YAMS

भाकृअनुप-केन्द्रीय कंद फसल अनुसंधान संस्थान
(भारतीय कृषि अनुसंधान परिषद्)
श्रीकार्यम, तिरुवनंतपुरम 695 017, केरल, भारत
ICAR-CENTRAL TUBER CROPS RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
Sreekariyam, Thiruvananthapuram 695 017, Kerala, India

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ICAR-Central Tuber Crops Research Institute
Sreekariyam, Thiruvananthapuram 695 017
Kerala, India
Tel.No. : (91) (471) 2598551 to 2598554
E-mail: director.ctcri@icar.gov.in
Website: https://www.ctcri.org

Published by
Dr. G. Byju
Director

Chief Editor
Dr. M. Nedunchezhiyan

Editors
Dr. Sheela Immanuel
Dr. M.L. Jeeva
Dr. H. Kesava Kumar
Dr. Visalakshi Chandra, C.
Dr. Chintha Pradeepika

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Design, Layout & Printing
Akshara Offset, Thiruvananthapuram, Kerala.
Ph: 0471-2471174, email: aksharaoffset@gmail.com

Contents

ICAR-Central Tuber Crops Research Institute

Sreekariyam 695 017, Thiruvananthapuram, Kerala, India

Dr. G. Byju
Director

Phone: 0471-2598431
Email: director.ctcri@icar.gov.in

From the Director

Yams (*Dioscorea* spp.) are a group of perennial, starchy tuberous plants that belong to the Dioscoreaceae family. These plants are widely cultivated and consumed in various parts of the world, particularly in Africa, Asia, and the Caribbean. Yams are an essential crop for many communities and hold significant cultural, nutritional, and economic importance. Yams are a rich source of carbohydrates, particularly complex carbohydrates, making them a staple food for millions of people. They also provide essential nutrients like fibre, vitamins (especially vitamin C and some B vitamins), and minerals (such as potassium and manganese), which contribute to a balanced diet. The crops are cultivated in various states across India, with the major yam-growing regions being Kerala, Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra, West Bengal, Assam, and parts of the north-eastern states. The choice of yam species vary depending on the specific agro-climatic conditions of each region.

The ICAR-Central Tuber Crops Research Institute is a premier national research organization that focuses on the development and promotion of tropical tuber crops in India and beyond. Established in 1963, it is located in Thiruvananthapuram, Kerala with a Regional Station at Bhubaneswar, Odisha and operates under the aegis of Indian Council of Agricultural Research (ICAR). The Institute has released 71 high yielding varieties, 83 production practices including organic farming and good agricultural practices, nine protocols for quality planting material production, 11 pest and disease management packages, 25 value added food products, 15 industrial products, seven computer simulation models/ information systems for tuber crops management and has helped to improve the productivity and profitability of tuber crop farming. The Institute plays a pivotal role in the advancement of research, technology dissemination, and promotion of tuber crops in India.

Due to the research efforts at ICAR-CTCRI, 17 high yielding yam varieties with desirable traits such as cooking and nutritional quality, uniform sized tubers, drought tolerance, dwarfness, suitable for intercropping and closer spacing has been developed to cater to the needs of yam growers. Also, improved agro-techniques, protocols for quality planting material production, cropping systems, integrated nutrient management, water and weed management, organic farming, integrated diseases and pest management, nematode management, value addition and processing were developed. I am happy to present the technical bulletin on 'Yams' covering the above said recommended practices to be adopted by the farmers and other stakeholders for higher yield and sustainable income.

I believe and hope that this technical bulletin will serve as a valuable reference material to researchers, entrepreneurs, farmers, students and other stakeholders related to yam production and utilization. I appreciate the efforts of the Chief editor and editors in bringing out this valuable ready reference on yams covering all aspects of yams cultivation and utilization.

15 December 2023

G. Byju

Yams

Scientific Name: *Dioscorea* spp.

Introduction

A tropical tuber crop, the yams (*Dioscorea* spp.), are grown in Africa, Asia, South America, the Caribbean, and the South Pacific Islands. Yams are regarded as a famine food and the fourth most significant crop after potato, cassava, and sweet potato, and it has a significant impact on the food habits of small and marginal agricultural families. It contains carbohydrates, flavanoids and micronutrients. Yams are a relatively healthy alternative to other tubers like potato as they have a lower glycemic index. There is enormous diversity in the wild and domesticated species that are being used by tribal communities as traditional food. However, systematic characterization of food quality traits in wild species is a major prerequisite for more consumption and cultivation.

Greater yam (*Dioscorea alata* L.) is the most economically important species originated in Southeast Asia specifically, in tropical Myanmar and Thailand, and is the most diversified and extensively distributed species throughout tropical Asia and the Pacific. The cultivated species of lesser yam [*Dioscorea esculenta* (Lour.)] Burk was known to be originated from China. White yam, (*Dioscorea rotundata* and *Dioscorea cayennensis* (both known as guinea yams) are the most popular and economically important yams in west and central Africa where they are indigenous. Aerial yam (*D. bulbifera* L.) is the most popular wild *Dioscorea* species which is native to Asia, tropical Africa, and Northern Australia. More than 60 million people in five West African countries *viz*., Nigeria, Ghana, Côte d'Ivoire (Ivory Coast), Benin, and Togo rely on the crop for their nutrition and socio-economic well-being. Over 90% of the world's crop, or over 50 million tonnes, are grown in about 4 million hectares each year in West Africa. Price of yams are high because of its high demand among urban population, particularly during the off-season. As a result, yams are a significant source of revenue for many farmers, particularly in West African coastal regions.

