



A review on morphological, genetic diversity and antinutritional factors of *Colocasia esculenta* (L.) Schott.

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Abstract

Colocasia esculenta (Taro) is a primitive, underutilized crop cultivated mainly for the consumption of both leaves and tubers. It is morphologically diverse with over 10,000 land acres. In world, *Colocasia esculenta* is the 5th most produced root crop mostly cultivated in tropical and sub-tropical areas. Being a cash crop, it has more value in earning foreign currency, for development in rural areas, and also in ensuring food security. There is a great controversy over geographical center of origin, but it is probably to be the Indo-Malayan region. Evidences shows that it has been independently domesticated over an area ranging from northeast India to Yunan province in China and New Guinea. Species number is disputed in the genus *Colocasia*, ranging from 5-10 with around 60 synonyms. Varieties can be categorized on the basis of morphological and genetic diversity.

Keywords: *Colocasia esculenta*, taro, genetic diversity, genetic markers, Himachal Pradesh

Introduction

Colocasia esculenta (L.) Schott an edible arum (taro) belongs to the monocotyledonous family Araceae. All the plants members belonging to the Araceae family are known as aroids. It is a primitive crop, native to the Indo-Malayan region probably Bangladesh and Eastern India [1]. It is believed that *Colocasia* has been evolved and domesticated from its wild ancestor i.e., *Colocasia esculenta* var. *aquatilis* either in North East or South East Asia [2]. Taro is cultivated all over the tropical regions and warm temperate zones over an area of approximately 1.56 million hectares with an estimated annual production of 8.94 million tons. Worldwide, taro is the 4th most consumed tuber crop [3]. It is used in developing countries like Africa, India, and Central America as staple crop or subsistence food. Among main root crops, taro is ranked 5th after potato, cassava, sweet potato, and yams. Top producer of taro is Africa with an occupying area of up to 88.4% and production of 73.6% followed by Asia and Oceania. Mainly, it is grown in developing countries using low input production systems [4]. In India, *Colocasia* inhabits an area of 0.052 million hectares with production of 0.0654 million tons and productivity of 12.57 tons per hectare. In India, it is mostly cultivated in Uttar Pradesh, Bihar, Punjab, West Bengal, Assam, Orissa, Himachal Pradesh, Utrakhland, Andhra Pradesh and Tamil Nadu [5].

This crop is characterized by having an underground stem, corms, leaves, flowers and chemical nutrients [6]. Not only corms but petioles and leaves are also used as a vegetable in Himachal Pradesh. Traditionally, leaves are eaten as leaf rolls commonly known as patoraas by the people of Himachal Pradesh [7]. Taro has a great diversity of flavanols. Phenolic compounds (including flavanols) show protective

activities against various human diseases, like cancer, cardiovascular disorders, diabetes, and Alzheimer's [8]. Some anti-nutritive compounds are also present in taro such as oxalates, uracil, lectins trypsin and inhibitors. Oxalates can become a cause of hypocalcemia and can accumulate in the form of crystals of stones in kidneys of humans, whereas, trypsin inhibitors can lead growth depression, pancreatic hypertrophy, and hyperplasia [9].

Plant Taxonomy

Colocasia esculenta an underutilized crop comes under the family Araceae and subfamily Aroideae. The plants belonging to the Araceae family are identified by diversity in their morphology, occurrence of various types of calcium oxalate crystals, and flowers with small spadix, unisexual or bisexual flowers that are covered by a spathe [10]. About 5-10 species are present in the genus *Colocasia*, with roughly 60 synonyms [11]. Linnaeus was the first to describe two species of *Colocasia* which are now popularly known as *Colocasia esculenta* var. *escuelnta* (dasheen type) and *Colocasia esculenta* var. *antiquorum* (eddo type). The word *esculenta* is a Latin word that means 'edible'. *Colocasia esculenta* is correlated to *Xanthomonas* and *Caladium* grown as ornamental often known as elephant ear so, *Colocasia esculenta* is sometimes called elephant ear. From a single specimen, only three species are known i.e., *C. gracilis* from Sumatra, *C. manii* from upper Assam, and *C. virosa* from Bengal in herbarium collection. Two of the common species *C. fallax* and *C. affinis* are found to be distributed in Northeastern India and Southeast Asia. Whereas, *C. gigantea* is wild variety found in the forest area of Indonesia and is cultivated all over Southeast Asia. *Colocasia esculenta* is most common grown species in about 10,000 land acres throughout the world [12].

