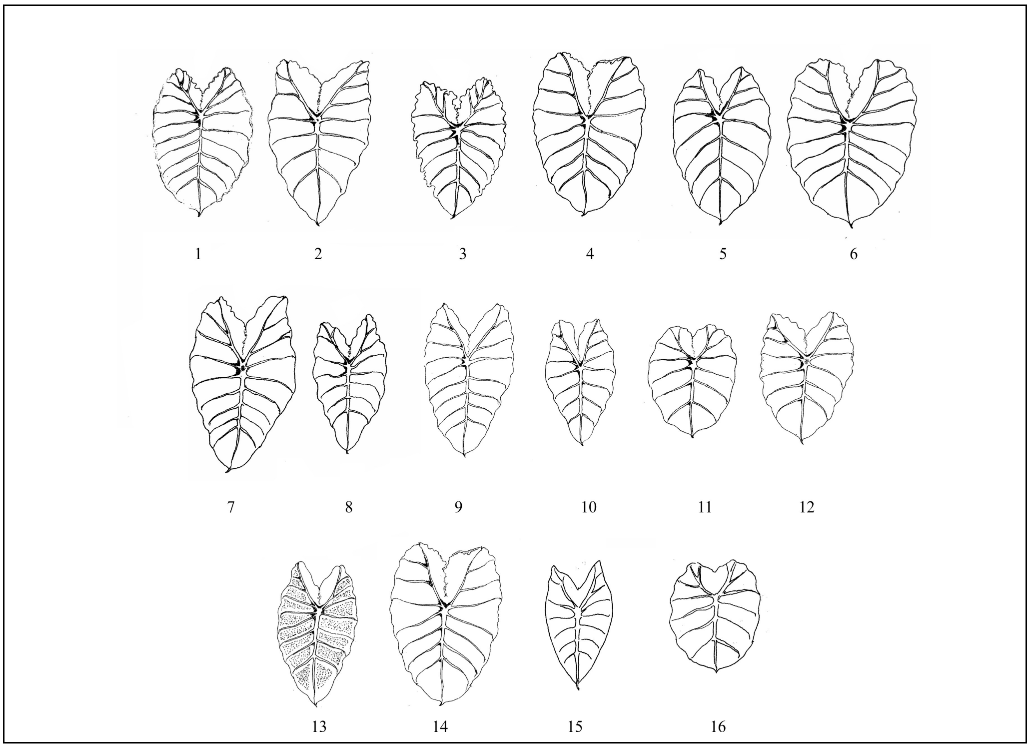


Fig. 3. Leaf types in taro

4.3.4. Leaf-sheath types in taro

Disposition of margin of leaf-sheath in main collections of taro appeared to have specificity in relation to different morphotypes identified. Observation on sheath-margin in taro indicated that mainly four groups as depicted in Table 12, figure 4 and Plate-II occur. Out of 474 accessions, the first group with 304 accessions representing 46 morphotypes has almost closed or converging sheath margin; the second group with 69 collections representing 23 morphotypes has medium close or medium wide leaf sheath, the third one with 96 accessions representing 11 morphotypes has very wide margin and the fourth one with 5 accessions representing 3 morphotypes happens to represent a specialised situation noticed only in advanced forms of var. *esculenta* cultivars in North Eastern Region in which margin on one side overlaps the other with an undulating raised part just below the ligule.

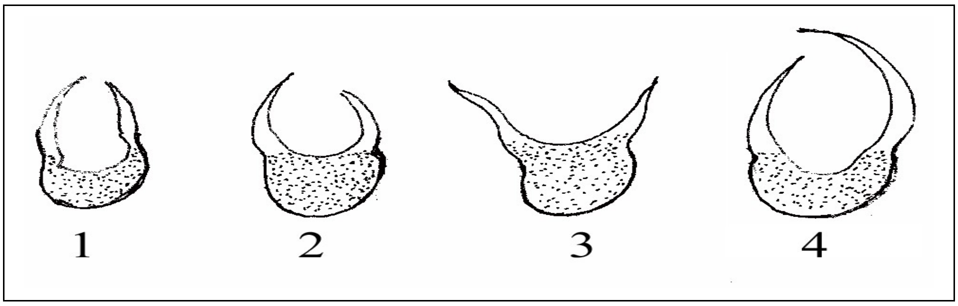


Fig. 4. Leaf-sheath types in taro

Table 12. Leaf-sheath types in taro

Leaf sheath margin type	Morphotypes	Number of Morphotypes	Number of	Characters
1	**2**	**3**	**4**	**5**
1	1,2,3,6,12,15,16,17,23,24,25,26,27,28,29,30,31,32,33,34,35,37,42,43,46,47,49,52,54,55,56,60,61,62,63,64, 65, 66, 67, 68, 70, 71, 74,76, 79, 81	46	304	Leaf sheath margin converging, 0.7

				-2.2 cm deep
2	4,5,13,14,18,19,20,21,22,36, 38,39, 40,44, 45,48, 51,53, 69,72, 75,77, 83	23	69	Leaf-sheath margin erect, or medium converging

				, 0.75-1.8 cm deep,
3	7, 8, 9, 10, 11, 41, 0,73, 78, 80, 82	11	96	Leaf-sheath margin diverging 1.0-1.83 cm

				deep
4	57,58,59	3	5	Leaf-sheath margin converging with one side overlapp

				ing the other towards the top 1.25-1.92 cm deep

Plate II. Leaf sheath types in taro

A. Leaf sheath type; B. Leaf sheath type2; C. Leaf sheath type 3;
D. Leaf sheath type 4


1


2


3


4


5


6


7


8


9

Plate III. Tuber types in taro

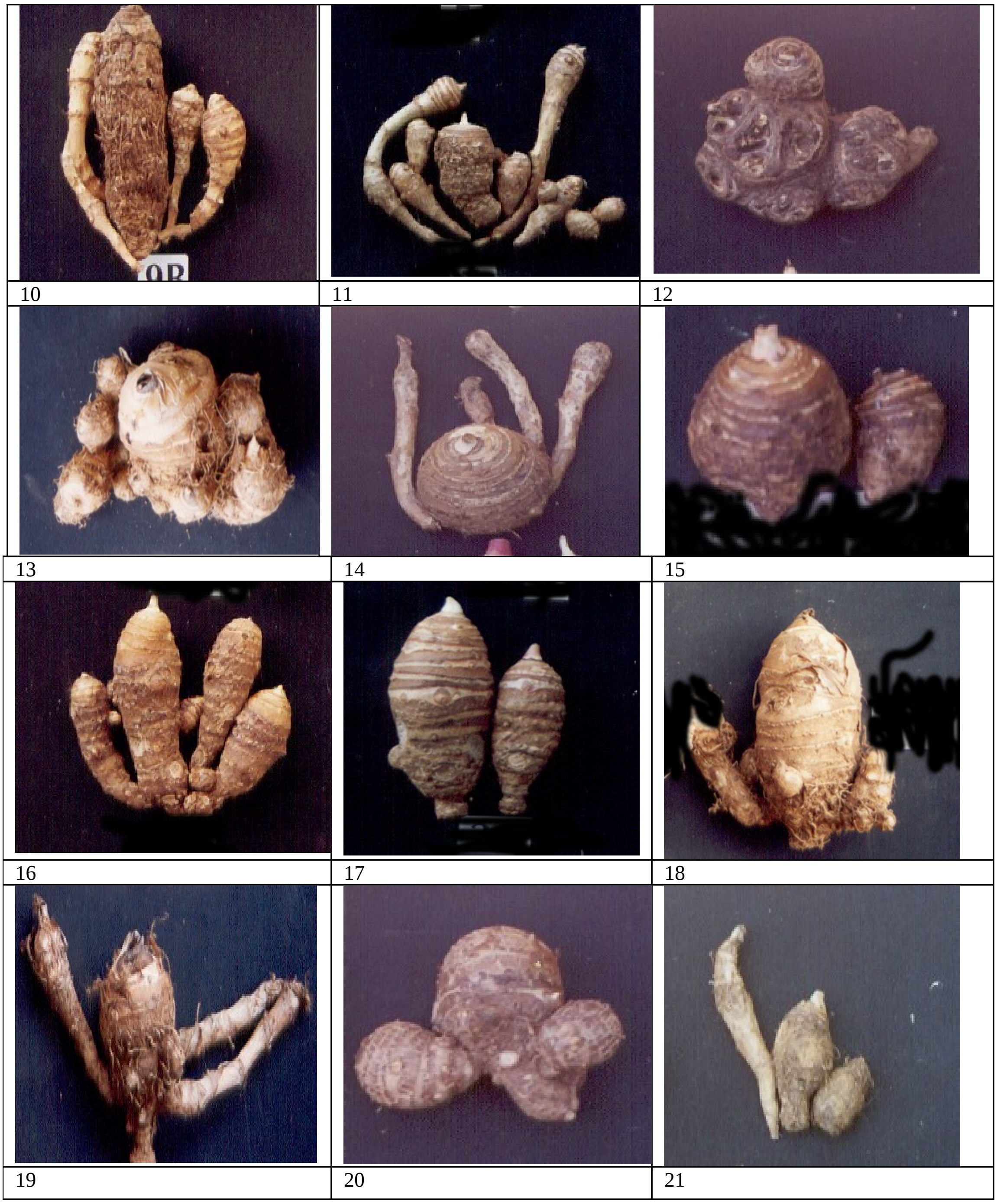


Plate III. Tuber types in taro (contd.)

A total of 21distinct tuber types have been recognized among 474 accessions of indigenous taro germplasm (Table 13, Fig. 5, Plate III to III). This could be further used to ascertain morphological affinity among the collections in relation to evolutionary pattern of this most important part as explained in discussion part. Tuber types were based mainly on the basis of shape and size of the mother tubers and lateral tubers and the presence of stolons or semi-stolons as furnished in table 10.

Table 13. Tuber types in taro

Tuber types	Morphotypes	Number of morphotypes	Number of collections	Salient features
1	**2**	**3**	**4**	**5**
1	1,2,35,37,41,45,49,50	8	148	Mother corm round, 5.0-8.5 cm long, 2.25-5.48 cm thick, cormels round to oval 8-15 in number, 5.75-10.25 cm long, 2.25-3.25 cm thick; highly tuberising
2	6, 7, 8, 10, 11, 26, 29, 32, 36, 42, 44, 48, 62, 63, 64, 75, 76, 77	18	126	Mother corm oval, 4.38-8.25 cm long, 2.95-7.0 cm thick, oblique, top shaped, cormels, oval, club shaped, 5-14 in number, 5.84-11.75 cm long, 1.98- 4.0 cm thick; moderately to highly tuberisig forms
3	4, 12, 31, 53,	4	25	Mother corm large, cylindrical, 6.0-10.92 cm long, 4.17- 6.0 cm thick, cormels 7-8 in number, cylindrical, spindle shaped, similar to corms in shape, 8.0-8.32 cm long, 2.53 – 5.0 cm thick, less tuberising

1	2	3	4	5
4	16, 28, 30, 40, 54, 61, 65, 74	8	22	Mother corms as in type three, 4.75-15.0 cm long, 3.2- 5.5 cm thick, cormels 4-17 in number, stoloniferous and semi-stoloniferous with enlarged club-shaped tops, 6.0-18.0 cm long, 1.1-3.0 cm thick, wild
5	9,27, 34, 46, 57, 80, 82	7	15	Mother corm large, top shaped, oblong, thicker towards top portion, 5.25-12.25 cm long, 2.88-5.21 cm thick; cormels club shaped, 3-13 in number, 6.25-11.25 cm long, 1.5 to 2.61 cm thick; less tuberising
6	33,66,79	3	3	Mother corm smaller, 3.0-7.5 cm long, 3.0-4.0 cm thick, round, ovoid, cormels oblong, stoloniferous, with enlarged globose tops, 5-10 in number, 8.5 – 16.6 cm long, 1.6 5-2.0cm thick
7	21	1	1	Mother corm medium to large, slightly conical, oblong, multifaceted, 7.0 cm long, 5.75 cm thick; cormels, long, cylindrical, club-shaped, 11 in number, 10.25 cm long, 2.1 cm thick; less tuberising
8	39	1	1	Mother corm spindle shaped, oblong, tapering on both ends, 8.0 cm long, 4.75 cm thick, cormels stoloniferous, 4 in number, 16.0 cm long, 1.6 cm thick

1	2	3	4	5
9	38	1	3	Corm large, globose, 9.0 cm long, 12.0 cm thick, cormels oblong, stoloniferous, 6 in number, 14.5 cm long, 3.5 cm thick
10	70,73	2	2	Mother corm large, long, spindle shaped, thin, 7.75-15.25 cm long, 3.48-4.75 cm thick; cormels oblong, thin stoloniferous, 11-13 in number, 7.13-9.75 cm long, 1.75-3.15 cm thick
11	14,78	2	6	Mother corm large, conical, top-shaped, 6.75-8.1 cm long, 4.1-4.75 cm thick; cormels semi-stoloniferous, cylindrical, club-shaped, branched, 6-10 in number, 6.0-13.1 cm long, 2.6 cm thick
12	22,55,72,81	4	5	Mother corm medium-large, top shaped, conical, multifaceted (usually more than two –three faces), 5.25 cm long, 4.75-9.5 cm thick; cormels long, cylindrical, club shaped, 5-26 in number, 5.5 cm-9.5 cm long, 2.0-7.0 cm thick
13	3,13	2	8	Mother corm large, thick, ovoid, drum shaped, 7.0-8.5 cm long, 4.75-9.0 cm thick; cormels cylindrical, thick, 9 in number, 8.5-9.0 cm long, 2.75-5.83 cm thick

1	2	3	4	5
14	19,20,51,52,56,60	6	16	Mother corm large, globose or ovoid, pointed at top, 6.33-10.5 cm long, 5.97-7.75 cm thick; cormels thinly cylindrical, long, club shaped, thicker at the top portion, 5-18 in number, 9.47-23.0 cm long, 1.8-3.85 cm thick
15	18,23,24,25,71	5	65	Mother corm globose, large, 7.07-8.75 cm long, 4.75-6.12 cm thick; cormels long, cylindrical , 6-18 in number, 7.0-9.5 cm long, 2.91-3.65 cm thick
16	47, 67	2	2	Mother corm large, long, cylindrical, thick, with rounded top, 8.75-12.75 cm long, 4.1-4.6 cm thick; cormels 12-16 in number, 12-16 in number, 9.25 cm long, 2.9 cm thick
17	43, 58, 59, 83	4	8	Mother corm spindle shaped with pointed tip, large, 12.0-20.17 cm long, 4.5-5.5 cm thick; cormels very few, 2-9 in number, similar to mother, 8.6-16.08 cm long, 2.85-4.0 cm thick
18	68	1	1	Mothr corm large, spindle-shaped, 11.5 cm long, 6.75 cm thick, thicker; cormels (tubers) few, 5 in number, 11.0 cm long, 4.75 cm thick, globose smaller ones attached to the base of the corm

1	2	3	4	5
19	69	1	1	Mother corm long, conical with broader top, 9.0 cm long, 5.0 cm thick, cormels few, 5 in number, 11 cm long, 2.0 cm thick, thin semi-stoloniferous
20	5	1	4	Mother corm ovoid, large, 8.69 cm long, 3.38 cm thick, cormels few around 10 in number, 7.56 cm long, 1.81 cm thick, smooth
21	15,17	2	12	Corm small, cylindrical, 4.25-6.89 cm long, 3.0-4.33 cm thick; similar cormels 10-11 in number, 6.09-6.25 cm long, 1.9-2.1 cm thick

Corms varied in shape and were globose, hemispherical or ovoid, thinly or thickly cylindrical or spindle-shaped. Lateral tuber shape varies from stolons, semi-stolons, club shaped, cylindrical, globose or ovoid in the wild forms to semiwild and cultivated forms. Stolons have the functions of an adventitious tuberous underground stem, but unlike the tubers they help the plants to regenerate and spread to other areas in wastelands, marshy places or along the natural or man-made streams. In the forest areas populations of a gregarious type of stoloniform taro was noticed in interior marshy areas or water streams; its stolons were noticed to freely extend to watercourses and break off and get dispersed to distant places where they establish and spread.

This type is exactly similar to the *C. esculenta* var. *aquatilis,* which is probably presumed to be the progenitor of cultivated taro (Matthews, 1991).

Tuber shape, size and disposition are very important characters in determining the cultivars in taro. Apart from it, most of the wild types are stoloniferous which can be compared with var. *stolonifera* and var. *aquatilis* which prefer marshy and waterlogged habitats in high rainfall areas. It also occurs in upland conditions of more moist shaded habitats.

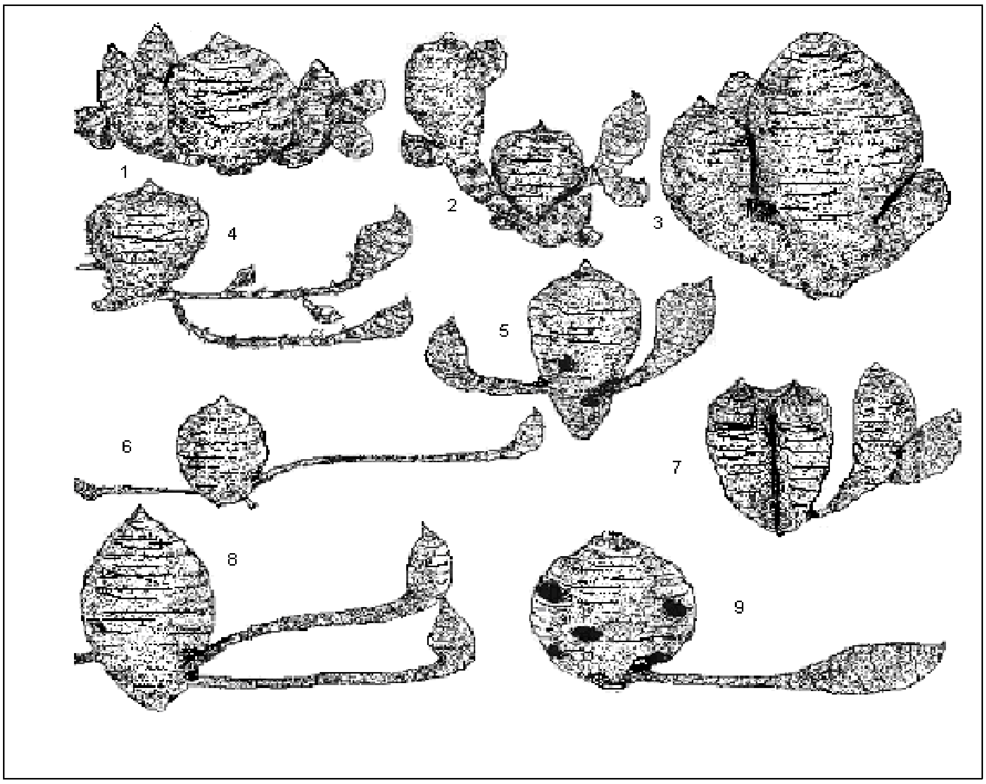


Fig. 5. Tuber types in taro

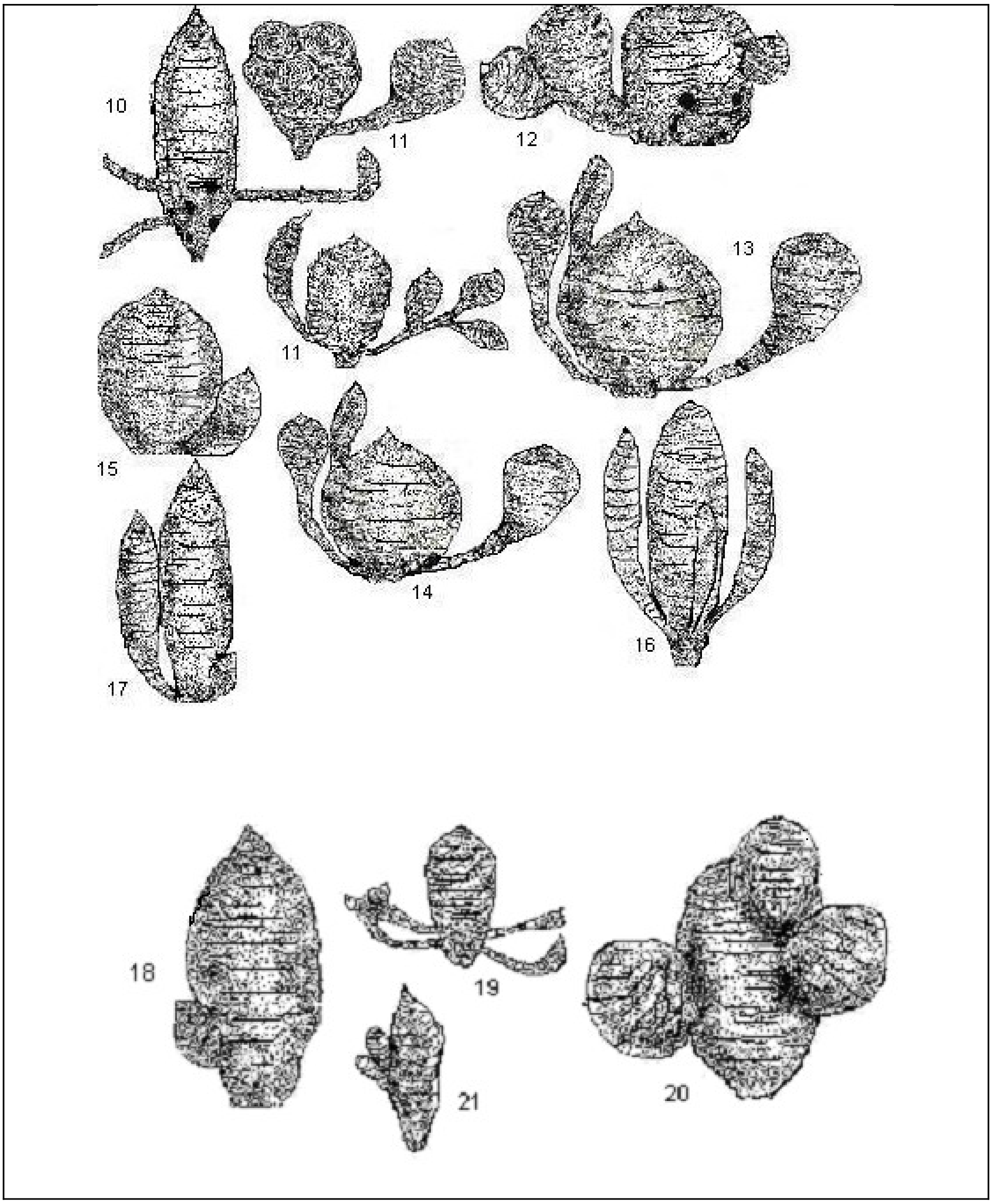


Fig. 5. Tuber types (contd.)

4.3.6. Morphotypes in taro

On the basis of variations in morphological features of natural populations of taro are compartmentalized first into various groups with respect to plant types, leaf types, sheath types, tuber types and finally into morphotypes. In the present study out of a total of 481 accessions of taro, 474 have been classified into 83 morphotypes (Table 14), Plates IV-1 to IV-4). An attempt has also been made to depict qualitative (Table 15) and quantitative characters (Table 16) of both aerial underground parts with morphotypes wise range mean, SD and phenotypic CV%. Maximum number of collections is noticed in M1 with 80 followed by M2 with 54. Number of accessions falling in these types varied from 1 in the case of morphotypes 9, 17, 21, 25, 33, 35, 36, 37, 39, 42, 45, 51, 53, 55, 56, 57, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 77, 78, 79, 81, 82 and 83 TO 80 IN M1. Less number of collections in these morphotypes indicates their rarity in cultivation or occurrence.

Table 14. Morphotypes identified in taro with available local names and distribution

Morphotypes	Number	Local names	Distribution
1	**2**	**3**	**4**
M01	80	Katchalu, Gogati,	Himachal Pradesh,
M02	54	Kannan, Kovvur,	Madhya Pradesh,
M03	5	Kusu	Pondichery, Kerala
M04	7	Walkawali local	Himachal Pradesh
M05	4	_	Maharashtra,
M06	3	_	Bihar, Nagaland,
M07	20	Cheruchembu,	Bihar, Kerala, Tamil

1	2	3	4
M08	17	Kannanchembu,	Kerala, Pondichery,
M09	1	_	Kerala
M10	7	Appoppanchembu,	Kerala
M11	36	Arattupuzhakannan,	Kerala, Karnataka
M12	16	_	Kerala, Arunachal
M13	3	Garokusu	Maharashtra, Assam
M14	5	Cheruchembu	Kerala
M15	11	_	Madhya Pradesh,
M16	5	_	Kerala, Karnataka
M17	1	_	Orissa
M18	19	Valiyachembu	Kerala, Karnataka,
M19	8	Kutchu	Assam, Meghalaya,
M20	2	_	Kerala
M21	1	Dudhukusu	Assam
M22	2	_	Kerala, Assam
M23	35	Cheruchembu	Kerala, Karnataka,
M24	9	Kottachembu	Kerala, Nagaland
M25	1	_	Unknown*
M26	21	Karuthakannan,	Kerala, Tamil Nadu
M27	5	Kudamalarchembu,	Kerala, Karnataka
M28	7	_	Kerala, Tamil Nadu
M29	2	_	Kerala, Tamil Nadu
M30	3	_	Kerala, Nagaland
M31	2	Podichembu	Kerala
M32	8	Karuthachembu,	Kerala
M33	1	_	Kerala
M34	2	_	Kerala
M35	1	Cheruchembu	Kerala
M36	1	_	Unknown*
M37	1	_	Kerala
M38	3	_	Kerala
M39	1	_	Tamil Nadu
M40	2	_	Tamil Nadu
M41	3	_	Tamil Nadu,
M42	1	_	Kerala
M43	3	_	Assam, Uttar
M44	2	_	Kerala
M45	1	_	Assam
M46	2	_	Assam
M47	1	Garokusu	Assam
M48	1	_	Assam
M49	1	_	Assam
M50	7	_	Uttar Pradesh,
M51	1	_	Assam

1	2	3	4
M52	3	_	Kerala, Assam
M53	1	_	Meghalaya
M54	2	_	Unknown*
M55	1	_	Karnataka
M56	1	_	Kerala
M57	1	_	Assam
M58	3	_	Nagaland
M59	1	_	Kerala
M60	1	_	Himachal Pradesh
M61	1	_	Arunachal Pradesh
M62	1	_	Thripura
M63	1	_	Kerala
M64	1	_	Assam
M65	1	_	----
M66	1	Kuchu	Assam
M67	1	_	North East **
M68	1	Guatiakusu	Assam
M69	1	Bankusu	Assam
M70	1	Narkiliakusus	Assam
M71	1	_	Nagaland
M72	1	_	Meghalaya
M73	1	_	North East **
M74	1	_	----
M75	1	_	Nagaland
M76	2	_	Assam, Arunachal
M77	1	_	---
M78	1	Kusu	Sikkim
M79	1	Panchmukhi	Assam
M80	2	_	Morth-East **,
M81	1	Kutchu	Sikkim
M82	1	_	Meghalaya
M83	1	Badai	Karnataka

* Original passport missing, ** Site not traceable from the available information.

4.3.7. Distribution of taro Morphotypes

Distribution of taro morphotypes in the country is given in the table 10 and figure 6. Morphotypes such as 8, 9, 10, 11, 14, 16, 20, 26, 27, 28, 29, 31, 32, 33, 34, 35, 37, 38, 39, 40, 42, 44, 55, 56, 59, 63 and 83 are from southern states especially from Kerala. Nine morphotypes are from North Indian states especially Maharashtra, Orissa, Himachal Pradesh, Uttar Pradesh, Madhya Pradesh, Delhi, etc. Certain Morphotypes such as 2, 7, 12, 13, 15, 18, 19, 22, 23, 24, 41, 50 and 52 have very wide distribution in North as well as in North East and South. Morphotypes such as 9, 10, 14, 20, 31, 32, 33, 34, 35, 37, 38, 42, 44, 56, 59 and 63 are endemic to Kerala, 17 to Orissa, 21, 45, 46, 47, 48, 49, 51, 57, 64, 66, 68, 69 and 79 to Assam, 39 and 40 to Tamil Nadu, 55 and 83 to Karnataka, 53, 72 and 82 to Meghalaya, 78 and 81 to Sikkim, 71 and 75 to Nagaland, 62 to Tripura, 61 to Arunachal Pradesh and 60 to Himachal Pradesh.

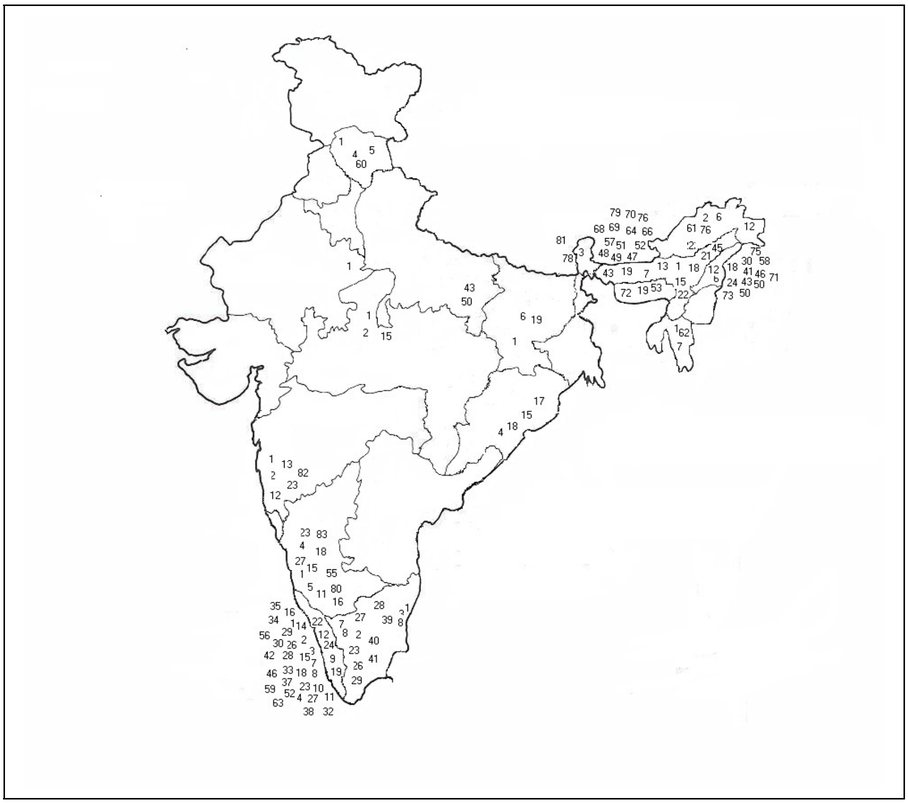


Fig. 6. Distribution of morphotypes in India

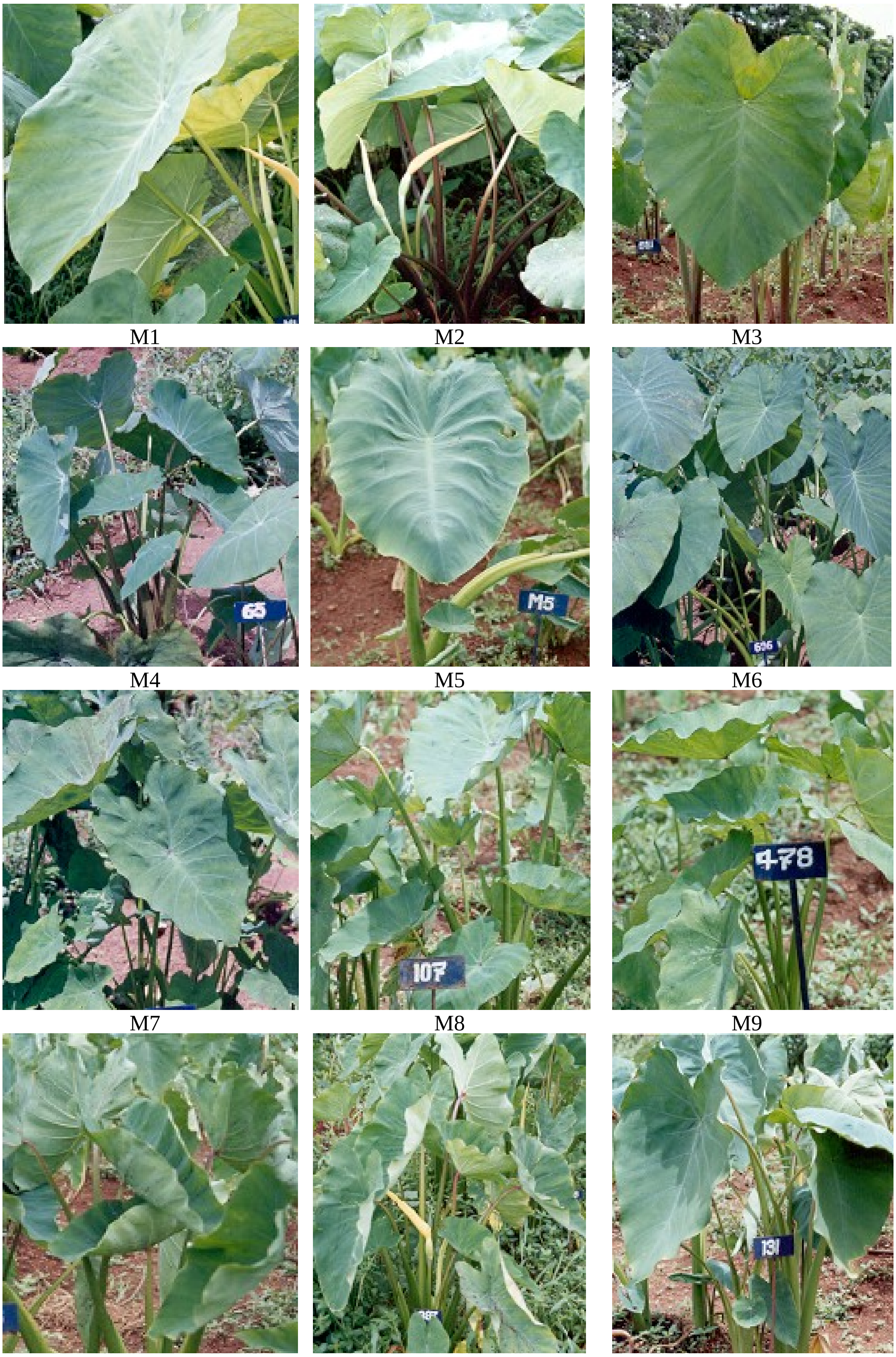


Plate IV. Morphotypes identified in *Colocasia esculenta*

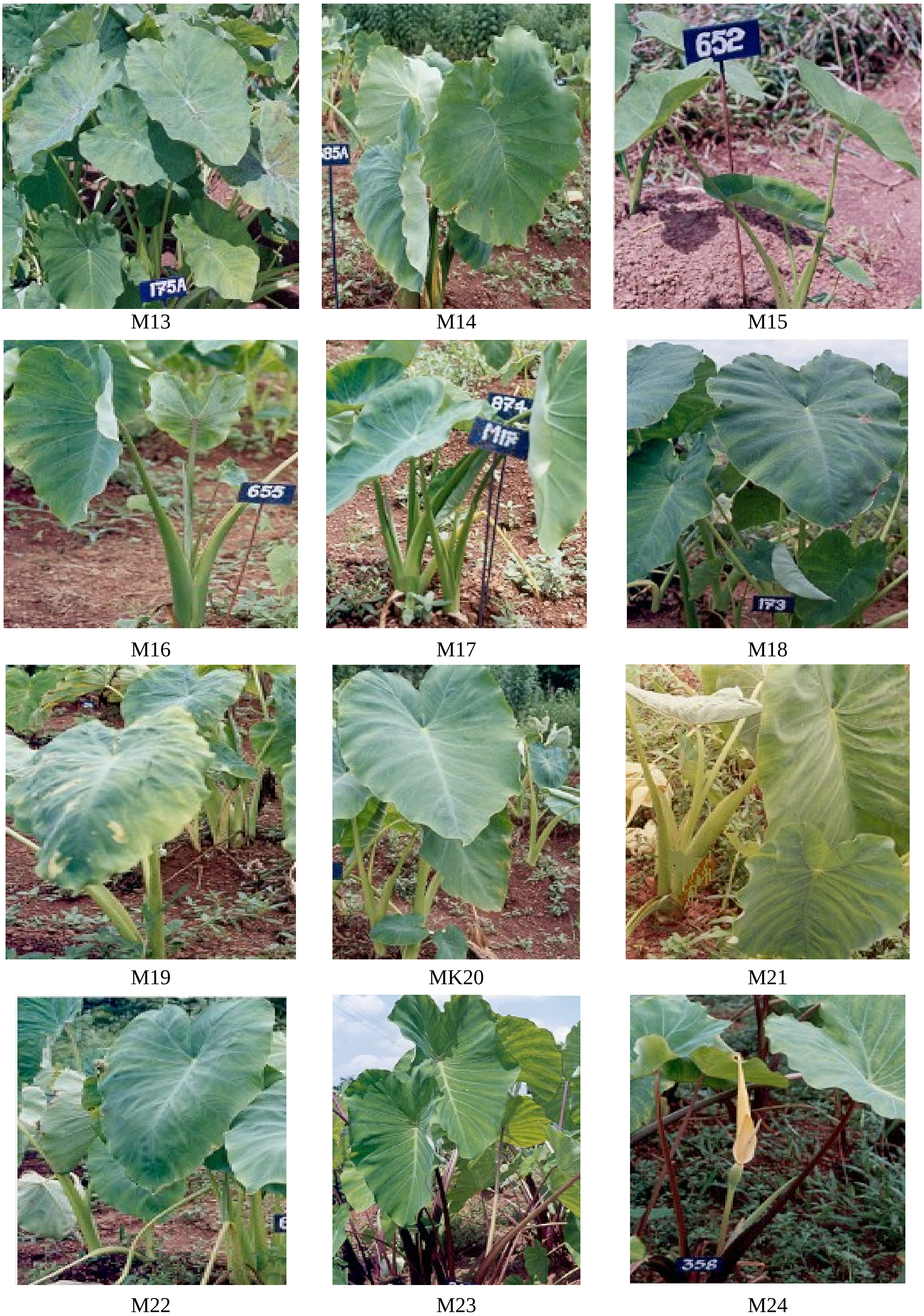


Plate IV. Morphotypes identified in *Colocasia esculenta* (contd.)

M25 M26 M27
M28 M29 M30
M31 M32 M33
M34 M35 M36

Plate IV. Morphotypes identified in *Colocasia esculenta* (contd.)

M37 M38 M39

M40 M41 M42

M43 M44 M45

M46 M47 M48

Plate IV. Morphotypes identified in *Colocasia esculenta* (contd.)

Plate IV. Morphotypes identified in *Colocasia esculenta* (contd.)

M62

M63

M64

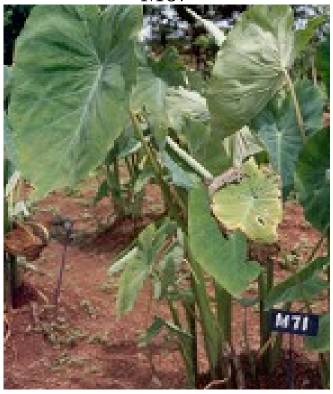
M65

M66

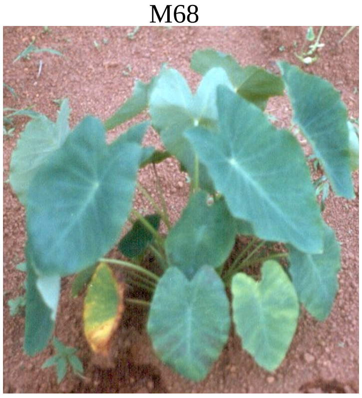
M67

M68

M69



M71

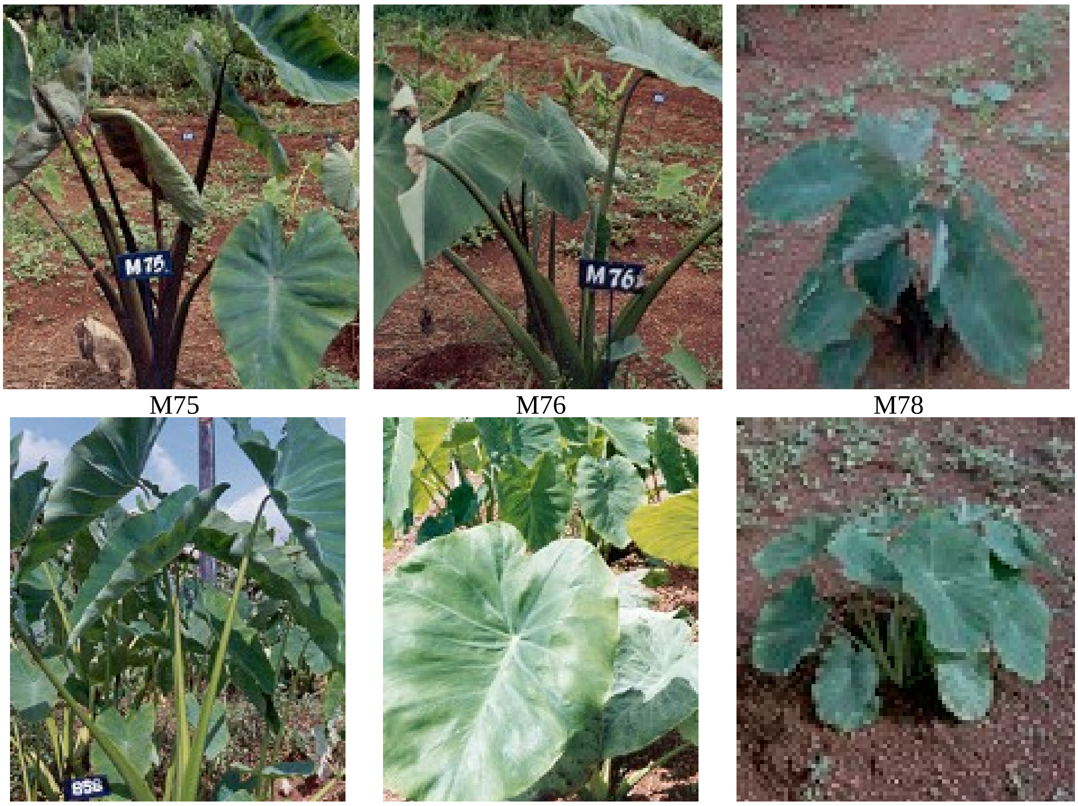


M72

M73

M74

Plate IV. Morphotypes identified in *Colocasia esculenta* (contd.)



M75 M76 M78

M79 M80 M81

Plate IV. Morphotypes identified in *Colocasia esculenta* (contd.)

4.3.8. Qualitative characters in taro morphotypes

Out of a total of 103 aboveground and belowground characters including qualitative and quantitative vegetative, floral parts, plant types, leaf types, sheath types, tuber types, and pest and disease tolerance 14 qualitative aerial characters including those on various plant, leaf, sheath, tuber types and excluding those of the floral parts and blight and aphid tolerance in the field epiphytotic condition are furnished in table 14. Floral characters were dealt under a separate head and the results of preliminary observation on pest and disease under another head. These qualitative characters seemed to be important in assigning them into 83 morphotypes and are given below as 14 descriptors and descriptor states. Frequency class distribution of 14 characters for 83 morphotypes is presented in table 15.

Qualitative descriptors and descriptor states of aerial parts

1. Morphotypes (M): Serial numbers assigned to morphotypes (1-83)

2. Lamina orientation (Lo): 1- Drooping, 2- Horizontal, 3- Cup-shaped, 4- Erect-apex up, 5- erect –apex down, 6-Semi-erect/Semi-droping

3. Lamina margin undulation (Lmu): 1- Low, 2- Medium, 3- High

4. Lamina margin colour (Lmc): 1-Light green, 2- Green, 3- Light purple, 4- purple, 5- Dark purple, 6-Light purple brown, 7- Brown, 8- Purple brown, 9-Dark brown.

5. Lamina colour (Lcol): 1- Light green, 2- Green, 3- Dark green, 4- Bluish green, 5- Green with purple blotches

6. Lamina- petiole joint colour (Lpjcol): 1- Light green, 2- Green, 3- Light purple, 4- Purple, 5- Whitish green, 6- Purple violet, 7- Dark purple violet, 8 – Purple brown, 9- Brown

7. Lamina thickness (Ltk): 1- Low, 2-Medium, 3- High

8. Symmetry of leaf (Lsy): 1- Symmetric, 2- Asymmetric

9. Presence of stolon (Psn): 1- Present, 2-Absent

10. Petiole top colour: (Ptc) 1- Light green, 2- Green, 3- Light purple, 4- Purple, 5- Dark purple, 6 – Light purple brown, 7- Purplish brown, 8- Whitish 9- Purplish green, 10- Greenish purple.

