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An Overview of Morphological Characterization in Sweet Potato (*Ipomoea batatas* Lam.) Varieties Across Kerala

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Abstract

Sweet potato (*Ipomoea batatas* Lam.) is the seventh most important food crop among the root and tuber crops grown in the world which is widely cultivated in tropic, sub tropic and warmer temperate regions. A wide variation exists among sweet potato varieties. The molecular markers Is an important genetic diversity analysis tool for enhancing duplicates identification. The samples were collected based on an elaborative iterative survey as well as traditional knowledge from local people. Thirteen different varieties *Ipomoea batatas* Lam. varieties (Kuravanpady 1, Kuravanpady 2, Jellipara 1, Jellipara 2, Kottathara, Kadanadu, Kanaka, Aruna, Kanjagad, Cherukizhangu 1, Cherukizhangu 2, Thodupuzha. Palakkad) were used for morphological characterization. Morphological data were collected 60 days after planting based on the descriptors for sweet potato (IBPGR, 1991) in all the 13 samples. The variable scored were twining, plant type, ground cover, vine inter node, vine pigmentation, vine tip pubescence, mature leaf shape, mature leaf size, abaxial leaf vein pigmentation, foliage colour, petiole length, petiole pigmentation, storage root and skin colour. Molecular characterization could be more effectively used in screening varieties among sweet potatoes if coupled with other molecular markers especially ISSR, matK and rbcL markers.

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Keywords

Ipomoea batatas Lam, Inter simple sequence repeats, Duplicates, Molecular characterization.

Introduction

Sweet potato (*Ipomoea batatas* Lam.) is the world's seventh most important food crop after wheat, rice, maize, potato, barley and cassava (Zhang *et al.*, 1998; Huaman *et al.*, 1999). The sweet potato is a plant that was probably originated in or near north western South America (Pearsall, 2008; Chalfant *et al.*, 1990; Austin, 1983). It is grown in more developing countries than any other root crop. China is the world's leading sweet potato producing country with about 90%of production (Zhang *et al.*, 1998; Huaman *et al.*, 1999). Sweet potatoes are grown in Africa, Asia and Latin America. World sweet potato production is around 124 million tons in an area of about 9.2 million hectares. Fourty countries count sweet potato among the five most important food crops produced on an annual basis. Japan and United States are among the few industrialized countries (Austin, 1988; Austin, 1983). Two main groups of sweet potato were known during the originated period. The age group, which was starchy and had a slightly sweet taste and the balata group, which was also starchy but markedly sweet in taste (Austin, 1988; Austin, 1983). Sweet potato originated in South America. The crop is cultivated in the tropics, sub tropics region (Zhang *et al.*, 1998; Huaman *et al.*, 1999).

The most common names of this plant in Latin America are batata, camote, boniato, batata doce, apichu and kumara (Zhang *et al.,* 1998; Huaman *et al.,* 1999). This species was first described in 1753 by Linnaeus as convolvulus batatas. However, in 1791 Lamarck classified this species with the genus lpomoea on the basis of the stigma shape and the surface of the pollen grains; therefore, the name was changed to *lpomoea batatas* Lam. (Austin 1983; 1988; Yen 1982; Huaman *et al.,*1999). The primary centre of diversity of sweet potato is located in north western South America (Colombia, Ecudor and Peru) and parts of Central America (such as Guatemala) where a great diversity of native sweet potatoes, weeds and wild lpomoea exists. Secondary centers of sweet potato diversity outside of the Americas are in china, Southeast Asia, New Guinea and East Africa (Austin 1983; 1988; Yen 1982).

Sweet potato is expected to play a vital role in combating the food shortages and malnutrition that may increasingly occurs as a result of population growth and pressure on land utilization (Naskar *et al.,* 2008b). It can produce high amount of energy per unit area per unit time. The protein content of sweet potato on a fresh weight basis is low, but the average protein production /ha from sweet potato in the tropics is same that of cereals, beans and chickpeas (Yamakawa, 1997).

The number of chromosomes in the sweet potato plant is 2n=6X=90. This indicates that it is hexaploid pant with a basic chromosome number X=15. Sweet potato is a dicotyledonous plant that belongs to the morning glory (Huaman *et al.,* 1999; Austin 1983; 1988; Yen 1982). The sweet potato is a member of convolvalacene; genus Ipomoea, sub genus Eriospermum, section Erispermum (family Batatas) and series Batatas (Austin and Human, 1996). The sweet potato plant consists of three main morphological parts: shoot, storage root and leaves. The people like wonderful flavour and health benefits of sweet potato. There are about 400 varieties are identified they depend up on the variety skin and fresh of the sweet potato (Rubatzky and Yamaguchi, 1997). The fresh colours are orange, cream, yellow, white and pink to deep purple. The white and yellow – orange flesh most common (Yamakawa, 1997).

Sweet potato shape is similar to a potato, it short and blocky with rounded end other times it will be longer with tapered ends (Bovell-Benjamin, 2007; Rubatzky and Yamaguchi, 1997). The intensity of yellow or the orange colour of this root vegetable plant is related to beta carotene content. The purple flesh naturally contains good number of anthocyanins and it exhibit highest antioxidant activity is comparison to other variety of sweet potato (Austin, 1983; Austin, 1988; Yen 1982). Sweet potato can be categorized into two different groups depending on the texture they have when they cooked in firm, dry and mealy others are soft and moist. In both kinds taste is starchy and sweet; the different verities have different unique taste. The orange coloured root vegetable is often known as a" yam" it is actually sweet potato (Austin 1983; 1988; Yen 1982).

Molecular DNA marker research in sweet potato is limited to gene pool evolution, genome characterization, duplicates identification and fingerprinting (Jarret *et al.*, 1992; Villordon and La Bonte, 1995; Villordon and La Bonte, 1996; Veasey *et al.,* 2008). Molecular marker will become indispensable tools in sweet potato crop improvement. The molecular marker can be used to detect duplicate genome and eliminate this genome in the germplasm. ISSR marker is mainly used for the duplicates identification because low cost and easy to use, for most genetic variation studies a good genetic marker is defined by high genetic variability and the ability to generate multi-locus data from the genome under study (Kumar *et al.,* 2009; Curto *et al.,* 2012). The generation of ISSR markers makes use of microsatellite sequence that are highly variable and ubiquitously distributed in the genome.

Sweet potatoes decrease the risk of obesity, diabetes, heart disease Sweet potatoes contain almost twice as much fibre as other types of potatoes (Shintani *et al.*, 1991; Oniang'o *et al.,* 2003). Contributing close to 7 grams of fibre per serving, they make an excellent starchy addition to any meal. Sweet potato is considered to be one of the highly nutritious foods (Rubatzky and Yamaguchi, 1997). The high fibre content gives them a "slow burning" quality. It maintaining a low sodium intake is essential to lowering blood pressure (Austin, 1983; Austin, 1988).Rich in beta-carotene may play a protective role against prostate cancer. Sweet potatoes are a great source of B6 vitamins, which are breakdowns the homo cysteine compounds, a substance that contributes to the hardening of blood vessels and arteries. Consume sweet potatoes or extracts from sweet potatoes help to control blood glucose level (Austin, 1983; Austin, 1988; Yen, 1982).

The main objectives of this study to characterize the morphological variations of sweet potato plant across Kerala.

Scope of the study

The study would enlighten the morphological diversity of sweet potato varieties in Kerala. The results could be further used to explore germplasm conservation and raising new varieties.

Taxonomical classification

Kingdom: Plantae-planta, plantes, plants, vegetal

Subkingdom: Viridiplantae

Infrakingdom: Streptophyta-land plants

Superdivision: Embryophyta

Division: Tracheophyta -vascular plants, tracheophytes

Subdivision: Spermatophytina-spermatophytes, seed plants, phanerogames

Class: Magnoliopsida

Order: Solanales

Family: Convolvulaceae-morning-glories

Genus: Ipomoea-morning glory

Species: *Ipomoea batatas* Lam.-Sweet potato

Sweet potato is the seventh most important food crop next to cassava among the root and tuber crops grown in the world (Ray and Ravi, 2005). It is cultivated in tropic, sub tropic and warmer temperate regions. The sweet potato is herbaceous and perennial plant propagated through vegetative modes. Sweet potato is a staple food in many of the developing countries. It is consumed both fresh and in the processed forms. It is also used as animal feed (Austin, 1983; Austin, 1988).

Origin of sweet potato

Ipomoea batatas Lam. is a dicotyledonous plant that belongs to the morning glory family covolvalanceae which is cultivated throughout the tropics, subtropics and warmer temperature regions (Austin, 1983; Austin, 1988). It is a staple food in many developing countries. It is an important food crop after wheat, rice, maize, potato, barley and cassava. It is native of tropical America and normally propagated by asexual means (Chen *et al.*, 1993). The exact location of its botanical origin is unknown but Central America is considered the primary diversity centre, while South America (Peru, Ecuador) is considered the secondary centre of diversity (Zhang *et al.*, 2000), as also is the Brazilian territory (Austin, 1988).

Sweet potato is one of the subsistence crops used in traditional shifting cultivation in Brazil, known as slash-and-burn agriculture (Peroni and Hanazaki, 2002). The history of this farming practice goes back to the Brazilian pre-colonial period where cultivation techniques have and still are being modified and adapted over time (Peroni *et al.*, 2007). This vegetable is one of the oldest vegetables known to man. The origin of sweet potato dates back to quite long time, to the prehistoric time (Zhang *et al.*, 2000). The history of sweet potato also revealed in mid-twentieth century, the orange fleshed sweet potato was introduced to the United States (Austin 1983; Austin, 1988; Yen, 1982). They give name is' yam' differentiating it from other variety of sweet potatoes. The primary centre of diversity of sweet potato is located in north western south America (Colombia, Ecudor and Peru) and parts of Central America (such as Guatemala) where a great diversity of native sweet potatoes, weeds and wild lpomoea exists. Secondary centres of sweet potato diversity outside of the Americas are in china, Southeast Asia, New Guinea and East Africa (Austin, 1983; Austin, 1988; Yen, 1982).

The common name of sweet potato such as batatus, tata, mbatata, etc. The other names such as bombe, bombai and so on associated with Indian city, Bombay acquired by the British in 1662 may be linked to a later spread of plant by British colonial influence (woolfe, 1992). Also in India and southeast Asia, sweet potato was introduced in their local name for example in Malaysia it is called Spanish tuber (Zhang *et al.*, 2000; Austin, 1983; Austin, 1988).

Morphology

The sweet potato belongs to a single species *Ipomoea batatas* Lam. It is a hexapolid plant with 2n=6X=90 chromosomes. Some plants are morphologically quite similar to *I.batatas* with 2n=4X=60 chromosomes (Austin, 1998). The sweet potato grown as an annual plant by vegetative propagation using either Storage roots or stems cuttings. That expands rapidly horizontally on the ground. The type of growth habit of sweet potatoes is erect, semi erect, spreading and very spreading. The techniques for rapid multiplication of

sweet potato that are used to obtain large number of stem cuttings in a short period of time, include the propagation from in vitro plantlets, the use of micro cuttings with 1-2 nodes, the production of mini storage roots and the sprouting of storage roots. The sweet potato plant consists of three main morphological parts: shoot, storage root and leaves (Zhang *et al.*, 2000; Austin, 1983; Austin, 1988).

Root

The sweet potato root system consists of fibrous roots that absorb nutrients and water. The storage roots are lateral roots, which store photosynthetic products. The root can be used for vegetative propagation.

The plant matures thick pencil roots that have some lignifications are produced. Other roots that have no lignifications are fleshy and thicken a lot are called storage roots (Austin, 1983; Austin, 1988).

Stem

Sweet potato stem is cylindrical. The internodes are present in stem. The stem length is approximately 1-5m long. The stem is mainly used for vegetative propagation. The internodes length can vary from short to very long, and, according to stem diameter, can be thin or very thick. Depending on the sweet potato cultivar, the stem colour varies from green to totally pigment with anthocyanins (red-purple colour). The hairiness in the apical shoots, and in some cultivars also in the stems, Varies from glabrous (without hairs) to very pubescent (Austin, 1983; Austin, 1988).

Leaves

The leaves are simple and spirally arranged alternately on the stem in a pattern known as 2/5 phyllotaxis. The edge of the leave lamina can be entire, toothed or lobed.

The base of the leaf lamina generally has two lobes that can be almost straight or rounded. The shape of the general outline of sweet potato leaves can be rounded, reniform (kidney shaped), cordate (heart-shaped), triangular, hastate (trilobular and spear-shaped with the two basal loves divergent), lobed and almost divided. The leaf colour can be green-yellowish, green or can have purple pigmentation in part of leaf blade. Some cultivars show purple young leaves and green mature leaves (Austin, 1983; Austin, 1988).

Flowers

Sweet potato cultivars differ in their ability of flower. Under normal conditions in the field, some cultivars do not flower. In general, buds of first, second, and third order are developed. However, single flowers are also formed. The flower buds are joined to the pedundle through a very short stalk called pedicel.

The colour of the flower bud pedicel, and Peduncle varies from green to completely purple pigmented. The flower is bisexual. Besides the calyx and corolla, they contain the stamens that are the male organs or androecium and the pistil that is the female organ or gynoecium (Austin, 1983; Austin, 1988).

Fruit and seeds

The fruit is a capsule, more or less spherical with a terminal tip, and can be pubescent or glabrous. The capsule turn's brown when mature. Each capsule contains from one to four seeds that are slightly flattened on one side and convex on the other. Seed shape can be irregular, slightly angular or rounded; the colour ranges from brown to black; and the size is approximately 3mm (Austin, 1983; Austin, 1988).

