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Underutilized Tropical Tuber Crops with Hidden Treasure of Food, Nutrition and Medicine

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ABSTRACT: *The underutilized root and tuber crops are hidden treasure of healthy nutritious food. These crops being rich in food, nutrition and resilient to biotic and abiotic stresses can also address the issues like 'Global Hunger Index', 'Malnutrition' and 'sustainable livelihood'. In general, tropical root and tuber crops are considered as the third important crops after cereals and grain legumes. These crops played an important role in food security, nutrition since inception of human habitation in mother earth. Now in the context of climate change, they are gaining the status as best source of adaptive food, nutrition and livelihood. These mainly include cassava (Manihot esculenta Crantz), sweet potato (Ipomoea batatas), taro (Colocasia esculenta), yams (Dioscorea sp.), elephant foot yam (Amorphophallus paeoniifolius), West Indian arrowroot (Maranta arundinacea) and other minor root crops. These crops are important to agriculture, food security and income for 2.2 billion people in the developing countries. They are also recognized as the most efficient transformers of solar energy into food energy. Apart from those major tropical tuber crops, there are some minor crops which are cultivated in small pockets in many parts of the world. Those are rich in functional food properties with nutritional potential and medicinal values. Among those, Chinese potato and arrowroot are having better visibility than rest of the minor tuber crops like yam bean, Queensland arrowroot, Curcuma, Typhonium, Costus, Tacca, Vigna species etc. An attempt was made at ICAR-CTCRI to evaluate yield, starch and other valued properties of these crops. These underutilized root and tubers are rich in minerals, vitamins, antioxidants and dietary fibre. They can play an important role in mitigating hidden hunger through diet diversification. Most of these crops are bestowed with resilience to global warming and climate change. Considering their wide adaptive, climate resilience properties coupled with high value traits, ICAR-CTCRI has taken up great challenge ahead to explore the potential of these 3rd world forgotton crops as source of food, feed, nutrition and health care.*

Keywords: *Chinese potato, arrowroot, curcuma, canna, food-nutrition, medicine.*

INTRODUCTION

Tropical root and tuber crops are considered as the third important crops after cereals and grain legumes. These crops played an important role in food security, nutrition since inception of human habitation in mother earth. Now in the context of climate change, they are gaining the status as best source of adaptive food, nutrition and livelihood. These mainly include cassava (*Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas*), taro (Colocasia esculenta), yams (*Dioscorea* sp.), elephant foot yam (*Amorphophallus paeoniifolius*), arrowroot (*Maranta arundinacea*) and other minor root crops. These crops are important to agriculture, food security and income for 2.2 billion people in the developing countries. Tuber crops have a higher biological efficiency to produce highest rate of dry matter per day per unit area among all the crops. They are also recognized as the most efficient transformers of solar energy into food energy.

International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) by International Food Policy Research Institute (IFPRI) indicate that root and tuber (R&T) crops will play pivotal role as source for diversified food, nutrition and other commercial products over the next two decades.

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Apart from the major tropical tuber crops like cassava, sweet potato, yams and aroids. There are some minor crops which are cultivated in small pockets in many parts of the world. Those are rich in functional food properties with nutritional potential and medicinal values. Among those, Chinese potato (*Solenostemon rotundifolius*) and arrowroot (*Maranta arundinacea*) are having better visibility than rest of the minor tuber crops like yam bean, Queensland arrowroot, Curcuma, Typhonium, Costus, Tacca, Vigna species etc. These minor corps are still grown wild and form an important starchy food for the tribal's inhabiting near to forest tracts. Some are important due to their medicinal as well as industrial applications. Many of these crops have not spread farther than their native habitat due to physiological constraints or lack of adaptability. In order to explore the potentialities of these unutilized and underutilized minor tuber crops, an intensive research programme was initiated at the Central Tuber Crops Research Institute, Thiruvananthapuram. An attempt was made at ICAR-CTCRI to evaluate these crops for tuber yield, biochemical characters, properties of starch and uses.

As part of the exploration programme for the collection of underutilized tuber crops, several exploration trips were made separately and jointly in collaboration with National Bureau of Plant Genetic Resources, Trichur. Exploration trips were carried out in different parts of Kerala, Tamil Nadu, Karnataka , Bihar, Jharkhand, Madhya Pradesh, Uttar Pradesh, Assam, Meghalaya and Nagaland. Apart from the tribal settlements, some rural villages were also visited for collecting the indigenous knowledge about the utilization of these minor tuber crops. A total of 258 accessions, belonging to 9 crops which included 87 accessions of Chinese potato, 145 accessions of Yam bean, 5 accessions of Canna, 4 accessions of Arrowroot, 2 accessions ofCostus and one accession each of Tacca, Vigna, 3 species of Typhonium and 10 curcuma species were collected and maintained in the field gene bank. All these crops were evaluated for tuber yield.

Biochemical characters like dry matter, starch, sugar and lipid content were estimated according to the standard methods (AOAC,1975). Starch was extracted from the tubers and studied for their rheological properties. The starch granule size was examined using Scanning Electron Microscope. The available information on botany, starch properties and uses of such nine tropical minor tuber crops of immense importance are presented as follows.