11. Petiole middle colour (Pmc): 1- Light green, 2- Green, 3- Light purple, 4- Purple, 5- Dark purple, 6 – Light purplish brown, 7- Purplish brown, 8- Whitish, 9- Purplish green,

12. Petiole base colour (Pbc): 1- Light green, 2- Green, 3- Light purple, 4- Purple, 5- Dark purple, 6- Light purple brown, 7- Purple brown, 8- Whitish green, 9- Dark purple brown, 10- Greenish purple

13. Sheath nature (Shn): 1-Closed, 2- Medium wide, 3- Wide open

14. Sheath margin colour (Scol): 1- Light green, 2- Green, 3- Light purple, 4- Purple, 5- Dark purple, 6- Whitish green, Dark Purple green, 8- Dark green, 9- Light purple brown

15. Ligule colour (Licol): 1- Light green, 2- Green, 3- Light purple, 4- Purple, 5- Purplish brown, 6- Purplish violet, 7- Dark Purple violet, 8- Dark purple, 9- Greenish purple

Table 15. Morphotype-wise qualitative characters in taro

M.type	Lo	Lmu	Lmc	Lcol	Lpjc	Ltk	Lsy	Ptc	Pmc	Pbc	Shn	Scol	Licol	Psn
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	1	3	1	2	1	2	6	1	1	1	2	5	1	2

2	1	3	4	3	2	2	6	6	3	1	5	5	2	2
3	1	2	4	3	1	2	11	10	6	1	6	4	1	2
4	1	2	4	2	5	2	1	1	11	2	4	7	1	2
5	1	3	1	3	1	1	11	1	1	2	3	3	2	2
6	5	2	3	2	1	2	1	1	1	1	3	6	1	2
7	3	3	1	2	6	1	2	2	2	3	2	2	2	2
8	3	3	5	2	7	3	1	1	1	3	1	8	1	2
9	4	3	5	2	7	3	1	1	1	3	1	8	1	2
10	3	3	6	3	8	3	6	2	2	3	1	6	1	2
11	3	3	8	2	9	3	7	10	2	3	1	6	2	2
12	3	3	7	3	9	2	7	10	2	1	3	6	2	2
13	3	3	1	2	1	3	1	1	1	2	1	1	2	2
14	1	3	1	3	1	2	1	2	7	2	1	2	2	2
15	3	1	2	1	1	2	1	2	2	1	1	2	1	2
16	4	2	4	3	1	2	6	6	3	1	5	5	2	1
17	4	1	1	2	1	1	2	2	2	1	1	1	2	2
18	5	2	1	2	5	3	8	1	1	2	3	4	2	2
19	5	2	1	2	5	3	8	1	1	2	9	4	2	2
20	5	2	1	2	5	3	8	1	1	2	3	4	2	2
21	5	2	1	2	5	3	8	1	1	2	3	4	2	2
22	5	2	1	2	5	3	8	1	1	2	3	4	2	2
23	6	3	5	2	4	3	4	4	9	1	4	9	1	2
24	6	2	5	2	4	3	4	4	9	1	4	9	1	2
25	6	2	5	2	4	3	4	4	9	1	4	9	1	2
26	1	2	5	4	4	2	4	5	5	1	4	9	2	2
27	6	2	5	4	4	2	9	8	5	1	4	9	2	2
29	6	1	4	3	4	3	7	2	2	1	2	4	1	2
30	3	2	5	4	4	3	10	10	2	1	7	10	2	1
31	1	2	8	2	9	3	7	10	2	1	1	6	2	2
32	3	3	5	5	4	5	5	9	10	1	3	9	2	2
33	6	2	1	1		2	11	11	11	1	1	3	2	2
34	6	3	7	2	8	2	9	8	10	1	1	5	2	2
35	6	2	5	2	4	3	4	5	5	1	7	4	2	2
36	5	3	1	2	1	3	11	11	4	2	4	2	2	2
37	6	3	5	2	4	3	11	3	3	1	4	4	2	2
38	6	2	1	2	1	2	5	5	5	2	8	9	1	1
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
39	3	2	7	2	4	3	10	2	2	2	1	2	2	2
40	3	3	5	4	4	2	4	5	5	2	8	9	1	2
41	5	3	3	2	1	2	2	1	1	1	3	1	5	2
42	6	2	1	2	6	1	2	2	2	2	1	2	2	2
43	6	2	3	2	4	2	3	7	1	1	1	1	4	2

44	6	2	4	3	7	1	2	5	2	2	2	2	3	2
45	6	2	3	2	8	2	2	4	2	1	2	3	4	2
46	6	2	2	1	2	1	2	1	1	1	1	1	9	2
47	6	2	2	1	2	1	2	1	1	1	1	1	9	2
48	5	3	2	2	2	2	2	2	2	2	2	8	9	2
49	5	3	2	2	2	2	2	2	2	2	1	8	9	2
12	3	3	7	3	9	2	7	10	2	1	3	6	2	2
13	3	3	1	2	1	3	1	1	1	2	1	1	2	2
14	1	3	1	3	1	2	1	2	7	2	1	2	2	2
15	3	1	2	1	1	2	1	2	2	1	1	2	1	2
16	4	2	4	3	1	2	6	6	3	1	5	5	2	1
17	4	1	1	2	1	1	2	2	2	1	1	1	2	2
18	5	2	1	2	5	3	8	1	1	2	3	4	2	2
19	5	2	1	2	5	3	8	1	1	2	9	4	2	2
20	5	2	1	2	5	3	8	1	1	2	3	4	2	2
21	5	2	1	2	5	3	8	1	1	2	3	4	2	2
22	5	2	1	2	5	3	8	1	1	2	3	4	2	2
23	6	3	5	2	4	3	4	4	9	1	4	9	1	2
24	6	2	5	2	4	3	4	4	9	1	4	9	1	2
25	6	2	5	2	4	3	4	4	9	1	4	9	1	2
26	1	2	5	4	4	2	4	5	5	1	4	9	2	2
27	6	2	5	4	4	2	9	8	5	1	4	9	2	2
29	6	1	4	3	4	3	7	2	2	1	2	4	1	2
30	3	2	5	4	4	3	10	10	2	1	7	10	2	1
31	1	2	8	2	9	3	7	10	2	1	1	6	2	2
32	3	3	5	5	4	5	5	9	10	1	3	9	2	2
33	6	2	1	1		2	11	11	11	1	1	3	2	2
34	6	3	7	2	8	2	9	8	10	1	1	5	2	2
35	6	2	5	2	4	3	4	5	5	1	7	4	2	2
36	5	3	1	2	1	3	11	11	4	2	4	2	2	2
37	6	3	5	2	4	3	11	3	3	1	4	4	2	2
38	6	2	1	2	1	2	5	5	5	2	8	9	1	1
39	3	2	7	2	4	3	10	2	2	2	1	2	2	2
40	3	3	5	4	4	2	4	5	5	2	8	9	1	2
41	5	3	3	2	1	2	2	1	1	1	3	1	5	2
42	6	2	1	2	6	1	2	2	2	2	1	2	2	2
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
43	6	2	3	2	4	2	3	7	1	1	1	1	4	2
44	6	2	4	3	7	1	2	5	2	2	2	2	3	2
45	6	2	3	2	8	2	2	4	2	1	2	3	4	2
46	6	2	2	1	2	1	2	1	1	1	1	1	9	2
47	6	2	2	1	2	1	2	1	1	1	1	1	9	2

48	5	3	2	2	2	2	2	2	2	2	2	8	9	2
49	5	3	2	2	2	2	2	2	2	2	1	8	9	2
50	5	2	5	3	4	3	2	5	5	5	3	8	9	2
51	6	3	5	1	4	2	2	1	1	1	2	1	6	2
52	6	3	8	2	9	3	2	7	2	2	1	1	6	2
53	6	2	1	2	1	2	2	2	2	2	2	4	6	2
54	1	2	4	2	1	2	1	1	1	1	1	8	9	2
55	1	3	1	3	1	1	2	1	1	1	1	3	3	2
56	5	3	4	2	1	3	3	1	1	1	1	5	1	2
57	6	2	3	2	9	3	1	3	3	6	4	3	6	2
58	6	2	5	2	4	2	1	5	5	5	4	4	5	2
59	6	2	5	2	3	2	1	3	4	4	4	1	3	2
60	3	2	5	3	1	3	1	1	1	3	1	3	3	2
61	2	2	2	4	6	1	2	10	2	2	1	3	3	1
62	6	3	4	2	3	1	2	4	1	1	1	1	3	2
63	6	2	1	2	1	3	2	1	1	1	1	1	3	2
64	5	3	3	2	1	2	1	1	1	1	1	3	6	2
65	1	2	7	3	8	2	2	7	12	2	2	3	6	1
66	2	2	5	4	6	1	2	8	8	5	1	4	4	1
67	1	2	4	2	1	1	1	1	1	1	1	6	6	2
68	5	2	1	1	1	3	1	1	1	1	1	1	1	2
69	3	2	2	2	2	1	2	1	2	2	2	1	3	2
70	2	2	3	2	1	1	2	1	6	6	1	1	1	1
71	5	2	4	3	3	1	2	4	2	2	1	3	3	2
72	6	3	3	3	3	1	2	10	2	10	2	1	3	2
73	3	2	6	2	1	1	2	2	2	2	3	4	3	1
74	3	2	2	3	2	2	2	6	6	3	1	5	5	1
75	3	3	4	2	1	1	1	1	1	1	2	6	6	1
76	6	1	2	3	1	2	1	7	2	2	1	1	3	2
77	6	3	3	2	3	2	1	4	1	1	2	3	4	2
78	6	3	5	2	3	2	1	10	9	9	3	4	9	2
79	6	3	3	1	1	2	1	1	1	1	2	1	3	2
80	6	2	1	1	1	1	1	2	2	2	3	1	2	2
81	6	2	2	1	3	2	1	3	1	1	1	1	6	2
82	6	2	1	2	1	1	2	1	1	1	3	1	3	2
83	2	2	4	4	3	2	2	8	8	5	2	4	4	2

Table 16. Frequency distribution of 14 qualitative characters in taro

		Descriptor states (classes)										
#	Descriptors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	Lamina orientation	12	4	11	3	15	33					
2	Lamina margin undulation	4	47	32								
3	Lamina margin colour	21	11	10	13	20	2	4	3			
4	Lamina colour	7	47	17	7	1						
5	Lamina petiole joint colour	28	7		16	6	4	3	4	6		
6	Lamina thickness	21	35	26	26		1	8				
7	Petiole top colour	25	8	4	10	5	4	8	7	2	6	3
8	Petiole middle colour	31	11	1	3	4	2	2	3	4	2	
9	Petiole base colour	30	25	11	3							
10	Sheath nature	44	25	11	3							
11	Sheath margin colour	30	5	17	15	4	3	3	43			
12	Ligule colour	5	7	16	15	7	14	1	2	15	1	
13	Symmetry of leaf	30	51	2								
14	Presence of stolon	11	72									

4.3.9. Aerial quantitative characters in taro

In Table 17, nine various vegetative quantitative characters of aboveground parts are furnished morphotypes-wise with range (minimum and maximum values), mean, Standard Deviation (SD) and phenotypic Coefficient of Variation (CV%). The phenotypic CV% for most of the morphotypes appears to be low indicating uniformity within the types i.e., between various individual collections within a group. However, in certain morphotypes the CV% is > 30% for some characters indicating higher extent of phenotypic variation within given types.

The range of CV% with respect to the computed values derived from the morphoptype-wise means for the entire stock varied from 24.0 to 236.64, 20.0 to 93.5, 11.0 to 57.5, 14.0 to 69.5, 11.0 to 50.0, 7.23 to 19.0, 6.5 to 12.0, 1.03 to 8.0 and 0.70 to 2.7 with respect to Plant height, Petiole length, Sheath length, Lamina length, Lamina width, Sinus width, Sinus depth, Leaf number and Sheath channel depth respectively. Wherever the value is of a single collection or accession no range, SD and CV% have been given.

Table 17. Aerial quantitative characters of taro morphotypes

Morpho	Para-meter	Plant height (cm)	Petiole length (cm)	Sheath length (cm)	Lamina length (cm)	Lamina width (cm)	Sinus width (cm)	Sinus depth (cm)	Leaf no.	Sheath depth (cm)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	Min.	70.75	59.5	32.25	32.5	27.5	7.25	7	3.5	1.3
	Max.	110	90	64.05	60	48.75	22.5	12.5	6	2.65
	Mean	93.6	77.52	45.58	46.81	38.37	13.5	9.71	4.36	1.77
	SD	9.61	7.09	5.55	4.93	3.98	3.02	1.91	0.44	0.31
	CV%	1.07	0.79	0.62	0.55	0.45	0.34	0.13	0.5	0.04
2	Min.	75.75	60.25	35.5	32.75	28.5	10.25	6.75	3	1.22
	Max.	115.5	96.25	57	55.5	43.5	19	13.25	5	2.75
	Mean	93.75	77.06	45.16	47.44	37.4	14.73	10.04	4.15	1.75
	3SD	8.13	7.19	4.78	4.38	3.12	2.05	1.46	0.52	0.3
	CV%	1.09	0.97	0.65	0.59	0.42	0.28	0.2	0.07	0.04

1	2	3	4	5	6	7	8	9	10	11
3	Min.	93.52	75.5	38	45	37.5	15.5	10.5	4	1
	Max.	99.5	81	43.5	48.5	41.75	19	12.5	5	1.45
	Mean	96.6	78.1	40.7	47	40.05	17.9	11.3	4.5	1.23
	SD	2.27	2.16	2.41	1.32	1.72	1.39	0.91	0.5	0.18
	CV%	1.045	1.242	2.826	0.052	1.923	3.464	3.54	4.889	6.504
4	Min.	71	58	31.5	28.5	24.5	10.5	7	4	1.1
	Max.	105	87	52	48	38	14.5	10.5	5.5	2.25
	Mean	89.22	72.94	42.5	37.94	31.39	12.94	8.44	4.89	1.52
	SD	10.68	9.49	6.33	5.71	3.72	1.36	1.13	3.55	0.35
	CV%	3.99	4.332	4.965	15.05	12.89	10.51	13.38	77.13	23.03
5	Min.	74	59	28.5	37	30	11.5	8	3.5	0.85
	Max.	87	69.5	40	42.5	36	14.5	9	5	1.75
	Mean	80.87	64.38	35	39.25	33.38	13.13	8.69	4.25	1.41
	SD	5.63	4.37	4.88	2.53	2.69	1.38	0.47	0.65	0.39
	CV%	5.06	6.79	13.94	6.45	8.05	10.51	5.41	15.29	27.66
6	Min.	78.52	64	28.5	31	29	13	9	4	1.05
	Max.	96	76.2	40.5	44.75	37.5	17	10	4	1.7
	Mean	88.33	71.33	35	39.75	34	15.58	9.5	4	1.4
	SD	8.95	6.43	6.06	7.6	4.44	2.24	0.5	-	0.33
	CV%	10.13	8.59	17.31	19.12	13.06	15.4	5.26	-	23.57
7	Min.	60.52	52	28.5	22.25	15.5	8	5	3.52	0.85
	Max.	88	72.5	40	35	27	15	10.5	5.5	0.19
	Mean	75.9	62.6	38.68	28.59	21.61	11.03	7.66	4.5	1.28
	SD	8.66	6.87	5.3	3.88	2.91	1.63	1.54	0.61	0.28
	CV%	11.41	10.97	13.7	13.57	13.47	14.78	20.1	13.56	21.71
8	Min.	73.5	55	35	28.75	22.75	5.38	6.75	4	1.1
	Max.	96	79.5	46	33.5	28	14	10	6	2
	Mean	84.71	69.09	41.28	31.63	25.44	10.83	8.51	4.94	1.59
	SD	7.26	6.38	2.96	1.61	1.64	1.87	0.83	0.56	0.25
	CV%	8.57	9.23	7.17	5.09	6.45	17.27	9.75	11.34	15.72
9	Mean	92.5	76	44.5	34.5	25.5	11.75	9	5	1.55

1	2	3	4	5	6	7	8	9	10	11
10	Min.	73.52	60	35	25.5	20	10.5	7.75	3.5	1.4
	Max.	100.5	85.5	50	33	27.75	14	9.75	6	2
	Mean	81.86	67.5	40.21	29.14	23.64	12.43	8.71	5	1.74
	SD	9.02	8.63	5.12	2.49	2.52	1.23	0.7	0.91	0.23
	CV%	11.02	12.79	12.73	8.54	10.66	9.9	8.04	18.2	13.22
11	Min.	39.5	32.52	17.5	19	12.75	6.75	5.5	4	0.95
	Max.	101	85	49	38.5	30.5	16.5	9.5	6	2.4
	Mean	85.19	70.07	40.1	30.64	23.76	12.84	-	5.39	1.83
	SD	9.64	8.32	5.01	2.98	2.81	1.93	-	0.65	0.3
	CV%	11.32	11.87	12.49	9.73	11.83	15.03	-	12.06	16.39
12	Min.	78	65.5	35	26.5	18	9.5	7	5	1.6
	Max.	103.5	88.5	63.5	43.5	34.5	18.5	14	6	2.5
	Mean	94.41	80.47	49.85	37.16	29.68	13.84	11.02	5.59	1.99
	SD	7.17	6.29	6.83	4.52	4.19	2.57	1.98	0.44	0.28
	CV%	7.59	7.82	13.70	12.16	14.12	18.57	17.97	7.87	14.07
13	Min.	86	69	50.5	40.5	33.5	9.75	7.5	4.5	2.25
	Max.	97.5	81	68	47.5	42.5	14	10.5	5.5	3.05
	Mean	93.33	75.83	57.5	43	38.17	11.92	8.67	4.83	2.7
	SD	6.37	6.17	9.26	3.91	4.51	2.13	1.61	0.58	0.41
	CV%	6.83	8.14	16.10	9.09	11.82	17.87	18.57	12.01	15.19
14	Min.	79	62.5	38	33.5	27.5	9	8.75	5	1.65
	Max.	91	75	49	39	32.5	11	11	5	2.05
	Mean	83.1	67.1	41.6	35.8	30.2	10	9.65	5	1.86
	SD	4.85	5.3	4.68	2.11	1.79	0.79	1.03	-	0.15
	CV%	5.84	7.90	11.25	5.89	5.93	7.90	10.67	-	8.06
15	Min.	70	59	30	25	17.5	6.25	6.25	4	1.05
	Max.	83	70	38	33	23	10.5	8.25	5	1.9
	Mean	75.77	64.07	33.59	29.64	21.27	7.23	7.3	4.5	1.53
	SD	4.56	3.75	2.52	2.25	1.63	1.19	0.62	0.5	0.22
	CV%	6.02	5.85	7.50	7.59	7.66	16.46	8.49	11.11	14.38

1	2	3	4	5	6	7	8	9	10	11
16	Min.	73	59	33	30.5	19.75	7	6.5	5	1.4
	Max.	74	62.5	36	31.5	25	11	10.25	5	1.5
	Mean	73.5	60.75	34.5	31	22.38	9	8.38	5	1.45
	SD	0.71	2.48	2.12	0.71	3.71	2.83	2.65	-	0.07
	CV%	0.97	4.08	6.14	2.29	16.58	31.44	31.62	-	4.83
17	Mean	74.5	60.5	31	30.5	21.5	8	7.5	5	1.8
18	Min.	61	50.5	27.5	24.5	17.5	7	7	3	0.8
	Max.	103	81.5	47	50	43.5	16	13	5	2.25
	Mean	82.2	65.88	39.85	40.35	34.35	12.58	10.59	1.03	1.82
	SD	10.28	7.59	4.95	6.37	6.7	1.87	1.6	0.34	1.38
	CV%	12.51	11.52	12.42	15.79	19.51	14.86	15.11	33.01	75.82
19	Min.	72	57	36	39	30.25	10	9.25	4	1.75
	Max.	88	75.5	45.5	49.5	40	14.5	11.5	5	2.35
	Mean	78	62.44	40.38	43.75	35.34	12.38	10.09	4.38	1.97
	SD	6.26	5.1	3.81	3.4	3.34	1.51	0.81	0.35	0.22
	CV%	8.03	8.17	9.44	7.77	9.45	12.20	8.03	7.99	11.17
20	Min.	77	59	37.5	45	38.5	9.5	9.75	3.5	1.65
	Max.	87	68	41	47.5	40	10.5	10.25	4	1.75
	Mean	82	63.5	39.25	46.25	39.25	10	10	3.75	1.7
	SD	7.07	6.36	2.48	1.77	1.06	0.71	0.35	0.35	0.07
	CV%	8.62	10.02	6.32	3.83	2.70	7.10	3.50	9.33	4.12
21	Mean	77	36.5	41	38.5	31.5	10	9.5	4	1.4
22	Min.	79.5	55	30	27	22	9	7.25	4	1.1
	Max.	84.5	62.5	37	43.5	36	11.5	10.25	4	2
	Mean	82	58.75	33.5	35.25	29	10.25	8.75	4	1.55
	SD	3.54	5.3	4.95	11.67	9.9	1.77	2.12	-	0.64
	CV%	4.32	9.02	14.78	33.11	34.14	17.27	24.23	0.00	41.29
23	Min.	121.95	56.5	30	38	32.5	8.5	6.5	2.5	1.5
	Max.	282.50	92.5	53	64	55	19	15	5	2.5
	Mean	231..64	73.65	41.69	51.52	42.9	13.97	11.67	3.65	2.01
	SD	82.00	9.25	5.5	6.04	5.34	2.41	1.75	0.52	0.21
	CV%	3.54	12.56	13.19	11.72	12.45	17.25	15.00	14.25	10.45

1	2	3	4	5	6	7	8	9	10	11
24	Min.	86.75	59.5	38	47	38.5	11.5	9	3.5	1.75
	Max.	116.5	95	54.5	67	52.5	17	13.5	4.5	2.85
	Mean	92.31	77.5	47.16	55.94	45.94	13.94	11.83	4	2.14
	SD	22.32	9.5	5.08	5.92	4.59	1.91	1.28	0.25	0.34
	CV%	7.42	3.16	1.69	1.97	1.53	0.64	0.43	0.08	0.11
25	Mean	98	73.5	43	54.5	41.5	13.5	12	4	2.2
26	Min.	62	54.5	30	27	20	8.5	7	4.5	0.9
	Max.	99.5	85.5	51	42.5	32.75	18.5	12.5	6.5	1.7
	Mean	83.17	69.89	40.13	33.96	25.83	11.88	8.88	5.19	1.31
	SD	10.3	8.71	5.34	4.68	3.84	2.32	1.4	0.46	0.28
	CV%	12.38	12.46	13.31	13.78	14.87	19.53	15.77	8.86	21.37
27	Min.	64	55	34	27.5	22.5	11.25	7.5	4.5	0.95
	Max.	124	110	77	53	47.5	17	14.5	5.5	2.7
	Mean	82.71	72.57	45.93	33.11	28.64	13.29	9.3	5.07	1.33
	SD	20.35	19.54	14.63	9.19	8.85	1.86	2.4	0.35	0.63
	CV%	24.60	26.93	31.85	27.76	30.90	14.00	25.81	6.90	47.37
28	Min.	69.5	64.5	34	32	25.5	11	9.5	3	1.42
	Max.	116.5	102	57	43.75	36.25	15	13.25	4.5	2.4
	Mean	97.22	85.93	49.79	38.39	30.43	13.5	11.43	3.93	1.79
	SD	15.07	11.37	7.59	3.59	3.69	1.63	1.2	0.45	0.36
	CV%	15.50	13.23	15.24	9.35	12.13	12.07	10.50	11.45	20.11
29	Min.	68.5	58	31.5	30	24	9	7.75	3	1.25
	Max.	71	61.5	33.5	31.5	26	9.5	8	4	1.3
	Mean	69.75	59.75	32.5	30.75	25	9.25	7.88	3.5	1.25
	SD	1.77	2.48	1.41	1.06	1.41	0.35	0.18	0.71	0.04
	CV%	2.54	4.15	4.34	3.45	5.64	3.78	2.28	20.29	3.20
30	Min.	51	45	26	24	17.5	9	7.25	4	1.3
	Max.	72.5	63.5	39	30.5	21.5	12.25	9.75	4.5	1.75
	Mean	61.75	52.25	32.5	27.25	19.5	10.75	8.5	4.25	1.53
	SD	15.2	13.08	9.19	4.6	2.83	2.48	1.77	0.35	0.32
	CV%	24.62	25.03	28.28	16.88	14.51	23.07	20.82	8.24	20.92

1	2	3	4	5	6	7	8	9	10	11
31	Min.	77.5	71.5	44	27	21.5	9.25	7	6	1.25
	Max.	91	80	47.5	27.5	22	10	7.5	6.5	1.3
	Mean	84.25	75.75	45.75	27.25	21.75	9.63	7.25	6.25	1.28
	SD	9.55	6.01	2.48	0.35	0.35	0.53	0.35	0.35	0.04
	CV%	11.34	7.93	5.42	1.28	1.61	5.50	4.83	5.60	3.13
32	Min.	72.5	61.5	31	28.25	21.5	12.5	9.25	5	1.3
	Max.	88	74.5	41	24.5	25.5	15.5	13.25	6	1.85
	Mean	78.16	67	36.83	31.42	23.08	13.33	11.46	5.42	1.6
	SD	5.49	4.2	3.6	2.31	1.33	1.17	1.2	0.49	0.23
	CV%	7.02	6.27	9.77	7.35	5.76	8.78	10.47	9.04	14.38
33	Mean	42	31	19	23	18	-	-	4	0.9
34	Mean	74	66.5	45.5	30.75	31	13.5	8.5	6	1.75
35	Mean	102	87.5	46	44	34	12	9.25	4	1.85
36	Mean	102.5	86.5	51.5	41.25	28	13.5	9.5	5	1.2
37	Mean	102.5	56	53.5	50.5	38.5	14.5	11	4	1.75
38	Mean	81	68	44	34.5	30.5	13	11.5	3.5	1.2
39	Mean	74	63.5	36.5	29.5	22.5	13.5	10	4	1.25
40	Mean	93.5	86.5	40.5	38.5	31.5	15	11.75	5	1.65
41	Min.	89.5	74	43	41.5	34	13.5	10.5	4	1.4
	Max.	105	88.5	49.5	48.5	38	17	12	4	2
	Mean	98.33	82.67	45.33	44.08	35.83	15.5	11.33	4	1.63
	SD	7.97	7.65	3.62	3.84	2.02	1.8	0.76		0.32
	CV%	8.11	9.25	7.99	8.71	5.64	11.61	6.71	0.00	19.63
42	Mean	85	67	36	24	21	-	-	8	1.3
43	Min.	89.5	71	40.5	32	29	12.5	8	4.52	1.5
	Max.	104.5	91	56.5	33	32	14.5	9.5	5	1.8
	Mean	97.33	86	50.17	32.33	30.5	13.67	8.67	4.67	1.65
	SD	7.52	6.25	8.51	0.58	1.5	1.04	0.76	0.29	0.15
	CV%	7.73	7.27	16.96	1.79	4.92	7.61	8.77	6.21	9.09
44	Min.	83	73.5	39	28	20	11	8.5	4	1
	Max.	95.5	83	46	36.5	29.5	12.5	8.5	5	1.1
	Mean	89.25	78.15	42.5	32.25	24.75	11.75	8.5	4.5	1.05
	SD	8.84	6.72	4.95	6.01	6.72	1.06	-	0.71	0.07
	CV%	9.90	8.60	11.65	18.64	27.15	9.02	0.00	15.78	6.67
45	Mean	90.5	78.5	48.5	29	24.75	12.5	9.5	4	0.95

1	2	3	4	5	6	7	8	9	10	11
46	Min.	68	60	29.5	32.5	26.5	12	7.5	4	1
	Max.	81	73.5	43.5	35	29	15	8	4.5	1.4
	Mean	74.5	66.75	36.5	33.75	27.75	13.5	7.75	4.25	1.2
	SD	9.19	9.55	9.9	1.77	1.77	2.12	0.35	0.35	0.28
	CV%	12.34	14.31	27.12	5.24	6.38	15.70	4.52	8.24	23.33
47	Mean	76.5	66	36.5	35.5	30	14.5	9	5	1.5
48	Mean	89	80	47.5	49.5	38.5	13	9.5	4	1.45
49	Mean	87	75	47	46	36	14.5	9.75	4	1.4
50	Min.	88	74	35	35	27.5	9.5	8.5	3	1.1
	Max.	102	88.5	47.5	47	39.5	17.5	10	4.5	1.8
	Mean	97	82.43	43	42.86	35.21	13.79	9.39	3.71	1.48
	SD	4.68	4.75	4	4.14	3.95	2.45	0.45	0.57	0.3
	CV%	4.82	5.76	9.30	9.66	11.22	17.77	4.79	15.36	20.27
51	Mean	116	93	55	55	44.5	16	10	4	2.25
52	Min.	92	75	38.5	47	38	14	9.5	4	1.35
	Max.	108.5	86	49	67	49	19.5	11	4	2.25
	Mean	99.17	82.33	44.17	55	42.67	16	10.17	4	1.83
	SD	8.46	6.35	5.3	10.58	5.69	3.04	0.76	-	0.45
	CV%	8.53	7.71	12.00	19.24	13.33	19.00	7.47	0.00	24.59
53	Mean	78	65	18	21	26	10	7.5	6	1.6
54	Mean	37	30	11	14	11	13	9	3	0.7
55	Mean	94	77.5	41	52.5	37	15.5	10.5	4.5	2
56	Mean	99	84.5	46.5	59	48	13.5	9.25	4	2
57	Mean	107.5	93.5	48.5	42.5	33.5	11.5	8.5	4	1.25
58	Min.	86.5	71.5	43	38	30.5	12	7.5	5.5	1.7
	Max.	105.5	95.5	58.5	46.5	41	13.5	10	6.5	2.05
	Mean	102.83	85.5	53	43.5	36.5	13	8.67	5.83	1.92
	SD	14.84	12.49	8.68	4.77	5.41	0.87	1.26	0.58	0.19
	CV%	14.43	14.61	16.38	10.97	14.82	6.69	14.53	9.95	9.90
59	Mean	94	77	47	43.5	33	12	8	6.5	1.55
60	Mean	57.75	93.5	53	69.5	50	17.5	11	4.5	2.15
61	Mean	90	79	41.5	28.5	19.5	13.5	9	3.5	1.35
62	Mean	80	66	31.5	36	29.5	11.5	8.25	4	1
63	Mean	56.5	47.25	27	28.5	26	11.5	8.5	5	1

1	2	3	4	5	6	7	8	9	10	11
64	Mean	92.5	76.5	44	49.5	40	19	12	4	1.44
65	Mean	54.5	50	27.5	25	17.5	16	9.5	4	0.7
66	Mean	71	64.5	36	28	24	11.5	9.5	4.5	1.1
67	Mean	94	79.5	55.5	45	35	15.5	9	4.5	1.1
68	Mean	91.5	75	49.5	45.5	37	16.5	9	5.5	1.25
69	Mean	60	56	22	21	15	9.5	8.25	6	1.2
70	Min.	61.5	53	26	23.5	15.5	9	6.5	5	0.85
	Max.	66	60.5	38	26.25	23.75	12.5	8	5	1.05
	Mean	63.75	56.75	32	24.88	19.63	12.75	7.25	5	0.95
	SD	3.18	5.3	8.49	1.95	5.83	2.48	1.16	-	0.14
	CV%	4.99	9.34	26.53	7.84	29.70	19.45	16.00	0.00	14.74
71	Mean	86	75.4	38	29	25.5	15.5	9.5	5	1.05
72	Mean	60	77	23.75	37	30.5	-	-	-	-
73	Mean	55	49.5	31	27	16.5	10	7.5	7	1
74	Mean	56.5	52.5	31	26	16.5	9.5	6.5	6.5	1
75	Mean	70	60	34.5	29.25	25.5	14.5	9.5	5	1.8
76	Min.	77	66.5	40	26	22	13.5	6.5	4	0.75
	Max.	79.5	72	41.5	28.5	25.5	14	9	5	0.8
	Mean	78.25	69.25	40.75	27.25	23.75	13.75	7.75	4.5	0.78
	SD	1.77	3.89	1.06	1.77	2.48	0.35	1.77	0.71	0.04
	CV%	2.26	5.62	2.60	6.50	10.44	2.55	22.84	15.78	5.13
77	Mean	63.5	54.5	32.5	24	18.25	10	6.5	4	0.75
78	Mean	75.5	62.5	34	30.5	24.5	14.5	8.5	5	1.35
79	Mean	53	44	24	23.5	18.5	10	7.5	4	0.7
80	Mean	44	36	13.5	27.5	25.5	---	---	3	1.1
81	Mean	53	73	19	24	20.25	10	8.5	5	1.5
82	Mean	24	20	15	15	13.5	----	----	----	----
83	Mean	77	70	40	30.5	27.75	----	----	----	----
For whole collections										
	Min.	24.00	20.00	11.00	14.00	11.00	7.23	6.50	1.03	0.70
	Max.	236.64	93.5	57.5	69.5	50	19	12	8	2.7
	Mean	107.38	68.36	38.99	36.23	29.18	12.80	9.25	4.58	1.47
	SD	246.016	14.484	9.889	10.553	8.393	2.317	1.340	0.967	0.402
	CV%	229.10	21.19	25.36	29.13	28.77	18.10	14.50	21.11	27.32

4.3.10. Underground quantitative characters in taro

Morphotype-wise Range, Mean, Standard Deviation and CV% of seven quantitative underground vegetative characters are also furnished in Table 18. Apart from these Range, Mean, Standard Deviation and phenotypic CV% are also given for the entire collection. The phenotypic CV% highly varied for all the characters within and between morphotypes. It was low for all the characters except for tuber fresh weight and mother fresh weight. The range, SD and CV% are not given for those morphotypes with one representative accession each. CV% for various charcters varied from 25.50 for mother tuber thickness to 66.87% in tuber number and mother tuber weight and 87. As compared to aerial characters variability observed was more in underground characters.

Table 18. Underground quantitative characters

Morpho-	Para-meter	Mother tuber Length (cm)	Mother tuber Thickness (cm)	Tuber Number	Tuber length (cm)	Tuber thickness (cm)	Tuber weight (g)	Mother tuber weight (g)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	Min.	4.55	2.9	4	5.8	2.45	125	30
	Max.	9.45	7.2	13	15.5	4.5	1900	700
	Mean	6.84	4.99	7.94	10.27	3.28	967.38	353.82
	SD	1.1	0.68	1.85	1.64	0.45	362.47	106.3
	CV%	16.08	13.63	23.30	15.97	13.72	37.47	30.04
2	Min.	4	3.25	4	5.2	1.43	200	150
	Max.	7.55	5.8	13	13	4.25	1550	550
	Mean	5.32	4.52	8.2	8.04	2.92	961.27	339.73
	SD	0.83	0.54	1.9	1.28	0.44	269.44	100.82
	CV%	15.60	11.95	23.17	15.92	15.07	28.03	29.68

1	2	3	4	5	6	7	8	9
3	Min.	6.5	3.75	9	6.5	2.25	750	450
	Max.	7.75	4.5	10	10	3.25	1200	550
	Mean	7	4.1	9.4	8.5	2.75	970	530
	SD	0.59	0.34	0.42	1.45	0.35	182.35	44.72
	CV%	8.43	8.29	4.47	17.06	12.73	18.80	8.44
4	Min.	7.5	2.75	4.5	6.75	1.75	550	300
	Max.	16	5.75	7	10.5	3.25	115.5	1100
	Mean	10.92	4.17	6.28	8	2.53	772.22	547.22
	SD	2.88	0.98	0.71	1.17	0.44	200.17	267.06
	CV%	26.37	23.50	11.31	14.63	17.39	25.92	48.80
5	Min.	7	2.75	6.5	5.5	1.5	250	250
	Max.	10.25	4.25	12.5	8.5	2.25	325	450
	Mean	8.69	3.38	9.75	7.56	1.81	306.25	312.5
	SD	1.81	0.67	3.2	1.39	0.38	37.5	94.65
	CV%	20.83	19.82	32.82	18.39	20.99	12.24	30.29
6	Min.	6	2.75	6.5	7.6	1.5	325	150
	Max.	7	3.25	9	8.75	2.5	800	450
	Mean	6.5	3	7.67	8.12	2.07	483.33	300
	SD	0.5	0.25	1.26	0.58	0.51	274.24	150
	CV%	7.69	8.33	16.43	7.14	24.64	56.74	50.00
7	Min.	3.5	2	2.5	3.25	1.5	50	30
	Max.	10.25	4.75	9	9.5	2.75	550	300
	Mean	6.09	3.65	6.93	5.84	1.98	251.5	176.5
	SD	1.4	0.82	1.95	1.57	0.29	120.71	87.66
	CV%	22.99	22.47	28.14	26.88	14.65	48.00	49.67
8	Min.	5	3.25	5	3.5	2	100	50
	Max.	11	5.25	16.5	9	3.25	800	600
	Mean	6.92	4.38	9.94	6.18	2.48	447.06	288.24
	SD	1.59	0.66	2.87	1.45	0.44	173.63	184.16
	CV%	22.98	15.07	28.87	23.46	17.74	38.84	63.89
9	Mean	5.25	4	10	6.25	2.5	600	200
10	Min.	3	2.5	5	4.75	2.05	100	25
	Max.	7.5	5.25	13	8.25	3	500	300
	Mean	5.03	3.46	8.43	6.12	2.48	342.86	93.57
	SD	1.58	0.92	2.7	1.17	0.32	142.68	101.23

1	2	3	4	5	6	7	8	9
	CV%	31.41	26.59	32.03	19.12	12.90	41.61	108.19
11	Min.	4.75	3.5	2.5	4.75	2	50	100
	Max.	9.25	7	7.5	9.5	4.85	1150	600
	Mean	5.93	5.01	5.05	6.53	2.86	487.71	366
	SD	0.84	0.69	1.33	1.21	0.51	212.52	128.5
	CV%	14.17	13.77	26.34	18.53	17.83	43.58	35.11
12	Min.	8	4	3	6.25	2	150	100
	Max.	12.25	7	10	12	4.5	950	900
	Mean	10.47	5.28	6.06	8.32	2.77	524.12	579.41
	SD	1.189	0.89	2.08	1.53	0.68	220.12	211.91
	CV%	11.36	16.86	34.32	18.39	24.55	42.00	36.57
13	Min.	8	6.5	8.5	7	2	500	350
	Max.	9.5	7.5	9	11	13	700	800
	Mean	8.5	7	8.67	9	5.83	600	516.67
	SD	0.87	0.5	0.29	2	6.2	100	246.64
	CV%	10.24	7.14	3.34	22.22	106.35	16.67	47.74
46	Min.	9	3.75	5	10.25	2.25	350	200
	Max.	11.25	4.5	19.5	12.25	2.5	11000	550
	Mean	10.13	4.13	12.25	11.25	2.38	725	375
	SD	1.59	0.53	10.25	1.41	0.18	530.33	247.49
	CV%	15.70	12.83	83.67	12.53	7.56	73.15	66.00
47	Mean	8.75	4.6	16.56	9.25	2.9	1150	500
48	Mean	5.75	5.65	14.3	8.75	3.1	900	600
49	Mean	6.35	4.85	13	8.25	2.6	650	700
50	Min.	4.5	4.75	10.5	5	2.5	550	400
	Max.	6	6.4	14	9	3.75	1450	980
	Mean	5.3	5.42	12.5	6.75	3.24	1102.86	632.86
	SD	0.61	0.61	1.12	1.51	0.44	318.42	230.7
	CV%	11.51	11.25	8.96	22.37	13.58	28.87	36.45
51	Mean	9	7.25	10.5	15.75	3	1000	1100
52	Min.	6.75	5.25	14.5	8.75	1.25	800	800
	Max.	10	6.75	21	21.5	2.4	920	1350
	Mean	8.5	6.25	17.17	16.5	1.8	873.33	1066.67
	SD	1.64	0.87	3.4	6.81	0.58	64.29	275.38
	CV%	19.29	13.92	19.80	41.27	32.22	7.36	25.82
53	Mean	6	6	8	8	4	100	500

54	Man	4	4	17	6	2	200	100
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
55	Mean	5.25	4.75	14.5	9.5	3.25	1600	510
56	Mean	10.5	7.75	7	23	2.25	500	1300
57	Mean	12	4.5	9	10.25	3.5	950	350
58	Min.	15.75	50	2	14.5	3.15	250	450
	Max.	23.75	5.75	4	17.75	4.1	1100	1100
	Mean	20.17	5.5	3	16.08	3.62	550	833.33
	SD	4.07	0.43	1	1.63	0.48	476.97	840.34
	CV%	20.18	7.82	33.33	10.14	13.26	86.72	100.84
59	Mean	14.25	4.75	4.5	8.6	2.85	200	600
60	Mean	8.75	7	9	26	2.75	1050	1200
61	Mean	6.5	4.5	7	7.5	1.1	260	250
62	Mean	4.65	3.5	12.5	7.5	2.75	400	150
63	Mean	6.5	3.9	9.5	8.1	0.1	700	250
64	Mean	5	5.1	10.56	8.25	2.66	1200	400
65	Mean	4	3.2	8.5	9	1.5	50	25
66	Mean	7.5	4	6.5	11.25	2	400	250
67	Mean	12.75	4.1	12	9.25	2.9	700	300
68	Mean	11.5	6.75	5	11	4.75	450	950
69	Mean	9	5	5	11	2	500	100
70	Min.	5.5	3.2	10.5	5.75	1.75	180	25
	Max.	10	3.75	10.5	8.5	1.75	200	100
	Mean	7.75	3.48	10.5	7.13	1.75	190	62.5
	SD	3.18	0.39		1.95		14.14	53.03
	CV%	41.03	11.21		27.35	0.00	7.44	84.85
71	Mean	8.75	4.75	17.5	7	3.25	1050	740
72	Mean	4	9	26	8	4	1400	600
73	Man	15.25	4.75	13	9.75	3.15	200	300
74	Mean	15.75	5.5	14	13.5	3	300	150
75	Mean	5	7	9	9	3	100	500
76	Min.	5.5	4	6	8.5	2.4	400	100
	Max.	6	4.5	13	12.75	2.75	700	170
	Mean	5.75	4.25	9.5	10.63	2.58	550	135
	SD	0.35	0.35	4.95	3.01	0.25	212.13	49.5
	CV%	6.09	8.24	52.11	28.32	9.69	38.57	36.67
77	Mean	6.5	2.95	11	7.25	2.75	450	150

78	Mean	6.75	4.75	10	6	2.6	350	300
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
79	Mean	5	3	10	8.5	1.65	50	50
80	Mean	11	5	6	8	2	---	---
81	Mean	5	5	6	7	2	800	600
82	Mean	---	---	----	---	----	----	---
83	Mean	13	5	2	11	4	200	200
For Whole collection								
	Min.	1.00	2.25	2.00	5.50	0.10	3.30	25.00
	Max.	20.17	9	26	26	7	1600	1300
	Mean	7.73	4.81	8.99	9.59	2.73	541.48	443.20
	SD	3.158	1.228	4.067	3.709	0.962	359.831	296.353
	CV%	40.84	25.50	45.26	38.66	35.19	66.45	66.87

4.3.11. Flowering in taro morphotypes

A total of 293 accessions of taro belonging to 55 morphotypes flowered during the course of present study. Others did not flower indicating very shy nature of flowering in the *ex - situ* field conditions at Vellanikkara. Table19 presents 13 quantitative characters of these morphotypes with Range, Mean and SD (for types having more than one collection) and Mean for types having one collection in each. The number of flowering accessions varied from to one each in M5, 17, 25, 28, 33, 34, 35, 36, 37, 43, 46, 47, 48, 49, 51, 55, 56, 58, 60, 63, 64, 65, 67, 68, 71, 75, 78, 79, 80 and 81-80 in M1. The major difference was noticed in the case of male part length and the sterile part length based on which two distinct groups related to *C. esculenta* var. *esculenta* (Plate.V.)and var. *antiquorum* (Plate V.4) could be recognized. This is provided in the following taxonomic classification section. Lower values of

Standard Deviation for most of the quantitative spike characters with respect to those morphotypes with more than one accession confirms uniformity within these groups. Though the male part length/sterile appendix length ratio as given in the following classification section being a key character in distinguishing the two major varieties recognized in cultivated and wild taro with a significant positive correlation (0.350684) between the two characters in the present study appears to be very much genetically related parameter in taro. The development of the inflorescence and its parts and separation of male and female parts in the evolutionary history of the family Araceae is perhaps related to evolution of protogyny in relation to the principles of thermogenesis (Dorothy, 1995) that helps anemophily in the genus. High degree of variation within the morphotypes observed has also the effect of polymorphism on the sexual characters.

Characters studied

1. Morphotypes (M. No.)
2. Number of collections flowered (No.)
3. Parameters (Para)
4. Days to flower (Dfl.): Number of days taken to flower from the day of planting
5. Days to femal anthesis (Dfa.): Number of days from the date of planting

6. Days to male anhtesis (Dma.): Number of days from the date of planting
7. Number of inflorescences per leaf axil (Nia.)
8. Peduncle length (Pl.)
9. Limb length (Ll.)
10. Tube length (Tl.)
11. Tube thickness (Tt.)
12. Female part length (Fpl.)
13. Neutral part length (Npl.):
14. Male part length (Ml.):
15. Sterile appendix length (Sal.):
16. Sterile appendix thickness (St.):

Table 19 Floral characters in morphotypes of taro

M No.	**No.**	**Para.**	**Dfl.**	**Dfa.**	**Dma.**	**Nia.**	**Pl. (cm)**	**Ll. (cm)**	**Tl. (cm)**	**Tt. (cm)**	**Fpl. (cm)**	**Npl (cm)**	**Mpl (cm)**	**Sal (cm)**	**Sat (cm)**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**10**	**11**	**11**	**12**	**13**	**14**	**15**	**16**
1	80	Min.	81	79	82	1	14	9.5	2.4	0.6	2	0.5	2.5	1.5	0.1
		Max.	104	102	104	4	59.5	27.5	7.2	3.5	4.5	3.8	8	7.2	2.2
		Mean	96.69	95.08	96.81	2.56	41.97	22.51	5.44	2.31	3.05	2.14	5.03	4.61	0.58
		SD	3.97	3.94	3.82	0.65	9.27	3.27	0.99	0.49	0.54	0.52	1.04	1.21	0.23
2	53	Min.	85	84	86	1	17	12.5	3.5	0.8	2	1.1	3	2	0.1
		Max.	102	100	102	3	72	28	7	3	8.5	5.5	7.8	5.3	0.8
		Mean	97.06	95.4	97.21	2.43	43.68	21.41	5.51	2.19	3.12	2.17	5.2	3.54	0.48
		SD	3.92	3.57	3.6	0.57	9.04	2.96	0.79	0.37	0.88	0.66	0.96	0.65	0.11
3	4	Min.	95	94	95	1	38	24.8	5.5	2	4	2	5.5	4.2	0.5
		Max.	101	99	101	3	47.5	32	6.7	2.5	4	3	8	7.5	0.8

		Mean	98.5	97	98.5	2.25	42.63	26.95	6.18	2.2	4	2.45	6.75	5.25	0.68
		SD	2.52	2.16	2.52	0.96	3.9	3.41	0.54	0.24	0	0.53	1.04	1.52	0.15

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
4	7	Min.	91	89	91	2	35	21	5.5	2	3	1	4.5	4.2	0.3
		Max.	99	97	99	3	54	26.3	7	2.5	4.6	2.5	7	8	0.8
		Mean	96.5	94.5	96.5	2.57	47.64	23.69	6.29	2.24	3.67	1.89	6.03	5.37	0.56
		SD	3.33	3.56	3.33	0.53	6.38	1.86	0.64	0.21	0.6	0.49	0.92	1.33	0.19
5	1	-	-	-	-	2	30	0	8	2.3	2	4	3.5	9.8	0.3
6	2	Min.	100	98	100	2	42	24	4.5	2	3	2.2	5	4.5	0.6
		Max.	100	98	100	2	43	25.2	4.5	2	3	2.2	5	5.5	0.7
		Mean	100	98	100	2	42.5	24.6	4.5	2	3	2.2	5	5	0.65
		SD	0	0	0	0	0.71	0.85	0	0	0	0	0	0.71	0.07
7	4	Min.	97	96	97	1	28	17.5	4	1.7	1.7	1.5	1	3.5	0.3
		Max.	117	115	117	2	42.5	29.5	7	2.3	4	2.5	6.2	4.1	0.6
		Mean	111.25	109.5	111.25	1.5	32.63	23.5	5.38	2	3.05	2	4.05	3.78	0.48
		SD	9.54	9.04	9.54	0.58	6.65	4.92	1.25	0.24	0.99	0.41	2.19	0.32	0.13
8	2	Min.	115	113	115	1	30	24.5	5	2	3	2	4.5	3.5	0.4
		Max.	115	113	115	2	33	30	6.5	2.2	3	2.5	5	3.5	0.6
		Mean	115	113	115	1.41	30.33	22.39	5.06	1.84	2.79	1.89	3.91	3.38	0.44
		SD	0	0	0	0.55	9.89	7.61	1.72	0.6	1.01	0.64	1.9	1.11	0.16
10	2	Min.	107	105	107	1	30	22.5	5	1.7	2.9	2	3.5	4	0.6
		Max.	116	114	116	2	33	24.5	6	2.2	3	2	4.5	4.2	0.6
		Mean	111.5	109.5	111.5	1.5	31.5	23.5	5.5	1.95	2.95	2	4	4.1	0.6
		SD	6.36	6.36	6.36	0.71	2.12	1.41	0.71	0.35	0.07	0	0.71	0.14	0
11	35	Min.	81	79	82	1	14.9	8	2	1	1.5	0.4	2	2	0.2
		Max.	117	115	117	3	52	26	6	2.5	3.5	2	5	5.5	0.7
		Mean	95.29	93.29	95.5	1.74	30.21	19.28	3.84	1.65	2.37	1.2	3.61	3.31	0.45
		SD	7.86	7.84	7.65	0.51	11.13	3.83	1.06	0.52	0.41	0.45	0.56	0.71	0.13
12	8	Min.	98	97	98	1	34	24	5	2	3	1	4.7	5.5	0.5
		Max.	102	101	102	3	55.5	36.5	9	4	5	3.2	6.5	7.7	0.8
		Mean	99.38	98.63	99.38	2	46.88	29.88	7.16	3.06	4.15	2.46	5.78	6.5	0.6
		SD	1.51	1.77	1.51	0.53	7.76	4.23	1.26	0.73	0.64	0.69	0.6	0.65	0.12
13	3	Min.	93	91	93	3	34	25	6	2.3	3	2.5	5	8.5	0.6
		Max.	99	97	99	5	49	27	7.8	3	4.5	3.5	6	10.5	0.8
		Mean	96.67	95	96.33	3.67	40	26.17	6.93	2.77	3.7	3	5.33	9.17	0.67
		SD	3.21	3.46	3.06	1.15	7.94	1.04	0.9	0.4	0.75	0.5	0.58	1.15	0.12
14	5	Min.	106	99	106	1	17.5	18	5	1.7	2	1.5	2.4	5.5	0.4

1	2	3	4	5	6	7	8	10	11	11	12	13	14	15	16
		Max.	115	113	115	2	30	19.5	6.5	3	3	2.5	5	8	0.5
		Mean	110.25	107	110.25	1.4	22.6	18.9	5.7	2.24	2.56	2.2	3.56	6.72	0.42
		SD	4.92	6.68	4.92	0.55	5.47	0.65	0.57	0.49	0.38	0.45	0.94	0.94	0.04
15	10	Min.	97	96	97	2	15.6	16.4	3.9	1	2	1.3	3.3	2.1	0.2
		Max.	106	105	106	3	39.5	26.5	5.7	2.5	3.4	2.5	6	4.2	0.6
		Mean	101.71	100.43	101.71	2.3	29.26	22.29	4.86	1.92	3.05	1.65	4.46	3.2	0.47
		SD	3.99	3.69	3.99	0.48	7.17	2.53	0.58	0.42	0.42	0.36	0.79	0.56	0.11
16	2	Min.	93	91	93	2	34	22.5	4	2	2.5	1.4	3.5	2.5	0.5
		Max.	101	99	101	3	40	26.2	5.5	2.2	3.2	2.4	3.8	3.2	0.5
		Mean	97	95	97	2.5	37	24.35	4.75	2.1	2.85	1.9	3.65	2.85	0.5
		SD	5.66	5.66	5.66	0.71	4.24	2.62	1.06	0.14	0.49	0.71	0.21	0.49	0
17	1		98	97	97	2	23	20	4.2	2	2.5	1.5	4.7	3.5	0.5
18	2	Min.	97	96	97	2	30	24	7	2.6	3.5	2.5	5	6.5	0.6
		Max.	99	98	99	3	34	25	8	3.5	4	3.5	5	7.7	0.6
		Mean	98	97	98	2.5	32	24.5	7.5	3.05	3.75	3	5	7.1	0.6
		SD	1.41	1.41	1.41	0.71	2.83	0.71	0.71	0.64	0.35	0.71	0	0.85	0
23	10	Min.	79	78	79	1	30	20	4	2	2.5	1	3.8	4	0.3
		Max.	115	113	115	3	53	29	8	2.6	4	4.5	6.2	8	0.8
		Mean	99.56	98	99.56	2.4	41	25.17	6.25	2.16	3.12	2.7	5.1	5.7	0.54
		SD	9.55	9.21	9.55	0.7	7.77	2.77	1.18	0.26	0.52	0.95	0.8	1.26	0.15
24	6	Min.	77	79	77	1	44	24.5	6	2	2	2	3	5	0.5
		Max.	104	102	104	3	61	34	7.5	3.5	5	3.8	7.4	8	0.8
		Mean	94	93.2	94	2	49.7	27.8	6.63	2.53	3.5	2.8	5.85	6.52	0.67
		SD	10.12	8.53	10.12	0.63	6.57	3.59	0.64	0.55	0.98	0.76	1.55	1.1	0.14
25	1		99	98	99	2	36	24	5	2.5	2.5	1.5	6.2	5.1	0.5
26	13	Min.	95	94	95	1	27	15.5	3.6	1.2	2	1	4.5	4	0.2
		Max.	100	99	100	3	52	22	8.2	2.5	4	3.2	6.5	6	0.6
		Mean	98	97	98.1	2.23	38.88	19.92	5.57	1.92	3.35	2.08	5.71	4.82	0.48
		SD	2.21	2.21	2.28	0.6	8.81	2.11	1.22	0.36	0.53	0.62	0.61	0.65	0.13
28	1		100	99	100	2	34	19	3	1.5	2	1	4.5	2.5	0.3
30	2	Min.	99	98	99	1	26	19	3.5	1.5	2	1.3	3.5	2	0.2
		Max.	103	101	103	2	30	20	5	2	3	1.5	4	3	0.4
		Mean	101	99.5	101	1.5	28	19.5	4.25	1.75	2.5	1.4	3.75	2.5	0.3
		SD	2.83	2.12	2.83	0.71	2.83	0.71	1.06	0.35	0.71	0.14	0.35	0.71	0.14
32	8	Min.	99	97	99	1	16.4	2	2.6	1.2	1.5	0.6	2.1	1.6	0.2
		Max.	101	99	101	2	38	25	5	1.8	3.1	2	6.5	3.4	0.5
		Mean	100	98	100	1.75	27.31	18.63	3.78	1.54	2.85	1.33	5.03	2.63	0.35
		SD	1.15	1.15	1.15	0.46	7.29	7.62	0.68	0.21	0.55	0.43	1.33	0.7	0.11
33	1		59	58	60	1	8.6	15.5	4.1	1.2	1.7	1.5	2.8	4.1	0.5
34	1		98	96	98	2	48	22	5	2	3	2.5	3	3	0.4

1	2	3	4	5	6	7	8	10	11	11	12	13	14	15	16
35	1		93	91	93	2	37	23	5.5	3	2.5	2.5	4.5	3.5	0.5
36	1		100	99	100	2	34	18	4.5	2	3	1.3	5	3	0.4
37	1		97	95	97	2	37	19	4.2	2	3	2.7	5	3.7	0.5
39	1		120	119	121	2	27	15.7	4.2	1.4	1.7	1.9	4.3	2.4	0.4
40	2	Min.	88	87	89	1	19	17.4	4	1.1	2.5	1.5	4.2	1.7	0.3
		Max.				2	22.3	18.5	4	1.4	2.7	1.5	4.5	2	0.3
		Mean				1.5	20.65	17.95	4	1.25	2.6	1.5	4.35	1.85	0.3
		SD				0.71	2.33	0.78	0	0.21	0.14	0	0.21	0.21	0
43	1		99	98	99	3	46.5	27	7	3	3.8	2.5	5.5	5	0.6
46	1		92	90	92	1	34	19	5	3	2	1.5	5	2.5	0.5
47	1		84	82	85	1	30	23	5.5	2.5	2.5	2	4.5	3.8	0.5
48	1		97	96	97	2	42	21.5	6.3	2	3.4	3.2	5.2	4.5	0.5
49	1					2	46	22	5.5	2	4	2	5.6	4	0.6
51	1		73	71	74	5	53	31	7	2.7	4.3	2.1	7	5.5	0.3
52	1		93	91	93	2	52	29	7	2.6	4	2.5	6.5	6.7	0.8
55	1		94	92	94	1	24	20.1	3.6	2	2.6	1.1	4.6	2.4	0.3
56	1		91	90	91	1	12.1	20.1	4.2	1.7	2.5	1.8	4.5	3.7	0.5
58	1		98	97	98	1	12.1	20.1	3.6	1.7	2.5	1.1	4.5	2.4	0.3
60	1		103	101	103	1	24	20.1	4.2	2	2.6	1.8	4.6	3.7	0.5
63	1		94	110	113	1	18.05	20.1	3.9	1.85	2.55	1.45	4.55	3.05	0.4
64	1		98	97	98	0	8.41	0	0.42	0.21	0.07	0.49	0.07	0.92	0.14
65	1		87	86	88	2	52	25	6.5	3	3.4	2.3	6.7	3.5	0.5
67	1		98	97	98	3	52	27.8	8.5	2	3.5	2	6.5	7.8	0.8
68	1		99	97	99	3	47	21	6	2.5	3	1.5	4.4	4	0.3
71	1		93	91	93	5	30	22	5	1.5	3.2	3	5	5.2	0.5
75	1		103	101	103	2	22.7	13.1	5.4	1.2	2.8	1.6	2.7	2.9	0.4
78	1		68	67	69	2	41	26	5.5	3	4	2	5.7	8.8	1
79	1		77	76	78	2	6.5	8.5	3.5	1	1.5	1.5	1.5	3.5	0.2
80	1		91	90	91	2	41.5	20.2	4.5	2.5	2.8	1	5.7	6.7	0.6
81	1		101	103	104	5	59	25	5.5	2.5	3.5	2.2	4	12	0.8

With respect to 5 qualitative characters studied (Table 20) peduncle colour and spathe colour (light green to green alone or either with light purple pigmentation and to purple) and limb colour (yellow to bright yellow) attracts the insects for pollination. Most of the flowering types (21 collections belonging to var. *esculenta*) emanate very good fragrance at the time of male anthesis and set fruits. The fruit setting types may be diploids and the others may be triploids. Most of the morphotypes with scent and seed setting types may be belonging to var. *esculenta* and others to var. *antiquorum*. The smell emenated during anthesis in the latter types though not abnoxious is certainly not fragrant. Such morphotypes predominantly have long sterile appendices, which are concealed in the spathe during anthesis, whereas in the former types the sterile appendices are very short and usually exposed during anthesis. Matthews (1995) reported fragrance in taro spikes at the time of anthesis in *C. aquatilis*. These characters, assume paramount importance in establishing the origin of the species. As per the earlier reports cultivated taro probably has two distinct lineages of origin (Pillai, 1972). During flowering, especially during male anthesis in the former types, fragrant spadices attract hundreds of insect pollinators (*Drosophyla* sp.) early in the morning. This confirms the earlier studies by Gagne (1982), Mitchell and Maddison (1983), Matthews (1995), and Carson and Okada (1980). Undoubtedly pollination in taro is by the specific insects and this has great significance in the evolution and spread of taro. It also establishes pollination by a specific set of insects in the region. The latter group does not attract many insects probably due to the absence of fragrance. Flowering, fruit setting and specificity of pollinators are probably few characters that may help in establishing regional or local wild type taro as suggested by Matthews (1995). However, such characters are also met within other morphotypes of taro probably confirming that *C. aquatilis* is in no way different from M16 (Plate I-1, 2 and 3, and Plate IV-1) found in Western Ghat region of India and closely similar other forms extending to Eastern and North Eastern parts of the country.

