Tuber Crops Manual

06 March, 2024

Tropical Tuber Crops: Production Technologies, Value Added and Functional Foods


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ICAR-CENTRAL TUBER CROPS RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
Sreekariyam, Thiruvananthapuram – 695017. Kerala.

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Contents

Tropical Tuber Crops: A potential crop for food, nutritional and energy security

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Importance of tropical tubers

Tropical tuber crops form an important staple serving as secondary or subsidiary food for about one sixth of world population in tropics and sub-tropics regions. It is third important group of food after cereals and pulses. Cassava or tapioca (*Manihot esculenta Crantz*), sweet potato (*Ipomoea batatas* (L.) Lam.), yams (lesser yam - *Dioscorea esculenta Burk.*, greater yam - *Dioscorea alata* L. and African white yam - *Dioscorea rotundata* Poir.), aroids: taro or arum- *Colocasia esculenta* (L.) Schott., tannia - *Xanthosoma sagittifolium* Schott. and elephant foot yam- *Amorphophallus paeonifolius* (Dennst) Nicolson.), Chinese potato (*Solenostemon rotundifolius* Poir.) and yam bean- *Pachyrrihizus erosus* L. are the most important tropical tuber crops. These crops have higher photosynthetic efficiency as food and energy producers and can serve as substitute for cereals due to higher carbohydrate and calorie content. The starch extracted from these crops have potential as sources of alcohol, starch, sago flour, liquid, glucose and as raw materials for many other industrial products and animal feed. Besides energy, root crops are also good sources of vitamins (especially vitamin A and vitamin C), dietary fiber and important minerals like calcium and phosphorus.

Nutraceuticals like antioxidants, anthocyanins, flavonoids, phenolics etc. in various root crops offer several health benefits to the consumers ranging from prophylactic effect on stress-related diseases like cancer and cardiovascular conditions, diabetes, hypertension, etc. to curative/therapeutic effect in conditions like piles and obesity. Hence tropical tuber crops share a place with cereals as dietary staples both in raw and processed forms. Moreover, these plants are hardy in nature and they can be grown on a wide range of soil, climate and environment and have the capacity to withstand adverse biotic and abiotic stresses, where other crops fail to grow. Tropical tuber crops in general are rainfed in nature. However, several studies have revealed that manifold increase in tuber yield could be achieved with irrigation and good agronomic practices. Because of the high photosynthetic efficiency and the consequent synthesis of carbohydrates, tuber crops are rated as one of the richest sources of energy. The higher biological efficiency and the highest rate of dry matter production per unit area per day make tuber crops inevitable components in our food security systems. They are also recognized as the most efficient converters of solar energy, cassava producing 250 x 10^3 kcal/ha and sweet potato 240 x 10^3 kcal/ha, as compared to 176 x 10^3 kcal/ha for rice, 110 x 10^3 kcal/ha for wheat and 200 x 10^3 kcal/ha for maize; hence these tropical root crops are known to supply cheap source of energy.

Tropical Tuber Crops of ICAR -CTCRI

Crop	**Scientific Name**	**Family**
Cassava	*Manihot esculenta* Crantz	Euphorbiaceae
Sweet potato	*Ipomoea batatas* (L.) Lam.	Convolvulaceae
Greater yam	*Dioscorea alata* L.	Dioscoreaceae
White yam	*Dioscorea rotund ata* Poir.	Dioscoreaceae
Lesser yam	*Dioscorea esculenta* (Lour.) Burkill	Dioscoreaceae
Aerial yam	*Dioscorea bulbifera* L.	Dioscoreaceae
Other yams	*Dioscorea hispida* Dennst.	Dioscoreaceae
	Dioscorea pentaphylla L.	Dioscoreaceae
Arvi/Taro	*Colocasia esculenta* var. *antiquorum(L)* Schott	Araceae
Bunda	*Colocasia esculenta* var. *esculento(L)* Schott	Araceae
Swamp taro	*Colocasia stoloniferum* (L.) Schott	Araceae
Tannia	*Xanthosoma sagittifolium* (L.) Schott	Araceae
Elephant foot yam	*Amorphophallus paeoniifolius* (Dennst.) Nicolson	Araceae
Giant taro	*Alocasia macrorrhizos* (L.) G. Don	Araceae
Giant swamp taro	*Cyrtosperma chamissionis* (Schott) Merr.	Araceae
Country potato	*Solenostemon rotundifolius* (Poir) J.K. Morton	Labiatae
Arrowroot	*Maranta arundinacea* L.	Marantaceae
Canna	*Canna edulis* Ker-Gawler/ *Canna indica* L.	Cannaceae
Winged bean	*Psophocarpus tetragonolobus* (L.) DC.	Leguminoceae
Yam bean	*Pachyrhizus erosus* (L.) Urb	Leguminoceae
Vigna	*Vigna co pensis* (L.) Walp.	Leguminoceae
Typhonium	*Typhonium spp.*	Araceae
Costus	*Costus speciosus* (Koenig) Sm. (J. Konig) C. Specht.	Costaceae
Shoti	*Curcuma spp.*	Zingiberaceae

Tuber crop starch invariably is superior to the conventional sources of starch and they are efficient biological producers of carbohydrates per unit area per unit time. In times of famine, tuber crops have come in handy to overcome catastrophies and provide relief from hunger. In the 21st century, nearly on fourth of the world population is estimated to be in severe poverty. With the burgeoning population in India, the food demand will be increased upto 40-60% by 2030. It is in the context that the tuber crops assume importance and together with due support of advanced technologies, have a greater role in meeting the food energy and nutrient requirements of the country in the coming years. The ever-increasing population levels coupled with rapidly shrinking cultivable area, increasingly fragile resources lead to a vast scope for diversification and value addition of tuber crops, and hence they offer a great opportunity for increasing the production, productivity and profitability.

Functionally important nutraceuticals in tuber crops

Most of the tropical tuber crops are rich in one or more functionally active principles, which can help combat various diseases. Dietary fiber content in food products either retaining the natural goodness of dietary fiber or fortified with dietary fiber sources have started occupying the shelves of food stores. Dietary fiber has many reported effects like reducing serum cholesterol, preventing colon cancer, maintaining good intestinal health as well as prophylactic action on cardiovascular diseases, diabetes and obesity. Among the tuber crops, cassava, yams, elephant foot yam and sweet potato are known to be rich sources of dietary fiber. The incidence of colon cancer is reported to be the lowest in the African population who consume lot of yams and cassava. Sweet potato is a wonder tuber crop having many nutraceutical principles like carotenes, anthocyanins, anti-oxidant flavonoids etc. in tubers and the eye protectant xanthophyll, lutein in its leaves. Taro is rich in mucilage, which has reported cholesterol and triglyceride lowering activities. Chinese potato is a rich source of flavonoids having potent anti-oxidant activity and hence beneficial as a free radical scavenger for the body.

Functional foods from tuber crops

Releasing the importance that functional foods could gain in the coming years in India, ICAR-CTCRI has developed a number of functionally important tuber crop based value-added food products, either protecting the natural nutraceuticals or through fortification with functional ingredients, wherever needed. These include pasta, extruded snack foods, fried snack foods etc. Pasta, which has its origin in Italy, has gained widespread acceptance in the world and is also becoming increasingly popular in India, due to the ease of cooking. Besides, pasta is also known to be a low glycaemic index (GI) food, which could be eaten by diabetic and obese people, due to the slow glucose release property. Until recent past, it was generally believed that high carbohydrate diets lead to diabetes and hence should not be taken in large quantities by the diabetic people. However, the recent concept of rating foods based on the glycaemic index has given a great relief to the diabetics. Glycaemic index gives stress to the quality of carbohydrates rather than quantity and the low GI foods like sweet potato are reported to release glucose slowly into the blood. Pasta products having the slow release property were developed from sweet potato, incorporating whey proteins to raise their protein quality. Orange fleshed sweet potato pasta also has high carotene retention, besides high protein content contributed by whey protein and is ideal as a Vitamin A rich food that could be introduced to the noon meal programme of schoolchildren.

Cassava

Cassava is a major root crop cultivated and utilized by around 102 countries of the tropical and sub-tropical regions of the world. Congo, Brazil, Thailand and Indonesia are the other major cassava growing countries of the world constituting 50% of the area under cassava, producing 64% of the world cassava. In India, the states like Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Nagaland and Assam are the major cassava producers with Tamil Nadu topping the list in both production and area. While cassava has major food value in Kerala and North-Eastern states of India, in other states such as Tamil Nadu, Andhra Pradesh and Maharashtra, its primary use is as an industrial raw material. The high photosynthetic ability of the crop coupled with the tolerance to pests, diseases and drought and adaptability to various agro-ecological zones as well as poor soils make cassava an ideal crop of the developing and less developed nations. Although the significance of cassava as a food crop is being shifted to an industrial crop for the manufacture of starch, sago, bioethanol etc. in several countries like Thailand, India, Indonesia and Vietnam, it is still a major food crop of the African continent. The productivity of cassava in India is the highest in the world (34.96 t ha^{-1}), which was possible through high yielding varieties and cultivation practices.

The major biochemical constituent in cassava is the storage carbohydrate, starch, which constitutes up to 65-70% of the dry matter. The tubers also contain sugars, minerals, vitamins, fat, fibre and protein to very less quantity. The general biochemical profile of cassava is given in Table 1. Level of sugars is very low in cassava (approximately 10.5g/100g), sucrose being the major sugar. Glucose, fructose and maltose are the other sugars present. Crude fibre content varies from 1 to 2 g/100g dry matter in tune with the maturity of the tuber. Dietary fibre which includes lignin also, comprises about 5% of dry matter of the tuber. Cassava tubers are rich sources of ascorbic acid and B-vitamins are also present in good amounts. Some cultivars with yellow flesh colour contain good levels of beta-carotene. Calcium and phosphorous are the important minerals present in the tubers.

Cassava leaves and tubers contain the anti-nutrient factors cyanogenic glucosides *viz.*, linamarin and lotaustralin which form hydrogen cyanide on coming into contact (injury, cutting grinding etc.) with enzyme linamarase which is also present in cassava tissue in high concentrations. The glucosides impart a bitter taste to fresh cassava tuber. Traditional methods of cooking, chipping and drying, parboiling and drying etc reduce the glucoside content to safe levels. The most effective way of detoxifying is grinding followed by sun drying, while fermentation is also a method to eliminate cyanoglucosides.

Table 1. Proximate, vitamin, and mineral composition of cassava roots and leaves

Principles	**Cassava roots[a,b,c]**	**Cassava leaves[a,b]**
Food energy (kcal)	110 - 149	91.0
Food energy (kJ)	526 - 611	209 - 251
Moisture (g)	45.9 - 85.3	64.8 - 88.6
Dry weight (g)	29.8 - 39.3	19 - 28.3
Protein (g)	0.3 - 3.5	1.0 - 10.0
Lipid (g)	0.03 - 0.5	0.2 - 2.9
Carbohydrate, total (g)	25.3 - 35.7	7 -18.3
Dietary fibre (g)	0.1 - 3.7	0.5 - 10.0
Ash[e] (g)	0.4 - 1.7	0.7 - 4.5
Thiamin (mg)	0.03 - 0.28	0.06 - 0.31
Riboflavin (mg)	0.03 - 0.06	0.21 - 0.74
Niacin (mg)	0.6 - 1.09	1.3 - 2.8
Ascorbic acid (mg)	14.9 - 50	60 - 370
Vitamin A (µg)	5.0 - 35.0	8300 - 11800[f]
Calcium (mg)	19 - 176	34 - 708
Phosphorus, total (mg)	6 - 152	27 - 211
Iron (mg)	0.3 - 14.0	0.4 - 8.3
Potassium[g] (%)	0.25 (0.72)	0.35 (1.23)
Magnesium (%)	0.03 (0.08)	0.12 (0.42)

Principles	Cassava roots[a,b,c]	Cassava leaves[a,b]
Copper (ppm)	2.00 (6.00)	3.00 (12.0)
Zinc (ppm)	14.00 (41.00)	71.0 (249.0)
Sodium (ppm)	76.00 (213.00)	51.0 (177.0)
Manganese (ppm)	3.00 (10.00)	72.0 (252)

Source: [a]Bradbury and Holloway (1988); [b]Woot-Tsuen and others (1968); [c]Favier (1977); [e]Ash refers to essential minerals as well as toxic elements such as heavy metals. [f]Lancaster et al., (1982); [g] On a fresh weight (dry matter) basis (adapted from Gil and Buitrago 2002).

Sweet potato

Sweet potato (*Ipomoea batatas* Lam.) is the second most important root crop and China is the leading producer accounting for almost 80% of the global production. Although sweet potato is cultivated in around 0.112 million hectares in India, with a total production of 1.132 million tonnes, its productivity (10.13 t/ha) is lower than the world average of 12.60 t/ha. It is largely grown for its large, starchy, sweet tasting, and tuberous roots. The young leaves and shoots are also eaten as greens. Sweet potato, which originated in the Yucatan peninsula in Latin America, seems to be the most widely dispersed root crop. It is adaptable and can grow under many different ecological conditions. It has a shorter growth period than most other root crops (3-5 months) and shows no marked seasonality. Under suitable climatic conditions it can be grown all the year round. Worldwide, sweet potato is the sixth most important food crop after rice, wheat, potatoes, maize, and cassava, while it is the 3rd most important agricultural product in terms of volume after plantain and cassava. In India, it is cultivated mainly in Bihar, Uttar Pradesh, Assam, Madhya Pradesh, Tamil Nadu, Kerala, West Bengal, Orissa, Karnataka and Jharkhand. The major use in India is as a food crop and the industrial use is in its nascent stage.

Nutritional profile of tubers

The starchy roots and nutritionally rich leaves are the most valuable parts of the sweet potato and hence it is also known as a super food. Nevertheless, the energy content of the sweet potato depends on the dry matter content and varies with cultivar, location, climate, day length, soil type, incidence of pest and diseases etc. Sweet potato tubers are rich in carbohydrates (80-90% on dry basis), which consists of starch, sugars, small amounts of pectins, hemicelluloses and cellulose. The dry matter varies from 13-48% and starch comprises 50-80% of the dry matter

(Table 2). Raw tubers contain 6-14% (of dry matter) sugars, mainly sucrose, glucose, fructose and maltose. On boiling or baking, a large increase (up to 45%) in sugars takes place in some cultivars due to the breakdown of starch into maltose and dextrin by the heat-stable β-amylase enzyme, which is present in high amounts in the tubers. Digestion of raw sweet potato starch by α-amylase was very low (2.4%) when compared to maize (9.2%) and wheat (17.6%). Considerable variability in the total sugar content has been reported even within different roots of same cultivars. During cooking, starch gets hydrolysed by the beta-amylase present in the tuber and maltose concentration increases. Since sweet potato is a good source of non-starch polysaccharides, which play a significant role in the prophylaxis of various diseases such as colon cancer, diabetes mellitus, cardiovascular diseases, hypercholesterolaemia and obesity, its importance is increasingly recognized globally as a health promoting food. The major non-starch Polysaccharides in sweet potatoes are cellulose, hemicellulose and pectins and these have the role of 'dietary fibre'. The raw sweet potato roots contain on an average 7% (dwb) dietary fibre which gets reduced during cooking.

Table 2. Nutritional profile of sweet potato tubers

Parameter	Quantity/100g edible portion (fwb)*
Energy	360 kJ (86 kcal)
Major nutrients (g)	
Carbohydrates	20.1
Starch	12.7
Sugars	4.2
Dietary fibre	3.0
Fat	0.1
Protein	1.6
Minor nutrients (mg)	
Beta-carotene	
(orange fleshed varieties)	8-14
Thiamine (Vit. B_1)	0.1
Riboflavin (Vit. B_2)	0.1
Niacin (Vit. B_3)	0.61
Pantothenic acid (B_5)	0.8
Vitamin B_6	0.2
Folate (Vit. B_9)	0.011
Vitamin C	2.4
Calcium	30.0
Iron	0.6
Magnesium	25.0
Phosphorus	47.0
Potassium	337
Sodium	55
Zinc	0.3

The crude protein content has been reported to range from 1.28 to 10.07% (dwb) among different cultivars grown under similar cultural management in a single season and the majority of the cultivars had a range of 4.5% protein. The tubers are rich in energy, minerals like potassium, phosphorus and Vitamin-C (Table 2). The high potassium to sodium ratio is advantageous for hypertensive patients.

Yams

Yams are grown in many tropical regions throughout the world. White yam (*Dioscorea rotundata*) is believed to be indigenous to the area stretching from Côte d'Ivoire to Cameroon and is generally considered the best edible yam in that region. The yellow yam (*Dioscorea cayenensis*) is also indigenous to West Africa, whereas the water yam (*Dioscorea alata*) has originated in South-East Asia. Yam production in Africa is concentrated in areas within 15 degrees of the equator. They are normally grown in high rainfall areas with distinct wet and dry seasons; they grow best on loose, fertile, well-drained soils.

Yams provide nutritional and food security to several millions of people especially in Africa. Apart from the major ingredients such as starch, yam tubers are also rich in various minerals and dietary fibre. The potassium content of yam (*D. alata*) was reported to be high and hence the tubers were suited for people having hypertension, but not for people suffering from renal failure. Tubers are also rich in dietary fibre that confers many health attributes to it and certain species of yams are used as medicines in oriental countries to prevent diarrhoea and diabetes. There are several species under *Dioscorea*, although the edible yams widely consumed are *D. alata*, *D. esculenta* and *D. rotundata*). Yam has been classified as one of the important staples in the diets of many tropical countries because of the carbohydrate composition. Dry matter content varies from 32-44% and starch constitutes the major carbohydrate in all the three species ranging from 51-90% of dry matter. *D. esculenta* contains high amounts of sugar, while the other two species are very low in sugar content (Table 3). The main sugars in yams were reported as glucose and sucrose and formation of maltose and fructose had been found during storage. Tubers contain mucilage (2.5% in *D. esculenta*, 1.4% in *D. alata* and 2% in *D. rotundata*, which is mainly composed of glycoproteins. Mucilages are bioactive natural products which possess anti-tumour, anti-inflammatory, and immune- modulatory and antioxidant activities.

The fat content in is generally low in the tubers (range: 0.04- 0.6% fwb). Protein content shows large variations among cultivars of the three species and most cultivars have *Ca.* 6-8% protein and the major amino acid present is arginine. Yam tubers are also rich in non-starch polysaccharides such as cellulose, hemicelluloses and pectin. Holloway et al. (1985) reported pectin, hemicelluloses, cellulose and lignin contents of 2.6%, 3.4%, 1.6% and 1.1% respectively in *D. alata* tubers and former three contribute towards dietary fibre in the tubers.

Table 3. Nutritional profile of edible yam (*Dioscorea* spp.) expressed per 100 g fresh weight

Parameters	*D. alata*	*D. rotundata*	*D. esculenta*
Major nutrients (g/100g fwb)			
Total carbohydrate	22-31	15-23	17-25
Starch	16.7-28	26.8-30.2	25
Free sugars	0.5-1.4	0.3-1	0.6
Crude protein	1.1-3.1	1.1-2.3	1.3-1.9
Crude fat	<0.1-0.6	0.05-0.1	0.04-0.3
Crude fibre	1.4-3.8	1.0-1.7	0.2-1.5
Ash	0.7-2.1	0.7-2.6	0.5-1.5
Energy (kcal)	140	142	112
Minerals and vitamins (mg/100g fwb)			
Phosphorous	28- 52	17	35-53
Calcium	28 -38	36	12-62
Iron	5.5-11.6	5.2	0.8
Vitamin C	-	2.0-8.2	6.0-12.0
Thiamine	0.05- 0.10	-	0.1
Riboflavin	0.03- 0.04	-	0.01
Niacin	0.5	-	0.8

*Source: Asiedu *et al*. (1997); Bradbury and Holloway (1988); Coursey (1967); Eka (1985); Muzac-Tucker *et al*. (1993) and Opara (1999); - indicates non-availability of data

Aroids

Aroids are important starchy tubers with high nutritive and medicinal values. These are food security crops in tropical countries mainly West Africa, South East Asia, Pacific Islands, Papua New Guinea Islands and the Caribbean Islands. The major edible crops coming under aroids are *Colocasia esculenta* (Taro), *Alocasia macrorrhiza* (Giant Taro), *Xanthosoma sagittifolium* (Tannia) and *Amorphophallus paeoniifolius* (Elephant foot yam). All parts of the plant are edible in the case of *Colocasia* and *Xanthosoma* while in *Amorphophallus,* corms and petioles are used as food. Approximately 400 million people include taro in their diets and it forms a staple food, mainly in humid tropics. Taro is mainly grown as a root crop or as a leafy vegetable. Giant swamp taro (*Cyrtosperma* sp.) is an important food crop in the Africa and north-east India. Starch is the major component of dry matter and it ranges from 18-28% of fresh weight in taro and 15-20% in Elephant foot yam. Sugar content is generally low in aroids. Dietary fibre content is 1.5 g in Elephant foot yam, 4.3 g in taro, 1.9 g in giant taro and 3.6 g in tannia. Lipid content ranges from 0.1 to 0.2% and protein content from 1.5 to 3.2% fresh weight. Taro and giant taro contain higher calcium content (up to 35mg) than EFY and tannia (12-14 mg). All aroids have high contents of phosphorus which is in the range of 49-60 mg. Iron content is 1.2mg in taro and Elephant foot yam, while 0.10 mg in tannia and giant taro. The tubers of taro and tannia contain mucilage, which has cholesterol and triglyceride lowering activities.

Taro

Taro [*Colocasia esculenta* (L.) Schott] belongs to the aroid family, Araceae and has originated from the humid tropical rain forests of South-East Asia. Taro is probably one of the oldest crops on earth and has been grown for more than 10,000 years in tropical Asia. Presently, it is cultivated in many tropical and subtropical countries around the world. In India, it is extensively grown in West Bengal, Bihar, Odisha, Uttar Pradesh, Assam, Kerala and some parts of Tamil Nadu and Andhra Pradesh. Taro is a subsidiary food crop and its tubers contain carbohydrates, calcium, protein and minerals like phosphorus and iron. The leaves, young shoots and corms of taro are also used for consumption. Starch is the major component of taro (70-80%) followed by protein (~11%) and the protein fraction is reported to be rich in essential amino acids except lysine. Taro tubers are reported to be low in fat, although it is a good source of minerals such as potassium. The small granule size of taro starch makes it an attractive source of weaning food, cosmetic powders and it is also reported to increase the bioavailability of nutrients. The small granule size (1-4 µm in diameter) makes taro starch a highly digestible food. Besides, the fine nature of starch granules imparts hypoallergenic property to taro starch. The amylose: amylopectin ratio is 1:7 and is different from the other tuber starches, which is usually 1:4. The important sugars are sucrose, fructose, maltose, glucose and raffinose, while the major organic acids are malic acid, citric acid and oxalic acid. The protein (~11% dwb) fraction is especially rich in threonine, leucine, arginine, valine and phenylalanine. The protein localization was reported to be more towards the periphery of the tuber and careful peeling is necessary to avoid loss of protein during processing.

The fat content ranges from 0.3-0.6%, making taro a low fat food. Taro tubers are reported to contain total soluble and insoluble dietary fibres in the range of 5.02-9.01%, while much lower levels of crude fibre (0.3-3.8%) were reported in the taro cultivars from Cameroon. Several workers have reported that taro tuber is a rich source of minerals such as iron, calcium and potassium and low in. A high potassium to sodium ratio is advantageous for hypertensive patients. Although the tubers are low in vitamins, the leaves of taro, which is widely consumed as a vegetable in many places are a rich source of beta-carotene, iron and folic acid. Yellow fleshed cultivars of taro are rich in phenolic compounds possessing anti-oxidant activity. The mucilage component of taro, although considered disadvantageous during processing, is a complex mixture of neutral polysaccharides, along with some fibre and protein. Nevertheless, the mucilage is important from the health point of view, imparting properties such as slow transit of food through upper GI tract, hold moisture to prevent constipation and lower blood cholesterol by binding bile.