Storage root

The storage roots are the commercial part of the sweet potato plant, and sometimes are mistakenly named "tubers". The parts of the storage roots are the proximal end, that joins to the stem, through a root stalk, and where many adventitious buds are found from which the sprouts are originated a central part.

The storage roots show the protective periderm or skin, the cortex or cortical parenchyma that, depending on the cultivar, varies from very thin to very thick (Zhang *et al.*, 2000; Austin, 1983; Austin, 1988).

The amount of the latex formed depends on the maturity of the storage root, the cultivar, and the soil moisture during the growing period. The latex drops are produced when the storage roots are cut and they darken very quickly due to the oxidation. The storage root surface is usually smooth but some cultivars show some effects such as alligator-like skin, prominent veins, horizontal constrictions or longitudinal grooves (Austin, 1983; Austin, 1988).

Nutritive value

The sweet potato is one of the most nutritious vegetables, the leaves and shoots are also edible, the starchy tuberous roots are by far the most important product. In some tropical areas, they are a staple food-crop. They are rich in dietary fibre, vitamin A, vitamin C, vitamin B6, complex carbohydrates, protein, iron, and calcium. The roots are most frequently boiled, fried, or baked. They can also be processed to make starch and a partial flour substitute. Industrial uses include the production of starch and industrial alcohol. All parts of the plant are used for animal feed). The orange-and red-fleshed forms of sweet potato are particularly high in beta-carotene, the vitamin A precursor. These deep orange-fleshed nutritional powerhouses add several important components to the diet. The vitamin A in sweet potatoes (consumed as beta-carotene then converted to vitamin A in the body) is also essential during pregnancy and lactation for hormone synthesis (Zhang *et al.,* 2000; Austin, 1983; Austin, 1988).

Characterization

Sweet potato can be characterized based on their morphological and molecular analysis. These processes can be used to eliminate duplicate sweet potatoes and crop improvement and that could be used in the future for either agriculture or environmental benefits.

Morphological characterization

The morphological characterization has been used for different studies include identification of duplicates, studies for genetic diversity patterns. The descriptors for sweet potato by CIP *et al.,* (1991) have been widely used to assess morphological variation in sweet potato collection such as variation in the vine, leaf, flower and storage root characteristics.

Molecular characterization

The molecular markers are used for the identification of duplicates, genetic analysis of sweet potato. The markers are important tool for molecular studies. Many molecular markers are used for identification of sweet potato, including Random Amplified Polymorphic DNA, Amplified fragment Length Polymorphism and Inter Simple Sequence Repeats (Hu *et al.,* 2003).

The molecular markers like SSR and ISSR have been used to identify duplicates in germplasm. The morphologically similar plants are molecularly different so the banding patterns can be used to analysis, identify the duplicates, elimination of duplicates and establishment of core collection. Thus, it becomes cost effective as the duplicates are eliminated (Hu *et al.,* 2003).

Molecular marker

Molecular markers are used to identify a particular sequence of DNA in a pool of unknown DNA. Inter-simple sequence repeat (ISSR) an ideal genetic marker for various studies, most notably on genetic variation/diversity, DNA finger printing, identification of duplicates and phylogenetics (Wamg *et al.,* 2012; shafiei -Astani *et al.,* 2015).

ISSR are regions in the genome flanked by microsatellite sequences. The markers make use of microsatellite sequence that is highly variable and ubiquitously distributed across the genome. This region consists of random repeats of simple pattern as (CT) n or (AC) n repeating sequence located between nucleus plant genome (Wamg *et al.,* 2012; shafiei -Astani *et al.,* 2015).

Inter simple sequence repeat ISSR markers are also popularly known as random amplified micro satellites (RAMs).ISSR experiments clarify some misconceptions and this marker using in the genetic variation studies The ISSR marker belongs to a class of multilocus. These markers usually produce multiple DNA fragments but they considered a locus in a single reaction (Wamg *et al.,* 2012; Shafiei -Astani *et al.,* 2015). The generation of a large number of loci across the genome of any species without the need to first known the DNA sequence of the target regions. Apart from it usage as genetic markers these dominant markers can also be used as initial steps for the development of co-dominant markers; RAPD for the development of single locus co-dominant 'sequence characterized amplified region (SCAR)' markers (Parana, 1993) and ISSR for the development of single-locus co-dominant microsatellite markers (Fisher *et al.,* 1996; Lian *et al.,* 2001; Adibah *et al.,* 2012).

This marker are mainly used for genetic variation studies a good genetic marker is defined by high genetic variability and the ability to generate multilocus data from the genome under study (Anne, 2006). The generation of ISSR markers makes use of microsatellite sequence that are highly variable and ubiquitously distributed in the genome. across the genome, at the same time achieving higher reproducibility compared to

using RAPDs and costs less in terms of time and money compared to using AFLPs. All these make ISSR an ideal genetic marker for various studies, most notably on genetic variation /diversity (Wang *et al.*, 2012; Shafiei-Astani *et al.*, 2015), DNA fingerprinting (Shen *et al.*, 2006) and phylogenetics (Iruela *et al.*, 2002). The ISSR markers mainly used for plant genetics studies, this marker can be very useful for clarify the experiment.

The basic procedure to conduct an ISSR genotyping experiment is simple:

PCR using an ISSR primer with genomic DNA (gDNA) as its template.

Use of agarose gel electrophoresis of PCR amplification products.

Scoring of ISSR band and

Data analysis.

gDNA as template for ISSR –PCR

Genomic DNA is commonly used as the template for ISSR-PCR, and is therefore an integral part for a successful ISSR experiment. In this experiment is the need to obtain high quality DNA as the starting material and to standardize the quality of template DNA used in each PCR reaction. DNA extracts depending on the extraction method and type of the sample may contain trace of cell debris and components that potentially inhibit PCR reaction, the purified DNA can be used for PCR reaction. Column based DNA extraction /purification kit. 10-50ng of good quality DNA is sufficient reaction.

ISSR primer design

An ISSR primer is usually 16-25 base pairs (bp) in length and comprises mainly or solely of repeated DNA motifs (2-4 bp each) meant to be complementary to microsatellite regions in the genome. Depending on the usage there are 3 forms of ISSR primers: unanchored (primer consists only of a repeated motif,5'-(AC)8-3'),5'-anchored (primer consists of a repeated motif with one or several non–motif nucleotides at the 5'-end,5'-GA(AC)8-3'),and 3'-anchored (primer consists of a repeated motif with one or several non–motif nucleotides at the 5'end,5'-(AC)8AG-3') (Reddy *et al.*, 2002). The different primers can be used to generate different ISSR band to evaluate genetic variability,3'- or 5' –anchored primer is mainly used. Unanchored ISSR primers may slip along the length of the complementary microsatellite region during PCR producing inconsistent amplification in every cell cycle and thus affecting the reproducibility of result. ISSR primers can be easily designed or customized to fit the needs of the experiment. The ISSR primers designed at the university of British Columbia (primer names usually starting with'' UBC'').

PCR amplification with ISSR primers (ISSR-PCR)

ISSR-PCR involves only one primer in each reaction, the single primer actually acts as both the forward and reverse primers which are essential for an amplification. ISSR-PCR is usually conducted with an annealing temperature (Ta) of 45-60°C, depending on the melting temperature (Tm) of the ISSR-primers (Reddy *et al.*, 2002).

Scoring of bands

The standards of scoring DNA bands generated for most dominant DNA markers and band scoring results may differ from person to person (Pompanon *et al.*, 2005; Meudt and Clarke, 2007) observing several points when scoring ISSR bands on the gel:

Score only clearly distinctive bands. Smeared bands could be the result of unspecific band of ISSR primers causing unintended amplification or the overlapping of several bands with similar DNA fragment sizes, both of which would make scoring difficult and inconsistent.

Score only bands with strong intensities. Bands with weak intensities tend to have low reproducibility and thus are best avoided. Set a standard band scoring size range before scoring usually in the range of 100-200bp. Electrophoresed through a 2%w/v agarose gel at 80-100v, the two ladders (100mb and 1 kb molecular ladders) can be loaded in each side of the gel and analysis the primer bands to differentiate the molecular weight. Finally, bands are recorded into the binary symbols, 1, for band presence whereas, 0, for band absence for subsequent analyses.

Identification of duplicate accessions

Sweet potato being a vegetative propagated crop has practically no genetic contamination even if a variety is cultivated for a long time in a particular area. However, as a consequence of a variety being grown for a long time simultaneously in several places, duplicate samples

might have been collected. After agro morphological characterization, the following 18 characters are used to identify duplicates of a sweet potato variety they are climbing ability, plant type, shoot tip pubescence, colour of leaf veins, stem diameter, pedicel length, pedicel colour, stem pigmentation, stem diameter, internodes length, root shape, leaf size, leaf shape, mature and immature leaf colour, form of root-stem connection, thickness of root skin. Molecular techniques are considered as the most advanced methods to ascertain the duplicate. Increasing attention is being given to rationalizing collection by identifying and combining and eliminating duplicate accessions. Duplicates may be identified on the basis of having a common origin- two accessions derived from the same original sample by sub sampling, seed exchange and regeneration are historical duplicates. Alternatively, biological duplicates may be defined on the basis of their genetic similarly. The concept of biological duplication embodies degrees of similarly, from sharing similar identified alleles to having all alleles present at identical frequencies. Historical duplicates are often difficult to identify because of a frequent failure to adhere to the standard of maintaining a copy of all passport data. With every accessions and errors in typing, transcribing, translating passport data. These problems prevent the routine applications of software to identify the duplicate sand necessitate intensive manual comparison of accessions by staff with excellent knowledge of the collections. Labour costs are therefore high. Even then reliability is low and for heterogeneous and variable accessions historical duplicates would cause a loss in genetic integrity or diversity respectively even if they could be accurately identified (Zhang *et al.*, 2000; Austin, 1983; Austin, 1988).

Germplasm conservation methods for sweet potato

The management of human use of the biosphere, so that it may yield the sustainable benefit to present generations; while maintaining its potential to meet the needs is called conservation. Plant germplasm is the genetic source used by the plant breeders to develop new cultivars which include seeds, pollen, cultured cells and leaves. Germplasm provides the material or genes which the breeder used to develop. Due to perpetuation problems of gene banks, alternative conservation methods are needed such as in vitro conservation and in situ conservation. The very objective of germplasm conservation is to preserve the genetic diversity of a particular plant or genetic stock for its use at any time in future. In recent years, many new plant species with desired and improved characteristics have started replacing the primitive and conventionally used agricultural plants. It is important to conserve the endangered plants or else some of the valuable genetic traits present in the primitive plants may lose. A global body namely International Board of Plant Genetic Resources (IBPGR) has been established for germplasm conservation. Its main objective is to provide necessary support for collection, conservation and utilization of plant genetic resources throughout the world.

In vitro Conservation

The conservation of germplasm in their natural environment by establishing biosphere reserves (national parks/gene sanctuaries) is regarded as in-situ conservation. This approach is particularly useful for preservation of land plants in a near natural habitat along with several wild relatives with genetic diversity. The in-situ conservation is considered as a high priority germplasm preservation programme. In vitro methods employing shoots, meristems and embryos are ideally suited for the conservation of germplasm of vegetative propagated plants. The plants with recalcitrant seeds and genetically engineered materials can also be preserved by this in vitro approach. There are three different approaches for then vitro conservation of germplasm. They are cryopreservation or freeze-preservation, Cold storage, low pressure or low oxygen storage.

There are many advantages associated with in vitro germplasm conservation they include; large quantities of materials can be preserved in small space. The germplasm preserved can be maintained in an environment, free from pathogens. It can be protected against the nature's hazards. From the germplasm stock, large number of plant can be obtained whenever needed. Obstacles for their transport through national and international borders are minimal since the germplasm is maintained under aseptic conditions.

Ex situ Conservation

Ex-situ conservation is the chief method for the preservation of germplasm obtained from cultivated and wild plant materials. The genetic materials in the form of seeds or from in vitro cultures, plant cells, tissues or organs) can be preserved as gene bank for long term storage under suitable conditions. For successful establishment of gene banks, adequate knowledge of genetic structure of plant populations and the techniques involved in sampling, regeneration, maintenance of gene

pools are essential. Usually seeds are the most common and convenient materials to conserve plant germplasm. This is because many plants are propagated through seeds and seeds occupy relatively small space. Further, seeds can be easily transported to various places.

Ex situ conservation measure can be complementary to in situ methods as they provide. Ex-situ conservation is the preservation of components of biological diversity outside their natural habitats. This involves conservation of genetic resources, as well as wild and cultivated species, draws on a diverse body of techniques and facilities. These include; Gene banks in vitro plant tissue and microbial culture collections, captive breeding of animals and artificial propagation of plants with proper reintroduction into the wild and collecting living organisms for zoos, botanical gardens for research and public awareness.

The rationalization is to be based on combining or eliminating duplicates it would clearly be preferable, from the perspective of minimizing the resulting loss of genetic integrity of the collection, to determine which accessions are true duplicates. However, this is an even more formidable task than identifying historical duplicates. Conventional trials for characterization and evaluation of germplasm are inadequate for the detection of biological duplicates for three reasons.

Hypothesis

The current research work is based on the following hypothesis

Morphological variations exist among varieties of sweet potatoes in Kerala.

Morphological variations could be better established for developing new hybrid varieties.