Table 20. Qualitative characters of inflorescence in 55morphotypes of taro

M. type	Peduncle colour	Limb colour	Spathe colour	Fragrance	Fruit setting
1	**2**	**3**	**4**	**5**	**6**
1	1	4	1	A	A
2	1/6	4	1/6	A	A
3	1	4	1	P	A
4	1/6	4	1	P	A
5	1	4	1	A	A
6	1	4	1	A	A
7	1	4	1	P	P
8	1	4	1	P	P
10	1	4	1	P	P
11	1	4	1	P	P
12	1	4	1	P	P
13	1	4	1	A	A
14	1	4	1	A	A
1	2	3	4	5	6
15	2	4	2	P	P
16	1	4	1	P	P
17	1	4	1	P	P
18	1	3	1	A	A
23	1/6	4/2	1/6	A	A
24	1	4	1	A	A
25	1/2	4/2	1/6	P	A
26	7	4/3	1/6	P	A
28	7	4/2	1/6	P	P

1	2	3	4	5	6
30	7	4	1/6	P	P
32	7	4	1/6	P	P
33	2	4	2	A	A
34	1	4	1	P	P
35	1	4	1	A	A
36	1	4	1	A	A
37	1	4	1	A	A
39	7	4	6	P	P
40	1	4	1	A	A
43	1	4	1	P	P
46	1	4	1	P	P
47	2	4/1	1	P	P
48	1/6	4	1	A	A
49	6	4	6	A	A
51	1	4	1	A	A
52	1	4	1	A	A
55	1	4	1	A	A
56	1	4/6	1	A	A
57	1	4	2/6	A	A
58	7	4	2/6	A	A
60	1	4	1	A	A
62	1	4	1	A	A
63	1	4	1	A	A
64	1	4/6	1	A	A
65	1	4	1	A	A
67	1	4	1	A	A
68	1	4	1	A	A
71	2	4/6	2	A	A
75	7	4	7	p	P
78	2	4	1	A	A
79	1	4	1	A	A
80	1	3	1	A	A
81	1	4	1	A	A

(1= Light green, 2= Green, 3=Yellow, 4= Bright yellow, 5= Cream, 6= Light purple, 7=Purple, A= Absent, P=Present)

4.3.12. Classification of flowering morphotypes into taxonomic groups

Out of 83 morphotypes, 293 collections belonging to 55 flowered and these could be classified into distinct groups (Table 21) based on three important parameters such as leaf types, male part/sterile part ratio, and the tuber types. The typical leaves, spadices and tubers of both wild and cultivated var. *esculenta* and var. *antiquorum* are furnished in Plate V as the standard. Diagrammatic representation leaf, inflorescence and tuber of typical wiled var. *esculenta* belonging to M16 (Fig. 6a) and typical var. *antiquorum* belonging to M13 (Fig. 6b) are furnished in order to clearly distinguish the two major varieties noticed Indian taro. The first criterion was the leaf width/length ratio and the leaf types to distinguish (oblong- sagittate) leaves in var. *esculenta* type (e) and (broadly sagitate) leaves in var. *antiquorum* type (a). With respect to M 80 the leaf type happened to be very distinct (sub-orbicular sgittate in shape with very shallow basal sinus and more shining nature and a leaf width/length ratio of 0.93) and hence kept as a suspected entity (DEE). The second criterion was the mother tuber (corm) thickness-/length ratio and other tuber characters such as shape and size, which happened to be very irregular in fixing a particular range for for var. *esculenta* group and var. *antiquorum* group. However, considering the variation in tuber size, shape and the extent of tuberisation these could be divided into E=*esculenta* (12 morphotypes), Ekan=*esculenta* kannan group (14), Ewild= escuelenta wild (4), Ewildkan= esculenta wild kannan (4), Eclub= esculenta club shaped tubers (3), Emulti= esculenta multifaceted tubers (2), A= antiquorum (5), Awild= antiquorum wild (2), and Kuda= Large spherical mother tubers (9). Sterile appendix length/male part length ratio happned to have a greater amount of accuracy in delimiting var. *esculenta* and var. *antiquorum* groups. The floral character is more dependable as reported by some workers in the past. In var. *esculenta* the sterile appendix length is shorter as compared to male part length. In the present case, the ratio obtained had a range from 0.22 in M80 to 3.0 in M68. The M80 found as wild in Coorg district in Karnataka was first suspected as a different entity at the time of collection due to its very sub-orbicular shape of leaves, thin soft nature of leaf lamina, shallow basal sinus, and very wide leaf sheath. It is indeed a suspected entity among morphotypes identified. All morphotypes giving a ratio of 1 or <1 were fixed as typical var. *esculenta* types and others giving a ratio > 1 were fixed as typical var. *antiquorum* types. Most of these *esculenta* types had oblong or conical/top shaped small to very large mother tubers. Finally it was assessed that in all the above parameters quite a lot of variation occurred indicating the polymorphic nature of the types identified in taro leading to classification of very few entities into typical *antiquorum* and *esculenta* types, and others into a mixed genomic types by accounting all the above three ratios and other leaf and tuber characters. Finally the combination of the three above classes resulted in identification of 10 distinct classes such as eee (21 morphotypes such as M7, 8, 11, 15, 16, 17, 26, 28, 30, 32, 33, 36, 39, 40, 43, 48, 55, 62, 75, 78 and 81), aae (2 morphotypes such as M1 and 2), aee (5 morphotypes such as M3, 4, 46, 47 and 58), aea (9 morphotypes such as M5, 6, 13, 14, 34, 57, 67, 68 and 69), eae (4 morphotypes such as M35, 37, 49 and 79), eea (4 morphotypes such as M10, 12, 63 and 65), dee (1 morphotype such as M80), a/kuda/a (5 morphotypes such as M 18, 23, 24, 25 and 56), a/kuda/e (3 morphotypes such as M51, 52 and 71), and e/kuda/e (1 morphotype such as M 60), and dee (1). Among these, typical *antiquorum* type with respect to leaf tuber and flower characters and seed-setting nature were absent in the types and in the collection perhaps pointing a contradiction to autogamous origin of taxonomically distinguished varieties in Taro. Natural hybridization as reported in *Colocasia* and *Alocasia* however remains as rejoinder to this complex situation and paves way for detailed molecular characterization in the species. A maximum number (21) of morphotypes were *esculenta* with respect to all the three parameters and 22 had very mixed characters of both var. *esculenta* and var. *antiquorum.* However few distinct groups with large oval mother tubers as noticed in the case of cultivated 'Kudachembu' variety of Kerala is combined with 8 *antiquorum* type of leaf types, 1 *esculenta* type of leaf type, and 6 *antiquorum* and 3 *esculenta* type of sterile appendices. This indicates that cultivated taro is highly polymorphic at all levels including even the most depended floral characters. The results also indicated that 16 were wild and 39 were cultivated types. Both cultivated and wild morphotypes had all the three above combinations suggesting presence of parallel evolutionary pattern in wild and cultivated types. Both the wild and the cultivated had all the combinations except for the var. *antiquorum* with all typical leaf, tuber and flower parts supporting the assumption that var.

esculenta types are the major wild and cultivated types and the var. *antiquorum* are non seed setting and may be the result of auto triplodization of var. *esculenta* wild and cultivated forms. The non seed setting M80 with the tuber character of var. *antiquorum*, flower character of var. esculenta and with entirely different leaf character and restricted in distribution in Coorg (one sample) and the other from Assam may be another very rare polymorphic type in the evolutionary chain of the taro.

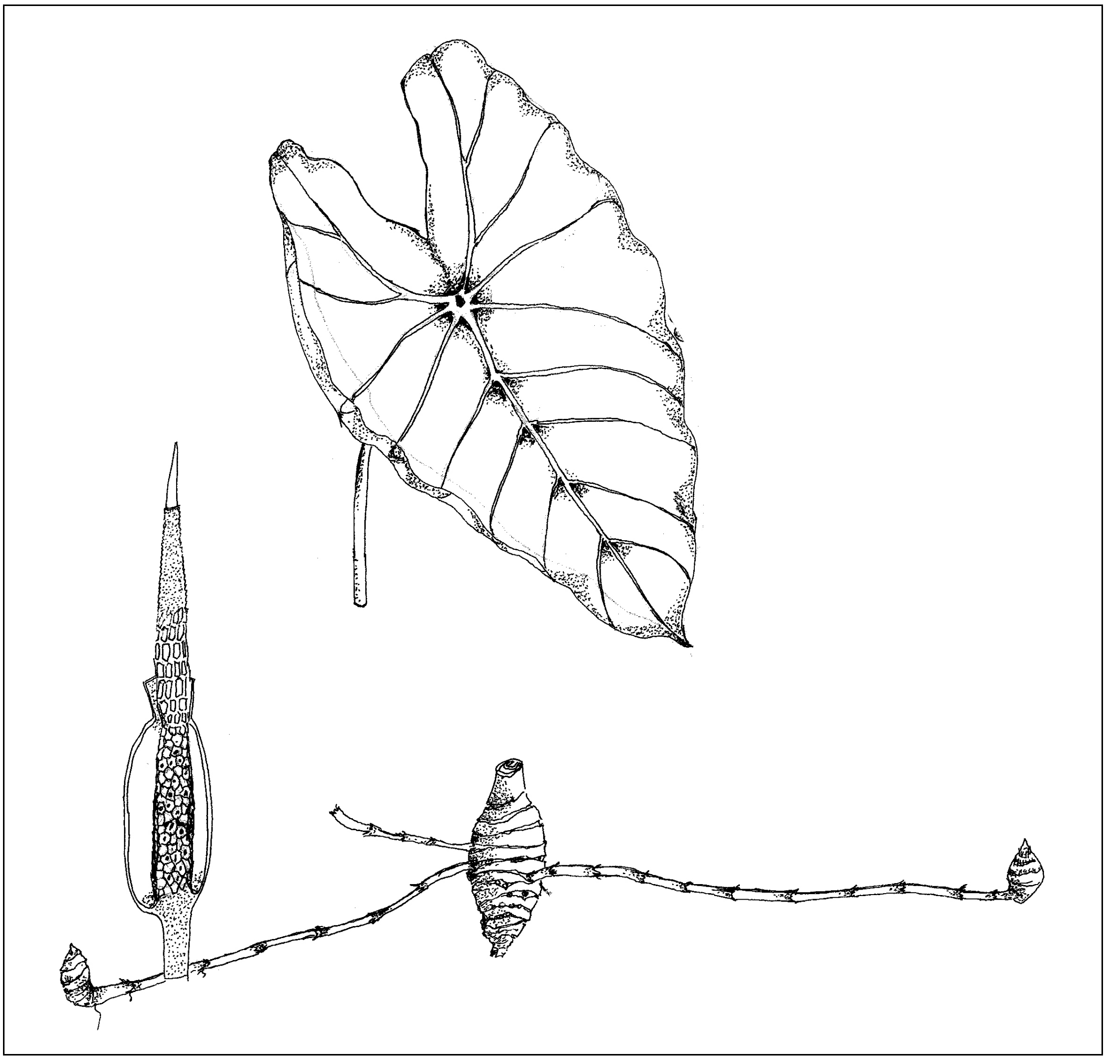


Fig. 6a Diagrammatic representation of typical wild var. *Esculenta*

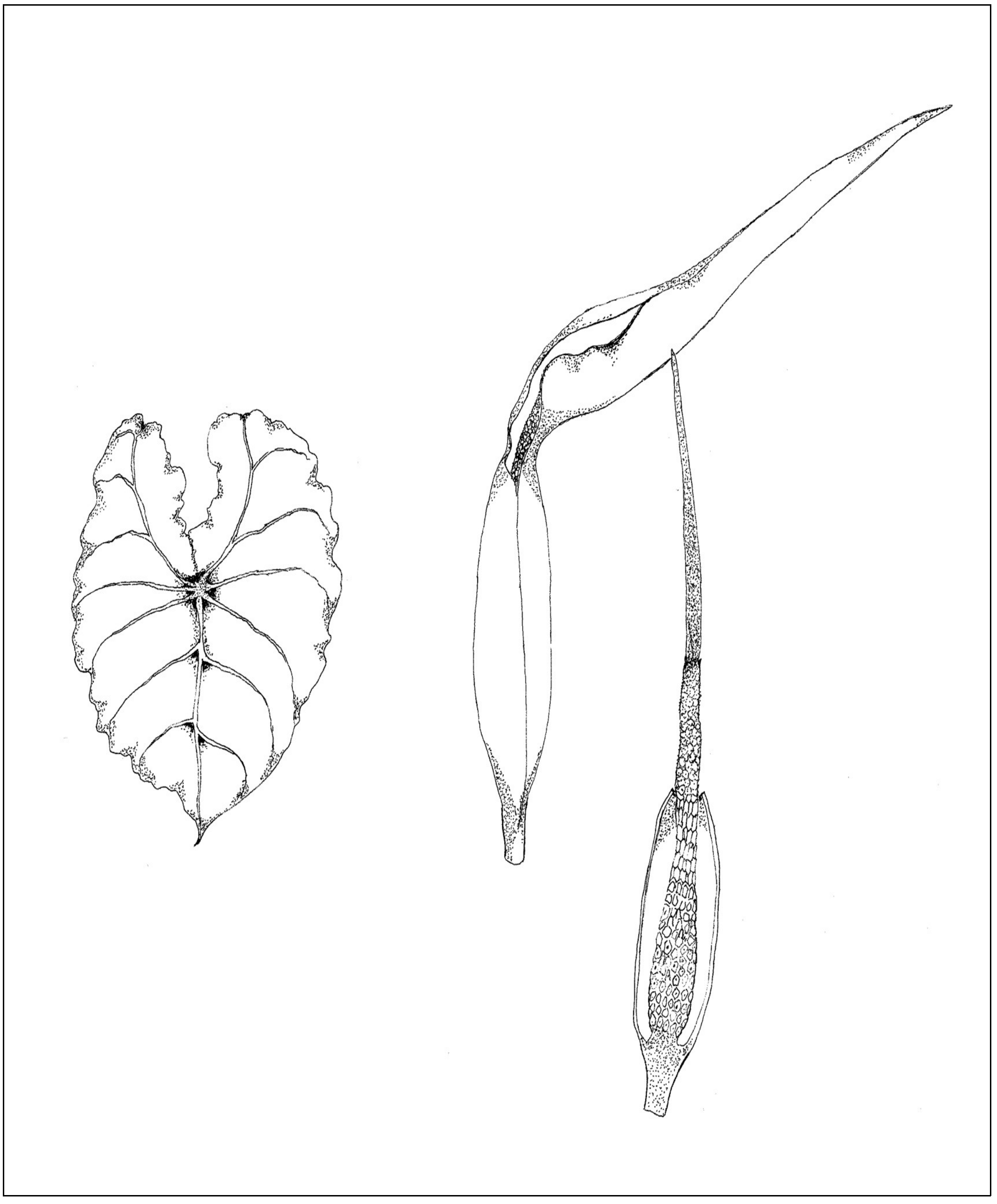


Fig. 6b Diagrammatic representation of typical wild var. *Antiquorum*

Table 21. Taxonomic groups identified in 55 types of Indian taro

Morpho-types	Leaf length/ width ratio	Group based on Leaf ratio & shape	Mother thickness /length ratio	Group Mother tuber ratio & shape	Sterile part/male part ratio	Group based on flower character	Final groups
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	0.82	A	0.73	A	0.92	E	A/A/E
2	0.79	A	0.85	A	0.68	E	A/A/E
3	0.85	A	0.59	E	0.78	E	A/E/E
4	0.83	A	0.38	E	0.84	E	A/E/E
5	0.85	A	0.39	E	2.80	A	A/E/E
6	0.86	A	0.46	Ekan	1.10	A	A/E/A
7	0.76	E	0.60	Ekan	0.83	E	E/E/E
8	0.80	E	0.65	Ekan	0.78	E	E/E/E
10	0.81	E	0.69	Ekan	1.03	A	E/E/A
11	0.78	E	0.85	Ekan	0.92	E	E/E/E
12	0.80	E	0.50	E	1.01	A	E/E/A
13	0.89	A	0.82	E wild	1.72	A	A/E/A
14	0.84	A	0.51	E wild	1.89	A	A/E/A
15	0.72	E	0.63	E	0.12	E	E/E/E
16	0.72	E	0.74	Ewkan	0.79	E	E/E/E
17	0.71	E	0.71	E	0.74	E	E/E/E
18	0.85	A	0.72	Kuda	1.42	A	A/Kuda/A
23	0.83	A	0.85	Kuda	1.08	A	A/Kuda/A
24	0.82	A	0.71	Kuda	1.08	A	A/Kuda/A
25	0.76	A	0.76	Kuda	1.05	A	A/Kuda/A
26	0.76	E	0.64	Ekan	0.96	E	E/E/E
28	0.79	E	0.53	Ewildkan	0.56	E	E/E/E
30	0.72	E	0.71	Ewildkan	0.67	E	E/E/E
32	0.74	E	0.75	Ekan	0.52	E	E/E/E
33	0.78	E	1.00	A wild	1.46	A	E/E/E

1	2	3	4	5	6	7	8
34	1.01	A	0.29	E	1.00	A	A/E/A
35	0.77	E	1.00	A	0.78	E	E/A/E
36	0.68	E	0.61	Ekan	0.60	E	E/E/E
37	0.76	E	0.93	A	0.74	E	E/A/E
39	0.76	E	0.74	Ewild	0.67	E	E/E/E
40	0.82	E	0.66	Ewkan	0.43	E	E/E/E
43	0.94	E	0.40	E club	0.91	E	E/E/E
46	0.82	A	0.41	E	0.60	E	A/E/E
47	0.85	A	0.53	Eclub	0.84	E	A/E/E
48	0.78	E	0.98	Ekan	0.87	E	E/E/E
49	0.78	A	0.76	A	0.71	E	E/A/E
51	0.81	A	0.81	Kuda	0.79	E	A/Kuda/E
52	0.78	A	0.74	Kuda	0.82	E	A/Kuda/E
55	0.71	E	0.91	Emulti	0.52	E	E/E/E
56	0.81	A	0.74	Kuda	1.20	A	a/kuda/a
57	0.79	A	0.38	E	1.05	A	A/E/A
58	0.84	A	0.27	E	0.79	E	A/E/A
60	0.72	E	0.80	Kuda	1.04	A	E/Kuda/A
62	0.81	E	0.75	Ekan	0.85	E	E/E/E
63	0.91	A	0.60	Ekan	1.07	A	E/E/A
64	0.81	A	1.02	Ekan	1.54	A	A/E/A
65	0.70	E	0.80	Ewkan	2.33	A	E/E/A
67	0.78	A	0.32	Eclub	1.18	A	A/E/A
68	0.81	A	0.59	E	3.00	A	A/E/A
71	0.88	A	0.54	Kuda	0.51	E	A/Kuda/A
75	0.87	E	1.40	Ekan	0.67	E	E/E/E
78	0.80	E	0.70	E wild	0.29	E	E/E/E
79	0.79	E	0.60	A wild	0.77	E	E/A/E
80	0.93	D	0.46	E	0.22	E	D/E/E
81	0.84	E	1.00	Emulti	0.69	E	E/E/E

(A = *antiquorum*, E = *esculenta*, Ekan = *esculenta* kannan, Ewild= *esculenta* wild, Awild = *antiquorum* wild, Ewildkan = *esculenta* wild kannan, Eclub = *esculenta* club shaped tubers, Emulti = *esculenta* multifaceted tubers, Kuda = mixed characters of *esculenta*, *amtiquorum* with large spherical mother tubers)

4.3.13. Numerical taxonomic studies in flowering taro morphotypes

Out of the 55 morphotypes that flowered, 54 were subjected to numerical taxonomic analysis based on 41 aerial, floral and underground characters (Table 22) in order to verify the above taxon groups identified as mentioned under 4.4.12 above.

Table 22. Details of 41 parameters used for numerical taxonomic studies

Morpho-types	Pt type	Plant height (cm)	Petiole length (cm)	Petiole Colour	Sheath type	Sheath length	Ligule colour	Leaf type
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	1	93.6	77.52	1	1	45.58	5	1
2	1	93.75	77.06	2	1	45.16	5	1
3	1	96.6	78.1	2	1	40.7	4	1
4	3	89.22	72.94	1	2	42.5	7	2
5	3	80.87	64.38	1	2	35.0	3	1
6	4	88.33	71.33	1	1	35	6	1
7	4	75.9	62.6	1	3	38.68	2	3
8	4	84.71	69.09	1	3	41.28	8	3
10	4	81.86	67.5	1	3	40.21	6	3
11	4	85.19	70.07	1	3	40.1	6	3
12	4	94.41	80.47	1	1	49.85	6	15
13	5	93.33	75.83	1	2	57.5	1	5
14	5	83.1	67.1	1	2	41.6	2	5
15	6	75.77	64.07	1	1	33.59	2	6
16	4	73.5	60.75	1	1	34.5	5	3
17	6	74.5	60.5	1	1	31	1	6
18	7	82.2	65.88	1	2	39.85	4	7
23	8	92.53	73.65	2	1	41.69	9	4
24	8	92.31	77.5	2	1	47.16	9	4
25	8	98	73.5	2	1	43	9	4
26	9	83.17	69.89	2	1	40.13	9	8

1	2	3	4	5	6	7	8	9
28	10	97.22	85.93	2	1	49.79	4	11
30	12	61.75	52.25	2	1	32.5	10	12
32	12	78.16	67	2	1	36.83	9	12
33	14	42	31	2	1	19	3	13
34	16	74	66.5	2	1	45.5	5	1
35	1	102	87.5	1	1	46	4	1
36	1	102.5	86.5	2	2	51.5	2	1
37	1	102.5	56	2	1	53.5	4	1
39	16	74	63.5	1	2	36.5	2	13
40	16	93.5	86.5	2	2	40.5	9	13
43	15	97.33	86	1	1	50.17	4	3
46	2	74.5	66.75	1	1	36.5	9	5
1	2	3	4	5	6	7	8	9
47	2	76.5	66	1	1	36.5	9	5
48	1	89	80	1	2	47.5	9	1
49	1	87	75	1	1	47	9	1
51	1	116	93	1	2	55	6	1
52	1	99.17	82.33	1	1	44.17	6	1
55	1	94	77.5	2	1	41	3	1
56	1	99	84.5	1	1	46.5	1	1
58	17	102.83	85.5	2	4	53	5	14
60	1	57.75	93.5	2	1	53	3	1
62	15	80	66	1	1	31.5	3	1
63	7	56.5	47.25	1	1	27	3	5
64	15	92.5	76.5	1	1	44	6	5
65	14	54.5	50	2	1	27.5	6	12
67	1	94	79.5	1	1	55.5	6	5
68	18	91.5	75	1	1	49.5	1	14
71	19	86	75.4	1	1	38	3	5
75	5	70	60	2	2	34.5	6	5
78	20	75.5	62.5	2	3	34	9	5
79	21	53	44	1	3	24	3	5
80	20	44	36	1	3	13.5	1	16
81	19	53	73	1	1	19	6	5

Table 22. (contd.)

M.	Lamina orientation	Lamina margin undulation	Lamina margin colour	Lamina colour	Lamina petiole joint colour	Lamina thickness	Leaf symmetry	Leaf number
1	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	1	3	1	2	1	2	1	4.36
2	1	3	4	3	10	2	2	4.15
3	1	2	4	3	1	2	1	4.5
4	1	2	4	2	5	2	1	4.89
5	1	3	1	3	11	1	2	4.25
6	5	2	3	2	1	2	1	4
7	3	3	1	2	6	1	2	4.5
8	3	3	5	2	7	3	3	4.94
10	3	3	6	3	8	3	3	5
11	3	3	8	2	9	3	2	5.39
12	3	3	7	3	9	2	2	5.59
13	3	3	1	2	1	3	2	4.83
14	1	3	1	3	1	2	2	5
15	3	1	2	1	1	1	1	4.5
16	4	2	4	3	10	2	2	5
17	4	1	1	2	1	1	2	5
18	5	2	1	2	5	3	2	1.03
23	6	3	5	2	4	3	1	3.65
24	6	2	5	2	4	3	1	4
25	6	2	5	2	4	3	1	4
26	1	2	5	4	4	2	2	5.19
28	6	3	5	3	9	2	1	3.93
30	3	2	5	4	4	3	2	4.25
32	3	3	5	5	4	5	2	5.42
33	6	2	1	1	0	2	2	4
34	6	3	7	2	8	2	2	6
35	6	2	5	2	4	3	2	4
36	5	3	1	2	1	3	2	5
37	6	3	5	2	4	2	2	4
39								
40	3	3	5	4	4	2	1	5
43	6	2	3	2	4	2	4	4.67
46	6	2	2	1	2	1	2	4.25
47	6	2	2	1	2	1	2	5
48	3	2	7	2	4	3	2	4
49	5	3	2	2	2	2	2	4

1	10	11	12	13	14	15	16	17
51	6	3	5	1	4	2	2	4
52	6	3	8	2	9	3	2	4
55	1	3	1	3	11	1	2	4.5
56	5	3	4	2	1	3	1	4
58	6	2	5	2	4	2	1	5.83
60	3	2	5	3	1	3	1	4.5
62	6	3	4	2	3	1	2	4
63	6	2	1	2	1	3	2	5
64	5	3	3	2	1	2	1	4
65	1	2	7	3	8	2	2	4
67	1	2	4	2	1	1	1	4.5
68	5	2	1	1	1	3	1	5.5
71	5	2	4	3	3	1	2	5
75	3	3	4	2	1	1	1	5
78	6	3	5	2	3	2	1	5
79	6	3	3	1	1	2	1	4
80	6	2	1	1	1	1	1	3
81	6	2	2	1	3	2	1	5

Table 22. (contd.)

1	18	19	20	21	22	23	24	25
1	46.81	38.37	13.5	9.71	1.77	1	6.84	4.99
2	47.44	37.4	14.73	10.04	1.75	1	5.32	4.52
3	47	40.05	17.9	11.3	1.23	1	7	4.1
4	37.94	31.39	12.94	8.44	1.52	3	10.92	4.17
5	39.25	33.38	13.13	8.69	1.41	4	8.69	3.38
6	39.75	34	15.58	9.5	1.4	2	6.5	3
7	28.59	21.61	11.03	7.66	1.28	2	6.09	3.65
8	31.63	25.44	10.83	8.51	1.59	2	5	3.25
10	29.14	23.64	12.43	8.71	1.74	2	5.03	3.46
11	30.64	23.76	12.84	10	1.83	2	5.93	5.01
12	37.16	29.68	13.84	11.02	1.99	3	10.47	5.28
13	43	38.17	11.92	8.67	2.7	17	8.5	7
14	35.8	30.2	10	9.65	1.86	11	8.1	4.1
15	29.64	21.27	7.23	7.3	1.53	21	6.89	4.33
16	31	22.38	9	8.38	1.45	4	6.75	5
1	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**

17	30.5	21.5	8	7.5	1.8	21	4.25	3
18	40.35	34.35	12.58	10.59	1.82	15	7.07	5.08
23	51.52	42.9	13.97	11.67	2.01	15	7.23	6.12
24	55.94	45.94	13.94	11.83	2.14	15	8.18	5.84
25	54.5	41.5	13.5	12	2.2	15	8.05	6.1
26	33.96	25.83	11.88	8.88	1.31	2	5.96	3.79
28	38.39	30.43	13.5	11.43	1.79	4	9.11	4.79
30	27.25	19.5	10.75	8.5	1.53	4	6	4.23
32	31.42	23.08	13.33	11.46	1.6	2	4.38	3.29
33	23	18	15.5	7.4	0.9	6	3	3
34	30.75	31	13.5	8.5	1.75	5	12.25	3.5
35	44	34	12	9.25	1.85	1	5	5
36	41.25	28	13.5	9.5	1.2	2	8.25	5
37	50.5	38.5	14.5	11	1.75	1	5.65	5.25
39	29.5	22.5	13.5	10	1.25	8	4.75	3.5
40	38.5	31.5	15	11.75	1.65	4	7.25	4.75
43	32.33	30.5	13.67	8.67	1.65	17	12.5	5.03
46	33.75	27.75	13.5	7.75	1.2	5	10.13	4.13
47	35.5	30	14.5	9	1.5	16	8.75	4.6
48	49.5	38.5	13	9.5	1.45	2	5.75	5.65
49	46	36	14.5	9.75	1.4	1	6.35	4.85
51	55	44.5	16	10	2.25	14	9	7.25
52	55	42.67	16	10.17	1.83	14	8.5	6.25
55	52.5	37	15.5	10.5	2	12	5.25	4.75
56	59	48	13.5	9.25	2	12	10.5	7.75
58	43.5	36.5	13	8.67	1.92	17	20.17	5.5
60	69.5	50	17.5	11	2.15	12	8.75	7
62	36	29.5	11.5	8.25	1	2	4.65	3.5
63	28.5	26	11.5	8.5	1	2	6.5	3.9
64	49.5	40	19	12	1.44	2	5	5.1
65	25	17.5	16	9.5	0.7	4	4	3.2
67	45	35	15.5	9	1.1	16	12.75	4.1
68	45.5	37	16.5	9	1.25	18	11.5	6.75
71	29	25.5	15.5	9.5	1.05	15	8.75	4.75
75	29.25	25.5	14.5	9.5	1.8	2	5	7
78	30.5	24.5	14.5	8.5	1.35	11	6.75	4.75
79	23.5	18.5	10	7.5	0.7	6	5	3
80	27.5	25.5	15.5	10	1.1	5	11	5
81	24	20.25	10	8.5	1.5	12	5	5

Table 22. contd.

M. types	Lateral tuber number	Lateral tuber length (cm)	Lateral tuber thickness	Lateral tuber weight (g).	Mother tuber weight (g)	Presence of stolon	Tuber flesh colour	Flower presence
1	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**
1	7.94	10.27	3.28	967.38	353.82	2	1	1
2	8.2	8.04	2.92	961.27	339.73	2	1	1
3	9.4	8.5	2.75	970	530	2	1	1
4	6.28	8	2.53	772.22	547.22	2	1	1
5	9.75	7.56	1.81	306.25	312.5	2	1	1
6	7.67	8.12	2.07	483.33	300	2	1	1
7	6.93	5.84	1.98	251.5	176.5	2	1	1
8	5	3.5	2	100	50	2	1	1
10	8.43	6.12	2.48	342.86	93.57	2	1	1
11	5.05	6.53	2.86	487.71	366	2	1	1
12	6.06	8.32	2.77	524.12	579.41	2	1	1
13	8.67	9	5.83	600	516.67	2	1	1
14	6.3	13.1	2.6	470	350	2	1	1
15	11.59	6.09	2.1	495.46	272.73	2	1	1
16	8	6.5	2	325	325	1	1	1
17	10	6.25	1.9	300	150	2	1	1
18	6.93	8.99	2.91	336.25	450	2	1	1
23	8.06	9.19	3.21	591.67	713.19	2	1	1
24	6.11	8.73	3.35	461.11	769.44	2	1	1
25	8	9.5	3.65	675	800	2	1	1
26	6.5	7.42	2.5	295.24	223.1	2	1	1
28	3.64	13.46	2.88	192.86	450	1	1	1
30	4	8.75	1.45	100	325	1	1	1

1	26	27	28	29	30	31	32	33
32	5.67	7.25	2.84	510.83	141.67	2	1	1
33	5	16.6	2	1000	1000	2	1	1
34	3	8.25	1.5	200	350	2	1	1
35	14	5.75	3.25	1600	1000	2	1	1
36	13	8.75	3.5	650	400	2	1	1
37	14.5	8.25	2.85	750	250	2	1	1
39	6	16	1.75	150	100	2	1	1
40	7.5	18	1.45	300	225	2	1	1
43	5.83	10	3.5	456.67	666.67	2	1	1
46	12.25	11.25	2.38	725	375	2	1	1
47	16.56	9.25	2.9	1150	500	2	1	1
48	14.3	8.75	3.1	900	600	2	1	1
49	13	8.25	2.6	650	700	2	3	1
51	10.5	15.75	3	1000	1100	2	1	1
52	17.17	16.5	1.8	873.33	1066.67	2	1	1
55	14.5	9.5	3.25	1600	510	2	1	1
56	7	23	2.25	500	1300	2	1	1
58	3	16.08	3.62	550	833.33	2	1	1
60	9	26	2.75	1050	1200	2	1	1
62	12.5	7.5	2.75	400	150	2	1	1
63	9.5	8.1	0.1	700	250	2	1	1
64	10.56	8.25	2.66	1200	400	2	1	1
65	8.5	9	1.5	50	25	1	1	1
67	12	9.25	2.9	700	300	2	1	1
68	5	11	4.75	450	950	2	1	1
71	17.5	7	3.25	1050	740	2	1	1
75	9	9	3	100	500	1	1	1
78	10	6	2.6	350	300	2	1	1
79	10	8.5	1.65	50	50	2	1	1
80	6	8	2	200	125	2	1	1
81	6	7	2	800	600	2	1	1

Table 22. contd.

Morpho-types	Inflorescence /axil	Peduncle length (cm)	Limb length (cm)	Tube length (cm)	Femalepart length (cm)	Neutral part length (cm)	Male part length (cm)	Sterile part length (cm)	Status (wild or cult.)
1	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**
1	2.56	41.97	22.51	5.44	3.05	2.14	5.03	4.6125	1
2	2.43	44	21	6	3	2	5	3.414545	1
3	2.25	43	27	6	4	2	7	5.23	1
4	2.57	48	24	6	4	2	6	5.1	1
5	2.3	30	22.5	8	2	4	3.5	9.8	1
6	2	43	25	5	3	2	5	5.5	1
7	1.5	33	24	5	3	2	4	3.33	1
8	1.5	32	27	6	3	2	5	3.5	1
10	1.5	32	24	6	3	2	4	4.1	1
11	1.74	30	19	4	2	1	4	3.341667	1
12	2	47	30	7	4	2	6	5.8	1
13	3.67	40	26.17	6.93	3.7	3	5.33	9.166667	2
14	1.4	22.6	18.9	5.7	2.56	2.2	3.56	6.72	2
15	2.3	29.26	22.29	4.86	3.05	1.65	4.46	3.2	1
16	2.5	37	24.35	4.75	2.85	1.9	3.65	2.89	2
17	2	23	20	4.2	2.5	1.5	4.7	3.5	2
18	2.5	32	24.5	7.5	3.75	3	5	7.1	1
23	2.4	41	25.17	6.25	3.12	2.7	5.1	5.5	1
24	2	49.7	27.8	6.63	3.5	2.8	5.85	6.5	1
25	2	36	24	5	2.5	1.5	6.2	6.3	1
26	2.23	38.88	19.92	5.57	3.35	2.08	5.71	4.8	1
28	2	34	19	3	2	1	4.5	2.5	2
30	1.5	28	19.5	4.25	2.5	1.4	3.75	2.5	2
32	1.75	27.31	18.63	3.78	2.85	1.33	5.03	2.625	2

33	1	8.6	15.5	4.1	1.7	1.5	2.8	4.1	2
34	2	48	22	5	3	2.5	3	3	2
1	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**
35	2	37	23	5.5	2.5	2.5	4.5	3.5	1
36	2	34	18	4.5	3	1.3	5	3	1
37	2	37	19	4.2	3	2.7	5	3.7	1
39	2	27	15.7	4.2	1.7	1.9	4.3	2.9	2
40	1.5	20.65	17.95	4	2.6	1.5	4.35	1.85	2
43	3	46.5	27	7	3.8	2.5	5.5	5	1
46	1	34	19	5	2	1.5	5	3	1
47	1	30	23	5.5	2.5	2	4.5	3.8	1
48	2	42	21.5	6.3	3.4	3.2	5.2	4.5	1
49	2	46	22	5.5	4	2	5.6	4	1
51	5	53	31	7	4.3	2.1	7	5.5	1
52	1.33	29.37	23.07	4.93	3.03	1.8	5.2	4.266667	1
55	2	52	25	6.5	3.4	2.3	6.7	3.5	1
56	3	52	27.8	8.5	3.5	2	6.5	7.8	1
58	3	47	21	6	3	1.5	4.4	3.3	1
60	5	30	22	5	3.2	3	5	5.2	1
62	2	35	22	5.5	3	3.5	3.5	0	1
63	2	22.7	13.1	5.4	2.8	1.6	2.7	2.9	1
64	2	41	26	5.5	4	2	5.7	8.8	1
65	2	6.5	8.5	3.5	1.5	1.5	1.5	3.5	2
67	2	41.5	20.2	4.5	2.8	1	5.7	6.7	1
68	5	59	25	5.5	3.5	2.2	4	12	1
71	1	65	25	6.5	4	2.2	4.5	2.3	1
75	2	34	22	4	3	1.5	4.5	3	1
78	2	27	18.2	5	3.3	1.7	5.1	1.5	2
79	2	15	14.5	3.5	2.2	1.2	3	2.3	2
80	4	16	13	5	3	2.5	5.5	1.2	2

81	2	18.7	16.1	3.9	2.5	1.7	4.2	2.9	2

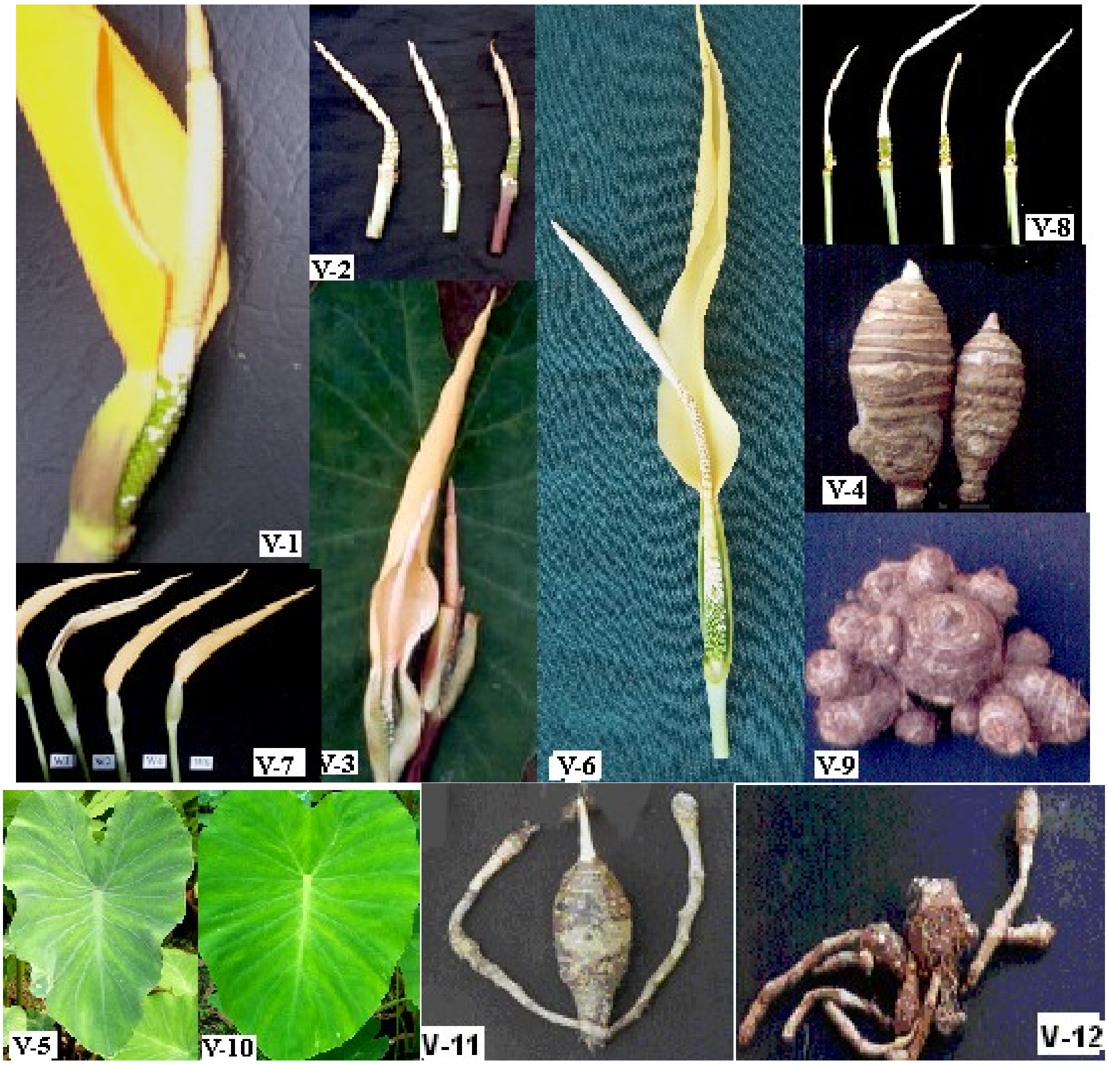


Plate v. Leaf, tuber and floral parts of two taxonomic groups of taro

V-1 & 2. Inflorescences of *C. esculenta* var. *esculenta*
V-3. Spadices of *C. esculenta* var. *esculenta*
V-4. Tuber of typical cultivated *C. esculenta* var. *esculenta*
V-5. Leaf of typical *C. esculenta* var. *esculenta*
V-6 & 7. Inflorescences of *C. esculenta* var. *antiquorum*
V-8. Spadices of *C. esculenta* var. *antiquorum*
V-9. Tuber of typical cultivated *C. esculenta* var. *antiquorum*
V-10. Leaf of *C. esculenta* var. *antiquorum*

V-11. Tuber of typical wild *C. esculenta* var. *esculenta* (with stolons & semi-stolons)
V-12 Tuber of typical wild *C. esculenta* var. *antiquorum* (with stolons & semi-stolons)

Dendrogram obtained (Fig. 7) showed 5 major groups including a small group with M5 and 18 and a loner (inlier), M49 from NE. The first and the second group bifurcated at 1. 33 CF and the first two major groups and the third with two types bifurcated at 1.42 CF. The fourth major group had its deviation from the third at 1.48 CF and the fifth group at 1.64 CF.

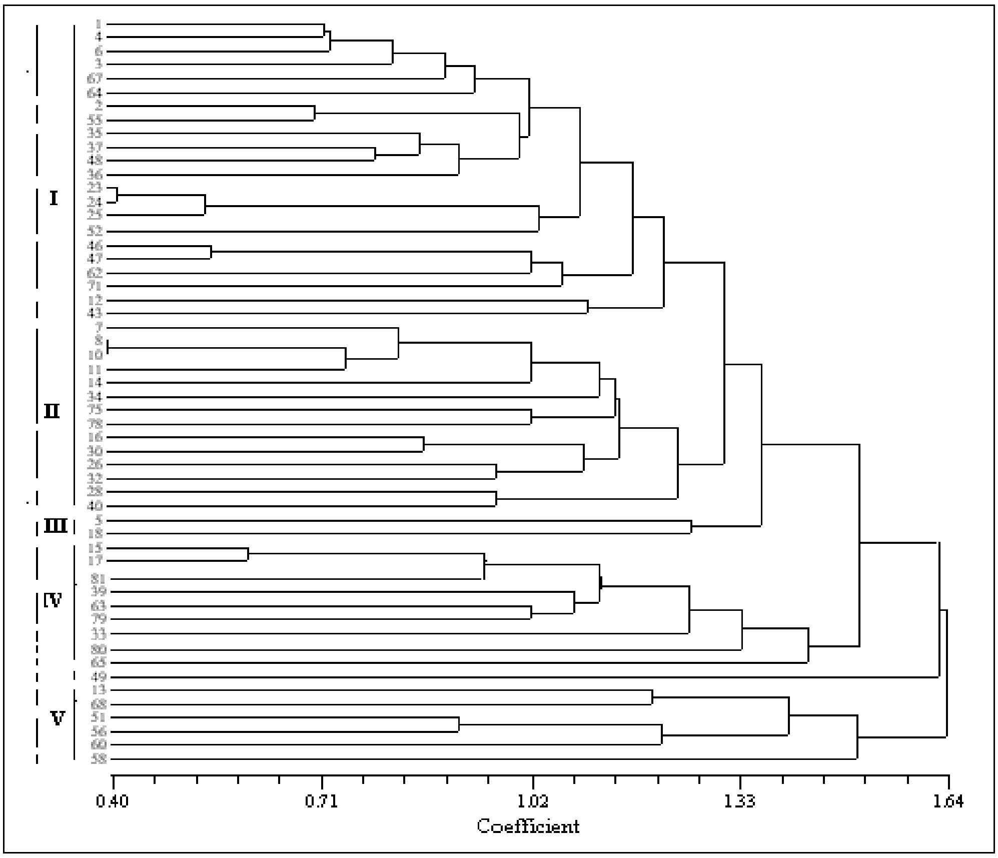


Fig. 7 Dendrogram of 54 flowering morphotypes in Taro

The major group 1 included mainly morphotypes originating from North, Northeast, East, Northwest, and Central India. This major group contained 5 sub groups and the first subgroup included M1, 4, 6, 3, 67 and 64, with mixed characters of *exculenta* and *antiquorum*, the second subgroup contained M2, 55, 35, 37, 48 and 36, the third subgroup included M46, 47, 62 and 71, and the fifth subgroup had M12 and 43.

