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Mini Review

Colocasia (*Colocasia esculenta* L.) in Northeast India

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Northeast India is rich in genetic diversity of horticultural crops and colocasia is one of the important crops. This region is rich in colocasia diversity for both cultivated and wild species particularly in *jhum* fields, homestead gardens, near water bodies, river banks, forests and road sides. Wide range of variability is observed in vegetative characters, corm and cormel characters, yield and quality characters. It is cultivated in *jhum* field as a mixed crop along with paddy and other crops like ginger, chilli, maize, turmeric etc. and in homestead garden, it is cultivated along with maize, cucurbits, chilli, King chilli, etc. The nutrient rich and gluten free tuber crop is an integral part of traditional cuisines of ethnic people of this region. All the plant parts of this ariod member are edible. Several traditional dishes have been prepared from leaves, petioles and tubers. The leaves, petioles and damaged tubers are also fed to pig and poultry. Recent past, the genetic diversity of colocasia is under threat due to urbanization, climate change, introduction of new crops, and pest and diseases and resulted in genetic erosion. The conservation of these vast gene pool is necessary.

Key words: *colocasia, botany, genetic variability, nutritive value*

INTRODUCTION

The Northeast India comprising of Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura occupies 7.7 per cent of total geographic area in India which accounts for 50 per cent of the biodiversity of the country (Deka et al., 2012). Northeast India is home of several tuber crops, of which, colocasia is one of the important edible aroids. It is found abundantly in Northeast India and cultivated widely in this region as a mixed crop along with paddy in *jhum* fields; as a mixed crop along with Xanthosoma, maize, leafy vegetables, chillies etc. in homestead gardens, and as mono crop in some isolated areas (Thirugnanavel et al., 2015). Corms, cormels, leaves, petioles and flowers are edible (Bose et al., 2003). It is an integral component in food chain and culture of many ethnic groups. They are preparing several traditional dishes from different parts of the plant. It also occupies substantial share in pig and poultry feed in rural areas. The tubers and leaves are rich in nutrients and have medicinal values.

Nutritive value

Colocasia, the starch corm, is rich in starch, minerals, and dietary fibre and free from gluten. It is rich in potassium, phosphorous, magnesium, calcium, and B complex (Mwenye et al., 2011; Mergedus et al., 2015). It has omega-3 fatty acids and amino acids. It helps in lowering blood pressure. Being a low glycemic index food, it will reduce the glucose level in the body thereby become good food for diabetic patients. It possesses medicinal values against stomac ulcer, fungal infections and tuberculosis (Singh et al., 2012). The leaves and

stems are also rich in minerals and vitamins. Over consumption of corm without proper cooking may lead to kidney stones. Proper cooking is essential to remove the calcium oxalate. The nutrient content present in the colocasia corm is mentioned below (Table 1).

Botany

Colocasia (*Colocasia esculenta*) belongs to the family araceae. The genus colocasia is derived from Egyptian word "*colas"* means taro. The species word '*esculenta*' means edible in Latin. The genus colocasia includes 16 species, of which few species are reported in Northeast India like *C. affinis, C. esculenta, C. fallax, C. gigantea, C. lihengiae* etc., among them *Colocasia esculenta* is edible. *Colocasia esculenta* is usually diploid (2n = 28) or triploid (2n = 42) (Ramachandran, 1978) and the basic chromosome number is x= 14 (Matthews, 1990). The plants are herbaceous perennials and cultivated mostly as annuals. This monocotyledonous, succulent plant grows up to a height of 30 cm to more than 2 m. The leaves are large, entire, ovate to sagittate and attached with on long petioles which are erect (Straus, 1983). It produces shallow fibrous and adventitious roots. The plant produces stolon or suckers. The lateral buds present in the corms arise in the form of cormels, stolons and suckers. The inflorescence arises at leaf axils in cluster of 2 – 5 and it consists of spathe, spadix, staminate flowers, pistillate flowers, neutral flowers and sterile appendage (Pardales, 1980). The staminate and pistillate flowers are small, sessile and monoecious. The stigma becomes receptive one day before the anther dehiscence and remains receptive a day after anther dehiscence. The pistillate flowers are covered by spathe. Self-incompatibility, natural constriction by spathe, different flower maturity times prevent self-pollination thus enables the cross pollination (Pardales, 1980).