Materials and Methods

Study area

Kerala state covers an area of 38,863 km^2 with a population density of 859 per km^2 and spread across 14 districts. The climate is characterized by tropical wet and dry with average annual rainfall amounts to 2,817 ± 406 mm and mean annual temperature is 26.8°C (averages from 1871-2005; Krishnakumar *et al.,* 2009). Maximum rainfall occurs from June to September mainly due to South West Monsoon and temperatures are highest in May and November (Figure 1).

Sample collection

Sampling locations were selected in Kerala based on an elaborative baseline survey conducted during February 2017 to July 2017. The samples were collected based on an elaborative iterative survey as well as traditional knowledge from local people. Different varieties of sweet potatoes were collected from different parts of Kerala.

Thirteen samples were collected from across Kerala and GPS position were noted using a Trimble Geoexplorer II (Trimble Navigation Ltd, Sunnyvale, California) and data were transferred using GPS pathfinder Office software (Trimble Navigation Ltd, Sunnyvale, California).

The thirteen different varieties *Ipomoea batatas* Lam. Varieties (Kuravanpady 1, Kuravanpady 2, Jellipara 1, Jellipara 2, Kottathara, Kadanadu, Kanaka, Aruna, Kanjagad, Cherukizhangu 1, Cherukizhangu 2, Thodupuzha. Palakkad) were used for morphological characterization.

Morphological characterization

Morphological data were collected 60 days after planting based on the descriptors for sweet potato (IBPGR, 1991) in all the 13 samples. The variable scored were twining, plant type, ground cover, vine inter node, vine pigmentation, vine tip pubescence, mature leaf shape, mature leaf size, abaxial leaf vein pigmentation, foliage colour, petiole length, petiole pigmentation, storage root and skin colour. The descriptors used in the present study (IBPGR, 1991) were given below.

Twining

Ability of vines to climb adjacent stakes placed in those accessions showing twining characteristics; 0 Non–twining, 3 Slightly twining, 5Moderately twining, 7 Twining, 9 Very twining.

Plant types

Length of main vines; 3 Erect (<75 cm), 5 Semi erect (75-150 cm), 7 Spreading (151-250 cm), 9 Extremely spreading (>250 cm).

Ground cover

Estimated percentage of ground cover recorded 35-40 days after planting; 3 Low (<50%), 5 Medium (50-74%), 7 High (75-90%), 9 Total (>90%).

Vine internodes

Average expression of at least three internodes located in the middle section of the vine.

Vine internodes length

Vine internodes length classified as; 1Very short (<3 cm), 2 Short (3-5 cm), 5Intermediate (6-9 cm), 9 Long (10-12 cm), Very long (>12 cm).

Vine internodes diameter

Vine internodes diameter classified as; 1 Very thin (<4 mm), 2 Thin (4-6 mm), 5 Intermediate (6-9 mm), 9 Thick (10-12 mm), Very thick (>12 mm).

Vine pigmentation

Anthocyanin (purple) pigmentation present in the veins beside the green colour. The predominant colour should be evaluated considering in the whole vein from base to tip. The secondary colour is more easily evaluated using younger veins. The predominant vine colour; 1 Green, 2 Green with few purple spots, 3 Green with many purple spots, 4 Green with many dark purple spots, 5 Most purple, 6 Mostly dark purple, 7 Totally purple, 8 Totally dark purple.

The secondary vein colour includes; 0 Absent, 1 Green base, 2 Green tip, 3 Green nodes, 4 Purple base, 5 Purple tip, 6 Purple nodes, 7 Other.

Vine tip pubescence

Degree of hairiness of immature leaves recorded at the apex of the vines; 0 Absent, 3 Sparse, 4 Moderate, 8 Heavy.

Mature leaf shape

Described from leaves located in the middle section of the vein. General outline of the leaf; 1 Rounded, 2 Reniform (kidney-shaped), 3 Cordate (heart-shaped), 4 Triangular, 5 Hastate (trilobular and spear-shaped with the basal lobes more or less divergent), 6 Lobed, 7 Almost divided.

Leaf lobes types

General outline of the leaf lobes; 1 No lateral lobes (entire), 2 Very slight (teeth), 3 Slight, 5 Moderate, 6 Deep, 8 Vey deep.

Leaf lobes number

Generally sweet potato has 1, 3, 5, 7, 9 leaf lobes.

Shape of central leaf lobes

General outline of the central leaf lobes; 0 Absent, 1 Toothed, 2 Triangular, 3 Semi-circular, 4 Semi-elliptic, 5 Elliptic, 6 Lanceolate, 7 Oblanceolate, 8 Linear (broad), 9 Liner (narrow).

Mature leaf size

The size of leaf was described; Small (<8cm), 5 Medium (8-15 cm), 7 Large (16-25 cm), 9 Very large (>25 cm).

Abaxial vein pigmentation

The abaxial vein pigmentation includes; 1 Yellow, 2 Green, 3 Purple spot in the base of main rib, 4 Purple spots in several veins, 5 Main rib partially purple, 6 Main rib mostly or totally purple, 7 All veins partially purple, 8 All veins mostly or totally purple, 9 Lower surface and veins totally purple.

Mature leaf colour

The mature leaf colour includes; 1 Yellow – green, 2 Green, 3 Green with purple edge, 4 Greyish–green, 5 Green with purple veins on upper surface, 6 Slightly purple, 7 Mostly purple, 8 Green upper, purple lower, 9 Purple both surfaces.

Immature leaf colour

The immature leaf colour includes; 1 Yellow green, 2 Green, 3 Green with purple edge, 4 Greyish–green, 5 Green with purple veins on upper surface, 6 Slightly purple, 7 Mostly purple, 8 Green upper, purple lower, 9 Purple both surfaces.

Petiole length

The petiole length; 1Very short (<10 cm), 3 Short (10-20 cm), 5 Intermediate (21-30 cm), 7 Long (31-40 cm), 9 Very long (>40 cm).

Petiole pigmentation

The petiole pigmentation; 1 Green, 2 Green with purple near stem, 3 Green with purple near leaf, 4Green with

purple at both ends, 5 Green with purple spots throughout petiole, 6 Green with purple stripes, 7 Purple with green near leaf, 8 Some petiole purple, other green, 9 Totally or mostly purple.

Storage root predominant skin colour

The predominant skin colour includes; 1 White, 2 Cream, 3 Yellow, 4 Orange, 5 Brownish orange, 6 Pink, 7 Red, 8 Purple red, 9 Dark purple.

Intensity of predominant skin colour

The intensity of predominant skin colour includes; 1 Pale, 2 Intermediate, 3 Dark.

Statistical analysis

The survey results were analyzed and descriptive statistics were done using SPSS 12.0 (SPSS Inc., an IBM Company, Chicago, USA) and graphs were generated using Sigma Plot 7 (Systat Software Inc., Chicago, USA).

Results and Discussion

Morphological data analysis

Most of the samples were collected from Palakkad district. They grow in high temperature and cold region. The weather conditions are effect the plant growth. Most of the accessions are high, erect and Kanjagad variety contain semi-erect ground cover. Morphological characters are almost same for 13 accessions but the accessions are grown in different climate so some morphological features are different. The most of accessions are non- twining, Palakkad sample contain twining character and Cherukizhagu 1 and 2 were highly twining in nature. The Kadanadu and Kottathara varieties leaf are almost divided. They are morphologically very similar. Other accessions leaves are lobed, Kanaka sample leaf is triangular, Kadanadu sample is hastate, Cherukizhagu 1and 2 is rounded, and Kuravanpady 2 is reniform of mature leaf shapes. Most of the sample shape of central leaf lobes is toothed, Kanjagad is lanceolate and Kottathara is linear. The 13 sample leaves mature leaf is green colour and immature leaf is purple colour. Vine tip pubescences are present in the Cherukizhagu 2 and heavy pubescence is appearing in Cherukizhagu 1 sample. Abaxial leaf vein pigmentation contain purple and green colours. Cherukizhage1 and 2 leaves are larger than other accessions and their leaves contain yellow spots. The Kadanadu and Thodupuzha sample contain flowering habit in the time period. The flower shape of limb is rounded, the sepal shape is elliptic and the sepal apex is acute. Most of the accessions storage root surface is cream and pink colour. The flesh is cream colour. The storage root surface defect is Veins like appearance.

Table.1 Different vernacular names of sweet potato (*Ipomoea batatas* Lam)around the globe and India.

Language	Names
Scientific names	*Ipomoea batatas* Lam
Name in various global languages	
French	Patatedouce
Spanish	La batata
English	Sweet potato
Name in various Indian languages	
Sanskrit	Raktaluh
Hindi	Shakrkand
Marathi	Kanamgi
Kannada	Sihigensu
Gujarati	Ratalu
Malayalam	Madhurakkilanngu
Tamil	Sarkaraivallikizangu

Fig.1 Mean monthly rainfall (mm), maximum and minimum temperatures (°C) in Kerala, India (1871-2005; Krishnakumar *et al.*, 2009).

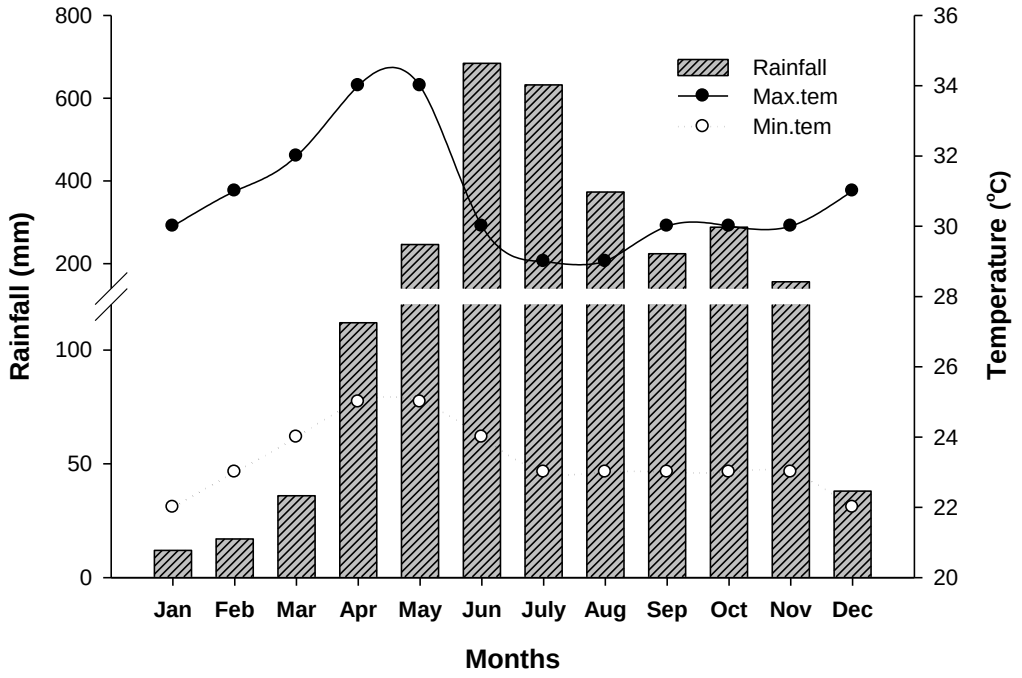


Fig.2 Map of Kerala showing the various sample collection point of *Ipomoea batatas* Lam.

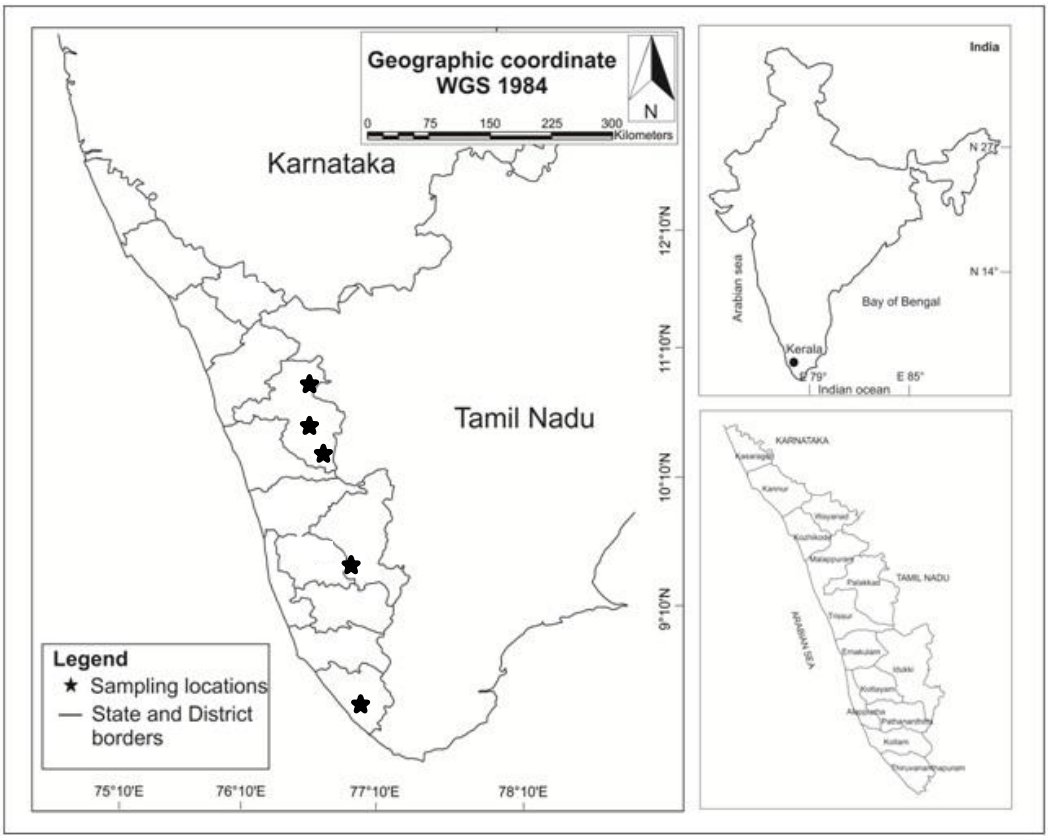


Table.2 Plant characteristics and properties of *Ipomoea batatas* Lam. varieties (Kuravanpady 1, Kuravanpady 2, Jellipara 1, Jellipara 2, Kottathara, Kadanadu, Kanaka, Aruna, Kanjagad, Cherukizhangu 1, Cherukizhangu 2,Thodupuzha. Palakkad) in Kerala.