Taro possesses more calories than potatoes. One hundred grams of root provides 112 calories and their calorie value chiefly comes from the starch present in the tubers. The roots are very low in fats and protein than in cereals and pulses (Table 4). They carry high quality phyto-nutrition profile comprising of dietary fibre, and antioxidants in addition to moderate proportions of minerals, and vitamins. Taro is one of the finest sources dietary fibres; 100 g flesh provides 4.1 g or 11% of daily-requirement of dietary fibre. Together with slow digesting complex carbohydrates, moderate amounts of fibre in the food help gradual rise in blood sugar levels. Yellow-fleshed roots and young tender leaves have significant levels of phenolic flavonoid pigment antioxidants such as β-carotenes and cryptoxanthin along with vitamin A. One hundred grams of fresh taro leaves provide 4825 IU or 161% of RDA of vitamin A. Altogether, these compounds are required for maintaining healthy mucus membranes, skin and vision. It also contains good levels of some of the valuable B-complex group of vitamins such as pyridoxine (vitamin B-6), folates, riboflavin, pantothenic acid, and thiamin. Further, the

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corms provide healthy amounts of some of important minerals like zinc, magnesium, copper, iron, and manganese. In addition, the root has very good amounts of potassium. The leaves of taro are rich in protein, minerals and are used for making curries and some sweet preparations.

Table 4: Nutrition value of taro (*Colocasia esculenta* (L.) schott) tubers (per 100 g fwb)

Principles	**Nutrient Value**		
	USDA (2003)	Hedges and Lister (2006)	Onwueme (1999)
Energy (kcal)	112	114	-
Major nutrients (g)			
Carbohydrates	26.46	26.80	13-29
Protein	1.50	1.34	1.4-3.0
Total Fat	0.20	0.11	0.16-0.36
Dietary Fibre	4.1	2.50	-
Ash	-	1.91	0.6-1.3
Vitamins (µg)*			
Folates	22		
Niacin	600	780	900
Riboflavin	25	29	40
Thiamin	95	28	180
Vitamin A	12	6	-
Vitamin C	4500	14300	700-900
Electrolytes (mg)			
Sodium	11	4.2	-
Potassium	591	489	-
Minerals (mg)			
Calcium	43	20.3	-
Iron	0.55	0.44	-
Zinc	0.23	2.06	-

Tannia [*Xanthosoma sagittifolium* (L) Schott] has its origin in South America and the Caribbean. The Spanish and Portuguese introduced it to Europe and were also responsible for spreading it to Asia. It moved from the Caribbean in the late nineteenth century, first to Sierra Leone and then to Ghana. In West Africa, *Xanthosoma* is more important than *Colocasia,* being popular for its corm, cormels, leaves and young stems. Although *Xanthosoma* is relatively new to the Pacific region, it has spread rapidly and widely, becoming quite an important crop in many of the islands. It is also widely cultivated in Puerto Rico, the Dominican Republic and Cuba and is important along the coastal mountains of South America, in the Amazon basin and in Central America. Nowadays, tannia is integrated in the staple diet of several countries in the Americas, West Africa, Asia and the Pacific. Tannia is nutritionally very similar to taro. The corm, cormels, and leaves are the economically important parts of the plant. Tannia corms contain 70-80% water, a high starch concentration that ranges between 22 and 40% and variable concentrations of nutrients. The approximate composition of Tannia corm on a fresh weight basis is presented in Table 5.

Elephant foot yam

Elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] is a popular tuber crop grown in many tropical and sub-tropical regions of South-east Asia. It is commercially cultivated in India, Malaysia, Thailand, Indonesia, the Philippines, China and Sri Lanka. Among the nearly 200 species of *Amorphophallus* worldwide, only *Amorphophallus paeoniifolius* (Elephant foot yam) and *A. Konjac* are commercially cultivated. Elephant foot yam (EFY) is basically cultivated as a food crop. Elephant foot yams have a unique and rich nutritional profile and offer a number of significant health benefits. This makes EFY a very potent food source when it comes to nutrition. The edible corm finds use as a nutritionally rich vegetable and is also an ingredient of several Ayurvedic preparations due to its medicinal and health benefits. The complete compositional profile of local Elephant foot yam variety grown in West Bengal, India has been studied and it is reported that the tubers contain high protein (9.81%), fibre (5.7%) and ash (4.83%) content in the edible tuber. Besides, high contents of Vitamin C (76.65 mg/100 g dwb) and α-tocopherol (Vitamin E; 900 mg/100 g dwb), both possessing anti-oxidant activity were also reported. Minerals such as potassium, calcium, magnesium and zinc were also reported to be high in this variety. The low fat content, coupled with the high fibre and protein could make Elephant foot yam a healthy and nutritious tuber for human consumption.

It provides energy of approximately 330 kJ/100g. The tuber has a water content of about 72-79% and carbohydrates constitute 18-24%. The fibre content is about 0.8%. Protein is in the range of 1.7-5.0%. Potassium, phosphorus and magnesium are the key minerals found in elephant yam. It also contains trace minerals like zinc, copper and selenium. Calcium is also present in appreciable amounts (50-56 mg/100g). It has omega-3 fatty acids. Elephant foot yam is high in Vitamin B6 content along with Vitamin C and Vitamin A. The fat content is about 0.2-0.4%. Elephant foot yam tubers are reported to be used in certain ayurvedic preparations. The anti-nutritional factor in the leaves and tubers of some cultivars of taro and Elephant foot yam is calcium oxalate crystals, which causes an irritant effect known as acridity. Nevertheless, there are several processing methods by which there levels could be reduced thus eliminating the acridity in most tubers.

Table 5: Nutritional profile of Elephant foot yam and tannia tubers (100g dwb)

Principles	Elephant foot yam*	Tannia**
Major nutrients (g)		
Carbohydrates	70.75	93.62
Protein	11.53	2.83
Fat	3.52	0.93
Crude fibre	14.32	0.88
Ash	6.90	1.74
Minor nutrients (mg)		
Potassium	3.81	525
Zinc	2.31	0.46
Sodium	-	66
Iron	34.02	0.42

Source: *Srivastava et al. (2014); Basu et al. (2014) ** Akpan and Umoh (2004)

Minor root and tuber crops

Apart from the major tropical tuber crops there are some minor crops which are cultivated in small pockets in many parts of the world. Two of these which have nutritional potential are Chinese potato (*Solenostemon rotundifolius)* and arrowroot (*Maranta arundinacea*).

Chinese potato

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, Lamiatae, which has more than 300 plants. The crop is believed 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 are rich in energy and the carbohydrate content is comparable to potatoes (Table 7). Besides, the tuber is reported to contain several amino acids such as arginine, aspartic acid and glutamic acid and minerals such as calcium and iron. The tubers possess flavor and have medicinal properties due to the high content of flavonoids.

Table 7: Nutrient content of Chinese potato *vis-à-vis* Potato*

Component/100 g 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)

Arrowroot

Arrowroot (*Maranta arundinacea*) is an under exploited tuber crop having tremendous potential in food and pharmaceutical industries. The tubers contain about 10% to 25% extractable starch, which, from a nutritional point of view, is the richest (unenriched) natural starch on the earth. The amylose content in starch ranges between 16 to 27%. Arrowroot starch is popular for its high digestibility and medicinal properties (The Wealth of India 1962). It possesses demulcent properties that soothes and protects irritated or inflamed internal tissues of the body and hence is given in bowel complaints. The starch is often used as a thickener in all kinds of foods. Arrowroot is used as an article of diet in the form of biscuits, puddings, jellies, cakes, hot sauces etc. and an easily digestible food for children and people with dietary restrictions. The lack of gluten in arrowroot starch makes it ideal as a replacement for wheat flour in baking. Arrowroot starch is a used for stomach and intestinal disorders, including diarrhoea.

References

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AGRO TECHNIQUES OF TROPICAL TUBER CROPS

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CASSAVA

Cassava (*Manihot esculenta*), popularly known as Tapioca in India, is the most important tuber crop cultivated in Kerala and Tamil Nadu, Assam, Andhra Pradesh and Karnataka. It is consumed both as freshly cooked tubers and as animal and poultry feeds. Tapioca is a raw material for many industries to produce starch, glucose etc. Cassava has enormous potential in India for poverty alleviation, food security and industrial uses due to its ability to grow and yield well in marginal and wastelands.

Growing condition

1. It grows better in warm and humid climate with well-distributed rainfall.
2. Tapioca grows on all types of soils, but saline, alkaline and ill-drained soils are not suitable.
3. It can tolerate drought, once it is established.

Time of planting

a. Cassava is grown as a rainfed crop in most of the states. Best planting season is April-May with the onset of south-west monsoon.
b. September- October coinciding with the north- east monsoon is also suitable for planting.
c. Plant may be done at any time of the year, if grown as an irrigated crop, but December-January planting will gives better yield.
d. June planting is ideal for Andhra Pradesh, Assam and Jagadalpur under rainfed condition.
e. Under irrigated conditions of Tamil Nadu, planting in September is found suitable.

Methods of Planting

Mound method

This method is suitable for poorly drained soils.

Planting of cassava is done on the mounds at a height of 25-30 cm.

Ridge method

Ridge planting is followed in sloppy lands for rainfed crop as well as for irrigated crop cultivated in level lands.

Ridges are prepared across the slope/along the contour to a height of 25-30 cm.

Flat method

Flat planting is followed in level lands having good drainage.

Planting material

Select the planting materials from mature, healthy stems having 2-3 cm diameter.

Discard the woody basal and tender top portions of the stem.

Prepare setts of 15-20cm length with a smooth circular cut.

Setts prepared from stems stored for 15 days with leaves give better sprouting and crop establishment.

Rapid propagation in cassava

A quick multiplication method showed that 5 cm cuttings with 2 full nodes increased the propagation rate by 30 times.

However, the initial propagation has to be done in a primary nursery and the sprouts should be transplanted to the main field after 40-45 days.

Planting and Spacing

Plant the setts vertically at 5 cm depth and avoid inverted planting.

A spacing of 90 x 90cm for branching/semi-branching and 75 x 75 cm for non branching/erect branching varieties are recommended.

Fertilizer application and intercultural operation

Application of 12.5 tonnes of FYM per ha. or *in situ* green manuring is recommended.

Application of NPK @ 100:50:100kg/ha is recommended in general and details are given in the following table.

Fertilizer recommendations

SI. No.	Fertilizer	Basal dressing (kg/ha)	Top dressing (kg/ha) 45-60 days after planting
1.	Urea	100	110
2.	Mussorie Phosphate/Rajphosphate	250	-
3.	Muriate of Potash (M.O.P)	85	85
Or			

1.	Urea	100	100
2.	Super Phosphate (single)	300	-
3.	Muriate of Potash (M.O.P)	85	85
Or			
1.	Urea	65	110
2.	DiAmmonium-Phosphate	110	-
3.	M.O.P.	85	85
Or			
1.	Urea	-	110
2.	Ammonium phosphate/	-	
	Factomphos (20:20)	250	-
3.	M.O.P	85	85
(For M-4 and local types, half the above fertilizer doses are recommended)			

a. Phosphorus application can be skipped for four years when available phosphorus status of the soil is high. Thereafter, a maintenance dose of 50 per cent need be applied.
b. For short duration varieties, application of NPK @ 75:25:75 kg/ha is recommended.
c. At TNAU, Coimbatore, application of neem coated urea followed by Sulphur coated urea recorded highest tuber yield in cassava.
d. Entire dose of phosphorus and half the dose each of nitrogen and potash are to be applied as basal dose and the remaining half dose of nitrogen and potash is applied 45-
e. 60 days after planting along with interculture and earthing-up.
f. Retain only two healthy shoots on opposite sides of the planted setts and remove rest of the sprouts at 30-45 days after planting.
g. First weeding and earth up are to be done 45-60 days after planting.
h. A second weeding and earthing up may be done 1-2 months after the first weeding and earthing up

Intercropping

i. Legumes are the most suited intercrops in cassava.
ii. Gives an additional net income of Rs.3000-5000/ha within 3- 4 months.
iii. Utilise light, water and nutrients more effectively from the interspaces of tapioca.
iv. Control weeds and adds organic matter and nitrogen to the soil.
v. Onion (*Allium cepa* L.) is also found to be a profitable inter crop.
vi. When French bean was grown as intercrop in cassava, it recorded the highest cost benefit ratio of 1:1.9 and yielded more than 25 t/ha in Assam.
vii. Inter cropping of cassava with groundnut is also found to be ideal as an intercrop in cassava.

viii. **Planting of main crop and intercrop**

- Select only bushy types of intercrop which mature within 100 days.
- Plant tapioca in the month of May-June at a spacing of 90 x90 cm.
- Dibble the intercrop seeds immediately after planting of tapioca.
- Apply the recommended dose of NPK to the tapioca as per schedule given for pure stand and intercrops about 30 days after sowing followed by light inter-culturing.
- Top dress tapioca immediately after harvest of intercrops with the recommended dose of fertilizers followed by earth up.

Cultivation details of intercrops

Name of Intercrop	Cultivar	Duration (days)	Spacing (cm)	No. of rows	Seed rate (kg/ha)	Fertilizer NPK (kg/ha)	Yield (kg/ha)
Groundnut	TMV-2, TMV-7, Pollachi-2	100	30 x 20	2	40-45 (kernel)	10:20:20	1200 (dry pod)
French bean	Contender	70	30 x 20	2	40	20:30:40	2000
Cowpea (grain)	S-488	90	30 x 15	2	20	10:15:10	800
Cowpea (vegetable)	Arka Garima	65	90 x 20	1	8	10:15:10	3000

Crop protection

Cassava mosaic disease

- Cassava mosaic disease is the serious problem in cassava and is caused by Indian cassava mosaic Gemini virus. Chlorotic areas intermixing with normal green tissue gives mosaic pattern. In severe cases, leaves are reduced in size, twisted and distorted, reducing chlorophyll content and photosynthetic area. It causes 25-80% yield reduction.

Control

a. Select a disease-free planting material.
b. Grow resistant varieties like Sree Padmanabha, Sree Reksha, Sree Swarna, etc.
c. Rogue-out plants with disease symptoms immediately and follow strict field sanitation.
d. Keep the fields free of self sown/ volunteer cassava plants which may serve as a source of inoculums and help the spread of disease.
e. Prompt disposal of cassava residue is essential.

Tuber Rot

- Tuber rot is caused by *Phytophthora palmivora*. Infected tubers show brown discoloration of internal tissues, rotten and emit foul smell and unfit for consumption or marketing and it causes heavy yield loss.

Spider mites

Occur during dry season from January to May. It feed on leaf sap, causing blotching, curling and leaf shedding.

Control

1. Spray Dimethoate or Monocrotophos 0.05% at monthly intervals starting from January whenever infestation occurs.
2. Spraying of water at runoff level on the foliage at 10 days interval is also effective.

Scale insect

- Scale insects infest the stems when stacked/ stored and occasionally in the field, causing drying of stem.

Control

- Select the stems free of scale insects for storage as well as planting.
- Store stems in vertical position in shade to prevent multiplication of scale insects.
- Spray the stems with 0.05% Dimethoate during storage as prophylactic measure.

Papaya mealybug

a. It feeds on the sap of plants and injects a toxic substance into its host, resulting chlorosis (yellowing), plant stunting, leaf deformation, early leaf drop etc.
b. They produce honeydew and this sticky layer is a perfect growth medium for a black fungus commonly known as sooty mold, that cover the entire leaf and cut the light available for photosynthesis.
c. The spread of infestation is achieved through planting materials, wind, water, rain, clothing, vehicle etc.
d. Passive transport of the pest is also possible through the field equipments, animals or people moving during field operations.

Control

a. Select pest free setts for planting.
b. Burn the severely infested plants.
c. Use a mixture of neem oil and soap solution for spraying**:** Add 20 ml of neem oil and 2-
d. 5 ml of soap solution in a plastic bucket and make up to one litre. Vigorously shake the solution till it looks milky white with foam. Dip the setts of cassava for 5 minutes in this solution, so larval stages of the mealybugs will be washed off and killed. Spray the same solution in mealybug infested cassava field also. Nozzle of the spray should be turned towards the lower side of the leaf and ensure full coverage by the spray fluid. A second spray after 15 days may ensure the death of residual population.
e. Insecticides like Profenophos 50 EC-2ml/l; Chlopyriphos 20 EC 4ml/l; Dimthoate 30
f. EC 2 ml/L are reported to be effective against mealybugs.
g. Plough the land to 20-25" depth using disc plough adopt ridge method of planting.
h. Adopt crop rotation with cereals, sugarcane and turmeric once in two years.

Harvesting

- Harvest the crop depending upon the maturity of the cultivar (6-7 months: H-165, Sree
- Prakash; 8-9 months: H-226, H-97; 9-10 months: Sree Sahya & Sree Visakham).
- Stack the stems vertically in well aerated shady places for subsequent planting.

SWEET POTATO

Sweet potato (*Ipomoea batatas* (L.) Lam.) is a dicotyledonous plant belonging to the family Convolvulaceae. It is widely cultivated in many tropical and subtropical countries of the world. This crop is the seventh largest food crop, cultivated in warm temperate, subtropical and tropical regions of the world. Under varied climatic conditions, sweet potato can be cultivated all around the year and complete crop loss under adverse climatic conditions is rare. Hence, it is considered as an “insurance crop or climate resilient crop.” The crop is widely cultivated in Southeast Asia, Latin America and Oceania regions. Sweet potato tubers are rich source of carbohydrates, fibre as well as an array of minerals and vitamins including iron, selenium, calcium, and the good source of vitamin A, vitamin B complexes and vitamin C. Consumption of sweet potato helps to control noncommunicable diseases, due to its high content of an antioxidant and bioactive compounds such as phenolic acids, anthocyanins, beta-carotene etc. While its leaves and tender stems (tops) contain additional nutritional components in much higher concentrations than the other popular leafy vegetables. In many parts of the world, sweet potato leaves are consumed as a vegetable. They are very rich in vitamins and minerals like vitamin B complexes, vitamin C, vitamin E, vitamin K, beta-carotene, iron, calcium, zinc and protein.

Conditions suitable

- It is a crop of tropical and sub-tropical region having wide adaptability.
- It performs better in well-drained loamy soils.

Planting season

- Under rainfed conditions, plant the vines during June-July.
- Under irrigated conditions, plant during October - November in uplands and during
- January-February in lowlands as a summer crop.

The recommended time of planting of the crop in the different States is given below:

States	**Ideal time of Planting**
Bihar, Assam, NE region and Uttar Pradesh	As a summer crop it is grown in February (with irrigation). In June sweet potato is raised as upland rainfed crop and in September-October as autumn crop. November is the ideal time for the *diara* land of Bihar where the crop is raised after the recession of flood.

Andhra Pradesh Tamil Nadu Maharashtra Madhya Pradesh Karnataka West Bengal Chhotanagpur Plateau of Bihar	Kharif and Rabi (with irrigation) May to September (with irrigation) Kharif and Rabi (with irrigation) August to September Kharif and Rabi (with irrigation) September to October August to September

Raising Nursery for planting material

- Use vines or tubers depending upon the availability, for raising nursery.
- If tubers are used, raise nursery in two stages - Primary nursery and Secondary nursery.

Primary Nursery

- Raise nursery three months ahead of planting.
- A nursery area of 100 m^2 is required to raise vines for planting one hectare.
- Make ridges 60 cm apart and plant healthy tubers (125-150 g) on the ridges at a spacing of 25 cm.
- Apply 1.5 kg urea at 15 days after planting.
- Irrigate the nursery as and when required.
- Clip off the vines to a length of 20-30 cm at 40-45 days age for planting in secondary nursery.

Secondary Nursery

- Prepare ridges at 60 cm apart.
- An area of 500 m^2 is required to plant vines obtained from 100 m^2 primary nursery.
- Plant the cutting 25 cm apart on the ridges.
- Top-dress the nursery with 5 kg urea in two split doses, 15 and 30 days after planting.
- After 45 days, prepare vine cuttings of 20-30 cm length from middle and top portion of vines.

Selection of vines for planting

- Top vine portion has been found to be superior planting material compared to bottom and mid vine portion and a length of 25 cm has been found to be the optimum.

Preparation of vines

- Store the cut vines of sweet potato with intact leaves in bundles under shade for two days prior to planting in the main field.

Preparing the field and planting

1. Make ridges at 60 cm apart having 25-30 cm height.
2. Plant the cutting at 20 cm spacing on the ridges.
3. Bury the vines horizontally with two to three nodes below the soil leaving the remaining portion above the soil.

Manuring and interculturing

a. Apply farm yard manure @ 5 tonnes/ha before preparing the ridges.

b. Apply fertilizers @ 50 kg N, 25 kg P_20_5, 50 kg K_20/ha Apply urea (55 kg) or ammonium sulphate (125 kg), rock phosphate (125 kg) and muriate of potash (85 kg) per hectare at the time of planting.

c. Top dress is done a month after planting, with 55 kg urea or 125 kg ammonium sulphate along the side of the ridges.

d. Earthing up and weeding is done along with top dressing.

Irrigation and interculturing:

1. Two irrigations in autumn and four irrigations in summer are effective for higher yield.
2. It is recommended to do the first interculture at 30 days after planting along with removal of weeds and turning of vine.
3. Application of second dose of nitrogen and potash along with earthing up is recommended 50-60 days after planting.

Crop protection

Sweet potato weevil *(Cylas formicarius)*

- Sweet potato weevil is the most important pest causing very severe damage to the crop.
- Adult weevil makes puncturing on vines and tubers.
- The grubs bore and feed by making tunnels.
- Even the slightly damaged tubers are unsuitable for consumption due to bitterness.
- Yield loss may go up to 100% in severe cases.
- On an average, 20-55% tuber loss occurs.

Control

1. Removal and destruction of the crop residues and use of healthy weevil free planting materials are recommended to control the pest**.**
2. Dip the vine cuttings in Fenthion or Fenitrothion 0.05% solution for 10 minutes before planting.

3. Two sprays of fenthion (0.05%) first at 40 DAP followed by second after a month (70
4. DAP) was recommended to control the sweet potato weevil effectively.
5. Reridging at 60 days after planting and drenching with 0.05 per cent fenthion and fenitrothion at 65 days after planting are also effective to check the weevil.
6. Install synthetic sex pheromone traps @ 1 trap/100 m2 area to collect and kill the male weevils.
7. Varieties with long neck (deep bulking type) have got less weevil infestation than shallow bulking types.
8. The planting of sweet potato in rotation with paddy crop to minimise the infestation of sweet potato weevil was recommended.

Feathery mottle (SPFMV)

a. Among the 12 virus symptoms recorded, feathery mottle (SPFMV) is widely occurred.
b. The primary spread is through planting material.
c. The disease cause up to 50% crop loss.

Control

- Use of virus free planting materials.
- The disease can be managed through field tolerant varieties viz. Sree Vardhini,

Harvesting

- Time of harvest is found to be very important in sweet potato and in general, a delay in harvest after 120 days increased infestation of sweet potato weevil.
- Remove the vines and dig out the tubers without injuring them.

YAMS

Yams *(Dioscorea spp.)* are tropical tuber crops which prefer long moist growing season. In India, they are cultivated largely in Southern and North Eastern states. There are three main species of yams grown in our country. Greater yam *(Dioscorea alata),* Lesser yam (*Dioscorea esculenta)* and White yam *(Dioscorea rotundata)* While greater yam and lesser yam are quite popular since ancient times, white yam is a recent introduction from Africa. Yams are normally consumed as vegetable; either boiled, baked or fried.

Conditions suitable

a. Yams grow well in warm and humid conditions. Yam cannot with stand frost.
b. Yams require deep well drained fertile soil and come up well with mean temperature of 30°C and a well distributed annual rainfall of 1200-2000mm.
c. March-April is the ideal time for planting.

Planting material

1. In the case of greater yam and white yam, tuber pieces of 250-300 g size can be used as planting material.
2. For rapid seed yam production, minisetts of 30 g size is ideal.
3. For planting lesser yam, medium sized tuber of 100-150 g is sufficient.

Land preparation

a. Plough/dig the land to a depth of 15-20 cm.
b. Open pits of 45 x 45 x 45 cm size for planting greater yam and white yam at a spacing of 90 x 90 cm.
c. Fill up three-fourths of the pit with top soil and FYM and reform into a mound.
d. For raising lesser yam, mounds may be formed at a spacing of 75 x 75 cm after applying of FYM.