The corm, the underground stem is starchy, compact and thick. It is composed of outer brown colour scars and scales and ground starchy parenchyma (Plucknett, 1976). The *raphide* idioblasts and laticifers are scattered around through the ground tissues and the *druse* idioblasts are scattered in the vascular tissues (Sunell and Healey, 1979). The corm is highly variable in size, shape, hydration, colour and nutritive values (Strauss *et al.,* 1980). Based on the corm morphology, the plant is botanically classified into two groups namely dasheen (*Colocasia esculenta* var. *esculenta*) and eddoe (*Colocasia esculenta* var. *antiquorum*). The dasheen type is characterized by large mother corm with very few small cormels and the eddoe type is characterized by small to medium size inedible mother corm with equal size of numerous edible cormels (Purseglove, 1972).

Genetic variability

Colocasia is believed to be originated in Southeast Asia, probably Indo-Burma region (Matthews, 1991). It is widely spread throughout the region in diverse agro-eco systems. Colocasia is highly polymorphic (Purseglove, 1972) and predominantly cultivated through corms. High level of genetic variability exists in corms and vegetative parts due to mutation in vegetative propagules (Mathews, 2004) and farmers selected different types according to their specific needs. Over the centuries, landraces continue to exist based on ability to survive in extreme natural calamities. Natural hybridization and introgression occur between and within species that results into new species and varieties. The resulted species or varieties vary in their ecological adaptation. In nature, evolution of new species or varieties by introgression or horizontal gene transfer is a natural phenomenon. This natural phenomenon leads to the occurrence of huge genetic diversity of colocasia in this ecological niche.

Northeast India is rich in colocasia and its wild relative's genetic diversity. Vast genetic diversity exists in this region, especially *jhum* fields, homestead gardens, near water bodies, river banks, forests and road sides for both cultivated and wild species (Sarma, 2001; Thirugnanavel et al., 2013; Angami et al., 2015). *Jhum* fields serve as reservoir of colocasia variability and several landraces have been grown in the same field. With inherited knowledge from ancestors, farmers gained experience of their own and selected the supreme landraces preferring to their choice that lead to the extinction of few landraces. Preference of the landraces greatly varies between the region and ethnic groups. Though the region is rich in genetic variability, the knowledge is limited and several authours have attempted to study the variability based on cytology, morphology and molecular markers. Vast genetic variation was observed for vegetative characters, corm and cormel characters, yield and quality among the colocasia germplasm available in Northeast Indian states (Table 2).

Pandey and Dobhal (1997) characterized 31 germplasm

Table 1. Nutrient content in colocasia

Nutrients	Availability /100g	Nutrients	Availability /100g
Moisture	70.3 %	Phosphorous	68 mg
Fat	0.1 %	Magnesium	106 mg
Protein	3.2 %	Sodium	1.6 mg
Starch	21.2 %	Potassium	356 mg
Energy	97 Kcal	Sulphur	7.4 mg
Vitamin B_1	0.09 mg	Iron	0.63 mg
Vitamin B_2	0.03 mg	Copper	0.20 mg
Vitamin C	Nil	Zinc	3.6 mg
Calcium	31 mg	Manganese	0.34 mg
Beta carotene	34 µg	Boron	0.09 mg