Chinese Potato (*Solenostemon rotundifolius*) (Poir) J.K. Morton

Solenostemon rotundifolius (Poir) J.K. Morton (Syn. *Plectranthus rotundifolius* Poir, *Coleus Parviflorus* Benth, Frafra potato, Hausa potato, Chinese potato) is a member of the family, Labiatae. The crop is speculated to have originated in Kenya or Ethiopia from where it spread to other parts of Africa and South-east Asia. The tubers are usually round or slightly elongated in shape with thin skin and are an important food item during lean periods in Africa. The tubers are rich in several minor nutrients and vitamins, which help in the proper functioning of the body. The tubers rich in calorie is comparable with potatoes (Table 1). Tubers are also rich in amino acids *viz.* arginine, aspartic acid, glutamic acid and minerals like calcium and iron. The tubers possess flavour are source of antioxidants, medicinal values in form of flavonoids.

Table 1
Comparaison of nutrient contents of Chinese potato andpotato

Component /100g fwb	*Potato*	*Chinese potato*
Energy(KJ)	322	394
Protein (g)	2.0	1.3
Fat (g)	0.09	0.20
Carbohydrate (g)	17	21
Fibre (g)	2.2	1.1
Sugar (g)	0.78	-
Calcium (mg)	12	17
Vitamin C (mg)	19.7	1.0
Thiamine (mg)	0.08	0.05
Iron (mg)	0.78	6.0

Source : Enyiukwu *et al.* (2014)

The flavonoids of Chinese potato have been reported to lessen blood cholesterol as well aspossess high antioxidant activity. There are several reports on the use of Chinese potato in Africa and Asia, for the treatment of dysentery, sore throat, eye disorders and hematuria. Despite these functional food properties, the importance of the crop is declining. These crops need commercial visibility through value added products and high value processed products.

In India, it is an important minor tuber crop grown extensively as a vegetable in most of the homestead gardens in Kerala and Tamil Nadu. It is a small herbaceous bushy annual with succulent stems and aromatic leaves. The plants bears a cluster of heteromorphous tuber with aromatic flavor, which makes it likeable as a delicacy among the vegetables.

It isgenerally raised as a monsoon crop and the duration is 4-5 months. Even though profuse flowering was observed during September-November season, the crop is completely sterile due to the lack of fertile pollen grains. Highly irregular meiosis and occurrence of desynapsis might have resulted in the complete sterility of the crop. The analysis of data on frequency of different size of tubers also revealed that no significant difference between the accessions. The average weight of medium and big size tubers were on par and the average weight of small and very small tubers were not significantly different on their mean values.

Significant difference was observed in tuber size within the accessions and not between the accessions. Evaluation of 87 accessions of Chinese potato showed that not much variation existed between the accessions in morphological or tuber characters. This may be the consequence of vegetative propagation and sterility of the crop. The promising 11 accessions were tested in the multilocation trial in Kerala and one accession 'CP-58' which recorded 25.0-28.0 t ha^{-1} tuber yield was released as 'Sree Dhara' in 1993, the first variety for Chinese potato. The dry matter and starch content of the tuber was 28.5 and 19.5 per cent respectively. In the year 2000 another selection 'Nidhi' was released by the Kerala Agricultural University. Thereafter other selections released as varieties are Sufala,Co-1 etc.

HIGH TOTIPOTENCY OF CHINESE POTATO

Chinese potato can propagate through tuber sprouts and cuttings easily. It is highly totipotent. In fact tissue culture of chinese potato was done to study in vitro, cell expressions of various drugs for remedies prior to therapeutic uses of new drugs. Any part of tissue can easily regenerate. In tissue culture study, it regenerated through axillary shoot proliferation, organogenesis and somatic embryogenesis. An elaborate study at ICAR-CTCRI Regional Centre revealed easy regeneration protocol through callusing and somatic embryogenesis (Figure 1 and 2). Plants were hardened (Figure 3) and produced bigger tubers in the field. Yield evaluation of in vitro grown different varieties of Chinese potato plants revealed good yield (Figure 4) in the range of 100-220 g/ plant. Starch recorded as 16.5-20% and dry matter 26.4-35.6%.Highest starch content (20%) was recorded in callus regenerated plants of Sree Dhara (SDC) [Table 2].

Table 2
Dry matter, starch, sugar contents of in vitro raised Chinese potato of different varietal sources

*Regenerants**	*DM (%)*	*Starch (%)*	*Sugar (%)*
SD 1	31.5	18.8	2.8
SD 2	30.4	18.3	2.6
Su 1	35.6	18.4	3.1
Su 2	34.2	18.2	3.4
Co 1	32.4	17.5	2.6
Co 2	30.8	17.8	3.0
Ni 1	28.0	16.5	2.6
Ni 2	26.4	17.2	2.2
SDC	28.4	20.0	1.8

*Source plants: SD – Sree Dhara, Su – Sufala, Co – Co - 1, Ni – Nidhi, SDC – Callus reg. SD.