Globally yams are grown in 61 countries. The African continent accounted for the highest production of 98.20% followed by America (1.38%), Oceania (0.57%), and Asia (0.24%). Among the different countries Nigeria (67%), Ghana (11%) and Ivory Coast (10%) are the major yams producing countries in the world. In India, yams are grown in an area of about 30,000 hectares, producing 8.10 lakh tonnes annually with an yield of 28 tonnes/ha. It is mostly cultivated in the states of Kerala, Tamil Nadu, Andhra Pradesh, Madhya Pradesh, Uttar Pradesh, Odisha, Gujarat and in North eastern states.

In India, there are more than 50 different species of *Dioscorea* reported in the states like Assam, Tamil Nadu, Kerala, Bihar, Odisha,West Bengal, Rajasthan, Gujarat and Maharashtra. Out of 50 species recorded, the maximum number of yam species have been recorded from Assam (19) followed by Tamil Nadu (16), West Bengal and Sikkim (15). The two most important species in India are *D. alata* (greater yam) and

D. esculenta (lesser yam). The African yam *(D. rotundata)* introduced into the country is another popular yam species. In India, yams play a major role in the diet of the people. Consumption as staple food is the most prominent use of yams, although certain medicinal applications prepared from yam products have also been in practice in local cultures. Although not yet fully explored, yams could provide important source for potential industrial usage. The different ways of preparing and consuming yams very much depend on the species and local traditions. Yams are rich in fibre, polyphenols and minerals like calcium, magnesium, iron, zinc and vitamins (Table 1 to 4).

Table 1. Nutritional profile of yams

Particulars	Yams
	Tuber
Proximate composition (FW)	
Moisture (%)	65.0-78.6
Crude protein (%)	1.10-3.05
Crude fibre (%)	0.6-1.4
Crude lipid (%)	0.03-0.27
Ash (%)	0.7-2.1
Starch (%)	15.9-28.0
Polyphenol (%)	-
N & Minerals (DW)	
N (%)	0.57
P (ppm)	4.8-58.0
K (ppm)	224-329
Ca (ppm)	4.4-14.0
Mg (ppm)	6.6-17.8
Fe (ppm)	0.14-1.15
Mn (ppm)	0.01-0.64
Zn (ppm)	0.24-0.49
Cu (ppm)	0.05-0.21
B (ppm)	0.08-0.09
Vitamins (FW)	
Vitamin A	0.18
Thiamine	0.031-0.10
Riboflavin	0.02-0.04
Nicotinic acid	0.07-0.47
Pot. Nic. acid	0.28-0.60
Ascorbic acid	10
Dehydroascorbic Acid	17.6
Vitamin C	5.0-27.6

Table 2. Nutritional profile of greater yam (*Dioscorea alata*) and physico-functional properties of starch

Particulars	Greater yam (*Dioscorea alata*)		
	Tuber	Vine	Leaf
Proximate composition (FW)			
Moisture (%)	67.97-72.54	79.68-84.67	77.38-81.49
Crude protein (%)	4.88-6.06	5.13-9.63	7.75-12.06
Crude fibre (%)	1.57-1.83	1.26-1.54	1.14-1.51
Crude lipid (%)	0.07-0.10	0.04-0.08	0.04-0.08
Ash (%)	1.12-1.92	1.31-1.94	1.52-1.81
Starch (%)	17.50-21.50	-	-
Polyphenol (%)	1.67-4.72	1.98-3.82	2.22-3.71
N & Minerals (DW)			
N (%)	0.78-0.97	0.82-1.54	1.24-1.93
P (ppm)	0.18-0.39	0.08-0.35	0.20-0.28
K (ppm)	0.24-0.47	0.51-1.64	0.97-2.01
Ca (ppm)	376-538	1364-2250	1736-2591
Mg (ppm)	770-968	2215-4215	2290-5031
Fe (ppm)	42.80-74.20	58.80-264.80	162.80-625.10
Mn (ppm)	3.80-9.60	14.80-117.00	268.40-640.60
Zn (ppm)	14.40-28.80	29.40-80.40	31.70-48.60
Cu (ppm)	2.40-3.80	15.10-21.40	18.40-24.80
B (ppm)	0.51-1.48	-	-
Physico-functional properties of starch			
Granule size (µm)	6-100	-	-
Amylose content (%)	15-25	-	-
XRD pattern	B	-	-
Gelatinization temperature (°C)	77-80	-	-
Peak viscosity (cP) 10 %	2500	-	-
Stability	Good	-	-
Swelling index (ml g^{-1})	28-35	-	-
Solubility (%)	13-19	-	-

Table 3. Nutritional profile of white yam (*Dioscorea rotundata*) and physico-functional properties of starch

Particulars	White yam (*Dioscorea rotundata*)		
	Tuber	Vine	Leaf
Proximate composition (FW)			
Moisture (%)	79.60-79.88	68.35-69.91	70.15-73.01
Crude protein (%)	9.75-9.88	4.19-6.06	4.19-5.06
Crude fibre (%)	1.0-1.18	1.25-1.69	1.18-1.21
Crude lipid (%)	0.05-0.06	0.09-0.11	0.06-0.07
Ash (%)	1.69-1.72	1.92-1.97	1.57-1.62
Starch (%)	-	19.60-22.60	17.80-21.50