Method of planting

1. Plant seed tubers of greater yarn/white yam on reformed mounds.
2. About 3000-3700 kg of seed material is required to plant one hectare.
3. After planting the tubers, completely cover them with soil.
4. Mulching hastens sprouting, controls the weed growth, regulate soil temperature and retain the soil moisture

Manuring and interculturing

1. Apply cattle manure or compost (FYM) @ 10 t ha^1 as basal dressing before planting.
2. A fertilizer dose of 80 kg N, 60 kg P_2O_5 and 80 kg K_2O per hectare in two split doses is needed for yams.
3. Half dose of nitrogen (87 kg of urea or 200 kg of ammonium sulphate), full dose of phosphorus (300 kg rock phosphate) and half dose of potash (67 kg of muriate of potash) are to be applied within a week after sprouting.
4. The remaining nitrogen and potash may be applied one month after the first application.
5. Top dressing of fertilizers should be followed by weeding and earthing up.

Management practices for intercrop

a. Yams can be raised as intercrops in coconut, arecanut, banana, rubber and robusta coffee.
b. In the case of rubber and coffee, intercropping should be restricted during the initial 3-4 years to avoid serious deleterious effects on the growth and yield of both the crops.
c. About 9000 plants can be accommodated at a spacing of 90 x 90 cm in 1 ha of coconut plantation, leaving 2 m radius from the base of the palms.
d. Both the main crop as well as intercrop should be separately and adequately manured.
e. Yam varieties such as Sree Latha, Sree Keerthi and Sree Priya are suited for intercropping.
f. Yams can also be intercropped in Nendran and Robusta varieties of banana.
g. In the interspaces of 2 rows of Nendran banana spaced at 3.6 x 1.8 m (1500 plants ha^{1}), 3 rows of yams can be planted to accommodate 8000 plants ha'.
h. It was also found that the levels of FYM, N and P to the intercrop as well as main crop could be reduced to half.
i. But the quantity of potash should not be reduced at any cost.
j. Robusta banana can be planted at 2.4 x 1.8 m to accommodate 2300 suckers. In between 2 rows of banana, 2 rows of yams can be planted to accommodate 6000 plants t ha^{1}.
k. In Robusta banana Dioscorea system, banana should be manured at the full recommended dosage and for yams, manuring at the 2/3rd recommended level is sufficient.
l. In young rubber plantations, during the initial 3-4 years yams can be intercropped.
m. But manuring at the full dose should be done for both the crops.
n. It is possible to accommodate about 6000 yam plants in 1 ha of rubber plantation after leaving 1.5 m radius from the base of the rubber plants.
o. When yams are intercropped in arecanut garden, about 7000 yams can be accommodated at a spacing of 90 x 90 ern, leaving 1 m radius from the base of the palms

Trailing

- Trailing is necessary to expose the leaves to sunlight.
- It is done within 15 days after sprouting by coir rope attached to artificial supports in the open area or to the trees where it is raised as an intercrop.

Crop protection

- Yam scale is found to occur on the tubers both under field and storage conditions.
- As a prophylactic measure, dip the planting material in Fenthion or Fenitrothion 0.05 per cent solution.
- Use scale free seed tuber for planting.

***Anthracnose* (Leaf spot)**

a. It is caused by *Colletotrichum gloeosporioides* Penz.
b. Among various *Dioscorea* species, *D. alata* is very susceptible to anthracnose whereas *D. rotundata* is more resistant.
c. The disease appears as brown pinhead like spots on the leaves and stems.
d. These spots become enlarged as the leaves approach full size, and they may develop pale yellow margins.
e. Sometimes the leaf spots run together to form large irregular blotches, the centers of which may fallout giving a shot hole effect Infected leaves usually fall off.

Control

1. This can be managed by adopting crop rotation,
2. Removal of debris and destruction.
3. Planting of healthy material and destruction of infected cultivars.
4. Ploughing immediately after harvest also helps to reduce the inoculums.
5. Spraying Dithane M-45 (0.2%) and Bavistin{0.25%) reduces disease severity.

Harvesting

- Greater yam and white yam becomes ready for harvest by 9-10 months after planting.
- Lesser yam takes 8-9 months for attaining maturity.
- Carefully dugout the tubers without making injury.

ELEPHANT FOOT YAM

Elephant *(Amorphophallus paeoniifolius)* foot yam is basically an underground stem tuber. Its cultivation is more or less limited to India, Philippines, Indonesia, Sri Lanka and South- East Asia. It has high dry matter production capability per unit area than most of the other vegetables. It is a popular tuber crop and is grown as a vegetable in many parts of India, especially South, East and North-Eastern States. It is a highly remunerative crop and is hence profitable

Climate and soil

- *Amorphophallus* is a tropical/sub-tropical crop and hence thrives well under warm humid climate with a mean annual temperature of 30-35°C and a well distributed rainfall of 1000 -1500 mm spread over a period of 6 - 8 months.
- It grows well on a variety of soils but a well drained sandy loam or sandy clay loam soil with a near neutral soil reaction is ideally suited for the crop.
- The soil should be rich in organic matter with adequate amount of available plant nutrients.

Planting season

- *Amorphophallus* undergoes a dormancy period of 45 to 60 days.
- Traditionally farmers take advantage of the dormancy period by planting during
- February - March so that the setts would sprout with the pre-monsoon showers.

Planting method

1. A good soil turning plough followed by pit formation is the traditional method of land preparation for *Amorphophallus.*
2. The pit size should be 60 x 60 x 45 cm.
3. The top soil is then mixed with farm yard manure or compost (2.5 kg/pit) in the pit prior to planting.
4. The planting material is placed vertically in the pits and is then covered with soil and compacted lightly.
5. *Amorphophallus* is planted shallow as deep planting would interfere with harvest operations, besides, most of its feeder roots are found on the surface.
6. A comparatively wider spacing of 90 x 90 cm has been recommended for planting *Amorphophallus.*

Planting material

- *Amorphophallus* corm is cut into setts of 750 - 1000 g, each bearing a portion of the central bud.
- Whole corms of size (500g) if available can also be used as planting material.

Manures and fertilizer application

a. Apply FYM/compost @2.0-2.5 kg/pit at the time of planting.
b. Apply fertilizers @ 40 kg N, 60 kg P_2O_5 and 50 kg K_2O_2 and at 45 days after planting along with weeding and intercultural operations.
c. Top dress with 40 kg N and 50 kg K_2O 30-45 days after planting along with shallow intercultural operations.

Management practices for intercrop

1. *Amorphophallus* can be intercropped profitably in coconut, arecanut, rubber, banana and robusta coffee plantations.
2. About 9000 plants can be accommodated at a spacing of 90 x 90 cm in 1 ha of coconut garden, leaving 2 m radius from the base of the palms.
3. Half the quantity of FYM (12.5 t ha^{1}) and one third of the NPK dosage (27:20:33) will be sufficient for an intercrop *of Amorphophallus* in coconut garden.
4. For intercropping *Amorphophallus* in banana should be planted at 3.6 x 1.8 m spacing to accommodate 1500 plants ha^{-1}.
5. In between 2 rows of banana, 3 rows of *Amorphophallus* can be grown at a spacing of 90 x 90 cm to accommodate 8000 plants ha^{-1}, leaving 45 cm from the base of banana.
6. For both the crops FYM, N and P can be reduced to half, whereas the entire quantity of K should be applied.
7. Care should be taken to manure both the main crop as well as the intercrop separately and adequately while intercropping *Amorphophallus* with arecanut, rubber and robusta coffee.

Intercultural operations

Mulching

Mulching immediately after planting with either dried grass, green/dried leaves is perhaps one of the most important cultural operations in *Amorphophallus.*

It not only conserves soil moisture and regulates soil temperature but also suppresses weed growth.

Weeding

- If proper mulching is done at planting, weeds would be suppressed to a large extent.
- Despite this, one or two manual weeding could be given, first at 45 days after planting and the second, one month after the first weeding.
- Fertilizer application can be combined with these intercultural operations.

Irrigation practice

- *Amorphophallus* is mostly raised as a rainfed crop.
- However, irrigation is required when monsoon fails specially in eastern India, where it is grown on a large scale.
- In the East Godavari district of Andhra Pradesh it is extensively grown in paddy fields, where water requirement of the crop is met through canal irrigation.
- Stagnation of water is harmful to the crop.

Crop protection

Collar rot

1. The disease is caused by a soil borne fungus *Schlerotium rolfsii.*
2. Water logging, Poor drainage and mechanical injury at collar region favour the disease incidence.
3. Brownish lesions first occur on collar regions which spread to the entire pseudostem and cause complete yellowing of the plant.
4. In severe case, the plant collapses leading to complete crop loss.

Control

a. Using disease free planting material.

b. Removal of infected plant materials and destruction.

c. Improving drainage

d. Incorporation of organic amendments like neem cake

e. Application of biocontrol agents viz. *Trichodrma harzianum*

f. Drenching the soil with 0.2% Captan can help to manage the disease.

Harvesting

- *Amorphophallus* becomes ready for harvest in about 8-9 months after planting.
- The crop attains maturity when total senescence takes place.

TARO

Taro, also known as *Colocasia,* is an important tuber crop of tropical and subtropical regions. In India, it is mainly cultivated in Eastern and Southern States. The tubers are mostly used as vegetable or as subsidiary food after roasting, baking or boiling and the leaves and petioles are also consumed as vegetable. Taro is a rich source of calcium, iron, phosphorus and vitamin A and C.

Climate and soil

It grows well in warm and humid conditions with mean temperature of 21-27° C and a well distributed rainfall of about 1000 mm during growth period.

In areas where rainfall is less, supplementary irrigation is required for successful production.

Taro comes up in all types of soils, but performs better in well drained fertile loamy soils.

Planting season

- Under rainfed condition, planting done during April to June is optimum.
- If grown as irrigated crop, it can be raised throughout the year.

Planting material

- Cormels as well as the mother corms can be used as planting materials, but cormels are ideal.
- Cormels weighing about 20-25 g are optimum planting material.

Land preparation

a. According to soil type and management practices, different methods of land preparation may be followed.
b. In sandy loams, pit method is better whereas in alluvial soils, raised mounds or beds are preferred.
c. Under irrigated condition, ridge and furrow system may be adopted.

Method of planting

1. Plant the cormels at a spacing of 60 x 45 cm.
2. About 37000 seed tubers are required to plant one hectare.
3. The cormels may be planted to a depth of 2.5-7.5 cm.
4. If planted at recommended spacing, approximately 800 kg of planting materials would be required to plant one hectare.

Mulching

- Planted seed tubers take 30 to 45 days for sprouting.
- Mulching helps to hasten sprouting, control of weed growth, regulate soil temperature and retain soil moisture.
- The planted seed tubers need to be mulched with green/dry leaves or dried grass.

Gap filling

- Under field conditions, 5-10 per cent of the seed corms fail to sprout. To overcome this situation, about 2000-3000 corms/cormels per hectare may be planted in a nursery at a close spacing, so that sprouted tubers from the nursery can be used for gap filling.

Manuring and interculturing

1. Apply 12 tons of FYM per hectare and mix it with the soil prior to planting.
2. Taro requires a fertilizer dose of 80 kg N, 25 kg P_2O_5 and 100 kg K_20/ha in two or three split doses.
3. One-third dose of nitrogen (60 kg of urea or 135 kg of ammonium sulphate), 125 kg of rockphosphate and one-third dose of potash (55 kg of muriate of potash) are to be apphed at two weeks after sprouting.
4. The remaining dose of nitrogen and potash may be applied in two equal split doses at monthly intervals after the first application of fertilizers.
5. Weeding and earthing-up are to be done along with the application of fertilizers.
6. Small, inefficient suckers from the mother plant have to be removed along with second weeding and earthing-up.

Crop protection

- Aphids are important pests attacking the leaves. The other pests include spider mites, thrips, grasshoppers, scale insects and mealy bugs.

Control

a. These can be controlled by spraying of Quinalphos or Dimethoate 0.05%.
b. Mealy bugs and scale insects damage the cormels and corms. Hence, select the cormels free of these pests for planting.
c. If infested, the seed cormels should be dipped in Dimethoate or Monocrotophos 0.05% solution for 10 minutes before planting.

Taro leaf blight

a. Taro leaf blight is caused by the fungus *Phytophthora colocasiae.*
b. Oval or irregular purplish or brownish necrotic lesions with water soaked periphery appear on leaves.
c. In severe cases, the entire leaf lamina and the petioles are affected giving a blighted appearance and collapse of the plant.
d. Heavy incidence cause up to 50 per cent crop loss.

Control

1. Use healthy planting materials.
2. Early planting to avoid heavy monsoon rains.
3. Use of field resistant varieties viz., Muktakeshi and Jankhri.
4. Removal of self-grown *Colocasia* plants.
5. Spraying the crop with fungicides viz. Mancozeb (0.2%), Metalaxyl (0.05%).
6. Treat the seed tubers with biocontrol agents *viz. Trichoderma viridae.*

Harvesting

- Crop will be ready for harvest at 6-8 months after planting.
- One month prior to harvest, all the suckers may be wrapped around the base of the other plant and covered with soil by earthing up, for arresting further vegetative growth and sprouting of tubers.
- Irrigation has to be withheld to hasten maturity.
- Harvesting is done by carefully uprooting the plants and the mother corms and cormels are separated.

COLEUS

Kurka/ Cheeva kizhangu or Chinese potato *(Solenostemon rotundifolius* Poir. *Syn.Coleus parviflorus* Benth, *Syn. Coleus rotundifolius* Chev. & Perrot) is a seasonal crop cultivated for its edible tubers in India, Sri Lanka, South- East Asia and parts of Africa. The tubers that resemble potato, are consumed as vegetable after cooking. The tubers have an aromatic flavour on cooking and have a delicious taste. Coleus is variously known as Hausa potato, country potato, Kafir potato, Innala and Kurka. It is a bushy herbaceous annual with succulent stems and aromatic leaves. The plant bears a cluster of dark-brown aromatic tubers at the base and lower parts of the stem.

Climate and soil

1. Coleus comes up well in hot-humid regions.
2. It requires very good rainfall for its growth and cannot withstand drought conditions.
3. In case, failure of rainfall, irrigation has to be provided for satisfactory growth.
4. It thrives well on medium-fertile soil having good drainage.
5. High content of clay in the soil restricts the tuber development.

Planting season

a. The planting is done from the month of July to October.
b. Planting in September has resulted in the production of fairly big tubers.

Raising nursery

1. Raise a nursery, approximately one and half months prior to planting.
2. An area of 500 m^2 is required to produce cuttings for planting one hectare of land.
3. Cattle manure or compost may be applied @ 1 kg/m^2 and ridges/ mounds may be prepared at a closer spacing (45/60 cm).
4. Healthy tubers that weigh about 15-20 g may be planted on the ridges/mounds so as to accommodate 75-100 kg tubers in 500 m^2 area.
5. Top - dress with urea (5 kg/500 m^2) at about three weeks after planting to encourage good plant growth.
6. Clip off the terminal portion of the plant devoid of roots to a length of 10-15 cm at about 45 days after planting.
7. To enable rapid multiplication of the planting material, single node cuttings can be planted directly in the secondary nursery.
8. Such single node cuttings produce axillary shoots within one week.

Land preparation and planting

1. Plough or dig the land to a depth of 15-20 cm and prepare ridges at a spacing of 45 cm.
2. Plant the cuttings at a spacing of 30 cm on the ridges either in vertical or horizontal position.
3. Horizontal planting of vines to a depth of 4-5 cm and exposing the terminal bud ensures quick establishment and promote tuber yield.
4. In loose soils having good drainage, planting can also be done on flat beds with provision for drainage.

Manuring, Inter-culturing and top-dressing

a. Apply 10 tonnes of FYM and NPK @ 30:60:50 kg/ha and incorporate into the soil at the time of land preparation.
b. Top-dress with 30 kg N and 50 kg K_2O at 45 days after planting.
c. This is followed by an inter-culturing and earthing-up of the soil at the base of the plant.
d. In case, the soil has eroded from the base of the plant, one more earthmg-up is required after 30 days to promote the tuber formation.

Fertilizer	Basal(Kg)	Top-dress (Kg)
Urea (N)	67	67
Rajphosphate (P_2O_5)	300	-
Muriate of potash (K_2O)	83	83

Crop protection

- Root knot nematode is a serious pest on coleus and the infested plants exhibit serious swellings or galls in the roots resulting in suppressed roots, stunted growth and wilting.

Control

- Therefore, emphasis may be given for the selection of nematodes free seed tubers for production of planting materials.
- Deep ploughing of the field immediately after the harvest exposes the soil and kills the nematodes.
- Summer fallowing also control the nematode.

Harvesting

- Harvest the crop when the plants dries-up at 4-5 months after planting.
- Pull out the plants and dig out the left over tubers in the field.
- Separate the tubers from the plant and destroy the crop residues.

ARROWROOT

Arrowroot *(Maranta arundinacae)* commonly known as "West Indian arrowroot' is an erect herbaceous plant belonging to the family Marantaceae. Arrowroot is primarily grown for its quality starch which is valued as food stuff particularly for infants and invalids. The crop is native of tropical America. In India, it is grown in North Eastern States, West Bengal, Assam and in South Indian states.

Climate and soil

- The crop grows best at temperatures of 20-30°C.
- A minimum annual rainfall of 950-1500 mm is required.
- The crop thrives best in deep, well drained, slightly acid loam soils under partial shade.

Planting season

- Planting should be done during the last week of May or in early June with the onset of monsoon.

Planting method

- Plough, the land to obtain a fine tilth.
- Prepare raised beds of 15-20 cm height and convenient length and breadth.
- Plant the rhizome bits of 30 cm at a depth of 5.0 - 7.5 cm and cover with soil.

Planting at a spacing of 30 x 15 cm produced significantly higher tuber yield.

Planting material

1. Arrowroot propagated from small pieces of rhizomes 4-7 cm in length, with 2-4 nodes known as bits.
2. Suckers are also occasionally used for planting after raising them in the nursery.
3. These suckers give rise to new plants which are uprooted and cut off to retain 10 cm of the shoot intact with roots.
4. The requirement of planting material is about 5.5 t ha^{1}.

Manures and manuring

- Application of 10 t ha^{-1} of FYM or compost is suitable for arrowroot cultivation.
- Application of 50kg N, 25kg P_2O_5 and 75kg K_2O ha^{-1} is required to get higher yields.

Intercultural operations

a. It is essential to keep the field clean and free of weeds during the first 3-4 months.
b. Earthing-up should be done along with weeding.
c. Mulching with green or dried leaves significantly influence tuber yield.

Irrigation practice

- The crop is grown purely as a rainfed crop. However, if dry spell occurs during the initial 3-4 months, supplementary irrigation at weekly intervals becomes necessary.

Harvesting

- The crop attains maturity in 10-11 months after planting.
- Maturity is indicated by yellowing, wilting and drying up of the leaves.
- At this stage, the plants are dug out and the rhizomes are separated.
- On an average 20-25 t ha^{-1} of yield can be realized.

YAM BEAN

Yam bean (*Pachyrrhizus erosus L*) belongs to the family Leguminosae and sub family Fabaceae (Papilionaceae). It is popularly known as Mishrikand in Hindi. Yam bean is a starchy root crop with comparatively high sugar content and moderate in ascorbic acid. In India, tender tubers are consumed as a vegetable. Young tubers are crisp, succulent and sweet and are highly preferred for salad making. The mature seeds have high content of alkaloids and insecticidal properties. In many developed countries the tubers are processed, canned and made many sweet preparations. The crop has been cultivated in Mexico and South America from pre-Colombian period and has originated from hot moist region of the river Amazon. The crop is now being cultivated in Philippines, China, Indonesia, Nepal, Bhutan, Burma and India. In India it is grown in parts of West Bengal, Bihar, Orissa and Assam.

Climate and Soil

1. Yam bean requires a hot humid climate and it adapts well in sub tropical and hot temperate frost-free zones.
2. Yam bean requires about 14-15 hours of photoperiod for good vegetative growth, however, shorter days are required for better tuberization.
3. A well-distributed rainfall during the growth period is required for optimum tuber yield.
4. Fertile, well-drained, sandy loam soil is best suited for cultivation of yam bean.
5. Water logging is deleterious for yam bean cultivation.
6. Optimum soil pH requirement is 6.0-7.0.

Planting season

- Traditionally yam bean is sown during June-July with the onset of rain in North-Eastern India and is usually harvested in December-January

Planting method

1. Deep ploughing of land followed by planking is necessary to pulverizes the soil.
2. Prepare mounds at a spacing of 0.75 - 1.00 m with 15 cm height.
3. Yam bean seeds can be sown on mounds at the rate of 3-5 seeds per hill.

Planting material

- Yam bean is usually raised by seed.
- The seed rate varies according to the spacing adopted.
- Normal seed rate is 20 - 60 kg ha^{-1}.

Manures and fertilizer application

- Application of 15-20 t of FYM or compost and a fertilizer dose of 80:40:80 kg NPK ha^{-1} has been recommended for getting optimum yields.
- Entire dose of P and K has to be applied at the time of planting along with half the dose of nitrogen.
- The remaining quantity of N is top dressed at 40-50 days after sowing along with interculturing and earthing-up.

Intercultural operations

1. Normally yam bean starts flowering at 75 days after sowing.
2. It is desirable to remove the flowers for getting better tuber yield.
3. There is significant negative correlation between tuber yield and pod formation.
4. It has been observed that spraying 2,4-D (50 ppm) at flower initiation stage causes flower drop and results in better yield of tubers.
5. It is advisable to do first interculturing at 40 days after sowing and the second 30 days after the first weeding.

Irrigation practices

- Normally there is no need to irrigate a June-July crop. In case, there is scarcity of rains, irrigation is essential, as yam bean requires lot of moisture.
- For September sown crop, it is advisable to give supplementary irrigation so that the crop will not face moisture stress during tuberisation.

Harvesting

1. Yam bean will be ready for harvest in 150 days after sowing.
2. If harvesting is delayed, cracking of tubers are more.
3. Harvested tubers can be stored for 2-3 days without any deterioration
4. The average yield of local cultivars is 18-20 t ha^{-1} while that of improved varieties like Rajendra Mishrikand produce 36-40 t ha^{-1}.

Reference

Agro-techiques of tuber crops ICAR-CTCRI

IMPROVED TUBER CROPS VARIETIES SUITABLE FOR NEH REGION

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The tuber crops are known for their high carbohydrate production in their underground tubers and hence they form cheap energy food for millions of people in the tropical and subtropical world. They are also used for animal feed as well as raw materials for several industrial products. The tuber crops especially cassava and sweet potato are mostly exotic in origin, and are under cultivation in the country for centuries. They are cultivated in India mainly in the agro-eco systems of sub–humid to humid coastal, humid rain fed and semi-arid and sub-tropical rainfed conditions. Tuber crops known for their adaptability are found cultivated in various production systems ranging from low land irrigated, upland rainfed and hill rainfed systems in Kerala; rainfed plains, irrigated plains and hill rainfed systems in Tamil Nadu; rainfed plains and hill rainfed systems in Andhra Pradesh and hill rainfed areas in Orissa and North eastern India. They are cultivated in different cropping systems as mono-crop, intercrop and as sequential crop mainly with rice. The research on varietal development in tuber crops is directed keeping in view of the agro-eco systems, production systems and cropping systems. The breeding objectives and varieties developed along with their suitability to different production/cropping systems are enumerated here.

CASSAVA

Cassava (*Manihot esculenta* Crantz) is the most important crop among the tropical root and tuber cropsal regions for it starchy tuberous roots, It belongs to the family Euphorbiaceae. The cultivated cassava is originated in South America and distributed to Africa and Asia. Cassava was introduced to India by the Portuguese when they landed in the Malabar region, presently part of Kerala state during the 17th century, from Brazil. Cassava is an outbreeding species possessing 2n = 36 chromosomes, and is considered to be an amphidiploid or sequential allopolyploids. The cassava plant is monoecious, protogynous and bears separate male and female flowers on the same plant. The major breeding objectives in cassava are, resistance to cassava mosaic disease (CMD), high yield, high starch, good culinary qualities, early maturity (6-7 months), tolerance to post-harvest physiological deterioration (PPD) etc.