Samples	Twining	Plant type	Ground cover	Vine internode length (cm)	Vine internode diameter (mm)	Predominant vine colour	Secondary vine colour
Kuravanpady 1	0	7	7	5	1	1	0
Kuravanpady 2	0	7	7	5	1	1	0
Jellipara 1	0	7	7	7	8	8	0
Jellipara 2	0	7	7	7	1	1	0
Kottathara	0	7	7	7	1	1	0
Kadanadu	0	7	7	5	1	1	0
Kanaka	0	3	3	5	1	1	0
Aruna	0	3	3	1	1	1	0
Kanjagad	0	5	5	3	1	1	0
Cherukizhangu 1	9	3	5	7	1	1	0
Cherukizhangu 2	9	3	5	7	1	1	0
Thodupuzha	0	9	9	3	3	1	0
Palakkad	7	9	9	3	3	3	0

Twining: 0 Non –twining, 3 Slightly twining, 5 Moderately twining, 7 Twining, 9 Very twining.
Plant type: 3 Erect (<75 cm), 5 Semi erect (75-150 cm), 7 Spreading (151-250 cm), 9 Extremely spreading (>250 cm).
Ground cover: 3 Low (<50%), 5 Medium (50-74%), 7 High (75-90%), 9 Total (>90%).
Vine internode length: 1 Very short (<3 cm), 2 Short (3-5 cm), 5 Intermediate (6-9 cm), 9 Long (10-12 cm), Very long (>12 cm).
Predominant vine colour: 1 Green, 2 Green with few purple spots, 3 Green with many purple spots, 4 Green with many dark purple spots, 5 Most purple, 6 Mostly dark purple, 7 Totally purple, 8 Totally dark purple.
Secondary vine colour: 0 Absent, 1 Green base, 2 Green tip, 3 Green nodes, 4 Purple base, 5 Purple tip, 6 Purple nodes, 7 Other.

Table.3 Plant characteristics and properties of *Ipomoea batatas* Lam. varieties (Kuravanpady 1, Kuravanpady 2, Jellipara 1, Jellipara 2, Kottathara, Kadanadu, Kanaka, Aruna, Kanjagad, Cherukizhangu 1, Cherukizhangu 2, Thodupuzha. Palakkad)in Kerala.

Samples	Vine tip pubescence	Mature leaf shape	Leaf lobes types	Leaf lobes number	Shape of central leaf lobe	Mature leaf size	Abaxial leaf vein pigmentation	Mature leaf colour
Kuravanpady 1	0	4	1	1	1	3	2	2
Kuravanpady 2	0	2	1	1	1	5	2	2
Jellipara 1	3	4	1	1	1	5	3	2
Jellipara 2	0	4	1	1	1	5	3	2
Kottathara	0	7	9	7	9	5	2	2
Kadanadu	0	5	7	5	5	5	3	2
Kanaka	0	4	5	3	4	5	7	3
Aruna	0	4	1	1	1	3	2	2
Kanjagad	0	6	7	5	6	5	2	2
Cherukizhangu 1	7	1	0	1	1	5	2	2
Cherukizhangu 2	5	1	0	1	1	5	2	2
Thodupuzha	0	6	1	1	2	7	2	2
Palakkad	3	4	1	1	2	5	2	1

Plant tip pubescence: 0 Absent, 3 Sparse, 4 Moderate, 8 Heavy.
Mature leaf shape: 1 Rounded, 2 Reniform (kidney-shaped), 3 Cordate (heart-shaped), 4 Triangular, 5 Hastate (trilobular and spear-shaped with the basal lobes more or less divergent), 6 Lobed, 7 Almost divided.
Leaf lobe type: 1 No lateral lobes (entire), 2 Very slight (teeth), 3 Slight, 5 Moderate, 6 Deep, 8 Vey deep.
Leaf lobe number: Generally sweet potato has 1, 3, 5, 7, 9 leaf lobes.
Shape of central leaf lobe: 0 Absent, 1 Toothed, 2 Triangular, 3 Semi-circular, 4 Semi-elliptic, 5 Elliptic, 6 Lanceolate, 7 Oblanceolate, 8 Linear (broad), 9 Liner (narrow).
Mature leaf size: Small (<8cm), 5 Medium (8-15 cm), 7 Large (16-25 cm), 9 Very large (>25 cm).
Abaxial leaf vein pigmentation: 1 Yellow, 2 Green, 3 Purple spot in the base of main rib, 4 Purple spots in several veins, 5 Main rib partially purple, 6 Main rib mostly or totally purple, 7 All veins partially purple, 8 All veins mostly or totally purple, 9 Lower surface and veins totally purple.
Mature leaf colour: 1 Yellow – green, 2 Green, 3 Green with purple edge, 4 Grayish –green, 5 Green with purple veins on upper surface, 6 Slightly purple, 7 Mostly purple, 8 Green upper, purple lower, 9 Purple both surfaces.

Table.4 Plant characteristics and properties of *Ipomoea batatas* Lam. varieties (Kuravanpady 1, Kuravanpady 2, Jellipara 1, Jellipara 2, Kottathara, Kadanadu, Kanaka, Aruna, Kanjagad, Cherukizhangu 1, Cherukizhangu 2, Thodupuzha. Palakkad)in Kerala.

Samples	Immature leaf colour	Leaf petiole length (cm)	Petiole pigmentation	Leaf length (cm)	Leaf thickness (mm)	Leaf petiole length (cm)	Storage root shape	Storage root surface defects
Kuravanpady 1	1	1	1	8.21 ± 0.05	1.02 ± 0.02	8.32 ± 0.05	8	2
Kuravanpady 2	2	1	1	10.77 ± 0.08	1.01 ± 0.00	9.54 ± 0.15	5	2
Jellipara 1	6	1	2	11.60 ± 0.05	1.04 ± 0.06	15.37 ± 0.21	7	3
Jellipara 2	6	1	1	10.32 ± 0.04	1.01 ± 0.01	9.50 ± 0.32	8	3
Kottathara	2	1	1	7.57 ± 0.21	1.02 ± 0.02	11.55 ± 0.23	9	1
Kadanadu	2	3	3	10.51 ± 0.32	1.03 ± 0.01	17.13 ± 0.06	3	1
Kanaka	6	1	1	15.15 ± 0.14	1.02 ± 0.00	7.52 ± 0.04	9	1
Aruna	6	1	1	7.26 ± 0.34	1.00 ± 0.01	6.84 ± 0.33	9	1
Kanjagad	9	3	2	13.51 ± 0.22	1.01 ± 0.01	11.96 ± 0.21	9	1
Cherukizhangu 1	2	3	1	9.34 ± 0.42	1.72 ± 0.00	10.57 ± 0.35	1	5
Cherukizhangu 2	2	3	1	9.13 ± 0.37	1.53 ± 0.05	11.54 ± 0.05	1	5
Thodupuzha	3	3	1	7.91 ± 0.41	1.02 ± 0.02	15.32 ± 0.11	9	1
Palakkad	3	1	1	7.53 ± 0.19	1.00 ± 0.01	13.56 ± 0.27	9	1

Immature leaf colour: 1 Yellow green, 2 Green, 3 Green with purple edge, 4 Grayish–green, 5 Green with purple veins on upper surface, 6 Slightly purple, 7 Mostly purple, 8 Green upper,purple lower, 9 Purple both surfaces.
Leaf petiole length: 1 Very short (<10 cm), 3 Short (10-20 cm), 5 Intermediate (21-30 cm), 7 Long (31-40 cm), 9 Very long (>40 cm).
Petiole pigmentation: 1 Green, 2 Green with purple near stem, 3 Green with purple near leaf, 4 Green with purple at both ends, 5 Green with purple spots throughout petiole, 6 Green with purple stripes, 7 Purple with green near leaf, 8 Some petiole purple, other green, 9 Totally or mostly purple.
Storage root shape:1-Round, 2-Round elliptic, 3-Elliptic, 4-Ovate, 5-Obovate, 6-Oblong, 7-Long oblong, 8-Long elliptic, 9-Long irregular or curved.
Storage root surface defects:1-Alligator-like skin, 2-Veins, 3-Horizontal constructions, 5-Longitudinal grooves.
Numbers represent means ± one standard error (SE) of the mean.

Table.5 Plant characteristics and properties of *Ipomoea batatas* Lam. varieties Kuravanpady 1, Kuravanpady 2, Jellipara 1, Jellipara 2, Kottathara, Kadanadu, Kanaka, Aruna, Kanjagad, Cherukizhangu 1, Cherukizhangu 2, Thodupuzha. Palakkad)in Kerala.

Samples	Storage root cortex thickness	Storage root skin colour	Storage root flesh colour	Distribution of the secondary flesh colour	Flower length* (cm)	Shape of limb*	Sepal shape*	Sepal apex*
Kuravanpady 1	3	2	2	1	No blossom	No blossom	No blossom	No blossom
Kuravanpady 2	1	6	2	1	No blossom	No blossom	No blossom	No blossom
Jellipara 1	1	2	2	1	No blossom	No blossom	No blossom	No blossom
Jellipara 2	1	6	2	1	No blossom	No blossom	No blossom	No blossom
Kottathara	1	8	2	2	No blossom	No blossom	No blossom	No blossom
Kadanadu	1	8	2	2	7.13 ± 0.37	7	3	1
Kanaka	1	8	2	2	No blossom	No blossom	No blossom	No blossom
Aruna	1	8	2	2	No blossom	No blossom	No blossom	No blossom
Kanjagad	1	8	2	2	No blossom	No blossom	No blossom	No blossom
Cherukizhangu 1	1	5	2	1	No blossom	No blossom	No blossom	No blossom
Cherukizhangu 2	5	5	3	1	No blossom	No blossom	No blossom	No blossom
Thodupuzha	1	8	2	2	No blossom	No blossom	No blossom	No blossom
Palakkad	1	8	2	2	7.20 ± 0.32	7	3	1

Storage root cortex thickness: 1 Very thin (<1mm), 3 Thin (1-2 mm), 5Intermediate (2-3 mm), 7 Thick (3-4 mm), 9Very thick (>4 mm).
Storage root skin colour: 1 White, 2Cream, 3 Yellow, 4Orange, 5Brownish orange, 6 Pink, 7 Red, 8 Purple red, 9 Dark purple.
Storage root flesh colour: 1 White, 2 Cream, 3 Dark cream, 4 Pale yellow, 5 Dark yellow, 6 Pale orange, 7 Intermediate orange, 8 Dark orange, 9 Strongly pigmented with anthocyanins.
Distribution of the secondary flesh colour: 0 Absent, 1 Narrow ring in cortex, 2 Broad rings in cortex, 3 Scattered spots in flesh, 4 Narrow ring in flesh, 5 Broad ring in flesh, 6 Ring and other areas in flesh, 7 In longitudinal sections, 8 Covering most of the flesh, 9 Covering all flesh.
Shape of the limb: 3 Semi-stellate, 5 Pentagonal, 7 Rounded.
Sepal shape: 1 Ovate, 3 Elliptic, 5 Obovate, 7 Oblong, 9 Lanceolate.
Sepal apex:1 Acute, 3 Obtuse, 5 Acuminate, 7 Caudate.
*: No blossom during the research period.Numbers represent means ± one standard error (SE) of the mean.