Classification

Table 1

Rank	Scientific Name
Kingdom	Plantae
Subkingdom	Tracheobionta
Super division	Spermatophyte
Division	Magnolophyta
Class	Liliopsida
Subclass	Arecidea
Order	Arales
Family	Araceae
Genus	<i>Colocasia</i> Schott (<i>Colocasia</i>)
Species	<i>Colocasia esculenta</i> (L.) Schott
Synonyms	<i>Alocasia dussil</i> Dammer <i>Alocasia illustris</i> W. Bulll

Vernacular names

Taro (English), Arvi, Kachalu (Hindi), Alupam, Alukam (Sanskrit), Alti Kachu, Kachu (Bengali), Kesavedantu (Kannada), Chempu, Madantha, Chempakizhanna (Malayalam), Alavi, Paterveliya (Gujarati), Alluu (Marathi), Sempu (Tamil Nadu).

Plant Morphology

Colocasia esculenta an perennial monocotyledons herb but grown as annuals. It reaches up to 1-2m in height, with a corm in the center lying beneath the soil surface, from which leaves and roots grow towards the upper side and lower side respectively while runners, cormels, and daughter corms grow towards the lateral sides. Petioles are long with heart shape green or purple leaves, fibrous roots, and cylindrical or irregular corm. The male inflorescence is long, cylindrical generally interposed neuters between the two. Erect appendix, elongated-conical or fusiform, subulate or abbreviate. 3-6 androus male flowers. Female inflorescence is short, flowers 3-4 gynous. Berries obconic, many-seeded. Seeds oblongs, sulcate. seed production, fruiting, and flowering in wild and cultivated *Colocasia* has not been completely understood^[13].



Fig 1: *Colocasia esculenta*

Morphological diversity

Taro is a highly polymorphic plant as a species with the phenotypic description associated with the size of the corms and the number of the cormels. A study conducted on the

diversity of taro in the Yunnan Province of China^[6] showed that based on morphological types categorized by farmers there were five uses i.e. (1) inflorescence, which produces huge flowers, mainly consumed as a vegetable; (2) single corm, fresh weight near about 2 kg having less number of cormels; (3) multicormel, with numerous cormels having good quality and yield as compare to corm; (4) multicorm, corm and cormels with similar size; and (5) petiole, with underdeveloped corm and without cormels and numerous, long stolons consumed as vegetables. Additionally, there is a wild morphotype (*Colocasia esculenta* var. *aquatilis*) in which the corm is underdeveloped without any cormels having lot of long stolons consumed as a vegetables. Widely cultivated variants are: (1) *C. esculenta* var. *esculenta* and (2) *C. esculenta* var. *antiquorium*^[14]. *Colocasia esculenta* var. *esculenta*, commonly known as 'dasheen' type, having a large, cylindrical corm with less number cormels and is considered related to the single-corm morphotype. *Colocasia esculenta* var. *antiquorium* is known as the 'eddoe' type, having a small, globular corm that possesses large cormels and is considered related to the multicormel morphotype as explained earlier^[6]. Dasheen type of taro is mainly grown in Asia and the Pacific. From India, 32 accessions of these two variants were analyzed using randomly amplified polymorphic DNA (RAPD), these two phenotypes were not distinguishable based on these genetic markers^[15]. In another study, 24 accessions of taro grown in India were analyzed for 14 characters: plant height, per plant number of leaves, length of petiole, days to maturity, per plant corms number, the weight of corm, length of the corm, girth of the corm, per plant cormels number, per plant total yield, dry matter, starch, the content of oxalate and protein. All the 14 characters among accessions showed high significant differences^[16].