Polyphenol (%)	1.61-2.22	2.13-5.02	1.94-3.02
N & Minerals (DW)			
N (%)	1.56-1.58	0.67-0.97	0.67-0.81
P (ppm)	0.12-0.14	0.23-0.29	0.32-0.39
K (ppm)	1.44-1.73	0.68-1.03	0.32-0.36
Ca (ppm)	1479-1910	417-435	320-378
Mg (ppm)	2355-2775	1230-1890	360-445
Fe (ppm)	324.20-432.80	56.60-72.60	58.40-59.40
Mn (ppm)	534.60-536.60	2.4-3.0	6.40-10.40
Zn (ppm)	39.60-49.20	23.20-28.80	18.20-23.40
Cu (ppm)	14.20-15.20	1.2-1.9	3.20-3.30
B (ppm)	-	0.73-0.83	0.47-0.62
Physico-functional properties of starch			
Granule size (µm)	5-70	-	-
Amylose content (%)	15-27	-	-
XRD pattern	B	-	-
Gelatinization temperature (°C)	72-80	-	-
Peak viscosity (cP) 10 %	2600	-	-
Stability	Good	-	-
Swelling index (ml g^{-1})	18-25	-	-
Solubility (%)	10-15	-	-

Table 4. Nutritional profile of lesser yam (*Dioscorea esculenta*) and physico-functional properties of starch

Particulars	Lesser yam (*Dioscorea esculenta*)		
	Tuber	Vine	Leaf
Proximate composition (FW)			
Moisture (%)	83.97-85.30	79.94-82.58	77.69-78.26
Crude protein (%)	4.38-5.63	6.75-9.00	10.56-11.56
Crude fibre (%)	1.05-1.16	1.17-1.43	1.14-1.36
Crude lipid (%)	0.03-0.04	0.05-0.06	0.05-0.06
Ash (%)	1.61-1.65	1.96-1.99	1.74-1.83
Starch (%)	-	-	-
Polyphenol (%)	4.37-4.41	1.75-3.22	2.13-5.02
N & Minerals (DW)			
N (%)	0.70-0.93	1.08-1.44	1.69-1.85
P (ppm)	0.06-0.08	0.07-0.24	0.21-0.27
K (ppm)	0.46-0.59	1.26-1.53	1.23-2.06
Ca (ppm)	1030-1425	1625-1985	1078-1456
Mg (ppm)	1860-2820	1525-2956	2897-3163
Fe (ppm)	94.60-129.40	142.60-162.40	342.10-541.00
Mn (ppm)	63.40-76.60	60.40-138.90	310.20-422.80
Zn (ppm)	12.40-36.10	23.80-56.40	33.20-53.60
Cu (ppm)	13.80-14.20	15.40-21.20	14.80-26.20

B (ppm)	-	-	-
Physico-functional properties of starch			
Granule size (µm)	2-15	-	-
Amylase content (%)	14-26	-	-
XRD pattern	B	-	-
Gelatinization temperature (◦C)	76-85	-	-
Peak viscosity (cP) 10 %	2300	-	-
Stability	Good	-	-
Swelling index (ml g^{-1})	24-27	-	-
Solubility (%)	10-16	-	-

Varieties

The ICAR-CTCRI has released varieties in all the three-cultivated species of *Dioscorea* suitable to different agro-climatic conditions of India varying for duration of maturity, trailing habit, tuber yield and nutritional quality (Table 5).

Table 5. Distinguishing characters of varieties and hybrids of yams

Sl. No	Name of the variety	Particulars
Greater Yam (*Dioscorea alata*)		
1	 Sree Keerthi	▪ Duration (months): 9-10 ▪ Yield (t ha^{-1}): 25-30 ▪ Areas for which recommended: Coastal and interior plains of Kerala ▪ Key specific traits: High yielding, large sized tubers, suitable for intercropping in mature coconut gardens as well as with banana
2	 Sree Roopa	▪ Duration (months): 9-10 ▪ Yield (t ha^{-1}): 25-30 ▪ Areas for which recommended: Coastal and interior plains of Kerala ▪ Key specific traits: Medium sized tubers with excellent cooking quality

3	 Sree Shilpa	▪ Duration (months): 8 ▪ Yield (t ha^{-1}): 25-28 ▪ World's first hybrid variety released in *D. alata* ▪ Areas for which recommended: Coastal and interior plains of Kerala ▪ Key specific traits: Medium sized, oval tubers with easy harvestability and good cooking quality
4	 Sree Karthika	▪ Duration (months): 9 ▪ Yield (t ha^{-1}): 28-30 ▪ Areas for which recommended: Kerala ▪ Key specific traits: Long oval tubers with excellent cooking quality and high yield
5	 Sree Neelima	▪ Duration (months): 8-9 ▪ Yield (t ha^{-1}): 30-40 ▪ Areas for which recommended: Kerala ▪ Key specific traits: Purple fleshed conical tubers with good cooking and nutritional quality
6	 Sree Swathy	▪ Duration (months): 9-10 ▪ Yield (t ha^{-1}): 35-45 ▪ Areas for which recommended: Kerala ▪ Key specific traits: Medium conical to irregular tuber with drought tolerance, good cooking and nutritional quality, resistant to anthracnose

7	 Orissa Elite	▪ Duration (months): 9 ▪ Yield (t ha^{-1}): 22-25 ▪ Areas for which recommended: Odisha ▪ Key specific traits: Long, cylindrical tubers with excellent cooking quality and field tolerant to leaf spot, scales and mealy bugs
8	 Bhu Swar	▪ Duration (months): 6-7 ▪ Yield (t ha^{-1}): 20-25 ▪ Areas for which recommended: Odisha ▪ Key specific traits: Long cylindrical to irregular tuber with excellent cooking quality
9	 Sree Nidhi	▪ Duration (months): 7-8 ▪ Yield (t ha^{-1}): 35-45 ▪ Areas for which recommended: Kerala & Odisha ▪ Key specific traits: Cylindrical tubers with good cooking quality and field tolerance to anthracnose