The second major group, on the contrary constituted types mainly from Southern region and included four subgroups. The first subgroup contained M7, 8, 10, 11 (‘Kannan’ types from Kerala) and wild semi-stoloniferous M14 and 34. The second subgroup included M75 and 78 (purple coloured wild types). The third subgroup included M16, 30, 26 and 32 (green and purple wild and cultivated types resembling more like var. *esculenta*). The fourth subgroup had two types such as M28 and 40.

The third group with 2 morphotypes such as M5 without stolons and with large mother tuber and the widely distributed M18 with large globose mother tuber with stolons from NE and South.

The, fourth major group contained two subgroups and three loners. The first subgroup h, ad M15, 17 and 81(typical *esculenta* types). The second subgroup included M39, 63 and 52; the fourth subgroup 62 and 71 and the fifth subgroup had M12 and 43 more towards *esculenta* and three loners such as M33, 80 and 65 all being distinct. M49 with *esculenta* type leaves, *antiquorum* type mother and *esculenta* type inflorescence was an inlier.

The fifth major group had two subgroups and loner such as M58. The first subgroup had M13 and 68 with more of *antiquorum* characters, and the second had 51, 56 and 60 with large mother tubers. The results indicated that the major groups did not have any affiliation to the taxonomic grouping at the higher level but association among types at subgroup levels. Thus the classification further showed a mixed trend in grouping to favor the consideration of taro as a large polymorphic group in India. These results will be further adjudged by isoenzyme and other studies as detailed in the following sections.

4. 4. Isoenzyme studies in taro

A total of 42 morphotypes of *Colocasia esculenta* and one of *C. affinis* were subjected to Esterase and 46 morphotypess of *C. escuelnta* and one of *C. affinis* as furnished in table 23 were subjected to SOD. The results indicated that enzyme bands as depicted by the zymogram varied from 2 to 8 bands for esterase and 2 to 6 bands for SOD. The pooled analysis of the data for both the enzymes in 40 morphotypes of *Colocasia esculenta* and *C. affinis* resulted in clustering of these into 4 major clusters and 8 sub-clusters without any special regard to the morphological similarity or distribution pattern of these types indicating the reported high polymorphism in vegetatively propagated taro.

Table 23. List of the morphotypes for genetic distance analysis

TCR	M.	IC No.	Place	District	State	Status
1	2	3	4	5	6	7
743	1	013720	Sandah	Sirmur	Himachal	C
505	2	086913	Ambai	Tirunelvelli	Tamilnadu	C
104	3	086919	Vennikkulam	Alappey	Kerala	C
085	4	086930	Badaben	Solan	Himachal	C
656	5	087175	Madapura	Coorg	Karnataka	C
683	6	087208	--		Nagaland	C
144	8	136690	Punalur	Kollam	Kerala	C
475	9	136698	Kainakari	Kottayam	Kerala	C
169	10	086979	Valara	Idukki	Kerala	C
391	11	070275	Vellambram	Malappuram	Kerala	C
298	12	070183	Kadanapally	Kannur	Kerala	C
175A	13	087010	--	--	Kerala	W
385A	14	070269A	Vaidyanattukara	Kozhikkode	Kerala	W
872	15	--	Cuttack	Cuttack	Orissa	C
656	16	096916	Madapura	Coorg	Karnataka	C
197	18	136691	Puravimala	Trivandrum	Kerala	C
338	22	068823	Meppadi	Wynad	Kerala	C
469	23	032834	Vandanmedu	Idukki	Kerala	C
511	26	087085	Parambikkulam	Palakkad	Kerala	C
434A	32	070318A	Mulloorkara	Thrissur	Kerala	C
498	35	087115	--	--	Kerala	W
825	36	----	--	--	--	C
514	37	087118	Nilambur	Malappuram	Kerala	C
567	39	087120	Adanur	S. Arcot	Tamilnadu	W
632	41	087136	Losami	Phek	Nagaland	C
475A	42	086939A	Velloor	Kottayam	Kerala	C
595	43	087127	Rangaphangabon	Karbi	Assam	C
153B	44	086971B	Uthimood	Kollam	Kerala	C

1	2	3	4	5	6	7
823	45	--	--	--	--	C
834	47	087138	Shakhalu	Lumhebota	Nagaland	C
640	49	087146		Silosagar	Assam	C
699	52	070307	Ammanikadu	Malappuram	Kerala	W
616	53	087168			Meghalaya	W
623	54	087169			North East	C
653	55	087184	Thithimathi	Coorg	Karnataka	C
419C	56	070303	Kanjirappuzha	Palakkad	Kerala	C
605A	57	087112			Assam	C
671B	60	087197	Raigarh	Sirmur	Himachal	C
644	67	087165			------	W
833	69	023451N	Sarapara	Goalpara	Assam	W
841	70	023472N	Butamari	Bongaigaon	Assam	W
619B	71			Ugma	Nagaland	C
609B	72	087041	K&J hills		Meghalaya	CW
863	73				North East	C
627	75	087167	Kensa	Mokokuchung	Nagaland	C
705	76	087230			Arunachal	C
813	77				Tamil Nadu	C
858	79	023647N	Palgaon	Gangtok	Sikkim	W
	Ca		Thalassery	Kannur	Kerala	W

(c = cultivated and w = wild)

4.4.1. Esterase

The banding pattern for esterase enzyme (Fig. 8) was distinct for each morphotype and *C. affinis* indicating a clear cut genetic difference between them at isoenzyme level. Further, the studies also agree upon the present Morphotypic classification of taro based on the subjective method of Mathews (1962) as far as the 44 morphotypes was concerned. Morphotypes such as M4, 8, 16, 26, 36, 37, 44, 45, 47, 57, 69, 72, 76 77, 79 and *C. affinis* had two bands each. Morphotypes such as M1, 2, 3, 5, 6, 9, 10,13, 35, 41, 42, 43, 52, 53, 54, 55, 67, 71 and 73 had three bands each; M11, 18, 22, 23, 49 and 60 had four bands each; M 15, 32 and 56 had five each, and M12 had

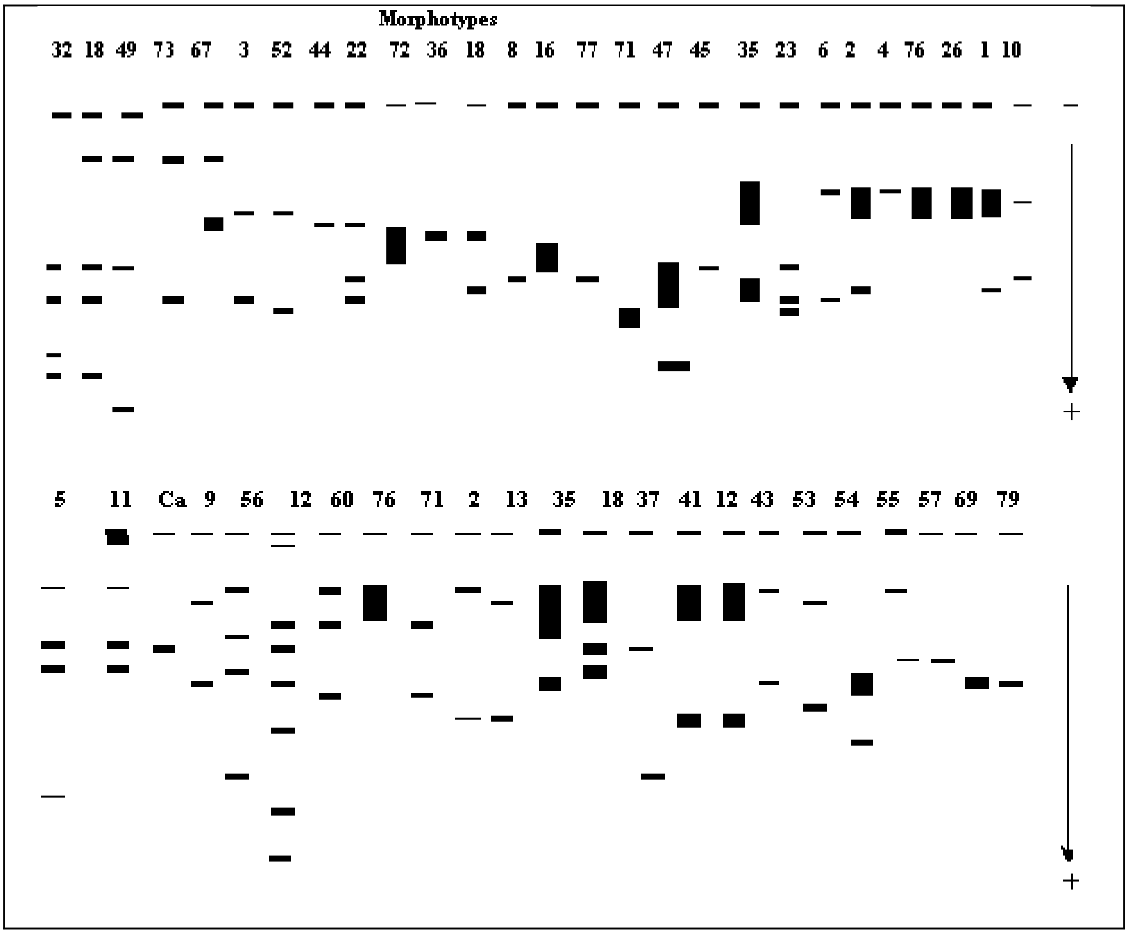


Fig. 8. Esterase banding pattern

8 bands. In the case of *C. affinis* (Ca) only two bands were found at a different length, thus indicating the clear genetic difference between it and cultivated and wild taro morphotypes. In the case of duplicate samples of M35, 71 and 76, banding pattern was similar indicating the accuracy of the analysis. Mobility in the case of M 1, 2, 16, 18, 26, 35, 41, 42, 47, 54, and 76 was restricted resulting in localized extra concentration of enzyme bands. In Zymogram for the esterase enzyme showed 4 main enzyme banding patterns

indicating the complicated nature in esterase enzyme system confirming the report by Gottlieb (1983).

4.4.2. Super Oxide Dismutase (SOD)

The banding pattern for C. *esculenta* and *C. affinis* as presented in zymogram (Fig. 9) indicated 16 distinct banding patterns. The overall results of SOD banding pattern showed that *C. affinis* (Ca) is very distinct from all the studied morphotypes of *C. esculenta* confirming its specific status beyond doubt. Morphotypes such as 6, 12, 16, 37, 43, 45, 47, 49, 53, 55, 69, 70, 71, 73, 75 and 79 had 2 bands each; M1, 3, 5, 8, 9, 10, 11, 13, 14, 15, 18, 22, 23, 26, 32, 35, 36, 39, 41, 42, 44, 52, 54, 56, 57, 60, 71, 72, 76 and 77 had three each; M4 had 4 bands and M2 had 5 bands. The picture of banding pattern appears to be less complex as compared to that of esterase enzyme. The SOD banding pattern in taro may perhaps be an indicator of the basic nature of the genome configuration or pattern that might had originally evolved either from two taxonomic species or varieties as described by Engler and Krause (1920). The simple banding pattern obtained may also

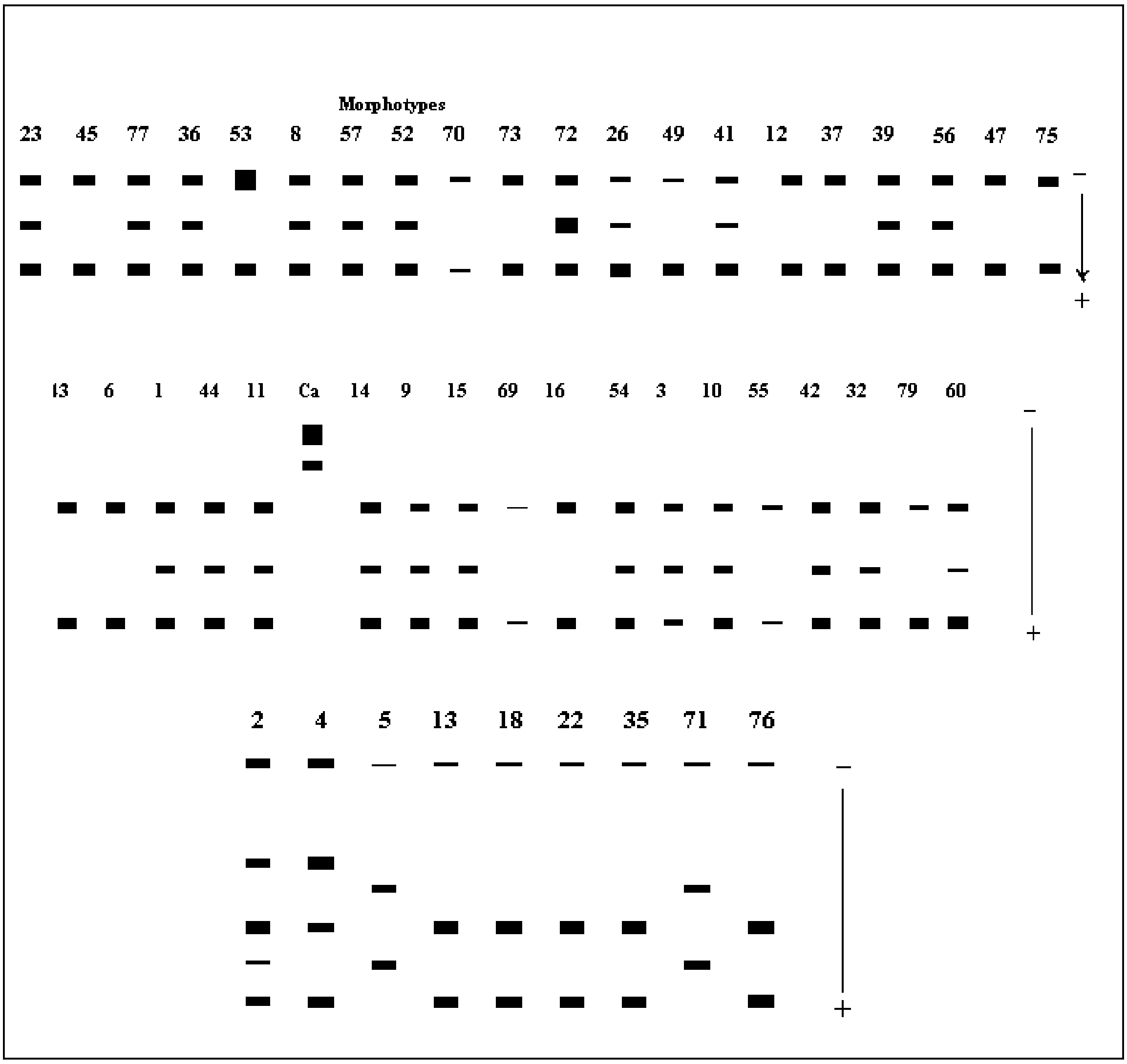


Fig. 9. Super Oxide Dismutase (SOD) banding pattern

describe the less active nature of the enzyme in certain types. Almost all the two-banded types were *esculenta* wild, cultivated or intermediate types based on the morphology noticed.

4.4.3. Genetic distance analysis based on Pooled data

A dendrogram (Fig.10) was obtained by analysis of the pooled data for the two enzymes studied. The data scored in a negative-positive matrix for absence and presence of bands in the case of both the enzymes was used to exhibit the interrelationship between various 40 morphotypes of taro and *C. affinis*. The results indicated that a total of 10 sub clusters under 4 major clusters and M12 and Ca as outliers not on the basis of morphological relationship or on geographical distribution were obtained. A total of 4 major groups such as I, II, III and IV were seen in the tree (Fig. 10). Each major group bifurcated into subgroups. Thus, the I^{st} major group had M1, 2, 26 and 36 under the subgroup1; M4, 6, 22, 44, and 60 under the subgroup 2 and M5, 35 and 76 under the subgroup 3. These morphotypes were mostly having 3 or more bands with respect to SOD banding pattern except for M 6 with 2 bands. This type is identified as cultivated one belonging to var. *esculenta*. Others mostly belonged to var. *antiquorum* or intermediate types. The II^{nd} major group contained M 3, 23, 52 and 54 under subgroup 4; M 10 and 56 under subgroup 5 and M8, 11, 15, 32, 37, 47 and 69 under subgroup 6. Again, all these morphotypes had 3 or more SOD bands except for M 8, 47 and 37. All belonged to either var. *antiquorum* or intermediate types. M47 and 37 with two bands were intermediate cultivated types and M69 was wild var. *esculenta* type. Morphotypes such as M3 and M 52, and M47 and M69 are genetically similar on the basis of observed isozyme pattern.

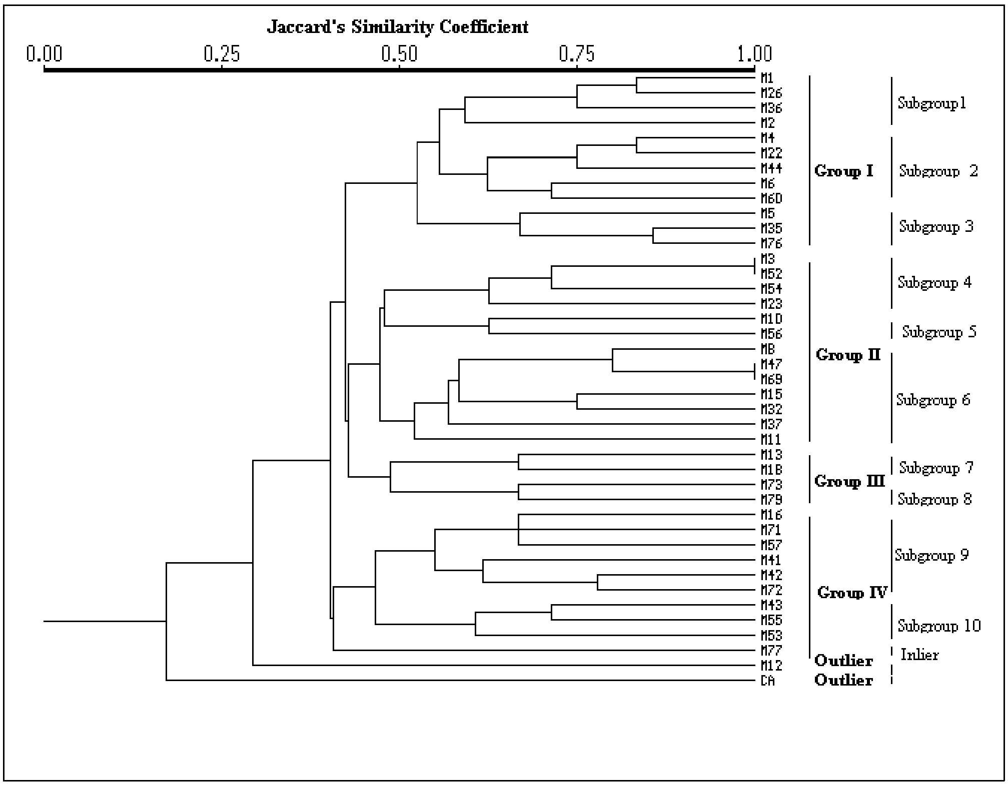


Fig. 10. Dendrogram of 40 morphytpes of taro and *C. affinis*

The III[rd] major group contained M13 and 18 under subgroup 7 and M73 and 79 under subgroup 8. M13 had 3 esterase bands and 3 Sod bands while 2 esterase and 3 SOD bands respectively. M13 is a semi-wild form Maharashtra and M18 is a related cultivated or rarely semi-wild form occurring in Karnataka, eastern and northeastern region of India. These are morphologically closer forms. M73 had 3 esterase bands and two SOD bands where as M79 had 2 esterase and SOD bands respectively. Both are stoloniform or semi-stoloniform types from northeastern parts of India. The IV[th] major group contained M16, 71, and 57 from Kerala and North East under subgroup 9; M41, 42 and 72 from South and Meghalaya under subgroup 10;

M43 and 53 from South and North and North East under subgroup 11 and M 77with unknown origin as a loner. M77 is an extremely different type and its passport is missing. Out of 10 morphotypes falling under the IVth major group 5 had characters of var. *esculenta* (3 wild and 2 cultivated) and others had intermediate characters. The M12 from Kerala, North and Northeast and *C. affinis* as two outliers. *C. affinis* was the farthest one confirming its specific status.

M12 is a common type found as cultivated in uplands under the rain-fed condition in Kerala, northern, eastern and western parts of the country. This being a very distinct cultivar is called as ‘Cheruchembu’ in central and northern Kerala and as ‘Kannan’ in Southern Kerala and forms a part of the major cultivar group of Kerala namely ‘Kannan’ group. This type has very distinctly compact plant type, narrowly sagittate, elongated leaf lamina, and mostly green-pigmented plant parts except for leaf-lamina centre, leaf-margin and ligule with purple violet colour. As indicated by the banding pattern, *C. affinis* is relatively a far away outliner indicating its least morphological and genetic similarity with other 40 morphotypes of *C. esculenta.*

In the first sub-cluster of Ist major cluster, morphotypes such as M1, 26, 36 and 2 are included and these have their origin in Himachal Pradesh and Kerala, situated in two far away and agro-climatically distinct regions, one in humid subtropics and the other in the humid tropics. Morphotypes 1 and 2 are morphologically very similar except for the purple pigmentation on the petiole in the latter and both these types are very commonly cultivated in the northern, northwestern and northeastern parts of the country rarely extending to southern region probably due to recent introduction. The M36 has an unknown origin and is morphologically closer to M26 which is very commonly cultivated in plains of central Kerala as ‘Karutha chembu’ and is very region-specific and has a medium plant type, leaf-lamina with purple violet centre and margin, blackish purple petioles, large mother and fewer large lateral tubers resembling mother tuber. ‘Muduvan’ tribe in Western Ghats of Kerala cultivates M26. It is also related to M2 in pigmentation of aerial plant parts. All of this flower in Thrissur condition and appear to be triploids, as these do not set fruits or seeds. In the case of the second sub cluster, morphotypes from far away geographical regions such as M4, 22, 44, 6 and 60 are included. The M4 and 60 are from Himachal Pradesh, 22 and 44 are from Kerala and M 6 is from Nagaland. Morphologically none is similar to the other in plant type, leaf type, sheath type and tuber type but all happen to be cultivated types from far away agro-climatic regions. All are intermediate types between var. *esculenta* and var. *antiquorum* in mother tuber and lateral tuber characters. The M4 appears to be more like var. *esculenta* with larger conical mother tuber and similar looking lateral tubers, however, the aerial morphology resembles that of var. *antiquorum*. M 22 in its tuber form appears to be intermediate, 44 and 6 are *antiquorum* types with medium corms and oblong or globose lateral tubers. M60 is a wild type belonging to var. *antiquorum* with semi-stolonifrorm, stalked or club shaped late erect lateral tubers. .

In the case of 3rd sub cluster, morphotypes such as M5 from Karnataka, 35 from Kerala and 76 from Arunachal Pradesh are included. These three types are again from two distinct regions, and M35 and M76 have some common leaf, plant, tuber and sheath characters but petiole colour is green in the former and dark purple in the latter. The M5 has very large plant type with flat drooping leaves and purple ligule and very distinct large oval mother and similar looking lateral tubers.

Under the major cluster II, the sub cluster no. 4 includes M3, 23, 52 and 54 from Kerala and Pondichery, M23 from Kerala, Karnataka, Madhya Pradesh and Tamil Nadu, M52 from Kerala and Assam and M54 having unknown origin. All the types in this cluster appear to be progressively evolved with respect to tuber characters (large and globose mother tubers with oblong, club shaped, cylindrical and long lateral tubers. Subgroup 5 contains M10 and 56 The M3, 23, 52 and 54 have larger mother tubers and lateral tubers except for M10 and M56, which are closer with similar tuber types resembling that of ‘Kannan’ group of Kerala. The dendrogram also indicated almost inseparable relationship between M3 and 52 in cluster No. 4 thus indicating a phenotypic divergence in genetically similar enzymatic groups.

Thus, morphological similarity is not always expressed in enzymatic grouping. In sub cluster 6, morphotypes such as M8, 32, 37 and 11, all being cultivated ones belong to var. *antiquorum* from Kerala. The M15 being a rare cultivated type, has elongated small mother tuber and lateral tubers resembling that of var. *esculenta* hailing from Orissa. Though from a closer geographical region, M47 being a cultivated var. *antiquorum* from Nagaland and M69 being wild cylindrical mother tuber and semi-stoloniform lateral tubers from Assam exhibit very diverse characters and are included in this. The M47 being a cultivated one is var. *antiquorum* and 69 being a stoloniform lateral tuber is var. *esculenta* hailing from northeastern region. Similarly, morphotypes such as 13 and 18 from Kerala are included in the 7th sub-cluster, and M73 from North-East and M79 from Sikkim are included in the 8th sub cluster under IIIrd major cluster. The M13 is a semi-wild and semi-stoloniferous type that occurs in Kerala extending its distribution sometimes to Konkan. The M18 being a large cultivated or run-wild form from North-East has large globose mother tuber and similar looking lateral tubers. Both are somewhat related morphologically to each other. The M73 and 79 from North-East have semi-stoloniform character of var. *esculenta* and large stoloniform tuber characters of var. *antiquorum* respectively. Thus, in this particular group a very clear-cut mixed trend is noticed indicating a clustering pattern irrespective of morphology based on which variety *esculenta* and *antiquorum* are separated. In the 9th sub cluster, under the IVth major cluster

M16, a wild form from Karnataka and M57 from Assam belonging to var. *esculenta* and 71 from Nagaland belonging to var. *antiquorum*, are included. The M41, a cultivated var. *antiquorum* form from Nagaland and Tamil Nadu, M42 a cultivated var. *esculenta* form affiliated to "Kannan' from Kerala and M72, a cultivated form belonging to var. *antiquorum* from Meghalaya are included in the subgroup 10. Subgroup 11 contains morphotypes such as M43 from Assam, Nagaland and Uttar Pradesh and M55 from Karnataka both belonging to typical var. *esculenta* cultivar. The last morphotype (M77), that comes under the major group. No. IV happens to be a loner and belongs to an intermediate type with an unknown origin.

An attempt has been made to assign 7 various morphological but subjectively assessed features along with major taxonomic groups identified on the basis of plant, leaf, floral and tuber characters in table 24.

Table 24 Morphotype wise description and major taxonomic groups

M. type	Major group	Minor group	Leaf type	Plant type	Sheath type	Tuber type	Stolon	Flower	Petiole colour	Taxonomic	Band
1	1	1	1	1	1	1	0	1	G	A/E Cult.	3
26	1	1	8	5	1	2	1	1	P	E Culti	3
36	1	1	1	1	2	2	0	1	P	E wild	3
2	1	1	1	1	1	1	0	1	P	A//E cult.	3
4	1	2	1	2	3	1	1	1	G/p	A/E cult.	4
22	1	2	6	1	2	12	0	0	G	A/Kuda cult.	3
44	1	2	1	1	2	2	0	0	G	A/E cult	3
6	1	2	1	2	1	2	0	1	G	A/E cult	2
60	1	2	1	1	1	14	1	1	G	A/Kuda cult	3

5	1	3	2	1	2	20	0	0	G	A/E cult	3
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
35	1	3	1	1	1	1	0	1	G	A/E wild	3
76	1	3	1	1	1	2	0	0	G	E cult	3
3	2	1	1	1	1	1	0	1	P	A/E cult	3
52	2	1	1	6	1	14	1	1	G	A kuda wild	3
54	2	1	1	1	1	4	0	0	G	A/E wild	3
23	2	1	7	1	1	15	1	1	P	A kuda cult	3
10	2	1	3	2	3	2	0	1	G	E/A cult	3
56	2	1	1	1	1	14	1	1	G	A kuda cult	3
8	2	2	3	2	3	2	0	1	G	E cult	3
47	2	2	1	1	1	1	0	1	G	A/E cult	2
69	2	2	1	5	2	19	1	0	P	E wild	2
15	2	2	5	3	1	21	1	1	G	E cult	3
32	2	2	11	2	1	2	1	1	P	E/E/E cult	3
37	2	2	1	1	1	1	1	1	P	A/E/E cult	2
11	2	2	3	2	3	2	1	1	G	A/E cult	3
13	3	1	4	4	2	3	1	1	G	A wild	3
18	3	1	6	1	2	15	1	1	P	A cult	3
73	3	2	5	3	3	10	1	0	G	E wild	2
79	3	2	5	4	3	6	1	1	G	E wild	2
16	4	1	3	2	1	4	1	1	G	E wild	2
71	4	1	1	1	1	15	0	1	G	E/A cult	3
57	4	1	15	7	4	3	0	0	P	E cult	3
41	4	1	1	1	3	1	0	0	G	A cult	3
42	4	1	1	1	1	2	0	0	G	A/E wild	3
72	4	1	5	1	2	12	0	0	G	A/Ecult m	3
43	4	2	1	1	1	17	0	1	G	E/A cult	2
55	4	2	1	1	1	12	0	1	P	A/E cult m	2
53	4	2	9	6	2	3	1	0	G	E wild	2
77	4	3	9	2	2	2	0	0	G	E/A cult	3
12	OL	OL	3	2	1	3	1	1	G	E/A cult	2
Ca	OL	OL								*C. affinis*	

[M. type = Morphotype numbers; Leaf type = different leaf type numbers; plant type = different plant type numbers; Sheath type = different sheath type based on margin disposition; Tuber type = Different tuber type numbers based on the shape size and nature of tubers; OL- Outlier (All these classes are based subjectively)]

4. 5. Correlation studies

Correlation analysis in 72 morphotypes based on 12 characters (Table 25) revealed that all the characters except for number of leaves and mother thickness showed significant correlation with yield. Highest positive correlation coefficients were obtained between leaf length and leaf width (0.917), mother weight and mother thickness (0.743), lateral tuber number and tuber yield per plant (0.711) and mother tuber thickness and leaf width (0.664). The correlation between number of suckers with mother tuber length, mother tuber thickness, and lateral tuber length and mother tuber weight were negative and non- significant. Similarly, it was also negative in the case of number of leaves with mother thickness, tuber length, tuber thickness, tuber number, plant height, leaf length and width.

Path coefficient analysis (Table 26) revealed that lateral tuber number had highest direct effect (0.5478) on total tuber yield followed by plant height (0.2877) and tuber mother yield (0.2561.The direct effects were negative for mother tuber length (-0.0286), mother tuber thickness (-0.0302),

Table 25. Correlation coefficients in 72 morphotypes of taro

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.000											
2	0.402	1.000										
3	0.297	0.221	1.000									
4	0.075	0.292	0.253	1.000								
5	0.062	0.182	0.174	0.368	1.000							
6	0.350	0.425	0.297	0.273	0.077	1.000						
7	0.382	0.618	0.245	0.212	0.254	0.618	1.000					
8	0.315	0.664	0.295	0.233	0.299	0.636	0.917	1.000				
9	-.036	-0.105	-0.064	0.236	0.531	0.106	0.146	0.133	1.000			
10	0.067	-0.357	-0.209	-0.265	-0.276	-0.065	-0.279	-0.290	0.005	1.000		
11	0.200	0.339	0.245	0.518	0.711	0.423	0.356	0.437	0.454	-0.212	1.000	
12	0.607	0.743	0.279	0.195	0.198	0.497	0.624	0.658	-0.009	-0.225	0.426	1.000

[Characters: 1-Mother tuber length (cm), 2-Mother tuber thickness (cm), 3- Lateral tuber length (cm), 4- Lateral tuber thickness (cm), 5- Lateral tuber number, 6- Plant height (cm), 7- Lamina length (cm), 8- Lamina width (cm), 9- Sucker number, 10-Leaf number, 11-Lateral tuber weight (g), 12-Mother tuber weight (g)]

Table 26 Direct (diagonal) and indirect effects of 11 yield components in taro

Chara-cters	1	2	3	4	5	6	7	8	9	10	11	Corr. With Yield
1	**-0.0286**	-0.0121	-0.0031	0.0156	0.0338	0.1007	-0.1168	0.0569	-0.0036	0.0017	0.1554	0.1999^{NS}
2	-0.0115	**-0.0302**	-0.0023	0.0607	0.0995	0.1221	-0.1892	0.1196	-0.0107	-0.0092	0.1902	0.3392**
3	-0.0085	-0.0067	**-0.0103**	0.0525	0.0946	0.0855	-0.0749	0.0532	-0.0065	-0.0054	0.0713	0.2449**
4	-0.0021	-0.0088	-0.0026	**0.2077**	0.2017	0.0786	-0.0650	0.0419	0.0240	-0.0068	0.0498	0.5184**
5	-0.0018	-0.0055	-0.0018	0.0765	**0.5478**	0.0223	-0.0779	0.0540	0.0540	-0.0071	0.0508	0.7112**

6	-0.0100	-0.0128	-0.0031	0.0567	0.0424	**0.2877**	-0.1893	0.1147	0.0108	-0.0017	0.1273	0.4227**
7	-0.0109	-0.0187	-0.0025	0.0441	0.1393	0.1779	**-0.3061**	0.1653	0.0148	-0.0072	0.1599	0.3559**
8	-0.0090	-0.0200	-0.0030	0.0483	0.1639	0.1830	-0.2807	**0.1803**	0.0135	-0.0074	0.1685	0.4373**
9	0.0010	0.0032	0.0007	0.0491	0.2906	0.0305	-0.0446	0.0240	**0.1017**	0.0001	-0.0023	0.4539**
10	-0.0019	0.0108	0.0022	-0.0550	-0.1511	-0.0187	0.0854	-0.0523	0.0005	**0.0257**	-0.0577	-0.2122^{NS}
11	-0.0174	-0.0224	-0.0029	0.0404	0.1086	0.1430	-0.1911	0.1186	-0.0009	-0.0058	**0.2561**	0.4262**

(Residual effect = 0.2798, NS = Not significant and ** = Significant at 1% level)

leaf length (-0.3061) and lateral tuber length (-0.0103), suggesting least importance for these traits in selection criteria to be adopted in this crop. High positive indirect effects were exerted by number of suckers on number of lateral tubers (0.2906).

4. 6. Analysis of variance in taro

In a separate preliminary evaluation trial conducted in two years on 427 and 459 accessions during the kharif cropping seasons of 2000 and 2001 respectively, 11 quantitative characters were observed and analyzed.

4.6.1. Analysis for 2000

A total of 12 important quantitative characters were subjected to computation for range, mean, SD and CV (Table 27) and analysis of variance (table 27). All the characters varied considerably, especially in the case of lateral tuber weight ranging from 40 to 950 g, mother tuber weight from 20 to 700 g and mother tuber number per clone from 1 to 7. Naturally values of CV (Coefficient of Variation) were on the higher side in all the characters analyzed indicating higher morphological variation for the studied characters in the collection. Maximum genotypic CV% for lateral tuber weight (54.0) followed by mother tuber weight (53.13) and mother number (43.90) was observed, indicating higher range of variability in these characters as compared to others. The results appear to have an evolutionary significance as the progressive evolution took place in the crop attuned to the development in size, quantity and shape of the useful plant parts i.e. underground tubers. Thus the wild ones have lesser amount of tuber in the case of wild var. *antiqiorum* type and more in its advanced cultivated forms, as also in the wild var. *esculenta* forms and cultivated forms. Results (Table 28) pertaining to 12 aerial and underground characters indicated that two characters such as mother tuber weight and lateral tuber weight of all the variants among blocks, treatments (ignoring blocks), treatments and treatments vs. checks were significant at 1% and 5% level. The characters such as plant height, petiole length, lamina length, lamina width of variants with a single degree of freedom for blocks comparison is significant at 1% and 5% level. The variability with respect to tuber thickness was not significant.

Table 27. Range, Mean, Standard Deviation and genotypic Coefficient of various quantitative characters (2000-trial)

Characters	No. of cases	Minimum	Maximum	Mean	SD	SE	CV
Plant height (cm)	427	27.00	116.00	72.76	14.23	0.69	19.57
Petiole length (cm)	427	25.00	90.00	57.89	11.21	0.54	19.37
Leaf length (cm)	427	12.50	65.50	36.80	9.50	0.46	25.81
Leaf width (cm)	427	8.50	56.00	30.29	8.30	0.40	27.39
Mother tuber length (cm)	427	2.00	21.00	7.61	2.25	0.11	29.57
Mother tuber thickness (cm)	427	1.50	11.00	5.03	1.32	0.06	26.34
Lateral tuber number	427	2.00	17.00	5.48	1.79	0.09	32.68
Lateral tuber length (cm)	427	3.50	21.00	8.67	2.71	0.13	31.33
Lateral tuber thickness (cm)	427	0.80	13.00	3.03	0.96	0.05	31.63
Lateral tuber fresh weight (g)	427	40.00	950.00	351.15	189.63	9.18	54.00
Mother tuber fresh weight (g)	427	20.00	700.00	210.26	111.72	5.41	53.13
Total fresh weight (g)	427	50.00	1300.00	545.04	237.75	9.18	43.62

Table 28. Mean squares from ANOVA (2000-trial)

Characters	Blocks (Eliminating treatments)	Treatments (Ignoring blocks)	Control varieties	New treatments	Control vs. Treatments	Error
	9	428	1	427	1	9
Plant height (cm)	661.41**	204.34	41.33	202.68	1074.27*	93.83
Petiole length (cm)	468.40**	130.98	19.01	125.68	2501.56**	54.98
Leaf length (cm)	567.89**	91.86	168.20	90.23	710.30**	53.23
Leaf width (cm)	496.40**	84.61	70.41	68.80	6836.09**	71.36
Mother tuber length (cm)	3.03	5.25*	1.51	5.06	90.80**	1.32
Mother tuber thickness (cm)	6.43**	1.81	1.51	1.75	27.47**	0.76
Lateral tuber number	19.04**	3.26	5.30	3.20	25.59**	1.31
Lateral tuber length (cm)	13.72	8.29**	6.96	7.37	404.79**	1.21
Lateral tuber thickness (cm)	0.25	0.92	3.36	0.92	0.00	0.92
Lateral tuber fresh weight (g)	133425.00**	38065.36**	1110.6	35961.00**	971479.94**	2238.38
Mother tuber fresh weight (g)	109938.25**	12707.36**	1008.25	12480.90**	120878.25*	2532.53
Total fresh weight (g)	133425.00**	36065.36**	1110.05	35961.00**	971479.94**	2238.38

(* Significant at 1% level, ** Significant at 5% level.)

4.6.1.1. Promising lines during 2000

Harvest data on yield indicated that four accessions belonging to three morphotypes were found to be promising giving fresh tuber yield of > 900g per plant (table 29).

Table 29. Promising lines during 2000

Coll. No.	TCR No.	IC No.	M. type	Yield/plant (kg)
19/49-2	880	IC-313070	3	1330
S 60/1046	84	IC- 86882	2	967
P9/84-3	513	IC- 86903	2	933
273 B	1	IC- 86837	1	900

4.6.2. Analysis for 2001

Out of a total of 472 accessions of taro grown consecutively for the second year in augmented design during 2001, 459 were subjected to observation on 12 quantitative characters (5 aerial & 7 underground) during the time of best crop growth and at the time of harvest. Two plants per collection were observed. Range, Mean, Standard Deviation (SD) and Coefficient of Variation (CV) for all the 12 characters were determined using MSTATC statistical programme. Analysis of variance for augmented design was done using Augmen-1 (Agrawal & Sapra, 1995). Among the collections, considerable variations were present for all the characters during the year 2001 also. Range, Mean and CV were worked out and furnished in Table 30. The CV% for all characters ranged from 13.83 for petiole length to 59.30 for lateral tuber weight. The highest variability as indicated by genotypic CV% was recorded for lateral tuber yield (59.30) followed by mother tuber yield (59.06) and lateral tuber number (38.97) confirming greater extent of variation in these characters. The results of 2001 trial indicated a trend similar to that of 2000. Thus the evolutionary significance of tuber parts in taro is more as a tuber crop as evident from greater variation in tuber characters of the collection.

Results as furnished in table 31 pertaining to 12 characters indicated that six characters such as plant height, lamina length, lamina width, mother tuber length, mother tuber thickness and mother tuber weight of all variants among treatments, treatment v/s control are significant at5 1% level. Ten promising lines of taro are furnished in table 28.

Table 30. Range, mean, SD and CV% for 11 quantitative characters (2001 trial)

Characters	Range	Mean	SD	SE	CV%
Plant height (cm)	36.75-124.0	87.93	12.30	0.57	13.99
Petiole length (cm)	32.50-110.0	72.94	10.09	0.47	13.83
Lamina length (cm)	19.0-69.5	40.49	9.45	0.44	23.32
Lamina width (cm)	12.75-55.0	32.64	8.22	0.38	25.17
Mother tuber length (cm)	3.0-23.75.	7.08	2.35	0.11	33.16
Mother tuber thickness (cm)	2.0-9.0	4.81	1.13	0.05	23.45
Lateral tuber number	1.0-1.21.02	7.73	3.01	0.14	38.97
Lateral tuber length (cm)	3.25-26.0	8.70	2.79	0.13	32.01
Lateral tuber thickness (cm)	1.10-14.0	2.89	1.03	0.05	35.53
Lateral tuber fresh weight (g)	50.0-1900.0	627.78	372.27	17.38	59.3
Mother tuber fresh weight (g)	25.0-1350.0	402.73	237.86	11.10	59.06
Total rhizome fresh weight (g)	75.0-2600.0	1029.42	501.16	23.39	48.68

Table 31. Mean squares from ANOVA (2001 trial)

Characters	Blocks (Eliminating treatments)	Treatments (Ignoring blocks)	Control varieties	New treatments	Control vs Treatments	Error
DF	9	460	1	458	1	9
Plant height (cm)	24.72	152.32**	19.02	151.31**	748.72**	28.40
Petiole length (cm)	52.05	1.03.54	46.52	101.70	1003.63**	41.46
Lamina length (cm)	10.22	89.13**	12.40	89.21**	126.09*	08.29
Lamina width (cm)	4.82	67.33**	2.18	67.50*	54.90**	7.11
Mother tuber length (cm)	0.59	5.64**	1.68	5.51**	69.03**	0.42
Mother tuber thickness (cm)	0.40*	1.27**	0.02	1.27**	0.65*	0.12
Lateral tuber number	12.39	9.07	10.51	9.07	9.26	6.79
Lateral tuber length (cm)	1.53	7.78	0.35	7.76	21.35**	1.58
Lateral tuber thickness (cm)	0.10	1.05**	0.04	1.05**	0.01	0.12
Lateral tuber fresh weight (g)	193966.78*	140023.28*	41861.40	138382.48*	896074.63**	40611.29
Mother tuber fresh weight (g)	1378.25*	57668.01**	1531.25	5657.98**	613954.75**	3197.92
Total rhizome fresh weight (g)	34341.95**	27315.95**	6600.65	27415.58**	1967.35	4886.09

(* Significant at 5%, ** significant at 1% level CD=6.98)

4.6.2.1. Promising lines during 2001

Harvest data on yield during 2001 indicated that 10 accessions belonging to 7 morphotypes giving a fresh tuber yield of > 700g per plant as furnished in Table 32 were found to be promising.

Table 32 Promising lines during 2001

Coll. No.	TCR No.	IC No.	M. type	Yield/plant (g)
NAF89/31	679	87204	01	700
DKH-51	636	87152	51	700
V2378	653	87174	55	703
NH/6-8A	617A	87188	58	733
BDJ-2164B	671B	87197B	60	750
128/81-32	423	70307	51	756
DKH-44A	631	87154	50	776
BD/7-112	635	87151	50	783
290 New Delhi	043	86855	01	783
53/81-6	208	87055	23	800

4.7. Principal Component Analysis

A total of 83 morphotypes based on 20 characters (12 quantitative and 8 qualitative) as depicted in table 33 were subjected to Principal Component Analysis. Out of a total of 12 principal compounds obtained in the study 6 appeared to be major components (Table 34) contributing a total of 68.75% accumulated variation. Principal Component wise Eigen values and percentage variability along with accumulated variability are presented in table 30. The values of 6 principal component scores (Table 35) showed

Table 33. Morphological characters used in Principal Component Analysis

	Characters	Descriptor states
	Quantitative	
1	Plant height (cm)	
2	Petiole length (cm)	
3	Lamina length (cm)	
4	Lamina width (cm)	
5	Sheath width (cm)	
6	Mother tuber length (cm)	
7	Mother tuber thickness (cm)	
8	Lateral tuber number	
9	Lateral tuber length (cm)	
10	Lateral tuber thickness (cm)	
11	Lateral tuber yield (g)	

12	Mother tuber yield (g)	
	Qualitative	
13	Lamina orientation	1. Drooping, 2. Horizontal, 3. Cup-shaped, 4. Erect apex up, 5. Erect apex down, 6. semi drooping
14	Leaf lamina margin undulation	1. Low, 2. Medium 3. High
15	Leaf lamina-petiole joint colour	1. Light green, 2. Green. 3. Light purple, 4. Purple, 5. Whitish, 6. Purplish violet, 7. Dark purplish violet, 8. Purplish brown, 9 Brown
16	Lamina thickness	1. Low, 2. Medium, 3. High
17	Sheath nature	1. Margin converging, 2. Margin erect, 3. Margin widely open, 4. Margin converging and one side overlapping the other towards the tip.
18	Tuber type	21 distinct subjective types
19	Plant type	9 distinct subjective types
20	Leaf type	18 distinct subjective types

that the vegetative and tuber characters influenced 68.75% accumulated variation up to sixth component only. In this accumulated variability, the first Principal Component explained 27.76% and was associated with plant height and plant type. The second component explained 13.72% variability and was related to Plant height and plant type. The third principal component with 9.25% variability was associated with plant height and leaf type. The fourth principal component with 6.88% variability was associated with plant height and leaf type. The fifth principal component with 6.08% variability was

Table 34. Eigen value, percent of the variability, and accumulated variability

Principal Components	Eigen value	Percentage variability	Accumulated variability
1	5.551	27.76	27.76
2	2.743	13.72	41.48
3	1.850	9.25	50.73
4	1.376	6.88	57.61
5	1.216	6.08	63.69
6	1.012	5.06	68.75

Table 35. Characters contributing to Principal Components

Characters	Principal Components					
	C1	**C2**	**C3**	**C4**	**C5**	**C6**
1	0.341 *	0.351*	0.382*	0.382*	0.083	0.129
2	0.056	0.003	-0.007	0.024	0.025	0.368*
3	-0.269	-0.228	-0.041	-0.041	0.080	0.103
4	0.100	0.187	-0.039	-0.040	- 0.569*	0.350*
5	-0072	-0.091	-0.138	-0.079	0.001	-0.076
6	-0.197	-0.202	0.062	0.066	0.152	-0.153
7	-0.117	-0.146	0.209	0.207	0.300*	-0.277
8	0.111	-0.001	-0.071	-0.057	- 0.558*	0.095
9	0.084	0.072	0.161	0.131	-0.007	-0.018
10	-0.030	0.125	0.008	-0.082	0.220	-0.154
11	-0.196	-0.150	0.019	-0.088	0.080	-0.179
12	-0.110	-0.094	-0.230	-0.265	-0.171	0.278*
13	0.168	-0.049	-0.114	-0.033	0.155	- 0.503*
14	-0.172	-0.177	-0.103	-0.049	-0.113	0.107
15	-0.241	-0.239	0.244	0.254	-0.228	0.287*
16	-0.317	-0.015	0.082	0.169	0.140	-0.174
17	-0.177	0.197	-0.161	-0.254	-0.054	- 0.256*
18	0.085	-0.186	-.261	-0.261	-0.143	0.154
19	0.639 *	0.698*	0.115	-0.095	0.025	-0.017

20	-0.082	0.126	-0.707*	0.673*	0.034	-0.009

related to lamina length, mother tuber length and mother tuber thickness. Finally, the sixth component with 5.06 variability was associated with petiole length, lamina length, mother tuber weight, lamina orientation, and lamina thickness and tuber type. Out of the 20 characters used for the study, 11 of them namely plant height, petiole length, lamina length, plant type, leaf type, mother tuber length, mother tuber thickness, mother tuber yield, lamina orientation, lamina thickness and tuber type could sufficiently explain the morphological variation obtained in the germplasm (Table 33). Six major components (Table 35) could contribute a total of 68.75 accumulated the rest 31.25%.

Character association depicted in table 36 gives extent of association between various characters in a two-way table. The characters are either positively or negatively associated with each other. The association varies from –0.45 to 0.96. The associations that are significant at 1% level are underscored and those at 1% level are asterisked. Positive significant correlation at 1% level varied from 0.28 to 0.96 and that at 5% level varied fro 0.22-0.27.