859 accessions were evaluated from PNG. 10 qualitative characters were used i.e., length of the corm, breadth of the corm, weight of corm, length of leaf, width of leaf, height of plant, cormels number, cormels weight, stolons number, sucker number. They also measure 20 qualitative traits including the color of various parts of the leaf blade and petiole, corm flesh and fiber color, and Taro leaf blight resistance. High variability was observed for these phenotypic traits among *Colocasia* accessions^[17].

Colocasia esculenta is generally grown from vegetative propagules rather than seeds. Insect pollinators of *Colocasia* specific to species are native to New Guinea and Indonesia, with one insect species found in Northern Queensland^[18]. In countries where these insets pollinators are not found, there is a bit of natural hybridization, which leads to the occurrence of very different morphotypes, even if they share the same genotype^[19].

Genetic diversity

Colocasia esculenta is a highly allogamous, protogynous, and polymorphic species^[20]. While studying diversity, diploids ($2n=2x=28$) and triploids ($2n=3x=42$) chromosomes using simple cytological techniques have been observed in taro^[21]. In Asia (including China, India, Indonesia, Japan, Thailand, and Vietnam), Africa, and South America triploids are most common, while diploids are more frequent in Asia, Oceania, and South America. In Polynesia, only diploid forms are present. In India, chromosome number of taro is $2n=14, 28,$ and 42 and $2n=36$ and 48 , this genetic instability is due to continuous

cultivation in the region of center of diversity ^[22]. Various kind of genetic markers can be used to study the genetic diversity of *Colocasia esculenta*. Generally, these markers are of two types (1) band based (isozyme, random amplified polymorphic DNA (RAPD), amplified fragment length polymorphism (AFLPs) and simple sequence repeats (SSRs, microsatellite), and (2) sequence-based (single nucleotide polymorphisms (SNPs), expressed sequence tags, and transcriptome profiling with next generation sequencing (RNA-seq). In *Colocasia esculenta*, depending upon the ploidy SSRs are bi-allelic or tri-allelic, due to ploidy issue, incomplete heterozygosity makes it impractical to get exact genotypes. Generally, SSRs scoring is considered to be more reliable and consistent than RAPDs and AFLPs. Advancements in high throughput sequencing have led to the recognition of 5278 SSR markers. Among these 62% were characterized as polymorphic based upon a test set of 100 primers ^[23]. Before this research, only 52 SSR taro-specific markers had been identified ^[24]. Recently more than 1700 SNP markers for taro have been developed ^[25].

Chemical composition

Starch

In taro corm, 70-80% (dry weight basis) starch having small granules (1-4µm in diameter) has been reported. Taro has been reported to be used in Hawaii and other Pacific islands for the preparation of infant foods because of its high digestibility. Being hypoallergenic due to the absence of gluten taro is mostly used in foods of baby and the diet of people sensitive to cereals and infants allergic to milk. Taro starch is considered to be good for patients with peptic ulcers, pancreatic disorders, chronic liver disorders, inflammatory bowel disease, and gall bladder problems. As compared to other cereals taro starch contains a higher content of amylose and amylopectin. Amylose/amylopectin ratio is 1:7. Sucrose is main sugar present in taro. Fructose, maltose, glucose and raffinose are also found. Malic acid (60%) is present in majority followed by citric acid (25%) and oxalic acid (15%) ^[26].

Moisture

Being a root crop taro has a very high moisture content. It accounts for two-third of the total weight of the fresh crops ^[27]. Generally, 60-83% of moisture content has been reported in taro ^[28]. It varies based on variety, growth conditions, and harvest time.

Protein

About 11% protein (dry weight basis) is present in taro which is more as compare to cassava, and yam. High amount of amino acids like leucine, arginine, valine, and phenylalanine are present in protein fractions. As compare to corm, the leaf contains more amount of methionine, lysine, cystine, phenylalanine, and leucine. Taro roots and rhizome have symbiotic soil bacteria, so it contains more amount of protein than other root crops. These bacteria help in fixing atmospheric nitrogen and also help in increasing nitrogen content in corm and leaf. The free-living nature of these soil bacteria helps taro to thrive under diverse environmental and ecological conditions ^[29].