The improved varieties were mainly developed through hybridization followed by clonal selection. Besides hybrids several landraces were also released for cultivation through clonal selection. Most of the released varieties are diploid in nature. Triploidy in cassava has been found to be correlated with growth vigour, increased starch content and higher tuber yield. Sree Harsha is the first triploid variety released in cassava with very high yield potential (60 t ha^{-1}) and starch (38-41%). Two triploid hybrids *viz.* 4-2 (Sree Athulya) and 5-3 (Sree Apporva) with high extractable starch content (30%) are in pre-release stage. Sree Rekha and Sree Prabha were evolved through heterosis breeding programme (Table1.). Several short durations (6-7 months) have been developed and are ideal for planting in paddy fallows. H-226 and H-165 are the most popular varieties in industrial belt of Tamil Nadu. Besides these varieties, CO.1, Sree Sahya, Sree Visakham, CO.3, H-119, CO (TP-4) and Sree Rekha are also grown in Tamil Nadu. Cassava mosaic disease (CMD) is the major problem in cassava. Recently a CTCRI variety *viz.* Sree Padmanabha (MNga-1) with CMD resistance was released in Tamil Nadu. Several hybrids with high yield and starch coupled with CMD resistance are in pre-release stage in CTCRI.

SWEET POTATO

Sweet potato (*Ipomoea batatas* (L.) Lam.) is introduced crop from South America and it belongs to the family Convolvulaceae. World sweet potato production is around 106 million tons in an area of about 8.1 million ha. Asia is the world's largest sweet potato producing region with the maximum production of 88.5 million tons in 4.4 million ha. China is the world's leading sweet potato producer with 81 million tons and contributes 76 per cent to the world's production. India is the seventh sweet potato producing country in Asia which is nearly one million tons, followed by Philippines (5 MT) and Bangladesh (3 MT). India and Taiwan, it is the one of the important stable food crop (FAO 2012). It is a cross pollinated crop due to its self-incompatible nature with chromosome number 2n=6x=90and lot of genetic variability available in this crop. The major breeding objectives in sweet potato are early maturity, high yield, resistance against sweet potato weevil, better culinary quality and increase in nutritional value especially for high starch, high carotene and high anthocyanin contents etc.

The major breeding methods include germplasm evaluation and clonal selection, intervarietal and interspecific hybridization and selection. Since the flowers are bisexual, emasculation is needed. The flowers when mature open before dawn, even after 2.00AM onwards and remain open for a few hours after dawn and wilt. Majority of the improved varieties have been developed from the progenies from open pollinated seeds. The sweet potato varieties developed by CTCRI are given in Table2. Among the CTCRI varieties, Sree Kanaka is a recently released, early maturing hybrid with orange coloured flesh due to high β-carotene content (8.8 - 10 mg/ 100g of fresh tuber). The sweet potato variety Sree Bhadra can be grown as a trap crop in for the control of nematodes. Kanjangad, a widely adapted variety grown in Kerala was developed from a landrace through clonal selection. The varieties released by Tamil Nadu Agricultural University includes CO.1, CO.2, CO.3 and CO-CIP.1. The major sweet potato varieties suited to Karnataka are H-41, H-42, Rajendra Sakarkand 43 and RS-35. In Andhra Pradhesh, the varieties *viz*. Samrat, Rajendra Sakarkand 43, Kiran, RNSP-1, RNSP-3 are recommended for cultivation. Rajendra Sakarkhand – 43 and RS-35 are grown in Assam. Location specific sweet potato varieties have been identified for Bihar that includes RS-5, RS-35, RS-92, RS-43, RS-47 and Sree Bhadra. The sweet potato varieties popular in Maharashtra are Varsha, RS-43, Konkan Ashwini and IGSP-4.

YAMS

Yams belong to the family *Dioscoreaceae* under Monocotyledons. In India, the main cultivated yams include, **Greater yam** (*Dioscorea alata* L.)**;** Chromosome number: 2n=2x=40,3x=60,4x=80; **Lesser yam** (*Dioscorea esculenta* Burk.); Chromosome number: 2n=9x=90,10x=100; **African/ white yam** (*Dioscorea rotundata* Poir.); Chromosome no: 2n=2x=40,3x=60,4x=80. The major breeding objectives in yams are, higher yield, Good tuber quality, early maturity, anthracnose resistance in greater yam, nematode resistance in African yam, round to oval tuber shape, shallow tuberization, dwarf/compact plant types that can grow effectively without staking, more shelf life.

Yams are normally diocious. Many of the landraces do not flower and also synchronization of male and female phase is difficult. Hence most of the varieties released are clonal selection from germplasm. The major yam varieties released by CTCRI are given in Table 3. Sree Shilpa is the only hybrid in greater yam released in India. Sree Karthika is the latest high yielding selection (30 t ha^{-1}) with compact tuber shape and good cooking quality. Sree Dhanya is a highly promising dwarf yam which eliminates the cost of staking. The white yam variety Sree Priya is ideal for intercropping in banana, coconut and rubber. Sree Latha and Sree Kala is the promising lesser yam varieties released in Kerala. In greater yam, besides CTCRI varieties, Konkan Ghorkand is popular in Maharashtra, Konuvari Aloo in Assam and CO-1 in Tamil Nadu. In Lesser yam Konkan Kanchan is a clonal selection popular in Konkan region of Maharashtra. Moa Aloo is a lesser yam variety with excellent culinary quality recommended for Assam region. Polyploidy in greater yam has been found to be correlated with growth vigour, increased tolerance to abiotic and biotic stress and higher tuber yield. Research work is in progress to develop promising triploid varieties in yams.

ARIODS

Among the crop plants belonging to the family *Araceae*, taro (*Colocasia esculenta* (L.) Schott) and elephant foot yam (*Amorphophallus paeonifolius* (Dennst) Nicolson.) are the major ones cultivated all over India. Both these crops are diploids with 2n=28. Triploid varieties are also available in taro. The major breeding objectives in sweet potato are, higher yield, good cooking quality (low acridity), disese resistance (leaf blight in taro; collar rot in elephant foot yam, virus resistance) and early maturity. The aroid varieties released by CTCRI are given in Table 4.). Most of the taro varieties are clonal selections from germplasm eg. Sree Reshmi and Sree Pallavi. Sree Kiran is the first taro hybrid released in India. Leaf blight caused by *Phytophthora colocasia* is the major disease in Taro. Among the improved varieties Muktakeshi has tolerance to leaf blight. Satamukhi, RNCA-1, Bhavpuri and KCS-2 are the popular varieties grown in Andhra Pradhesh. Muktakeshi, Sonajuli and Jhankri are grown in Orissa. CO-1 released by Tamil Nadu is recommended for Tamil Nadu. Three improved varieties *viz*. Gajendra, Sree Padma and Sree Athira were released in elephant foot yam. Sree Athira is a recently released hybrid of elephant foot yam with high average yield of 40 t ha^{-1}.

Chinese potato

Chinese potato is a minor tuber crop native of India grown mostly in open garden lands in Kerala and is extensively cultivated as a major component in the mixed cropping system in Tirunelveli district of Tamil Nadu. Sree Dhara (CTCRI), CO1 (TNAU) and Nidhi (KAU) are the clonal selections released in Kerala.

Table 1. CASSAVA VARIETIES RELEASED BY ICAR-CTCRI

S.No.	Name of the variety	Avg. Yield (t ha^{-1})	Potential yield (t ha^{-1})	Maturity (Months)	Cooking quality	Starch (%)	Year of Release and remarks
1	H-97	25-35	40	10	Good	27-31	1971, Starchy variety suitable for industries suited to upland rainfed and irrigated plains
2	H-165	33-38	45	8-9	Good	23-25	1971, Short duration variety , popular in hill rainfed of Tamil Nadu and Andhra Pradesh
3	H-226	3035	40	10	Good	28-30	1971, Popular in Tamil Nadu in rainfed plains and , some parts of Andhra Pradesh, very much suitable for industries . Comes up well in irrigated plains also.
4	Sree Visakham	35-38	45	10	Good	25-27	1977, Short duration, High in carotene content, Cooking quality good, suitable as sequential crop in rice fallows and inter crop in coconut gardens.
5	Sree Sahya (11-2304)	35-40	45	10-11	Good	29-31	1977, Long duration crops , Upland rainfed
6	Sree Prakash (S-856)	30-35	40	7 (Early maturing)	Good	29-31	1987, Short duration suitable as sequential cropping in rice fallows
7	Sree Harsha (2-14)	35-40	60	10	Good	38-41	1996, Starchy variety for industrial areas, irrigated plains
8	Sree Jaya (CI-649)	26-30	58	6-7 (Early maturing)	Excellent	24-27	1998,Short duration suitable for low land and becoming popular in rainfed plains of Andhra Pradesh
9	Sree Vijaya (CI-731)	25-28	51	6-7 (Early maturing)	Excellent	27-30	1998, Short duration suitable for low land and becoming popular in irrigated plains of Tamil Nadu. Suitable as intercrop in coconut gardens
10	Sree Rekha (TCH-1)	45-48	65	10	Excellent	27-29	2000, Upland rainfed and irrigated plains of Tamil Nadu
11	Sree Prabha (TCH-2)	40-45	60	10	Excellent	26-28	2000, Upland rainfed and irrigated plains of Tamil Nadu
12	Sree Padmanabha	38	46	9-10	Excellent	25.8	2006, Irrigated plains of Tamil Nadu
13	Sree Athulya	35-40	70	10	Good	30.2	2014, Field tolerant to Cercospora leaf spot,

							spider mite and scale insect, Ideal for cassava-based industry
14	Sree Apoorva	35-40	70	10	Good	29.9	2014, Field tolerant to Cercospora leaf spot, Ideal for cassava-based industry
15	Sree Swarna	35-40	55	7-8	Excellent	25.2	2015, Field tolerant to cassava mosaic disease, light yellow flesh
16	Sree Pavithra	35-40	69	9-10	Excellent	24.4	2015, High K efficiency
17	Sree Reksha	45-50	80	8-9	Good	27-31	2017, Resistant to cassava mosaic disease, tolerant to PPD
18	Sree Sakthi	45-50	70	9-10	Good	26-32	2018, Resistant to cassava mosaic disease, Industrial variety, resistant to PPD
19	Sree Suvarna	45-50	70	7-8	Good	25-27	2018, Resistant to cassava mosaic disease
20.	Sree Kaveri	>50	75	9-10	Good	28	Similar to H-226, high yield, CMD resistant, drought tolerant

Table –2. SWEET POTATO VARIETIES RELEASED BY ICAR-CTCRI, TRIVANDRUM

Sl No.	Name of variety	Average yield ($t\ h^{-1}$)	Maturity (Days)	Quality attributes				Year of release and remarks
				Cooking quality	Starch (%)	Sugar (%)	Carotene (Iu/g)	
1.	H-41	20 – 25	120	Cooks easily, Sweet, low fibre	-	-	-	1971, Kerala
2.	H-42	22 – 25	120	Cooks easily, Sweet less fibre	-	-	-	1971 , Kerala
3.	Varsha (H-268)	25	120	Good	14 – 16	2.2 – 2.8	-	1983, Maharashtra State
4.	Sree Nandini (76 – OP 217)	20 – 25	100 – 105	Excellent, Cooks well, Sweet	13 – 18	3.3 – 4.4	-	1987 Kerala State, paddy fallows
5.	Sree Vardhini (76 – OP 219)	25	100 – 105	Cooks well with attractive colour	13 – 15	-	1200	1987 Kerala State, carotene rich, dual purpose variety, upland and low land
6.	Sree Retna (X-108-2)	20 – 26	90 –105	Excellent	22 – 23	1.5 – 2.0	3200 – 3500	1996, Kerala State
7.	Sree Bhadra (S-1010)	20 – 27	90	Excellent	18 – 20	-	800 – 1000	1996 Kerala State, popular in Bihar
8.	Gouri (85-16)	19.0	110-120	Fair	16.59	5.87	8,800	1998, Orissa State, upland and low land conditions
9.	Sankar (85-70)	13.73	120	Excellent	-	-	-	1998 Orissa State upland and low land conditions

10	Sree Arun	20-28	90	Good	19.7-20.4	1.5-1.6	-	2002, upland and low land conditions
11	Sree Varun	20-28	90	Good	20.6-21.5	1.5-1.6	-	2002 upland and low land conditions
12	Kalinga	17.2	105-110	Excellent	28	2.5-3.3	-	2004, high starch, good for food and fodder
13	Sree Kanaka	10-15	75-85	Good	14.7	1.8	8.8-10	2004, very high carotene, upland
14	Goutam	18.9	105-110	Very good	24-25.5	2.5-3	-	2005, uplands and hilly areas
15	Sourin	16.2	105-110	Good	24.8-25.6	2.8-3.5	-	2005, rainfed and irrigated, withstands mid season drought
16	Kishan	17	110-120	Good	18.2	3.0-3.5	-	2005, tolerant to weevil, withstands mid season drought
17	Bhu Sona	20-24	105-110	Good	18.8-19.7	2-2.4	13.2-14.4 mg/100 g	2017, tolerant to weevil, withstands mid season drought and salinity
18	Bhu Kanti	20-24	105-110	Good	16-18.8	1.9-2.2	6.2-7.8 mg/100 g	2017, tolerant to weevil, withstands mid season drought and salinity
19	Bhu Ja	22	105-110	Good	16.6-17.2	2.4-3	5.5-6.4 mg/100 g	2017, salinity tolerant
20	Bhu Swami	20-24	105-110	Excellent	20.8-21.2	3-3.7		2017, tolerant to weevil, salinity tolerant, suitable for processing industries
21	Bhu Krishna	18	100-110	Good	19.5	1.9-2.1		2017, 85-90 mg/100 g anthocinin, salinity tolerant

Table 3. YAM VARIETIES RELEASED BY ICAR-CTCRI, TRIVANDRUM

S. No	**Name of the variety**	**Avg. yield (tha^{-1})**	**Potential yield (tha^{-1})**	**Maturity (Months)**	**Cooking quality**	**Starch (%)**	**Year of Release Remarks**
Greater Yam							
1	Sree Keerthi	25-30	54	9-10	Good	20-22	1987, large sized tubers intercropping in banana and coconut
2	Sree Roopa	25-30	44	9-10	Good	16-18	1987, intercropping in coconut
3	Sree Shilpa	28	40.4	8	Good	17-19	1998,first hybrid, oval medium sized tubers, early harvesting
4	Sree Karthika	30	46	9	Good	21.4	2004, excellent cooking quality

5	Orissa elite	25	30	6-7	Excellent	20.1	2005, excellent cooking quality
6	Sree Swathy	35	50	8	Good	20.02	2014, tolerant to antharanose and drought
7	Sree Neelima	33	45	9	Good	18.1	2014, purple fleshed tubers
8	Sree Nidhi	35	45	8-9	Good	23.2	2017, medium sized tubers, tolerant to antharanose
9	Bhu Swar	20-25	30	6-7	Excellent	18-20	2017, tolerant to antharanose
White Yam							
1	Sree Priya	35	48	9-10	Excellent	19-21	1987, intercropping in banana and coconut
2	Sree Subhra	35	48	9-10	Excellent	21-22	1987,drought tolerant
3	Sree Dhanya	20	39	9	Good	22-24	1993, first dwarf variety, no need for staking, suitable for closer spacing
4	Sree Swetha	30	40	9	Good	22.02	2017, dwarf, non climber
5	Sree Haritha	46	60	9-10	Excellent	24.02	2017, drought tolerant
Lesser Yam							
1	Sree Latha	25	35	8	Good	18-19	1983, intercropping in banana and coconut
2	Sree Kala	20	36	7 1/2	Excellent	23-25	1993, oval smooth tubers

Table 4. AROID VARIETIES RELEASED BY ICAR-CTCRI, TRIVANDRUM

S. No	Name of the variety	Avg. yield (tha^{-1})	Potential yield (tha^{-1})	Maturity (Months)	Cooking quality	Starch (%)	Year of Release and Remarks
Taro							
1	Sree Rashmi	18	32	7	Very good	14.5-15.5	1987, acrid free edible leaves, corms and cormels.

							Gives economical yield under low input levels.
2	Sree Pallavi	16	18	7	Very good	24.5	1987, tall variety with large number of small sized tubers. Field tolerant to leaf blight and Dasheen mosaic virus
3	Muktakeshi	20	30	5-6	Excellent	17.8	2002, non acrid, leaf blight resistant, field tolerant to Dasheen mosaic virus, aphids, cut worm and scale insects, suitable for upland and lowland during summer and rainy season.
4	Sree Kiran	17.5	28.5	6-7	Good	17.8	2004, first hybrid taro in India, long keeping quality of tubers, moderately susceptible to leaf blight.
5	Pani Saru 1	15.7	20.2	6-7	Good	12	2005, field tolerant to leaf blight, suitable for water logged / submerged condition with long keeping quality of tubers
6	Pani Saru 2	13	18	6-7	Good	17	2005, field tolerant to leaf blight, suitable for water logged / swampy / submerged and upland condition of Orissa
7	Bhu Kripa	12	18	6-7	Excellent	12.3-14.2	2017, field tolerant to leaf blight, suitable for water logged / swampy / submerged, salinity and drought tolerant
	Bhu Sree	12	18	6-7	Excellent	15.6-17.3	2017, field tolerant to leaf blight, salinity and drought
Elephant Foot Yam							
1	Sree Padma	42	80.2	8-9	Very good		1998, first variety from Kerala, fairly tolerant to mosaic disease and field tolerant to collar rot.
2	Sree Athira	40.5	45.6	9-10	Good	18	2006, first genetically improved variety, high tuber yield

Table 5. CHINESE POTATO VARIETY RELEASED BY ICAR-CTCRI, TRIVANDRUM

No	Name of the variety	Pedigree	Avg. yield (tha^{-1})	Potential yield (tha^{-1})	Maturity (Months)	Cooking quality	Starch (%)	Year of Release and Remarks
1	Sree Dhara	Clonal selection from indigenous germplasm	25	28	5	Good	16-20	1993, high yielder, first variety in Chinese potato in Kerala and India, susceptible to root knot nematode.

Reference

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Quality planting material production of cassava, sweet potato and Chinese potato

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Tuber crops are known as crops for adversity, there are many instances showing the life sustaining role of tuber crops in times of natural calamities and famine. They do not need prime land for cultivation. These crops can be grown in marginal farms.They have resilience to adverse climatic conditions and never let down the farmer who can expect a reasonable harvest even when other crops fail. Tropical tuber crops include Cassava, Sweet Potato, elephant foot yam, taro, tannia, yams, yam bean, arrow root etc. Comprise a group of plants with modified root or stem as starchy storage organ which may be enlarged roots, corms, rhizomes, or tubers usually harvested from below ground. They are the third most important food crops after cereals and grain legumes and are unique in their inherent qualities like high dry matter production and capacity to withstand the vagaries of climate change. These crops can be grown under warm humid conditions of tropical as well as sub-tropical agro-ecosystem. They played a key role in the diet of early human being before evolution of settled agriculture. Till today, these crops ensure food security to millions of people in the tropical and subtropical countries either as stable or subsidiary food for about one fifth of the world population.
In India, tropical tuber crops grow almost under all environmental conditions except temperate climate. Cassava is cultivated in an area of 0.18 million ha with a total production of 6.94 million tons and the average yield is 37.93 t/ha (FAOSTAT, 2021). In India, it is cultivated in 12 states and 2 union territories, but the major producers are the states of the southern peninsular region, Kerala, Tamil Nadu and Andhra Pradesh.

Seed is an important input for any crop. These crops are vegetatively propagated and their multiplication ratio is very low. The multiplication rate of cassava, Sweet Potato and Chinese Potato are 1:10, 1:15 and 1:14, respectively. In the case of tropical tuber crops, the seed requirement is mainly met through traditional seed system where farmers keep a portion of their produce as seed for next season. As a result of continuous use of same planting material year after year, the qualities of seed/ planting materials get deteriorated due to degeneration and lack of proper knowledge of farmers about the seed production technique.

Planting material production: Rapid propagation of tropical tuber crops is limited by the incidence of pests and diseases as well as the very high volume and quality of the planting materials, because of these limitations and the high cost of seeds and costs involved in transportation, a formal seed system of these crops is not available at present. After harvest, the farmers keep a portion of the produce for their planting during the next season. This conventional seed system has got many limitations such as spread of diseases and pests, poor yield, etc.

Quality planting material production in Cassava by conventional method:

Cassava (*Manihot esculenta* Crantz**)** is an important tropical tuber crop and ranks fourth in the world, after rice, wheat and maize, as a source of calories for human consumption and popularly known as tapioca, is a native of Brazil in Latin America and was introduced to India especially in Kerala state by the Portuguese in the 17th century. Recognizing its nutritious and delicious character, it was popularized as a food crop by his Highness Sree Visakham Thirunal, the then Maharaja of the erstwhile Travancore princely state, who ruled the state during AD1880-1885.

Climate: Cassava grown better in warm humid climate with well distributed rainfall.

Time of planting: Planting of cassava can be done throughout the year under irrigated conditions. As a rain fed crop best time of planting is April- May with the onset of monsoon rains. The next best season is August-September with the onset of north-East monsoon rains.

Land preparation: Soil physical condition influences the plant growth and hence proper tillage is required for the cassava cultivation. In light textured soil flat method of land preparation, in heavy textural soil mound method and under irrigated condition ridges and furrow method of land preparation required.

Selection of quality planting material: Disease and pest free planting material of 9-10 months maturity having a thickness of 2-3 cm may be selected for planting, stakes obtained from bottom and middle portion of the stem after discarding the 1/3 from the total length of the stem from the top is preferred for the preparation of stakes for planting.

Stake length and depth of planting: A stake length of 15-20 cm more suitable for planting and stakes can be planted to depth of 5cm.

Method of planting stakes: Different methods of plantings stakes such as vertical, (90^0 to the ground), slanted (45^0 angle) and horizontal, showed that vertical planting resulted in more uniform formation of callus tissue around the cut surface, which helped in the uniform distribution of tuber forming roots all around the base of the plant.

Spacing: Based on the branching behaviour, cassava genotypes are classified into branching, semi-branching and non-branching type. Non-branching type requires a spacing of 75x75 cm while semi-branching and branching types require 90x90 cm for optimum production, normally one stake is planted per hill.

Shoot number per hill: The sprouts emerging from the top buds are more vigorous than those emerging from the lower nodes of the stake. Remove of excess sprouts by retaining two per plant at opposite sides is better for the production of more number of tubers per plant.

Gap filling: under field condition, all the stakes planted may not establish due to the use of poor quality planting material and adverse weather conditions, which necessitated gap filling within a reasonable time. At the time of planting stakes in the main field, about 5 per cent of the stakes with 600 no may be planted separated at a very close spacing of 4x4 cm in a nursery area of one square metre with pot watering so that the settling at the age of 20-25 days old may be uprooted and used for gap transplanting.

Inter culture and earthing up: Inter cultureing is important especially in the early stage of the crop for the control of weeds and to improve the physical condition of the soil. Once the cassava plant grown enough canopies to cover the entire field, weeds do not generally become a problem. The first inter cultureing shall be sufficiently deep, done at 45-60 days after planting and a shallow inter culturing and earthing up given one month after the first.

Manures and fertilizers: Cassava crop producing a yield of 30 t/ha removes 187 Kg nitrogen, 33Kg phosphorus and 233 kg potassium per ha. A basal dose of 12.5 tons FYM/ compost along with a fertilizer dose of 50kg nitrogen, 50kg phosphorus and 50 kg potassium is recommended at the time of land preparation.When the crop attains 45-60 days after planting, a top dressing of 50 kg nitrogen and 50 kg potassium/ha has be applied along with the first intercultural operation. For short duration varieties of cassava and local types a fertilizer dose of 50:25:50 Kg N, P_2O_5, K_2O/ha is recommended in splits of 25:25:25 Kg/ha of N, P_2O_5 and K_2O as basal and 25:25 kg of N and,K_2O as top dressing (Ravindran, C.S., *et al*., 2013).

Irrigation: In Kerala, the crop is mostly grown under rain fed crop where as in Tamil Nadu it is grown under irrigated condition. For proper establishment of cassava stakes/settlings in the main field. Sufficient moisture should be ensured in the field for the first twenty days after planting. Cassava requires sufficient soil moisture for sprouting of stakes and subsequent establishment. The stage of the crop most sensitive to moisture is tuberization. Up to tuberization the crop needs irrigation at 10 days interval and there after once in 20 days.

Harvest: The crop is ready for harvest at 10-11 months after planting. Short duration varieties can be harvested from 6-7 month stage. Delayed harvest may result in deterioration in the cooking quality of the tuber. A good crop of high yield varieties of cassava produced an yield of 35-40 tons/ha in 10-11 months whereas short duration varieties of 6-7 months duration recorded an yield of 28-30 ton/ha under ideal conditions.