Table 36. Character association

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
17	1																			
2	0.96	1																		
3	0.78	0.72	1																	
4	0.76	0.71	0.96	1																
5	0.66	0.53	0.63	0.62	1															
6	0.29	0.32	0.18	0.2	0.14	1														
7	0.42	0.46	0.55	0.57	0.4	0.26	1													
8	0.07	0.16	0.14	0.07	-0.13	0.18	0.24	1												
9	0.33	0.35	0.46	0.43	0.28	0.39	0.43	-0.11	1											
10	0.46	0.45	0.38	0.44	0.32	0.3	0.64	0.19	0.08	1										
11	0.44	0.47	0.54	0.49	0.19	0.13	0.31	0.53	0.1	0.34	1									
12	0.51	0.46	0.61	0.62	0.44	0.18	0.1	0.16	0.45	0.42	0.5	1								
13	0.03	0.03	0.07	0.15	-0.03	0.03	0.21	0.06	0.01	0.15	0.08	0.3	1							
14	.25*	.27*	0.29	0.29	.26*	-0.12	0.18	0.18	0.04	0.11	0.19	0.11	-0.07	1						
15	.25*	0.28	-0.03	-0.03	0.15	0.07	-0.08	-0.15	-0.05	-0.09	-0.12	-0.02	0.03	0.13	1					
16	0.28	0.21	0.31	0.3	0.37	-0.07	0.17	-.23*	0.19	0.22	0.04	0.18	0.09	0.12	0.29	1				
17	0.01	-0.01	-0.09	-0.08	-0.07	0.18	-0.07	-0.15	-0.12	0.06	0.13	0.17	0.12	0.13	0.19	0.06	1			
18	0.13	0.09	0.28	.27*	0.19	0.34	0.3	0.05	.27*	.22*	0.02	0.3	-0.05	-0.21	-0.21	-0.04	-0.02	1		
19	-.26*	-.24*	-.27*	-.24*	-0.16	.27*	-0.07	-0.45	0.08	-0.1	-0.39	-0.14	0.03	-0.2	0.04	0.02	0.18	0.05	1	
20	-0.11	-0.12	-0.08	-0.06	-0.07	0.31	0.001	-0.41	0.09	0.06	-0.31	-0.04	0.08	-.24*	0.09	0.16	.24*	0.12	0.61	1

(* = Significant at 5% level, Underscore = at 1% level)

Based on the two major Principal Components such as 1 and 2 obtained in the analysis, a scatter diagram is presented (Fig. 11). Eighty-three morphotypes could be scattered in a pattern that could very clearly indicate the genetic convergence as well as divergence in the species as depicted by the morphology of various types in the studies. The diagram has been conveniently compartmentalized into 4 quadrants. The first quadrant contained 18 morphotypes (M13, 18, 19, 20, 23, 24, 25, 28, 43, 51, 52, 56, 57, 58, 59, 60, 67 and 68) belonging to 7 major taxonomic groups. In the second quadrant, 22 morphotypes (M14, 22, 26, 27, 29, 30, 31, 32, 33, 34, 38, 39, 53, 61, 65, 66, 69, 73, 74, 75, 80 and 83) belonging to 8 major groups occur. In the third quadrant, 20 morphotypes (M6, 7, 8, 9, 10, 11, 15, 16, 17, 45, 46, 54, 62, 63, 70, 76, 77, 78, 79, 81 and 82) belonging to 9 major groups are found. Finally, in the fourth quadrant 21 morphotypes (M1, 2, 3, 4, 12, 21, 35, 36, 37, 40, 41, 42, 44, 47, 48, 49, 50, 55, 64, 71 and 72) belonging to 6 major groups are distributed.

The cultivated types and the corresponding wild types have been identified. Taxonomic grouping has been done in the case of 55 flowering morphotypes under the part 4.3.12 based on the morphological characters. Taking those taxonomic groups of 55 morphotypes into consideration, the present results clearly indicate that the distribution pattern of morphotypes in the scatter diagram is irrespective of their pre-determined taxonomic status and the original eco-geographical situations. The present results of PCA clustering again support the results of grouping obtained in numerical taxonomic study and the Isoenzyme study. Thus the Indian taro happens to be a polymorphic species-complex with large amount of morphological variations in vegetative and floral parts. Hence, its amenability to classification based on these characters is very remote. However more dependable character appears to be the male part/sterile part length ratio by which the types can be clearly divided into var. *antiquorum* and var. *esculenta* as visible from the results dealt in part 4.3.12.

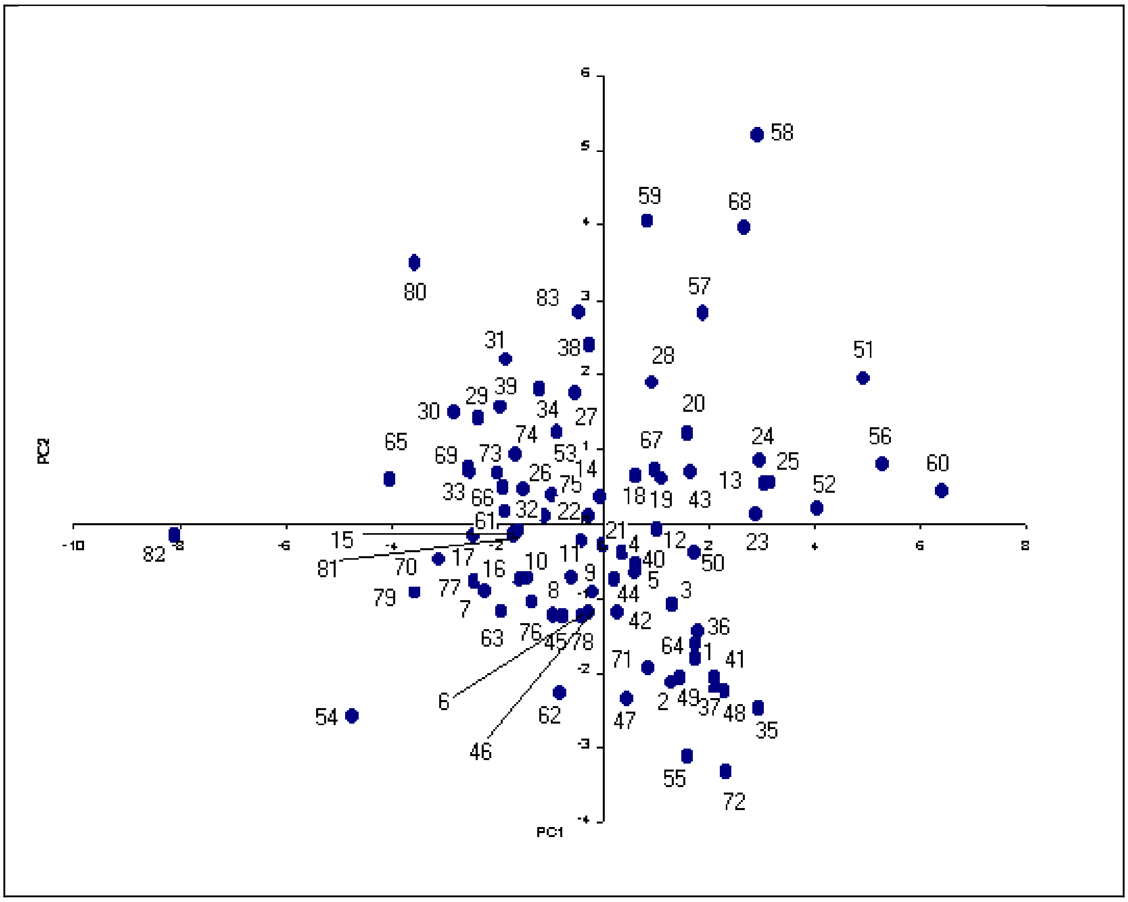


Fig. 11. Cluster diagram of taro morphotypes based on two major Principal Components

4. 8. Regeneration in taro

Taro is a clonally propagated crop and as such time taken for regeneration of planted tuber is an important factor that favours the early crop vigour and good tuber yield. A total of 473 accessions belonging to 83 morphotypes were observed for the number of days taken for regeneration of the planted tubers from the date of planting in the maintenance plots. The data furnished morphotypes-wise in table 37 showed that the mean varied only moderately irrespective of the morphological and other variations noticed in these collections. The average value for the collection was 11.35 and the range was from 8.87 days in M3 to 18.75 in M54. The Standard Deviation for the collection was 1.50 and the phenotypic CV% was 14.05, which is legitimate, and the variation within the collection is meager. Finally, the correlation between the time taken for regeneration and the total fresh tuber weight was negative (-0.25326), which meant higher the regeneration days lower the yield and lower the regeneration days higher the yield.

Table 37. Days taken for regeneration of planted tubers in the field

Morpho-types	Number of collections	Mean	Morpho-types	Number of collections	Mean	Morpho-types	Number of collections	Mean
1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
M1	80	10.4	M29	2	10	M57	1	9.67
M2	53	10.59	M30	3	13	M58	3	12.67
M3	5	8.87	M31	2	10.5	M59	1	12.67
M4	7	11.38	M32	8	11.08	M60	1	10.33
M5	4	11.19	M33	1	10.33	M61	1	10.67
M6	3	11	M34	2	9.5	M62	1	11
M7	20	14.66	M35	1	12	M63	1	10.33
M8	17	12.1	M36	1	10.67	M64	1	10.33
M9	1	11.67	M37	1	11.5	M65	1	9.67
M10	7	12.76	M38	3	12.17	M66	1	10
M11	36	11.29	M39	1	12	M67	1	10
M12	16	11.25	M40	2	11.5	M68	1	11.67
M13	3	10.33	M41	3	10.44	M69	1	11.67
M14	5	13.07	M42	1	11	M70	1	12.5
M15	11	12.51	M43	3	10.78	M71	1	9
M16	5	11.57	M44	2	12.33	M72	1	10.33
M17	1	14.67	M45	1	12.25	M73	1	10
M18	19	10.6	M46	2	11.75	M74	1	13
M19	8	9.33	M47	1	11	M75	1	13.5
M20	2	9.17	M48	1	11	M76	2	12
M21	1	11.33	M49	1	11	M77	1	10.33
M22	2	14.5	M50	7	10.19	M78	1	11.67
M23	35	10.08	M51	1	9.67	M79	1	11.33
M24	9	9.82	M52	3	11.5	M80	2	12.17
M25	1	9.67	M53	1	10.33	M81	1	12
M26	21	11.17	M54	2	18.75	M82	1	-
M27	5	12.6	M55	1	15.5	M83	1	13.5
M28	7	9.67	M56	1	9.67			

Computed values for the entire collection

Min.	8.87

Max.	18.75
Mean	11.35
SD	1.59
CV%	14.01

(Correlation between rhizome weight and time taken for regeneration=0.25326)

4.9. Senescence and crop maturity

Taro being a tropical tuber crop, the growth period is usually long and it bienniates and perenniates in wild forms whenever enough moisture is available. The crop growth stops by sudden senescence of aerial plant parts such as leaves and petiole and this coincides with the maturity of the crop *i.e.* mother and lateral tubers which are economically useful. A total of 444 accessions falling in 82 morphotypes were observed for days taken for senescence or crop maturity. Morphotype-wise computed data for minimum, maximum, mean, SD and CV% and are furnished in table 38 along with the same for the entire collection. Minimum, maximum, mean, SD and CV% were not furnished for those morphotypes with only one collection each. The results very clearly indicated that the range for days taken to senescence was very narrow from 159 days to 173 days with a difference of only 14 days. Morphotype wise range showed very negligible variation indicating a uniform senescence for the collection within a type. SD and phenotypic CV% also was very negligible never going above 3 and 2 respectively for the morphotypes. With respect to the entire collection, SD was 3.102 and CV% was 1.86. In most of the collections within a morphotype there was very narrow range or no variation at all. However, the correlation between the crop duration in days and the total rhizome weight were positively (+0.191409) correlated.

Table 38. Days to senescence in taro

M. type	Parameter	Days	Number
1	**2**	**3**	**4**
1	Min.	159	75
	Max.	166	
	Mean	164.2667	
	SD	2.344247	
	CV%	1.427099	
2	Min.	160	50
	Max.	167	
	Mean	164.2	
	SD	1.641304	
	CV%	0.999576	
3	Min.	168	4
	Max.	171	
	Mean	169.5	
	SD	1.290994	
	CV%	0.761649	
4	Min.	160	7
	Max.	167	
	Mean	163.8571	
	SD	2.035401	
	CV%	1.24218	
5	Min.	162	5
	Max.	168	
	Mean	166.4	
	SD	2.607681	
	CV%	1.567116	

M. type	Parameter	Days	Number
1	**2**	**3**	**4**
12	Min.	162	15
	Max.	166	
	Mean	164.3333	
	SD	1.046536	
	CV%	0.636837	
13	Min.	169	3
	Max.	169	
	Mean	169	
	SD	0	
	CV%	0	
14	Min.	169	5
	Max.	169	
	Mean	169	
	SD	0	
	CV%	0	
15	Min.	162	5
	Max.	169	
	Mean	164.6	
	SD	2.607681	
	CV%	1.584253	
16	Min.	160	3
	Max.	166	
	Mean	163.5	
	SD	3	
	CV%	155.777	

1	2	3	4
6	Min.	166	3
	Max.	167	
	Mean	166.6667	
	SD	0.57735	
	CV%	0.34641	
7	Min.	162	21
	Max.	169	
	Mean	165.9545	
	SD	1.675518	
	CV%	1.009624	
-	-	-	-
8	Min.	164	17
	Max.	167	
	Mean	165.5294	
	SD	1.06757	
	CV%	0.644943	
9	Mean	168	1
10	Min.	163	8
	Max.	166	
	Mean	164.875	
	SD	1.246423	
	CV%	0.755981	
11	Min.	162	35
	Max.	168	
	Mean	164.7714	
	SD	1.330319	
	CV%	0.807372	
25	Mean	171	1
26	Min.	165	18
	Max.	171	
	Mean	168.3	
	SD	2.693	
	CV%	1.599	
27	Min.	168	3

1	2	3	4
17	Mean	162	1
18	Min.	163	20
	Max.	171	
	Mean	170.5	
	SD	2.438	
	CV%	1.433	
19	Min.	167	8
	Max.	171	
	Mean	169.5	
	SD	2.67	
	CV%	1.221	
20	Min.	171	2
	Max.	172	
	Mean	171.5	
	SD	0.707	
	CV%	0.412	
21	Mean	171	1
22	Mean	169	1
23	Min.	167	36
	Max.	172	
	Mean	170.7	
	SD	1.129	
	CV%	0.861	
24	Min.	169	9
	Max.	171	
	Mean	170.111	
	SD	1.054	
41	Min.	167	3
	Max.	168	
	Mean	167.6667	
	SD	0.57735	
	CV%	0.344344	
42	Min.	167	1
	Max.	168	

1	2	3	4		1	2	3	4
	Max.	171				Mean	167.75	
	Mean	169.667				SD	0.5	
	SD	1.528				CV%	0.298063	
	CV%	0.9			43	Min.	0	3
28	Min.	0.572973	7			Max.	0	
	Max.	172				Mean	168	
	Mean	149.228				SD	0	
	SD	53.58625				CV%	0	
	CV%	35.90899			44	Mean	168	1
-	-	-	-			Min.	170	
29	Mean	162	1			Max.	170	
30	Min.	0.572973	3			Mean	170	
	Max.	172				SD	0	
	Mean	139.151				CV%	0	
	SD	60.17172			45	Min.	170	2
	CV%	43.24204				Mean	170	
31	Min.	169	2			SD	0	
	Max.	170				CV%	0	
	Mean	169.5			46	Min.	171	2
	SD	0.707107				Max.	173	
	CV%	0.417172				Mean	172	
32	Min.	162				SD	1.414214	
	Max.	168				CV%	0.822217	
	Mean	164.5714			47	Mean	171	1
	SD	2.070197			48	Mean	171	1
	CV%	1.257932			49	Mean	171	1
33	Mean	167	1		50	Min.	167	7
34	Min.	162	2			Max.	168	
	Max.	170				Mean	167.7143	
	Mean	166				SD	0.48795	
	SD	4				CV%	0.290941	
	CV%	2.409639			51	Mean	173	1
35	Mean	169	1		52	Min.	171	3
36	Mean	172	1			Max.	171	
37	Mean	167	1			Mean	171	
38	Min.	168	3			SD	0	

1	2	3	4
	Max.	168	
	Mean	168	
	SD	0	
	CV%	0	
39	Mean	167	1
40	Min.	167	2
	Max.	167	
	Mean	167	
	SD	0	
	CV%	0	
-	-	-	-
59	Mean	171	1
60	Mean	168	1
61	Mean	173	1
62	Mean	168	1
63	Mean	169	1
64	Mean	173	1
65	Mean	166	1
66	Mean	169	1
67	Mean	169	1
68	Mean	171	1
69	Mean	167	1
70	Min.	166	2
	Max.	166	
	Mean	166	
	SD	0	
	CV%	0	

1	2	3	4
	CV%	0	
53	Mean	170	1
54	Mean	168	1
55	Mean	168	1
56	Mean	173	1
57	Mean	167	1
58	Min.	168	3
	Max.	169	
	Mean	168.6667	
	SD	0.57735	
	CV%	0.342303	
71	Mean	165	1
72	Mean	171	1
73	Mean	167	1
74	Mean	169	1
75	Mean	167	1
76	Min.	168	2
	Max.	170	
	Mean	169	
	SD	1.414214	
	CV%	0.836813	
77	Mean	167	1
78	Mean	166	1
79	Mean	169	1
80	Mean	167	1
81	Mean	168	1
82	Mean	167	1

Computed values for the entire collection

Min.	Max.	Mean	SD	CV%	Total
139.15	173..0	166.71	3.102	1.860	456

(Correlation with rhizome yield = + 0.191409)

4.10. Organoleptic studies in Taro for taste and acridity

4.10.1. Taste of tubers

A total of 409 accessions belonging to 69 morphotypes and 426 accessions belonging to 57 morphotypes were subjected to organoleptic test for taste and acridity respectively of cooked tuber flesh. Table 39 showed the frequency-class distribution of 409 accessions belonging to 69 morphotypes for tuber flesh taste and the results indicated that there existed large variation within and between morphotypes. However, both cultivated and wild morphotypes tasted low to better indicating polymorphic variation within the morphologically uniform types even at biochemical level. Frequency-class distribution for tuber taste presented in figure 12 showed abnormally higher number of accessions in the germplasm with better tuber taste, as the majority of the accessions were cultivated. Figure 12, therefore showed an abnormal curve, as tastier accessions were more in numbers than the others.

Table 39. Frequency class distribution for tuber taste

M. type	Classes			Coll. Number		M. type	Classes			Coll. Number
	Low	Medium	High				Low	Medium	High	
1	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**
1	18	10	42	70		38	0	0	2	2
2	18	5	30	53		39	0	0	1	1
3	1	0	3	4		40	0	0	2	2
4	0	1	8	9		41	1	2	0	3
5	0	3	2	5		43	0	1	1	2
6	0	1	2	3		45	0	0	2	2
7	4	1	14	19		46	0	0	1	1
8	2	2	8	12		47	0	0	1	1
9	1	0	0	1		48	0	0	1	1
10	2	5	0	7		49	0	0	1	1

1	2	3	4	5		1	2	3	4	5
11	2	2	24	28		50	1	2	4	7
12	2	4	11	17		51	0	0	1	1
13	0	0	1	1		52	1	1	1	3
14	0	0	2	2		53	1	0	0	1
15	0	1	13	14		54	0	1	0	1
16	0	0	1	1		55	0	1	0	1
17	0	0	1	1		57	0	0	1	1
18	2	3	15	20		58	0	0	2	2
19	1	0	6	7		61	0	0	1	1
20	1	0	0	1		62	0	1	0	1
21	0	0	1	1		63	0	0	4	4
22	0	0	2	2		66	0	0	1	1
23	3	5	21	29		68	0	0	1	1
24	2	0	8	10		69	0	0	1	1
25	0	1	0	1		70	0	0	2	2
26	2	2	13	17		71	0	0	1	1
27	0	0	2	2		72	0	0	1	1
28	3	1	3	7		73	0	0	1	1
29	0	0	1	1		75	1	0	0	1
30	0	0	2	2		76	0	0	1	1
32	0	0	5	5		77	0	0	1	1
33	1	0	0	1		79	0	0	1	1
34	1	0	0	1		81	0	1	0	1
35	1	0	0	1		82	0	0	1	1
36	0	0	1	1						
Total number of collections						409				

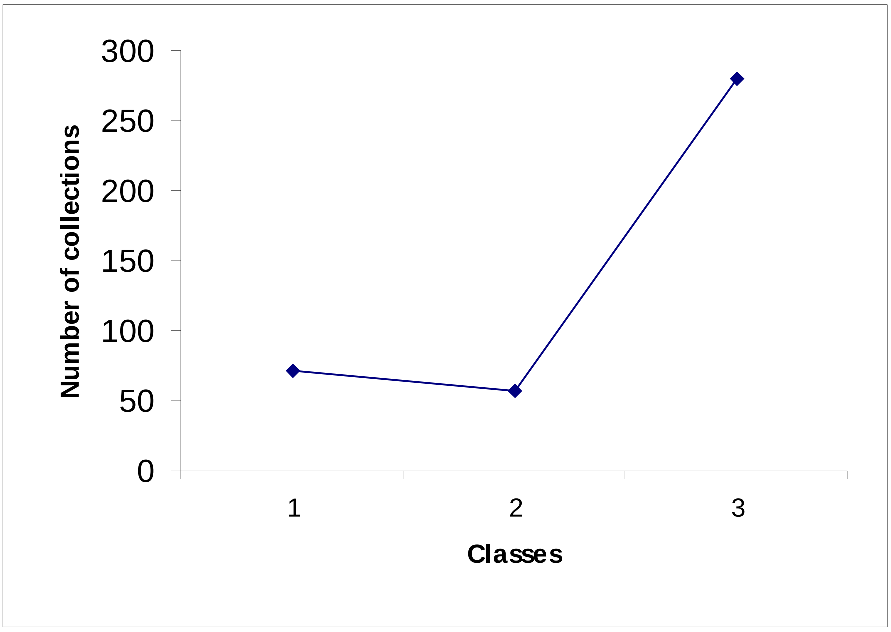


Fig. 12. Frequency class distribution of tuber flesh taste

4.10.2. Acridity in taro tuber

A total of 426 accessions of taro belonging to 57 morphotypes were subjected to acridity of tuber. With respect to tuber acridity, 79 accessions belonging to 28 morphotypes (M1, 2, 3, 5, 6, 7, 8, 11, 12, 16, 23, 24, 26, 28, 29, 30, 31, 32, 35, 39, 40, 41, 45, 48, 49, 51, 52 and 75) as furnished in table 40 were free of acridity. Figure 13 showed almost normal distribution of the acridity of tuber flesh in the collection with moderately acrid types in majority; and few lesser acrid collections as it showed highly advanced character under domestication and evolution of the naturally acrid species.

Table 40. Frequency class distribution for tuber acridity

M. type	Classes				Coll. number		M. type	Classes				Coll. number
	Absent	Low	Medium	High				Absent	Low	Medium	High	
1	**2**	**3**	**4**	**5**	**6**		**1**	**2**	**3**	**4**	**5**	**6**
M1	5	67	2	1	75		M32	2	2	1	0	5
M2	1	65	2	4	72		M34	0	1	0	0	1
M3	2	2	1	0	5		M35	1	0	0	0	1
M4	0	8	0	0	8		M36	0	1	0	0	1
M5	1	1	1	0	3		M37	0	1	0	0	1
M6	1	1	1	0	3		M38	0	1	0	0	1
M7	16	3	2	0	21		M39	1	0	0	0	1
M8	7	6	2	1	16		M40	2	0	0	0	2
M9	0	0	1	0	1		M41	3	0	0	0	3
M10	0	3	0	3	6		M43	0	1	0	0	1
M11	2	6	2	24	34		M45	1	0	0	0	1
M12	10	4	0	1	15		M46	0	1	0	0	1
M13	0	1	2	0	3		M47	0	0	0	1	1
M14	0	0	5	0	5		M48	1	0	0	0	1
M15	0	8	2	0	10		M49	1	0	0	0	1
M16	1	1	0	0	2		M50	6	1	0	0	7
M18	0	18	1	0	19		M51	1	0	0	0	1
M19	0	4	0	1	5		M52	1	1	0	1	3
M20	0	1	0	1	2		M55	0	1	0	0	1
M22	0	2	0	0	2		M57	0	1	0	0	1
M23	25	5	3	0	33		M58	0	1	0	0	1
M24	9	0	0	0	9		M62	0	0	0	1	1
1	**2**	**3**	**4**	**5**	**6**		**1**	**2**	**3**	**4**	**5**	**6**

M25	0	0	0	1	1		M63	0	0	1	0	1
M26	9	9	2	0	20		M66	0	1	0	0	1
M27	0	0	0	1	1		M71	0	1	0	0	1
M28	6	0	0	0	6		M75	1	0	0	0	1
M29	1	1	0	0	2		M76	0	2	0	0	2
M30	1	0	0	0	1		M77	0	1	0	0	1
M31	1	0	0	1	2							

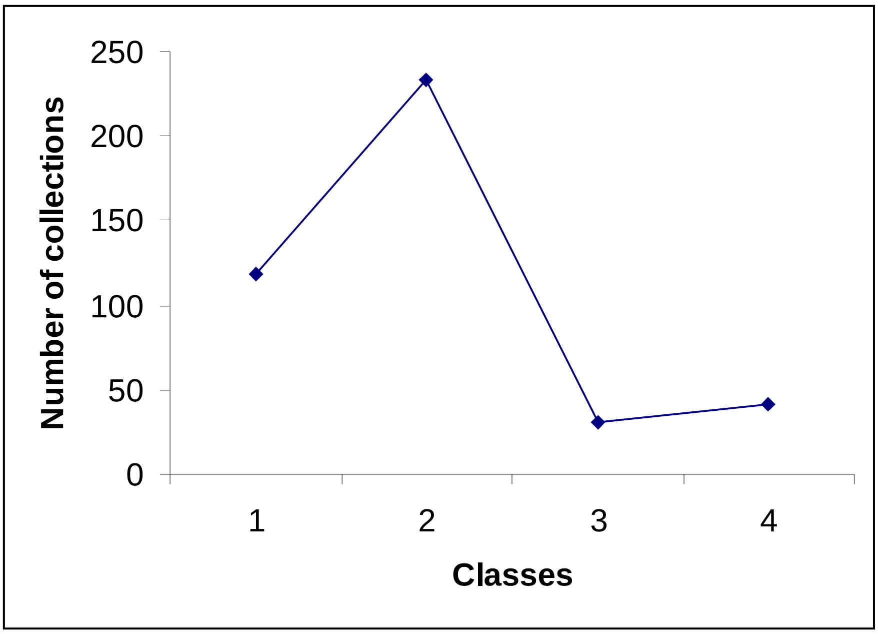


Fig. 13. Frequency class distribution of tuber flesh taste

4.10.3. Leaf lamina and petiole acridity

With respect to leaf petiole and lamina acridity, representative samples of 450 accessions belonging to 76 morphotypes and 472 accessions belonging to 76 morphotypes at tender stage were observed. Lamina and petioles at tender stage were selected from the field and 10 gm of each were cooked in boiling water for ten minutes and tasted and acridity was recorded in 0-3 scale. Frequency-class distribution was worked out and given in table 41 and 42 for leaf lamina and petiole acridity respectively. All the morphotypes could not be tested due to leaf blight and aphid damage on leaves and petiole.

With respect to leaf acridity and petiole acridity none was free of it. However, 138 accessions belonging to 44 morphotypes such as 1, 2. 3, 4,5, 6,7, 8, 10, 11, 12, 13, 15, 18, 21, 22, 23, 24, 26, 27, 28, 30, 32, 39, 41, 42, 47, 49, 50, 54, 55, 58, 61, 62, 63, 64, 65, 66, 70, 77, 78, 79, 80 and 81 had low acridity in leaves. Fig 14 shows almost normal frequency-class distribution curve for the lamina acridity as expected in a population.

With respect to petiole acridity, 225 accessions belonging to 57 morphotypes such as 1, 2, 3, 4, 5, 6, 7, 8, 11, 12, 13, 14, 15, 18, 19, 22, 23, 24, 26, 27, 28, 29, 30, 32, 34, 38, 43, 45, 46, 47, 48, 49, 50, 52, 54, 55, 57, 58, 61, 62, 63, 64, 65, 66, 67, 68, 70, 71, 72, 73, 76, 77, 78, 79, 80, 81 and 82 had low acridity. Similarly the petiole acridity frequency distribution also gave a normal curve.

Table 41. Frequency-class distribution for leaf lamina acridity

M. type	Classes				Coll. number		M. type	Classes				Coll. number
	Absent	Low	Medium	High				Absent	Low	Medium	High	
1	**2**	**3**	**4**	**5**	**6**		**1**	**2**	**3**	**4**	**5**	**6**
1	0	38	30	7	75		40	0	0	2	0	2
2	0	13	35	22	60		41	0	1	0	2	3
3	0	2	2	1	5		43	0	2	1	0	3
4	0	3	1	6	10		45	0	0	1	0	1
5	0	2	2	0	4		46	0	0	1	0	1
6	0	1	1	1	3		47	0	1	0	0	1
7	0	2	13	7	22		48	0	0	1	0	1

8	0	2	10	3	15		49	0	1	0	0	1
9	0	0	0	1	1		50	0	1	6	0	7
10	0	0	6	0	6		51	0	0	0	1	1
1	**2**	**3**	**4**	**5**	**6**		**1**	**2**	**3**	**4**	**5**	**6**
11	0	7	16	10	33		52	0	0	3	0	3
12	0	3	10	8	21		53	0	0	0	1	1
13	0	1	0	0	1		54	0	1	0	0	1
14	0	0	2	1	3		55	0	1	0	0	1
15	0	9	4	2	15		57	0	0	1	0	1
16	0	0	1	0	1		58	0	1	1	0	2
17	0	0	1	0	1		61	0	1	0	0	1
18	0	8	15	0	23		62	0	1	0	0	1
19	0	0	6	0	6		63	0	1	1	0	2
20	0	0	1	0	1		64	0	1	0	0	1
21	0	1	0	0	1		65	0	1	0	0	1
22	0	1	1	0	2		66	0	1	0	0	1
23	0	9	15	9	33		67	0	0	1	0	1
24	0	3	4	2	9		68	0	0	1	0	1
25	0	0	1	0	1		69	0	0	1	0	1
26	0	4	7	6	17		70	0	2	0	0	2
27	0	1	0	1	2		71	0	0	1	0	1
28	0	2	5	1	8		72	0	0	1	0	1
29	0	0	1	0	1		73	0	0	1	0	1
30	0	1	1	0	2		75	0	0	1	0	1
32	0	2	2	1	5		76	0	0	2	0	2
33	0	0	1	1	2		77	0	1	0	0	1
34	0	0	1	0	1		78	0	1	0	0	1
35	0	0	0	1	1		79	0	1	0	0	1
36	0	0	0	1	1		80	0	1	0	0	1
37	0	0	1	0	1		81	0	1	0	0	1
38	0	0	1	0	1		82	0	0	1	0	1
39	0	1	0	0	1		83	0	0	1	0	1
Total	0	116	197	92	395			0	22	29	4	55

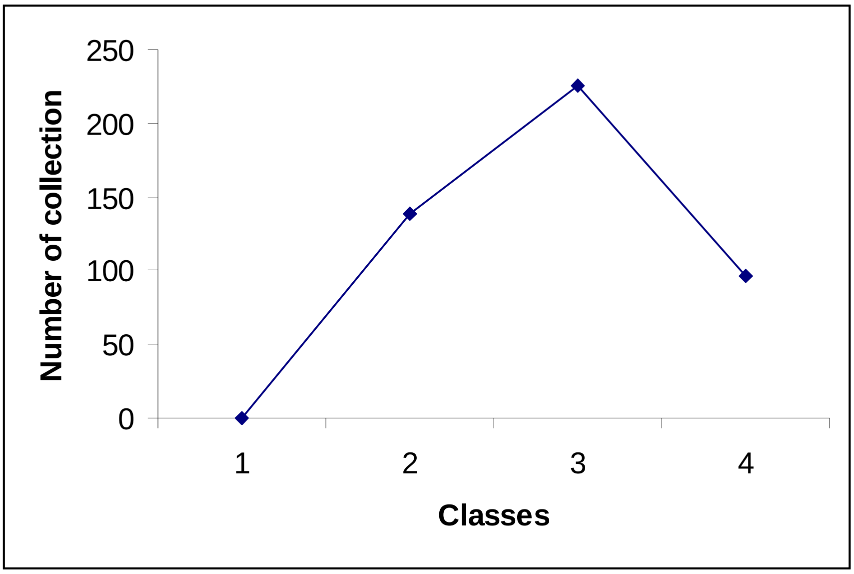


Fig. 14. Frequency-class distribution of leaf lamina acridity

Table 42. Frequency-class distribution for leaf petiole acridity

M. type	Classes				Coll. number	M. type	Classes				Coll. number
	Absent	**Low**	**Medium**	High			**Absent**	Low	Medium	High	
1	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
M1	0	1	2	3	75	M40	0	1	2	3	2
M2	0	53	21	1	70	M41	0	0	2	0	1
M3	0	28	40	2	5	M43	0	0	1	0	3
M4	0	1	4	0	10	M45	0	2	0	1	2
M5	0	4	6	0	4	M46	0	1	0	1	1
M6	0	4	0	0	3	M47	0	1	0	0	1
M7	0	2	1	0	21	M48	0	1	0	0	1
M8	0	3	14	4	17	M49	0	1	0	0	1
M9	0	4	10	3	1	M50	0	1	0	0	7
M10	0	0	0	1	6	M51	0	4	3	0	1
M11	0	0	6	0	33	M52	0	0	0	1	3
M12	0	14	14	5	20	M53	0	2	1	0	1
M13	0	8	10	2	10	M54	0	0	1	0	1
M14	0	10	0	0	3	M55	0	1	0	0	1
M15	0	1	1	1	14	M57	0	1	0	0	1
M16	0	9	3	2	1	M58	0	1	0	0	2
M17	0	0	0	1	1	M61	0	2	0	0	1
M18	0	0	1	0	23	M62	0	1	0	0	1
M19	0	7	15	1	11	M63	0	1	0	0	2
M20	0	3	8	0	1	M64	0	2	0	0	1
M21	0	0	1	0	1	M65	0	1	0	0	1
M22	0	0	1	0	2	M66	0	1	0	0	1
M23	0	2	0	0	33	M67	0	1	0	0	1
M24	0	15	11	7	9	M68	0	1	0	0	1
M25	0	4	3	2	1	M69	0	1	0	0	1
M26	0	0	1	0	17	M70	0	0	1	0	2
M27	0	4	10	3	2	M71	0	2	0	0	1
M28	0	1	0	1	8	M72	0	1	0	0	1
M29	0	3	4	1	1	M73	0	1	0	0	1
M30	0	1	0	0	2	M75	0	1	0	0	1
M32	0	1	1	0	5	M76	0	0	1	0	2
M33	0	2	0	3	2	M77	0	1	1	0	1
M34	0	0	2	0	1	M78	0	1	0	0	1
M35	0	1	0	0	1	M79	0	1	0	0	1
M36	0	0	1	0	1	M80	0	1	0	0	1
M37	0	0	0	1	1	M81	0	1	0	0	1
M38	0	0	1	0	1	M82	0	1	0	0	1
M39	0	1	0	0	1	M83	0	0	1	0	1
Total	0	187	193	44	418	Total	0	40	14	6	54

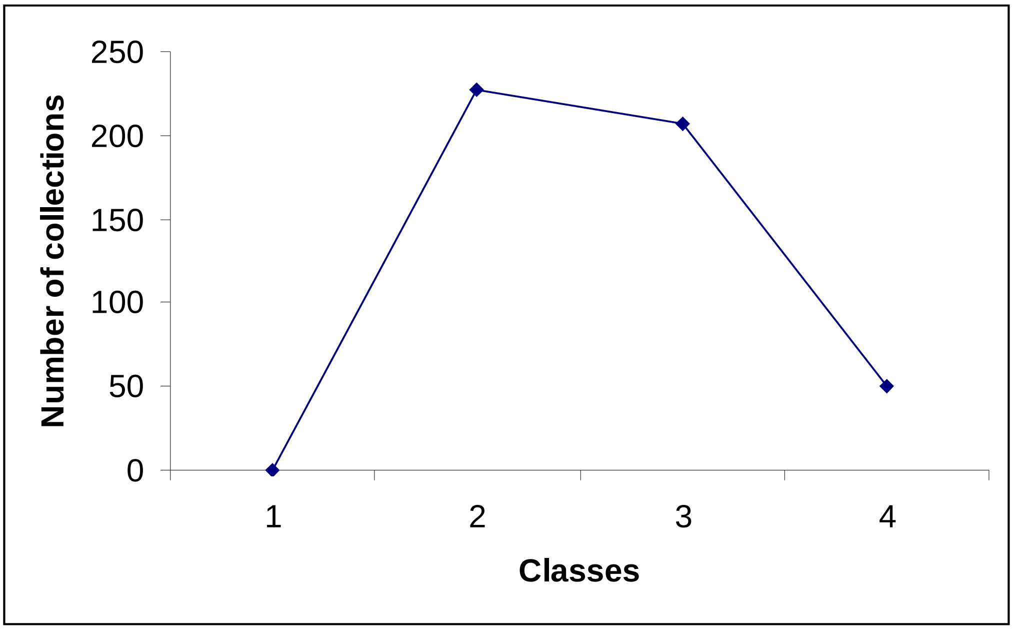


Fig. 15. Frequency class distribution of leaf petiole acridity

4.11. Chemistry of taro tubers

With respect to chemistry of taro tubers three compounds such as oxalic acid, soluble sugar and protein contents were studied and dealt in three parts as below.

4.11.1. Oxalic acid content

Tubers of 33 collections representing one each of 33 morphotypes were subjected for oxalic acid content (Table 43). Oxalic acid in the form of calcium oxalate crystals is supposed to cause the itching sensation by the tuber and other plant parts on the human body including the mouth, tongue and throat while it is processed and consumed as a food. Estimation of the oxalic acid in taro is therefore important judging the palatability of the tubers. The results of oxalic acid content in taro as furnished in table 43 showed that moderate variation existed in various morphotypes. The range is from 0.142 g to 0.428 g per 100 g of fresh tuber. The accession IC87165 belonging to M33 from Kerala had the lowest oxalic acid content followed by M3 from Kerala and Pondichery and IC 136758 belonging to M31 from Kerala.

Table 43 Oxalic acid content in 33 morphotypes

Sl. No.	TCR No.	IC No	M. type	Oxalic acid (g/100 g)		Sl.No.	TCR No.	IC No.	M. type	Oxalic acid (g/100g)
1	2	3	4	5		1	2	3	4	5
1	541	86909	2	0.33		18	825	313060	36	0.345
2	851	266620	3	0.22		19	514	87118	37	0.245
3	887A	259994A	4	0.236		20	584	87125	41	0.265
4	785	313056	5	0.287		21	681	87206	43	0.154
5	454A	86991	11	0.242		22	153B	86971B	44	0.353
6	132	87003	12	0.234		23	823	266630	45	0.264
7	838	313064	13	0.352		24	640	87146	49	0.375
8	385A	70269A	14	0.27		25	631	87154	50	0.34
9	869	266625	15	0.256		26	423	70307	52	0.39
10	170	87024	18	0.328		27	653	87174	55	0.347
11	582B	87078	23	0.289		28	419C	70303C	56	0.378
12	200	87051	24	0.419		29	605A	87112A	57	0.378
13	875	210373	25	0.234		30	797	136761	58	0.371
14	350	70234	26	0.36		31	692	872217	61	0.428
15	792B	136758	31	0.224		32	532B	136701	63	0.371
16	434A	70318A	32	0.375		33	644	87165	67	0.142

17	498	87115	35	0.375						

Values for the entire collection					
Min.	Max.	Mean	SD	CV%	Types
0.142	0.428	0.31	0.073	23.92	33

4.11.2. Soluble sugar content

Sugar content in tubers determines the taste and energy contained in taro and this has been estimated in 56 morphotypes (Table 44). The range for the sugar content was from 0.10 g in IC87208 of M6, a cultivar from North-East to 5.1 g in IC 70230 of M28, a wild type from Kerala. The mean value for the morphotypes studied was 2.38 g per 100 g of fresh tuber weight. CV% (34.06) showed good amount of variation for the soluble sugar content among morphotypes. With respect to soluble sugar content IC70230 (M28) with 5.1% from Kerala, IC266620 (M3) from Sikkim with 4.39%, and IC86909 (M2) from Kerala with 4.31% were ahead of all others.

Table 44. Soluble sugar content in tubers of 56 morphotypes

Sl.No.	TCR No.	IC No.	M. type	Sugar content (g/100g)		Sl.No.	TCR No.	IC No.	M. type	Sugar Content (g/100g)
1	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**
1	541	86909	2	4.31		29	498	87115	35	2.53
2	851	266620	3	4.39		30	825	313060	36	1.77
3	887A	259994A	4	0.15		31	514	87118	37	2.66
4	785	313056	5	0.14		32	554	87123	40	2.52
5	683	87208	6	0.1		33	584	87125	41	3.61
6	146	86944	7	0.15		34	681	87206	43	2.04
7	531	86972	8	0.18		35	153B	86971	44	1.45
8	478	136698	9	0.13		36	823	266633	45	2.97
9	454A	86991	11	0.15		37	419B	70303B	46	1.6
10	132	87003	12	0.08		38	613B	87144	48	1.48
11	838	313064	13	0.43		39	640	87146	49	1.43
12	385A	70269A	14	0.232		40	631	87154	50	2.57
13	869	266625	15	1.09		41	423	70307	52	1.51
14	655	86916	16	1.31		42	653	87174	55	2.42

15	170	87024	18	1.02		43	419C	70303C	56	2.51
16	613A	87043A	19	0.76		44	605A	87112	57	1.62
17	515	136699	20	1.35		45	797	136761	58	3.72
18	860	266613	21	1.08		46	434B	70318B	59	3.4
19	582B	87095B	23	1.96		47	671B	87191B	60	2.56
20	200	87051	24	1.5		48	692	87217	61	1.55
21	875	210373	25	2.07		49	532B	136701B	63	1.42
22	350	70234	26	1.66		50	828	313059	66	3.48
23	592A	87096	27	1.86		51	644	87165	67	2.74
24	346	70230	28	5.1		52	831	313069	68	2.3
25	242	87105	29	2.33		53	619B	87158A	71	2.42
26	638	87153	30	2.59		54	705	87230	76	1.81
27	792B	136758B	31	3.18		55	858	266617	79	1.93
28	434A	70318A	32	2.1		56	854	266618	81	2.49

Values for the entire collection

Min.	Max.	Mean	SD	CV%	Types
0.10	5.1	2.38	0.811	34.06	56

4.11.3. Protein content of taro tubers

Protein content of tubers in taro was observed in 53 morphotypes (Table 45) and the range was from 1.0% on dry weight-basis in IC136761 (M43) from Kerala to 11.8% in IC266620 (M2) from Kerala. Mean value for the protein content was 8.67% and the CV% was 22.07%, which showed a moderate degree of phenotypic variation between the studied morphotypes. Morphotype 2 scored the maximum protein content of 11.8% from Kerala, followed by IC 86916 (M16) from Assam with 11.7% and IC87230 (M76) from Karnataka with 11.4%. Values of higher protein content obtained on dry weight basis indicated the existence of very nutritious types in Indian taro collection.

Table 45.Protein content in tubers of 53 morphotypes

S No.	TCR No.	ICNos.	Morpho-types	Protein% On fresh wt. basis	S No.	TCR No.	ICNos.	Morpho-types	Protein% On fresh wt. basis
1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
1	541	86909	2	11.80	28	825	313060	36	7.1
2	851	266620	3	9.40	29	514	87118	37	8.12
3	887A	259994A	4	10.30	30	554	87123	40	9.1
4	785	313056	5	6.30	31	584	87125	41	8.24
5	683	87208	6	9.30	32	681	87206	43	5
6	146	86944	7	9.70	33	153B	86971	44	8.6
7	478	136698	9	9.60	34	823	266633	45	8.9
8	454A	86991	11	9.30	35	419B	70303B	46	6.3
9	132	87003	12	9.60	36	613B	87144	48	9.2
10	838	313064	13	10.60	37	640	87146	49	7.8
11	385A	70269A	14	9.50	38	631	87154	50	6.9
12	869	266625	15	8.70	39	423	70307	52	8.7
13	655	86916	16	11.40	40	653	87174	55	9.2
14	170	87024	18	10.00	41	419C	70303C	56	1
15	515	136699	20	10.40	42	605A	87112	57	8.5
16	860	266613	21	10.80	43	797	136761	58	7.4
17	582B	87095B	23	9.90	44	434B	70318B	59	9.3
18	200	87051	24	10.70	45	671B	87191B	60	8.2
19	875	210373	25	7.60	46	692	87217	61	7.3
20	350	70234	26	9.20	47	532B	136701B	63	8.5
21	592A	87096	27	11.00	48	644	87165	67	7.9

1	2	3	4	5	1	2	3	4	5
22	346	70230	28	6.20	49	831	313069	68	8.7
23	242	87105	29	5.90	50	619B	87158A	71	10.2
24	638	87153	30	6.2	51	705	87230	76	11.7
25	792B	136758B	31	5.9	52	858	266617	79	10.4
26	434A	70318A	32	8.0	53	854	266618	81	10.9
27	498	87115	35	6.4					

Values for 53 morphotypes					
Min.	Max.	Mean	SD	CV%	Types
1.0	11.8	8.67	**1.912**	**22.07**	**53**

4.12. Cost of *ex situ* maintenance in taro

Maintenance of vegetative propagated germplasm, especially those of tuber bearing crops and their relatives is expensive and there is a need for monitoring of the expenditure periodically for proper advance planning for availing funds in time. In the case of taro germplasm maintenance based on the existing labour wages, tractor rental charges and cost of various items of inputs as on 05.06.03 at Vellanikkara, Thrissur was estimated to be Rs. 58. 25 per collection (Table 46). The estimate accounts for maintenance of taro in the nursery, in the open field and in the chiller cabinet simultaneously in a year. It does not account the salary of the Scientist or technical people as they are also involved in several other related activities.

Table 46. Expenditure for field-maintenance of taro germplasm at Thrissur

S.No.	Items of work/inputs	Number of labour days/	Other in puts	Rate per unit *	Amount
1	**2**	**3**	**4**	**5**	**6**
Nursery					
1*	Pot mixture preparation, filling poly- bags and planting in nursery	20		166.00	3320.00
2	Cost of poly-bags		5 kg	80.00	400.00
3	Cost of Farm Yard Manure		0.10 tone	450.00	45.00
4	Cost of sand		0.10	4000.00	40.00
Total					3805.00

1	2	3	4	5	6
Field cultivation					
5	Ploughing (two disking + 1 cultivating)		3 hours	250/hour	750.00
6*	Bed preparation and layout	10		166.00	1660.00
7*	Cow Farm Yard Manure application	03		166..00	498.00
8	Cost of Farm Yard Manure		1.5 tons	450/ton	900.00
9*	Planting	03		166.00	498.00
10*	Mulching	5		166.00	830.00
11*	Weeding and earthing up (twice)	20		166.00	3320.00
12*	Fertilizer application	4		166.00	664.00
13	Cost of fertilizer		100.0 kg	400.0	800.0
14*	Fungicide and insecticide application in field	4		166.00	664.00
15*	Harvesting and cleaning	20		166.00	3320.00
13	Cost of labels		10 sq. ft.	7.00	70.00
16	Cost of cloth bags		480	3.20	1536.00
17	Cost of fungicide (Bavistin)		120g	77.0/g	93.00
18	Cost of insecticide (Two applications)		120.0	30.00/g	36.00
Total					15639.00
Chiller cabinet storage					
19*	Fungicide application on harvested tuber	6		166.00	996.00
20*	Bagging and storing in chiller cabinet	4		166.00	664.00
21**	Running cost of chiller cabinet	5 months	1.10 unit/hour	5.67	5748.00
22	Maintenance cost for chiller cabinet (approx.)			1000.00	1000.00
	Total				8408.00
Total expenditure for 480 accessions of taro					27852.00
Cost of maintenance for one collection of taro in the field, nursery and in chiller cabinet together					58.25

* Rates of labour worked out on the basis of current salary of Beldars working at the station. Other rates calculated as per the current rates and prices.

**One chiller cabinet was used for maintenance of 1500 accessions of taro, turmeric, Curcuma, ginger, coleus etc hence running charge (electricity charge) cannot be split for any one crop.

4.13. Pests and diseases

Among the pests and insects that attack the edible aroids, Aphid (*Aphis gossypii* G.) belonging to Aphidae: Homoptera, (Anonynous, 1978) is very important and sometimes results in the destruction of the crop under more favourable conditions of intermittent rains and sunshine. Among the diseases in taro, leaf blight caused by *Phytophthora colocasiae* Raciborski, undoubtedly, is the most dreaded disease.

4.13.1. Aphid infestation in taro

In a total of 477 accessions of taro including 475 accessions falling under 81 morphotypic groups and 2 in ungrouped category, symptoms of *Phytophthora* leaf blight appeared. In general, the whole collection was infested intensely (Plate-VI). The observed values for aphid infestation (Table 47) varied from 1-9 scale and the mean value for the whole collection was 4.985 with a standard deviation of 0.376. The results indicated that the infestation intensity varied from 1 in M64 to 7 in M39 and M40. M56 with a score of 2, M71, 72, 74 and 80 each with a score of 3 were the ones with a low incidence of aphid infestation pointing to their tolerance to the stress. Table 48 gives the details of 15 accessions that are met with low infestation (1-3). The lowest infestation (1) was noticed in IC87225 belonging to M64 and IC 266635 to M80 (Plate-VI) hailing from Northeast. This was followed by collections from Kerala and Assam. One wild accession IC 70161 (M14) and IC70303C (M56), another cultivated one from Kerala also had very low infestation.