Fat

Taro contains a very low content of fat i.e., 0.3%-0.6% which is mostly comprised of lipids of the cell membrane. It varies among the different cultivars ^[27].

Crude fiber

Dietary and non-dietary fiber are present in taro. According to research carried out in Cameroon and Chad on six cultivars of taro, 0.3%-3.8% crude fibre content has been reported in the taro ^[27]. Another study on six cultivars of taro grown in American Samon a larger range from 5.02-9.01% of soluble and insoluble fiber was found ^[30].

Ash

Fairly high amount of ash is present in taro ranges from 3.54-7.78%. From which it can be concluded that good amount of mineral content is present in taro ^[31].

Mineral

Taro contains appreciable amount of minerals including iron, calcium, sodium, magnesium, phosphorus, zinc, copper and potassium. Patient with high blood pressure is recommended for high potassium to sodium ratio food ^[27].

Vitamins

In corms and leaves of taro Vitamin C and vitamin B complex are reported in higher ratio. β-carotene, iron, folic acid is present in the cooked leaf of taro which protects against anemia ^[27].

Anti-nutritional factors

One of the major limiting factors in taro root is the presence of antinutrients. They have negative impacts on taro as a food. They also have positive impacts on taro as a crop that can be grown with minimum use of pesticides and fungicides. Mucilage, oxalic acid, tannins, cyanide, lectins, alpha-amylase inhibitors, protease inhibitors are the antinutrients present in taro ^[4].

Mucilage

Droplets of slimy substances called mucilage exudate from the exposed surface when raw taro corms are cut into pieces. Crude mucilage is a mixture of neutral polysaccharides, a small amount of fiber and protein ^[32]. The mucilage in taro corm is good for health because it gets digested very easily and the ability to bind bile to lower blood cholesterol, slow down blood sugar, slow down the transportation of food through upper digestive tract, absorb water and keep moisture to soften stool ^[33].

Oxalate

When raw or unprocessed food from taro is eaten it impart an acrid taste or cause irritation due to the presence of oxalates. Needle-like calcium oxalate crystals, raphides can penetrate soft skin and cause acidity. Discomfort in the tissue is caused by an irritant present on the raphides (protease) ^[34]. Due to harmful effects on health, the consumption of a high number of oxalates is a matter of concern ^[35].

Protease (trypsin and chymotrypsin inhibitor)

Acridity is caused by protease inhibitors ^[34]. Acridity is found in the corms, which cause extreme itching, stinging, or burning in the mouth and throat, followed by swelling or mild irritation or itching externally ^[36]. The presence of acidity is considered a natural defense against herbivores. There are several methods including a wash with an acidic ingredient or sodium bicarbonate which can help to reduce acidity. The activity of trypsin inhibitor will increase at

first, then disappear after cooking of corms. To remove trypsin activity, boiling for 20 minutes is enough^[33].

Lectins

Lectin is one of the most important protein present in the storage organ of taro and other members of Araceae. It is a storage protein with additional biochemical defense functions^[37].

Alpha-amylase inhibitors

Alpha-amylase is an enzyme that helps in the digestion of starch in humans and animals. The enzymes are present in small intestine and saliva the which can be inhibited by enzyme-specific inhibitors from most of the plants. The alpha-amylase inhibitors in taro corms can deactivate human salivary and pancreatic amylase^[38]. Alpha-amylase inhibitors lose activity *in vitro* after boiling for 30 minutes as they are sensitive to heat.

Conclusion

Taro is the ancient cultivated crops. It shows great morphological diversity. Although taro is 5th most produced root crop but not much studies available on its genetic resources. Being a staple and tuber crop taro is grown for it underground corms. Corms of taro are consumed as a vegetable as they contain high amount of carbohydrates, proteins, vitamins and minerals. Apart from its nutritional factors taro also possesses some antinutritional factors which are mainly responsible for acidity.