Yam Bean (*Pachyrrhizus erosus* (L.) Urban)

Pachyrhizus erosus L. yam bean belonging to the family *Papilionaceae* is a leguminous plant with a taproot

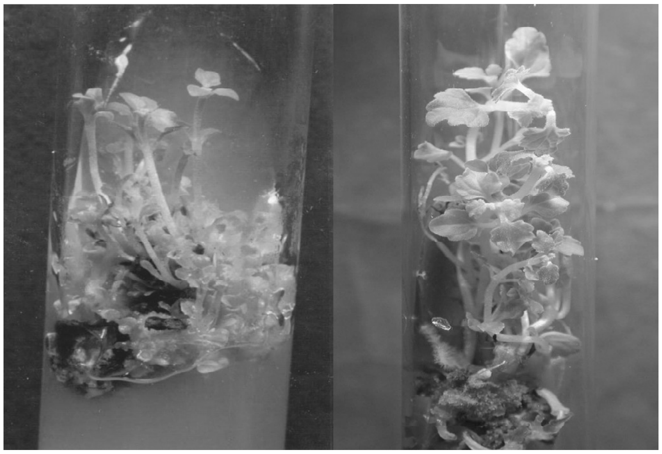


Figure 1. Callusing and regeneration in Chinese potato.

system characterized by tuber production. This plant mainly grows in tropical and subtropical areas in the world. Cultivation of yam bean is expected to lead to sustainable agriculture because its tuber is nutritious and a highly productive crop. It is reported that yam bean tuber contains 32% soluble sugars and 15% starch as storage carbohydrates by dry weightand 1.4% protein by fresh weight.In addition, it is known that the mature pods and seeds of yam bean contain rotenone (an isoflavonoid) as a secondary metabolite. Such seeds extract is great demand especially for organic farming which can prevent harmful insects in a vegetable field.

Its potential as cash crop and to meet required food and nutrition demands especially in frazile zones have been revalidated in recent years.

The morphological diversity recorded in this species appears to be centred in Central America. Its cultivation spread to Indonesia and further introduction took place from the Philippines and Indonesia via Ceylon and India along the west coast of the African continent. Yam bean a herbaceous vine, it shows wide variation in leaflet shape, from dentate to palmate. Morphological characters of the legumes (pods), both qualitative and quantitative, are also used to separate the species. The colour (olive-green, brown, or reddish brown) and shape (flat and square to rounded) of seeds are also specific to the species. Yam bean propagated through seeds. Generally through self pollination.

Table 3
Yield trial of Yam-bean, 2011-12, ICAR-CTCRI RC, Bhubaneswar

Sl. No.	*Accession*	*Yield (t/h)*
1.	L.No. 3	29.86
2.	L-19	24.84
3.	EC:100546	22.34
4.	8 × 9	38.93
5.	DPH-9	20.83
6.	DPH-58	16.66
7.	DPH-88	16.66

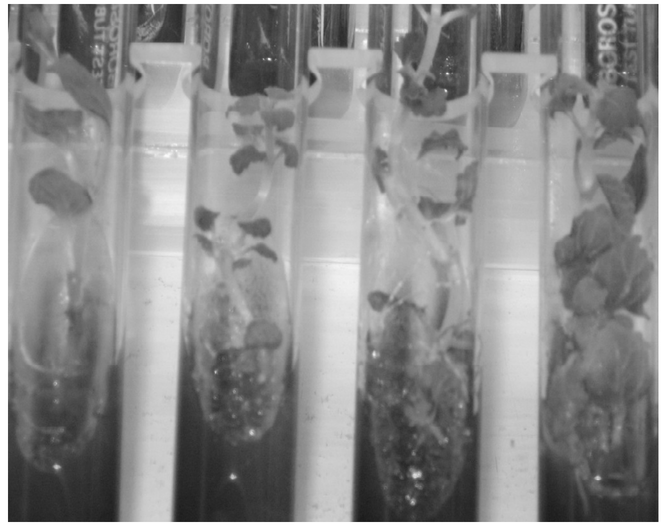


Figure 2. Cultures of different varieties of Chinese potato.

Sometimes tubers are used for planting when particular genotype is desired to be maintained. It grows well on light sandy soil. The plants are pruned once or twice after two months of planting in order to restrict vegetative growth and encourage better tuber development. The crop matures in 6-8 months. Non-flowering plant produces best quality tubers. Hence when grown for tubers, the buds or inflorescence and removed to prevent flower development. Yam bean being a legume, fixes nitrogen and hence increased the soil fertility.

The 191 accessions of yam been were evaluated for tuber yield and biochemical characters. The dry matter ranged from 9.17-21.82%, starch varied from

Table 4
Yield trial of Yam-bean, 2012-2013, ICAR-CTCRI RC, Bhubaneswar

Sl. No	*Accession*	*Yield (t/h)*
1.	L-19	30.51
2.	L No.3	29.35
3.	8 × 9	31.1
4.	ECI00546	23.95
5.	DPH-9	19.9
6.	DPH-58	21.56
7.	DPH-70	19.98
8.	DPH-88	20.37
9.	BCYB-1	18.91
10.	BCYB-2	21.86
	CD(0.05)	*2.6*

Table 5
Dry Matter (%) of Yam-bean, 2012-2013, ICAR-CTCRI RC, Bhubaneswar

Sl. No	*Accession*	*R1*	*R2*	*Mean (Dry matter %)*
1.	L-19	20	20.4	20.2
2.	L No.3	18	17.8	17.9
3.	8 × 9	20.6	20.85	20.73
4.	ECIW546	20	19.77	19.885
5.	DPH-9	20	20.24	20.12
6.	DPH-58	18	17.8	17.9
7.	DPH-70	18	19.2	18.6
8.	DPH-88	19	19.45	19.23
9.	BCYB-1	20	20.5	20.25
10.	BCYB-2	19	18.9	18.95
	CD(0.05)			*0.717*

3.63-15.78% and sugar content ranged from 3.07-5.43%. Recurrent evaluation selected 8 promising parents from collection at ICAR-CTCRI and its Regional Centre (Table 3).