Storage of stakes: Fresh stakes from mature plants are ideal for obtaining best results. However, when they are not available due to prolonged drought or even excess moisture many producers have to preserve the stem before it is being used for cultivation. Long storage causes loss of moisture and stems are also exposed to many pests. Uncut stems can be usually stored in shady, well ventilated areas. In southern Maxico, bundle of stakes are kept upside down under mango trees as long as 8 weeks. In the south of Brazil, stakes are stored up to 8 weeks horizontally in the open.

Quality planting material production of cassava through minisett technique:

Minisett Technique: ICAR-CTCRI, Thiruvananthapuram has developed a novel technique for quality planting materials production of tuber crops by Minisett techniques. The technologies are propagated extensively for rapid propagation of planting materials of tuber crops. Based on this concept, the minisett experimental trial was conducted at ICAR-CTCRI during the period 2001-2006 for generated valuable data for optimizing the size of setts, method of planting, nursery practices, spacing and nutrient requirement for the rapid production of quality planting materials in tuber crop (James George *at al*., 2004).

In the minisetts technique, first select the mature plant, disease free stems (preferably those obtained from meristem culture), two nodes as the optimum size for rapid production of planting material in cassava. Minisetts are prepared from healthy stems by making two node cutting using a sharp hack saw blade, top one-third portion is usually discarded in the traditional system, however in minisett technique, the whole stem is used. when tip cuttings are taken, it is advisable to place them in water so as to prevent dehydration. The stem just below the growing tip is very tender with prominent axillary buds. hence from this portion, cuttings with four nodes are taken instead of two as the latter may dry up very fast.

Preparation of minisetts: During the minisett preparation, sufficient care should be taken such that no damage is caused to the axillary buds. Shade net house should be ideally on a flat field and the soil should be well drained and devoid of stones and pebbles. A shade net house of 30x7 m dimension with frame with GI Pipe and shade net of 35% percent shade. preferably near water source. Since the minisetts ought to be free of any diseases and pests, it is essential to raise them in a protected environment. Make raised beds 20 cm height of soil and sand, mixed in the ratio of 1:1 .A nursery area of 45 m^2 is required for producing minisetts for planting one hectare of land, or 18 m^2 of nursery area of planting 1 acre.

Planting minisett in nursery: Furrows are made across the width of the bed with a khurpi or small hand hoe about 5 cm deep. Two node cuttings are then planted in the furrow, end to end horizontally, with the buds facing either side. A spacing of five cm is could be provided between two rows. Minisetts planted in the row is then covered with a fine layer of soil and sand mixture. The two nodes setts must be planted horizontal position with spacing 5x5 cm.

Comparison of multiplication ratio

Cassava minisett technique

Nursery management of minisett: The minisett would started sprouting in a week time. it is advised to spray dimethoate (0.05%) at fortnightly intervals as a prophylactic measure against pests like white fly which is responsible for spreading cassava mosaic disease (CMD).Therefore, if an infected minisett is found, it should be immediately uproot and destroyed.

Transplanting minisett to main field: The mini sett planting material will be ready for transplanting in the main field after in 3-4 weeks. Two to three fully opened leaves stage is the optimum time for transplanting. Uprooting minisett from nursery beds could be with help of a Khurpi, taking maximum possible care not to damage the roots, prior to uprooting, the main field should be properly prepared.It should be thoroughly ploughed and brought to a fine tilth. About 12.50 t/ha of dry FYM is spread in the field. The ridges of 30 cm height are taken with a spacing of 45cm between the ridges. Uprooted minisett are then carefully planted on the ridge at spacing 45cm. About the 50,000 minisett could be transplanted in 1 ha of land.

Transplanting in main field:

Quality planting material production of cassava: field view

Management of transplanted minisett: The transplanted minisett usually gets established in a week time. After established, fertilizer of NPK 50:50:50 Kg /ha may be applied as basal dose and second dose of fertilizers 50:50 Kg/ha N and K may be applied as top dressing. Weeding and intercultural operations could be done at the application of second dose of fertilizers.it is advised to spray dimethoate (0.05%) at fortnightly intervals as a prophylactic measure against pests like white fly. The minisett crop would mature in about 8-9 months.

Harvest: On harvest from a hectare, about 60,000 cassava stems and 75-80 tons tuber could be obtained by adopting minisett technique, where as in the traditional production system, about 24,000 stems and 30 tons/ha of tubers could be obtained. if minisett technique is adopted for further multiplication, then minisett for planting 50-60 ha could be obtained in the next generation. Minisett technique multiplication ratio 1:60 and traditional method multiplication 1:10 in cassava (James George *at al*., 2004).

Cassava minisett technique

2. Quality planting material production in Sweet Potato:

Sweet potato (*Ipomoea batatas* L. Lam.) is one of the important tropical tuber crops in terms of production, economic value, contribution to calories and protein. Sweet potato is a native of South America and is the seventh most important staple food of many developing nations. It is cultivated for human food, animal feed and raw materials in industries. It is grown in several agro ecological zones and plays a vital role in the farming and food systems in southern and eastern regions of India. Sweet potato is a herbaceous perennial plant and produces edible tubers. However, it is grown as an annual plant by vegetative propagation using either storage roots or vine cuttings. Sweet potato matures in 3-5 months, and stores well in soil as a famine reserve crop, has high productivity per unit area and performs relatively well in marginal soils, which makes it as an ideal crop for food security.

In India, sweet potato is one of the important staple food crops among tribals, which are consumed as snack and also used to a limited extent as animal feed.

The total area under sweet potato cultivation in India (including orange- fleshed sweet potato) was about 130.6 thousand hectares during 2017-18 with a production of about 1500 thousand tons The orange-fleshed varieties of sweet potato contain high levels of beta- carotene, a precursor of Vitamin A.

Consumption of orange- fleshed sweet potato when they are available builds up the human body's stores of vitamin A. The unutilized vitamin A is stored in the liver for several months. This enables the body to build up a reserve to avoid vitamin A deficiency during the times when access to vitamin A-rich foods is limited.

The orange-fleshed sweet potato (OFSP) helps in combating Night blindness and Bitot Spot diseases caused by Vitamin A deficiency. The orange- fleshed sweet potato (OFSP) tubers have high carbohydrate content, allowing them to produce more edible energy per hectare per day than other common sources of carbohydrates such as rice and wheat. Sweet potato leaves and vines are excellent sources of vitamins A, B (thiamine, niacin, and pyridoxine) and C and contain comparatively high levels of protein, calcium and antioxidants.

Sweet potato plants **Sweet potato tubers**

Improved varieties

The ICAR-CTCRI has released 21 improved varieties in sweet potato with various quality traits for food and nutritional security and income generation. The details of the varieties are given in the table 1.

Climate

Sweet potato is grown in tropical, sub-tropical and warmer temperature regions. It can be grown in elevations from sea level up to 2000 m above mean seal level. Warm sunny days and cool nights are very much favourable for storage root formation. Short days with a low light intensity promote root development and it requires a day length below 11.5 hours to promote flowering. Root formation requires cool temperature while the weather should be warm for root bulking.

The sweet potato plant requires a temperature range of 21 to 26°C, well- distributed rainfall of 75 to 150 cm along with adequate sunshine for profitable production.

Soil

Sweet potato can be grown on a wide range of soils but sandy loams reasonably high in organic matter with a permeable sub soil are ideal for cultivation. A well-drained sandy and clay loam soils with reasonably high organic matter with permeable sub-soils are ideal for sweet potato cultivation. Sweet potato is an acid-tolerant crop and yields are usually high in acidic soils (pH - 5.5 to 6.5).

Planting Season

Sweet potato can be cultivated as rainfed crop during Kharif season (June-August), and with supplemental irrigation during Rabi season (October-December). A Rabi planted sweet potato produces higher tuber yield under warm sunny days, cool nights with moderate rainfall. It can also be grown in summer season (February-May) with irrigation in lowlands.

Orange fleshed Sweet potato Varieties

The biofortification work conducted at ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI), Thiruvananthapuram and its Regional Centre at Bhubaneswar, Odisha, has resulted in the release of six orange-fleshed varieties - *Bhu Sona,* Sree *Kanaka, Bhu Kanti, Bhu Ja, Gouri*, and Sree *Rethna*.

Among the released varieties, the Beta (β)- Carotene content ranged from 3.2 - 3.5 mg/100g (Sree *Rethna*) to 11.5 - 12.5 mg/100g (*Bhu Sona*).

Planting material production

Nursery Preparation:

Sweet potato is propagated through vine cuttings obtained either from freshly harvested plants from the field or from the nursery.

Vines obtained from the nursery should be healthy and vigorous for maximum tuber production. If tubers are used, raise the nursery in two stages – primary and secondary.

Primary nursery:

Raise nursery three months prior to planting in the main field. For planting one hectare of land, about 100 $m^2$of primary area and about 100 kg of medium sized weevil free seed tubers (125-150 g each) are required. Make ridges of 60 cm apart and plant healthy tubers on ridges giving a spacing of 20 cm. In water scarce areas, plant the tubers in rows. To ensure quick growth of vines, it is top dressed with 1.5 kg urea / 100 m^2 at 15 days after planting. The nursery is irrigated whenever required. After 45 to 50 days, the vines are cut to a length of 20 to 30 cm for further multiplication in the secondary nursery.

Secondary nursery: Vines collected from the primary nursery are further multiplied in the secondary nursery in an area of 500 m^2 to produce enough vines for planting in one hectare of land. Farmyard manure or compost is applied @1 kg m-2 and ridges are formed at a spacing of 60 cm. Vines obtained from the primary nursery or from freshly harvested crop are planted in the secondary nursery at a spacing of 20 cm on the ridges. To ensure enough vegetative growth, 5 kg urea is applied in two splits at 15 days and 30 days after planting. Irrigate first three days and thereafter on alternate days for one week. Thereafter irrigation may be restricted at once in three days. After 45 days, vines are cut to a length of 20-30cm for planting in main field.

Selection of vines for planting in the main field

After 45 -50 days in the secondary nursery, the vine cuttings of 20 to 30 cm long from the middle and top portions are harvested for planting in the main field.

Cut vines with intact leaves are stored under damp/shaded conditions for two days prior to planting in the main field to promote better root initiation, easy establishment of vines and higher tuber yield. The leaves of the vines can be removed when the vines are to be transported to distant places to reduce the bulkiness.

Preparation of vines: The apical vine cuttings are found to be the best for high yield. A vine length of 20-30 cm with atleast 3-5 nodes is ideal for planting. The cut vines with intact leaves when stored under shade for two days prior to planting in the main field promote better root initiation, early establishment of vines and high tuber yield. The leaves can be removed when the vines are to be transported to distant places to reduce bulkiness.

Planting materials of sweet potato

Land preparation

The land is ploughed or dug to a depth of about 20 cm and harrowed to pulverize the soil.

In general, mounds, ridge and furrows, and flat bed methods are practiced in sweet potato cultivation. When the sweet potato is cultivated in areas experiencing drainage problems, mounds are ideal while ridges and furrows are suitable for sloppy lands.

In case of ridge planting, prepare ridges of 90 cm apart having 45 cm ridge height. When sweet potato is planted on mounds, no specific spacing is followed.

Advantages of growing sweet potato in ridges:

1. When cultivated in sloppy land, it prevents soil erosion
2. Efficient pest management
3. Easier harvesting
4. Less possibility of deformed tubers
5. Produces larger size tubers
6. Provides Higher and better quality tubers

Land preparation and planting: Plough the soil to a fine tilth. Mounds, ridges and furrows and flat bed methods are recommended at different places. Make ridges at 60 cm apart having 25-30 cm height, plant the vine cuttings in the soil at a spacing of 60 x 20 cm with both the ends exposed and middle portion buried in the soil.

Time of planting

Under rain-fed conditions, it is best to plant sweet potatoes early in the rainy season so that establishment can take place quickly.

In areas where the rainy season is prolonged, planting may be timed so that the crop matures just as the rainfall begins

Planting method

Plant two cuttings per hill on the ridges either horizontally/ inclined/ vertically and place them 20 cm apart in ridges with minimum of two to three nodes placed inside the soil.

If there is no rain, sprinkle water immediately after planting the vines and continue watering for first 10 days for better establishment

Nutrient management: Apply farmyard manure @ 5 t ha-1 prior to planting and N,P_2O_5, K_2O fertilizers @ 50:25:50 kg ha^{-1}. (Apply urea (55 kg) or ammonium sulphate (125 kg), rock phosphate (125 kg) and muriate of potash (85 kg) per hectare at the time of planting. Top dress with 55 kg urea or 125 kg ammonium sulphate at 30 days after planting along with intercultural operations and earthing up.

Irrigation: To ensure proper sprouting and establishment of vines, a moist seed bed is required for 4-5 days. Tuber initiation phase which falls between 8 and 20 days after planting is very critical and maintenance of soil moisture during this period is essential to obtain economic yield.

Plant protection

Sweet potato weevil is the most destructive pest causing very severe damage to the crop. Adult weevil punctures the vines and tubers. The grubs bore and feed by making tunnels. The weevil infestation is high during dry seasons especially when farmers delay the harvesting of tubers. Average yield loss is 20-55% which may go up to 100 % in severe cases.

Management

- Select weevil free healthy planting materials
- Dip the vine cuttings in Fenthion (0.05 %) or Fenitrothion (0.05 %) solution for 10 minutes before planting
- Remove and destruct all alternate hosts
- Earthing up at 30 and 60 days after planting
- Install the sex pheromone trap @ one trap 100 m^{-2} for mass trapping of the male insects
- Timely harvest of the tubers and destruction of crop residues by burning

Sweet potato weevil (*Cylas formicarius*)

Sweet potato weevil is the most important pest causing very severe damage to the crop.

Adult weevil punctures the vines and tubers. The grubs bore and feed the stem and tubers by making tunnels. Attack is high during dry seasons or when farmers delay in harvesting of tubers. Yield loss may go up to 100%. On average 20 to 55% tuber loss occurs.

IPM for Sweet Potato Weevil

Select weevil free healthy planting material.

Dip the vine cutting with an insecticide with the active ingredient Imidacloprid (3 ml in 10 liters of water) for 10 minutes before planting.

Reridge the crop at 30 and 60 Days after planting.

Install the sex pheromone trap @one trap/100 m2 for mass trapping the male weevils.

Harvest at 105-110 days.

Destroy the crop residues after harvest by burning.

Sweet potato feathery mottle virus: Among the different viruses, sweet potato feathery mottle virus is widely observed in sweet potato which causes crop loss upto 50 % . Feathery and purple pattern in the leaves are the common symptoms and the primary spread is through planting materials.Among the 12 viruses, sweet potato feathery mottle virus (SPFMV) is widely observed. The most common symptom of SPFMV is a feathery, purple pattern in the leaves.

Primary spread is through planting material and also by aphids. The SPFMV causes up to 50% yield loss.The SPFMV can be managed through field tolerant varieties like Sree Vardhini, and the use of virus free planting materials as well as meristem culture plants.

Management

- The disease can be managed through field tolerant varieties like Sree Vardhini and use of virus free quality planting materials as well as meristem culture plants.

Harvesting:

- Harvesting is done at crop maturity depending on the duration of the cultivated varieties
- Remove the vines and dig out the tubers without making injury. Good quality, well shaped and pest and disease-free tubers are selected for planting materials
- Apical vines produced from healthy tubers without pests and diseases are selected as planting materials
- Vine cuttings are to be stored upright side under shade for two days before planting

- All tubers and vines for planting materials purpose are to be transported in net bags or well aerated containers to avoid excess heat damage
- Sweet potato is ready for harvest when the leaves turn yellow and begin to drop. Maturity can also be assessed by cutting sample tubers in the field and examining the color of the latex exudation. Latex from mature tubers remains creamy white, while in immature tubers when cut, the latex turns black.
- Harvesting must be timely. If the crop is left too long in the ground the tubers can become prone to rotting and weevil attack
- The field is irrigated two to three days prior to harvesting to facilitate easy lifting of the tubers. After removing the vines the tubers are dug out without causing injury.
- Yield : 20 to 25 t /hectare.
- **Curing** For successful storage and marketing, it is necessary to cure the harvested tubers. Covering the freshly harvested tubers with a polythene sheet (6" – 8" height above the tubers) spread open in a well-ventilated place can help in reducing fungal infection by over 10% thereby increasing shelf life by 60%. Curing facilitates toughening of the skin and healing of wounds thereby reducing the risk of shrinkage, post-harvest infection, and decay. Curing enhances the culinary quality of the sweet potato tubers.
- **Washing:** The cured tubers should be washed in water using a sponge to remove all soil particles Care must be taken to minimize the removal of surface skin. This operation can be done by hand or by a specialized washing machine.

Storage of tubers:

- Sweet potatoes are often consumed within 2-3 weeks without storing. However, storage often becomes necessary to extend the availability of fresh roots throughout the year and also fetch a good market price.
- In general, the cured sweet potatoes can be stored for 6-8 months at ambient temperature.
- The rotting of sweet potatoes in storage is closely related to injury during harvest and subsequent handling. This can be prevented by prompt curing, careful handling, and discarding of infected tubers before storage
- Problems associated with improper storage conditions - Dry matter loss and pithiness, sprouting in storage, excessive shrinkage and development of fungal diseases during storage.
- Ideal storage method - Storing tubers in pits and covered with paddy straw, will result in only less than 20% loss when stored for six months.

3. Quality planting material production of Chinese potato

Chinese potato (*Plectranthus rotundifolius*) is one of the important tropical tuber crops grownin India, Sri Lanka, South East Asia and parts of Africa mainly for edible purpose. Chinese potato is known as *Koorka* and *Cheeva Kizhangu* (Malayalam) and *Chiru Kizhangu* (Tamil). The tubers resemble potato in appearance, consumed as vegetable after cooking which has an aromatic flavour and delicious taste. It is a bushy herbaceous annual with succulent stems andaromatic leaves. It grows well under tropical and sub tropical conditions.

The plant produces a cluster of dark brown aromatic tubers at the base and lower parts of the stem. The tubers contain dry matter (31-33%) and starch (18-21%) with a characteristic flavour due to essential oils (0.05 to 0.12%) which is preferred by the consumers. Themoisture content of the tubers ranges between 73-75%. The tubers are also rich in minerals like calcium and iron and contain vitamins viz., thiamine, riboflavin, niacin and ascorbic acid.

Chinese potato (Coleus) is supposed to be a native of Central East Africa but has adapted wellin South East Asia including India and Sri Lanka. In India, it is mainly cultivated in Kerala (Thrissur, Palakkad, Kasaragod and Kannur), Tamil Nadu (Tirunelveli, Tenkasi, Tuticorin, Virudhunagar and Kanyakumari) and in tribal settlements throughout the country.

Chinese potato field

Chinese potato tubers

Soil

A fertile well drained sandy loam to alluvial soil rich in organic matter is ideal for cultivation of Chinese potato. Heavy clay soils are not suitable and the crop cannot withstand water logging as excess soil moisture reduces tuber yield considerably. It is desirable to cultivate the crop on ridges and furrows to avoid water stagnation. The best soil pH requirement rangesbetween slightly acidic to neutral (6.6-7.0).

Climate

Coleus comes up well in hot humid climate. A comparatively lower temperature in night thanday time favours better tuber development. It grows well in subtropical and hot temperature areas where there is no incidence of frost. It requires a reasonably good rainfall for its growth and cannot withstand drought conditions. In case rains are not received, irrigation has to be provided for establishment of the crop. Tuber yield is reduced considerably under shaded conditions.

Planting season

The planting is done from the month of July to November depending upon the irrigation facilities. The planting in September has resulted in the production of fairly big tubers. In most parts of the country, it is cultivated in rainy season as a monsoon crop.

High yielding variety

A promising selection (CP-58) was released as a variety 'Sree Dhara' by ICAR-CTCRI for cultivation in the states of Kerala and Tamil Nadu. It has a yield potential of 25t ha^{-1}. The dry matter is about 28.5 per cent and the starch content is 19.5 per cent.


Sree Dhara: Improved variety of Chinese potato released by ICAR-CTCRI

Nursery

Nursery area of 500 m^2 (12.5 cents) is required to produce sufficient stem cuttings (suckers) for planting in one hectare of land. Nursery is prepared approximately 1.5 to 2 months prior to planting. Mature, disease free and healthy seed tubers that weigh about 15-20 g are used for planting in nursery beds of 15 cm height and width of 1 m and convenient length. A total of 75-100 kg seed tubers are required for planting in 500 m^2 area. Farm yard manure or compost is applied @ 1 kg m^{-2} and ridges/mounds are prepared at a spacing of 45 cm. The seed tubers are planted at a depth of 4 cm in rows with 45 x 30 cm spacing.

Irrigation is given immediately after planting to ensure adequate soil moisture for establishment of suckers. The tubers start sprouting within 15 days and grow to a height of 15-20 cm in about three weeks time. To ensure good vegetative growth, top dressing with urea @ 5 kg is applied at three weeks after planting. Irrigation is provided once in four days. The stem cuttings get ready for planting in the main field at about 45 to 60 days after planting. The stem cuttings of 10-15 cm length from top and middle portion are collected and stored under shade in bundles with intact leaves before planting in the main field. The plants can also be retained in the nursery for another 2-3 weeks for the onset of monsoon. To enable rapid multiplication, single node cuttings are planted directly in the secondary nursery. Such single node cuttings produce auxiliary shoots within one week. To control leaf folding caterpillars and stem borers, dipping the stem cuttings in insecticide solution (Dimethoate 30 EC @1.7 ml/l) for 10 minutes prior to planting is recommended as seed treatment.

Land preparation and planting

The crop is raised both under upland and lowland situations where there is no water logging. Soil is deeply ploughed to a depth of 20-25 cm so that the soil gets pulverised and levelled. Prepare ridges of 15-30 cm height at a spacing of 45 cm. Plant the stem at a spacing of 30 cmon the ridges either in vertical or horizontal position. Horizontal planting of stem cutting of 15-20cm length with 5 leaves are planted to a depth of 4-5 cm and exposing the terminal bud ensures quick establishment and promote tuber yield. In loose soils having good drainage, planting can also be done on flat beds with proper drainage. Irrigation is given immediately after planting to ensure adequate soil moisture for establishment of suckers. If sufficient rain is not received, supplementary irrigations are to be given for proper growth and development.

Intercultural operations

A weeding and earthing up at 6 weeks after planting along with top dressing of fertilizers are to be done. It is important at this stage to cover a portion of the stem with soil to promote better tuberization and tuber development. One more earthing up has to be given one month after the first earthing up (Hrishi and Mohankumar 1976).

Nutrient management

Application of FYM @ 10 t ha^{-1} and NPK @ 30:60:50 kg ha^{-1} and incorporate into the soil at the time of land preparation (Raj Mohan and Sethumadhavan (1980). Top dressing with 30 kg N and 50 kg K2O at 45 days after planting is recommended to promote good vegetative growth and tuber formation (Geetha,1983). This is followed by intercultural operations and earthing up of the soil. In case, the soil is very loose and chance for eroding from the base of the plant, one more earthing up has to be given to promote tuber formation.

Harvesting

Harvesting is done when the leaves and shoots of the plants dry up at 4-5 months after planting. The plant may be uprooted after loosening the base with pick axe/spade/hand hoe orany other sharp implements. The tuber may be separated from the plant and the crop residues may be recycled in the field. The tuber yield ranges from 20-25 t ha^{-1} .

Harvesting of Chinese potato tubers

Harvested tubers and different grades of Chinese potato

Quality standards for planting materials production of Chinese potato

- The planting material crop is separated from other crops meant for ware purpose by a distance of at least five meters to avoid crop admixture and spread of viral diseases.
- Isolation - Planting material production fields shall maintain minimum isolation distance 5 meter for foundation seed and certified seed.
- Selected from healthy planting materials that are disease free, true-to- type and selected from a reliable source.
- The foundation or certified seed should be used and the stocks should be replaced every 3 to 4 years.