10	 Sree Hima	▪ Duration (months): 7-8 ▪ Yield (t ha^{-1}): 35-45 ▪ Areas for which recommended: Kerala ▪ Key specific traits: Medium sized digitate fused tubers, high yielding with excellent cooking quality
White Yam (*Dioscorea rotundata*)		
1	 Sree Priya	▪ Duration (months): 9-10 ▪ Yield (t ha^{-1}): 35-40 ▪ Areas for which recommended: Coastal and interior plains of Kerala ▪ Key specific traits: Cylindrical tubers, high yielding with excellent cooking quality, drought tolerance and suitable for intercropping with banana
2	 Sree Subhra	▪ Duration (months): 9-10 ▪ Yield (t ha^{-1}): 35-40 ▪ Areas for which recommended: Coastal and interior plains of Kerala ▪ Key specific traits: Cylindrical tubers, high yielding with excellent cooking quality, drought tolerance and suitable for intercropping with banana

3	 Sree Dhanya	▪ Duration (months): 9 ▪ Yield (t ha^{-1}): 15-20 ▪ First dwarf yam variety ▪ Areas for which recommended: Kerala ▪ Key specific traits: Dwarf bushy variety suitable for closer spacing (60 x 60 cm)
4	 Sree Swetha	▪ Duration (months): 8- 9 ▪ Yield (t ha^{-1}): 25-30 ▪ Areas for which recommended: Kerala ▪ Key specific traits: Dwarf bushy variety suitable for closer spacing (60 x 60 cm)
5	 Sree Haritha	▪ Duration (months): 9-10 ▪ Yield (t ha^{-1}): 45-50 ▪ Areas for which recommended: Kerala ▪ Key specific traits: Excellent cooking quality with good flavour

Lesser Yam (*Dioscorea esculenta*)		
1	 Sree Latha	▪ Duration (months): 8-9 ▪ Yield (t ha^{-1}): 20-25 ▪ Areas for which recommended: Kerala, Bihar, Maharashtra, Andhra Pradesh, Assam and West Bengal ▪ Key specific traits: Oblong to fusiform tubers, high yielding with excellent cooking quality and wide adaptability
2	 Sree Kala	▪ Duration (months): 8-9 ▪ Yield (t ha^{-1}): 20-25 ▪ Areas for which recommended: Coastal and interior plains of Kerala ▪ Key specific traits: Oval smooth tubers, early maturing (7.5 months), with excellent cooking quality.

Climate and Soil

Climate

Yams require warm temperature of 25-30° C for better growth. Temperature below 20°C restricts their growth and yams cannot tolerate frost. Yams are relatively tolerant to dry conditions. However, being long duration crop, it requires 1200-2000 mm rainfall during crop growing period for better growth and tuber yield. Day length greater than 12 hours at the early stage promotes the vine growth, while short photoperiod favours satisfactory tuber production. Though yams are sun loving crops, it can tolerate partial shade.

Soil

Fertile sandy loam soil is ideal for growing yams. Loose, deep soil with high organic matter content and having pH of 5-7 is most suited for yams. Yams cannot sustain water logging. Since, they are long duration crops, they prefer soils rich in K content. In kitchen and homestead gardens, yams receive lot of ash, which is rich in K content.

In Odisha, greater yam is commercially cultivated in heavy clay soils/ black cotton soils which are rich in K content by forming huge ridges and planting 50-70 g tuber setts on the top of the ridges. Huge ridges and smaller size tuber setts help tuber bulking within the ridges and prevent developing tubers in contact with submerged soil even under heavy rainfall. In Andhra Pradesh, greater yam is commercially cultivated in fertile alluvial soils of Godavari and Krishna delta regions.

Propagation and planting materials

Yams are propagated vegetatively through small whole tubers or tuber pieces. The whole yam of one kg weight is considered as seed yam. The seed yams are cut into setts (small pieces) while small tubers are planted as such. The small whole tubers or seed yams are preferred for their earliness and uniformity in sprouting. The average weight of 200-300 g tuber/sett is optimum for the cultivation of *D. alata* and *D. rotundata* whereas 100-125 g is ideal for *D. esculenta.* In storage condition, yam tubers remain dormant for about 2 months, hence quick dipping in 4-8% solution of ethylene chlorohydrin followed by dry storage is used to break the dormancy. Yam can also be propagated through vine cuttings as it is a very useful technique for rapid multiplication of desirable cloned material, but tuber production by this method is slow.

Yam propagule

Seed yam production through minisett technique

A major hindrance in the popularization of high yielding varieties is its very low multiplication ratio. Traditionally yam is cultivated by making setts of 200-250 g from mother seed yam. From 1 kg mother seed yam only 4-5 setts could be obtained limiting the multiplication ratio to just 1:4-5. This low multiplication ratio implies

- high cost of planting materials
- long time required for multiplying sufficient planting materials
- difficulty in transportation
- low availability of quality planting materials in improved varieties

Seed yam (1 kg weight) can be produced through minisett technique by reducing the weight of planting material to 30 g, a multiplication ratio of 1:24-30 could be obtained from one kg of seed yam after considering waste and damages. Even by reducing the weight of planting material to 30 g minisett, the yam still has the capability to sprout, because buds are spread all over the periderm (skin surface) of yam tuber. Periderm is vital for sprouting in yams. Hence, retaining and protecting periderm in each piece of tuber/sett is essential. Yam tuber, by nature has apical dominance; however, when they are cut in to small size, the dormant buds get activated and would eventually sprout, subject to the availability of congenial environment. Hence, any portion of yam tuber with periderm is capable of sprouting and producing a new plant. Further, once the roots are produced from a yam tuber, the physiological system governing the growth of the crop would prompt the root to draw nutrients from the soils and not from the seed material. As a matter of fact, the size of the seed material is immaterial as far as sprouting of a yam tuber is concerned.