Plate VI. Aphid Infestation in Taro

1. Aphid infested taro filed at Vellanikkara
2. Aphid tolerant line (IC87225) belonging to M64
3. Aphid tolerant line (IC266635) belonging to M80)

Table47. Morphotype-wise tolerance of taro collections to *Aphis gossipii*

M type	Acession	Range	Mean	SD	M type	Accessio	Range	Mean	SD
1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
M1	80	4-9	6.90	0.836	M41	3	3-4	3.67	0.577
M2	54	5-9	6.63	0.896	M42	1	--	5.00	
M3	5	3-5	3.80	0.837	M43	3	--	6.00	
M4	7	5-7	5.86	0.900	M44	2	--	6.00	
M5	4	6-7	6.25	0.500	M45	2	--	6.00	
M6	3	4-6	5.53	1.155	M46	2	5-6	5.50	0.710
M7	20	5-7	5.70	0.657	M47	1	--	3.00	
M8	17	2-6	4.65	1.057	M48	1	--	5.00	
M9	1	--	4.00	--	M49	1	--	5.00	
M10	7	5-6	5.43	0.535	M50	7	--	5.00	
M11	36	4-7	5.47	0.736	M51	1	--	5.00	
M12	16	5-6	5.63	0.500	M52	3	2-4	2.67	1.154
M13	3	4-6	5.33	1.155	M53	1	--	4.00	
M14	5	2-5	3.20	1.304	M54	2	--	6.00	
M15	11	2-5	3.91	1.136	M55	1	--	5.00	
M16	5	3-7	5.00	1.581	M56	1	--	2.00	
M17	1	--	6.00	--	M57	1	--	6.00	
M18	20	5-6	5.20	0.410	M58	3	--	5.00	
M19	8	5-6	5.34	0.518	M59	1	--	5.00	
M20	2	6-7	6.50	0.710	M60	1	--	4.00	
M21	1	--	6.00	--	M61	1	--	4.00	
M22	2	6-7	6.50	0.710	M62	1	--	4.00	
M23	32	4-6	4.72	0.683	M63	1	--	4.00	
M24	9	4-6	4.89	0.601	M64	1	--	1.00	
M25	1	--	5.00	--	M65	1	--	6.00	
M26	21	4-6	4.71	0.644	M66	1	--	4.00	
M27	5	4-6	5.43	0.976	M67	1	--	5.00	
M28	7	5-6	4.75	1.655	M68	1	--	5.00	
M29	2	--	5.00	--	M69	1	--	6.00	
M30	3	--	5.00	--	M70	2	3-5	4.00	1.414
M31	2	4-6	5.00	1.414	M71	1	--	3.00	
M32	8	--	6.00	--	M72	1	--	3.00	
M33	1	--	5.00	--	M74	1	--	3.00	
M34	2	6-7	6.50	0.710	M75	1	--	6.00	
M35	1	--	5.00	--	M76	2	--	5.00	
M36	1	--	5.00	--	M77	1	--	4.00	
M37	1	--	6.00		M78	1	--	5.0	
M38	3	--	5.33	0.577	M79	1	--	5.00	
M39	1	--	7.00		M80	2	1-5	3.00	2.828
M40	2	--	7.00		M81	1	--	4.00	

Collection mean = 4.985, Range = 0-9, SD = 0.376

Table 48. Aphid tolerant lines in Taro

TCR No	IC No	M type	Origin	Local name	Score
1	**2**	**3**	**4**	**5**	**6**
154	86919	03	Kerala	Cheruchembu	3
155	86954	08	Kerala	-- do--	3
265A	70150A	14	Kerala	--	2
276	70161	14	Kerala	Wild	2
309	70194	14	Kerala	Cheruchembu	3
868	313065	15	Orissa	--	3
869	266625	15	Orissa	--	3
870	313066	15	Orissa	--	3
655	86916	16	Karnataka	Wild	3
618B	87163	52	Meghalaya	--	2
646	87157	52	Assam	--	2
419C	70303C	56	Kerala	Cheruchembu	2
700	87225	64	Assam	--	1
465	--	74	--	--	3
862	266635	80	North East	--	1

4.13.2. Leaf blight disease incidence

The disease symptoms that appeared in the first week of July had slowly advanced and finally, on weakening of the rains in the third week of July, the brown spots had started spreading and joining together to form larger blotches towards the margin.

A total of 473 accessions could be observed and the morphotype-wise infected mean leaf-area percentage and SD as furnished in table 49 indicated less uniformity in percentage leaf area infected in different collections within some morphotypes further indicating a certain amount of intra-group variability which may be caused by chance infection under uncontrolled field condition. The infected leaf-area percentage ranged from 0.01% in several collections to 61.4% in IC 87163 (M52). The percentage of infected leaf-area was low in M65 (varied from 0.01 to 4.99%). None of the accessions was found to be completely free of infection but indicated only high degree of tolerance collections to the disease in field epiphytotic conditions. Wherever the number of accessions observed are less than two no range is furnished.

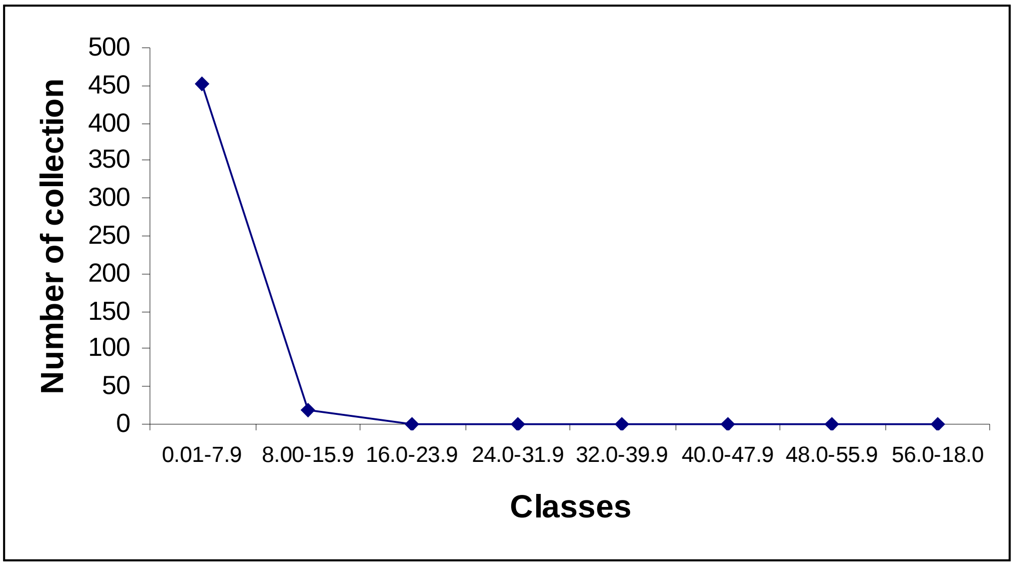


Fig. 16. Frequency-class distribution of leaf blight incidence in taro

With respect to frequency class distribution of infected leaf area percentage, 8 classes were obtained at a mean-class interval of 7.9% and the frequency curve obtained in the study (Fig. 16) indicated an abnormal distribution pattern having very high frequency for the first class i.e., 0.01 to 7.99, very few in the next class and only one in the third, seventh and eighth classes. A negative correlation existed between percentage leaf area infected and the fresh tuber yield.

A total of 59 accessions belonging to 22 morphotypes with 0.05% or less infected leaf-area (Table 50) were assumed to have some amount of tolerance as compared to the others. Maximum field tolerance was shown by collections from Kerala followed by 5 from Himachal Pradesh, 4 from Tamil Nadu, 3 from Sikkim, 2 each from Karnataka, and Nagaland and I each from Maharashtra and Meghalaya. These collections can be further used for screening under the controlled conditions in order to isolate blight tolerant lines in the crop for incorporation in the crop improvement programme.

Table 49. Morphotype-wise picture of percentage of leaf-area with blight infection

M.	Samples	Mean	SD	Range	Freq.	M. typ	Samples	Mean	SD	Range	Freq.
1	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
1	79	4.495	6.254	0.23-50.66	LMH	43	3	1.28	1.002	0.42-2.38	L
2	54	3.212	2.718	0.28-14.85	L-M	44	2	0.410	0.014	0.4-0.42	L
3	5	0.079	0.091	0.01-0.21	L	45	2	11.560	14.340	1.42-21.7	LH
4	7	0.613	0.473	0.08-1.19	L	46	2	5.45	3.564	2.93-7.97	LM
5	4	0.275	0.070	0.19-0.36	L	47	1	0.88	--	--	L
6	3	1.383	1.770	0.09-3.40	L	48	1	4.21	--	--	M
7	20	0.478	0.318	0.05-1.17	L	49	1	3.86	--	--	L
8	11	0.258	0.137	0.06-0.51	L	50	7	2.46	2.491	0.15-6.11	LM
9	7	0.560	0.432	0.10-1.26	L	51	1	2.82	--	--	L
10	7	1.824	1/745	0.53-5.57	LM	52	3	23.95	32.446	4.3-61.4	MH
11	36	0.271	0.280	0.03-1.17	L	53	1	0.96	--	--	L

1	2	3	4	5	6		1	2	3	4	5	6
12	16	1.404	3.806	0.04-15.38	LH		54	2	0.45	0.467	0.120-0.78	L
13	3	2.847	3.220	0.03-6.36	LM		55	1	1.07	--	--	L
14	5	3.998	4.651	0.20-12.06	LH		56	1	0.1	--	--	L
15	10	1.740	2.592	0.02-6.90	LM		57	1	0.96	--	--	L
16	4	0.283	0.100	0.17-0.41	L		58	3	3.12	4.798	0.34-8.66	LM
17	2	0.455	0.346	0.21-6.70	L		59	1	0.02	--	--	L
18	20	0.522	0.691	0.03-3.01	L		60	1	0.194	--	--	L
19	8	0.452	0.409	0.07-1.28	L		61	1	0.49	--	--	L
20	2	0.435	0.375	0.17-0.7	L		62	1	0.2	--	--	L
21	1	0.410	--	--	L		63	1	0.06	--	--	L
22	2	0.455	0.163	0.34-0.57	L		64	1	0.06	---	--	L
23	35	0.435	1.277	0.01-7.2	LM		65	1	0.05	--	--	L
24	9	0.328	0.411	0.61-1.16	L		66	1	0.12	--	--	L
25	1	0.080	--	--	L		67	1	0.03	--	--	L
26	21	1.09	2.845	0.01-13.10	L		68	1	0.32	--	--	L
27	5	0.490	0.581	0.01-1.38	L		69	1	0.46	--	--	L
28	7	0.994	1.995	0.03-5-47	LM		70	2	0.175	0.219	0.02-0.33	L
29	2	0.205	0.276	0.01-0.40	L		71	1	0.85	--	--	L
30	3	0,053	0.04	0.03-0.10	L		72	1	1.81	--	--	L

1	2	3	4	5	6		1	2	3	4	5	6
31	2	0.010	--	--	L		73	1	0.00	--	--	L
32	8	0.261	0.545	0.02-1.6	L		74	1	0.01	--	--	L
33	1	0.070	--	--	L		75	1	0.33	--	--	L
34	2	0.050	0.028	0.03-0.07	L		76	2	0.895	1.096	0.12-1.67	L
35	1	4.86	--	--	M		77	1	0.15	--	--	L
36	1	0.52	--	--	L		78	1	0.05	--	--	L
37	1	1.38	--	--	L		79	1	0.80	--	--	L
38	4	0.533	0.377	0.11-1.01	L		80	2	1.48	1.669	0.3-2.66	L
39	1	5.05	--	--	M		81	1	7.68	--	--	M
40	1	0.14	--	--	L		82	1	--	--	--	L
41	3	0.067	0.081	0.01-0.16	L		83	1	1.97	--	--	L
42	1	0.25	--	--	L		Total	475	1.908	4.479	0.01-61.4	LMH

(L- Low = 0.01-5%, M- Medium = 5.1-10%, H- High = >10%)

Table 50. Blight tolerant lines

S.No.	IC No.	M. type	Percentage of infected leaf area	Origin		S.No .	IC No.	M. .type	Percentage of infected leaf area	Origin
1	2	3	4	5		1	2	3	4	5
13A	086917	M3	0.01	Kerala		716	136704	M23	0.02	Tami Nadu
851	266620	M3	0.02	Sikkim		811	266629	M23	0.04	Himachal
118	086949	M7	0.05	Kannataka		815	266628	M23	0.04	Himachal
386	070270	M11	0.05	Kerala		358	070242	M24	0.01	Kerala
389	070273	M11	0.04	Kerala		564	086067	M24	0.03	Kerala
424	070308	M11	0.05	Kerala		600	087141	M24	0.01	Nagaland
426	136697	M11	0.03	Kerala		320	070204	M26	0.04	Kerala
134	087005	M12	0.05	Maharashtra		394	070278	M26	0.02	Kerala
621	087008	M12	0.04	Meghalaya		400B	070284	M26	0.04	Kerala

1	2	3	4	5		1	2	3	4	5
175A	087010A	M13	0.03	Kerala		665	087083	M26	0.05	Kerala
542	087012	M14	0.02	Kerala		801	136764	M26	0.01	Himachal
868	---	M15	0.02	Orissa		273	070158	M27	0.01	Kerala
183	087030	M18	0.03	Kerala		328	070212	M28	0.04	Kerala
480	087033	M18	0.03	Kerala		337	070221	M28	0.03	Kerala
532A	136701A	M18	0.04	Kerala		243	087107	M29	0.01	Kerala
208	087055	M23	0.02	Kerala		435	087110	M31	0.01	Kerala
216	---	M23	0.01	---		792B	136758B	M31	0.01	---
263	070148	M23	0.02	Kerala		413	079297	M32	0.04	Kerala
281	070166	M23	0.02	Kerala		434A	070318	M32	0.03	Kerala
297	070182	M23	0.01	Kerala		590	087112	M32	0.03	Kerala
304	070189	M23	0.01	Kerala		802	136769	M32	0.02	Himachal
5310	070195	M23	0.01	Kerala		820	136770	M32	0.02	Himachal
322	070206	M23	0.01	Kerala		584	087125	M41	0.01	Nadu
334	070218	M23	0.02	Kerala		617	087188	M41	0.03	Nagaland
335	070219	M23	0.01	Kerala		434B	070318B	M59	0.02	Kerala
384	070268	M23	0.01	Kerala		879	266634	M65	0.05	---
469	087060	M23	0.01	Kerala		664	087180	M67	0.03	Karnatakaa
525	087065	M23	0.01	Kerala		824B	---	M74	0.01	---
582B	087036B	M23	0.01	Tamil Nadu		855	2666616	M78	0.05	Sikkim
586B	087019B	M23	0.01	Tamil Nadu						

5. DISCUSSION

5.1. Exploration and sampling methodoloy

A total of 993 accessions of taro have been collected in 28 exploration and collection trips conducted in different parts of India and also on transfer of collected germplasm from these parts to Vellanikkara. Out of this a total of 481 accessions which survived at the beginning of the studies were used for the purpose.

Collection strategy, methodology and logistics have been discussed in detail for all the vegetatively propagated crop plants by Huaman *et al.* (1995) and the suckers and tubers were stated to be the suitable propagules in them. In most of the cases mature corms (primary and secondary mother tubers) and cormels (lateral tubers) from farmers stocks and live suckers from the field were collected which served the purpose in the present study. The observations during the explorations indicated that there is a tendency for over sampling in certain types in certain areas having wider and frequent occurrence. This was due to the fact that local names for a specific variety varied from place to place. Sampling sites varied from place to place and season to season, and of course, the collector did not have an initial clear-cut picture of the variability of the cultivated and wild taro that occurred in the surveyed areas. Farmers in many occasions did not have the idea of the variety they were holding and simply called them by various common names in different languages. Most of the initial trips were coarse-grid and multi-crop expeditions in southern region and elsewhere for assessing variability existed in such areas. Thus earlier practice of sampling the materials from nearby sampling sites for the crop lead to over sampling and a composite sampling technique was never adopted in such cases. Later on, as the knowledge on the crop variability increased and crop specific expeditions were carried out in centers of diversity, morphotypic sampling/selective sampling as advocated by Hawkes (1980) was done to reduce the over sampling and avoid redundancy in *ex situ* field conservation. The recommended procedure was the adoption of selective sampling strategy for such crops like taro and yams. In several occasions market sampling could also be done as suggested by Hawkes (1975, 1991) where morphotypes from a large area of cultivation of the crop might be present in the markets. After the studies, it could be very clearly understood that taro being a vegetatively propagated crop, to amass the existing variability in any region sampling of types on the basis of subjective morphology as suggested by Hawkes (1980) is the best suited method rather than adopting random sampling at specified distances depending upon the nature of variation observed by the collector as in the case of seed crops with autogamous or allogamous breeding behaviour. This might really reduce the efforts, time and expenditure involved in survey, collection, characterization, evaluation and *ex situ* conservation of the variability. The point can be very clear in the light of results obtained in morphotypic classification of the germplasm as dealt in chapter 6. The random sampling method is based on the breeding behaviour of the crop as far as the cultivated seed crops are concerned. Marshal and Brown (1975) and Brown (1989) based on the allelic constitution of the sample size in relation to the neutral alleles (Kimura & Crow, 1964) present in the population subjected to sampling advocated this method. This, in practice effects the inclusion of at least all the alleles that have a frequency distribution of >0.5% in the said population. The classification studies in the present work itself very clearly substantiate that only a total of 83 types could be identified in 474 collections. Thus some sort of over-sampling of certain types in certain agro-ecological niches in the case of M1, 2, 7, 8, 9, 10, 11, 12, 20, 21, 22, 23, etc. led to such a situation.

5. 1.1. Areas covered

Areas covered for the collection indicated that 6 major geographical areas such as northeastern, northwestern, eastern, central, northern and southern regions in India, which were covered fully or partially in the exploration and survey part (Fig. 2). These regions roughly represent the 7 phytogeographical zones identified in the country and as reported by Arora and Nayar (1984) while dealing with the wild relatives of crop plants in India.

The regions surveyed included North-East of Phytogeographical zone II and III, Eastern region of zone VI, North-Western region representing zone I, Northern and Central regions representing zone IV, Western region representing parts of zone VII and Southern region representing parts of zones VI and VII. The North-Western region falling under zone V is represented by only few samples which are market samples indicating almost absence of taro cultivation in this dry belt. The latitude of taro cultivation varied from 8° 85' N in the extreme south to 35° 0' in the in Himachal Pradesh and in all longitudes except in extreme arid desert conditions in Rajasthan. The areas covered included states of Assam, Arunachal Pradesh, Nagaland, West Bengal, Sikkim, Meghalaya, Orissa, Jharkhand, Thripura, Mizoram, Andhra Pradesh, Karnataka, Tamil Nadu, Pondichery, Kerala, Maharashtra, Madhya Pradesh, Uttar Pradesh, Delhi, Rajasthan, and Himachal Pradesh. There was a clear tendency of more concentration of taro cultivation in North-East, Southern region, Eastern region and North-Western hilly region of India.

5.1.2. Agro-ecology of taro in India

From the survey and the samples collected it was evident that taro as a crop is mainly cultivated under the subsistence farming in most of the areas surveyed and very seldom as a commercial crop. Usually taro diversity is more in high rainfall areas in North-East, South-Western and Eastern regions (Orissa and its border places with Andhra Pradesh) as reported earlier by

Velayudhan and Muralidharan (1987). Various tribes and ethnic groups inhabit these areas especially in North-Eastern and Eastern region. In Kerala, cultivation was very wide spread in the past, which at present has dwindled mainly due to changes in crop priorities under the changed cropping pattern.

Mixed cultivation of taro with other horticultural crops (Plate I-11) and plantation crops were seen in Kerala whereas mostly mono-cropping in North-Eastern region in backyards, roadsides partly inundated areas, along the channels, shaded areas, etc. In Northern and Central parts and in Tamil Nadu restricted commercial cultivation of the crop probably aiming at the urban markets was noticed.

Occurrence of wild taro (Plate I) from the tropical evergreen forests at low elevations to marshy areas in high rainfall areas, irrigation canals, seasonal water falls, streams in the forests and roadsides (were noticed all over. The wild taro has been found to be spreading fast in moist and marshy locations including semi-arid areas in tropics. This further strengthens the belief on its origin in wet tropics and Plate VI. Aphid Infestation in Taro gradual spread towards less wet and drier areas in the country as opined by Purseglove (1975). Both upland rain-fed and wetland cultivation are noticed. It was found to be growing in all types of soil from sandy coastal alluvium, laterite, sandy-loam, black cotton soils and forest alluvium. In North and North-East planting in two seasons one in Jan.-February and the other in

May-June was noticed. In Plains of Asssam, planting is done during Jan.-February under water logged situation. Upland planting is done always during the pre-monsoon periods. Taro cultivation under puddled condition as reported in Fiji could not be noticed anywhere in India. However, var. *esculenta* type taro cultivation in waterlogged situation has been noticed in Konkan and in Uttar Kannada of Karnataka. In Kerala, subsistence farming under slightly shade-loving situation is noticed.

5.1.3. Local cultivars and wild types with names

During the exploration and collection of taro germplasm from different areas a total of 56 local names could be listed in the passport data (Table 7). From the passport information it was evident that most of the accessions collected did not bear local names either due to the absence of such specific names in Kerala and Assam. Further local names include some common names that are related to wild types of taro. 'Kadukesu' in Kannada, 'Kattuchembu', 'Velichembu', 'Marambu chembu' and 'Marambu' in Malayalam, 'Jungli saru' in Oriya, 'Kattuseppai kilangu' in Tamil are in use for wild types of taro in different places. One cultivar name at different places may be either specific for one distinct type or may sometimes be connected to different types irrespective of their similarity in morphology due to some mistake in exact identity by local farmers. The list also includes names of three important released types from CTCRI, Thiruvananthapuram. The names denoted mostly specific morphological features of the cultivars like ‘Pnchamukhi’ with multiple faced mother tubers, ‘Suikachu’ meaning long thin pointed and cylindrical mother tuber, ‘Krichembu’ or ‘Karutha chembu’ connected to dark purple petiole, ‘Kudachmbu’ with very large umbrella like leaves, ‘Choriyan chembu’ with itching tuber flesh, ‘Cheruchembu’ with small mother and lateral tubers, ‘Kannan chembu’ with light purple or purple spot on the middle of lamina, ‘Karutha kannan’ with purple spot in the centre of the leaf and with purple petiole, ‘Chuvanna kannan’ with red spot on the center of lamina, ‘Thamarakkannan’ meaning type with lotus like leaves with a spot in the centre of lamina, ‘Adukkachembu, with very compact tubers, ‘Podichembu’ with small tubers, ‘Kottachembu’ with compact large underground tubers like basket, ‘Appooppan chembu’ with more roots and persistent leaf sheaths on tuber parts, and ‘Duddh kusu’ with good tuber with the taste of milk. Names sometimes also denoted the situation and places of taro cultivation or occurrence, like ‘Nanachembu’ meaning irrigated taro and ‘Malaraman’ or ‘Malaariyan’ meaning type cultivated in mountainous or hilly situations. Names also denoted the place of origin of the type like ‘Kovvur local’, ‘Berhampuri local’ and ‘Walkawali local’. This was due to the tendency of the crop breeders and the collectors to name the local cultivars with the name of the original place of collection. All the names with ‘Kannan’ suffix are from mostly Kerala and neighbouring areas and are morphologically closer to the common local wild type such as M16 as given under classification. Though 89 local names including breeder's numbers have been furnished under review part only 59 could be obtained.

5.2 Maintenance of taro germplasm

5.2.1. Field maintenance

Taro collection is mainly maintained in *ex situ* field condition, which is a difficult and costly affair. Loss of germplasm is usually encountered due to various factors such as extreme situations of blight disease, aphids, and armyworm infestation and storage rot caused by *Pythium* spp. during the repeated cultivation and storage of tubers during summer. Maintenance of the collections by annual regeneration in the field with a duplicate set in the nursery under potted condition in the shade house and later on with one more duplicate set in the chiller cabinet during summer storage has considerably reduced the germplasm loss. Loss of germplasm in the nursery due to damage at the transit stage after sampling is also noticed. The general observation on the collections maintained is that seasonal planting of the main collection in the open upland field under rain-fed condition at Vellanikkara followed by keeping of duplicates as potted plants in the 25% shaded condition with protective irrigation during summer could solve the problem to certain extend. Though 481 (Table 7) accessions could be subjected to study at certain stage of the study as in the case of observation on plant types, only 475 accessions could be subjected to characterization for floral and spike characters by these methods. Use of chiller cabinets at 13 °C and at 71% RH was also done in the case of harvested and cleaned tubers after dipping the tubers in Dithane M45 (3%) solution for 5 minutes and drying in shade for two days during the summer solved the problem to greater extend in summer storage. This method enhanced the storage for more than one year. Thus the taro germplasm subjected to the present study was being maintained in all the three above conditions during the time of the study. However some of the collections belonging to distinct morphotypes were lost during the last year of the study leading to inability to take photographs and to observe certain parameters of certain morphotypes. These types being very rare were from distant geographical areas.

5. 2.2. Cost of *ex situ* maintenance of taro

Cost of *ex situ* maintenance of taro germplasm in the field genebank is an expensive affair and it has been calculated as provided in the results part based on the existing costs of inputs and labour wags in connection with field operations, prices of manure, fertilizers, land ploughing, cost of electricity for running summer storage modules and other chemicals in 2003 at Vellanikkara. The estimated cost of maintenance @ Rs. 58.25 per collection indicated for the first time that it is an expensive affair and the escalating costs in coming years may be a challenge to the conservationists for maintenance of vegetative propagated crops in general and taro in particular. The piece of information is first of its kind reported so far in India.

5. 3. Classification of taro germplasm

Classification of indigenous taro germplasm was initially done by subjective method proceeding from differentiating the plant-types, leaf-types, sheath-types, tuber types and finally differentiating morphotypes supported by objective data.

5.3.1. Plant types in taro

With respect to plant types, a total of 9 groups have been identified in 481 collections based on subjective assessment of the plant stature, appearance, colour, etc of aerial parts under *ex situ* condition at Vellanikkara, Thrissur. Since the aerial parts are mainly petioles, leaf sheath, leaf lamina, stolons and exposed rhizome parts, similarities and dissimilarities between various accessions could be easily distinguished by comparing live plants in the field during the main growing season. The plants, either erect or semi erect combined with the leaf disposition pattern, lamina shape, suckering habits, etc. decide the plant types. The plant types belonged roughly to various morphotypes and different recognized taxonomic groups. Though there tends to have difference of opinion in the minds of researchers on the scientific credibility of these types, the present study indicates that all these types are realistic impressions in the mind as in the case of conventional taxonomy and if fragmented either to quantitative data or to qualitative data one by one becomes absurd. However, these types in totality provide a sensible picture of the variability present in the germplasm. Here, application of one or two characters for differentiating a taxonomic variety may miserably fail due to Polymorphism in the studied species. Some plant types in taro as depicted in Plate IV may tend to resemble others in aerial characters but will be distinct morphotypes if viewed from other angles such as sheath types, tuber types, etc. The results indicate that the most compact plant types in taro are noticed in M7, 8, 9, 10, 11, 12, 15 and 17 and these can be useful for high density planting for large scale cultivation.

5.3.2 Leaf types in taro

Similarly, 481 collections were differentiated into 16 leaf-types (Table 11) and figure 3 based on appearance in relation to leaf shape, colour, leaf basal sinus width, depth, undulation, margin undulation, presence of pigmentation in the center of the leaf as detailed in the Table 11. Generally the var. *antiquorum* type leaves tend to be broader in the middle giving a suborbicular shape where as in var. *esculenta* type leaves tend to be longer and broader towards much above the middle. However there are antiquorum types with slightly oblong leaves. The leaf shape in taro forms an important key character in differentiating these morphotypes into the above major groups and has been used in the present study for classification. Earlier studies on this aspect have not been met with in literature.

5.3.3. Sheath types in taro

Sheath margin disposition in collections of taro appeared to have specificity in relation to different morphotypes identified. Observation on sheath margin in taro indicated that mainly four groups as depicted in table 10, figure 4 and at the end of plate 2 occur. Out of 474 accessions The first group with 304 accessions have almost closed sheath margin; the second group with 69 collections has medium close or medium wide leaf sheath margins, the third one with 96 accessions has very wide margin and the fourth one with 5 accessions happens to represent a specialised situation noticed only in advanced forms of var. *esculenta* cultivars from north-eastern Region in which margin on one side overlaps the other with an undulating raised part just below the ligule. This specialised nature of sheath margin was located in typical cultivated accessions of var. *esculenta* from Northeast could not be assigned to all the well-recognized cultivated var. esculenta from different regions of the country.

5.3.4. Tuber types in taro:

By grouping the corm (mother tuber) and cormel (lateral tuber) shape and size in 474 accessions of indigenous taro germplasm could be divided into 21 distinct types on the basis of subjective method as furnished in Table

13, Figure 5 and Plate 2. This can be further used to ascertain probable morphological affinity among the collections in relation to evolutionary pattern of the economically useful underground parts in taro which is usually subjected drastically to human selection pressure. In the present study it is observed that there are several distinct groups of tuber types providing certain clues to the evolution of various types of taro cultivated in India through introduction, domestication and acclimatization to various edaphic, climatic and selection pressures under prolonged cultivation in different regions of the country. A probable evolutionary path way purely on the basis of comparative morphology in taro tuber types has been chalked out (Fig. 17). Thus apparently, there is a strong probability of gradual evolution of morphotypes in taro with small to medium round mother tubers with round or cylindrical lateral tubers (T1) from wild tuber types with small round mother tubers and lateral long thin stolons (tuber type 6) through intermediate tuber types with round or oblique mother and semi-stoloniform lateral tubers (T2). Part of the morphotypes belonging to this group have more var. *antiquorum* characters but also sometimes has intermediate characters of both var. *esculenta* and var. *antiquorum* as well. Tuber type 2 may also be connected to a second evolutionary path where the wild type with oblique mother tuber and stoloniform tubers (T4) evolved into tuber types such as T11 and T2 and also multifaced mother tuber types (T12) through the two faced mother tuber types (T21). The individual morphotypes falling under this section include mainly morphotypes belonging to ‘Kannan’ group of Kerala with M7, 8, 9, 10 and

11predominantly with characters of var. *esculenta* as discussed earlier and some related morphotypes from North-East such as M12. The common wild type of this group is the M16 and probably is *C. esculenta* var. *aqualtilis*, the possible progenitor of taro as reported by Matthews (1991). This type with green colour occurs very commonly in all marshy areas in rain forests and along the drainages and fringes of paddy fields in tropics and subtropics. It is very certain that this type is not very distinct from *C. esculenta* var. *esculenta* in floral morphology and hence there is hardly any reason for its consideration as distinct variety than var. *esculenta*. The multifaced conical and oblique mother tuber types with club shaped lateral tubers are specially evolved forms (T11 and T12) found in North and North-East extending to Kerala have plant characters of 'Kerala Kannan' group of var. *esculenta*. Wild types with large mother tuber and long lateral stolons (T9) are related to such types with large globose mother tubers and semi-stolonform, club shaped but erect lateral tubers and with club shaped erect or semi-erect tubers (T14) which probably evolved into type with similar globose, large mother tubers and similar large few lateral tubers (T15). The morphotypes falling under the above tuber types have very close aerial morphological characters and are sometimes called 'Bilathichembu', 'Malaraman' or 'Kudachembu' and are perhaps introduced in Kerala. These combine floral and aerial vegetative characters of both var. *esculenta* and var. *antiquorum*. On the other hand, forms related to type 1 with similar mother tuber shape and size with tuberous cormels as in the case of tuber type1 depicts the var. *antiquorum* cultivated type. Both of these are related and there is greater chance of evolution of tuberous types from the stoloniform type. The major evolutionary path in cultivated type of taro having tuber types (T17) hailing mostly from North-East and South-West with large long cylindrical mother tubers (corms) and similar looking few lateral tubers (cormels) appears to be from the typical wild var. *esculenta* forms (T10) with very cylindrical or spindle shaped mother tubers and long thick stoloniform lateral tubers having common occurrence in these parts gradually through the intermediate semi-stolonoform tuber types (T8 and T16). All these types have typical floral and vegetative characters of var. *esculenta*. Thus considering the morphological affinities of various tuber types containing morphotypes and major taxonomic types in taro with due respect to the significance of evolution of tuber types under the human and natural selection pressures as also influenced by the genetic factors, wild types could eventuate by reversion on escape from cultivation and hence suggested that the wild types of taro might originate polyphyletically both from its wild type ancestor and cultivated forms as suggested by Matthews (1995). Thus, the evolutionary pathways for the absolute make up of various present day cultivated forms of taro in a large geographical area that of a country like India render very confusing picture. Both diploid and triploid forms with large amount of point and structural aberrations in chromosomes of triploid taro as reported earlier by several authors and these findings

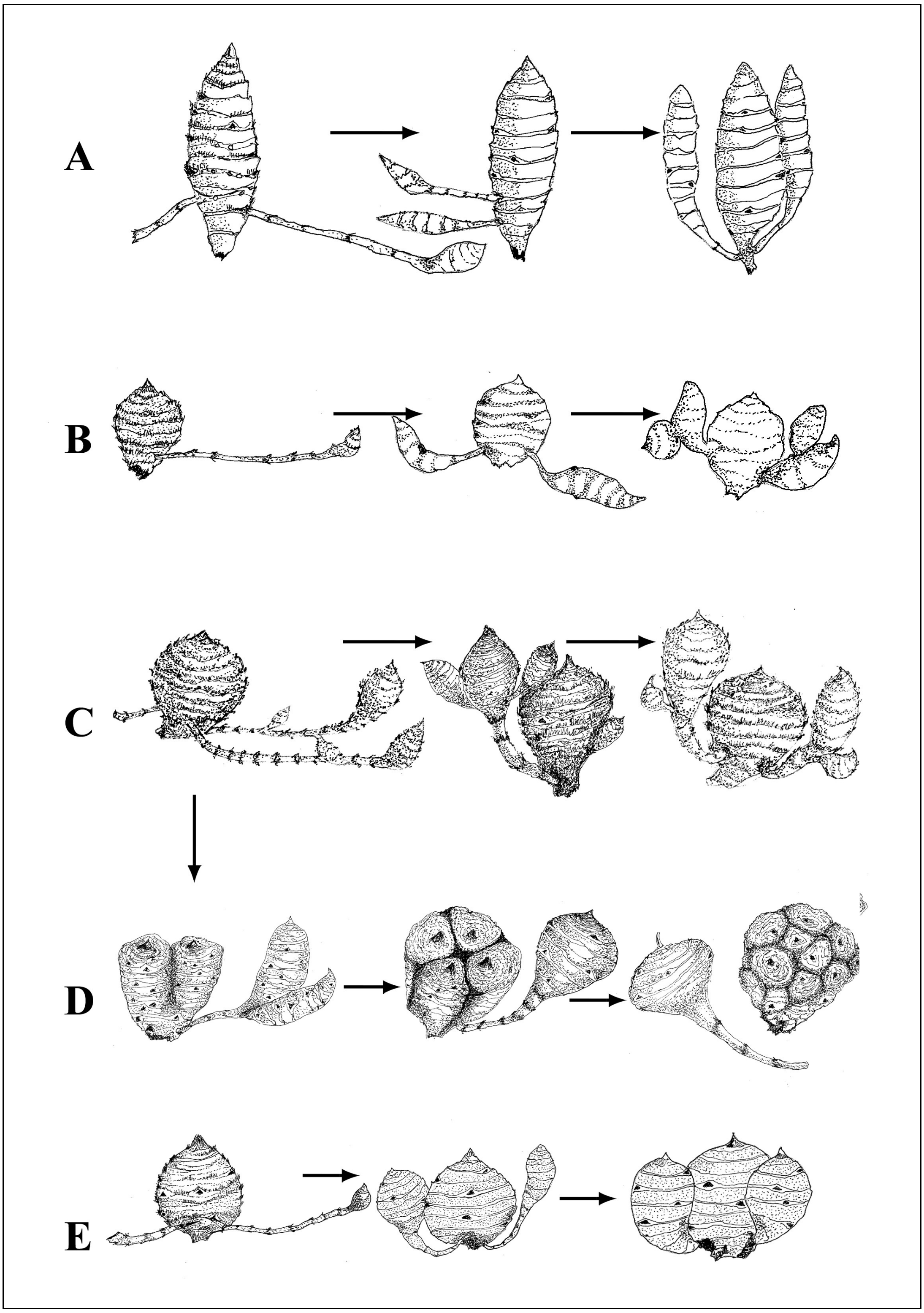


Fig. 17. Presentation of probable evolutionary pathways for tuber types in taro

(A = Evolution of typical var. *esculenta* tubers with cylindrical or spindle shaped mother as found in North East and in south-western regions, B = evolution of typical var. *antiquorum* tubers with spherical, oval mothers and spherical mother and small lateral tubers noticed all over India, C = evolution of typical var. *esculenta* (‘Kannan’ group) tubers with conical, oblique mother, cylincdrical or club shaped tubers found very commonly in Kerala, D = evolution of typical var. *esculenta* tubers with multifaced mother as an offshoot of ‘Kannan’ as noticed in North-East, and E = evolution of intermediate types with large globose mother forms as noticed in Kerala and North-East)

not very conclusive can virtually lead to further studies in future at genetic and molecular levels to throw light on the non-centre origin, domestication and evolution of cultivated taro crop in indifferent areas. These results though more on the speculative side of interpretation has not been dealt in detail in the literature probably due to the fact that the crop is considered to be extremely polymorphic in nature.

Thus, in taro domestication took place in different pockets widely distributed in Asian region and the earlier contentions on its origin and domestication in Indo-Malayan region by Plucknett (1976), South-East Asia by Zeven and Zukovsky (1975), India by Spier (1951) and in North-Eastern region of India by Kuruvilla and Singh (1981) happen to be only partially true in the light of these findings. Rather Non-centre origin (Harlan, 1975) as reported in the case of certain other crops by several authors may be a more acceptable proposal in taro as well, as morphologically very much-related wild and parallel cultivar forms occur in localised regions. Of course, the crop-spread and adaptation to newer areas during the pre-historical times leading to localised set of cultivated races in time and space cannot be ruled out until and unless the genetic lineages within and between such existing localised populations are worked out further.

5. 3.5. Morphotypic classification

Genetic resources activities in such a reportedly very complex crop species such as taro is naturally met with difficulties due the occurrence of extreme levels of morphological variation pointing to the existence of infra-specific groups each having morphologically very similar clones occurring either in the same or in different and faraway ecological niches. The situation leads to confusion in determining the origin of taro and also in the conventional taxonomic sense. Grouping of individuals in a population based on morphological characters of analytical nature may help in delimitation of possible entities within a taxon but in a highly polymorphic species such as taro is, distinct subjective morphotypes (Velayudhan *et al.* 1993) need the objective validation using several characters that are quantitative and qualitative in nature. In the present study therefore form a part of such validation. Thus, the validation can be done by pictorial scatter diagrams (Anderson, 1957), polygonal graphs and several other statistical methods such as coefficient of association (Sneath, 1957), correlation coefficients (Sneath and Sokal, 1962), taxonomic distance (Sokal, 1962), Cluster analysis (Sneath and Sokal, 1962), discriminant function (Fischer, 1936), canonical and principal component analysis (Rao, 1952 and 1964) and factor analysis (Lawly and Maxwell, 1963) can be employed in classification with the help of computers. Taxonomically confusing species such as taro is the best example of a biological species where the members or groups of similar morphological entities are either reproductively isolated or not and hence Matthews (1997) quoted Hay (1996) that no formal infra-specific taxa be recognised in the species.

Compartmentalisation of variation in plants in general and crop plants and other economically useful species in particular is the basis to understand them in depth and to communicate to others. This also helps in advanced studies leading to proper, easy and cheaper conservation by avoiding redundancy and for their proper utilisation. The use of classification is pretty old in the history of systematics and with the proposal of the biological species concept looked into the 'empirical' fact that the living organisms do not vary continuously on the whole range, but they fall into more or less well defined groups which are commonly called species. The same principle may also stand true or valid in infra specific groups that have been noticed in taro. This point is very particularly true in the case of vegetatively propagated crop like taro in which variations are trapped in time and space due very limited chance of out breeding. In most of the seed crop species on the other hand subjected to out breeding, inbreeding and various natural and human selection pressures result in continued infra specific variation in localised populations in time and space, the land races with minimal variation within each population and maximum in between them can be grouped into cultivars based on ICNCP (International Code of Nomenclature for Crops) rules. Finally Accessions of wild and cultivated taro (*Colocasia esculenta* (L.) Schott) from different agro ecological and physiognomic zones of India have been grouped into 83 morphotypes as depicted morphotype wise in table 1 and Plate 2. Grouping was done step by step subjectively from plant types to leaf types, sheath margin types and tuber types. Finally, grouping of 475 collections was done on subjective basis by comparison of live plants (both aboveground parts and underground parts) repeatedly over the years in order to finalize various distinct morphological types (Velayudhan *et al.,* 1993). The morphotypes happened to be either local cultivars or wild types from areas surveyed. A morphotype is a plant type and is both a distinct phenotypic and genotypic (ecotype) entity. Its expression in relation to a specific environment is very specific. With respect to all the qualitative characters studied the accessions included in each individual morphotypes had uniform character distribution and with respect to the quantitative characters the phenotypic CV% for each morphotypic mean had lower values indicating least variation among accessions within any given morphotype. Thus the morphotypes happened to be the uniform entities though located in the same niches or in wider agro-climatic niches. This may also support a wider distribution of similar types in wide agro climate either due to crop introduction from one region to the other by humans. The distribution map of these morphotypes indicated that maximum diversity was noticed in northeast and southwestern region of India. In taro different morphotypes noticed in the wild and cultivated conditions may be the result of different ploidy levels, vegetative mutations, rarely possible natural crossing giving rise to variants/intermediate types, species spread and isolation in time and space and natural and human selection pressures in relation to the cultural needs. Even in the case of certain morphotypes the reproductive parts (flowers) of the plant has been almost degenerated. Usually flowering is very rare in cultivated types, fruit and seed setting is also restricted to diploid types under cultivation and in the wild as per earlier reports. There are also very closer morphotypes such as M18, 19, 20, 21 and 22 forming closer group having less pigmented, thick suborbicular leaved, large corm mothered type, M23, 24 and 25 forming another group with large plant type, large orbicular leaves, light purple pigmented petioles and sheath to purple pigmented, large mother rhizomes. However within these two groups different morphotypes were isolated using underground rhizome characters such as presence of stolons and shape of cormels (semi-stoloniferous, round, oval, spatulate tubers etc).

5.4. Flowering in taro

A total of 289 accessions of taro belonging to 55 morphotypes flowered during the course of studies. In taro, limitations in flowering, lack of synchrony, pollen sterility and protogyny have been reported to be the main constraints (Shantha et al., 1999). Only 10% of the germplasm flowered and limited number of accessions set seeds. This posed a problem in improvement of the crop by conventional methods. Sexual degeneration of vegetative propagated crops such as *Dioscorea alata* has been reported earlier (Abraham and Nair, 1990). Table19 presents 13 quantitative characters of flowering types indicated that the major difference was noticed in the case of male part length and the sterile part length based on which two distinct groups related to *C. esculenta* var. *esculenta* and var. *antiquorum* could be recognized. This is provided in the following taxonomic classification section (Numerical taxonomy). Lower values of Standard Deviation (SD) for most of the quantitative spike characters with respect to those morphotypes having more than one accession confirms uniformity within the groups. Though the male length/sterile appendix length ratio as given in the following classification section being a key character in distinguishing the two major varieties recognized in cultivated and wild taro with a significant positive correlation (0.350684) between the two characters in the present studies appears to be very much genetically related parameter in taro. The development of the spike and its parts, separation of male and female parts in the evolutionary history of the family Araceae is perhaps related to evolution of protogyny in relation to the principles of thermogenesis (Dorothy, 1995) that helps insect pollination in the genus. High degree of variation within the morphotypes observed has also the effect of polymorphism on the sexual characters.

With respect to 5 qualitative characters studied most of the flowering esculenta types emanate very good fragrance (21 types) at the time of male anthesis and set fruits. The fruit setting types (17 types) may be the diploids and the others may be triploids. Most of the morphotypes with fragrance and seed setting may belong to var. *esculkenta* and others to var. *antiquorum*. However, the intermediate types as discussed in the classification part may also be also a cause for shy flowering and non seed setting in taro. Though protogyny as reported earlier by Jos and Vijaya Bai (1977) and Rajendran *et al*. (1977) and presently noticed in all collections may be evolutionarily an advanced character to prevent natural selfing and promote crossing in the crop. Evidently the fragrance emenated during anthesis in the *esculenta* types is another supporting evidence to it. In others, smell at the time of anthesis though not fragrant is not obnoxious. Such morphotypes predominantly have long sterile appendages, which are concealed in the spathe during anthesis where as in the former types the sterile appendages are very short and usually concealed within the spathe during anthesis. In both cases the natural insects have been noticed. Matthews (1995) has reported fragrance in taro spikes at the time of anthesis in *C. aquatilis*. These characters, assume paramount importance in establishing the origin of the species in taro as per the earlier reports that cultivated taro probably has two distinct lineages of origin (Pillai, 1972). Fragrant spikes attract hundreds of insect pollinators (*Drosophyla* sp.) early in the morning. This confirms the earlier studies by Gagne, 1982;

Mirtchell and Maddison, 1983; Matthews, 1995 and Carson and Okada, 1980). Undoubtedly pollination in taro is by the specific insects and it has great significance in the evolution and spread of taro. It also establishes that pollination by a specific set of insects in the region. Probably the absence of fragrance in the latter group does not attract many insects. The flowering, fruit setting and specificity of pollinators are probably few characters that may help in establishing regional or local wild type taro as suggested by Matthews, 1995. However, such characters are also met within other morphotypes of taro probably confirming that *C. aquatilis* is in no way different from M16 found in Western Ghat region of India and closely similar other forms extending to Eastern and North eastern parts of the country. These have been now proved to be var. *esculenta* because of their short sterile appendix and longer male part length. To conclude the section it is to be added that in the Indian germplasm of the species only three distinct types of spikes are noticed such as 1. with shorter sterile appendix, 2. with longer sterile appendix with beading and the third with longer sterile appendix with linear shape and obscure beading. Hence though var. *aquatilis* type has been reported as the progenitor of cultivated taro with its shorter sterile appendix and long stoloniferous cormels noticed in rainforests extending to coastal areas and midlands in Kerala is no way different from *C. esculenta* as far as key characters are concerned.

5. 5. Numerical taxonomy in flowering morphotypes

5.5.1. Identification of taxonomic groups

A total of 292 collections belonging to 55 morphotypes flowered and these could be classified into distinct groups (Table 21) based on three important parameters (indices) such as leaf leaf width/leaf length ratio, mother tuber thickness/mother tuber length and male part/ female part ratio. Typical var. *esculenta* and var. *antiquorum* leaves, spadix and tubers are furnished in plate 1 as the standards. Though in the present classification, few vegetative characters such as leaf shape (Leaf width/ breadth ratio), shape of the corm (thickness by length ratio) and spike characters such as male part length and sterile appendix shape and length (sterile appendage/ male part length ratio and presence beading on sterile appendix) were taken into consideration. However, as compared to leaf and rhizome characters, spike characters were found to be rather more dependable. This was due to the fact that in many cases the vegetative characters exhibited various grades of overlapping. The first criterion was based on the leaf width/length ratio and the leaf type to distinguish oblong sagitate leaves in var. *esculenta* type (e) and broadly sagitate leaves in var. *antiquorum* type (a). The second criterion was based on the mother rhizome thickness /length ratio and also other tuber type characters which happened to be very irregular in fixing a dependable range for var. *esculenta* type and var. *antiquorum* type. This is due to the presence of more intermediate types in morphotypes. However, considering the variation in rhizome size, shape and extend of tuberisation these could be divided into typical *esculenta* with oblong cylindrical corms, *esculenta* wild type with stolons, wild 'kannan' (wild tuber type related to types that of cultivated 'kannan' cultivars in Kerala. These may be compared to var. *aqualitlis* but not varying from the wild *esculenta* types as per the spike characters, but resembling more cultivated *esculenta* ('kannan') in tuber characters. Types related to 'kannan' cultivars in Kerala), var. *antiquorum* wild (with stolons or semi-stolons) and cultivated var. *antiquorum* (with small to medium large globose, oval, rarely oblong corms and small oblong, oval, globose or club shaped cormels) are furnished in table 20. Coming to distinguishing the types on the basis of sterile appendix length/male part length ratio, it happned to have a greater amount of accuracy in delimiting ratios for var. *esculenta* and var. *antiquorum*. This spike character is therefore more dependable as reported in the past. One can notice several vegetative characters of both aboveground and Engler and Krause (1920) used several vegetative characters of underground and aboveground parts in combination with spike characters in their classification of *Colocasia esculenta* into different varieties. Most of these vegetative characters such as leaf shape, size, colour and petiole colour appear to be polymorphic in nature and tend to vary considerably in the species. This was due to the fact that they based both cultivated and wild accessions. As per the results obtained in the present study spike character such as male part length, sterile appendix length, presence of beading on the sterile appendage happen to be very stable characters and hence classification of *Colocasia esculenta* into infra-specific varieties may have to be revised. As per the present evidence indicates that *C. aquatilis* is no way different from the *C. esculenta* with plenty of polymorphic variations as far as vegetative characters are concerned. In var. *esculenta* the sterile appendix length is shorter as compared to male part length. In the present case the ratio obtained had a range from 0.22 in M80 to 3.0 in M68. The M80 found as wild in Coorg district in Karnataka was first suspected as a different entity at the time of collection due to its sub orbicular shape, and the thin soft nature of leaf lamina and the very wide leaf sheath. It is indeed a suspected entity among morphotypes identified. All morphotypes giving a ratio of 1 or <1 were fixed as typical var. *esculenta* types and others giving a ratio > 1 were fixed as typical var. *antiquorum* types. Most of these *esculenta* types had oblong or conical/top shaped small to very large corms. Finally it was assessed that in all the above parameters quite a lot of variation occurred indicating the polymorphic nature of the types identified in taro leading to classification of 21 entities into typical var. *esculenta* and others (34 in number) into mixed types with characters of both var. *esculenta* and var. *antiquorum* with varying combinations of all three above parameters representing a mixed genomic group. No seed setting types in any of this mixed genomic group has been obtained. Finally the combination of the three above classes resulted in identification of 10 distinct classes such as eee (21), aae (2), aee (5), aea (9), eae (4), eea (4), a/kuda/a (5), a/kuda/e (3), e/kuda/e

(1) and dee (1). Among these typical *antiquorum* with respect to leaf tuber and flower characters and seed setting nature were absent in the types and in the collection perhaps indicating an autogamous origin of taxonomically distinguished varieties in Taro. Natural hybridization as reported in *Colocasia* and *Alocasia* however remains as rejoinder to this complex situation and paves way for detailed molecular characterization in the species and a taxonomic revision on Asian taro. A maximum number (21) of morphotypes were *esculenta* with respect to all the three parameters and 32 had very mixed characters of both esculenta and *antiquorum*. However few distinct groups with large oval mother rhizome as noticed in the case of cultivated ‘Kudachembu’ variety of Kerala is combined with 8 *antiquorum* type of leaf types one *esculenta* type of leaf type, 6 *antiquorum* type of floral character and 3 *esculenta* type of flower character. This indicates that taro is highly polymorphic at all levels including even the most depended spike characters. The results also indicated that 15 were wild and 39 were cultivated types. Both cultivated and wild morphotypes had all the three above combinations suggesting presence of parallel evolutionary pattern in wild and cultivated types. Both the wild and the cultivated had all the combinations except for the var. *antiquorum* with all typical leaf, rhizome and flower parts supporting the assumption that var. *esculenta* types are the major wild and cultivated types and the var. *antiquorum* are non seed setting and may be the result of auto triplodization of var. *esculenta* in wild and cultivated forms.