- Chinese potato is propagated asexually by means of stem cuttings and tubers
- Land used for planting material production of Chinese potato shall be free of volunteer plants.
- Avoid Chinese potato crop residues and drainage from other Chinese potato fields.
- The cutting obtained from the apical portion of the stem (10-15 cm) with at least 2-3 nodes is found to be optimum for tuber production
- Use disease free healthy planting materials for planting.
- Use of meristem cultured disease free plants.
- Strict field sanitation and rogue out infected or self-grown plants and burn
- Spray Profenophos 50 EC@ 2 ml/l (or) Dichlorvos 76 EC @ 2 ml/ l (or) Acephate 75 SP @ 2g/lit, Chlorpyriphos 20 EC @ 2ml/l (or) Imidacloprid 17.8 SL @ 0.5 ml/l (or) Thiamethoxam 25 WDG @ 0.5 g/l at 7 days interval for control of insect.
- Remove the stem and dig out the tubers without injuring them.
- Only the well-shaped, disease or pest free without any defects is selected as planting material. The pest and disease-free vines without any defects are selected as planting material. Apical vines are preferred.
- Stem may be stored under shade for one -two days before planting. Stored stem are superior to fresh vines. Store the planting material vines upright side under shaded conditions.
- Dust and debris from the grading and packing area must not come in contact with planting material. Stem must be stored in well-ventilated, shaded places before planting.
- All tubers and vines for planting material must be transported in net bags or well-aerated containers to avoid excess heat damage due to respiration and close packing

Seed Village Programme (SVP)

Seeds refer to all propagating materials. It is the most important and comparatively low cost input in agriculture. The quality of seed is to be maintained by various good agricultural practices and at all levels in the supply chain. The availability of quality seed at proper time determines the agriculture growth through accelerated productivity. Replacement of the farmer saved seeds with the certified and high-quality seeds may increase the yield potential to 15-25%.

Seeds are the main factor which decides the productivity of other inputs. Small and marginal farmers are often at a disadvantageous position in adopting the agricultural technology related to genetic enhancement of production potential of agricultural crops. This is because of centralized production and distribution of improved seeds by research organizations/seed companies. Though the organized sectors are producing large quantity of seeds, the supply chain is unable to meet the huge demand for seeds across the country. Thus, the farming community depends largely on external sources for seeds. Seed village programme provides an alternative to this problem and helps farmers to become self-reliant. This initiative needs both organized communities and scientific backstopping. The seed village concept not only ensures good quality seeds for enhancing productivity but also helps in distribution of seeds among the villagers. It also helps in generating income for the community members resulting in improved livelihood.

Seed Village Programme aims at improving the quality of farm saved seeds. It is also termed as ‘compact area approach’. The quality seed is the key input in agriculture. The seed replacement rate is 100% for hybrid seeds and for non-hybrids it is every 3 to 4 years. Therefore, it is essential to upgrade the availability of quality seeds to raise the Seed Replacement Rate (SRR). Information on the gap between the demand and supply of quality seeds helps to decide upon the creation of seed villages in every block to cater to the needs of farmers.

A village, wherein trained group of farmers are involved in seed production of various crops and serve to the essentials of themselves, fellow farmers of the village and farmers of the neighbouring village in appropriate time and at economical cost is called Seed Village. State Department of Agriculture, State Agricultural Universities, ICAR Institutes, Krishi Vigyan Kendras, State Seeds Corporation, National Seeds Corporation, and State Farms Corporation of India (SFCI), State Seeds Certification Agencies and Department of Seed Certification are the implementing agencies.

Objectives : Specific objectives of Seed Village Programme are:

- Increasing production of certified/quality seeds.
- Increasing Seed Replacement Rate in different important crops.
- Upgrading the quality of farm saved seeds through farmers’ participatory seed production.
- Familiarizing new varieties to uplift varietal replacement.
- Securing availability of seed in contingent situation.

Seed villages for Chinese potato

Seed villages for Chinese potato were established for increasing the quality seed production of improved varieties.

Partners: Tuber crop growers, scientists/staff of ICAR-CTCRI, officials of state Department of Horticulture and KVK were the partners in seed village programme (SVP).

- Lead Institute: ICAR-CTCRI, Thiruvananthapuram
- Supporting Institutes: Department of Horticulture, Govt. of Tamil Nadu/KVK, Tirunelveli
- Chinese potato growers

Selection of seed growers of Chinese potato

A total of 60 farmers (with 50 cents plot each) those farmer had interest in taking up scientific interventions were selected during 2018-2019 to 2021-2022 with the help of State Department of Horticulture, Government of Tamil Nadu/KVK by following the guidelines of SVP (Table 3). Improved variety of Chinese potato ‘Sree Dhara’ was supplied to the farmers for proving its technical feasibility and economic viability. Demonstrations under SVP were conducted by multidisciplinary team from ICAR-CTCRI comprising scientists and technical staff. Quality planting materials and critical inputs were supplied to the farmers for establishing demonstration plots under SVP. Monitoring and field inspection were carried out during the crop growth period.

Fig. 1.View of demonstration plots on Chinese potato (Sree Dhara) under SVP

Decentralized Seed Multiplier (DSM) for quality planting material of tuber crops: The objective is to establish the tuber crop farmers' network for production of quality planting materials of tuber crops under the guidance of ICAR-CTCRI. The beneficiary farmers of on farm demonstrations and frontline demonstrations. of ICAR-CTCRI under various R&D projects who cultivate tuber crop varieties in less than 1 ha area approved as Decentralized Seed Multiplier (DSM) of quality planting material of tuber crops. A team of scientists monitor the planting material production on regular basis and provide agro-advisories as per the standard seed guidelines, the planting materials are of requisite quality standards as per ICAR-CTCRI guidelines.

Conclusion: Chinese potato is basically propagated through vegetatively by stem cuttings. Non availability of good quality planting material of Chinese potato is at the time planting is major constraints for farmers. There is an urgent necessity to produce large quantity of good quality planting of Chinese potato through farmers participatory approaches as seed villages and Decentralized Seed Multiplier (DSM) of quality planting material of Chinese potato. This crop requires improvements for seed certification standards. More area should covered with seed village programme, demanding and highly practical approach which needs to be encouraged to facilitate production and timely distribution of quality seed of Chinese potato.

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Quality planting material production in Yams, Elephant Foot Yam and Taro

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1. Quality planting material production in Yams: Yams (Dioscorea spp.)Yam is another important tuber crop and is considered as staple food cropin many parts of western, Africa especially Nigeria. Three important varieties cultivated species of Dioscorea are *Dioscorea alata*, *Dioscorea rotundata* and *Dioscorea esculenta.*

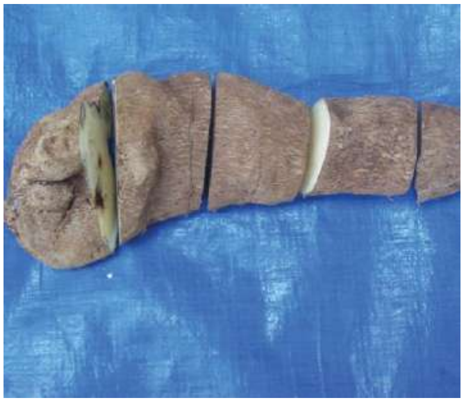
Planting material of yam: Yam is propagated vegetatively and seed yamof whole tuber is the ideal source of planting material. Surface of yam tuber of peridem has buds spread all over and hence any portion of the yam surface is capable of sprouting under optimum conditions. Traditionally yam is cultivated by making sett of 250 grams from mother seed yam. These are planted in moundsformed over pits at a spacing of 90 x90 cm from one kg mother seed yam only four sett could be obtained. Yam multiplication ratio very low with 1 :4. This low multiplication ratio implies high cost of planting materials, long time required formultiplying sufficient planting materials, difficulty in bulk quantity transporting and low availability of quality planting materials in improved varieties.

Minisett: The institute has developed a novel technique for quality planting materials production of yam crop by Minisett techniques. The technologies are propagated extensively for rapid propagation of planting materials of yam. Based on this concept, the minisett experimental trial was conducted at CTCRIin D. *rotundata* with 15, 30, 45 and 60 g minisett in order to standardize the optimum minisett size. Minisett were raised initially in nursery of sand medium and subsequently after a month when 50 per cent of the minisett have sprouted then they were transplanted in the main field (James et al. 2004). While preparing minisett adequate care should be taken to see that the periderm in each minisettis intact.

Preparation of minisett: For preparing minisett the tuber is first cut into small cylindrical pieces of about 5 cm lengths. From these cylindrical pieces, minisett of about 30 g weight is prepared.

Planting in Nursery: In nursery, yams were planted with the cut surface up and put under light shade to avoid direct sunlight, 5 cm deep. Spacing betweentwo rows is 5 cm Nursery shed of 35 %. Pre-sprouting of minisett in seed beds isresorted to, as direct planting of minisetts in the main field may result in uneven sprouting and casualties leading to non-uniform stand. Optimum size of minisett was identified as 30 g.

Transplanting yam minisetts: Sprouted minisetts are pulled out carefully using khurpi, without damaging the roots and are transplanted on the rodges,45 cm apart, thus accommodating about 34,000 plants, while in the conventional method of planting 90x90 cm with 24,000 in a hectare.



Preparation of minisetts – cut to cylindrical **Further cut to 30 g sizepieces of 5 cm length**

Minisett technique in yam **Quality planting material production of Greater yam: field view**

Management of transplanted yam minisett : It is essential that the vines ofyam be trailed and it found that trailing of vines increased yield 20%. Applicationof FYM 10 t/ha at the time field preparation. Chemical fertilizer should be applied NPK@100:50:100 kg/ha. As basal application, 50 percent dose of the N,K and fulldose of P could be applied within a week after transplanted minisetts.remaining 50 per cent of fertilizer could be applied one month after the application of the first split dose. along with the fertilizer application, weeding and earthing up alsoshould be essentially done.

Harvest: Harvsert is done with the help of a sharp hoe, taking sufficient careas not to injure the tubers. This is because bruised tubers can not be stored as planting material. At harvest, on an average about 40 percent of tubers ranging inweights from 300g to 3.0 kg could be obtained. By adopting minisetts technique, results indicated that multiplication ratio in yams could be enhanced to 1:24 fromthe traditional method1:4.

2. Quality planting material production in Elephant foot yam

Elephant foot yam*: (Amorphophallus paeoniifolius) Amorphophallus* popularly known as elephant foot yam, is an underground stem tuber and is traditionally cultivated using 750g to1000g corm setts used as planting materialin EFY. It could be planted either as cut pieces or whole corm. The traditional waythe multiplication ratio is only about 1:3. However , use of such a large planting material as mother seed corm results in high cost of planting materials, low multiplication ratio leads to long time required for multiplying sufficient planting materials, difficulty in bulk quantity transporting and low availability of quality planting materials in improved varieties. These limitations could be overcomeby adopting minisett technique. By this technique, instead of large seed corms, small corm pieces (Minisetts) of 100g weight is used as planting material forseed production. The minisett field experimental trial was conducted at CTCRI, Trivandrum (James et al. 2004). The study revealed that 100g minisetts at 60 x45 cm spacing would be ideal for rapid planting material production in elephant footyam. The multiplication ratio increased in minisett technique to 1:15 as compared to traditional method 1:3.

Preparation of minisetts: In EFY, buds are located in a ring at the center of the corm.As a matter of fact,setts made outof the corm should essentially havea portion of the central bud, failing which, the sett may not sprout. About15 minisetts could be made from a corm weighing 1.5Kg.which may be treated withTrichoderma mixed in cow dung slurry. They are then spread under shade cover for one day prior to planting in the main field. this treatment would protect the crop against attack from Schlerotiumroifsil, a soil borne fungus which causescollar rot disease.

Planting of minisetts: Unlike cassava and yams, EFY is not planted in the nursery, since studies have shown that transplanted minisetts of EFY run therisk of high mortality rate, about 20-40 per cent. They mostely fail to establish probably because they are not able to withstand the shock experienced during theprocess of transplanting. It has therefore been optimized that minisetts could be planted straight into the main field for seed production. the field is prepared by thorough digging or ploughing and pits are taken at a reduced spacing of 60x45cminstead of the conventional 90x90cm.A total of 37,000 minisetts could be plantedin a hectare of land while by the traditional method only 12,345 setts would be accommodated in a hectare (Ravindran et al. 2013).

The pits could be of 30cm deep and the top soil replaced after mixing it withwell rotten cow dung, about 2kg/pit along with Trichoderma, If available. The minisetts are then planted at the centre is planted of the pit with the bud portion facing up. A small layer of soil is packed over the minisetts which are further covered with sufficient quantity of dry or green mulch. Traditionally elephant foot yam is planted during April-March. Theminisetts will be sprout in about twoto three weeks. If the seed crop is to be raised under irrigation, then plantingof minisetts could be advanced to make seed materials available for off season planting.

Field management: On sprounting, the newly developed rootswould started drawing plant nutrients from the soil and not from the mother seed corm. Basal application of fertilizers could be done when 50 per cent of the planted minisetts sprout, fertilizers NPK applied @100:50:100 Kg/ha. Nitrogen and potash are applied in two splits 50 per cent of the total requirement as basal and remaining dose as top dressing, one month later. Phosphate fertilizer could be applied in single dose as basal. Weeding and earthing up could be done along with fertilizerapplication.

Drenching of soil at the base of crop with fungicide Bavistin @4g/l isadvisable against collar rot.

Harvest: The crop would mature in about 9-10 months time, indicated by the senescence stage. Harvest is done using hand hoe or spade by manually, but care should be taken as not to injure the corm, since corm with bruise may easily catch infection while storage. size of the harvested corm from minisetts wouldbe in the range of 600g to1.5 kg per plant. Average yield could be expected in therange of 40 to 50 ton/ha. Multiplication ratio of minisett technique in EFY could be thus enhanced to 1:15 from the conventional method 1:2.

Storage: Harvested corms are cleaned and spread out under a shade cover for two days prior to storage, which helps in the healing injuries or bruises on thecorm. The corm could be safely stored on racks in a well ventilated store house facilitating diffused light. While placing on racks, it is advisable to keep them without touching one another. EFY could be stored this way in viable condition for a period of three months.

Minisetts technique in elephant foot yam

3. Quality planting material production in Taro and Tannia

Taro (*Colocasia esculenta*) and Tannia (*Xanthosoma sagittifolium*)**:** Both taroand tannia are very popular crops in Aroids. They are cultivated as a vegetable crop in India. In India both taro and tannia are very popular in most of the states, especially in Kerala, Tamil Nadu, A.P, Odisha, West Bengal and Assam.

Planting material: Cormels as well as mother corms are used as planting materials, however, cormels are found to be ideal as planting materials. Conventionally, cormels weighing 20-25 g used as planting material in taro while in tannia about 60g size is used as planting material. minisett technique significantlyincrease multiplication ratio. Raising minisetts in nursery is not required in these crops, since they get easily established while planting straight in the field.

Traditionally farmers set apart a portion of their harvested corms and cormels as planting materials for the next planting. Both taro and tannia have inherently higher multiplication ratio as compared to other tuber crops, being 1:20 and 1:10 respectively (Ravindran et al. 2013). As such the need for enhanced multiplicationratio for rapid production of planting materials is comparatively less .However, minisett technique has been found to be quite useful for quick and large scale production of quality planting materials in these aroids.

In the minisetts technique, first select the mature mother corms are selected from healthy plants at harvested, such selected mother corms are first cut into cylindrical pieces and then cut horizontally into minisetts of about 10gram weight(15 g for tannia).If minisetts are raised in nursery, they could be transplanted in a month time to the prepared main field. A major advantage of minisetts in taroand tannia is that the cormels, which are the economic part of these crops, can be fully marketed since only corms would be required for minisett multiplication (James et al. 2004). Even if cormel is to be used as planting material in taro, only1/4th of the conventional quality needs to be stored as planting material.

10, 20 and 30 g minisetts

Minisett preparation from corm of Colocasia

Quality planting material production of Taro: field view

Field management: The soil has to be thoroughly ploughed and broughtto a fine tilth. The mini setts are then directly planted in the main field in mounds formed over pits or on raised ridges at a spacing of 45x30cm for taro and 45x45cmfor tannia. Application of FYM 12.5 t/ha prior to planting and fertilizers as NPK@80:25:100 Kg/ha is found effective for the minisetts. N and K should be applied in two equal splits along with the intercultural operations, the first soon after sprouting and second one month later. Mulching is very important and essential for obtaining higher cormel yield. By adopting minisett technique the multiplication ratio can be enhanced from 1:20 to 1:120 in taro and from 1:10 to 1:80 in tannia.

Harvesting and storage: Harvesting of taro and tannia is done at thesenescence stage of the crop, in about 6 to 8 months time after planting. On harvest, corms are separated from cormels and are stored separately, spread out on floor. Care must be taken to see that the cormels and corm are not heaped on the floor. The harvested materials must be stored in a well-ventilated storage shed,facilitating diffused light.

Production and post-harvest processing machineries for Tropical tuber crops

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Introduction

Tuber crops are important sources of starch after cereals, besides being used as a staple or supplementary food. The perishable nature of tropical tuber crops and the difficulties in long distance transport, storage and marketing constitutes major problems for farmers. In order to overcome this problem, *in situ* production of starch and value addition near the farm site is recommended. The produce will also ensure promotion of cottage and small-scale industries besides ensuring food security by incorporating starch to a certain extent in various food preparations. The starch content varies with the tuber crop varieties (15-35%) and cassava (*Manihot esculenta* Crantz) possesses the highest amount of starch. Cassava is the most important starchy root crop of the tropical world. The degree of mechanization depends on the size of the land and availability of machines for each unit operation involved in cassava processing.

Having high amount of starch (25-35%) in cassava tuber, it finds extensive applications in food, feed and industrial sectors. Being a crop with adaptability to wide range of soil, climate and environment of the tropics and sub tropics and requiring minimum agronomic input and care for its growth, cassava can be very well fitted into the cropping system prevailing in our country. As per the production database of Food and Agriculture Organization of the United Nations, in 2013, it was estimated that cassava covered a total harvest of 276.76 Million Tonnes from 20.39 Million Hectares globally. India has a leading position in global cassava scenario due to high productivity level of 31.60 Tonnes per Hectare from an area of 0.20 Million Hectares with a total production of 4.34 Million Tonnes compared to the world average of only about 13.57 Tonne per Hectares (Krishnakumar and Sajeev, 2018; FAO, 2015). In India, Kerala, Tamil Nadu and Andhra Pradesh lead in the production of cassava.

Tractor operated cassava stake cutter cum planter

The manual planting of cassava requires a large number of human labourers. It is time consuming. Currently due to industrial growth, labour shortage is a major constraint in cassava production especially during peak cultivation period. Therefore a tractor operated single row cassava stake cutter cum planter has been developed by ICAR-CIAE Regional centre, Coimbatore, Tamil Nadu, India. It

has a main frame, stake cutting system, stake planting mechanism, transmission system and ridger. The cutting system consists of two counter rotating shafts with two numbers of blades each placed at equal distance. The stake planting mechanism consists of a set of counter rotating rubber wheels. Both the stake cutting and stake planting mechanisms get transmission from the tractor PTO with suitable power transmission system. The equipment when in operation attached to a 35-40 hp tractor forms a single ridge with the cassava stem cut into stakes of 24 cm length and planted on top of the ridge vertically at a metered distance of 45 cm. The actual field capacity of the planter is 0.18 ha/h. The cost of operation of cassava planter is Rs.3125/ha and it saves 60% in cost compared to manual planting. The cost benefit ratio and payback period of developed planter worked out to be 2.06 and 4.31 year respectively. The cost of the unit is about Rs.90,000/-.

Harvesting tools

Harvesting plays an important role in the primary processing of cassava. Any physical damage to the roots during the harvesting operation enhances physiological deterioration and pathological infection of the tubers which are already perishable by nature. The time lag between harvesting and any processing operation such as chipping and drying or starch extraction induces proportional quantitative and qualitative losses.

Cassava, a root crop, is harvested by lifting the tubers from the soil. Conventionally, the soil around the cassava stem is dug up by a spade and the plant is then uprooted. Harvesting by such method is quite strenuous and slow. Sometimes, cutting the soil by spade leads to substantial damage in the form of cuts, bruises or complete breakage of roots and the damaged roots are more susceptible to infection by fungus and bacteria. Cassava plant cannot be uprooted by hand alone since the force needed to pull out a plant at times exceeds human strength. The farmers harvest the plant after a shower or, if possible, after irrigating the plot to wet and soften the soil. It is, therefore, necessary to apply some low cost tools which can be operated by hand. Two types of cassava uprooting tools have been developed at CTCRI. These harvesting tools reduce the effort of lifting to about one-fourth and one-third, respectively.

First order lever type harvester

The first order lever type harvesting tool comprises of a long lever supported on a fulcrum which in turn is supported at the top of a stand. The shorter arm is bent down and has a stem holding mechanism at its far end. The stem gripping mechanism consists of a fixed jaw, a pivoted jaw and a spring to keep the two jaws open while a wire rope tends to close them through a tightening arrangement. During operation, the jaws open just enough to get around the cassava stem under spring tension on one side and rope tension on the other side. As the longer arm is lowered the rope tension increases, holding the jaws around the stem tightly. Further lowering of the longer arm uproots and raises the cassava plant out of the soil. The tool has a mechanical advantage of four and its total weight is 14 kg.

The average direct pull required to uproot the cassava plant from the soil as measured by dynamometer was 60 kg in H-165 variety and 74.5 kg in H-226 variety. The force required to uproot the tubers by the harvester depended on various tuber characteristics. The mean force required to lift the tubers with the harvester was 18.2, 30.8 and 30.3 kg for M4, H-165 and H-226 varieties, respectively. It is apparent that force has association with number of tubers per stand in M4 and H-226 varieties, weight of the tubers in all the three varieties and mass length of the tubers in H-165 and H-226 varieties.

Second order lever type harvester

This harvesting device has a mechanical advantage of 3.4, total weight of 8 kg and overall length of 2.1 m. The height of the fulcrum at the far end of the lever can be adjusted which facilitates uprooting of cassava plants raised on flat bed as well as on mounds or ridges. A self - tightening mechanism has been used to grip the cassava stem between the two jaws. Initially the jaws are opened by means of a metallic wire rope to get a hold around the stem. After gripping the stem, the plant is uprooted by rising up the effort end of the lever. If the plant is uprooted by applying few gentle jerks, instead of a one-stroke uprooting, the tubers do not break and get easily detached from the soil.

To harvest one hectare of cassava by the harvesting tools require 14-15 man days whereas 30-34 man days are necessary for traditional manual operation. The average force exerted on the handle of the lever is about 18-30 kg for uprooting a cassava plant whereas the average direct pull required to uproot the cassava plant from the soil is 60 - 80 kg. The primary objective of these mechanical devices is to reduce the drudgery involved with traditional manual harvesting. Their low initial cost and economic viability make them an efficient practical solution to cassava harvesting.

Tractor drawn cassava harvester

The most difficult operation in cassava production is harvesting. Harvesting is one of the serious bottlenecks in the primary processing of cassava. Manual harvesting is slow and associated with drudgery and high root damage, especially under arid conditions. This situation tends to increase the total cost of production. Manual cassava harvesting requires 40 man-hour per hectare. To enable the cassava farmers for easy harvesting without more damage, Tamil Nadu Agricultural University has released the harvester in 2014. It was the following features.

a. Unit works well double row in sandy soils and with single row in heavy soils at optimum moisture content
b. Coverage was 0.08 ha/hour for single row and 0.12 ha/hour for double row
c. Un dug tuber was 2.5 per cent and damage was less than 1 per cent
d. Cost of the harvester is Rs.35,000/-
e. Cost of operation as a single row harvester is Rs.6415/ha and it saves 20 per cent of harvesting cost when compared to manual harvesting.
f. Cost of operation of two row cassava harvester is Rs.4472/ha and it saves 35 per cent of cost when compared to manual harvesting.

Conventional methods of cassava chipping

To overcome this difficulty in the marketing and utilization of cassava and to avoid heavy post-harvest losses, the roots need to be processed into some form of dried product with longer storage life. The simplest and also the most common mode of processing cassava is conversion of tubers into chips. The hydrogen cyanide is also reduced from root tissues during slicing and drying operations. Cassava chips are used for edible purposes and preparation of flour. Dried cassava chips/flour is also used in animal feed formulations. In Industry, it serves as a raw material for manufacturing starch, dextrin, glucose and ethyl alcohol.