Preparation of minisetts

For preparing minisetts, the tuber is first cut into small cylindrical pieces of about 5 cm length. From these cylindrical pieces, minisetts of about 30 g weight is prepared. Adequate care should be taken to see that each minisett has a surface layer of periderm, since minisetts without periderm will not germinate. Treating the minisetts with the combination fungicide, Carbendazim + Mancozeb (2 g l^{-1}) or cow dung slurry is very beneficial to the crop. Such treated minisetts should be spread out under shade for a day prior to planting.

Planting in nursery

Minisetts are planted in the nursery in furrows made across the bed (soil-sand mixture in the ratio 1:1), 5 cm deep, with cut surface facing up. This helps to prevent drying up of the periderm. Spacing between two rows is 5 cm. After planting, they must be covered with a thin layer of soil/sand mixture. Light irrigation soon after planting followed by light intermittent irrigations till sprouting is preferable. Thereafter, as per need the nursery may be irrigated. The *D. alata* minisetts sprout within a fortnight and on reaching three to four leaves stage it becomes ready for transplanting. However, *D. rotundata* minisetts are found to take about a month for sprouting. It is therefore essential to time the nursery planting in accordance with the on-set of monsoon, if the crop is to be raised as rainfed. While *D. alata* nursery could be raised during first week of May, so as to transplant during the first week of June in Kerala, minisetts of *D. rotundata* could be planted in nursery during third week of April for subsequent transplanting in June.

Transplanting yam minisetts

As mentioned above, transplanting should invariably be done after receipt of rains, on ensuring proper moisture content in the soil. After field preparation ridges are to be made, 60 cm apart. Sprouted minisetts are pulled out carefully using *khurpi*, without damaging the roots and are transplanted on the ridges, 45 cm apart, thus accommodating about 37,000 plants, while in the conventional planting (90 x 90 cm) 12,345 plants could be accommodated in a hectare. The minisetts establish in the field in about a weeks' time.

Management of transplanted yam minisetts

It is essential that the vines of yam be trailed since it is found that trailing of vines enhances tuber yield by about 20 per cent. With regard to the plant nutrition requirement, application of well decomposed FYM @ 10 t ha^{-1} at the time of field preparation is essential. Chemical fertilizers should be applied in the form of N-P_2O_5-K_2O @ 100-50-100 t ha^{-1}. As basal application, 50 per cent of the N and K and full dose of P could be applied within a week after establishment of the transplanted minisetts. Remaining 50 per cent of fertilizers could be applied one month after the application of the first split dose. Along with the fertilizer application, weeding and earthing up also should be essentially done.

Preparation of minisetts of yam

Yam protray nursery

Stages of minisett development

Field establishment of minisetts

Seed yam production through minisett technique

Storage of seed yams

It is advisable to give a healing time to the harvested seed yams prior to their storage, by spreading them under semi shade condition for a day. This helps in natural healing of all the little wounds on yam tubers so that they do not get rot while in storage. Yams can be stored in the open condition by tying on to live shade trees, which is a common practice is west African countries. Under Indian conditions, it is ideal to store yams on a rack, taking care that the tubers do not touch each other. These racks could be placed in a well-ventilated storage shed facilitating diffused light inside. Yams can thus be stored well.

Agro-techniques

Time of planting

Yams are generally grown as rainfed crop and hence, it is planted with the onset of pre-monsoon showers. The time of planting for various states (Table 6) are as follows:

Table 6. Time of planting of yams with respect to different states

Time of planting	States
March-April	Kerala
April-May	West Bengal, Assam, Meghalaya, Manipur, Sikkim, Arunachal Pradesh, Mizoram, Nagaland and Tripura
May-June	Odisha, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Chhattisgarh, Jharkhand, Bihar, Gujarat and Rajasthan

Yams can be planted through-out the year with protective irrigation when the temperature prevails >25°C.

Method of planting

Yams are planted by various methods in different places depending on soil types. In loose sandy type of soils, they can be planted in flat beds or pits followed by mounds. Ridge and furrow method is practiced in the heavy soils. In mild sloppy land, the ridges are prepared across the slope to conserve soil and water.

Spacing and plant population

The planting spacing of yams vary with the species, growth habit and purpose of planting. *D. alata* and *D. rotundata* require wider spacing due to their luxuriant growth and broad leaves. A spacing of 1x1 m with a plant population of 10,000 plants ha^{-1}, or 90 x 90 cm with a plant population of 12,345 plants ha^{-1} is recommended. For *D. esculenta,* a close spacing of 75 x 75 cm with a plant population of 17,700 plants ha^{-1} is optimum.

Seed rate

Seed tubers of greater yam/white yam required is about 2500-3700 kg ha^{-1} whereas, seed tubers of lesser yam required is about 1800-2700 kg ha^{-1}.

Land preparation

Plough/dig the land to a depth of 15-20 cm. 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. Fill up three-fourth of the pit with top soil and FYM. Place the tuber sett of 200-300 g in the pits. After planting the tuber sett, completely cover them with soil. Then reform the pits into a mound. For raising lesser yam, open pits of 30 x 30 x 30 cm size at a spacing of 75 x 75 cm. Fill up three-fourth of the pit with top soil and FYM. Place the tuber sett of 100-150 g in the pits. After planting the tuber sett, completely cover them with soil. Then reform the pits into a mound. In Odisha, greater yam is planted on ridges which is formed 0.9-1.0 m apart. The ridge height is about 45 cm. In black cotton soil, ridge and furrow system of planting is recommended.