Fig.3 Sweet potato (*Ipomoea batatas* Lam.) description a) flower, b) root tubers, c) roasted sweet potatoes, d) and f) different culinary preparations of sweet potatoes, e) steamed root tuber, g) different varieties of sweet potatoes. Photo courtesy: Wikipedia.https://en.wikipedia.org/wiki/Sweet_potato

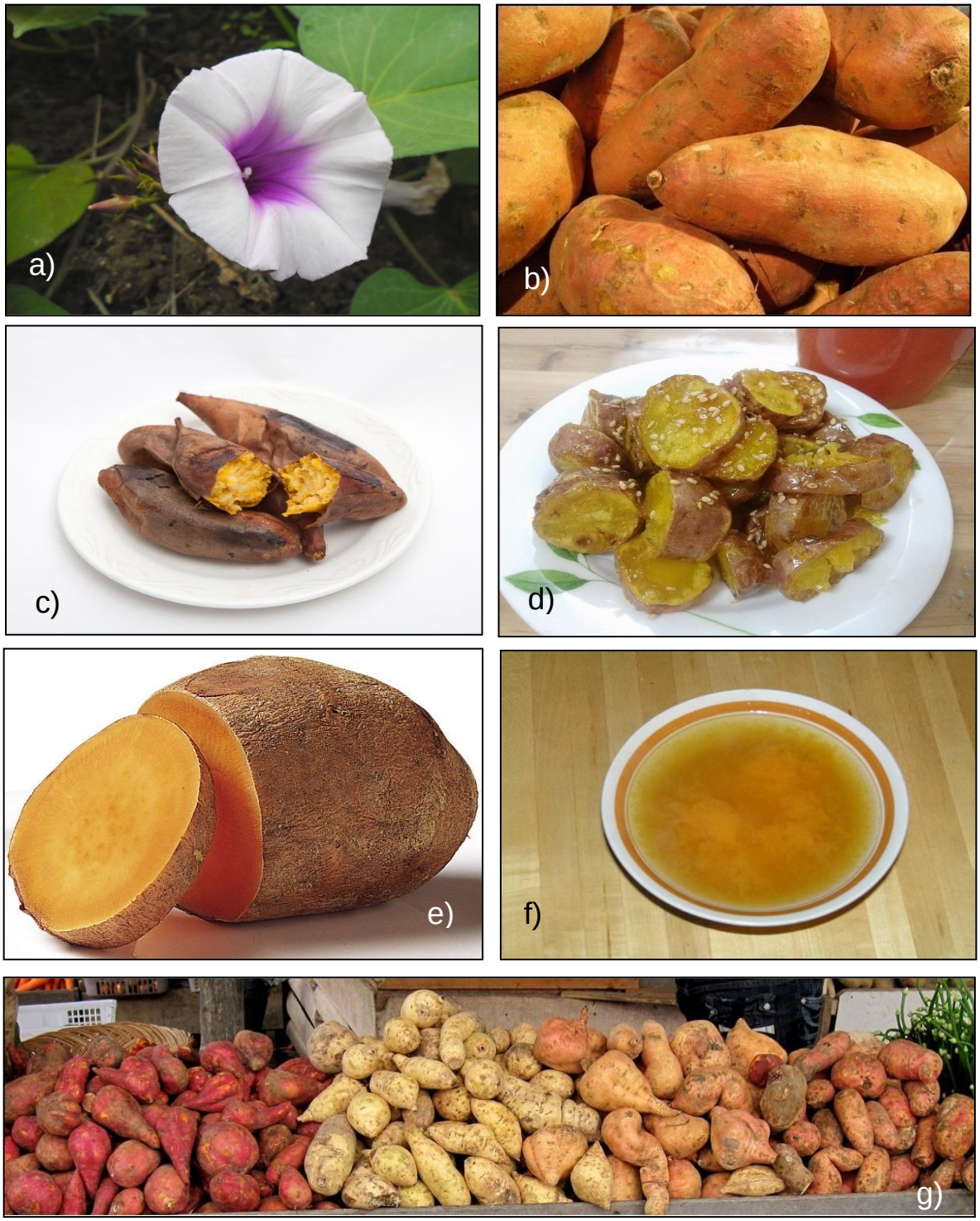


Fig.4 Description of the different varieties of sweet potatoes (*Ipomoea batatas* Lam.) a) Kuravanpady 1, b) Kottathara, c) Jellipara 1, d) Jellipara 2. Authors own images.

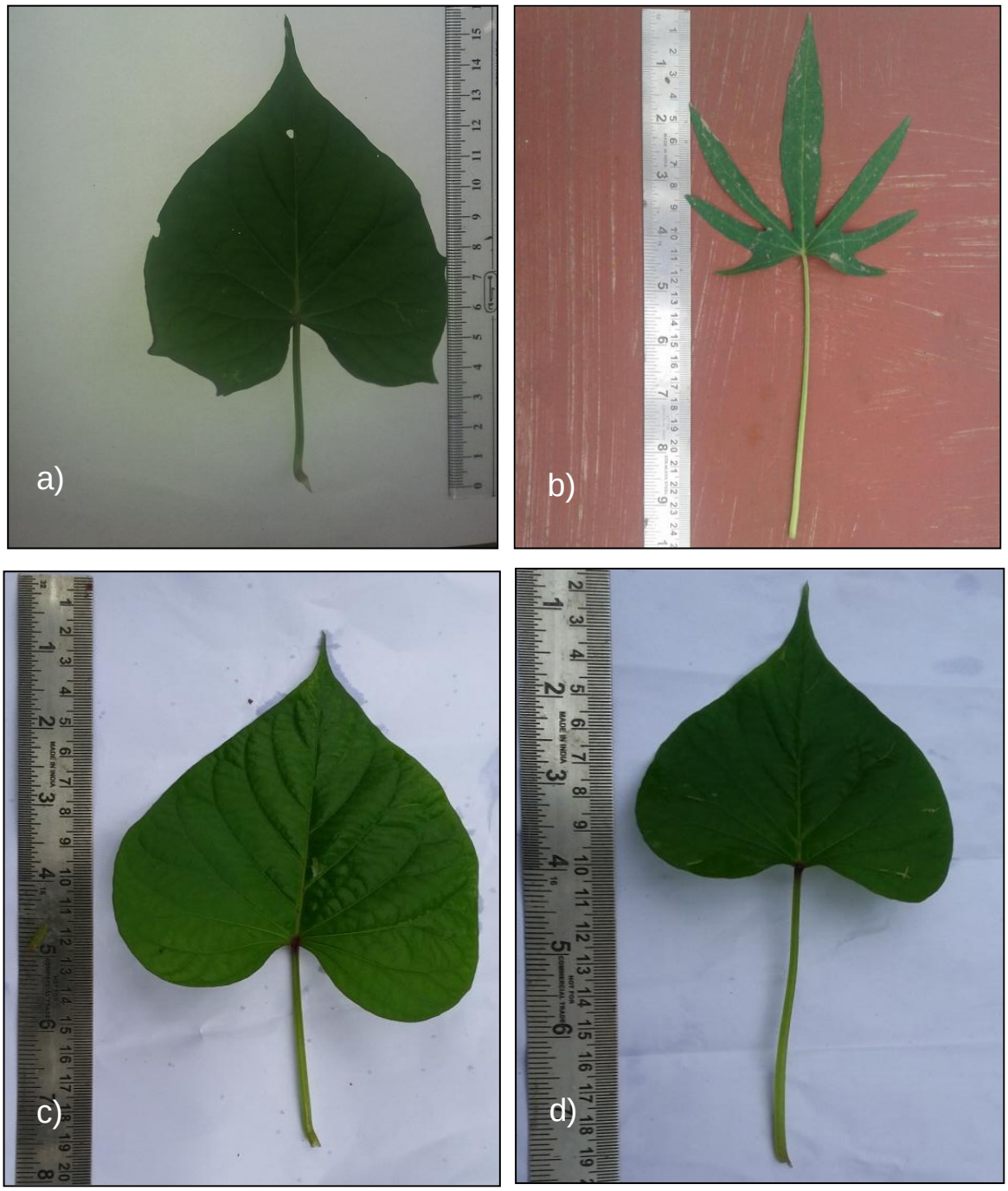


Fig.5 Description of the different varieties of sweet potatoes (I*pomoea batatas* Lam.) a) Kuravanpady 2, b) Aruna, c) Kanaka, d) Kanjangad. Authors own images.

Fig.6 Description of the different varieties of sweet potatoes (*Ipomoea batatas* Lam.) a) Kadanadu, b) Cherukizhangu 1, c) Cherukizhangu 2, d) Thodupuzha. Authors own images.

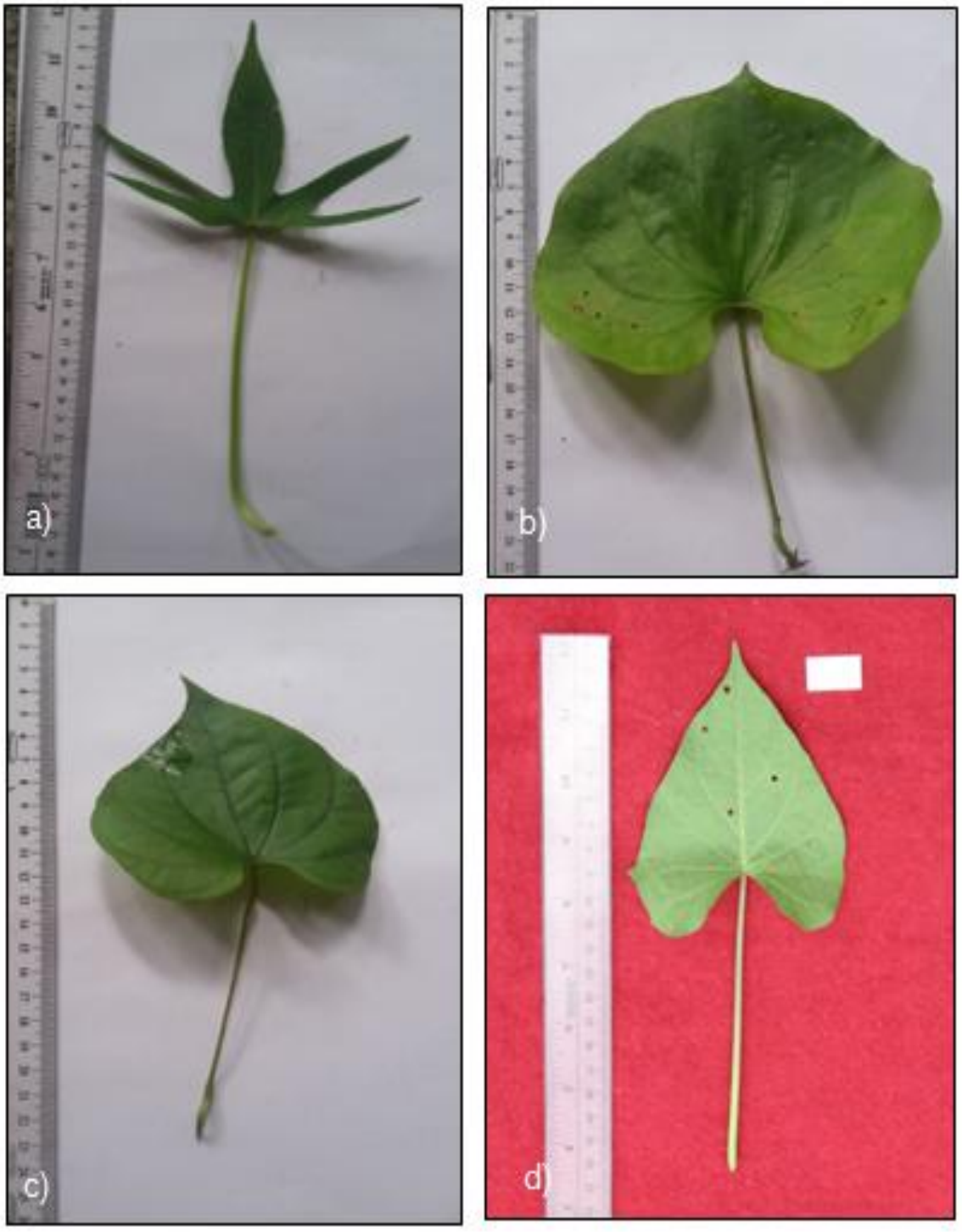


Fig.7 Description of the different varieties of sweet potatoes (*Ipomoea batatas* Lam.) a), d) and e)Kuravanpady 1, b) and c) Kuravanpady 2, f) Kuravanpady 1.Authors own images.

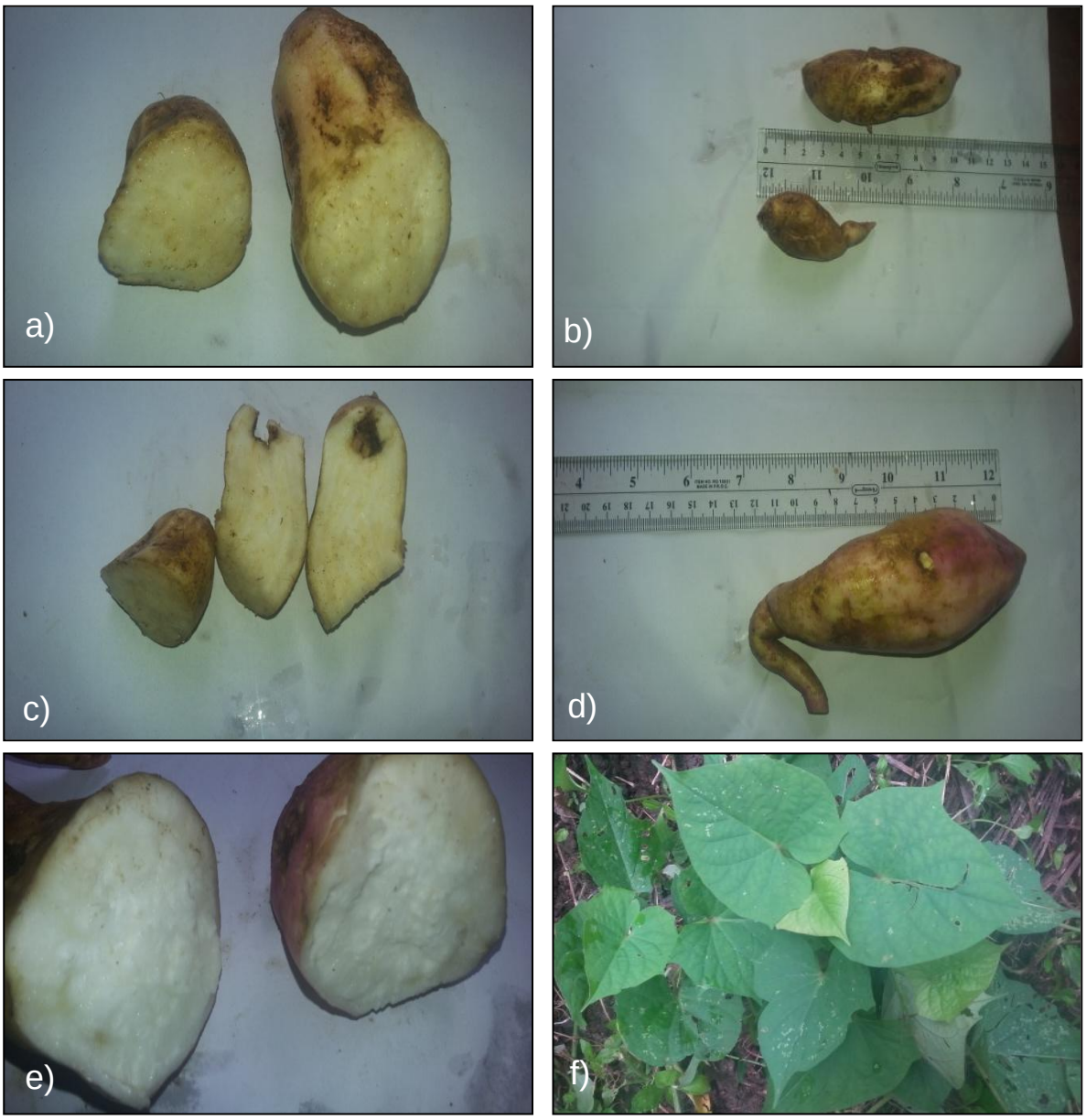


Fig.8 Description of the different varieties of sweet potatoes (*Ipomoea batatas* Lam.) a), Jellipara 1, b) Kottatharac) Jellipara 2.Authors own images.