Yield of hybrid line 8 × 9 was significantly higher (38.9 t/ha) than other lines. ICAR-CTCRI along with other coordinating centres are being engaged in yam bean improvement programmes and have already released many improved varieties through All India Co-ordinated Research Project on Tuber Crops [AICRP(TC)].

The improved varieties released in yam bean are Rajendra Mashrikand-1 (RM-1), RM-2 and five more are in advanced trials for release in Dholi. At Bhubaneswar the hybrid line 8 × 9 (Figure 5) is in advanced trial for release and five promising genotypes are under AICRP recommended various trials.

Ten promising lines of Yam bean (four each from Bhubaneswar, Dholi and two from BCKV) were

Figure 4. Tubers of in vitro raised Chinese potato plants

Figure 3. Hardening of Chinese potato.

selected for breeding through diallele design (Table 4 and Figure 6). The Yield of hybrid line 8 × 9 was significantly higher (31.1 t/ha) than other lines followed by the entry L-19 (30.51t/ha), L No-3 (29.35 t/ha) and EC100546 (23.95 t/ha) of Bhubaneswar. The Dholi lines showed moderate yield [Table 4]. The dry matter content was found to be higher in the hybrid line 8 × 9 (Table 5). Of the 10 entries tested, 8 × 9 Was found to be highest with respect to harvest index (Table 6).

Improvement of yam bean through diallele crosses is also under way at Regional Centre, Bhubaneswar. Such breeding efforts resulted in

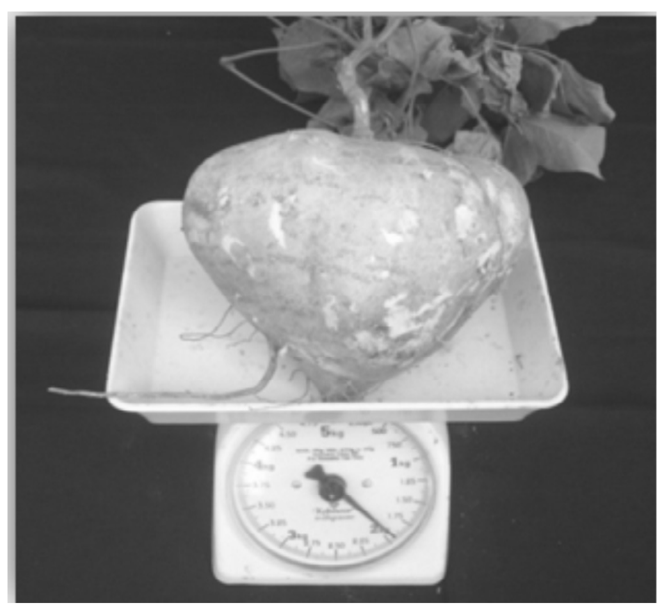


Figure 5 Yam bean hybrid 8 × 9 generated yield more than 30t/ha

Table 6
Harvest index (%) yam bean, 2012-2013, ICAR-CTCRI RC, Bhubaneswar

Sl. No.	*Accession*	*Harvest index R1*	*Harvest index R2*	*Harvest index R3*	*Mean (Harvest index %)*
1.	L-19	81	79	73	77.67
2.	L No.3	79	57	81	72.33
3.	8 × 9	83	85	86	84.67
4.	ECIW546	73	76	77	75.33
5.	DPH-9	73	67	71	70.33
6.	DPH-58	81	69	70	73.33
7.	DPH-70	73	79	82	78
8.	DPH-88	81	79	78	79.33
9.	BCYB-1	74	71	72	72.33
10.	BCYB-2	61	76	80	72.33
	CD(0.05)				*3.5*

Figure 6 Diallele crosses of yam bean (ICAR-CTCRI RC)

developing 45 (Table 7, Figure 6) different combination of ten selected parental sources. Quest for valued traits like early maturity, high dietary fibers, low sugar contents with good yield are being going on with the filial generation of diallele crosses.

Queensland Arrowroot (*Canna edulis*ker-Gawler)

Canna edulis is perennial herb, growing to a height of 1.0-2.5m, leaves are arranged spirally with a prominent midrib and numerous lateral veins. It is widely distributed throughout thetropics and sub-tropics. It is grown for its branched and fleshy rhizomes. The plant is hardy and in view of low incidence of pest and diseases as well as the wind resistance of the crop, it is considered easy to grow in the typhoon region (Kurtia, 1967) . In Japan it is grown as a fodder crop. It is commercially cultivated in Australia for its starch. In India, it is grown for the edible. The flowers of ornamental cannas are large and more beautiful and variable in colour than the edible types. Although both types of canna store starch in the root-stocks, the edible types have more