Manures and fertilizers/biofertilizer

FYM or compost @10 t ha^{-1} should be applied at the time of land preparation. In addition to organic manures, N-P_2O_5-K_2O @ 80-60-80 kg ha^{-1} for *D. alata* (greater yam) and *D. esculenta* (lesser yam), whereas 100-50-100 kg ha^{-1} for *D. rotundata* (white yam) has been recommended for Kerala. For Odisha, N-P_2O_5- K_2O @ 80-60-80 kg ha^{-1} is recommended for greater yam. Full dose of P_2O_5 and half dose of nitrogen and K_2O should be given at the time of sowing while remaining doses of nitrogen and K_2O should be applied again in two split doses along with first and second weeding and earthing up.

In greater yam cultivation, drip fertigation of N-P_2O_5-K_2O @ 100-60-100 kg ha^{-1} is recommended. Application of fertigation in 60 splits (N-P_2O_5-K_2O @ 100-60-100 kg ha^{-1}) at 3 days interval with first split/dose 10 days after planting is recommended. Customized fertilizer (grade N-P_2O_5-K_2O-Mg-Zn-B @ 8-11-21-3.84-0.84-0.315) can be applied in soil @ 625 kg ha^{-1} i.e. @ 51g $plant^{-1}$ within two months of planting.

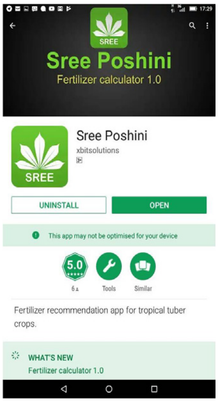
Yams can be organically cultivated. Apply FYM @ 15 t ha^{-1} + neem cake @ 1 t ha^{-1} + biofertilizers, *Azospirillum* @ 3 kg ha^{-1}, mycorrhiza @ 5 kg ha^{-1} and phosphobacteria @ 3 kg ha^{-1} at the time of planting. Inter-sow green manure cowpea (seed rate @ 20 kg ha^{-1}) between yam mounds and incorporate green matter at 45-60 days after sowing along with ash @ 1.5 t ha^{-1}.

Table 7. SSNM recommendations for yams in India based on calibrated QUEFTS model

O.C (%)	Yield target (t ha^{-1})				Available P (kg ha^{-1})	Yield target (t ha^{-1})				Available K (kg ha^{-1})	Yield target (t ha^{-1})			
	10	20	30	40		10	20	30	40		10	20	30	40
	N rate (kg ha^{-1})					P_2O_5 rate (kg ha^{-1})					K_2O rate (kg ha^{-1})			
Below 0.5	80	120	-	-	Below 10	60	75	-	-	Below 180	80	120	-	-
0.5 – 0.8	60	80	120	-	10-20	45	60	75	-	180-280	60	80	120	-
0.8 – 1.2	40	60	80	120	20-30	30	45	60	75	280-360	40	60	80	-
Above 1.2	25	40	60	80	Above 30	15	30	45	60	Above 360	25	40	60	80

Sree Poshini (Mobile app for SSNM)

Considering the rapid spread of internet and mobile technology among Indian farmers, the ICAR-CTCRI recently launched a mobile app, Sree Poshini which is available for free download at Google Playstore. Sree Poshini is a very simple mobile app, which helps the tuber crops farmers to calculate the fertilizer requirements of cassava and other tuber crops based on SSNM technology.



Sree Poshini : a mobile app

Foliar liquid micronutrient formulations

The ICAR-CTCRI has developed a microfood formulation containing zinc, copper, boron, iron and manganese at 1, 0.4, 0.3, 0.75 and 0.5% concentrations prepared based on crop requirements for yams. This customized liquid micronutrient formulation, commercially available in the market as 'Micronol Yams' may be applied as foliar spray @ 5 ml per litre thrice at 2, 3 and 4 months after planting. One litre of the formulation in 200 litres of water is required for spraying in one acre.

Multi micronutrient formulation commercialized for yams

Water Management

Yams are relatively tolerant to drought, but it gives better tuber yield with the supplement of water. Yams should be irrigated immediately after planting to ensure quick and uniform sprouting. In dry period, before the onset of the monsoon, it can be irrigated to maintain the soil moisture in the field. The crop is sensitive to water logging. In greater yam cultivation, application of drip irrigation at 80% of cumulative pan evaporation (CPE) is recommended. Irrigation may be stopped one month before harvesting for hastening the maturity of the tubers as well as drying and withering of roots on the tubers. However, an irrigation may be given one day before harvesting to facilitate easy digging and to prevent tuber damages.

Weeding and earthing-up

In initial stage, after a week of sprouting, weeding and earthing-up should be done sufficiently deep for the better growth. The second weeding and earthing up should be done one month after the first one. It takes up to 40 days for sprouting of yams. The critical stages for weed interference in yams coincide with growth phases when leaf development and tuber bulking were maximum.

Mulching

Mulching, after the planting of setts or tubers has its own importance. It provides protection from excessive temperature, conserves soil moisture, and ensures quick and uniform sprouting of the tubers and suppression of weeds, ultimately resulting in the increase in tuber yield. Dried farm waste @ 2 t ha^{-1} is recommended as mulch under rainfed conditions, which helps to conserve soil moisture and improves the sprouting percentage.