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References

1. R Plucknett, DL Edible aroids: Alocasia, Colocasia, Cyrtosperma, Xanthosoma (Araceae). Evolution of Crop Plants. NW Simmonds, ed, 1976.
2. Matthews PJA possible tropical wildtype taro: Colocasia esculenta var. aquatilis. Indo-Pacific Prehistory Association Bulletin, 1991:11:69-81.
3. Revill PA, Jackson GVH, Hafner GJ, Yang I, Maino MK, Dowling ML, Harding RM. Incidence and distribution of viruses of taro (Colocasia esculenta) in Pacific Island countries. Australasian Plant Pathology, 2005:34(3):327-331.
4. Rao VR, Matthews PJ, Eyzaguirre PB, Hunter D. The Global Diversity of Taro: ethnobotany and conservation, 2010.
5. Reddy PP. Tropical root and tuber crops: an overview. Plant protection in tropical root and tuber crops, 2015, 1-15.
6. Jianchu X, Yongping Y, Yingdong P, Ayad WG, Eyzaguirre PB. Genetic diversity in taro (Colocasia esculenta Schott, Araceae) in China: An ethnobotanical and genetic approach. Economic Botany, 2001:55(1): 14-31.
7. Singh P, Sharma HR. Nutritional and Organoleptic Evaluation of Colocasia Leaf Rolls Supplemented with Different Protein Sources. Journal of Human Ecology, 2003:14(6):467-469.
8. Soto-Vaca A, Gutierrez A, Losso JN, Xu Z, Finley JW. Evolution of phenolic compounds from color and flavor problems to health benefits. Journal of Agricultural and Food Chemistry, 2012:60(27):6658-6677.
9. Guchhait S, Bhattacharya A, Pal S, Mazumdar D, Chattopadhyay A, Das AK. Quality evaluation of cormels of new germplasm of taro. International journal of vegetable science, 2008:14(4),304-321.
10. Henriquez CL, Arias T, Pires JC, Croat TB, Schaal B A. Phylogenomics of the plant family Araceae. Molecular phylogenetics and evolution, 2014:75:91-102.
11. Matthews PJ. Aroids and the Austronesians. Tropics, 1995:4(2/3):105-126.
12. Ivancic, A., & Lebot, V. The genetics and breeding of taro. Editions Quae. 2000
13. Kirtikar KR, Basu BD. Indian Medicinal Plants. Dehradun, India. International book distributors, 2005:1:478-79.
14. Deo PC, Tyagi AP, Taylor M, Becker DK, Harding RM. Improving taro (Colocasia esculenta var. esculenta) production using biotechnological approaches. The South Pacific Journal of Natural and Applied Sciences, 2009:27(1):6-13.
15. Lakhanpaul S, Velayudhan KC, Bhat KV. Analysis of genetic diversity in Indian taro [Colocasia esculenta (L.) Schott] using random amplified polymorphic DNA (RAPD) markers. Genetic Resources and Crop Evolution, 2003:50(6),603-609.
16. Cheema DS, Singh H, Dhatt AS, Sidhu AS, Garg N. Studies on genetic variability and correlation for yield and quality traits in Arvi [Colocasia esculenta (L.) Schott]. In I International Conference on Indigenous Vegetables and Legumes. Prospectus for Fighting Poverty, Hunger and Malnutrition, 2006:752:255-260.
17. Singh D, Mace ES, Godwin ID, Mathur PN, Okpul T, Taylor M, Jackson G. Assessment and rationalization of genetic diversity of Papua New Guinea taro (Colocasia esculenta) using SSR DNA fingerprinting. Genetic Resources and Crop Evolution, 2008:55(6):811-822.
18. Hunt HV, Moots HM, Matthews PJ. Genetic data confirms field evidence for natural breeding in a wild taro population (Colocasia esculenta) in northern Queensland, Australia. Genetic resources and crop evolution, 2013:60(5):1695-1707.
19. Kuruvilla KM, Singh A. Karyotypic and electrophoretic studies on taro and its origin. Euphytica, 1981:30(2):405-413
20. Quero-García J, Courtois B, Ivancic A, Letourmy P, Risterucci AM, Noyer JL, Lebot V *et al.* First genetic maps and QTL studies of yield traits of taro (Colocasia esculenta (L.) Schott). Euphytica, 2006:151(2):187-199.
21. Mace ES, Godwin ID. Development and characterization of polymorphic microsatellite markers in taro (Colocasia esculenta). Genome, 2002:45(5):823-832.
22. Ghosh Dastidar S. Colocasia esculenta: an account of its ethnobotany and potentials (Doctoral dissertation), 2009.
23. You Y, Liu D, Liu H, Zheng X, Diao Y, Huang X, Hu Z *et al.* Development and characterisation of EST-SSR markers by transcriptome sequencing in taro (Colocasia