Table 7
Diallele cross in Yam Bean, 2012-2013, ICAR-CTCRI RC, Bhubaneswar

Sl. No.	*Accessions(Cross)*	*No. of seeds*
1.	1 × 2	13
2.	1 × 3	20
3.	1 × 4	22
4.	1 × 5	16
5.	1 × 6	38
6.	1 × 7	19
7.	1 × 8	21
8.	1 × 9	21
9.	1 × 10	24
10.	2 × 3	18
11.	2 × 4	10
12.	2 × 5	14
13.	2 × 6	13
14.	2 × 7	12
15.	2 × 8	19
16.	2 × 9	15
17.	2 × 10	15
18.	3 × 4	35
19.	3 × 5	13
20.	3 × 6	16
21.	3 × 7	13
22.	3 × 8	16
23.	3 × 9	7
24.	3 × 10	13
25.	4 × 5	10
26.	4 × 6	17
27.	4 × 7	12
28.	4 × 8	16
29.	4 × 9	13
30.	4 × 10	28
31.	5 × 6	14
32.	5 × 7	10
33.	5 × 8	15
34.	5 × 9	16
35.	5 × 10	14
36.	6 × 7	15
37.	6 × 8	9
38.	6 × 9	18
39.	6 × 10	13
40.	7 × 8	14
41.	7 × 9	18
42.	7 × 10	11
43.	8 × 9	7
44.	8 × 10	22
45.	9 × 10	11

fleshy rhizomes with better flavor, taste, low fibre and less tannin content than the ornamental types (Arbizu, 1994).

The rhizomes are formed in a compact mass. The small terminal portion of the rhizomes are used for planting. Duration of the crop varied from 8-12 months. The tubers are eaten boiled or baked. Starch is obtained from the tubers by a process of rasping, washing and straining. The final product is a shiny, cream coloured powder. Starch is easily digestible and used as food for children and invalids. Based on the leaf and emerging leaf colour and other morphological characters the five accessions in the germplasm are grouped into three morphotypes namely, dark purple, purple and green accessions. Out of five accessions only tow (dark purple and green) are edible. The leaves of edible accessions are bigger than the non edible accessions. Eventhough flowering was observed in all the accessions no seed set was observed in the edible accessions. The yield data revealed that maximum yield of 32.8 t ha^{-1} was recorded in the park purple accessions followed by 24.7 t ha^{-1} in the green accession. In the other three accessions the yield varied from 11-20 t ha^{-1}.

Tubers of dark purple and one green accession was more fleshy, had better taste and low fibre and phenol content than the other three accessions. The biochemical analysis of tubers indicated the dark purple accession had higher dry matter (35.7%) and starch (27.03%) compared to other accessions.

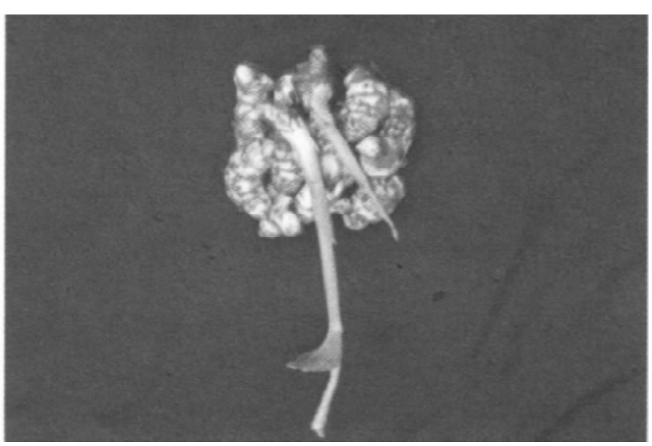
The studies on physico chemical properties also revealed that canna starch has good potential in food application since it possesses high viscosity, gel strength and high phosphours content (Moorthy *et al*, 2002). Hermann (1994) reported that the bakery products prepared from canna starch are much lighter, crispier and tastier than those from wheat.

West Indian Arrowroot *Maranta arundinacea* L.

West Indian Arrowroot (*Maranta arundinacea* L.) is a perennial herb, cultivated for its edible rhizomes, throughout the tropical countries of the world.

It is an under exploited tuber crops having tremendous potential in food and pharmaceutical industries. The tubers contain about 10% natural starch available on the earth. The amylose content in starch ranges between 16 to 27%. Arrowroot starch is popular for its high digestibility and medicinal properties thus used as digestible food for children and people with dietary restrictions. The starch is often used as a thickener in all kinds of foods. It is also used as base for starch derived food products like biscuits, puddings, jellies, cakes, hot sauces etc. The lack of gluten in arrowroot starch makes it ideal substitute for wheat flour in baking.