Staking

Yam being a trailing herb requires staking. Staking or trailing of vines is an essential operation in yams for increasing tuber production. Staking exposes the leaves to sun light which encourages greater photosynthesis. The emerging shoots should be provided artificial supports to avoid any injuries for the tender shoots. It is done within 15 days after sprouting by coir rope attached to artificial supports/wooden/galvanized iron stakes in the open area or to the trees where it is raised as intercrop. *D. alata* and *D. rotundata* plants trail to a height of 3-4 m., whereas *D. esculenta* requires comparatively lesser height of staking. In Andhra Pradesh, *D. alata* was found growing without staking as done in that of sweet potato. The farmers were happy with the yield of the crop. Maize was the best companion crop in greater yam cultivation and serves as live staking under Indian conditions which reduces 60% anthracnose incidence and increases yield up to 26.30 % in yams.

Harvesting

Yams are generally harvested at 7-10 months after planting, depending on the species and varieties. *D. esculenta* matures early as compared to other species. Yellowing of leaves and complete drying up of the vines indicates the maturity of crop. Harvesting is done with the help of a sharp hoe, taking sufficient care as not to injure the tubers. This is because bruised tubers cannot be stored as planting material. Tuber size ranging from 800 g to 1200 g per plant could be obtained. By adopting minisett technique the multiplication ratio in yams could be enhanced to 1:24-30 from the traditional method 1:4-5. During harvesting carefully dig out the tubers without causing injury. Two general practices are adopted for harvesting the yams *i.e.,* single harvesting and double harvesting. Double harvesting consists of removing the mother tubers after two months of growth and allowing for subsequent production of side tubers, but it is not economical as compared to single harvesting.

Cropping systems

Ideal crop sequences can generate more income. In Bihar, yam-wheat-green gram and yam-potato-green gram cropping sequence is followed. Greater yam+maize intercropping system is recommended for Odisha, Bihar and Andhra Pradesh.

Intercropping in yam

Intercropping of maize (*Zea mays*), sorghum (*Sorghum bicolor*) and redgram/pigeonpea (*Cajanus cajan*) increased the tuber yield of greater yam apart from additional yield from intercrops compared to sole cropping of greater yam. Production efficiency of yam+maize/ sorghum/redgram was higher than sole yam. Similarly, energy output: input ratio and energy use efficiency were higher in yam+maize/sorghum/redgram than sole yam. The reduction of anthracnose (*Colletotrichum gloeosporioides*) incidence in greater yam was 58-62.30 % when included maize as an intercrop. Greater yam+maize intercropping system resulted in 36.70 % higher tuber equivalent yield than sole greater yam with gross and net returns of ₹ 93,625 ha^{-1} and ₹ 38,535 ha^{-1}, respectively. Inclusion of maize as an intercrop in greater yam resulted in additional net returns of ₹ 22,055 ha^{-1}.

Greater yam + maize intercropping system

Input management for greater yam+maize intercropping is very vital to achieve higher yields. Greater yam+maize intercropping system with a fertilizer dose of N-P_2O_5-K_2O @ 100-75-100 kg ha^{-1} (125% recommended dose of fertilizer of greater yam) along with mulching (2 t ha^{-1} dried farm waste) was recommended for rainfed conditions of Odisha.

Drip irrigation and fertigation is a unique technique for enhancing higher yield in greater yam+maize intercropping system. At an early stage of greater yam+maize intercropping system, the demand for water was more due to simultaneous growth of maize and greater yam. After harvest of maize cobs (90 days after planting), the growth of maize was stopped and the haulm was left in the field to act as live staking for greater yam. Hence, the water demand is only for greater yam from 91 DAP. Greater yam is a drought resistant trailing herb. Hence, drip irrigation is recommended 100 % of CPE during 1-90 DAP + at 80% of CPE during 91-270 DAP for greater yam+maize intercropping system. In greater yam+maize intercropping system, fertigation of N-P_2O_5-K_2O @ 120-90-120 kg ha^{-1} is recommended for achieving greater tuber equivalent yield, water and nutrient use efficiency.

Nutrient use efficiency is enhanced by split application of fertilizers. In greater yam + maize intercropping system, application of fertigation in 60 splits at 3 days interval is recommended for higher greater yam equivalent yield.

Yam as intercrop

Depending on soil and climatic conditions and local situations yams can be grown as an intercrop in coconut, arecanut, banana, rubber and robusta coffee. In young coconut plantations (<8 years), plenty of sunlight is available which allow intercropping. In order to utilize these natural resources efficiently along with soil nutrients and water, easily adaptable and cultivable yams are recommended. In established coconut garden (cv. West Coast Tall) in the age group of 25-30 years, trailing genotypes of yams *viz.* Sree Priya (white yam) and Sree Keerthi (greater yam) could be profitably intercropped. Intercropping of greater yam did not affect the growth and nut yield of coconut. Under properly managed intercropping system, coconut yield was increased by 5-15%. About 9000 plants can be accommodated at a spacing of 90 x 90 cm in 1.0 ha of coconut plantation, leaving 2 m radius from the base of the palms (Table 8). Yam varieties such as Orissa Elite, Sree Latha, Sree Keerthi and Sree Priya are suitable for intercropping. Yam sett weight of 200 g was found optimum for Odisha conditions. Both the main crop as well as intercrop should be separately and adequately manured.

Table 8. Management practices for yams intercropped in coconut gardens

Crop	Time of planting	Suitable variety	Method of planting, spacing and plant population ha^{-1}	Manures FYM ($t\ ha^{-1}$) NPK ($Kg\ ha^{-1}$)	Duration (months)
Greater yam	April-May	Sree Keerthi	Pits 90 x 90 cm (9,000 plants)	9; 80:60:80	8-9
Lesser yam	April-May	Sree Latha	Pits 75x75 cm (12,000 plants)	8; 60:30:60	7
White yam	April-May	Sree Priya	Pits 90 x 90 cm (9,000 plants)	9; 80:60:80	8-9

When yams are intercropped in arecanut, about 7000 yams can be accommodated at a spacing of 90 x 90 cm, leaving 1.0 m radius from the base of the palms. Care should be taken to manure both the main crop as well as the intercrop separately and adequately. 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. Manuring at the full dose should be done for both the crops. It is possible to accommodate about 6000 plants in 1.0 ha of rubber plantation after leaving 1.5 m radius from the base of the rubber plants.