(Balagopalan *et al*., 1999)

collected from Assam, Meghalaya and Nagaland for eight characters. They observed significant variability for morphological and yield characters. Choudhary et al. (2011) evaluated 14 colocasia germplasm from Arunachal Pradesh and Tripura and found high value of Phenotypic Co-efficient of variation and Genotypic co-efficient of variation for plant girth, no. of suckers, no. of cormels and yield. High level of genetic variability for plant growth, corm, cormel, yield and quality characters were observed among 40 colocasia germplasm collected from Northeast India (Angami et al., 2015). In the initial years, the genetic variability studies were carried out based on morphological characters. For reliable information, use of molecular markers is essential. Khatemenla et al. (2019) used 10 SSR markers to characterize 22 colocasia germplasm from Arunachal Pradesh, Assam, Meghalaya and Nagaland. The germplasm were grouped into two clusters. They found high level of similarity index (0.89) indicated a low level of genetic variability among the germplasm. In future, high number of molecular markers with large population size covering all the Northeastern states should be used for characterization.

Colocasia cropping systems

Jhum cultivation is the predominant form of agriculture in many parts of Northeast India and colocasia is inseparable from *jhum*. In most parts of the region, colocasia is cultivated in *jhum* field along with paddy and other crops like ginger, chilli, maize, turmeric etc. as a mixed crop (Chatterjee et al., 2021). The *jhum* field serves as a major reservoir of colocasia genetic diversity. In each *jhum* field, different germplasm of colocasia have been planted. The farmers keep minimum of 3 germplasm to maximum of 11 germplasm in their field. In mixed cropping system, the combination of crop species vary in each state and mostly rice based. The mixed cropping system with colocasia based cultivation found in this region is mentioned in table 3. In homestead garden, it is one of the important vegetable with other crops like maize, cucurbits, chilli, King chilli, etc in the region. Homestead garden serves as a huge reservoir for colocasia diversity and most of the home garden contains three or more varieties. Colocasia is cultivated as perennial crop in home garden. The people do not harvest the tubers at a time. Instead, they harvest the tubers whenever they require. Monocropping of colocasia is uncommon and is restricted to some isolated pockets in this region, particularly in Nagaland and Manipur. The harvested tubers are sold in nearby markets. Monocropping leads to decline in soil fertility and the crop becomes susceptible to more pest and disease infestation. Continuous cultivation in the same filed affects the yield drastically.

Customary cuisines from colocasia

Ethnic people have rich knowledge on traditional foods that evolved over centuries by the interaction of their cultures with local ecosystems (Kuhnlein, 2009). People of Northeast India prepare several unique cuisines from rich ethno-botanical resources that are naturally rich in nutrients. Tuber crops play a crucial role in the food and nutritional security of NEH people. Colocasia is a predominant root crop in this region and many traditional recipes have been prepared from tubers, leaves and petioles. Besides foods, they have also

Table 2. Variability observed in Northeast India's colocasia germplasm

S.No	Characters	Unit	Range
1	Plant height	cm	96.3 - 154.8
2	No. of suckers	No	0 - 7.3
3	Corm length	cm	3.89 - 16.9
4	Corm diameter	cm	2.5 – 15.2
5	Corm weight	g	36.11 – 1500.0
6	Cormel weight	g	13.34 – 65.31
7	Starch content	%	10.84 – 29.61
8	Moisture content	%	63.81 – 80.56
9	Dry matter content	%	19.91 – 35.78
10	Calcium oxalate content	mg/100 g	0.23 – 1.78

(Buragohain *et al*., 2013; Angami *et al*, 2015; Thirugnanavel *et al.,* 2015)

Table 3. Different mixed cropping system in Northeast India

State	Mixed cropping system
Arunachal Pradesh	Paddy + Maize + Vegetables + Ginger + Colocasia
	Upland paddy + colocasia + Ginger + Cucurbits
	Millets + maize + cassava + Colocasia + beans + cucurbits + ginger + turmeric + chilli + leafy vegetables
Manipur	Upland paddy + cassava + colocasia + vegetables
	Pumpkin + colocasia + cucumber/ cassava
	Paddy + maize + chilli + colocasia + beans
Meghalaya	Arhar + vegetables + colocasia
	Jhum paddy + vegetables + colocasia + ginger
Nagaland	Jhum paddy + maize + colocasia + soyabean + cucumber
	Paddy + maize + colocasia
	Colocasia + ginger + chilli + cucurbits + Xanthosoma

(Sajeev *et al*., 2010)

mastered the art of preservation of leaves, petioles and tubers. It is consumed throughout the year in both fresh and processed forms. It is one of the major components in their diet during lean season which cater to their energy and nutritional needs, thereby providing food and nutritional security. The consumption rate is higher during lean season *i.e.* July–September.