Under the conventional practice, cassava tubers are sliced with the help of hand- knives with or without peeling the outer skin and rind. Chips are then dried in the sun for 3 to 5 days depending upon the weather conditions. However, cassava chips are produced in various forms, sizes and shapes at different places. The method is tedious and time consuming and leads to uneven and delayed drying. The output by manual chipping has been found to vary from 11 to 37 kg/hr while the chip thickness varies from 2.7 to 12.5 mm.

The sliced tubers are usually dried in the open air under sunlight by spreading them in a single layer on cemented floor, bamboo mat, rock surface or sometimes even on bare earth. Chips dry better on rocks and are white in colour. Depending upon the weather conditions it takes 2 to 5 days to dry cassava chips. The chips should be turned periodically during the drying period until the moisture content reaches 13 to 15%. The chips are considered dry when they are easily broken but too hard to be crumbled by hand. In order to remove the tedium of operation and to produce chips of uniform shape and thickness, the CTCRI has developed hand-operated as well as pedal operated chipping machines and a motorized chipper to increase operational convenience and output.

Hand operated chipping machine

The machine consists of two concentric mild steel drums, the annular space between which is divided into compartments for feeding the tubers. A rotating disc at the bottom of the drum carries the knives assembly. Thickness of chips can be changed by introducing spacing washers between the disc and the blade. A pair of H.S.S. bevel gears is provided to operate the machine manually with a crank arm. Tubers are fed into the compartments from the top and the chips are collected at the bottom. The machine is supported on four mild steel legs. Overall dimensions of the machine are 360 x 520 x 620 mm and weight is 33 kg. The average outturn of the hand-operated cassava chipping machine is up to 120 kg/h for 6.9 mm thick chips, which is 3 to 5 times more than the traditional method.

Table 1. Capacity for the hand-operated chipping machine

Average chip thicknes	Average outturn, kg/h	
	Intermittent operation	Continuous operation
Machine chipping		
2.	2	3
4.	6	9
6.	7	11
Manual chipping		
12.	2	

Pedal operated chipping machine

The pedal operated chipping machine is a modified version of the earlier prototype with additional provision of a pivoted pedal for transmitting the power to the cutting disc through suitable belt and pulley drive mechanism. A trimming knife is also provided on the frame to remove the woody neck portion of the tubers before feeding into the compartments. Four castor wheels are fixed to the legs of the machine to make it portable. The overall dimensions of the machine are 1170 x 930 x 950 mm and the weight is 72 kg.

Two persons are required for the most efficient operation of the machine, one to trim and feed the tubers and another to rock the pedal. Height of the operator's seat can be adjusted according to the convenience of the operator. Thickness of the chips can be adjusted from 0.9 to 10 mm. Blades can be easily removed for sharpening or replacement.

The capacity of the machine increases from 83 to 768 kg/h for increase in chip thickness from 0.9 to 6.9 mm. However, for further increase in chip thickness up to 10.0 mm, the average output gradually decreases to 529 kg/h (Table 3). In the case of chipping *Dioscorea rotundata* (white yam) tubers, which resemble cassava tubers in shape and size, the average outturn of the machine was found to be 471 kg/h for chips of 4.73 mm average thickness.

Table 2. Capacity of the pedal operated chipping machine at different chip thickness compared to manual chipping

Machine chipping		Manual		
Chip thickness,	Capacity, kg/h	Chip thickness, mm	Capacity, kg/h	
			One Labour	Two Labour
0.	83			
2.	297	2.7	10.7	21.7
3.	341			
4.	460			
5.	554	5.6	25.1	50.2
6.	768			
8.	679	9.8	36.7	73.4
10.	529			

Motorised chipping machine

The motorized chipper developed is run with a 0.5 hp single phase motor through suitable belt drive. The feed hopper consists of two concentric rows of 25 cm high ms cylinders. The outer row of cylinders is of 10 cm diameter while the inner row of cylinders meant for thinner tubers are of 7 cm diameter. A mild steel (MS) circular disc of 87 cm diameter and 10 mm thickness carries two pairs of stainless steel blades. A brick masonry foundation with a sloping chute serving as chips outlet is constructed with the motor and the chipper installed over it. Necessary modifications have been incorporated to provide accessibility and facilitate removal of blades for sharpening and/or insertion of spacers for changing chip thickness. Safety guards are provided for the V - belts and shafts. The square outlet made with flat ms walls below the disc guide the chipped tubers into the chute without spillage resulting from the centrifugal force of the rotating disc.

The rotational speed of the cutting disc is optimized between 80 - 100 RPM so as to overcome the jolting of tubers within feed cylinders while producing chips thicker than 5 mm at the reduced angular velocity. The output of the machine has been found to be 286, 655 and
1091 kg/h for chip thicknesses of 2.5, 5.3 and 9.9 mm, respectively.

Advantages

These machines have the following advantages**:** higher output, low operational cost, moderate initial cost, accommodates all sizes of tubers, easy to operate, requires no special skill to operate, production of uniform chips, adjustable chip thickness, convenience of feeding the tubers into the machine. However, mechanical chipping with this machine results in breakage of chips (2-5%).

Production of starch

The tubers are highly perishable and cannot be stored for more than 2-3 days after harvest. The poor shelf life and bulkiness of cassava tubers pose a great problem in transporting these tubers from the farm to the market or factory sites. Hence to avoid heavy post harvest losses, it is necessary to process them immediately. They are generally consumed as vegetable after boiling, and are mainly processed for flour and starch and hence into many value added products. Cassava starch with its unique physic-chemical and functional properties finds wide application in food, paper, textile, adhesives etc. The starch granules are usually locked up in cells together with other constituents and have to be separated from all other constituents to get the pure form of starch.

The wet extraction process for the production of starch from cassava tubers consists of washing, peeling, rewashing of peeled tubers, rasping, screening, settling, purification, pulverization and drying. In this process, the washed and peeled roots of cassava are disintegrated with addition of water into pulp by a crusher/rasper which releases the starch granules from the fibrous matrix. The resulting slurry is pumped onto a series of vibratory screens of different mesh sizes (80, 150, 260 and 300 mesh) and during the process, the fibrous waste (Thippi) will be retained in the screens, the starch milk passing through the sieve is channeled into sedimentation tanks for settling. After settling for at least 8 hours, the supernatant liquor is run off and the starch cake settled at the bottom is scooped up for sun drying.

The starch granules are usually locked up in cells together with other constituents and have to be separated from all other constituents to get the pure form of starch. Manufacture of cassava starch is carried out in three types of establishments viz., cottage industries (50-60 kg/day/man), small scale industries (40-50 t/day) and large scale industries (100 t/day and above). Processing of tubers by wet milling is chiefly employed for the extraction of starch in all types of cassava industries irrespective of their production capacity. The various unit operations involved in the wet milling process is given in Fig. 1.

a. Washing

It is done to remove and separate all adhering soil as well as protective epidermis to get colourless (white) pure starch. Roots are washed manually in tanks with water or by using mechanical washers worked on the principle of mechanical scrubbing.

b. Peeling

It is carried out with the help of special knives designed for peeling to minimize the loss of edible fleshy part of the tubers. To get a good quality product, washing is done before and after peeling of tubers.

c. Rasping

The tubers are turned into pulp or mash using a rasper which destroys the cellular structure, rupture the cell walls and release the starch as discrete, undamaged granules from other insoluble matters. Rasper consists of a solid wooden roller around which a punched metal sheet with its protrusions facing outside is nailed. The drum rotates inside housing with a hopper at the top for feeding the tubers and with a perforated metallic plate underneath, through which the rasped pulp passes into the sump below. Water is continuously added during rasping. In this method, 70-90% rasping effect is obtained during first rasping operation itself.

d. Sieving or Screening

It is done by rinsing the pulp mass on screens by addition/sprinkling of water, continuously to it. The pulp is pumped into a series of diminishing mesh sizes. The sieving is completed when the water running out of the screen is partially clear. The starch milk obtained after screening is collected in tanks and from where it is channeled for sedimentation. Residual pulp remaining on the screen after second pass is taken for drying in the sun and is used as an ingredient in cattle feed.

e. Settling or sedimentation

It includes a series of operations performed to separate the pure starch from other contaminants. Settling process should be completed as quickly as possible to prevent chemical, enzymatic and microbial reactions. Settling tanks or tables are used for this purpose. Starch milk is allowed to settle for a period of about 8-12 hr in the settling tanks whose capacity varies with the processing capacity of the factory. Starch settles at the bottom of the tank and the supernatant fruit water is let off through the outlets provided at different depths of the tank. The upper layer of settled starch contains many impurities and is scrapped off and rejected.

f. Tabling

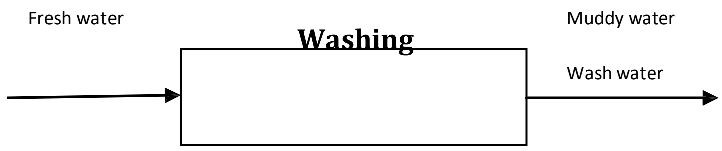
It is a semi continuous settling process followed to reduce the time of contact between the starch and fruit water. The settling table consists of successive sets of slightly inclined channels or troughs. The starch milk is allowed to flow along the trough and when sufficient starch settles at the base of the channel, the flow of starch milk is temporarily stopped and the starch is removed manually.

g. Drying

Starch cake so settled contains 35-40% moisture. It is scooped out and broken into small lumps and spread in thin layer on a large clean open area for sun drying to reduce the moisture content to 15-20 %.

h. Bolting

Dried cassava starch consisting of hard agglomerates is pulverized or milled into powder form, screened to remove the foreign particles and ensure lump free uniform product. The starch powder so obtained through the bolting process is stored in a dry place and packed in polyethylene or gunny bags for marketing/storage.



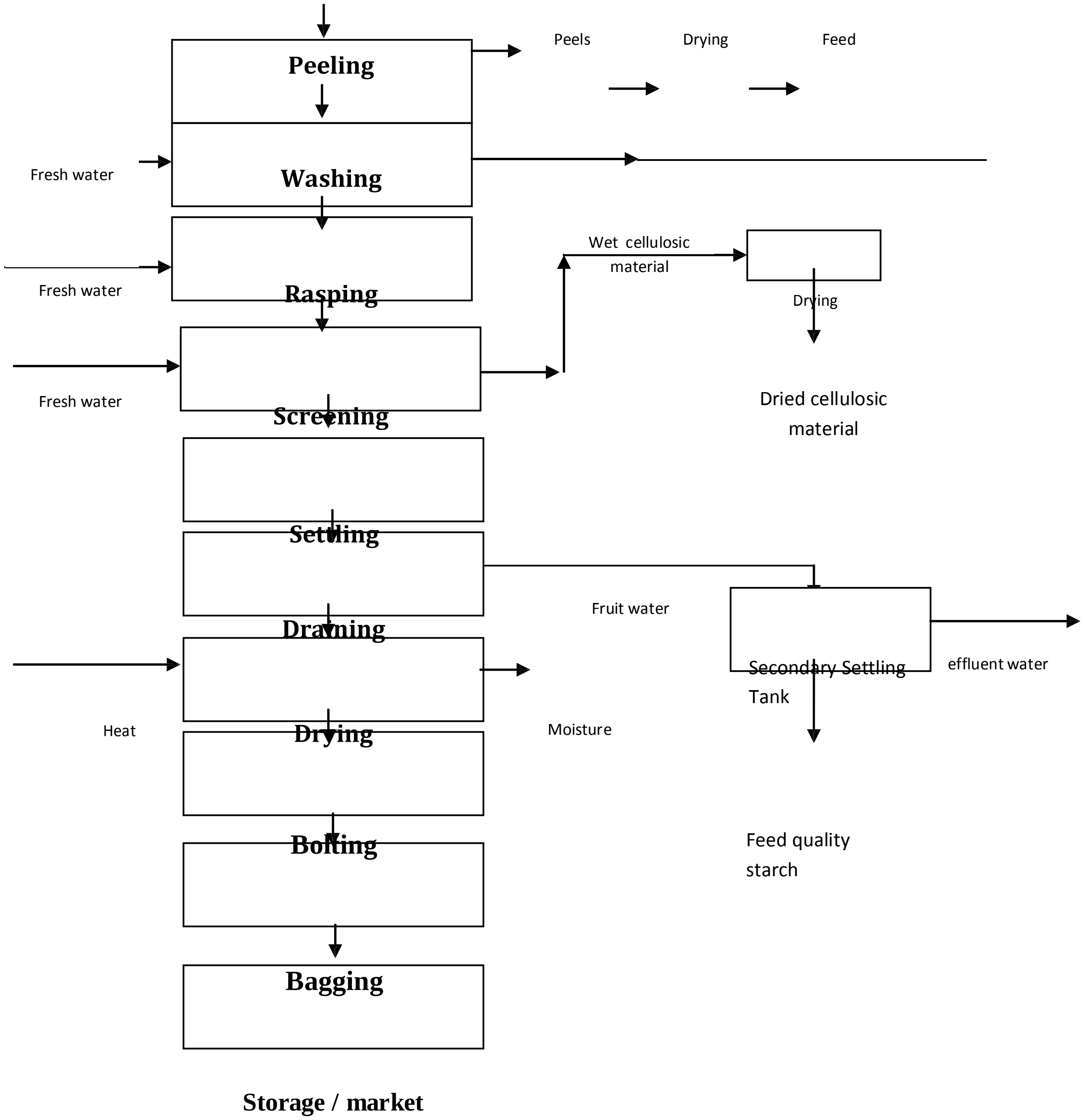


Fig. 1. Wet milling process for the extraction of starch from cassava tubers

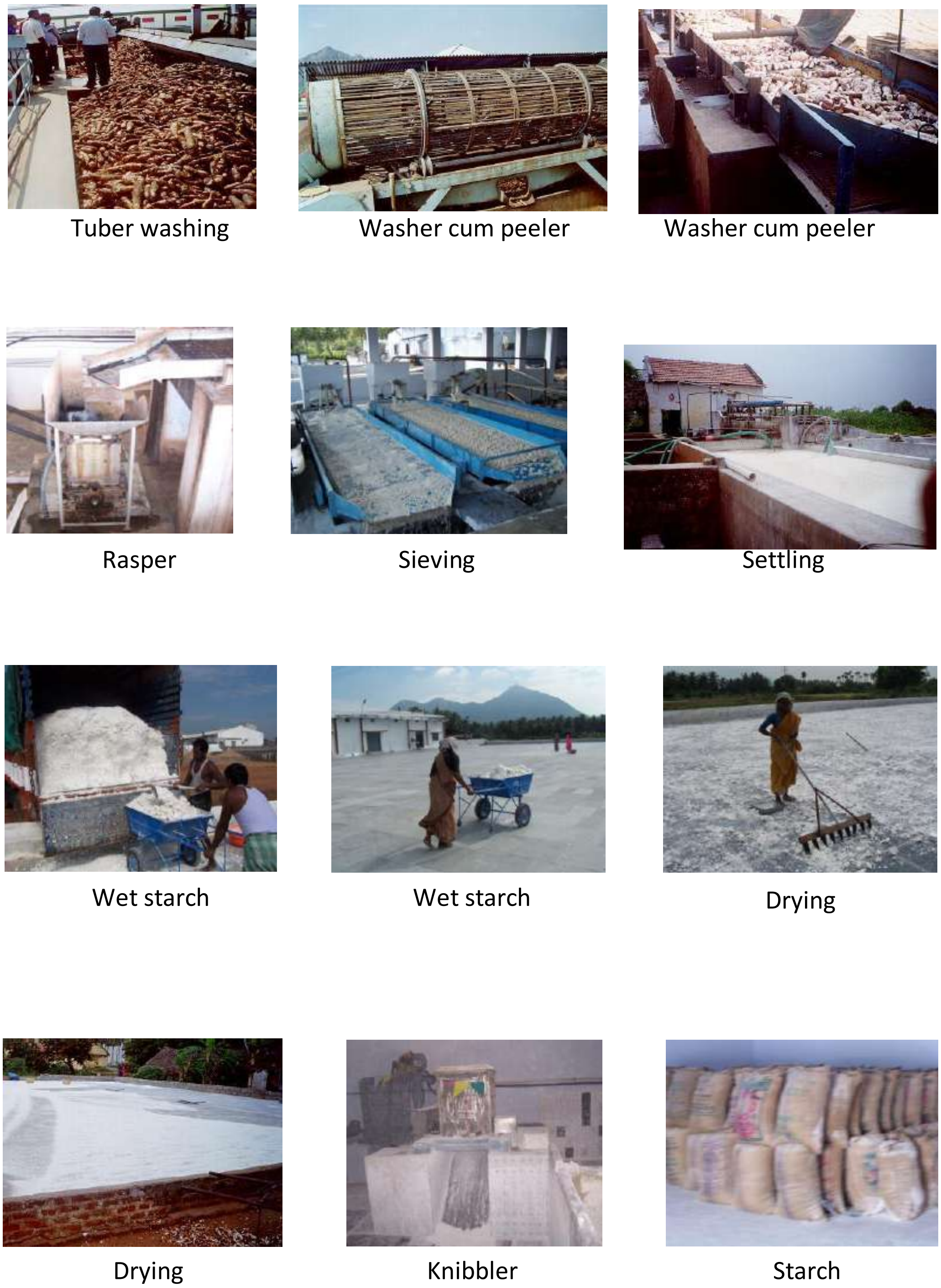
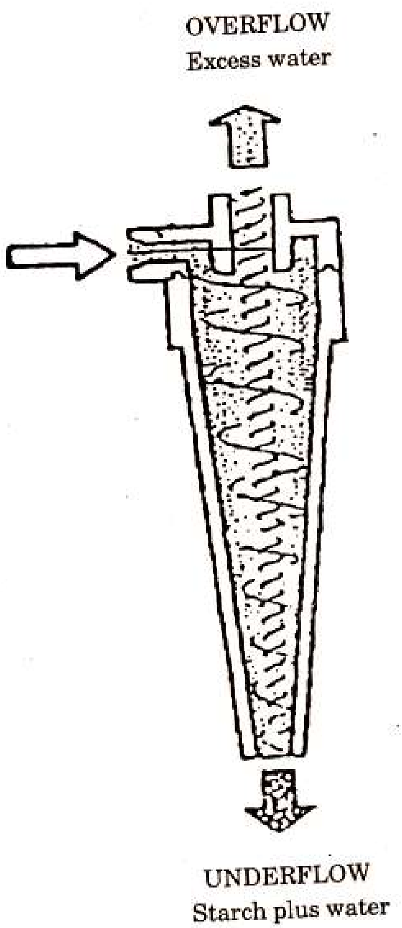


Fig. 2. Machineries and processes involved in the extraction of cassava starch

Among the various unit operations in starch extraction, the most important one is the mechanical disintegration of the cell wall and washing out of the starch granules by water. It can be done manually or by using machines depending upon the required throughput capacity. All starch/sago units require voluminous water for their operations. The processing of tapioca in a tonne of sago and starch requires water amounting 30000 litres. As this industry consumes more water, a huge quantity of effluent is bound to release. In absence of systematic disposal of sago waste water, it is being released on open lands and in water bodies affecting village life and ecology. Undiluted sago waste water released in water bodies is a major source of contamination of environment.

Hydroclone: The quality of tapioca finished products i.e. starch & sago mostly depend upon the quality of fresh water used in factories. But now days the availability of fresh water is becoming a problem for many units retarding the production at so many factories. During extraction of cassava starch large amount of water required for crushing and sieving. This volume can be reduced if the starch milk flowing from the sieving system is passed through a hydroclone.



A hydroclone is a simple piece of equipment which has no moving parts. It consists of a set of nozzles, usually made of plastic, inside a water tight steel fabrication. It is used to divide the mixture of solid particles and water into two output portions. The majority of solid particles is concentrated into a smaller volume of water and exit at the bottom of hydroclone. This is called the underflow. Excess water is removed from the top of the hydroclone called the overflow. The starch milk has to be collected in a specially constructed sump tank. From the tank it has to be pumped to the hydroclone at the correct operating pressure. The concentrated starch milk from the bottom of the hydroclone is directed to the settling tanks. The excess water, which contains a small amount of fine starch and dirt, can be recycled to the crushers to replace the fresh water normally used for crushing.

Mobile starch extraction unit

The major components of the machine (Fig.1) are hopper to feed the tubers, crushing disc or cylinder with nail punched protrusions rotating inside a crushing chamber to crush the tubers, sieving tray to remove the fibrous and other cellulosic materials, stainless steel or plastic tanks to collect and settle the sieved starch suspension, tuber storage chamber, handle and wheels for easy transportation from place to place and a frame to support these components. A sieve plate with 7 mm holes is provided at the outlet of the crushing chamber to prevent the tuber pieces to pass along with the crushed mash to the sieving tray. Overall dimension of the machine is 135 cm (width) x 180 cm (length). The height of 130 cm is provided so that tubers can be fed by a person standing on the ground. Addition of water during the processing can be controlled through a water pipe with holes fixed inside the hopper along its length and during sieving by a shower attachment connected to the water line. It is operated by a single phase electric motor of 1 hp and 1450 rpm. A power generator (fuel: kerosene, rated power: 1.1 kW, specific fuel consumption: 700 g/kWh, 1500 rpm) is also attached to the rasper frame to use as an energy source in remote and tribal areas where there is no electric power

The maximum extractable starch in the tubers as calculated by chemical method was 24.1, 21.0 and 13.4% and the starch extracted by manual method was about 22.6, 17.7 and 6.2% for cassava, sweet potato and *Amorphophallus*, respectively. When the tubers were crushed using mobile plant, the amount of starch extracted was 20.3, 15.9 and 5.3% giving rise to the recovery of starch as 84.2, 75.1 and 39.6 % for cassava, sweet potato and *Amorphophallus*, respectively when compared to the maximum extractable starch (chemical method of extraction). The reduction in the value of recovery compared to the manual method is due to the difference in the mechanism of crushing and also the less retention time of the tubers in the crushing chamber of the machine (continuous feeding) compared to mixie (batch feeding). It is also observed that recovery was highest for cassava, followed by sweet potato and *Amorphophallus* probably due to the comparative soft texture of cassava. Also in the case of *Amorphophallus*, presence of mucilaginous substance hindered the settling of starch granules thereby enhancing the starch content in the waste pulp.

Purity of starch extracted with the machines was fairly good in all the samples (82-85%). Capacity of the machine was 200, 135 and 120 kg/h with a rasping effect of 61.10, 57.98 and 40.32% for cassava, sweet potato and *Amorphophallus*, respectively.. The residue obtained after drying the waste pulp or thippy is about 5-8% of the tubers and contains starch and fibre. The viscosity characteristics measured as peak, trough, final, pasting temperature, peak time, swelling volume and solubility are given in Table. 2. The viscosity values for peak 2884, 3335 and 2431 cP, trough 902, 1608 and 1039 cP and final 540, 825 and 987 cP, pasting temperature 71.05, 75.45 and 80.75 °C were obtained for the cassava, sweet potato and *Amorphophallus* starch extracted with the machine. It has provisions for easy transportation, to store peeled and sliced tubers, easy removal of the rasper disc, convenient to operate and easy to fabricate and maintain. These machines are suitable for use in villages, adding value to produce and generating additional employment.

Blade type rasper

The rasper consists of a crushing drum made up of a mild steel pipe of 8.5" diameter and 14.5" length having 4 mm thickness, with 20 blade sets fixed on the circumference with a gap of about ½". Each blade set consist of 3 power saw blades of 1.5 mm thick and 10 teeth per inches fixed inside an angle iron of 1.25x1.25" with aluminium flat spacers of 5 mm thick placed in between them throughout the length . The blades are fixed to the angle iron at three equidistant positions, one at each end and one at the centre by 8mm nut and bolt. The crushing cylinder is fixed on a trapezoidal angle iron (2.5"x2.5", 6 mm thick) frame of size 23.5x20" bottom and 32.5x20" top and height of the frame is 30". To prevent vibration during rotation of the machine, an angle iron of 1.5x1.5" size is welded diagonally to the opposite corners to the frame. The frame is fixed to the floor by 6" long and 15 mm diameter foundation bolts at the four corners of the frame. The crushing cylinder is fixed on a shaft of 26 mm diameter which is rotated inside a ball bearing of 52 mm diameter. The power to the crushing drum is provided by 3 hp 3 phase electric motor with belt (B51) and pulley (3.5" at the motor side and 4" at the rasper). The drum is rotated inside the crushing chamber which is made up of two halves, the bottom half portion is 14" long and 11.5" diameter. The top cover size is 16x16x13.5". Gap between the blade set and crushing chamber is about 6 mm. A changeable sieve plate of 13" length and 4" width having holes of 5 mm diameter (12 holes/ inch) is provided in the bottom half to filter the starch pulp without any bigger pieces. While feeding the tubers, the tubers are expelled from the feed inlet and to avoid that a slanting projection was given at inlet point of the hopper of size 16x16x13.5"

When the tubers were crushed using rasper, the amount of starch extracted was 18.98% giving rise to the recovery of starch as 83.39% when compared to the maximum extractable starch in the tubers as calculated by chemical method as 22.8%. The capacity of the machine was found to be about 900- 1000 kg/h. The rasping effect values were found to be 78.25 %. The residue obtained after drying the waste pulp or Thippi is about 5-8% of the tubers and contains starch and fibre.