Fig.9 Description of leaves and petiole of different varieties of sweet potatoes (*Ipomoea batatas* Lam.) a) Palakkad, b) Kottathara, c) Kuravanpady 2, d) Aruna. Authors own images.

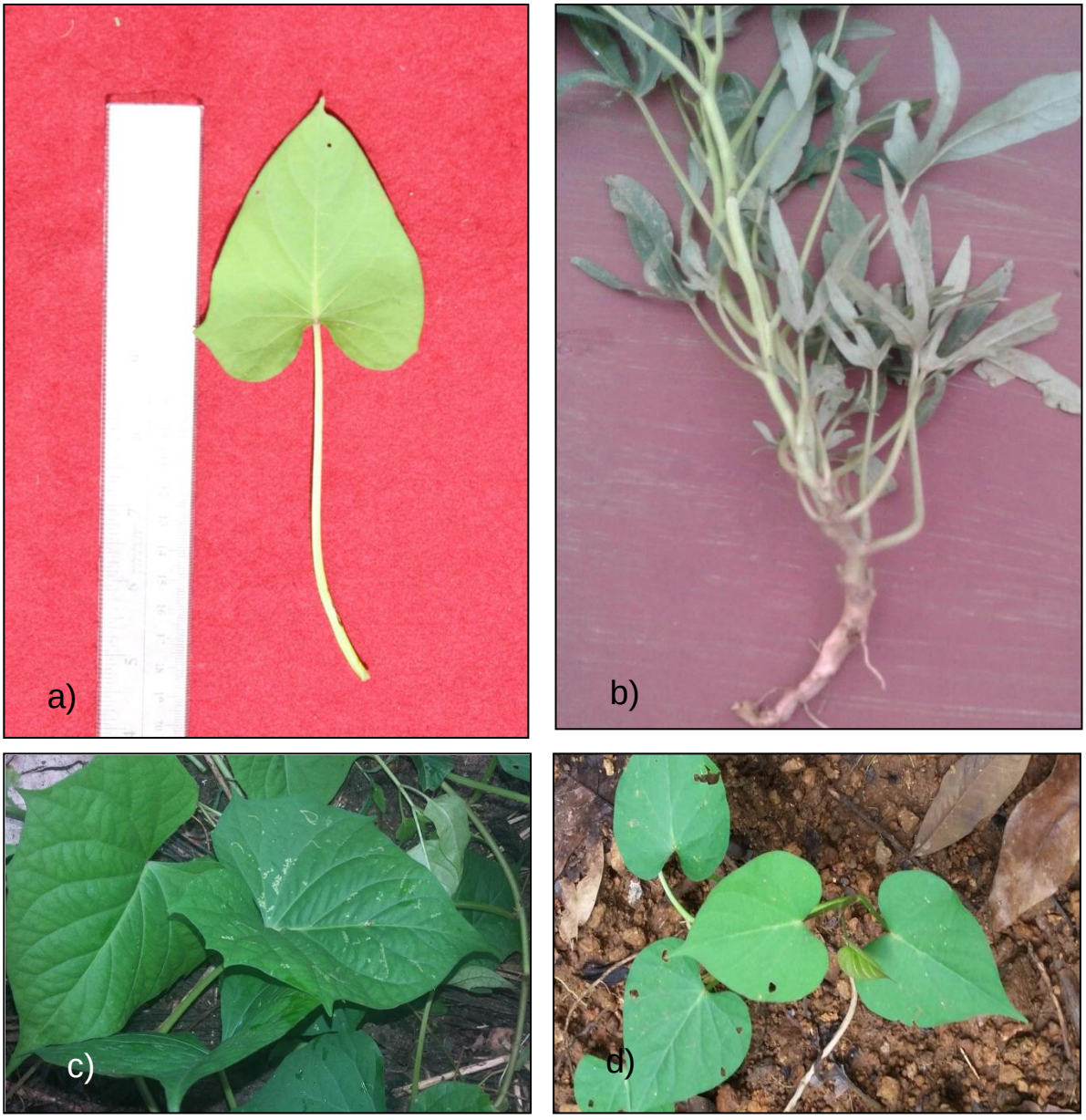


Fig.10 Description of leaves and petiole of different varieties of sweet potatoes (*Ipomoea batatas* Lam.) a) Kanaka, b) Kanjangad, c) Kadanadu, d) Cherukizhangu 1, e) Cherukizhangu 2, f) Thodupuzha. Authors own images.

Fig.11 *Ipomoea batatas* Lam general outline of the leaf; 1-Rounded, 2-Reniform, 3-Cordate, 4-Triangular, 5-Hastate, 6-Lobed, 7-Almost divided (IBPGR, 1991).

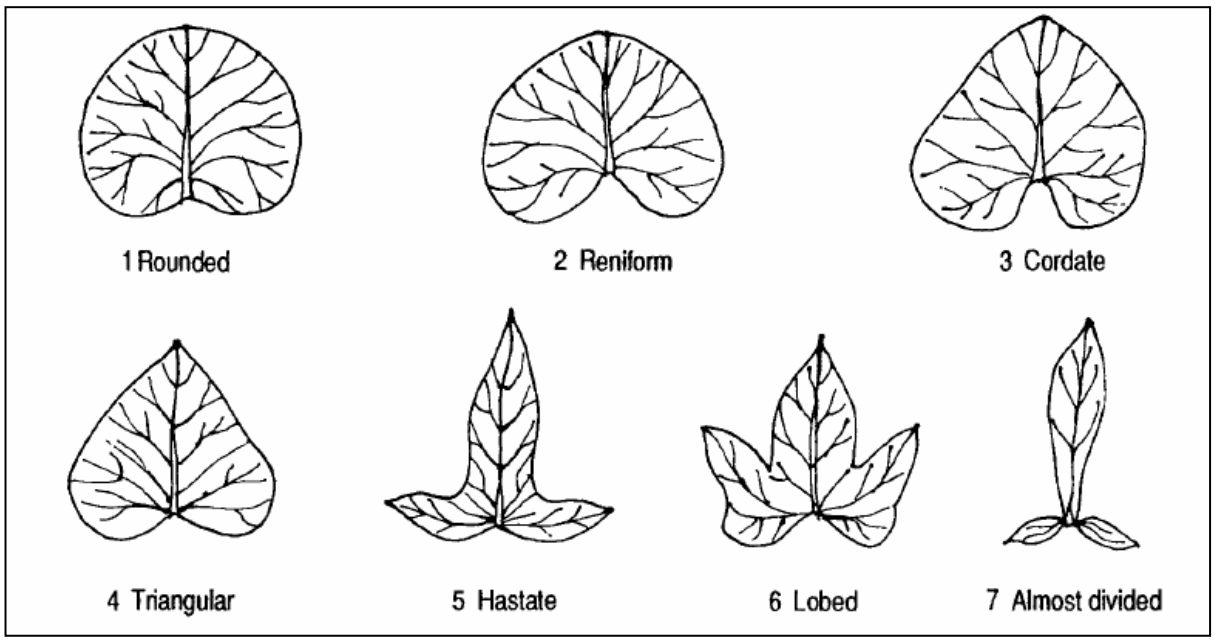


Fig.12 *Ipomoea batatas* Lam leaf lobe type; 0-No lateral lobes, 1-Very slight (teeth), 3-Slight, 5-Moderate, 7-Deep, 9-Very deep (IBPGR, 1991).

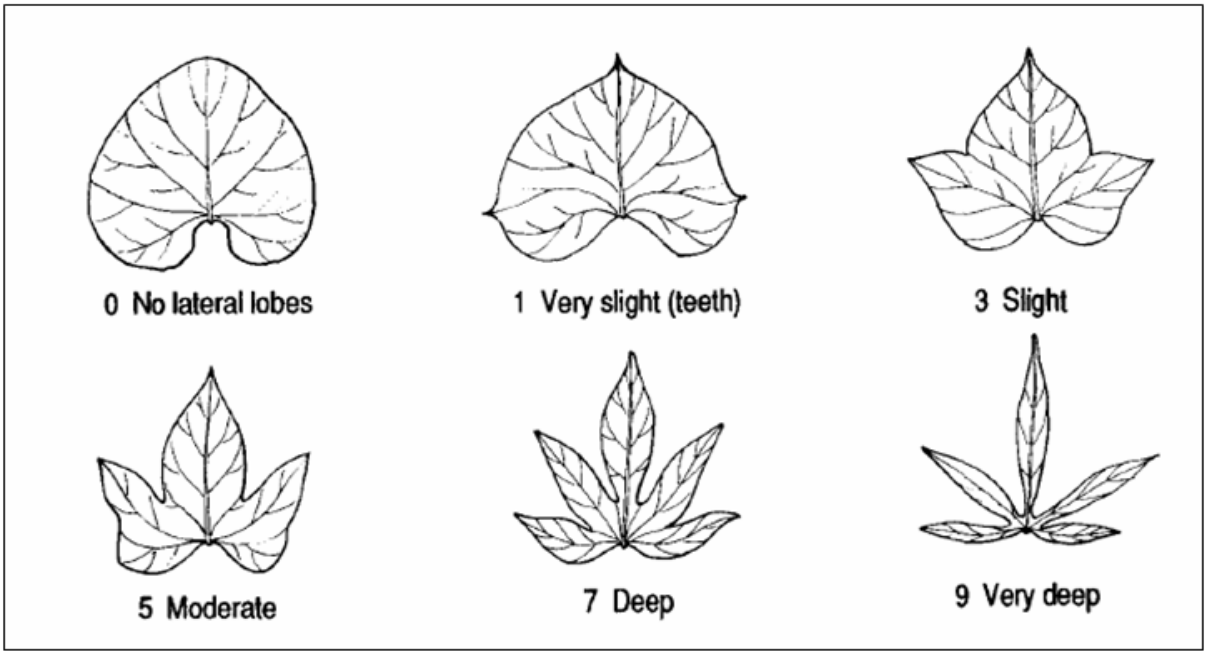


Fig.13 *Ipomoea batatas* Lam leaf lobes number; 1-Single, 3-With three, 5-With five, 7-With seven, 9-With nine (IBPGR, 1991).

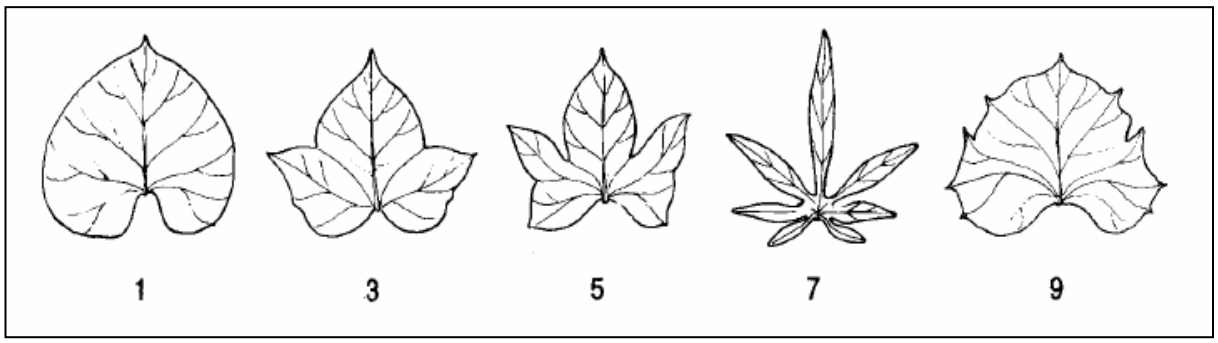


Fig.14 *Ipomoea batatas* Lam shape of the central leaf lobe; 1-Toothed, 2-Triangular, 3-Semi-circular, 4-Semi-elliptic, 5-Elliptic, 6-Lanceolate, 7-Oblanceolate, 9-Linear (narrow) (IBPGR, 1991).