People consume the young unfolded leaves, young leaves, mature green leaves, mature dry leaves, young petioles, mature petioles, mother corms and cormels. The edible parts of colocasia are mostly eaten as boiled vegetable. Besides, they can be roasted, baked, or fried and can be eaten alone or along with other dishes. Ethnic recipe from colocasia is prepared mainly by boiled tuber, vegetable curry using fresh parts of colocasia, and vegetable curry from semi-processed colocasia. The traditional foods prepared from colocasia by different ethnic groups are mentioned table 4.

Animal feed

Pig is the most common animal proteins consumed by the people and almost each household are rearing pigs in small scale. The non-availability of the commercial feed in rural areas of Northeast India and high cost of feed materials restrict the farmers to purchase the commercial feed and the farmers are not in a position to feed the balanced diet. The villagers mainly depend on kitchen waste, locally available grasses (*Spilanthus sp, Bidens biternata*, *Hibiscus sp, Conyza auriculata, Polygonum chinensis,* etc.), rice bran, etc for feeding of pig (Kumaresan et al., 2007; Haldar et al., 2017). Colocasia leaves, petioles and damaged tubers are one of the important ingredients in low input traditional pig feeding (Patra et al., 2014; Singh et al., 2019). Colocasia leaves are rich in protein, vitamins and minerals. The leaves contain 21 – 23 per cent crude protein. The tubers are potential precious energy source for animals due to high energy content. The people collect colocasia leaves and petioles both from wild and cultivated species. The collected leaves, petioles, and tubers are cut into small pieces. The kitchen wastes, water and other grasses are also mixed with them before cooking in big steel or aluminum vessels. These cooked materials are fed to pigs. The farmers offer averagely 1.3 – 3 kg kitchen waste and 1 kg locally available leaves per pig per day (Kumaresan et al., 2006, 2009).

Pest and diseases

Taro leaf blight, corm rot, soft rot, dasheen mosaic virus, corm bores, white flies, hoppers, thrips, and mites are the major limiting factors in colocasia production. Of which, taro leaf blight and corm borer are the serious disease and pest that cause economic damage worldwide. In Northeast India, taro leaf blight and corm borers possess serious problem and cause considerable damage to the crops.

Leaf blight

Taro leaf blights (TLB) caused by *Phytophthora colocasiae* Rociborski is the major devastating disease in colocasia (Misra *et al*., 2008) that threatens the sustainable cultivation of the crop in the entire North Eastern region. In Northeast India, it was first reported in Assam (Chowdhury, 1944). The fungus mainly affects leaves, and the infestation extends to petioles, and flowers. In corm, the fungus causes corm rot. Small, light brown or dark brown spots will appear on the upper surface of the leaves. The circular spots enlarge soon and rapidly spread to the other parts. Lower side of the leaves, water soaked, dry, grey spots are noticed. The disease spread quickly when temperature is 20 – 28 ^{0}C with relative humidity of more than 85 % (Sahu *et al*., 2000). The incubation period of the pathogen is 2-4 days at optimal temperatures of 24-27 °C. Sporangia and zoospores are spread by rain splash and wind-blown rain between plants or within the same plan. The pathogen is spread from field to field and over long distances by infected planting material. The leftover corms in the field after harvest can also serve as inoculums. The zoospores can survive in the soil for up to 3 months. The disease is widespread in Northeast India and the disease intensity is high in higher altitudes than mid and lower altitudes (Pongener and Daiho, 2016). It could cause more than 50 % yield loss (Misra, 1996). The landraces growing in this region show wide variability for tolerance to this disease. Most of the varieties are susceptible and few landraces recorded some degree of field tolerance (Thirugnanavel *et al.,* 2015). Some of the wild types of taro have resistance to this disease. These types may be utilized as parental material for developing disease tolerant taro varieties in taro improvement programmes.