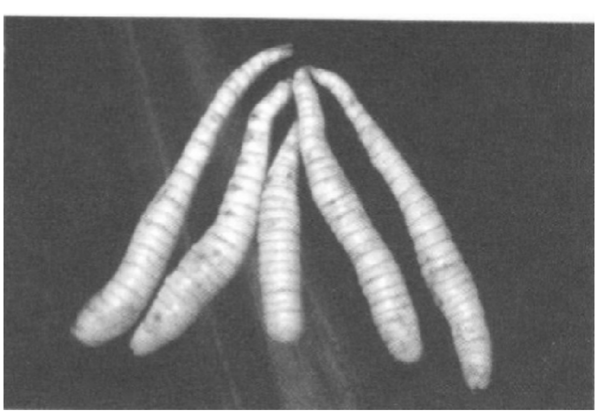
The plant is an erect, perennial herb, 1.0-1.5 m high shallow-rooted with rhizomes penetrating into the soil. The plant thrives best in light, well drained,



loamy or sandy soil and partial shade is beneficial. It is propagated by tips of rhizomes known as 'bits' which contains 2-4 nodes. The small rhizome containing eyes are used for planting. The is ploughed and the bits are planted, 5.0-7.5 cm deep and 30 cm apart. Usually planting is done in May. The shoots come up within 15 days. Irrigation is necessary during the growing period and the flowers are nipped off as they appear. The rhizomes are ready for harvest in 10-11 months after planting. Maturity is indicated by yellowing, wilting and drying up of leaves. Harvested rhizomes are 20-45 cm long and 2.5 cm thick.

The tubers are eaten boiled or baked and the bulk of the material is used for the production of starch. Arrowroot starch is a fine, white powder and it is tasteless and odourless when dry, but a faint odour develops when it is wet or cooked. The starch granules are ovoid or ellipsoid in shape. The starch is easily digestible and valued as a food especially for infants, invalids and convalescents. It is used in the preparation of biscuits, cakes puddings and jellies. It possesses demulcent properties and is given for correcting bowel complaints. It is employed as a suspending agent in the preparation of barium meals the starch is preferred in tablet making since it disintegrates fast. Arrowroot starch is used as a base for face powders and in the preparation of special glues (CSIR, 1962).

Four accessions of arrowroot collected from Kerla, Bihar, Madhya Pradesh and Shillong are maintained in the germplasm. The tuber yield of four accessions ranged Shillong are maintained in the germplasm. The tuber yield of four accessions ranged from 22-25 t/ha under open conditions. There was no significant difference between the accessions for tuber yield, morphological and biochemical characters. Tuber contains 30.69-31.25% dry matter and 17.20-18.86% starch.



Curcuma Species

Out of 10 Curcuma species, two species C. *amada* and C. *zedoaria* and distributed throughout India in the wild and cultivated forms ; four species C. *aerugiosa*, C. *brog*, C. *caesia* and C. *sylvatica* occur in wild conditions and distributed throughout north eastern part of india. C. *malabarica* and C. *aromatic* occur in south India while C. *raktakanta* and C. *harita* are distributed throughout Kerla (Velayudhan et al, 1999).

The root stocks and sessile tubers vary in colour from pale yellow, orange yellow, lemon yellow, green and blue (Velayudhan et al, 1999). This is the most valuable character for the identification of the species. Tuber taste and aroma also vary considerably. Most of the species have a camphoraceous odour and some are odourless and tasteless. Out of the 10 species, only C. *amad*a and C. *sylvatic*a posses mamngo aroma in the rhizomes.

The tuber yield of different species varied from 1.0-2.0 kg per plant. The biochemical composition of the different curcuma species showed that dry matter ranged from 21.2-31.4%. Maximum starch was recorded in C. *malabarica* (21.4%) followed by C. *caesia* (19.86%) and C. *brog* (18.0%). All the other speices possess 10-15% starch.

Scanning electron microscopy studies revealed that the starch granules are round or oval in shape and consisted of both small sized and large size ones. The granule size ranged from 6-25 μ for C. *zedoaria*, C. *raktakanta*, C. *caesia*, C. *aerugsoma* and C. *aromatic*. In C. *malabarica*, C. *brog* and C. *sylvatica* it varied from 10-40 μ m.

Considering the plant characteristics of the various species of curcuma, all of them may contain medicinal principles and a thorough biochemical and clinical investigation on all the species would be highly useful.

Curcuma brog Val.

Plants are semi erect with green leaves and light green midrib. Root stocks are oblong, long fusiform tubers, pale yellow flesh with camphoraceous smell and bitter taste.

Plant height :80-100 cm
Yield : 1.5-2.0 kg / plant
Dry matter : 30.40%
Starch : 18.00%
Sugar : 0.99%
Lipids : 0.79%
Starch Granule Size : 10-40 μ m

Curcuma malabarica Vel.

Plants are semi erect with green leaf sheath and light purple midrib. Root stocks are slightly oblong, fusiform tubers, pale blue flesh with camphoraceous smell and bitter taste.

Plant height : 100-120 cm
Yield : 1.5-2.00 kg/plant
Dry matter : 31.4%
Starch : 21.4%
Sugar : 0.91%
Lipids : 0.75%
Starch Granule Size : 10-40 μ m

Curcuma amada Roxb.

Plants are semi erect with green leaves and leaf sheath. Root stocks are oblong, pale yellow or white in colour with mango aroma and no taste.

Plant height :85-100 cm
Yield : 1.25-1.50 kg/plant
Dry matter : 22.40%
Starch : 10.22%
Sugar : 0.72%
Lipids : 1.01%
Starch Granule Size : 8.60-21.60 μ m

Curcuma aromatica Salisb

Plants are semi erect, leaves with green leaf sheath and green midrib. Root stocks are oblong with fusiform tubers, camphoraceous smell and bitter taste.

Plant height : 75-90 cm
Yield : 1.25-1.50 kg / plant
Dry matter : 28.80 %
Starch : 15.00%
Sugar : 0.99%
Lipids : 1.27%
Starch Granule Size : 10.0-33.30 μ m

Curcuma zedoaria Rosc.