The non-seed setting M80 (dee) with rhizome character of var. *antiquorum*, spike character of var. *esculenta* and with entirely different leaf character and restricted in distribution in Coorg (one sample) and the other from Assam may be another very rare polymorphic type in the evolutionary chain of the taro. This was suspected for a different taxonomic entity at the time of collection.

5.5.2. Numerical taxonomic studies in 54 flowring taro morphotypes

The above-mentioned 54 taro morphotypes that flowered in the past were also subjected to numerical taxonomic analysis based on 41 aboveground, belowground and floral characters (Table 22) in order to verify the above major groups identified in the above part.

Phenogram obtained as presented in fig. 7 showed 4 major groups, a small group with M5 and 18 and a loner (inlier, M49 from NE). The first and the second group bifurcated at 1. 33 CF and the first two major groups and the third with two types bifurcated at 1.42 CF. The fourth major group had its deviation from the third at 1.48 CF and the fifth group at 1.64 CF.

The major group 1 included mainly morphotypes originating from north, North-East, east, northwest and Central India extending to Orissa and border of Andhra Pradesh. Except very few from south, it contained 5 sub groups and the first subgroup included M1, 4, 6, 3, 67 and 64. The second subgroup contained M2, 55, 35, 37, 48 and 36. The third subgroup included M46, 47, 62 and 71. The fifth subgroup had M12 and 43.

The second major group, on the contrary constituted types mainly from southern region and included four subgroups. The first subgroup contained M7, 8, 10, 11 (‘Kannan types from Kerala) and wild semi-stoloniferous M14 and 34. Accessions of this subgroup have the spike characters of *esculenta*. The second subgroup included M75 and 78 (purple coloured wild types). The third subgroup included M16, 30, 26 and 32 (green and purple coloured wild and cultivated types more like var. *esculenta*). The fourth subgroup had two types such as M28 and 40.

The third group with 2 morphotypes such as M5 without stolons and large mother and a widely distributed M18 with large globose mother corm with stolons from NE and South.

The fourth major group contained two subgroups and three loners. The first subgroup had M15, 17 and 81(purely green coloured typical *esculenta* types). The second subgroup included M39, 63 and 79 more towards esculenta and three loners such as M33, 80 and 65 all being distinct. M49 with esculenta leaves, *antiquorum* mother and *esculenta* flower was an inlier.

The fifth major group had two subgroups and loner such as M58. The first subgroup had M13 and 68 with more of *antiquorum* characters and the second had 51, 56 and 60 with large mother corms. The results indicated that the major groups did not have any affiliation to the taxonomic grouping at the higher level but association among types at subgroup levels. Thus the classification further showed a mixed trend in grouping to favour considering taro a large polymorphic group in India. The following cytological investigations in the past may through ample light on the repeated statement about the taro as very complex polymorphic species.

Mookerjea (1955) has suggested 7 as primary basic number of the family and numbers higher than 10 were presumed to be of polyploid origin. These diploid and triploid forms occur in both varieties (Yen & Wheeler, 1968; Plucknett *et al.*, 1970; Marchant, 1971; Barrow, 1957; Ramachandran, 1978). Zhang and Zhang (1984) reported that 30 out of 90 cultivars were diploids. The report of Sharma and Sarkar (1963) indicated chromosome numbers of 2n = 2x=22, 26, 28, 38 and 42 existed in taro. Of 199 taro varieties examined in pacific region 137 had 2n =28 and 62 had 2n=42. Vijaya Bai (1982) reported 2n=42 in collections from Nigeria. Other chromosome counts such as 2n=12, 36 and 42 are by Choudhary and Sharma (1979), Rao (1947) and Delay (1951). In diploids the meiosis was almost normal and in triploids many abnormalities were observed resulting in pollen infertility. Krishnan *et al.* (1970) reported desynapsis in the species. Karyomorphological studies by Sharma and Sarkar (1963), Kuruvilla and Singh (1981), Sreekumari and Mathew 1995 made them to advocate the North Eastern origin of taro. The present results give rather a very confused picture with respect to genetic relationship between various morphotypes as presented in the dendrogram.

However the existence of two distinct taxonomic entities (two distinct species such as *C. esculenta* and *C. antiquorum* as suggested by Pillai (1972) is consistent with the results obtained in classification of 55 flowered types into two clear cut major taxonomic groups; one having shorter sterile appendix with longer male part (e) and the other with longer sterile appendix in relation to shorter male part (a). However existence of a large number of intermediate forms in the classification and their confused relationship exhibited by the numerical taxonomic studies will have to be understood in relation to further clarification of Pillai (1972) that the cultivated species has evolved by involving two complex polyploid types during the course of cultivation. The Kariotype was asymmetrical and only V - shaped and J - shaped chromosomes were present. According to him *C. antiquorum* is the most premitive of the genus as it has an asymmetrical karyotype. This cannot be taken as such as the present morphotypes contained several entities with wild stoloniform types with prominent *esculenta* characters as well as antiquorum characters. Coates *et al*., 1988 have given clue to minor differences in chromosme morphology and few cytotypes in diploid and triploid taro were reported in collections from a wider geographical region. Similar studies in a large number of representative collections from different agro ecological situations of India by Sreekumari (1992) gave a detailed information and she contented that notable degree of chromosomal structural changes have operated during the course of evolution of this complex species. They also distinguished few karyotypically distinguishable cytotypes.

5. 6 Correlation studies in morphotypes

Several attempts have earlier been made in studying correlation and path analysis in several tuber crops including Taro (Thankamma Pillai *et al.*, 1995, Kamalam *et al.*, 1977, Parthesaradhy *et al.*, 1986, Rajendran *et al.*, 1985, Rekha *et al.*, 1981, Thamburaj and Muthukrishnan, 1976 & Nasker *et al.*, 1986) based on limited number of varieties. Since a large number of accessions have been amassed from different agro ecological zones of the country and subjected to observation on a number of morphological characters, an attempt has also been made to study the correlation and path coefficient analysis in 12 important yield attributing quantitative characters of aerial and underground parts of 72 indigenous accessions of taro each representing a morphotype group. The wide range of morphological variation that exist in the crop with a view to pin point direct and indirect effects of various correlation coefficients and to establish the inter relationship/ inter dependence of the various characters studied. The study was aimed to trace those characters, which may be useful in breeding and selection work in the crop.

Path coefficient analysis (Table 26) revealed that tuber number had highest direct effect (0.5478) on tuber yield followed by plant height (0.2877) and mother weight (0.2561). Higher positive direct effect of number of tubers on yield was also reported in tuber crops like Cassava (Rajendran *et al.*, 1985; Rekha *et al.,* 1991), Sweet Potato (Thamburaj & Muthukrishnan, 1996) and Taro (Thankamma pillai *et al.*, 1995). The direct effects were negative for mother length (-0.0286), mother thickness (-0.0302), leaf length (-0.3061) and tuber length (-0.0103), suggesting less importance for these traits in selection criteria to be adopted in this crop. High positive indirect effects were exerted by number of suckers on number of tubers (0.2906). The low residual effect of 0.2798 obtained in the study indicates the adequacy and legitimacy of the characters used. The heritability studies also indicated the importance of yield and the associated characters in taro in the past (Thankamma Pillai & Unnikrishnan, 1990).

5.7 Principal Component Analysis

The results indicated that out of a total of 12 components obtained in the analysis, of 20 aboveground and belowground characters, the first five components accounted for 63.69% accumulated variation (the first principal component explained 27.76% variation, the second 13.72%, the third 9.25% variation, the fourth 6.88% and the explained 6.08% variation). The rest of the components numbering 7 could contribute only 33.5% variation. This meant that the existing variation of the morphotypes were determined by combined effect of plant height, lamina thickness, leaf type, plant type, leaf type, sheath width, corm thickness, lamina margin undulation, tuber type and corm yield, cormel thickness and leaf petiole joint colour. Thus the above characters were associated with each other in order to impart variation in taro. Those characters which were maximum responsible for contributing to the differences among these morphotypes were determined on the basis of original variables with greater influence on the components. For the purpose, the mean values from the highest and the lowest eigen vectors were considered as the threshold for selection of the most contributing variables in each component (Fundora *et al*., 1992).

Based on the first two principal components a scatter diagram as presented in fig. 11, eighty-two morphotypes could be scattered in a pattern that could very clearly indicate the genetic convergence as well as divergence among morphotypes in the species as depicted by the morphology of various types. The disrtibution of morphotypes in the first quadrant of the figure 11 indicates the presence of 20 types (M 12, 13, 14, 18, 19, 20, 23, 24, 25, 28, 43, 51, 52, 56, 57, 58, 59, 60, 67 and 68) belonging to 6 major groups as per the details furnished in table 5. In the second quadrant, 22 morphotypes (M11, 22, 26, 27, 29, 30, 31, 32, 33, 34, 38, 39, 53, 61, 65, 66, 69, 73, 74, 75, 80 and 83) belonging to 8 major groups occur. In the third quadrant, 20 morphotypes (M5, 6, 7, 8, 9, 10, 15, 16, 17, 45, 46, 54, 62, 63, 70, 76, 77, 78, 79, 81) belonging to 9 major groups are found. Finally, in the fourth quadrant 20 morphotypes (M1, 2, 3, 4, 21, 35, 36, 37, 40, 41, 42, 44, 47, 48, 49, 50, 55, 64, 71 and 72) belonging to 6 major groups are distributed. All the 82 morphotypes of taro without any regard to the taxonomic affiliations or evolutionary pattern and geographic distribution are found to scatter in the cluster diagram (Fig. 11). The result probably confirms the non-centric origin of taro in a wide geographic situation irrespective of any clear cut evolutionary pattern with respect to their the major grouping of flowering types as in the above chapter confirming the results obtained under the numerical taxonomic studies and Isoenzyme studies in the present treatise. This confirms the earlier opinion of Hay (1996). The population that has been classified into the morphotypes of a biological species have variants of sympatric and allopathic nature with similar types occurring in geographically faraway situations and different types in the same situation. Though, the cluster diagram obtained on the basis of the first two principle components of the PCA gives a very confused picture of clustering in relation to the major groups identified on the basis of the corm and cormel characters, some glimpses pertaining to the probable evolutionary pathways in the indigenous germplasm of taro can be speculated. First of all, the clustering does not adhere to the geographical distribution of the morphotypes. Secondly, it also does not indicate any pattern in grouping of wild and cultivated types together probably confirming the reported polymorphism in the species probably derived from both polyphyletic and paraphyletic origin of taro (Pillai, 1972).

5. 8. Isoenzyme studies in taro

In Isoenzyme studies, results for 44 accessions subjected to Esterase enzyme analysis indicated distinct banding pattern for all the collections. The overall results indicated that as compared to lesser variation in isozyme groups obtained in Japanese taro types having very narrow genetic base (Isshiki *et al.*, 1997), Indian taro in particular gave region wise greater difference especially in southwest, northeast and the northwest. The results of esterase enzyme banding also support that morphotypes studied for variation are distinct. Also the banding pattern for Esterase enzyme was highly complicated in taro confirming the report by Gottlieb (1983). Where as the SOD banding pattern was less complicated and did not agree with any criteria except for the geographic distribution and most of the types showing three bands in the zymogram were from the southern region except for M57, 72, 41, 54, 71 and 76 hailing from northeastern region and 1 and 60 from northwestern region and those with 2 bands were from northeastern region except for 37 and 55 from southern region. M5 with five bands and M4 with 4 bands were from South and northeastern region respectively. Dendrogram (Fig.10) obtained after pooling of positive and negative scores for presence and absence of bands in the case of two enzymes did not show any specific pattern of clustering that could be associated with origin, domestication and the present classification of the collections. The results were comparable to overall results obtained in grouping of taro morphotypes into major taxonomic groups and their association as furnished in numerical taxonomy part and clustering of morphotypes given in principal component analysis studies indicating a very peculiar situation of extreme levels of polymorphism at all levels. With respect to various varieties under *C. esculenta* identified under wild situations Hay (1996) quotes Nicolson, (1979, 1987) who considered it was hopeless to maintain taxa in such a polymorphic and plastic species and further quoted Coates *et al.* (1988) and Hotta (1983) that a classification would be erected in which perhaps two (or perhaps more) taxa were polyphyletically interderived and mutually paraphyletic. It is logical formally to recognize a single taxon, *C. esculenta* in which cultivars and informal wild types are recognized. He suggested to logically considering only a single taxon. *C. esculenta (*L.) Schott with cultivars and various varieties Now, however the natural hybridization suspected in between *Colocasia* and *Alocasia* has been suggested by Long and Ming Liu (2001) and has been demonstrated by Yoshino (1994, 1995) and Yoshino *et al.* (1998) between *C. esculenta* var. *aquatilis* and *Alocasia brisbanensis*.

The results offer support to the non-centric origin of taro cultivars in a large geographical region with different and faraway agroclimates giving rise to a series of local domesticates and their derivatives. This virtually lead to existence of distinct groups of cultivars from a common taxonomic entity (*C. esculenta*) with two floristic and cytological varieties such as var. *esculenta* and var. *antiquorum* in two distant regions such as southwestern and northeastern. There is a preponderance of var. *esculenta* and var. *antiquoprum* cultivars in northeast as compared to southeast. The situation there can be compared with cultivated banana, an important tropical fruit plant having its origin and diversity in a wider geographical region as discussed by Harlan (1975). Thus in taro in India has many intermediate types between two taxonomic entities probably the diploid *C. esculenta* and triploid *C. antiquorum* in the collection. The possible allopolyploid origin of taro with two karyotypes prior to autogamous polyplodization as giving rise to several intermediate types cannot be ruled out. The results suggest the need for taking up similar studies in a world germplasm for more supporting evidences for advocating origin of taro separately in different areas from the existing wild relatives in the region irrespective of crop introduction, migration, running wild and acclimatizing in distant areas. However, the study supports the greater diversity in Indian taro than that has been revealed by the earlier studies by Kuruvilla and Singh (1981) and later on by Sreekumari and Mathew (1991). The results of clustering pattern based on esterase and SOD enzymes did not show much association of clones based on morphological similarities and geographical distribution as against the report by *Rodriguez et al.* (2001) that similar studies based on esterase and peroxidase enzymes resulted in grouping of African, Japanese, South East Asian and Philippine accessions. This means a differentiation in relation to enzyme banding pattern with respect to geography is possible only when the sampling area is really very wide almost as wide as its present natural distribution including continents rather than a large country like India.

Various chromosome counts has been made in taro by different authors however, 2n =28 and 42 are the commonest. The present result thus indicated possibility of confirming the report of Pillai (1972) regarding the origin of taro as cultivated species by evolving two complex polyploid series during the course of cultivation. Thus both diploid and triploid cultivated and wild forms may be present. Apart from that, the possibilty of evolution of intermediate types along with the diploid esculenta and triploid *antiquorum* types both in the wild and cultivated situation either by natural and human selection or by chance natural hybridisation, seggregation, triplodization and genetic stabilization acclimatization and adaptation to different niches as depicted by different wild and cultivated morphotypes noticed in Indian taro. Running wild and reversion in evolution has also been noticed in taro and as such all the workers also report an admixture of innumerable polymorphic types without much genetic change.

5.9 Analysis of variance

Higher genotypic CV% in the case of Corm length (29.57 and 33.14) Corm thickness (26.34 and 23.45), Cormel number (32.68 and 38.97), Cormel length (31.33 and 32.01), Cormel thickness (31.63 and 35.53), Cormel weight (54.00 and 59.06), Corm weight (51.13 and 59.3 for 2000 and 2001trials respectively) as depicted in Table 27 and 30 indicate greater genetic variation in the belowground characters as compared to most of the aboveground characters. Highest CV% obtained for corm and cormel fresh weight during both the years, established the above fact beyond any doubt. This agrees in principle with the results obtained with respect to tuber types in taro that rhizome characters are evolutionarily more dynamic than the others as it is the productive and reproductive part of the crop centered around which cultivars evolved.

Further corm (mother tuber) and cormel (lateral tuber) fresh weight for both the years were significantly different at 1% level. Thus 4 lines giving fresh rhizome yield of over 900 g per plant (Table 29) during 2000 and 10 lines giving over 700 g per plant (Table 32) during 2001were promising. The treatments x control for both the years were also significantly different. The above preliminary evaluation in crop genetic resources studies is to assess the general productivity of the crop collection including those characters, which are associated with the crop productivity. Preliminary evaluation is done for at least two years or in two locations. As the number of accessions subjected to the evaluation varied in two years and hence pooled analysis was avoided.

The promising lines can be subjected later on for detailed evaluation at multilocation trials along with the controls.

5. 10. Regeneration in taro

Time taken for regeneration of planted rhizome in the field in days showed very meagre difference with a phenotypic CV% value of 14.05 indicating less variation irrespective of the great variability obtained in morphotypic classification and other studies. This shows that the dormancy in taro is governed mainly by the availability of moisture on the vicinity of the tubers and the planting after few pre-monsoon showers in the upland condition covered by mulch (dry leaves) triggers the regeneration process immediately. This is a typical tropical or subtropical marshy plant and the entire evolution starts from there to the upland conditions without deviating much from the original habit under high rainfall situation at Vellanikkara. In marshes, taro is found to grow throughout the year as moisture is plentiful and in uplands taro stops growth immediately after cessation of rains. In Kerala condition, the second flesh of the matured clones is noticed in case the harvest is delayed by few days after beginning of the second monsoon in October-November. However, this short range of time (8.87-18.75 days as in the case of M3-M54) for regeneration is negatively correlated (-0.25326) to the mean rhizome weight of the morphotypes. The results are very interesting as lesser the time taken for regeneration better was the rhizome yield. This means the energy required for the regeneration physiology is diverted more to early plant vigour and better yield in plants. Accessions of M3 with very fast regeneration rate contain two released varieties such as Sree Rasmi and Sree Pallavi (Edison *et al.*, 2005).

5. 11. Senescence and crop maturity in taro

Taro being a tropical tuber crop, the growth period is usually long and it bienniates and perinniates in wild forms whenever enough moisture is available. The crop growth stops by sudden senescence of upper plant parts such as leaves and petiole and this coincides with the maturity of the crop *i.e.* corm and cormel which are economically useful. Morphotype wise computed data as furnished in table 34 indicated that the range for senescence was moderately broad from 139 days to 172 days with a difference of 33 days (over a month) providing short duration types suited to medium rain fall areas and under protective irrigation. Morphotype wise range showed very negligible variation with in each indicating almost uniform senescence for the collections within a type. SD and phenotypic CV% also was very negligible never going above 3 and 2 respectively for the morphotypes. Similarly, with respect to the entire collection SD was 3.102 and CV% was 1.86. However, days taken for senescence or crop maturity was positively correlated (+0.191409) with the rhizome weight of the plant indicating higher crop duration and higher yield are correlated vice versa in lesser duration types.

5.12. Organoleptic studies in taro

5.12.1. Taste of tubers:

A total of 409 accessions belonging to 69 morphotypes and 426 accessions belonging to 57 morphotypes for tuber flesh taste and acridity respectively were subjected to observation. Table 39 showed the frequency class distribution of accessions belonging to 69 morphotypes for tuber flesh taste and the results indicated that there was quite large variation in within and between morphotypes. However, both cultivated and wild morphotypes showed less tasty or tastier tubers indicating polymorphic variation in within the morphologically uniform types at biochemical level. Figure 12 showed abnormal curve, as tastier accessions were more in numbers than the others. This is due to the fact that maximum number of accessions was cultivars.

5.12.2. Tuber acridity

With respect to tuber acridity, 79 accessions belonging to 28 morphotypes (M1, 2, 3, 5, 6, 7, 8, 11, 12, 16, 23, 24, 26, 28, 29, 30, 31, 32, 35, 39, 40, 41, 45, 48, 49, 51, 52 and 75) were free of acridity. The frequency curve presented in Fig. 13 indicated that in taro germplasm most of the accessions observed fell in acridity free class or low acrid class as compared to medium or high acrid classes. This may be due to the fact that most of the collections observed fell under cultivars class, which were subjected to selection by the farmers for acrid free lines. However less acrid types were also present rarely in wild ones. Hegnauer (1987) is of the opinion that compounds irritating mucous membranes are identified as protocatechutic aldehyde and hmogenetisic acid and their glucosides.

5.12.3. Leaf and petiole acridtiy

With respect to leaf and petiole acridity, 450 accessions belonging to 76 types and 472 accessions belonging to 76 morphotypes respectively were observed at tender stage. Frequency class distribution was worked out and given in table 36 and 37 for leaf and petiole acridity respectively.

With respect to leaf acridity and petiole acridity none was free of it. However, 138 accessions belonging to 43 morphotypes such as 1, 2. 3, 4,5, 6,7, 8, 10, 11, 12, 13, 15, 18, 21, 22, 23, 24, 26, 27, 28, 30, 32, 39, 41, 42, 47, 49, 50, 54, 55, 58, 61, 62, 63, 64, 65, 66, 70, 77, 78, 79, 80 and 81 had low acridity in leaves. With respect to petiole acridity, 225 accessions belonging to 57 morphotypes Such as 1, 2, 3, 4, 5, 6, 7, 8, 11, 12, 13, 14, 15, 18, 19, 22, 23, 24, 26, 27, 28, 29, 30, 32, 34, 38, 43, 45, 46, 47, 48, 49, 50, 52, 54, 55, 57, 58, 61, 62, 63, 64, 65, 66, 67, 68, 70, 71, 72, 73, 76, 77, 78, 79, 80, 81 and 82 had low acridity in petiole. In the case of leaf and petiole acridity in taro there was low frequency for low acrid lines as the collections were rarely subjected to selection for this factor by farmers in India as the crop is mainly grown here for vegetable use of the tuber and if done it was probably only under restricted situations. None of the accessions were completely free of acridity including those grown for leaf and petiole purpose in West coast of Kerala. It is to be remembered that local people sometimes use petioles of even wild types after proper processing during the time of food scarcity.

Acridity in taro unlike in other aroids reported to contain less itchiness which is due to allergic reaction of body (O'Hair & Asokan, 1986). Tang and Sakai (1983) observed that a number of related agents cause aroid acridity. Saha and Hussain suggested that the calcium oxalate content was not necessarily related to amount of irritation. The cooked taro though did not change the structure of crystals reduced the itching to a considerable extent. The same washed in alcohol also reduced itching. Chromatographic separation and analysis they attributed the irritation to a glycoside, 3, 4-diglucosilicbenxaldehyde, similar to the compound in *Amorphophallus*. Suzuki *et al.* (1975) in a separate study attributed the acrid factor to the glucoside and its aglycone. Genetic variation has been noticed in all aroids (O' Hair & Asokan, 1986) domesticated ones were with less acridity.

5.13. Chemistry of taro tubers

With respect to chemistry of taro three compounds such as oxalic acid, soluble sugar and protein of tubers were studied in some of the morphotypes and dealt in three parts as below.

5.13.1. Oxalic acid content

Tubers of 35 collections each representing one morphotype at random were subjected for Oxalic acid content. Oxalic acid in the form of calcium oxalate crystals was supposed to cause the itching sensation by the tuber and other plant parts on the human body including the mouth, tongue and throat while it is processed and consumed as a food. This happens to be partially true as per the reports by Tang and Sakai (1983) and Suzuki *et al.* (1975) as other related agents and glycosides and its aglycone. Oxalic acid in taro therefore is important in judging the palatability of the tubers. The results of oxalic acid content in taro as furnished in table 43 show that moderate variation exists in various morphotypes. The range is 0.142 g. to 0.428 g. per 100 g of tuber. The collection number 644 (IC 87165) belonging to M33 from Kerala had the lowest oxalic acid content followed by M3 from Kerala and Pondichery and M31 from Kerala. Results on tuber acridity test also showed less to medium acridity in tubers of 4 accessions and more in one accession of M3. Morphotype M3 contains released varieties from CTCRI as stated earlier. Two forms of Calcium oxalate crystals such as druse and raphide forms have been reported in taro with the highest concentration at 2-3 mm on the exterior edge of the corms (Sunell & Healy, 1979). Sunell and Healy (1981) suggested that it a part of their defense system against insects and pests. Since oxalic acid itself does not indicate the level of acridity in a type the collection needs detailed investigation on the aspect of acridity associated chemical parameters. Hegnauer (1987) is of the opinion that compounds irritating mucous membranes are protocatechutic aldehyde and homogenetisic acid and their glucosides.

5.13.2. Soluble sugar content

Sugar content in tubers also determines the taste and energy contained in taro and this has been estimated in 56 morphotypes. The range for the sugar content was from 0.10 g in 683 (M6), a cultivar from Northeast to 5.1 g in 346 (M28) in a wild type from Kerala and the mean value for the morphotypes studied was 2.38 g per 100 g of tuber. CV% (34.06) showed good amount of variation for the soluble sugar content among morphotypes. With respect to soluble sugar content 346 (M28) with 5.1% from Kerala, 851 (M3) from Sikkim with 4.39%, 541 (M2) from Kerala with 4.31% were ahead of all others.

5.13.3. Protein content

Protein content of tubers in taro was observed in 53 morphotypes and the range was from 1.0% on fresh weight basis in TCR 419C (M 43) from Kerala to 11.8% in 541 (M2) from Kerala. Mean value for the protein content was 8.67% and the CV% was 22.07%, which showed a moderate degree of phenotypic variation between the studied morphotypes. Morphotype 2 scored the maximum protein content of 11.8% in TCR 419C (M2) from Kerala, followed by TCR 858 (M16) from Assam with 11.7% and 655 (M16) from Karnataka with 11.4%. The results show a condierable variation in the types identified in taro and taro appears to be comparatively more nutritive than several other tropical tubers such as Cassava, yams and other aroids its nutritive value (O' Hair & Asokan, 1986).

5.14. Pests and diseases

5.14.1. Aphid infestation

A total of 477 accessions of taro including 475 accessions falling under 81 morphotypic groups were subjected to observation of aphid infestation under natural field epiphytotic condition (Plate 5.1). The observed values for aphid infestation varied from 1-9 scale and the mean value for the whole collection was 4.985 with a standard deviation of 0.376. Table 44 depicts morphotype wise variation in observed values for aphid infestation. The results indicated that the infestation intensity varied from 1 in M64 to 7 in M39 and M40. Morphotype 56 with a score of 2, M71, 72 74 and 80 each with a score of 3 were the ones with a low incidence of aphid infestation pointing out its tolerance to the stress.

None of the accessions were free of aphid infestation under the field epiphytotic condition in Vellanikkara indicating that the place during the rainy season is a hot spot for aphid. Table 44 gives the details of collections that are met with low infestation (1-3). The lowest infestation (1) was noticed in IC87225 belonging to M64 (Plate IV) and 266635 to M80 (Plate VI) hailing from North East. This was followed by collections from Kerala and

Assam. One wild accession IC 70161 and another cultivated one from Kerala also had very low infestation.

These collections may be subjected for further detailed observation under controlled conditions with a view to identify more tolerant lines and incorporate the responsible genes in crop improvement programme. Palaniswami and Pillai, (1980) did detailed work on both aphids on aphid infection on taro. Survey on the occurrence of aphids and spidermites and their predators in important aroid growing areas in South India have been done by Palaniswami & Pillai (1981). The infestation during the third week of August, immediately after the cessation of rains was so severe that by the first week of September all the leaves wilted except in very few lines indicating Vellanikkara as a hot spot for taro aphid infestation during the main growing season..

5.14.2. Leaf blight incidence

No preliminary screening of taro collections representing a wide variability and encompassing both wild and cultivated taro has ever been carried out earlier except that by Velayudhan *et al.* (1993) in a similar study on 54 morphotypes of taro. The present study was conducted with a view to list out the probable tolerant lines in a large indigenous germplasm collection for their incorporation in detailed screening studies under controlled condition. NBPGR regional station has been amassing indigenous taro cultivars and its wild relatives from different parts of the country since 1978 and these as a basic stock has been subjected to the present preliminary screening in field epiphytotic condition at Vellanikkara, Thrissur as a part of the overall PGR study on the crop germplasm under the USIF funded project. The present report pertains to the results of the above study.

Out of 473 accessions could be observed and the morphotype wise infected mean leaf area percentage and SD as furnished in Table 49 indicated less uniformity in percentage leaf area infected in different collections within some morphotypes indicating a certain amount of intra-group variability which may be caused by chance non infection under uncontrolled field condition. The infected leaf area percentage ranged from 0.01% in several collections to 61.4% in IC 87163 of M52. The percentage of infected leaf area was low in M 65 (varied from 0.01 to 4.99%). None of the accessions were found to be completely free of infection indicating only highly varying degree of tolerance to the disease in field epiphytotic conditions.

With respect to frequency class distribution of infected leaf area percentage, 8 classes were obtained at a mean class interval of 7.9% and the frequency curve obtained in the study indicated an abnormal distribution pattern having very high frequency for the first class i.e. 0.01 to 7.99, very few in the next class and only one in third, seventh and eight classes. A negative correlation existed between percentage leaf area infected and the fresh tuber yield.

Total of 59 accessions belonging to 22 morphotypes with 0.05% or less infected leaf area (Table 50) were assumed to have some sort of tolerance as compared to the others. Maximum field tolerance was shown by collections from Kerala followed by 5 from Himachal, 4 from Tamil Nadu, 2 each from Karnataka, Sikkim, and Nagaland and I each from Maharashtra, Meghalayaya and Sikkim. These collections can be further used for screening under the controlled conditions in order to isolate blight tolerant lines in the crop.

Leaf blight disease adversely affects the crop yield in all taro-growing areas of South East Asia and Pacific islands. Misra and Chowdhury (1997) have conducted detailed investigation on this aspect in India and have prepared a very useful report in which they have listed the countries where blight is a very serious problem. In India, it is very serious in Southern, North Eastern and Eastern regions enjoying a higher annual rainfall and humid weather. The past assessment of crop production in the country based on the field experiments indicated about 50.39% crop loss in the case of susceptible varieties and 26.6% in tolerant varieties (Misra & Chowdhury, 1997).

6. CONCLUSION

1. In the present studies on taro a total of 991 indigenous accessions have been collected.

2. Out of 991 accessions collected, 481 could be subjected for the detailed study.

3. The collections hailed from different regions of India, such as Southern, South-Western, Eastern, North-Western, North-Eastern and Western regions lying between 8° 85’ N latitude in the extreme southern region to 35°0’ North latitude in Himachal Pradesh and in all longitudes except in extreme desert conditions in Rajasthan.

4. Ecology of cultivated and wild taro indicated that it occurred as cultivated and as wild in marshes to upland situations under high rainfall to low rainfall situations.

5. Ethnobotanical information collected during the exploration of the wild and cultivated taro in India and survey of literature disclosed its innumerable uses as a vegetable, famine food, as an offering in temple, and as a medicine.

6. A total of 59 names cultivar and common names have been encountered in the passport information.

7. Collections during the study period could be maintained in *ex situ* by keeping one set in the open field, one set in the nursery under 25% shade during the main season and harvested tuber materials in the chiller cabinet running at 13.0° C and 71% RH during summer period.

8. The coast of maintenance of taro germplasm collection could be calculated based on the labour and other input coasts that existed at Vellanikkara during 2003 and it was worked out to be Rs. 58.61 per sample per year without much loss of germplasm.

9. In the case of main collection, the accessions were differentiated first subjectively into 9 plant types, 16 leaf types, 4 sheath types, 21 tuber types and finally into 83 morphotypes.

10. Morphotype-wise quantitative (With low CV% within a morphotypic group) and qualitative data along with figures and plates have been furnished to validate these types.

11. Results of Isoenzyme studies in 42 accessions representing 42 morphotypes of taro and one accession of *C. affinis* for esterase and 46 accessions of taro representing 46 morphotypes and one of *C. affinis* for SOD indicated that enzyme banding pattern as depicted by the

zymogram varied from 2 to 8 bands for esterase and 2 to 6 bands for SOD. The results of banding pattern for esterase supported morphotypic classification. The pooled analysis of the results for both the enzymes in 40 morphotypes of *Colocasia esculenta* and one of *C. affinis* resulted in clustering of these into 4 major clusters and 8 sub-clusters without any special regard to the morphological similarity or distribution pattern of these types supporting the reported high polymorphism in taro.

12. Correlation studies between the mean values for 12 aerial and underground quantitative characters of 72 morphtypes indicated positive correlation of all the characters except for number of leaves and mother tuber thickness with tuber yield.

13. Principal Component Analysis done on the basis of 12 quantitative and 8 qualitative characters with respect to 83 morphotypes indicated 68.75% accumulated variation in first 6 Principal Components and the scatter diagram based on the first and the second Principal Components showed very confused dispersal of the morphotypes unrelated to the status, morphological relationship or distributional pattern indicating high level of polymorphism in these characters.

14. In Analysis of Variance on the basis of trials conducted during 2000 and 2001 for 427 and 459 accessions of taro respectively lateral tuber

weight and mother tuber weight showed significant differences for both the years. Four accessions yielding over 900 g per plant during 2000 and 10 accessions giving over 700 g per plant tuber yield during 2001 were promising.

15. A total of 293 accessins belonging to 55 morphotypes flowered. Major taxonomic grouping of these flowering morphotypes was done on the basis of three key characters such as leaf width/length ratio, sterile appendix length/ male part length ratio and mother tuber thickness/ length ratio. This resulted in identity of 10 major classes such as aae, aea, aee, akudaa, akudae, ekudae, dee, eae, eea and eee. Classes other than eee showed a combination of various leaf, inflorescence and tuber type characters of var. *antiquorum* and var. *esculenta* indicating existence of intermediate types in taro. In numerical taxonomic studies giving rise to the genetic tree showed a grouping of morphotypes, which are morphologically dissimilar in many cases. The results therefore quite clearly showed an admixture of aerial, inflorescence and underground characters in different types of indigenous taro germplasm confirming the earlier report on origin of taro based on cytology by Pillai (1972) that the cultivated species has evolved by involving two complex polyploid types during the course of cultivation either in a poly-philetic or para- phyletic way.

16. Failure in grouping cultivated and wild types of the main collections confirming the taxonomic grouping as per reported taxonomical classification is a bone of contention in the present studies. This probably indicated either an inclusion of unknown or unidentified genomes in natural interspecific hybrids domesticated and perpetuated in different situations in India by the farmers or the natural hybrid derivatives evolved, existed and perpetuated in faraway ecological niches. Thus in taro, an Asian revision of the genus is urgently needed which should be supported not only by morphology but also by cytology and molecular characterization of distinct morphotypes and suspected taxonomic entities.

17. Observation on time taken for regeneration of planted tuber at Vellanikkara with respect to 475 accessions gave a range of 8.87 days to 18.75 days probably indicating its true tropical nature without much dormancy for tubers and its governance by the availability of moisture.

18. With respect to senescence in taro, time taken for maturity took 139 days to 173 days with a moderate range of over one month indicated the strong possibility for selecting short duration types for crop improvement.

19. Results of organoleptic studies on the taste of 409 accessions belonging to 69 types showed abnormally higher number of

germplasm in tastier group indicating the preponderance of cultivated types being selected more for tuber taste by the farmers. With respect to acridity of tubers 426 accessions belonging to 57 morphotypes, 29 were with less tuber acridity.

20. With respect to leaf acridity, 450 accessions were observed and none of the accessions were free of it, but 138 accessions belonging to 43 morphotypes had low acridity. With respect to petiole acridity 472 accessions belonging to 76 morphotypes were observed and none was free of it. However, 225 accessions belonging to 57 morphotypes had low acridity. The results along with normal frequency class distribution in both cases indicated low priority given by the farmers to selection of less acrid leaf and petiole bearing lines in India as the crop is mainly grown as a vegetable tuber.

21. With regards to chemistry of taro tubers oxalic acid content in 35 morphotypes, soluble sugar content in 56 morphotypes and protein content in 53 morphotypes could be studied. Oxalic acid content varied from 0.142 g to 0.428 g per 100 g of fresh tuber. However higher oxalic acid content in tuber is not directly connected with acridity. Soluble sugar content varied from 0.10% to 1.5 % and the Protein content from 1.0 to 11.5% on dry weight basis.

22. Screening of taro collections for aphid infestation and leaf blight disease incidence in 477 and 473 accessions respectively were carried out and the results showed considerable variation. Though none was free from both aphid infestation and leaf blight disease incidence under field epiphytotic condition, 15 had low infestation in the first case. Leaf blight varied from 0.01% to 61.5% leaf-area damage. The results open up possibility of subjecting the accessions with low pest and disease incidence to further screening under controlled conditions.

7. SUMMARY

Taro, *Colocasia esculenta* (L.) Schott being a crop of considerable importance as a secondary staple food and a vegetable in tropics of Asia extending to tropical Africa and Americas under subsistence agriculture lately faced a stiff competition from other tuber crops leading to fast depletion of its resources all over. The extent of genetic erosion faced by the crop in India is quite extensive under subsistence farming due to changing cropping pattern in relation to changed crop priorities. Under the wild situation also, genetic erosion is imminent under the fast rate of habitat destruction. Hence, the need of its collection, characterization, evaluation, conservation and utilization has been emphasized thirty years back and accordingly a strategy has been adopted in India. The past studies in this regard in India were in piece-meal and hence the present study on taro genepool was planned and executed with a view to collect, characterize, classify, evaluate, conserve, and utilize its germplasm for the crop improvement in a holistic approach. Taro having its origin in tropical and subtropical regions enjoying higher amount of rain fall in South-East Asia, have good amount of variability especially in North-East, South-West, East and North-West (lower Himalayas).

The study was planned under the project USIF 862 and conducted at National Bureau of Plant Genetic Resources Regional station's Farm located at Vellanilkkara, Thrissur, Kerala, India. A survey of literature covering various important aspects of taro viz. origin, taxonomy, ecology, ethnobotany, etymology, cytogenetics and breeding, cultivation, exploration and collection, characterization, evaluation, classification, conservation, pests and diseases, chemistry, nutritive value, etc. have been furnished. A total of 991 accessions of taro including cultivated and wild types could be amassed through exploration and collection trips and from transfers from different parts especially from southwestern, eastern, northeastern and northwestern, and central parts of India with passport information. Taro was distributed in areas with moderate to very high rain fall situations. The wild taro was noticed in forest areas, marshes, waste lands, and along the water courses and roadsides. Sampling sites in the above surveyed areas constituted farmers fields, roadsides, farm houses, farm stores, tropical undisturbed forests and market places. The passport collected indicated 59 local names for the wild and cultivated types of taro in India. Total of three species such as *C. esculenta, C.affinis* (Run wild from gardens in Karnataka) and *C. fallx* from Meghlaya could be collected. Information on several culinary preparations and other uses of taro could be noticed among local people and some ethnic groups. It was mainly a subsistence crop in important taro growing areas. Commercial cultivation was very rare as noticed in Tamil Nadu and Uttar Pradesh. It used to be cultivated under uplands with or without irrigation, paddy lands on raised beds, under shaded condition and in shallow marshes in North East.

Part of the produce under the subsitance crop production went to the local or distant markets. Out of the collectd accessions a total of 481 were classified subjectively into 9 plant types, 16 leaf types, 4 leaf sheath margin types, 21 tuber types and finally into 83 morphotypes and their geographic distribution was furnished.

These accessions were subjected to detailed characterization, classification and evaluation studies. For characterization a total of 103 qualitative and quantitative characters were used. Frequency distribution of 15 qualitative characters was furnished. The aerial (10) and underground quantitative characters (9) were observed, computed and the results indicated lesser amount of variation within morphotypes supporting the existence of morphotypes in taro.

Preliminary evaluation of the majority of the collections was carried out for two years and the analysis showed significant differences among accessions of main collection for yield parameters and promising lines were identified for two years. Promising lines of taro for higher fresh tuber weight yield during 2000 and 2001 have also been furnished.

Only 292 accessions belonging to 55 morphotypes flowered. A total of 13 quantitative and 5 qualitative characters of inflorescences could be collected in 54 morphotypes. The flowering morphotypes could be classified into *C. esculenta* var. *esculenta*, var. *antiquorum* and several intemediates of these types. Numerical taxonomical study in 54 flowering morphotypes resulted in a dendrogram having five major groups of morphotypes and subgroups not strictly on the basis of taxonomic classes. Thus the genetic tree obtained showed very confusing picture of grouping.

Correlation study conducted on 12 quantitative characters in 72 morphotypes of taro indicated high positive correlation coefficients between leaf length and leaf width, mother tuber weight and thickness, lateral tuber number and fresh tuber yield, and mother tuber thickness and leaf width. Path coefficient analysis showed that lateral tuber number had direct effect on total tuber fresh yield. Principal Component Analysis study based on 12 quantitative and 8 qualitative characters on 83 morphotypes of taro indicated that 6 Principal Components gave an accumulated variability of 68.75%. Characters along with percentage value of each contributing to various 6 Principal Components are also furnished.

Isoenzyme studies for Esterase in 42 morphotypes of taro and *C. affinis* could exhibit a complicated banding pattern that justified the morphotypic groping where as similar studies on SOD enzyme exhibited simpler banding pattern. The pooled analysis using the score of banding pattern for both the enzymes in 40 morphotypes and *C. affinis* resulted in a dendrogram having 4 major clusters with sub clusters and two outliers without indicating any affiliation to the possible taxonomic grouping or to geographical distribution of the morphotypes.

Observation on pest (Aphid) and disease (Leaf blight) infestation could be carried out under field epiphytotic conditions and promising lines for tolerance to these could be listed. Organoleptic studies on taste of tubers and acridity of cooked tuber, leaf and petiole could be done in order to identify more tasty and less acrid lines in taro. Frequency class distribution for these parameters were also worked out and presented.

Chemistry of taro tubers with respect to oxalic acid content, soluble sugar content and protein content in one collection each of 33, 56 and 53 morphotypes respectively was studied and promising types could be identified.

Out of 991 accessions 481 accessions could be maintained in *ex situ* field genebank supplemented by maintenance of potted plants under shaded condition and storage of harvested tubers in chiller cabinets. Cost of *ex situ* maintenance of taro germplasm could be worked out and given. Finally, 22 conclusions derived in the present studies are presented at the end.

10. REFERENCES

Abraham, A. and K. Ramachandran. 1960. Growing *Colocasia* embryos in culture. *Cur. Sci*. 29: 342-343.

Abraham, A., Panikkar, P. K. S. and P. M. Mathew. 1964. Polyploidy in relation to breeding in tuber crops. *J. Ind. Bot. Soc.* 43: 118-122.

Abraham, K., S. G. Nair, M. K. Sreekumari and M. Unnikrishnan. 1986. Seed set and seedling variation in greater yam (*Dioscorea alata* L.). *Euphytica* 35: 337-343.

Abraham, K. and P. Gopinathan Nair. 1990. Floral biology and artificial pollination in *Dioscorea alata* L. *Euphytica* 48: 45-51.

Abruna-Rodriguez, F., Vicente Chandler, E. Rivera and J. Rodriguez. 1982. Effect of soil acidity factors on yields and foliar composition of tropical root crops. *J. Soil Sci. Soc. America 46*: 1004-1007.

Arditti, J. 1981. Tissue culture of taro. In: *Proc. Costed. Symp. Tissue Culture of economically important plants.* Singapore. pp. 83-84.

Arditti, J. and M. S. Strauss. 1979. *Taro tissue culture manual*. South Pacific Commission, Information document No. 44-1973. Noumea, New Caledonia.

Agrawal, R. C. and R. L. Sapra. 1995. Augment 1: A microcomputer-based programme to analyze augmented randomized complete block design. *Ind. J. Plant Genet. Resour.* 8 (1): 63-69.

Alamu, F. and C. R. McDavid. 1978a. Effect of time and method of application of gibberellic acid on growth and promotion of flowering in Tannia (*Xanthosoma sagittifolium*). *Trop. Agric.* (Trinidad) 55: 235-242.

Alamu, F. and C. R. McDavid. 1978b. Promotion of flowering in edible aroids by gibberellic acid. *Trop. Agric*. (Trinidad) 55: 81-86.

Allen, O. N. 1937. Taro and Fundamental products ‘Poi’. *Food Manuf*. 12: 80-82.

Alvarez-Garcia, L. A. and A. Cortes-Mnllor. 1971. Currutaca- a *Pythium* soft rot of *Xanthosoma* and *Colocasia* spp. in Puerto Rico. *J. Agril. Univ. Puerto Rico.* 55: 78-84.

Amalraj, V. A., K. C. Velayudhan, R. C. Agrawal and R. S. Rana, 1993. *Banana Genetic Resources.* Sci. Monograph No.3. NBPGR Regional Station, Thrissur.

Aminoff, D., W. W. Binkly, R. Schaffer and R.W. Mowry. 1970. Analytical methods for Carbohydrates. In: Pigman and Horton (Ed.) *The carbohydrates*. Academic Press, New York. pp. 763-764.

Anderson, E. 1957. A semigraphic method for the analysis of complex problems. *Proc. Nat. Acad. Sci.* 43: 923-927.

Anonymous. 1960. Proteins. In: Horowitz. W. (Ed.) *COAC Official methods of Analysis.* 9 th Edition. Washington DC. p. 169.

Anonymous. 1978. *Pest control in tropical root crops*. PANS MANUAL No. 4. Cent. Overseas Pest Res., Min. Overseas Dvpt. London.

Anonymous. 1980. *Descriptors for Colocasia*. AGP: IBPGR/79/52. Rome, Italy.

Anonymous. 1984. *COAC Official Methods of Analysis*. Calcium Oxalate. 14 th Edition. COAC, Washington DC. pp. 611-612.

Anonymous. 1986a. *Root and Tuber Crops, Directory of Germplasm.* IBPGR, Rome, Italy.

Anonymous. 1986b. Araceae. In: Peter Hanlet (Ed.) *Mans Field Encyclopedia of Agricultural and Horticultural crops.* Springer, V: 2317-2340.

Anonymous. 1988. *In-vitro storage* of *Colocasia, Xanthosoma* and *Cryptocoryne germplasm*. *IBPGR report, No*. 88-96. IBPGR, Rome, Italy.

Anonymous.1989a. *FAO Production year Book*. FAO, Rome, Italy.

Anonymous. 1989b. *Annual Report for the year 1988-1989*. NBPGR Regional Station, Vellanikkara, Thrissur, Kerala, India.

Anonymous. 1999a. *Descriptors for Taro (Colocasia esculenta).* IPGRI., Rome, Italy. pp. 1-56.

Anonymous. 1999b. *Annual Report for the year 1998-1999*. NBPGR Regional Station,

Anonymous. 2001. *Mansfield's Encyclopedia of Agricultural and Horticultural Plants* (Except ornamentals). Springer -Verlag, Berlin. pp. 2332-2334.

Arakeri, H. R. 1956. A. Note on storage and Germination requirement of seeds of Suran (*Amorphophallus campanulatus). Ind. J. Genet*. 1: 27-29.

Arano, H. 1956. Karyotaxonomic studies on the tribe Tubuliflorae of Compositae. 1. Karyotype analysis and its phylogenetic considerations in the sub-tribe Gnaphalineae. *Jap. J. Genet*. 31: 137-143.

Arano, H. 1957. The Karyotype studies and its karyo-taxonomic considerations in the tribe Mustisieae. *Jap. J. Genet.* 32: 293-99.

Arano, H. 1963. Cytological studies in the subfamily Carduoideae (Compositae) of Japan. XIV. The karyotypic analysis on the genus *Artemis. Bot. Mag*. 76: 459-465.

Arano, H. 1965. The karyotype and speciation in the sub family Carduoideaeic (Compositae) of Japan. XVI. *Jap. J. Bot*. 19: 31-97.

Arora, R. K. and E. Roshini Nayar. 1984. *Wild relatives of crop plants in India. Sci. Monograph* No. 7. NBPGR, New Delhi. pp. 1-90.

Asana, J. J. and R. N. Sudaria. 1931. On the number of chromosomes of some Indian Araceae. *J. Univ. Bombay* 7: 56-62.

Ashokan, P. K., R. V. Nair, and N. N. Potty. 1987. Agric. Res. J. Kerala. 1985, 23 (1): 124-128.

Bailey, L. H. 1925. *Mannual of cultivated plants.* Macmillan, London. pp. 135-136.

Ball, E. A. and J. Arditti. 1977. Tissue culture of taro, *Colocasia esculenta* (L.) Schott. *J. Hort. Sci*. 52: 373-382.

Banerji, I. 1934. Sterility in female gametophyte of *Colocasia antiquorum* L. Schott. *Curr. Sci.* 2: 432.

Banerji, I. 1937. Sterility in *Colocasia antiquorum* (L.) Schott *J. Ind. Bot. Soc.* 16: 159-164.

Bao, S. Y., Mao, P. Y. and S. X. Yuvan. 1998. *A brief history of plant collection in Yunnan* (1919-1950). China Science Technology Press, Beijing.

Barrau, J. 1957. Les Aracees a Tubercules Alimentaires des Iles do Pacificifique. *Sud. J. Agril. Trop. Bot. Appl.* 4: 34-52.

Barrau, J. 1959. Fruits et grains du taro, *Colocasia esculenta* (L.) Schott. *J. Agril. Trop. Bot. Appl.* 6: 436.

Barroah, H., Barroah, S. and R. K. Goswami. 1987. Screening and evaluation of some local *Colocasia* (*Colocasia esculenta* (L.) Schott) and *Xanthosoma* (*Xanthosoma sagittifolium* (L.) Schott cultivars of Assam. In: T. Ramanujam, P.G. Rajendran, N. Thankappan, C. Balagopal, and R. D. Nair (Eds.), *Tropical Tuber crop - Production and utilization.* Indian Society of Root Crops, CTCRI, Trivandrum, pp. 59-62.

Bergquist, R. R. 1974. Effect of fungicide rate, spray interval, timing of spray application and precipitation reaction in relation to control of *Phytopthora* leaf blight of taro. *Ann. Bot*. 38: 213-221.

Bhat, K. V., S. R. Bhat, and K. P. S. Chandel. 1992. Survey of isozyme polymorphism for clonal identification in *Musa* L. I. Esterase, Acid phosphatase and Catalase. *J. Hort. Sci*. 67: 501-507.

Birader, R. S., T. Venkateswaralu, and N. Hrishi. 1978. Leaf-area estimation in *Colocasia*. *J. Root Crops* 4 (2): 51-53.

Bogner, J. 1987. Morphological variations in Aroids. *Aroideana* 10 (2): 4-10.