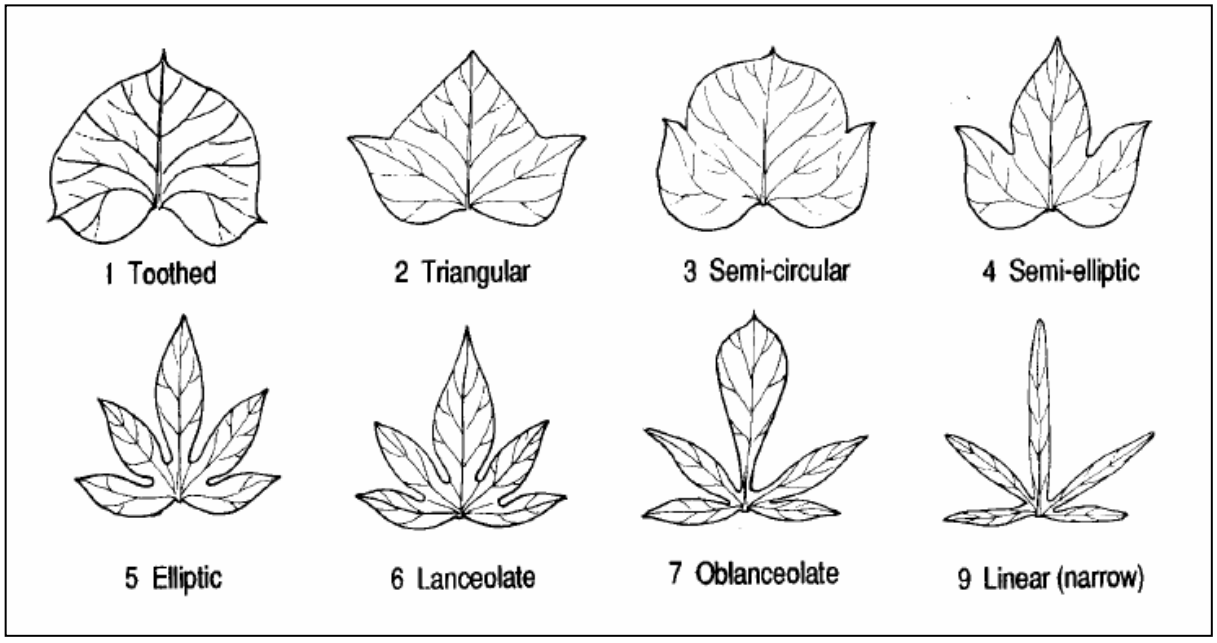


Fig.15 *Ipomoea batatas* Lam mature leaf size (IBPGR, 1991).

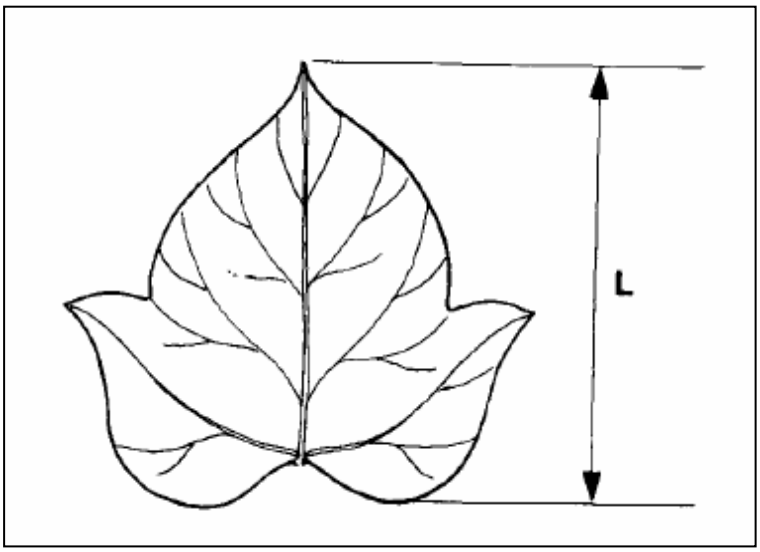


Fig.16 *Ipomoea batatas* Lam mature leaf petiole length (IBPGR, 1991).

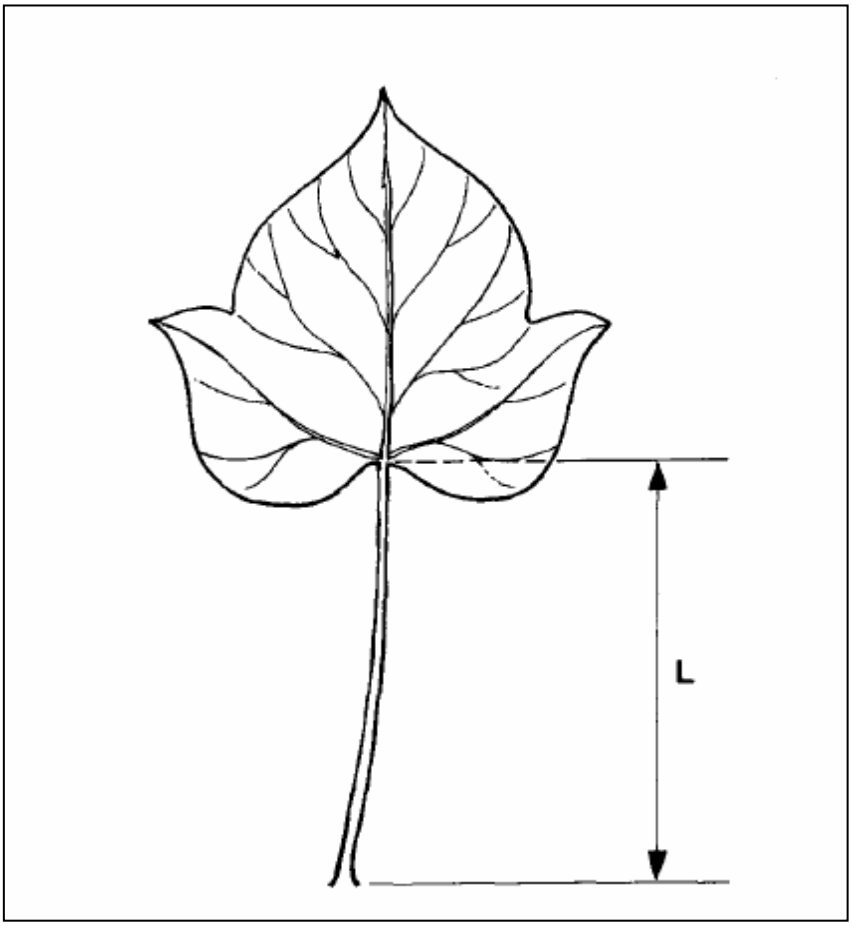


Fig.17 *Ipomoea batatas* Lam storage root shape; 1-Round, 2-Round elliptic, 3-Elliptic, 4-Ovate, 5-Obovate, 6-Oblong, 7-Long oblong, 8-Long elliptic, 9-Long irregular or curved (IBPGR, 1991).

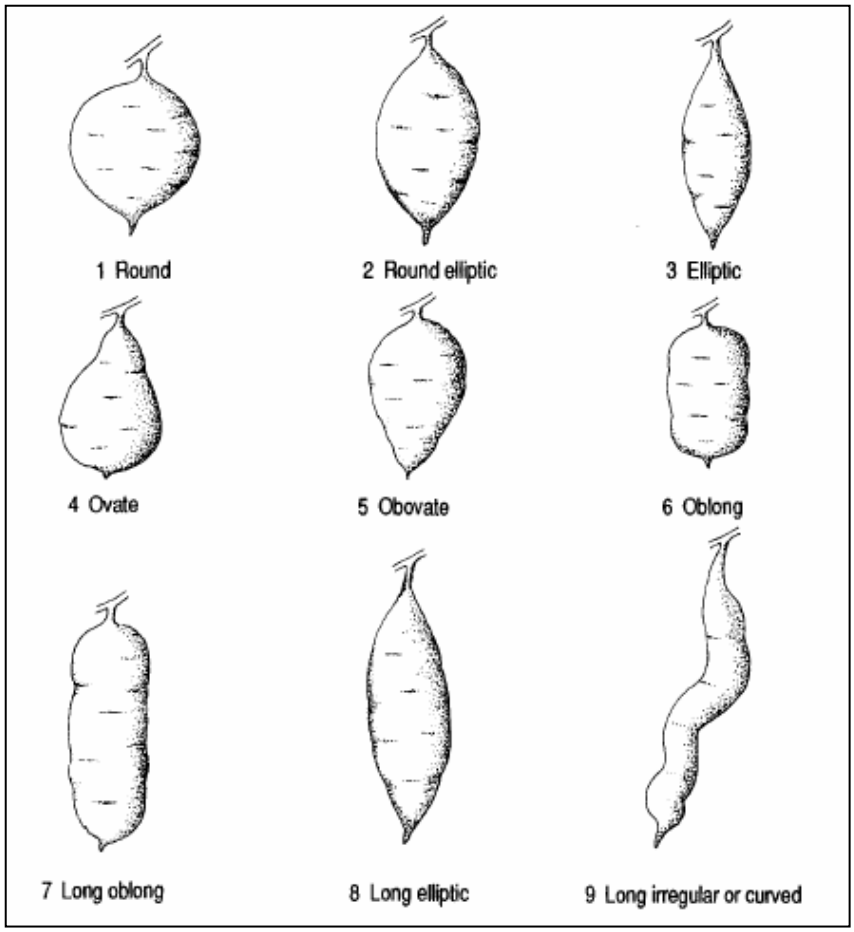


Fig.18 *Ipomoea batatas* Lam storage root surface defects; 1-Alligator-like skin, 2-Veins, 3-Horizontal constructions, 5-Longitudinal grooves (IBPGR, 1991).

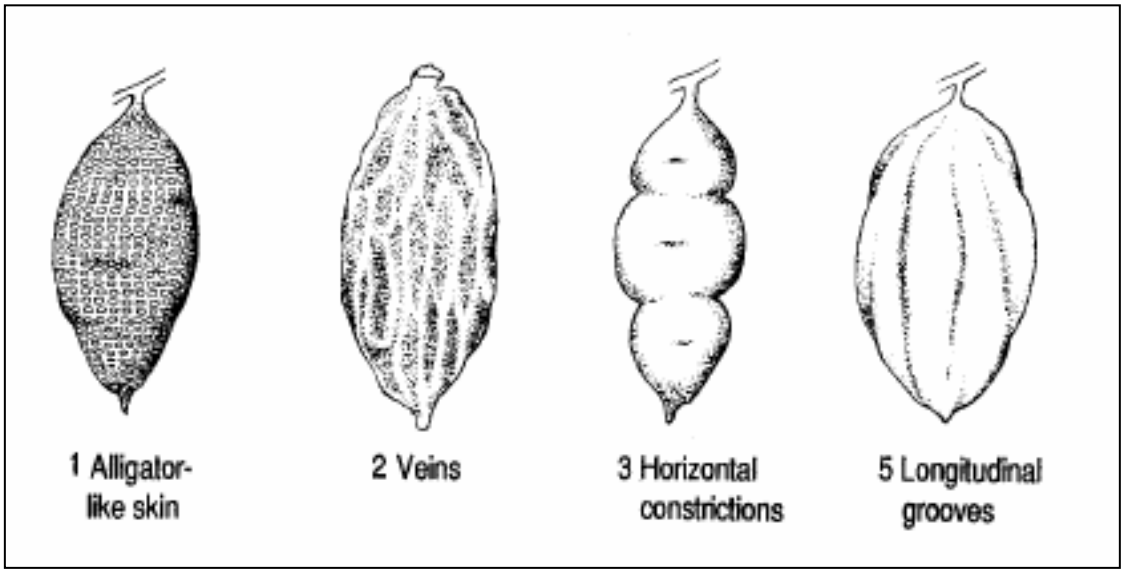


Fig.19 *Ipomoea batatas* Lam distribution of secondary fleshy colour; 1-Narrow ring in cortex, 2-Broad ring in cortex, 3-Scattered spots in flesh, 4-Narrow ring in flesh, 5-Broad ring in flesh, 6-Ring and other areas in flesh, 7-In longitudinal sections, 8-Covering most of the flesh, 9-Covering all flesh (IBPGR, 1991).