- esculenta (L.) Schott). Molecular Breeding, 2015:35(6):1-11.
24. Lu Z, Li W, Yang Y, Hu X. Isolation and characterization of 19 new microsatellite loci in *Colocasia esculenta* (Araceae). American journal of botany, 2011:98(9):239-241.
 25. Helmkampf M, Wolfgruber TK, Bellinge MR, Paudel R, Kantar MB, Miyasaka SC, Shintaku M. Phylogenetic relationships, breeding implications, and cultivation history of Hawaiian taro (*Colocasia esculenta*) through genome-wide SNP genotyping. Journal of Heredity, 2018:109(3):272-282.
 26. Jane J, Shen L, Chen J, Lim S, Kasemsuwan T, Nip W. Physical and chemical studies of taro starches and flours 1 2. Cereal Chem, 1992:69(5):528-535.
 27. Onwueme I. Taro cultivation in Asia and the Pacific. RAP publication, 1999:16:1-9.
 28. Huang AS, Tanudjaja LS. Application of anion-exchange high-performance liquid chromatography in determining oxalates in taro (*Colocasia esculenta*) corms. Journal of agricultural and food chemistry, 1992:40(11):2123-2126.
 29. Lucy M, Reed E, Glick BR. Applications of free living plant growth-promoting rhizobacteria. Antonie van leeuwenhoek, 2004:86(1):1-25.
 30. Nip W, Muchille J, Cai T, Moy JH. Nutritive and non-nutritive constituents in taro (*Colocasia esculenta* (L.) Schott) from American Samoa. Journal of Haw. Pac. Agri, 1989:2,1-5.
 31. Njoku PC, Ohia CC. Spectrophometric estimation studies of mineral nutrient in three cocoyam cultivars. Pakistan Journal of Nutrition, 2007:6(6):616-619.
 32. Smith DS, Cash, JN, Nip WK, Hui YH. (Eds.). Processing vegetables: science and technology. CRC Press, 1997.
 33. Hollyer J Taro: Mauka to Makai. A Taro Production and Business Guide for Hawai'i Growers. University of Hawaii at Manoa. College of Tropical Agriculture and Human Resources, 1997.
 34. Bradbury JH, Nixon RW. The acidity of raphides from the edible aroids. Journal of the Science of Food and Agriculture, 1998:76(4):608-616.
 35. Savage GP, Catherwood DJ. Determination of oxalates in Japanese taro corms using an *in vitro* digestion assay. Food Chemistry, 2007:105(1):383-388.
 36. Osisoguo IUW, Uzo JO, Ugochukwu EN. The irritant effects of cocoyams. Planta medica, 1974:26(06):166-169.
 37. Van Damme EJ, Goossens K, Smeets K, Van Leuven, F., Verhaert P, Peumans WJ. The major tuber storage protein of araceae species is a lectin (characterization and molecular cloning of the lectin from *Arum maculatum* L.). Plant Physiology, 1995:107(4),1147-1158.
 38. Soudy ID, Delatour P, Grancher D. Effects of traditional soaking on the nutritional profile of taro flour (*Colocasia esculenta* L. Schott) produced in Chad. Revue Méd Vét, 2010:137-42.