Bogner, J. and D. H. Nicolson. 1991. A revised classifcation of Araceae with dichotomous keys. *Willdenowia* 21: 35-50.

Bronson, B. 1966. Roots and the subsistence of the ancient Maya. *South West J. Anthropol.* 22: 251-279.

Brown, A. H. D. 1989. Core collections: a practical approach to genetic resources management. *Genome* 31: 818-824.

But, P. P. H., S.Y. Su, and Y. C. Kong. 1980 Vascular plants used in Chinese medicine. *Fitoterapia* 51: 245-264.

Burtt, B. L. Infraspecific categories in flowering plants. *Biol. J. Linn. Soc.* 2: 233-238.

Carson, H. L. and T. Okada. 1980. Drosopholidae associated with flowers in Papua New Guinea I. *Colocasia esculenta*. *Kontyu, Tokyo.* 48: 15-29.

Chandel, K. P. S., R. Pandey, R. Chowdhury, S. M. Balachandran and Neelam Sharma. 1988. Biotechnology, its role in conservation of plant genetic resources. In: R.S. Paroda, (Ed.) *Plant Genetic Resources Indian Perspective.* NBPGR, New Delhi. pp. 499-516.

Chandra, S. 1982. Taro Research and developments in Fiji. *In:* E. H. Balen, and M. Villanueva, (Eds.), *Proceedings on 5th International Symposium on tropical root and Tuber crops.* 567-578.

Chandra, S. (Ed.) 1984. *Edible aroids*. Clarendon Press, Oxford. pp. 252.

Chang, T. K. 1958. Dispersal of the taro in Asia. *Assoc. Am. Geogr.* 48: 255-256.

Chang, K. C. 1970. The beginning of agriculture in the Far East. *Antiquity* 44: 175-185.

Coates, D. J., D. E Yen, and P. M. Gaffey. 1988. Chromosome variation in taro, *Colocasia esculenta*: implication for origin in the Pacific. *Cytologia* 53 (3): 551-560.

Coursey, D. G. 1968. The edible Aroids. *World Crops*. 20(4): 25-30.

Chowdhury, J. B. and A. Sharma. 1979. Chromosome studies in certain members of Araceae. *Genet. Iber*. 30: 161-187.

Darlington, C. D. and A. P. Wylie. 1955. Chromosome atlas of flowering plants. George Allen and Uniwin Ltd., London.

David F. Gori. 1983. Post pollination phenomena and adaptive floral changes. *In*: C. Eugine, A. Jones and R. John Little (Eds.) *Handbook of experimental Pollination Biology*. Scientific and Academic editions, New York. pp. 31-72.

D e la Pena, R. S. 1971. The edible aroids in Asian Pacific area. *Roy. Int. Soc. Trop. Root Crops* 2: 136-140.

Delay, G. 1951. Nombres chromosomiques chez . *Rev. Cytol.* (Paris). 12: 67-72.

Deway, D. R and K. H. Lu. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.* 51: 515-518.

Dorothy, C. B. 1995. Thermogenesis in Aroids. *Aroideana* 18: 32-81

Drury, H. 1873. *Useful Plants of India with notices of their chief value in commerce, medicine and arts*. William H. Allen & Co. London.

Edison, S., K. C. Velayudhan, C. S. Easwari Amma, Santha Pillai, B. B. Mandal, M. N. Sheela, B. Vimala, M. Unnikrishnan and Zakir Hussain. 2005. Tropical Root and Tuber Crops, *In:* B. S. Dhillon, R. K. Thyagi, S. Saxena and G. J. Randhawa (Eds.), *Plant Genetic Resources: Horticultural Crops*. Narosa Publishing House, New Delhi. 228-251.

Engler, A. 1879. Araceae. *In:* de Candolle, A. & C. (Ed), *Monographiae Phanerogamarum.* Masson, Paris. Vol. 2, p. 681.

Engler, A. and K. Krause. 1920. Adittamentum ad Araceae – Colocasioideae. *In*: A. Engler (Ed.), *Das Flazenreich* 71(IV. 23E): 3-132.

Federov. A. 1969. *Chromosome numbers of Flowering Plants.* George Allen & Unwin Ltd., London.

Figueres, K. C. 1981. *Colocasia esculenta* in the Pacific. Aroideana 4: 28-30.

Fisher, R. A. 1936. The use of multiple measurements in taxonomic problems. *Ann. Eugenics* 7(2): 179-188.

Frankel, O. H. 1984. Genetic perspectives of germplasm conservation. *In*: W. Arber, K. Llimensee, W. J. Peacock, and P. Starlinger (Eds.), *Genetic manipulation: Impact on man and society.* Cambridge University Press, Cambridge. pp. 161-170.

Fukushima, E., S. Ivasa, S. Tokumasu, and M. Iwamasa. 1962. Chromosome numbers of the taro varieties cultivated in *Japan. Chromo. Inform. Servi*. (Japan) 3: 38-39.

Fundora, Z., Vera, R., Yaber, E. and O. Barrios. 1992. *La estadistica multivariada en la sanidad vegetal*. INIFAT-MINAGRI, La Habana, Cuba.

Gagne, W. C. 1982. Staple crops in subsistence agriculture: their major insect pests, with emphasis on biogeographical and ecological aspects. *In*. J. L. Gressitt (Ed.) *Biogeography and ecology of New Guinea*, Dr. W. Junk, The Hague. I: pp. 229-259.

Garcia, Q., J. L. Noyer, X. Perrier, J. L. Marchar and V. Lebot. 2003. Gerplasm stratification of taro (*Colocasia esculenta*) based on agro-morphological descriptors, validation by AFLP markers. *Euphytica* 137(3): 387-395.

Ghani, F. D. 1981. Conservation and utilization of *Colocasia* sp. (cultivars) and edible aroids (Keladi) in Malaya. *Tropical Root and Tuber Crops News Letter* No. 12-13: 38-46.

Ghani, F.D., 1987. *Characterization and evaluation of Malaysian taro cultivar collection*. Spl. Issue Poster News Letter. IBPGR Regional Committee for South East Asia. New Delhi, pp. 66-72.

Gollifer, D. E. and J. F. Brown. 1974. Phytopthora leaf blight of *Colocasia esculenta* in the British Solomon Islands. *Papua New Guinea Agric. J*. 25: 6-11.

Gooding, H. J. and J. S. Campbell. 1961. The improvement of cultivation methods in dasheen and eddoe (*Colocasia esculenta*) growing in Trinidad. *Proc. Amer. Soc. Hort. Sci., Carbb. Reg.* 5: 6-20.

Gottlieb, L. 1983. Isozyme number and phylogeny. *In*: U. Jenson and D. Fairbrothers (Eds.), *Proteins and nucleic acids in plant systematics*. Springer-Verlag, Berlin. Pp. 209-221.

Grayum, M. H. 1999. Evolution and phylogeny of Araceae. *Ann. Missouri Bot. gard.* 77: 628-697.

Greenwell, A. B. H. 1947. Taro-with special reference to its culture and uses in Hawaii. *Econ. Bot.* 1: 276-289.

Haines, H. H. 1924. *The botany of Bihar and Orissa, Part V*. Adlard & Son, London.

Harlan. J. R. 1971. Agricultural origins: Centers and Non-centers. *Science* 174: 468-474.

Harlan, J. R. 1975. *Crops and Man*. American Society of Agronomy, Crop Science Society of America, Madison, Wisconsin. pp. 1-195.

Harlan, J. R. and J. M. J. de Wet. 1971. Towards a rational Classification of cultivated plants. *Taxon* 20: 509-517.

Haudricourt, A. 1941. Les Colocasees Alimentaires (Taros et Yautias) *Rev. Bot. Appl. Agric. Trop. 21: 40-65.*

Hawkes, J. G. 1975. *Vegetatively Propagated Crops*. *In*: Frankel, O. H. & Hawkes, J. G. (Eds.), Cambridge University Press, Cambridge. pp. 117-21.

Hawkes, J. G. 1980. *Crop genetic resources Field Collection manual*. IBPGR and RUCARPIA, Rome.

Hawkes, J. G. 1989. *In:* D. R. Harris and G. C. Hillman (Eds.) Domestication of roots and tubers in the American tropics. *Foraging and farming* pp. 481-503.

Hawkes, J. G. 1991. Theory and Prcactice of collecting germplasm in a center of diversity. *In*: J. M. M. Engels, J. G. Hawkes and M. Worede (Eds.) *Plant Genetic Resources of Ethiopia*. Cambridge University Press, Cambridge. pp. 189-201.

Hay, A. 1996. A new Bornean species of *Colocasia* Schott (Araceae, Colocasieae), with a synopsis of the genus in Malesia and Australia. *Sandakania* 7: 31-48.

Hay, A. and D. J. Mabberley. 1991. Transference function and the origin of Aroid: their significance in early angiosperm evolution. *Bot. Jahrb. Syst*. 113: 339-428.

Hegnauer, R. 1987. Phytochemistry and Chemotaxonomy of the Araceae. *Aroideana* 10 (2): 17.

Hill, A. F. 1939. The nomenclature of the taro and its varieties. *Harvard Univ. Bot. Mus. Laflets* 7: 113-122.

Hirai, M. 1988. Isozyme analysis of plant. *In*: S. Higuchi (Ed.) *In vitro culture of horticultural plant*s. Shibata garasu Co., Ltd., Tokyo. (In Japanese) pp. 95-99.

Hirai, M., T. Sato and K. Takayanagi. 1989. Classification of Japanese cultivars of taro (*Colocasia esculenta* (L.) Schott) based on electrophoretic patterns of the tuber proteins and morphological characters. *Japan. J. Breed.* 39: 307-317.

Holliday, P. 1980. *Fungal diseases in tropical crops*. Cambridge University Press, Cambridge. pp. 1-607.

Hooker J.D. 1883. Aroideae. *In*: G. Bentham & J. D. Hooker, *Genera Plantarum.*Reeve, London. 3: 955-1000

Hotta, M. 1970. A system of the family Araceae in Japan and adjacent areas. Part I. *Mem. Fac. Sci. Kyoto Univ. Series of Biol*. 4: 72-96.

Hotta, M. 1983. Taxonomy and origin of root crops in East Asia. *In*: K. Sasaki (Ed.), *The search for Japanese culture*: *Origin of Japanese Agriculture*. NHK (Japanese Broadcasting Corporation). Tokyo. pp. 18-42. (In Japanese, unpublished English translation by M. Hotta.)

Hutchinson, J. 1934. *Araceae. In*: J. Hutchinson (Ed.), *The Families of Flowering Plants.* Macmillan, London. 1, 2: 117-124.

Hutchinson, J. 1959. *Araceae. In*: J. Hutchinson (Ed.), *The Families of the Flowering Plants.*2nd edition. Clarendon Press, Oxford. pp. 627-635.

Hutchinson, J. 1973. *Araceae. In*: J. Hutchinson (Ed.), *The Families of the Flowering Plants.* 3rd. edition. Clarendon Press, Oxford. pp. 774-785.

Isshiki, S., M. Nakada, Nakamura, N. Tashiro, Y. and S. Miyazaki. 1995. Genetic systems and variations of isozymes in wild taro (*Colocasia esculenta* Schott.) *J. Japan. Soc. Hort. Sci.* 64 (1): 113-119.

Isshiki, S., Nakamura, N., Tashiro, Y. and S. Miyazaki. 1997. Genetic analysis of AAT, IDH and SKDH Isozymes in Taro (*Colocasia esculenta* (L.) Schott.). *Bull. Fac. Agr. Saga University* 82: 23-27.

Isshiki, S**.**, Nakamura, N. Tashiro, Y. and S. Miyazaki. 1998. Classification of the cultivars of Japanese taro (*Colocasia esculenta* (L.) Schott) by isozyme analyses. *J. Japan. Soc. Hort. Sci.* 67: 521-525.

Ito, T. 1942. Chromosome and Sexualitat von der Araceae. *Cytologia* 12: 313-325.

Jaccard, P. 1908. Nourvelles recherches sur la distribution Jorale. *Bull. Soc. Vaud. Sci. Nat.* 44: 223-270.

Jackson, G. V. H. 1980. *Diseases and pests of taro*. South Pacific Commission, *Nowmea*, New Calidonia.

Jackson, G.V. H. and D. E. Gollifer. 1975. Diseases and pest problems of taro in British Solomon Islands. *PANS* 21: 43-45.

Jackson, B., Ball, E. A. and J. Arditti. 1977. Tissue culture of taro, *Colocasia esculenta* (L.) Schott. *J. Hort. Sci*. 52: 373-382.

Jackson, G. V. H. and P. M. Pelomo. 1979. Breeding resistance to diseases of taro, *C. esculenta* in Soloman Islands. *In*: Prov. Report. *Int. Symp. Taro and Cocoyam, Baybay, Phillippines.* International Foundation for Science, Stockholm, 5: 287-298.

Jackson, G. V. H., Gollifer, D. E. and F. J. Newhook. 1980. Studies on the taro leaf blight fungus *Phytopthora colocasiae* in Solomon Islands: control by fungicides and spacing. *Ann. Appl. Biol.* 96 (1): 1-10.

Jackson, G. V. H. and I. D. Firman, 1984. Guidelines for movement of taro and other aroids within Pacific. *In*: S. Chandra (Ed.), *Edible aroids*. Clarendon Press, Oxford, U.K. pp. 194-211.

Jianchu, X., Yongping, Y., Yingdong, P., Ayad, W. G. and P. B. Eyzaguirre. 2001. Genetic diversity in taro (*Colocaisa esculenta* Schott, Araceae) in China: An Ethnobotanical and Genetic Approach. *Econ. Bot.* 55(1): 14-31.

Johnson, R. A. and D.N. Wichern. 1988. Applied Multivariate Statistical Analysis. 2nd ed. Prentice Hall, New York.

Jos, J. S. and S. G. *Nair.* 1976. Multiple sporocytes in meiotic cells of triploid *Colocasia esculenta*. *Genetic Iberica* 28: 279-287.

Jos, J. S and K. Vijaya Bai, 1977. Stigma receptivity in Colocasia. *Ibid* 3 (2): 25-28.

Joseph, J. K. 2006. Personal communication on taro cultivation in UP hills. NBPGR Regional Station, Vellanikkara, Thrissur, India.

Joseph, J. K. 2007. Personal communication on taro cultivation in Goa. NBPGR Regional Station, Vellanikkara, Thrissur, India.

Joseph, K. and U. M. Kunju. 1981. Effect of mulching and size of seed materials on the tuber yield and quality of *Colocasia* (*C. esculenta* (L.) Schott). *Agril. Res. J. Kerala.* 19 (2): 128-130.

Kamalam, P., Biradar, R.S., Hrishi, N. and P. G. Rajendran.1977. Path analysis and correlation studies in sweet potato (*Ipomoea batatas* Lam.) *J. Root crops* 3 (1): 5-11.

Kambuou, R. N. 1985. Papua New Guinea. IBPGR News Letter for South East Asia 9 (3): 13-15.

Kawahara, T. 1978. Chromosome number of taros in Nepal and India. *Chromosome information service* (Japan) 24: 4-5.

Keleney, G. P. 1962. The origin and introduction of the basic food crop of New Guinea people. *Papua New Guinea Agric. J.* 15: 7-13.

Kephart, S. R. 1990. Starch gel electrophoresis of plant isozymes: A comparative analysis of techniques. *Amer. J. Bot.* 77: (5): 693-712.

Khanna, P.P. and Neeta Singh. 1991. Conservation of Plant Genetic Resources. *In*: R. S. Paroda, and R. K. Arora (Eds.) *Plant Genetic Resources Conservation and Management.* IBPGR, Regional Office for South and South East Asia, New Delhi. pp. 231-245.

Kikuta, K., L. D. Whitney and G. H. Parris. 1937. Seeds and seedlings of taro (*Colocasia esculenta*). *Ann. J. Bot*. 25: 186-188.

Kikuta, K., L. D. Whitney and G. H. Parris. 1938. Seed and seedlings of taro, *C. esculenta. Aroideana* 4: 116-117.

Kimura, M. and J. F. Crow, 1964. The number of alleles that can be maintained in a finite population. *Genetics* 49: 725-738.

Kirthikar, K. R and B. D. Basu. 1918. *Indian Medicinal Plants*. Bishan Singh & Mahindrapal Singh, Dehra Dun, Vol. 4: 2613-2616.

Kitamura, S. 1949. Notes on Araceae of Japan. *Acta Phytotaxonomica et geobotanica* 14: 5-8.

Kokua, N. L. 1977. *Taro (Kalo): Uses and recipes.* Honolulu Pacific Botanical Garden, Kuwai, Hawaii.

Kreike, C. M., Van. Eck, and V. Lebot. 2004. Genetic diversity of taro, *Colocasia esculenta* Schott in South East Asia and the Pacific. *Theoretical and Applied Genetics* 109 (4): 761-768.

Krishnan, R., Magoon, M. L and K. Vijaya Bai. 1970. Meiosis in desynaptic diploid *Colocasia antiquorum* Schott. *Genetica Agraria*. 24: 325-334.

Kumar, R. and S. C. Dubey. 1996. Screening of Colocasia genotypes for resistance to Phytopthora leaf blight. *In*: G.T. Kurup, M. S. Palaniswamy, V. P. O. Potty, G. Padmaja, S. Kabeerathumma and S.V. Pillai (Eds.). *Trop. Tuber crops Problems, Prospects and Future Strategies*. pp. 388-390.

Kumazawa, S., K. Nuichi, and F. Honda.1956. Classification of taro varieties in Japan. *J. Japan. Soc. Hort. Sci.* 25: 1-10.

Kundu, B. C. 1967. Some edible rhizomatous and tuberous crops of India. *Proc. Int.* Symp. *Trop. Root Crops* 1(1): 124-130.

Kurakubo, Y. 1940. Chromosome numbers of Araceae. *Bot. & Zool.* 8:1492.

Kurihara, H. 1979. Trends and problems of konjak (*Amorphophophallus konjac*) cultivation in Japan. *Japan Agric. Res. Qaurt*. 13: 174-179.

Kuruvilla, K. M. and A. Singh. 1981. Karyotypic and electrophoretic studies on taro and its origin. *Euphytica* 30: 405-413.

Lawly, D. N. and A. E. Maxwell. 1963. *Factor analysis as a statistical method*. Butterworths, London.

Lebot, V. and K. M. Aradhya. 1991. Isozyme variation in taro (*Colocasia esculenta* (L). Schott.) from Asia and Oceania. *Euphytica* 56: 55-66.

Lebot, V. and K. M. Aradhya. 1992. Collecting and evaluating taro (*Colocasia esculenta)* for isozyme variation in Taro. *Plant Genetic Resources News Letter* 90: 47-49.

Lee, M. S., J. H. Lee, and S. O. Yu. 1979. Effect of seed tuber age and weight on major characters in different local strains of taro, *C. antiquorum* Schott. *J. Korean Soc. Hort. Sci.* 209: 134-141.

Leon, J. 1977. Origin evolution and early dispersal of root and tuber crops. *In*: L.Cock, Macintire, R and M. Graham, (Eds.), *Proceedings of the Fourth Symposium of the International Society for Tropical Tuber crops.* The International Research Center, Ottawa.pp. 20-36.

Li, H. L. 1969. The vegetables of ancient China. *Econ. Bot.*. 23: 253-260.

Li, H. L. 1970. The origin of cultivated plants in Southeast Asia. *Econ. Bot.* 24: 3-19.

Li Heng and A. Hay. Classification of the genus Gonatanthusi, in Chinese. *Acta Bot. Yunnanica* 14(4): 373-378.

Li, H. and C. L. Long. 1999. A new species of *Colocasia* from Mts. Gaoligong, China. *Feddes Repert* 110: 5-6.

Li, H. and Z. X. Wei. 1993. *Colocasia heterochroma*, a new species of *Colocasia* from Araceae from Yunnan, China. *Acta Bot. Yunnanica* 15 (1): 16-17.

Lila Jacob. 1985. *Compendium on Summer Institute on Recent Advances in Production and Utilization of Tropical Tuber Crops*. CTCRI, Trivandrum. pp. 164-170.

Long, C. L. and K. M. Liu. 2001. *Colocasia ihengiae* (Araceae: Colocasieae), a new species from Yunnan. *Bot. Bull. Academia Sinica* 42: 313-316.

Mabberley, D. J. 1997, The Plant-Book: a Portable Dictionary of the Vascular Plants, 2nd Edition. Cambridge University Press, Cambridge, U. K.

McSorley, R., O' Hair, and J. L. Parrado. 1983. Nematodes associated with the edible genera *Xanthosoma* and *Colocasia* and their effects on yield. *Nematropica* 13: 165-180.

Maeda, Y. 1932. Cytological studies in Colocasia. *Proc. Crop Sci. Soc. Japan* 4: 315-318.

Mahony, F. 1960. Taro cultivation in the Turk district. *In*: Anthropol. Working papers. pp. 69-98.

Malathy, V. G and P. Santa. 1981. A transmissible mosaic disease in of edible aroids. *J. Root Crops* 7:77-78.

Mandal, B. B. 1999. Conservation biotechnology of endemic and other economically important plant species of India. *In*: E. E. Benson (Ed.), *Plant Conservation Biotechnology*. Taylor and Francis Ltd., London, UK. pp. 211-25.

Manzano, A. R., Adolfo A. Rodriguez Nodals, Maria I. Roman Gutierrez, Zolia Fundora Mayor and Leonor Castineiras Alfonso. 2001. Morphological and Isoenzyme variability of Taro (*Colocasia esculenta* L.Schott) germplasm in Cuba. *Plant Genet. Resources newsletter* No.126: 31-40

Marchant, C. J. 1971. Chromosome variation in Araceae 2. Ricardiae to Colocaseae. *Kew Bull.* 25: 47-56.

Marshal, D. R. and A. H. D. Brown. 1975. Optimum sampling strategies in genetic conservation. *In*: O. H. Frankel and J. G. Hawkes (Eds.), *Crop Genetic Resources for Today and Tomorrow.* Cambridge University Press, Cambridge.

Massal, E. and J. Barrau. 1956. *Food plants of South Sea Islands.Tech. Paper 94.* South Pacific Commission, Nuomea, New Caledonia.

Mason, L. E. 1953. Oceania: Ethnology. *Encyclopedia Britannica* 16: 695-698.

Mathews, B. 1962. Broadcast discussion, BBC Net world thru, Puke, Out of your senses, Listner, 67: 25-51 as quoted by P.H. Davis and V.H. Hollywood in principles of angiosperm taxonomy. Robert L. Kreiger Pub. Co. New York. p. 113.

Matthews, P. J. 1991. A possible tropical wild type taro: *Colocasia esculenta* var. *aquatilis*. *Indo-Pacific Prehistory Assn. Bull.* 11: 69-81.

Matthews, P. J. 1987. Wild taro in the context of cultivation. *Aroideana* 10: 9-13.

Matthews, P. J. 1990. The origins, Dispersal and Domestication of Taro. Unpublished Ph.D. Thesis, Australian National University, Australia.

Matthews, P. J. 1995. Aroids and the Astronesians. *Tropics* 4 (2): 105-126.

Mathews, P. J. 1997. Field guide for wild type of taro *Colocasia esculenta* (L.) Schott Plant Genet. Resources Newsletter. 110: 41-48.

Matthews, P. J. 2000. An introduction to the History of taro as food. *In*: M. Nakatani, and Komaki, K. (Eds.). *Proceedings of the 12th Symposium of the Int. Soc. Trop. Root Crops ISTRC* on Potential of root crops for food and industrial research, Tsukuba, Japan. pp. 484-497.

Matthews, P. J., Matsushita, Y., Sato, T. and M. Hirai. 1992. Ribosomal and Mitochondrial DNA variation in Japanese taro (*Colocasia esculenta* (L.) Schott). *Japan. J. Breed.* 36: 100-111.

Matthews P. J. and R. Terauchi. 1994. Genetics of Agriculture: DNA variation in taro and yam. *In*: J. G. Hather (Ed.) *Tropical Archaeobotany Applications and New Development*s. Routledge, London and New York. pp. 251-262.

Mathur *et al.* As quoted by Shanmugavelu, K. G. 1989. *Production technology of Vegetable Crops.* Oxford & IBH Publishing Co. Pvt. Ltd. pp. 617-627.

Maurya (1977) As quoted by Shanmugavelu, K. G. 1989. *Production technology of Vegetable Crops.* Oxford & IBH Publishing Co. Pvt. Ltd. Pp. 617-627.

Mayo, S. J., J. Bogner and P. C. Boyce. 1997. *The genera of Araceae*. Royal Botanic Gardens, Kew- England.

Melin, A. 1981. The production of seed by taro, *Colocasia esculenta*. *Aroideana* 4(1):

Mehta, Y. R. 1959. As quoted by Shanmugavelu, K.G. *Production Technology of Vegetable Crops.* Oxford & IBH Pub. Co. Ltd. pp. 617-627.

Menon, A. S. 1995. *Kerala Charithram* (In Malayalam), S. Viswanathan Printers & Publishers Ltd. Madras. pp. 1- 602.

Michail, S. H. and M. A. Salem. 1981. Studies on dry rot of *Colocasia antiquorum. Phytopathol. Z.* 100: 157-161.

Miller, C. D. 1927. *Food values of Poi, Taro, and Limu*. B. P. Publshop Museum Bulletin 64. Honolulu, Hawaii.

Misra, R. S. 1991. Prevalence of *Phytopthora* leaf blight of *Colocasia* in northeastern and eastern India. *Phytopthora News Letter* 17: 36.

Misra, R. S. 1993. Prevalence and assessment of yield losses of *Phytopthora* leaf blight of Colocasia in Northern and Eastern parts of India. *In*: *Proceedings of the International Symp. on Tropical tuber crops.* CTCRI, Trivandrum.

Misra, R. S. and S. R. Chowdhury. 1997. *Phytopthora leaf blight disease of taro, Technical Bulletin Ser. 21.* CTCRI, Trivandrum. pp. 1-31.

Mitchell, W. C. and P. A. Maddison. 1983. Pests of taro. *In*: J. K. Wang (Ed.) *Taro: A review of Colocasia esculenta and its potentials.* University of Hawaii Press, Honolulu. pp. 180-235.

Miyazaki, S., Tashiro, Y., Kawazava, K., Yangawa, M., and M. Tabaru. 1986. Promotion of flowering in taro by treatment of seed corms and young plants with gibberillic acid. *J. Japanese Soc. Hort. Sci.* 54 (4): 450-459.

Miyazaki, S., Tashiro, Y and A. Takeshita. 1987. Flowering of taro (*Colocasia esculenta* Schott) plants treated with gibberellic acid. Bull. *Faculty Agriculture, Saga University* 63. 1-14.

Monge, M., Gomez, L, Valverde, R. and O. Arias. 1989. Preliminary evaluation of field performance of taro plants (*Colocasia esculenta* var. *antiquorum*) obtained by shoot tip culture. *Agronomia* 11 (3): 189-194.

Mookerjea, A. 1955. Cytology of different species of Aroids with a view to trace the basis of their evolution. *Karyologia* 7: 221-291.

Muralidharan, V .K. 1992. *Personal communication about food habits of people of Fiji.* NBPGR Regional Station, Vellanikkara, Thrissur, India.

Nair, V. 1989. Personal communication on taro shade tolerance. Kerala Agril. University, Vellanikkara, Thrissur, India.

Nakajima, G. 1934. Chromosome numbers in some Angiosperms. *Jap. J. Genet*. 9: 1-5.

Naskar, S. K., Ravindran, C. D. and G. Srinivasan. 1986. Correlation and path analysis in sweet potato. *J. Root crops* 12(1): 33-35.

Nelson, N. 1944. A photometric adaptation of the Somogyi method for determination of Glucose. *J. Biol. Chem.* 153: 375-380.

Nicolson, D. H. 1960. A brief review of classifications in Araceae. *Baileya* 18: 62-67.

Nicolson, D. H. 1979. Araceae. *In*: Smith, A. C. (Ed.) *Flora Vitiensis Nova.* Pacific Tropical Botanical Garden, Hawaii. I: 438-460.

Nicolson, D. H.1987. Derivation of Aroid generic names. *Aroideana* 10 (3): 15-25.

Nyman, L. P. and J. Arditti. 1985. Germination of taro seeds. *Aroideana* 8(3): 83-88.

Ochse, J. J. and R. C. Backuizen van den Brink. 1977. *Vegetables of Dutch East Indies*. Department of Agriculture, Industries & Commerce, Buitenzorg, Java.

O' Hair, S. K. and M. P. Asokan. 1986. Edible Aroids: Botany and Horticulture. *Hort. Review*. 8: 42-99.

Okonkwo, C. A. C. 1988. 'Anayamanaya' cocoyam. *Aroideana* 11(1): 10-11.

Onwueme, I. C. 1978. *The tropical tuber crops*. Wiley, New York.

Onwueme, I.C. 1999. *Taro cultivation in Asia and Pacific*. Food and Agriculture Organization of the United Nations Regional Office for the Asia and the Pacific, Bangok.

Onyilagha, J. C. Omenyi, A. S., Illoh, H. C. and J. Lowe. 1987. *Colocasia esculenta* (L.) Schott, *Colocasia antiquorum* Schott, how many species. *Euphytica.* 36(2): 687-692.

Packard, J. C. 1975. *The Bougainville taro blight*. Pacific island study programme, University of Hawaii, Honolulu. p. 144.

Palaniswamy, M. S. and K. S. Pillai. 1980. Parasites on *Aphid gossypii*. G. G. infesting taro and tannia. *Cur. Sci.* 49 (21): 830

Palaniswamy, M. S. and K. S. Pillai. 1981. Studies on the predators of aphid and spidermites infesting edible aroids. *J. Root crops* 7 (1&2): 61-64.

Pardales, J. R. Jr. 1985. Gabi and Yautia: their classification and description. *Philippine Root Crops-Digest* 1 (3):

Pardales, J. R and M. R. Villanueva. 1984. Cultural management for lowland taro under monoculture system in Philippines. *In*: S. Chandra, (Ed.). *Edible Aroids.* Clarendon Press, Oxford. pp. 45-51.

Parris G. L. 1941. Diseases of Taro in Hawaii and their control. *Hawaii Agric. Experiment Stn. Circ.* 18. pp. 1-29.

Parthasaradhy, V. A., Medhi, R. P. and S. P. Ghosh. 1986. Path coefficient and discriminant functions in sweet potato. *South Indian Hort*. 34 (4): 221-223.

Patel, M. Z., Saelea, J. and G. V. H. Jackson. 1984. Breeding strategies for controlling diseases of taro in Solomon Islands. *Proc. Int. Soc. Trop. Root Crops* 6: 143-149.

Pillai, R. V. R. 1969. The Karyotype study of *Colocasia antiquorum* Schott. *Curr. Sci*. 38: 595-96.

Pillai, R. V. R. 1972. Cytotaxonomical study of the cultivated species of the genus *Colocasia* Linn. *J. Assam. Sci. Soc.* 15 (1): 66.

Plowman, T. 1969. Folk uses of new world aroids. *Econ. Bot.* 23: 97-122.

Plucknett, D. L., de la Pena, R. S., and F. Obrero. 1970. Taro (*Colocasia esculenta*): A review. *Field Crop Abstr.* 23: 413-26.

Plucknett, D. L. and R. S. de la Pena. 1971. Taro Production in Hawaii. *World Crops* 23: 244-249.

Plucknett, D. L. 1976. Edible aroids: *Alocasia, Colocasia, Cyrptosperma*, and *Xanthosoma. In*: N. W. Simmonds (Ed.) *Evolution of crop plants*. Longman, London and New York. pp. 10-18.

Plucknett, D. L. 1983. Taxonomy of the genus *Colocasia*. *In*: J. K. Wang (Ed.), *Taro: A review of Colocasia esculenta and its potentials*. University of Hawaii Press, Honolulu. pp. 14-19.

Porteres, R. 1960. La Sombre Aroide Cultivee *Colocasia antiquorum* Schott or Taro de Polynesia Essaid's Etymology Semantique. *J. Agric. Trop. Appl*. 7: 109-192.

Purseglove, J. W. 1975. *Tropical crops. Monocotyledons.* (Vol. 1 & 2 combined). Longman, London. pp. 61-69.

Quero-Garcia, L. Noyer, X. Perrier, Marchar, J. L. and V. Lebot. 2003. A germplasm stratification of taro (*Colocasia esculenta*) based on agro-morphological descriptors, validation by AFLP markers. *Euphytica* 137(3): 387-395.

Radford, A. E. 1986. *Fundamentals of Plant Systematics.* Harper and Row, New York.

Rajendran, P. G., Hrishi, N. and S. B. Maini. 1977. Genetic variability on Amorphophallus seedlings. *J. Root Crops* 3:55-56.

Rajendran, P. G., Lakshmi, K. R. and M. Unnikrishnan. 1985. Genetics and path coefficient analysis in cassava. *Proc. Tropical tuber crops Nat. Symp*. pp. 1-5.

Ramachandran, K. 1978. Cytological studies on South Indian Araceae. *Cytologia* 43: 289-297.

Rana, P. and D. Adhikary. 2005. Developing Agricultural markets through business services. ADB-DFID MMWP Workshop, Manila, Philippines.

Rao, C. R. 1952. *Advanced statistical methods in biometrical research*. John Wiley & Sons, New York.

Rao, C. R. 1964. The use and interpretation of Principal Component Analysis in applied research. *Sankya* 26: 329-358.

Rao, N. S. 1947. A note on chromosome number in *Colocasia antiquorum*. *Curr. Sci.* 16: 229.

Rao, M. N. and W. P. Polacchi. 1972. *Food composition table for use in East Asia.* FAO, Rome.

Rattanbury, J. A. 1956. Cytotaxonomy and the migration of primitive people. *Nature* 178: 545-546.

Rattanbury, J. A. 1957. Chromosome numbers in New Zealand angiosperms. *Trans. R. Soc. N. Z.* 84: 936-938.

Ravindran, C. S. 1985. *Compendium on Summer Institute on Recent Advances in production and utilization of tropical tuber crops.* CTCRI, Thiruvananthapuram. pp. 164-170.

Rekha, V. R., Manikandan Nair, P., Sreekumar, S. G., Balakrishnan Asan and M. R. C. Pillai. 1991. Path analysis of yield components in a few cassava cultivars. *J. Root rops* 17(1): 35-38.

Rodriguez M. A., Rodriguez, N. A. A., Guitierrez, M. I. R., Mayor, Z. F. and L. C. Alphonzo. 2001. Morphological and isoenzyme variability of taro (*Colocasia esculenta* (L.). Schott) germplasm in Cuba. *Plant Genet. Resources News Lett.* 126: 31- 40.

Saha, B. P. and M. Hussain. 1983. A study of the irritating principles of aroids. *Ind. J. Agric. Sci.* 53: 833-836.

Santha, V. P., Pillai, P. K. T., Nair, P. G. and H. K. Hore. 1999. Collecting taro and other tuber crops from NEH region of India. *Ind. J. Pl. Genet. Resour*. 13; 151-155.

Sarnaik and Peter (1986) as quoted by Shanmugavelu, K. G. 1989. *Production technology of Vegetable Crops.* Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi. pp. 617-627.

Saud, B. K. and R. K. S. M. Barua. 2000. Panikachu - special taro cultivation in Southern Assam. *Intensive Agriculture* 38 (9-10): 26-27.

Sauer, C. O. 1969. *Agricultural origins and dispersal. The domestication of animals and foodstuffs.* MIT Press, Cambridge, MA.

Schott, H. W. 1832. Araceae. *In*: H. W. Schott & S. Endlicher (Eds.) *Meletemata Botanica.* C. Gerald, Vienna. . pp. 16-22.

Sen, H., Das, S., and A. K. Dwivedi. 1998. Stolon production of Swamp taro [*Colocasia esculenta* (L.) Schott], as influenced by different organic and inorganic nitrogenous fertilizers. *J. Root Crops* 24 (1): 81-84.

Sethuraman S. P., Nedumchezhiyan, M. and S. K. Naskar. 2005. Swamp taro production System in the North Bengal Region of India. *J. Root Crops* 31 (2): 149-152.

Shanmugavelu, K. G. 1989. *Production Technology of Vegetable Crops.* Oxford & IBH Pub. Co. Pvt. Ltd., New Delhi. pp. 617-627.

Sharma, A. K. and M. K. Das. 1954. A study of karyotypes and their alterations in Aroids. *Agron Lusit.* 16: 23-48.

Sharma, A. K. and A. K. Sarkar. 1963. Cytological analysis of different cytotypes of *C. antiquorum*. *Bull. Bot. Soc. Bengal* 17:16-22.

Shaw, D. E. 1975. Illustrated notes on flowering, flowers, seed and germination in taro (Colocasia esculenta). *Papua New Guinea Dept. Agri. Stock and Fischers Res. Bull.* 13: 39-59.

Shaw, D. E., Plumb, R. T. and G. V. H. Jackson. 1979. Virus diseases of taro (*Colocasia esculenta*) and *Xanthosoma* sp. in Papua New Guinea. *Papua New Guinea Agric. J.* 340: 71-97.

Sneath, P. H. A. 1957. The application of computers to taxonomy. *J. Gen. Microbiol*. 17: 201-226.

Sneath, P. H. A. and R. R. Soakal. 1962. Numerical Taxonomy. *Nature* 193: 855-860.

Soakal, R. R. 1962. Distance as a measure of taxonomic similarity. *Syst. Zool.* 10: 70-79.

Spier, R. F. G. 1951. Some notes on the origin of taro. *South Western J. Anthropology* 7: 69-76.

Spriggs, M. J. T. 1982. Taro cropping systems in the South East Asian Pacific region: Archaeological evidence. *Arch. Oceania* 17:7-15.

Sreekumari, M. T. 1992. Cytomorphological and cytogenetic studies in edible aroids. Ph. D. Thesis. University of Kerala, Trivandrum.

Sreekumari, M. T. 1997. Cytological studies in taro - A review *J. Root Crops* 23(1): 1-7.

Sreekumari, M. T. and P. M. Mathew.1989. Karyomorphology of six cultivars of taro (*Colocasia esculenta* Schott). *New Botanist* 16: 127-135.

Sreekumari, M. T. and P. M. Mathew. 1990. Karyomorphology of Five morphotypes of Taro (*Colocasia esculenta* (L.) Schott). *Cytologia* 56:215-218.

Sreekumari, M. T. and P. M. Abraham. 1991a. Karyomorphology of five morphotypes of taro (*Colocasia esculenta* (L.) Schott. *Cytologia* 56: 218-218.

Sreekumari, M. T. and P. M. Mathew. 1991b. Karyotypically different morphotypes in Taro (*Colocasia esculenta* (L.) Schott). *Cytologia* 56: 399-402.

Sreekumari and P. M. Abraham. 1991c. Chromosomal variation in taro (*Colocasia esculenta* (L.) Schott. *J. Root Crops,* ISRC Nat. Symp. 1990. Special issue. Pp. 27-29.

Sreekumari, M. T. and P. Mathew. 1992. Distribution of diploid and triploid taro in India. *J. Root Crops* 18(2): 132-133.

Sreekumari, M. T. and P. M. Mathew. 1993. Meiosis in triploid Taro (*Colocasia esculenta* (L.) Scott. *J. Cytol. Genet*. 28: 7-11.

Sreekumari, M. T. and P. M. Mathew. 1995. Karyotype distinction in Indian Taros. *J. Cytol. Genet.* 30 (2): 143-149.

Staritsky, G. 1980. In vitro storage of aroid germplasm. *PGR News Letter* 42: 25-27.

Strauss, M. S. and J. Arditti. 1979. Seed culture and micro propagation of taro. *In: Proc. Symp. on Taro and Cocoyam.* Baybay, Philippines Int. Foundation for Science (Stockholm) Prov. Report pp. 279-286.

Strauss, M. S., Michaud, J. D. and J. Arditti. 1979. Seed storage and germination and seedling proliferation in Taro, *Colocasia esculenta* (L.) Schott. *Ann. Bot*. 43: 603-612.

Strauss, M. S., Stephens, G. C., Gonzales, C. J., and J. Arditti. 1980. Genetic variability in taro. *Ann.. Botany* 4: 429-437.

Sturtevant, E. L. 1919. Notes on edible plants. *Rep. N.Y. Agric. Exp. Stn*. pp. 69-70.

Subramanyan, D. 1979. Cytological studies in *Colocasia antiquorum* Schott. *J. Cytol. Genet.* 14: 179-184.

Sujatha, V. S., Sheshadri, V. S., Srivasthava, K. N., and T. A. More. 1991. Isozyme variation in muskmelon (*Cucumis melo* L.). *Ind. J. Genet*. 51: 438-44.

Sunell, L. A. and P. L. Healy. 1979. Distribution of calcium oxalate crystals, idioblasts in corms of taro (*Colocasia esculenta*). *Amer. J. Bot.* 66:1029-1032.

Sunell, L. A. and P. L. Healy. 1981. Crystallization in plant cells: Raphid idioblasts in taro leaves. *J. Cell Biol*. 91: 33.

Suzuki, M., Kano, M. Mitani, A., Mochida, F. and M. Ariki. 1975. On the irritant substance, 3,4-diglycisilicbenzaldehyde in taro, *Colocasia antiquorum*. *J. Japan. Soc. Food Sci*. 45: 1075-1077.

Tahara, M., Suefuji, S., Ochiai, T. and H. Yoshino. 1999. Phylogenetic relationships of Taro, *Colocasia esculenta* (L.) Schott and Related Taxa by Non-coding Chloroplast DNA Sequence Analysis. *Aroideana* 22: 79.

Tang, C. S. and W. S. Sakai. 1983. Acridity of taro and related plants. *In*: J. K. Wang (Ed.), Taro. Univ. of Hawaii Press, Honolulu. pp. 148-163.

Tanimotto, T., Tsuchiya, H., and T. Matsumoto. 1983. Geographical variation in morphological characters of inflorescence in taro (*Colocasia esculenta* Schott). *Jap. J. Breeding* 33 (3): 259-268.

Tanimoto, T. and Matsumoto, T. 1986. Variations of morphological characters and isozyme pattern in Japanese cultivars *Colocasia esculenta* L. Schott and *C. gigantia* Hook. *Jap. J. Breeding* 36 (2): 100-111.

Thamburaj, S. and C. R. Muthukrishnan. 1976. Association of metric traits and path analysis in sweet potato. *Madras Agric. J*. 63(1): 1-8.

Thankamma Pillai, P. K and M. Unnikrishnan.1990. Heritability studies in taro. *J. Root Crops*. (ISRC Nat. Symp. Special issue). pp. 53-56.

Thankamma Pillai, P. K. and M. Unnikrishnan. 1993. Taro Genetic Resources. Tech. Bull. Series. CTCRI, Trivandrum.

Thankamma Pillai, P. K., Lakshmi, K. R. and M. N. Sheela. 1995. Correlation and path analysis in Taro. *J. Root. Crops* 21(2): 86-89.

Thankappan, M. 1985. Leaf blight of taro – a review. *J. Root Crops 2* (1 &2): 1-8.

Trujillo, E. E. 1967. Diseases of the genus *Colocasia* in the Pacific area and their control. *Proc. of the International Symposium of Tropical Root Crops Trinidad.* Feb. 13-16.

Trujillo, E. E. 1971. A list of diseases of economic plants in the Trust Territory of Pacific Islands. Trust Territory of Pacific Islands, Department of Resources and Development, Division of Agriculture, Fiji. 1-2.

Trujillo, E. E. and M. Aragaki. 1964. Taro blight and its control. *Hawai Farm Sci.* 13 (4): 3-4.

Trujillo, E. E. and T. Menezes. 1995. Field tolerance of Micronesian taros to *Phytopthora* blight. *Phytopathology* 85 (12): 1564

Tumana, C. W. 1987. Collecting taro germplasm in Papua New Guinea *IBPGR, News Letter* 11(2): 7-8.

Unnikrishnan, M. and M. N. Sheela. 2000. Biotechnology in conservation and improvement of tuber crops. *In*: K. L. Chadha, P. N. Ravindran and

Shahijram (Eds.), Biotechnology in horticultural and Plantation crops. Malhotra Publishing House, New Delhi, India.

Unnikrishnan, M., P. K. Thankammmi Pillai, K. Vasudevan, G. G. Nair, J. S. Joss, M. T. Thankppan and M. S. Palaniswami, 1987. Genetic Resources of Tuber Crops. *Tch. Bull. Series 8*. CTCRI, Trivandrum.

Vasquez, E. A. 1990. Yield loss in taro due to Phytopthora leaf blight. *J. Root Crops.* 16: 48-50.

Velayudhan, K. C, K. I. Asha, C. Rajalakshmy and R. S. Liji. 2003. *Cassava Genetic Resources. Sci. Monograph No. 5.* NBPGR Regional Station, Thrissur. pp. 1-109.

Velayudhan, K. C. and V. K. Muralidharan. 1987. Variability of a collection of *Colocasia* from the wild. *In:* Proc. *Tropical Tuber Crops Nat. Symp*. CTCRI, Thiruvananthapuram. pp. 45-49.

Velayudhan, K. C., Muralidharan V. K. and T. A. Thomas, 1989. Genetic Resources of Tropical Tuber crops. *Ind. J. Pl. Genet. Resources*. 2 (1): 70-72.

Velayudhan, K. C., V. K. Muralidharan, V. A. Amalraj, and T. A. Thomas, 1990a. *Genetic Resources of Dioscorea alata L. Sci. Monograph No.1.* NBPGR Regional Station, Thrissur.

Velayudhan, K. C., V. K. Muralidharan and P. Meagle Joseph, 1990b. Variability in yield and quality characters in taro (*Colocasia esculenta*). *Ind. J. Pl. Genet. Resources.* 3 (1): 102-106.

Velayudhan, K. C., V. K. Muralidharan, V. A. Amalraj, T. A. Thomas, and R. S. Rana, 1991. Studies on the morphology, distribution and classification of an indigenous collection of taro. *J. Root Crops* 17 (2): 118-129.

Velayudhan, K. C., Muralidharan, V. K., Amalraj, V. A., T. A. Thomas and R. S. Rana.1993. *Genetic Resources of Taro. Sci. Monograph* No. 2. NBPGR, New Delhi.

Vellejos E. 1983. Enzyme activity staining. *In*: S. D. Tankshy and J. J. Star (Eds.), *Isozymes in Plant Genetics and Breeding*, Part A. Elsevir Science Publishers B. V., Amsterdam. pp. 469-516.

Vicente-Chandler, J., Abruna, F., Badillo, F. and J. F. Rodriguez-Garcia. 1983. The effect of soil acidity factors on crop yields. IX. Taniers. *J. Agric. Univ. Puerto Rico* 67: 446-452.

Vijaya Bai, K. V., 1982. *Cocoyams.* IITA Ann. Rep. for 1982. International Institute Tropical Agriculture, Ibadan, Nigeria. pp. 116

Vijaya Bai, K. V., Magoon, M. L. and R. Krishnan. 1971. Meiosis and pollen mitosis in diploid and triploid *Colocasia antiquorum* Schott. *Genetica* 42: 187-198.

Wang, J. K. 1983. *A review of Colocasia essculenta and its potentials.* University of Hawaii Press, Honolulu.

Wang Zongxun. 1996. A New Latin, Chinese, English Botanical Nomenclature. Chinese Academy of Sciences, Institute of Botany, Aviation Industry Publisher, Beijing.

Watt, G. 1885. *Dictionary of the Economic Products of India, Vol. I.* Superintendent of Government Printing, Calcutta.

Wiersema, J. H and León B. 1999. *World Economic Plants: a Standard Reference*. CRC Press, LLC.

Wilson, J. E. 1981. Effects of formulation and method of applying gibberillic acid on flower promotion in cocoyam. *Exp. Agric*. 17: 317-322.

Wilson, J. E., and W. J. Cable. 1984. Promotion of flowering and seed production and seedling screening in minor edible aroids. *Proc. Int. Soc. Trop. Root Crops* 6: 151-156.

Yawalkar, K. S. 1992. *Vegetable crops of India.* pp. 63-64

Yen, D. E. & J. M. Wheeler. 1968. Introduction of taro into the Pacefic: the indications of the chromosome numbers. *Ethnology* 7: 259-267.

Yongping, Y., Jianchu, X., and P. Eyzaguguirre. 2003. Taro biodiversity management and conservation in Yunnan, China. *In*: ICIP-ESEAP. (Ed.), *Conservation and sustainable use of Agricultural Biodiversity*. International Potato Centre Regional Office for the East, Southeast Asia and the Pacific, Bogor. Indonesia. pp. 89-99.

Yoshino, H. T. 1994. Studies on the phylogenetic differentiation in Taro, *Colocasia esculenta* Schott. Unpublished Ph. D. Thesis, Kyoto University, Japan.

Yoshino, H. 1995. Some species of the genus *Colocasia* having chloroplast DNA of *Alocasia macrorrhiza* var. *variegata*. *In*: H. Li (Ed.), *Proceedings of the VI International Aroid Conference.* Editorial Department of Acta Botanica Yunnanica, Kunming.

Yoshino, H., Ochiai, T. and M. Tahara. 1998. An artificial inter-generic hybrid between *Colcasia esculenta* (L.) Schott and *Alocasia macrorrhiza* var. variegata G. Don. *In*: *Proceedings of the Monocots II and Grass* III. Sydney. As quoted by Long, C. L. and K. M. Liu. 2001. *Colocasia ihengiae* (Araceae: Colocasieae), a new species from Yunnan. *Bot. Bull. Academia Sinica* 42: 313-316.

Zandvoort, E. A. 1987. *In-vitro* germplasm conservation of tropical aroids. *Acta Botanica Neerlandica* 36 (2): 150.

Zhang, G. M. and Z. H. Zhang. 1984. Studies on the chromosome number of the main *Colocasia esculenta* cultivars in China. *Actn. Horti. Sinica* 11(3): 187-195.

Zettler, F. W., Foxe, M. J., Hartman, R. D., Edwardson, J. R. and R. G. Christie. 1970. Filamentous viruses affecting dasheen and other araceous plants. *Phytopathology* 60: 983-987.

Zeven, A. C. and P. M. Zhukovsky. 1975. *Dictionary of cultivated plants and their centres of diversity*. PUDOC, Wageningen. pp. 1-219.