Corm borer

Corm borer (*Aplosonyx chalybaeus*) belongs to the family Chrysomelidae and order Coleoptera is the most damaging pest of colocasia. The adult causes damage up to 20 – 30 % in leaves and 80 – 90 % in corms (Rajasekhara Rao, 2013). The pest was first reported in Meghalaya, Northeast India (Barwal, 1988). The adults are shiny, bright metallic blue or pink in colour. The beetle infestation is noticed during May in Northeast India, and the activity of these beetles is more during June to August. The female lay eggs in leaf sheath, and they hatched in 4 – 5 days. The larvae mainly feed the corms by making holes and tunnels into it. They are mainly found in the soil around the corms. The affected corms become rot and become unfit for marketing and animal feed. The severely affected plant will die and foul smell will come from the

Table 4. Traditional cuisines prepared from various parts of colocasia

Cuisine	Parts used
Pan iromba (taro chutney), Pan thongba (taro curry), Uti curry, Hawaijar Pan Thongba, Uti chutney, Bal kan, Manglok curry, Hinjang, Chagem pomba, Teangwan, Tunggan, Teanghoi, Teang, Tunkhon, Tung Pai, Tungkhai, Tunguhok	Tubers/corms
Dolhou, Fluo, Teangyakhoi, Fluo curry, Tungrhak, Anishi	Leaves and shoots
Dolhou, Shouhwan, Tung Rahak Sui, Tungkungsui	Petiole

(Sethuraman *et al.,* 2013, 2014)

affected plants. The adult beetles feed the leaves and make several circular holes. The adult beetles hide in the cracks and crevices in the soil and places in the sheath. They are active during the day time. The infestation is high in mono cropping than mixed cropping system.

CONCLUSION

Northeast India is rich in biodiversity several crop species. Of which, colocasia is one of the important edible aroid. The tubers are rich in starch, and other nutrients. The leaves are rich in crude protein. Rich genetic diversity is found in jhum fields, homestead gardens, road sides, water bodies and wild for both cultivated and wild species of colocasia. The crop attained prime importance among the ethnic groups and became one of the important staple foods after rice and maize. The leaves, petioles, and tubers are edible and play a vital role in livelihood and nutritional security of rural poor. Several ethnic foods have been prepared from leaves, petioles and tubers and the leaves, petioles and damaged tubers are fed to the pigs along with local grasses and kitchen waste. The crop is affected by number of pest and diseases. Phytophthora leaf blight and corm borer are the important disease and pest that cause considerable damage to the crop in Northeast India. All the germplasm present in this region are susceptible to the disease and pest. Morphological and molecular characterization of colocasia germplasm indicated a high level of genetic variability exists in this region. However, little or no attention has been given for conservation of colocasia. This has resulted in loss of several valuable germplasm. Further, Phytophthora leaf blight, corm borer, climate change, urbanization, decline in soil fertility, change in food pattern, introduction of new crops and varieties possess a great threat to these genetic diversity. Therefore, it is necessary to take urgent steps to collect and conserve these germplasm.

AUTHOR CONTRIBUTION

Thirugnanavel Anbalagan collected the data from different research articles and reviewed. Bidyut C. Deka, Sethuraman Sivakumar, Lily Rangnamei, and Naksungla Walling corrected and approved for the publication.

COMPETING INTERESTS

The authors declare that they have no conflicts of interest associated with this publication.

ETHICS APPROVAL

Not applicable.

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