Production of sago/sago wafers

The manufacturing process consists of washing, peeling, crushing, settling, powdering, sizing, roasting, drying and polishing. In this process, tapioca tubers are washed and the outer skin and the inner rind of tapioca are removed either manually or mechanically. The peeled roots are washed again and disintegrated in a rasper with serrated surface. The suspension is sieved through 200 and 300 mesh sieves for complete starch recovery. The resultant suspension is then settled in a sedimentation tank for overnight and then settled starch is removed and partially dried (40 to 45 % MC w.b) and passed through coarse sieves of 20 to 30 mesh sieve to make it into powder form. The powdered wet starch is converted into granules by power operated granulator. The globules are then roasted in pans (100°C for about 7 to 8 min) dried in the sun for about 8 to 12 hr depending up on the intensity of sunshine. The roasted and dried sago is passed through polisher to break the lumps and obtain smooth polish surface in order to obtain final product. The nutritional composition of tapioca sago per 100 gram is presented as below.

Table 4. Nutritional profile of sago

S.No	Parameters	Value
1.	Moisture content (%)	12.00
2.	Energy (Kcal)	350.00
3.	Starch (%)	98.00
4.	Protein (%)	0.20
5.	Fat (%)	0.05
6.	Crude fibre (%)	0.18
7.	Iron (mg/100g)	1.30
8.	Calcium (mg/100g)	10.00
9.	Ash (%)	0.30
10.	pH	6.0

Sago (sabudana) holds special place in India. It is a traditional processed food product of India and commonly used as a food (known as khichadi) during festive season and fasting in western and central part of India (Maharashtra and Madhya Pradesh) and used as baby food (West Bengal). It is also used as a food thickener in several food preparations and in South India, it is used to make Kheer by adding milk. Sago is rich in carbohydrate and provides slightly higher energy (350 Kcal) than cassava starch (347 Kcal).

Sago is classified into two types *viz.* Roasted sago (commercial sago) and

boiled sago (Nylon sago). It is also commercially available in different grades viz., super fine, milky white, best, pearl and broken. Sago is easily digestible, rich in carbohydrate and its size generally ranges from 2 to 4.5 mm, produces a sudden boost of energy when it is consumed. Since sago is rich in carbohydrate it is highly recommended for quick recovery of patients. When cooked, sago turns from opaque white colour to translucent and becomes soft and spongy. Sago is very heat sensitive, if it is subjected to fry, it will turn into a sticky, gluey mass, which is nearly impossible to separate.

In South India, sago is used to make sun dried wafers that are used like papad. Presently about 95 % sago wafer production units are functioning in and around Namagiripettai in Namakkal district of Tamil Nadu. The various unit operations involved in preparation of sago wafer are collection of wet starch, sieving of wet starch, sizing, arranging the globules in aluminium die, steaming, sun drying and packing.

Feed granulator

The low palatability of the cassava based feed due to the powdery nature of flour gave way for the particle size up gradation by the process of pelleting, granulation or globulation. Development of a centrifugal granulator for feed preparation based on cassava flour offers better scope for the in situ consumption and farm scale processing of tubers.

A drum type centrifugal granulator consisted of a cylindrical drum mounted horizontally on a shaft installed on a trapezoidal angle iron frame work with the help of two ball bearings. Provisions were also made to spray water using a knapsack sprayer through one side of the drum while the granulator is in operation. A rectangular slot is provided at the down slope of the drum for feeding the materials and to take out the granulated feeds. The machine can be operated by manually and also by an electric motor (0.75 hp). Flours of different feed formulations i.e., cattle feed and poultry feed were fed to the granulator, started granulating by rotating the machine, simultaneously spraying the water using a knapsack sprayer and the resulting granules were dried. Feed granules of optimum properties can be obtained by adjusting the moisture content as 51-68%, rotational speed 40 rpm and rotational time 2-6 min depending upon the ingredients used in the feed. The capacity of the machine worked out to be 20 kg/h.

Liquid adhesive plant

Tuber starch forms an important ingredient in the manufacture of liquid adhesive or gums. The gums produced by incorporating starch have good flow characteristics, ready for use and ideal for small scale industry. It gas wide applications in carton sealing, corrugated board, bottle and container labelling, bill pasting, cigarette seaming and paper bag making.

The liquid adhesive plant consists of a double concentric stainless steel drum of 125 litre capacity, the annular space of which is filled with oil for heating with the help of strip heaters. A stirring mechanism is provided at the top cover of the drum to uniformly mix the suspension while heating. The gums after preparation is taken out by a hand pump. Starch suspension at predetermined concentration is taken in the drum and heated up to 70-80°C by continuously stirring to avoid lumps formation. Sodium hydroxide, borax and formaldehyde were added at different proportions to get good tack and storability of the final product.

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Entrepreneurship Development through Value added products from Tropical Tuber Crops

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Introduction

Agriculture and agro processing has been the main source of income generation in rural areas since long. However, due to lack/unawareness of appropriate cost effective food processing and preservation technologies for agri business at rural level and establishment of large processing industries at organized level, people involved in these sector were moved away. Considering these, in recent years, rural agro based industries has been given considerable attention by the planners, financial organizations, development agencies and research institutes and various schemes for promotion and development of food processing industries has been implemented by different govt. agencies. Agro processing industry is employment intensive and for every Rs.1 crore invested, it creates 18 jobs directly and 64 indirectly in the organized sector and 20 jobs in the unorganized sector across the supply chain.

Agro processing involves a set of technologies carried out for conservation and handling of agricultural produce to make it suitable as food, feed, fibre, fuel or industrial raw material. It provides a vital link between farmers and consumers 3and ensures uniform supply of quality food material throughout the year both in rural and urban sectors. The additional employment generated through agro industries help to improve the standard of living of the rural folks and prevent the migration of people from rural to urban areas in search of employment. It not only process products by adding value to make the material readily usable and remunerative, but also helps to conserve the produce by reducing post-harvest losses and make avenues for the utilization of agricultural. wastes and by products.

Post-harvest losses

All India Coordinated Research Project on Post Harvest Technology, Ludhiana conducted a study on assessment of post-harvest losses of major agr crops and commodities and the post harvest losses of major crops in our countries as recorded by them in 2012 are given in Table 1 and the remunerative losses are estimated to be around Rs. 44143 crores. The post harvest losses takes places in different stages viz., harvesting (infestation by insects in the field before or during the course of harvesting), transit (inadequate transportation or packaging causing injuries), storage (inappropriate storage structure that allow infestation by worms and insects, attack by predators), development or continuation of physiological activities (germination, respiration), distribution (inadequate packaging (causing injuries)) and processing (inferior processing technologies causing both qualitative and quantitative losses).

Table 1.Postharvest losses of major agricultural commodities

Agrl produce	Post-harvest losses, %
Cereals	3.87-5.96
Pulses	4.28-6.06
Oilseeds	2.76-10.07
Fruits	5.77-18.05
Vegetables	6.88-12.98
Plantation crops and spices	1.12-7.87
Livestock produce	0.77-6.92

Value addition and product diversification

Value addition and product diversification of agrl produce through appropriate cost effective technologies are the only steps to reduce post-harvest losses and provide remunerative price to the famers for their produce. Value addition to agricultural and horticultural produces provides opportunities for income and employment generation, provides good quality food material to local/rural population at relatively lower prices, supply primary processed raw materials to large industries in cities. Value addition can be done either at primary levels like unit operations carried out at producers' level or in the vicinity of farm which improves quality/transforms the produce into more useful form like cleaning, dehulling, sorting, polishing/pearling, grading, size reduction /grinding, drying and storage or at secondary level like unit operations that are carried out either directly or after primary processing, that transform the produce into products generally for direct consumption which are done usually away from farm either in unorganized or in organized sectors. Value addition has the following advantages viz., for farmer, it provides relatively better price than production process, for processor, it provides service / earning opportunity, for consumer, it provides better quality / convenience products and for nation, it helps to generate employment for its larger population.

Agro processing centres

Agro-processing industries can be divided into three categories: a) small scale processing: suitable for personal subsistence of a farmer which caters to needs of a new local market, b) intermediate processing: this operation may be by an individual or by a group of processors. The raw material may be self grown or on contract farming and c) large scale processing: this is a highly mechanized operation requiring substantial supply of raw material or economical business proposition. In terms of the cost involved in establishing agro industries, they are classified as micro enterprise: the investment in plant and machinery does not exceed twenty five lakh rupees, small enterprise: the investment in plant and machinery is more than twenty five lakh rupees but does not exceed five crore rupees and medium enterprise: the investment in plant and machinery is more than five crore rupees but does not exceed ten crore rupees.

Major challenges for agro processing industries are consumer education with regard to processed foods, need for distribution network and cold chain, backward/ forward integration from farm to consumers, development of marketing channels, development of linkages between industry, government and institutions and streamlining of food laws. The following analysis are to be done prior to start with processing industries and we should find answers to these for the successful implementation of the projects: Where are we now? How did we get here? Where will we go without policy change? Is this where we would like to be? How can we modify our effort, if need be? and with this change, will we be close to our objectives**?**

The basic principle for the establishment of agrl. enterprise especially in rural areas is based on surplus production in a defined area. In general, for such type of industry, the following model is followed: $S = P_t - (U_n + P_l)$ where S = surplus produce , Pt = total production, Un = total utilization of produce by the population , PI = total loss during various operation . The above model helps to decide the capacity of industry (processing plant) to be installed, to select the equipment and other related materials, to decide the capital investment and recovery of the same, to helps in search of market for the produce and to develop the management structure for proper functioning of the industry

Steps in establishment of agro-processing centres

1. Collect bench mark information of the selected village and cluster of villages in respect of crops grown, processing of farm produce, and the demand for processed products and their supply
2. Identify suitable post harvest equipments/technologies based on the crop production scenario of the cluster and also study their techno-economic feasibilities.
3. Finalize official formalities towards infrastructure facilities
4. Install processing equipments and introduction of proper technologies at the model agro-processing centre
5. Periodically observe the functional performance and monitoring of installed processing machines.
6. Develop modalities to explore credit assistance from banks to procure additional processing equipments as and when needed.
7. Develop strategies to include such processing activities which enable the agro- processing to run for more than 9 months in a year.
8. The SHGs of women be involved in all the value added activities as well as marketing of products.
9. Obtain technical advice from the competent source to update and keep phase with the changing environment in value addition activities

Tuber crops - Potential raw material for rural agro industries

Tuber crops are important sources of starch after cereals, besides being used as staple or supplementary food. Being the crops with adaptability to wide range of soil, climate and environment of the tropics and sub tropics and requiring minimum agronomic input and care for growth, they can be very well fitted into the prevailing cropping system. Cassava and sweet potato are the most important among the tuber crops and other tubers are grown as vegetable crops in homestead or semi commercial scale. Tuber crops though branded as poor man’s crops in rural areas have considerable unrealized potential for processing into high end products for food, feed and industrial uses. The perishable nature of tropical tuber crops and the difficulties in long distance transport, storage and marketing constitutes major problems for farmers whose bargaining power is at its lower edge. In order to overcome this problem also, *in situ* value addition near the farm site is recommended. The produce will also ensure promotion of cottage and small-scale industries besides ensuring food security by incorporating tuber flour/starch to a certain extent in various food preparations. Central Tuber Crops Research Institute, a pioneer in the R&D activities of tropical tuber crops evolved number of value addition technologies suitable for home, farm and industrial front. Technologies are available for making fried chips with good colour and texture, rava similar to wheat semolina, quick cooking dehydrated tubers etc. Tubers flour is a major ingredient in composite formulations to produce several fried products, extruded products, pasta etc. Starch, besides being used a as an industrial raw material in paper and textile industries, can be used for making sago, wafers, alcohol, adhesives, glucose, biodegradable plastics, super absorbent gels etc. Agro-industrial transformation of these crops by linking improved production and processing technologies, marketing techniques and institutional innovation in processing technologies ensure food security, rural employment and adequate remuneration to the producers.

Creating Entrepreneurship

An entrepreneur is defined as "person one who starts an enterprise". He looks for change and response to it. Innovative person who maximizes his profits by adopting new strategies in products or services

Entrepreneurship is the process of designing, launching and running a new business (OR) Capacity and willingness to develop, organize and manage a business venture along with any of its risks to make a profit

Purpose of Entrepreneurship

- To **stabilise market prices** of agricultural commodities
- To get **assured income** from farm produce
- To **generate additional income** by utilising farm produce
- To **utilise the additional revenue** or surplus money for the profitable business
- To generate income to **sustain family**
- To achieve **sustainable and equitable development**

Entrepreneurial Characteristics:

Being an entrepreneur requires specific characteristics and skills that are often achieved through education, hard work, and planning.

- **Risk Taker**

  Businesses face risk. Entrepreneurs minimize risk through research, planning, and skill development.

- **Perceptive**

  Entrepreneurs view problems as opportunities and challenges.

- **Curious**
  Entrepreneurs like to know how things work. They take the time and initiative to pursue the unknown.

- **Imaginative**

  Entrepreneurs are creative. They imagine solutions to problems that encourage them to create new products and generate ideas.

- **Persistent**

  True entrepreneurs face bureaucracy, make mistakes, receive criticism, and deal with money, family, or stress problems. But they still stick to their dreams of seeing the venture succeed.

- **Goal-setting**

  Entrepreneurs are motivated by the excitement of staring a new business. Once achieved, they seek out new goals or ventures to try.

- **Hardworking**

  Entrepreneurs need a great deal of energy to see a venture start and succeed. Yet they are not deterred by the long hours to achieve their goal.

- **Self-confident**

  Entrepreneurs believe in themselves. Their self-confidence takes care of any doubts they may have.

- **Flexible**

  Entrepreneurs must be flexible in order to adapt to changing trends, markets, technologies, rules, and economic environments.

- **Independent**

  An entrepreneur's desire for control and the ability to make decisions often makes it difficult for them to work in a controlled environment.

Entrepreneurial Opportunities in Agriculture:

- Diversification:
- Organic farming:
- Food preservation, processing and packaging:
- Production of agro-inputs
- Floriculture

The following section describes the various innovative and low cost value addition technologies available in tuber crops suitable for the micro and macro level food ventures to elevate the status of these crops from subsistence level to a commercial commodity. This will in turn help the grass root level to generate additional income and employment, helping them to make the rural population self reliant by providing remunerative prices to their bio-produce and value added products.

Cassava starch, sago and wafers

The process of extraction of starch consists of peeling, rasping, screening, settling and drying. Peeled roots of cassava are disintegrated into pulp by a rasper which releases the starch granules from the fibrous matrix. The resulting slurry is pumped onto a series of vibratory screens and the fibrous waste (thippi) is retained on them and the starch milk passing through the sieves are channeled into sedimentation tanks. After at least 8 hours of settling, the supernatant liquor is run off and the starch cake settled at the bottom is scooped up for sun drying on a cement floor. Sago (Saboo dana) is manufactured from the partially dehydrated (35-40% m.c) starch cake. The lumps are broken in a spike mill and then globulated on a gyratory shaker. The globules are graded according to size and then partially gelatinized by roasting on shallow metal pans. Finally the sago pearls are dried in the sun on cement flour for 6-8 hours. The agglomerates are separated by means of a spike beater and polished before bagging. Wafers are

Fig.1. Cassava sago wafers

made by arranging the wet granules in suitable dies and steaming. The steamed granule take the shape of the die and after drying, it can be separated out from the dies and packed.

Cassava rava and porridge

Cassava or tapioca (*Manihot esculenta* Crantz) is one of the important tuber crops valued for its high starch content (25-35%). Cassava rava is a pre-gelatinized granular product similar to wheat semolina and finds use as a breakfast recipe product. For the preparation of cassava rava, the tubers are peeled and sliced into round chips. It is then partially cooked by boiling in water for 5-10 min, decanting the steep water, sun-drying the parboiled pieces and powdering coarsely in a hammer mill. This is then sieved through fine sieve to separate out the finest fraction which can be converted to porridge powder by flavoring with cardamom and fried powdered cashew nuts. The residue is sieved through larger mesh size sieve to obtain rava. The uneven large pieces are again powdered to recover the rava.

Fried cassava chips

Fried cassava chips presently available in the market are often too hard to bite and bear no comparison with potato chips. This leads to poor acceptability of the product and lower price. Research at CTCRI has shown that excellent quality fried chips can be made from cassava tubers, by soaking the chips in acetic acid-brine solution for 1 h, parboiling for 5 min, surface drying and deep frying in oil. This facilitates in the removal of excess starch and sugars from the cassava slices, with the result that light yellow crispy chips can be obtained, having soft mouth feel and good texture.

Fig. 1. Cassava fried chips

Cassava based Extruded Products

The demand for extruded snack products is expanding at a phenomenal rate in developed and developing countries. Extrusion cooking is a high temperature short time cooking process designed for processing of starchy as well as proteinaceous materials. The use of extrusion cooking has distinct advantages like versatility, high productivity, low cost, product shapes, high product quality and production of new products.

Fig. 2. Extruded product

Several cereal based extruded products are available commercially. But tuber crop based extruded snack product has yet to appear in the market as we lack both technologies for value addition and products acceptable to elite/urban populace. Being the treasure house of starches with complex physico-chemical properties, cassava can be extruded to obtain a variety of nutritionally enriched, ready to eat/cook products. Cassava tubers after washing, peeling and slicing into chips are dried and powdered in a hammer mill. The dry flour after conditioning to 12-15% moisture content is extruded by maintaining appropriate temperatures at different sections of the barrel and die of the food extruder. Cassava being rich in carbohydrates and lacking in protein content, addition of low cost protein sources like wheat, finger millet, soy flour etc. gave more nutritional and market value products**.**

Protein and Fibre Enriched Functional Foods

The cost of making value added snack foods from cassava could be considerably reduced, if wet cassava paste is used instead of cassava flour. Such an innovation was made in making a highly acceptable crisp snack food viz., chitchore from cassava. The wet cassava tuber paste is mixed with ingredients like *maida*, cheese, salt, sugar, baking powder and white pepper. The dough after proofing for 1h is spread into sheets and cut into small discs of 1cm diameter. These are then deep fried in oil.

Fig. 3. Cassava chitchore

Keeping an eye on the health conscious consumers, mini- papads are developed from cassava flour by adding fibre sources like wheat bran, oat meal, rice bran and cassava fibrous residue. The fibre sources are added to gelatinized cassava slurry and mixed thoroughly. The spicy condiments are also added and spread on plastic sheets which are then dried in the sun for 36h. The papads are peeled off from the sheets and packed. The deep fried products have soft and crisp texture. Mini- papads with high protein content (7-15%) could be made from cassava flour by adding protein sources like cheese, defatted soy flour, prawn powder and whey protein concentrate along with other spicy condiments. The papads are allowed to dry for 36h, after which they are separated from the sheets and packed. This could be deep fried in oil before use.

Fried Snack Foods from Cassava

Cassava Pakkavada: This is a hot snack food having good texture and taste made out of cassava flour. The other ingredients include *maida*, bengal gram flour, salt, chilli powder, asafoetida, baking soda and oil. The ingredients are thoroughly mixed and made into dough with hot water (50°C), proofed for 1h and then extruded through hand extruder having flat rectangular holes, into hot oil.

Cassava Sweet Fries:This is a sweet snack food made out of cassava flour, *maida*, baking soda and oil. The ingredients are mixed well and made into dough with hot water (50°C). The dough after proofing for 1h is hand extruded through die having round holes,
into hot oil. The fried product is then coated with sugar by dipping for a few minutes in sugar syrup having thick consistency.
Cassava Nutrichips: This is a high protein snack food made out of cassava flour by mixing with other ingredients like *maida*, groundnut paste, egg, salt, sugar, *sesame*, coconut milk, baking soda and oil. After mixing the ingredients, hot water is added and mixed to form smooth dough. The dough after proofing is made into small balls which are then spread into sheets of 0.2cm thickness. This is then cut into dimon shape using a sharp knife and deep fried in oil.
Cassava crisps: This is a soft and good textured crispy snack food made from cassava
flour, *maida*, rice flour, bengal gram flour, salt, baking soda, turmeric powder and oil. The dough made with hot water is proofed for 1h and then extruded through the small pore size die having round holes. The deep fried material is mixed with fried nuts, curry leaves etc. before packing.

Other products include: Cassava nutrichips (without egg), Cassava salty dimons, Cassava hot sticks, Cassava salty fries, Cassava sweet dimons etc. for which also formulations are available.

Fig. 4. Cassava sweet fries, nutrichips and pakkavada

Tea time snack foods

Tasty cutlets could be made from cooked and mashed cassava tubers by mixing with other ingredients like onion, ginger, green chillies, green peas (cooked), beetroot spice mix etc. and preparing cutlets in the conventional manner. Cooked cassava tubers could be made into tasty samosas and bondas by onion, ginger, green chillies, green peas and spices and this is used as a filler to thin chapattis, shaping to the samosas by folding and fixing the edges. This is then deep-fried in oil. Bondas are made by shaping the mix into balls and coating with thick batter of basan and deep-frying.

Sweet potato based products

Sweet potato (*Ipomoea batatas* Lam.) is cultivated throughout the tropics and warm temperate regions of the world for its starchy roots, which can provide nutrition, besides energy. A number of novel food products with functional value are being developed worldwide. Sweet potato tubers with their low glycaemic index have additional value as a food for diabetics. There are a range of primary food products that could be made from sweet potato like chips, flakes, frozen products, French fries, puree, jam, squashes etc., while it is also the raw materials for a host of secondary products like noodles, sugar syrups, alcohol, pasta etc.

Sweet potato based composite flours have been used in many countries for making small baked goods like cakes, cookies, biscuits, doughnuts etc. Sweet potatoes are consumed at home level, mainly after cooking, baking or converting into fried chips. The roots are often converted to canned or pureed form, to enhance the shelf life. Sweet potato based baby foods are preferred in many countries as the first solid food for infants. Canning of sweet potato is widely practiced in the United States, to enhance the storage life and ensure round- the year availability of the product.

Sweet potato roots are transformed into more stable edible products like fried chips, crisps, French fries etc. Sweet potato puree, is a primary processed product from the roots, which is used directly as a baby food or used for mixing various food items like patties, flakes, reconstituted chips etc. High quality puree can be made from white, cream or orange- fleshed sweet potatoes and also from tubers of any size or shape

Sweet potato has assumed great significance in recent years as a health food due to the various bioactive principles in it. It was found that high protein/fibre pasta could be made from sweet potato using protein sources like whey protein concentrate or defatted soy flour pr fibre sources like wheat bran or oat bran. Use of orange fleshed sweet potato variety, Sree Kanaka resulted in a dark orange coloured pasta which had low starch digestibility and high resistant starch content, besides high carotene content.

Sweet potato roots can be termed as a '3-in-1' product, as it integrates the qualities of cereals (high starch), fruits (high content of vitamins, pectins etc.) and vegetables (high content of vitamins, minerals etc.). The beneficial effects of these ingredients have been appropriately put to use by converting the roots into a number of intermediary food products like jam, jelly, soft drinks, pickles, sauce, candies etc

Fig. 7. Sweet potato squash, jam and noodles

Conclusions

With lot of self-help groups operating in the rural areas, a number of innovative and low cost technologies have been implemented and have found success in the grass root level, helping them to generate additional income and employment. The technologies developed by CTCRI suitable for the micro and macro level food ventures will help to make the rural population self-reliant by providing remunerative prices to their bio-produce and value added products

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