Plants are erect with green leaf sheaths and light purple midrib. Root stocks are oblong with fusiform tubers, dark orange flesh colour, camphoraceous smell and bitter taste.

Plant height : 135-150 cm
Yield : 1.25-1.50 kg / plant
Dry matter : 25.0 %
Starch : 14.06%
Sugar : 1.3%
Lipids : 0.78%
Starch Granule Size : 6.60-23.00 μ m

Curcuma aeruginosa Roxb.

Plant are semi erect with green leaves and dark purple midrib. Root stocks are oblong, fusiform tubers, camphoraceous smell and bitter taste.

Plant height : 85-100 cm
Yield : 1.25-1.50 kg / plant
Dry matter : 29.30 %
Starch : 14.10%
Sugar : 1.41%
Lipids : 0.47%
Starch Granule Size : 6.66-33.30 μ m

Curcuma harita Mangaly and Sabu

Plants are semi erect with green leaf sheath and midrib. Root stocks are oblong, fusiform tubers, white or cream flesh colour, camphoraceous smell and bitter taste.

Plant height : 75-90 cm
Yield : 1.00-1.25 kg/plant
Dry matter : 24.1%
Starch : 14.32%
Sugar : 1.11%

Curcuma caesia Roxb.

Plants are erect with purple leaf sheath and midrib. Root stocks are oblong, fusiform tubers, dark bluish flesh colour with camphoraceous smell and bitter taste.

Plant height : 85-95 cm
Yield : 1.00-1.25 kg/plant
Dry matter : 31.00 %
Starch : 19.86%
Sugar : 0.84%
Lipids : 0.81%
Starch Granule Size : 6.66-26.60 μ m

Curcuma raktakanta Mangaly and Sabu

Plants are semi erect with dark purple leaf sheath and brown midrib on the leaves. Roots stocks are oblong, fusiform tubers with camphoraceous smell and slightly bitter taste.

Plant height : 100-125 cm
Yield : 1.50-1.75 kg / plant
Dry matter : 28.80 %
Starch : 14.20%
Sugar : 0.62%
Lipids : 1.15%
Starch Granule Size : 6.66-26.60 μ m

Curcuma sylvatica Val.

Plants are semi erect with green leaves and midrib. Root stocks are oblong, fusiform tubers, white with pale yellow flesh, mango aroma and bitter taste.

Plant height : 100-125 cm
Yield : 1.00-1.25 kg / plant
Dry matter : 21.20 %
Starch : 10.34%
Sugar : 1.11%
Lipids : 0.76%
Starch Granule Size : 10.33-36.60 μ m

Typhonium Species

The genus Tryphonium includes perennial tuberous herbs distyributed though out India. In CTCRI three species of Typhonium are maintained in the germplasm. Out of three species, maximum yield was observed in T. *trilobatum*. There was not much difference between the dry matter and starch content between the species. However maximumdry matter (36.44%) and starch content (23.68%) was observed in T. *flagelliforme*.

Scanning Electron Microscopic studies revealed that starch granules are polygonal, or round in shape and consist of both small and large sized ones. Small sized granules ranged from 3-10 μ m and the large granules varied from 10-20 μ m.

Typhonium trilobatum Schott.

Typhonium trilobatum distributed in the northeastern region of India. The plants are erect with trilobed leaves grown to a height of 50-75 cm. The globose tubers are acrid and used as a vegetable (CSIR,1976).

Plant height :40-50 cm
Tuber Yield : 150-200g / plant
Dry matter : 33.00 %
Starch : 22.50%
Sugar : 0.71%
Lipids : 0.92%

Typhonium flagelligorme

Typhonium flagelliforme. The tubers are globose and leaves are hastate and sagittately cordate in shape.

Plant height :20-25 cm
Tuber Yield : 75-100g / plant
Sugar : 1.06%
Lipids : 0.76%
Dry matter : 36.44 %
Starch : 23.68%

T. divaricatum Deone

T. divaricatum is a perennial herb with sagitate leaves and sub-globose small tubers. The tuber yield varied from 25-50g/plant

Dry matter : 32.00%
Starch : 23.07%
Sugar : 1.42%
Lipids : 0.85%

7. *Costus Speciosus* (Koenig) Sm.

The genus Costs includes about 175 species of perennial herbs. Costus speciosus is a common plant with tuberous rhizome distributed throughout India up to an altitude of 4000 ft. It is common in Bengal and Konkan areas and often cultivated as an ornamental plant. It attains a height of approximately 1.0-1.5m and white coloured flowers appear on the top of the plant. The rhizome has purgative and tonic properties. The root is used as tonic and anthelminthic in Uttar Pradesh (CSIR, 1950).

About 200 plants were evaluated for 3 years. Rhizome is edible and is used after cooking. The flesh is white, mucilaginous, feeble astringent but has no aroma. Compared to other tuber crops the fibre content is high.