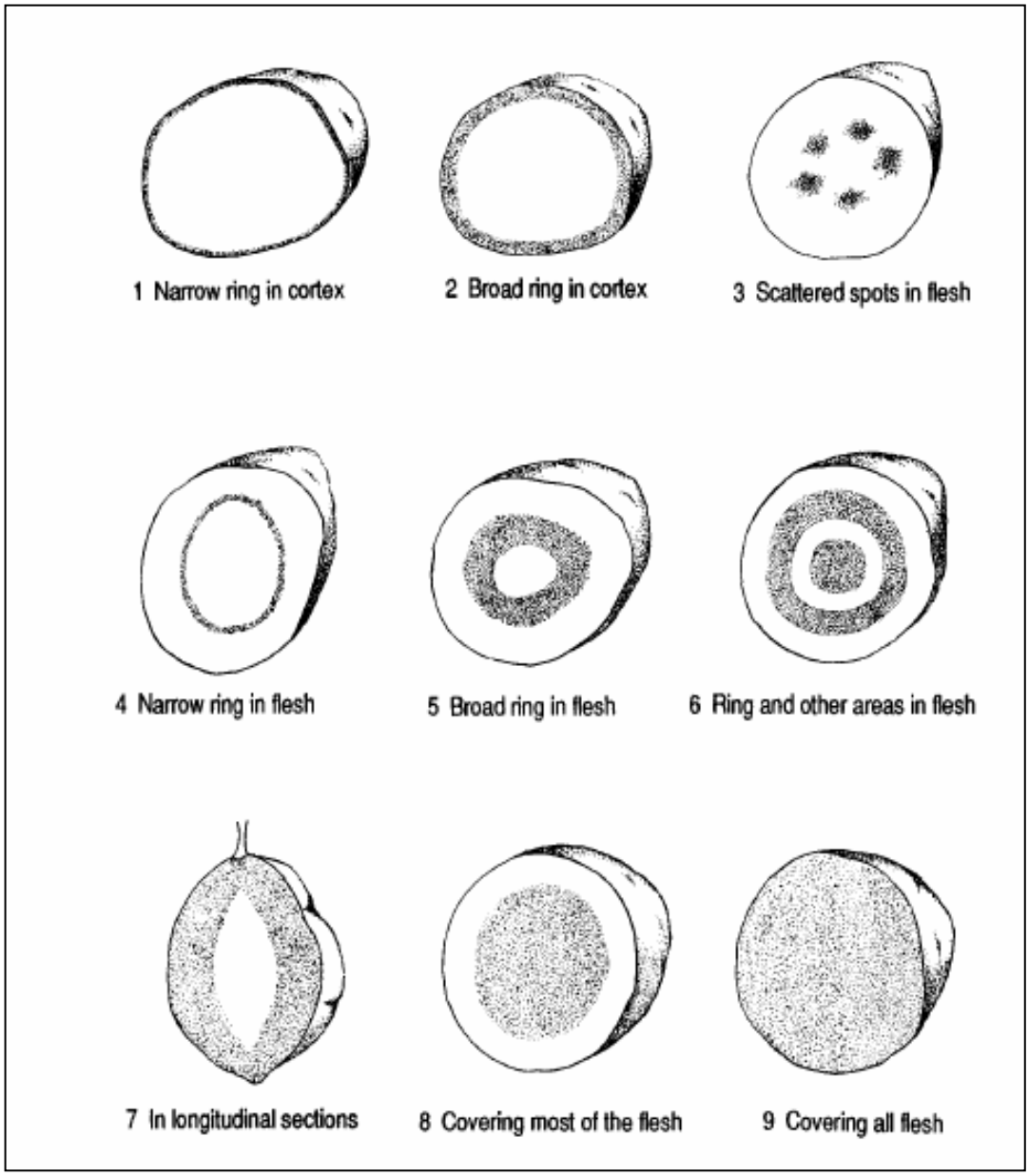


Fig.20 *Ipomoea batatas* Lam flower size; L-length, W-width (IBPGR, 1991).

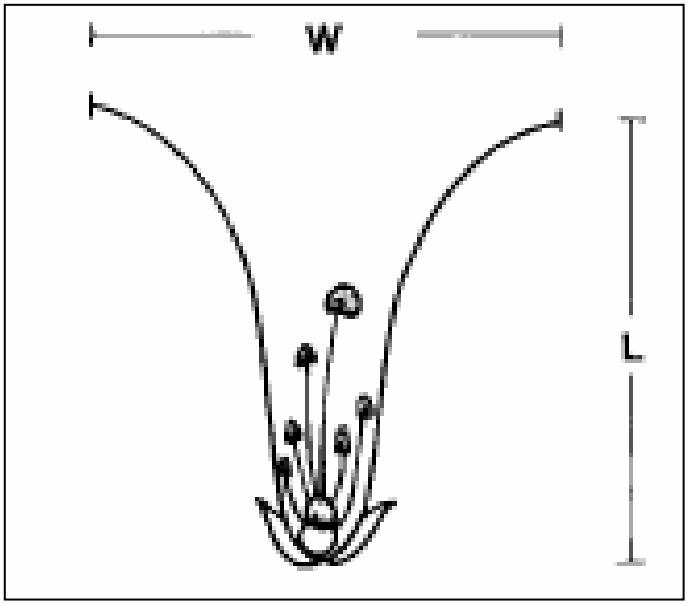


Fig.21 *Ipomoea batatas* Lam flower shape of limb; 3-Semi-stellate, 5-Pentagonal, 7-Rounded (IBPGR, 1991).

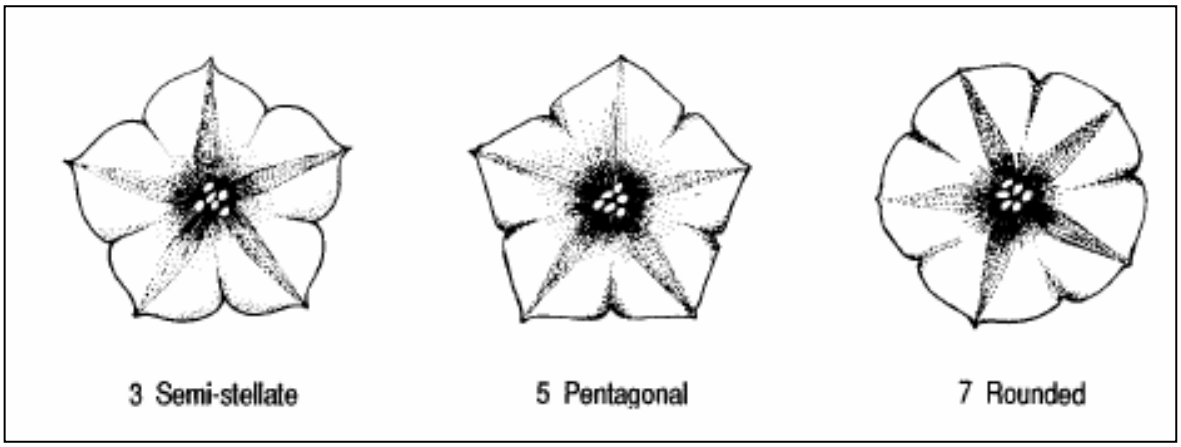


Fig.22 *Ipomoea batatas* Lam sepal shape; 1-Ovate, 3-Elliptic, 5-Obovate, 7-Oblong, 9. Lanceolate (IBPGR, 1991).

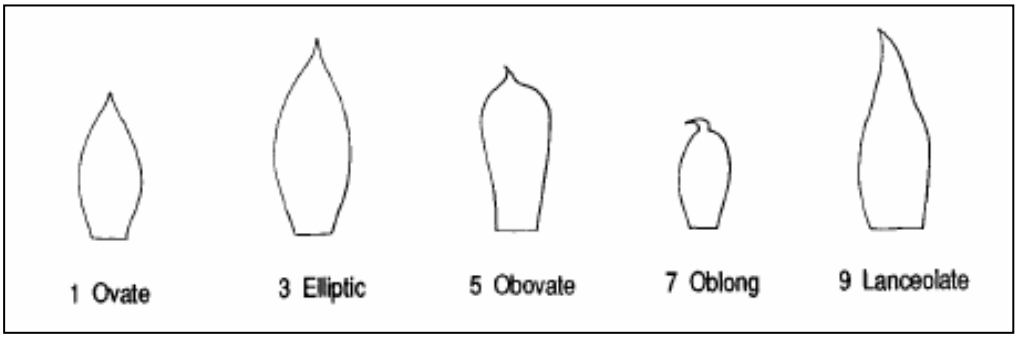


Fig.23 *Ipomoea batatas* Lam sepal apex; 1-Acute, 3-Obtuse, 5-Acuminate, 7-Caudate (IBPGR, 1991).

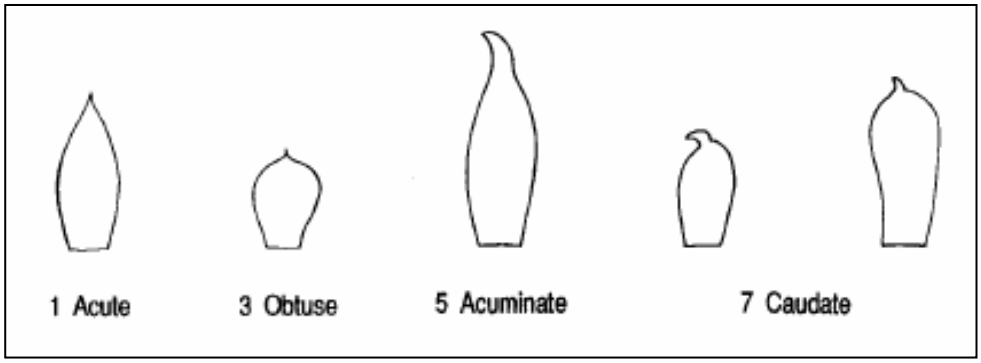


Fig.24 *Ipomoea batatas* Lam flower stigma exersion; 1-Inserted, 3-Same height as highest anther, 5-Slightly exerted, 7-Exerted (IBPGR, 1991).

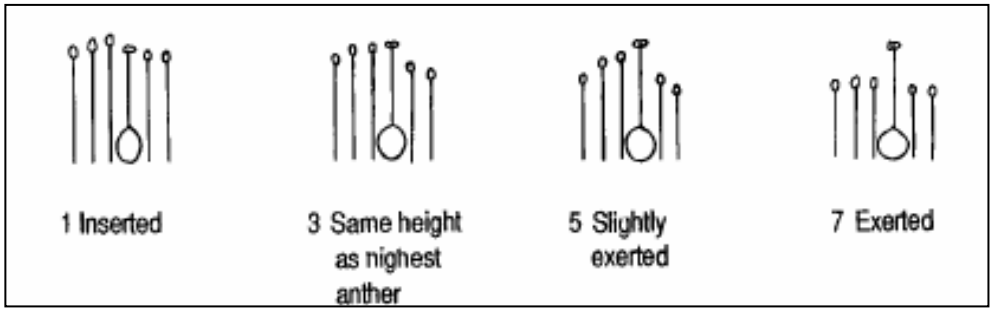
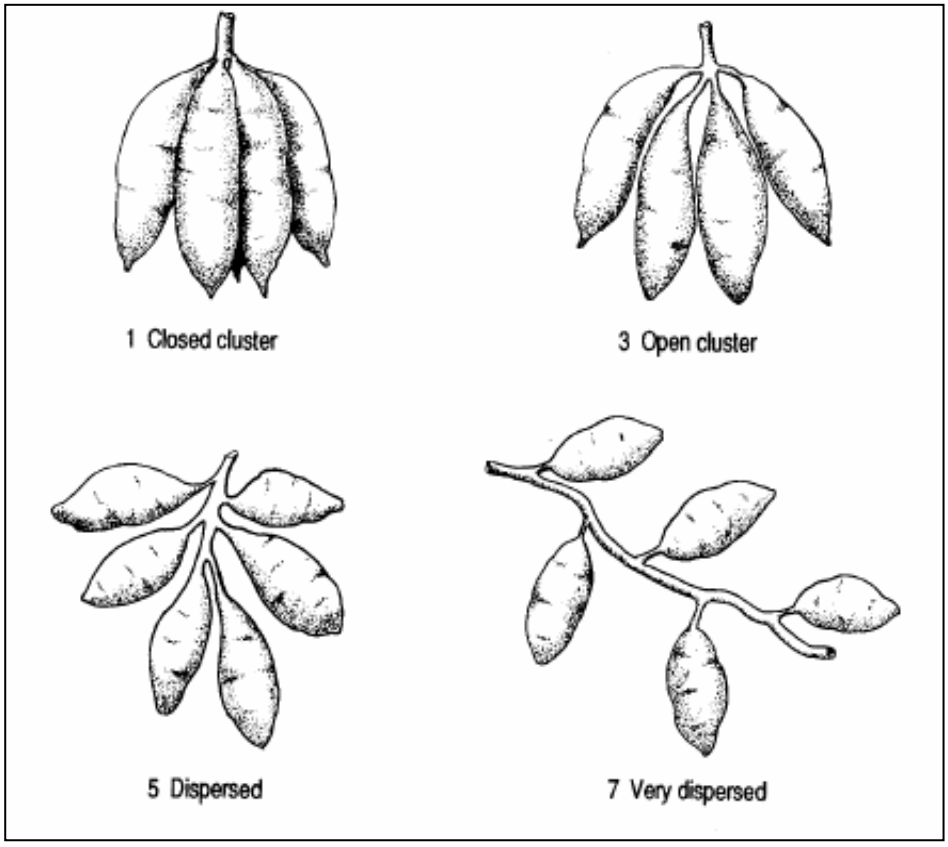


Fig.25 *Ipomoea batatas* Lam storage root formation; 1-Closed cluster, 3-Open cluster, 5-Dispersed, 7-Very dispersed (IBPGR, 1991).



The sweet potato is a human food and animal feedstuff. Sweet potato contains a number of advantage which give it an exciting potential role in combating the food shortages and malnutrition that may increasingly occur as a result of population growth and pressure on land utilization. Sweet potato provides significant amounts of energy and protein. Its production efficiency of edible energy and protein are outstanding in the developing world (woolfe, 1992). This study has provided preliminary morphological characterization of the different accessions of sweet potato cultivated in the different agricultural zones in Kerala. The accessions are grouped based on similarity and shared characters showed limitations of using only morphological traits in characterization of sweet potato. Morphological characterization has been used for various purposes including identification of duplicates, studies of genetic diversity patterns and correlation with characteristics of agronomic importance (CIAT, 1993). Sweet potato cultivars are generally distinguished on the basis of morphological traits and have a wide variability of botanical characteristics. Phenotypic characterization in sweet potato is done by assessing variations in the vine, leaf, flower and storage root characteristics (Huaman, 1991) and it has been traditionally used for identification of sweet potato cultivars. ISSR makers could be more effectively used in screening accessions among sweet potatoes if coupled with other molecular markers especially maturase K (matk) and rubisco (rbcL) (Vazhacharickal *et al.,* 2017a; Vazhacharickal *et al.,* 2017b; Vazhacharickal *et al.,* 2017c) markers.

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