Tuber yield : 1.30-1.50 kg/plant
Dyr matter : 16.40 (%)
Starch : 10.48%
Sugar : 1.30%

***Tacca Pinnatifida* Forst and Forst. F.**

The genus Tacca includes about 30 species of perennial herbs with tuberous or creeping rhizomes. Tacca pinnatifida originated in south east Asia and widely distributed in the moist tropics of Asia, Austrlia and Pacific islands. The plant is perennial herb and grows to a height of 60-90 cm. the tubers are globose, 15-20 cm in diameter and harvested after the tops have died down. The tubers are used for the treatment of piles. A bitter extract prepared by washing the grated tubers in running water is rubefacient and is given for diarrhea and dysentery (CSIR, 1976).

The fresh acrid, bitter tubers are peeled, macerate, repeatedly washed in several changes of water and strained through a coarse cloth. The final product when dried yields nutritive starchhaving excellent culinary properties. The product is known as ‘Fiji’ or ‘Tahiti’ or ‘East Indian arrowroot’ starch. The starch is used to prepare porridges, cakes and other sweet meals. It is also mixed with wheat flour for making bread. The starch is recommended as a food for invalids and also used as laundry starch (CSIR, 1976). The evaluation of the few plants showed that the tuber yield varied from 150-250g/plant and the shape of tubers resembles potato. The tubers possess 22.40% dry matter and 10.22% starch and 0.54% sugar content.

***Vigna Vexillata* (L.) A Rich**

Syn.* Vigna capensis *Walp.

The genus Vigna includes climbing or trailing herbs, distributed mostly in the tropical and sub-tropical regions. In India, nearly 15 species are known, some of which form an important protein supplement and some are valued as green manure or cover crop (CSIR, 1976). It is a new unexploited edible tuber crop (Chandel *et al.*, 1972). It grows wild in western Ghats, central Peninsular hills, western Himalayas and Meghalaya. The plant is a twining herb with stipulate, alternate trifoliate leaves. Tubers are fusiform and one tuber is borne on each plant. However, 2 tubers or branched tubers are also observed in some plants. Tubers are 5-11 cm long, 1.5-2.0 cm broad. The tubers have an easily peelable skin. The seeds can be used as a nutritious vegetable. These group of plants usually require low inputs and adapted to varying agro climatic conditions and are tolerant to biotic and abiotic stresses.

Microscopic examination of starch granule revealed that they are round cupuliform or convex or biconvex in shape and composed of small and large grains. The size of small grains ranged from 3.8-7.0 μ m.

Tuber yield : 95-100 g/plant
Dry matter : 19.80%
Starch : 9.7 %
Sugar : 1.28%

CONCLUSION

The evaluation of minor tuber crops showed that some of these crops have high yield potential (> 30t ha^{-1}) and can act as a carbohydrate reserve to support the food security of the country. Canna starch resembles yam starch in most of the functional properties. The starch has good potential in food application due to its high viscosity, gel strength and paste stability. Arrowroot starch is commercially used in the preparation of different types of biscuits and other bakery products. All curcuma species are used by the local people for the starch extraction because of its medicinal properties. The tubers of Costus, Typhonium, Vigna and Tacca are used as a vegetable. Considering the importance of these crops and food, medicine and for industries these underutilized crops can be exploited at the commercial level. The high nutritional qualities indicate that the cultivation and consumption of these crops may be helpful in overcoming the nutritional deficiencies predominant in many rural areas of the country.

Current Context and Future Thrust

In the present context of rapid increases of population and consequent shortage of food grains, collection and utilization of various types of unutilized and underutilized tuber crops are considered very essential. Ample scope exists for the exploitation of these minor tuber crops for correcting the deficiencies arising on the food shortage of the country in the yearto come. Tuber crops are the third important food crops after cereals and legumes. They contribute about 6% of the world's dietary calories and also sources of animal feed and raw materials for industrial products.

The present phase of climate change compounded with various issues in agri horticultural sectors all over the world. Such as reducing availability of quality water, nutrient deficiency in soils, climate change, farm energy availability, loss of biodiversity, emergence of new menace, IPRs and trade security. India and developing nation will be affected severely. Food, nutrition, livelihood and environmental security for the billion plus population in our country is a greater challenge. As we know, India will be the most populous nation with 1.69 billion people by 2050. It indicates a growing demand for dietary calorie in India till 2050.On the otherhand global production of wheat and rice has been projected to decline by 2-6% by 2030 and 5-11% by 2050. The likely demand supply gap of major food grains can be effectively bridged by tuber crops that are rich sources of carbohydrate. It is predicted that cereal consumption in India will decline from 60% of total kcal uptake at present to 48% by 2050. On the contrary, there will be considerable increase in vegetable consumption including roots and tubers. In India, it is estimated that around 48% of all children under the age of five are stunted, 74.30% suffer from anemia, 62% suffer from vitamin A deficiency and 31.30% suffer from iodine deficiency.

These root and tuber crops, especially underutilized R and T are rich in minerals, vitamins, antioxidants and dietary fibre. They can play an important role in mitigating hidden hunger through diet diversification. Most of those have higher biological efficiency as food producers with high dry matter production per unit area per unit time. The tuber crops have proved to be life sustaining crops in natural vagaries and famine. Most of these crops are bestowed with resilience to global warming and climate change. Considering their wide adaptive, climate resilience properties coupled with high value traits, ICAR-CTCRI has taken up great challenge ahead to explore the potential judiciously of these 3rd world crops as source of food, feed, nutrition and health care.

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