Cashew was introduced in India during the latter half of the 16^{th} century for the purpose of afforestation and soil conservation. Initially intercropping received little attention in the cashew. But intercropping has become popular with the systematic establishment of large-scale orchards. It is practiced in the first few years (4-5 years) when there is sufficient space between crop rows with the main objective of deriving some income until the cashew starts giving economic returns. Lesser yam is grown as an intercrop in cashew plantation at Dapoli of Konkan region of Maharashtra. The variety Konkan Kanchan gave 20 t ha^{-1} tuber yield as an intercrop in cashew plantation in Konkan Region of Maharashtra.

Greater yam intercropping in coconut plantation

Organic farming

- Yam species respond well to organic farming.
- It is advisable to plant greater yam anthracnose disease resistant varieties like Sree Keerthi, Sree Swathy or tolerant varieties like Sree Nidhi and Sree Karthika.
- Plant organically produced tuber pieces of 200-300 g for white yam and greater yam and medium sized tuber of 100-150 g for lesser yam.
- Apply FYM @ 15 t ha^{-1} (1.2 kg $plant^{-1}$) in pits at the time of planting.
- Apply neem cake @ 1 t ha^{-1} (80-85g pit^{-1}) in pits at the time of planting.
- Apply biofertilizers, *Azospirillum*@ 3 kg ha^{-1}, mycorrhiza @ 5 kg ha^{-1} and phosphobacteria @ 3 kg ha^{-1} for trailing genotypes of white yam, greater yam and lesser yam and *Azospirillum*@ 3 kg ha^{-1} and mycorrhiza @ 5 kg ha^{-1} for dwarf white yam at the time of planting.
- Inter-sow green manure cowpea (seed rate @ 20 kg ha^{-1}) between yam mounds and incorporate green matter at 45-60 days. The green matter addition from the green manure will be @ 15-20 t ha^{-1}.
- Apply ash @ 1.5 t ha^{-1} (120 g per plant) at the time of incorporation of green manure.
- The average tuber yield under organic farming is 24.4, 21.0 and 19.0 t ha^{-1} for *D. rotundata*, *D. alata* and *D. esculenta*, respectively.

- Organic farming helps in lowering bulk density and improving the water holding capacity and porosity of the soil.
- The pH, organic C, available N, P and K status of the soil were appreciably higher in organic farming.
- The cooking quality, dry matter, mineral contents (P, K, Ca, Mg, Cu, Zn, Fe and Mn) and bio-chemical constituents of tubers (starch, crude protein, total sugar, reducing sugar and total phenols) remained unaffected. However, organic tubers had slightly higher dry matter and crude protein contents.

Pest management

Scale insect

Yam scale insect (*Aspidiella hartii Cockerell*) is the major pest in India. This is an important pest of yams and also affects ginger, turmeric, taro and elephant foot yam. The pest problem is perpetuated through seed tubers.

Symptoms

In severe infestation, attacked plants show drying due to continuous sucking and desapping. The infested tubers shrivel affecting the quality, viability and marketability. The nymphs are parasitized by an aphelinid *Physcus comperi* H. and an encyrtid *Adelencyrtus moderatus*. Planting material can be made pest free after shade drying of tubers dipped in 1.5 % *Nanma* or Neem-soap solution for 10 minutes. They are also controlled by dipping the infested tubers in solution prepared using 2 % of cassava or yam bean seed oil (Petroleum ether extract) with 0.01% surfactant for 10 minutes and shade drying.

Yam Scale insects

Disease management

Anthracnose

In yams, anthracnose caused by *Colletotrichum gloeosporoides* is the major disease worldwide including India. *D. alata* is highly susceptible to this disease which causes 30 to 60 % yield loss. It is also observed in *D. esculenta*.

Symptoms

The disease causes different types of symptoms depending on the cultivar. It appears as small dark brown or black spots or lesion on leaves, petioles and vines. In some cases, the lesion is often surrounded by a yellow halo, otherwise enlarged and coalesces, resulting in extensive necrosis of the leaves, leaf fall and die-back of the vines. It causes cupping of the leaves also due to necrosis on the abaxial surface which arrest the interveinal growth of the leaves. The withered leaves and stem die- back give the plant a scorched appearance. So, it is also called as scorch disease.

Causal organism

This disease is caused by *C. gloeosporoides*. The pathogen is unable to survive in the soil for more than few weeks, and it is able to survive between growing seasons on crop debris. It is possible that spores from these plants also affect the yam crop. The fungus is also commonly isolated from soil and is tuber-borne. It is a ubiquitous pathogen infecting many crops and weed. Lesser yam is also affected by the pathogen.

Management

- Removal of debris of the harvested crop which is the source of propagules.

Anthracnose symptoms in greater yam

- Summer ploughing after harvest to expose the propagules in soil.
- Growing greater yam cultivars resistant (Sree Karthika) and highly tolerant (Sree Keerthi, Sree Roopa) to anthracnose.
- Selection of symptom free tubers for planting.
- Foliar spraying of Carbendazim 0.05 % for seven times (spraying after the initiation of symptom, three times at 15 days interval and then monthly interval for another four times).

Cercospora leaf spot

It is severe in greater yam (*D. alata*) and widespread throughout the tropical countries. In India, the disease is observed in Kerala, Tamil Nadu, Andhra Pradesh, Maharashtra, Bihar, Odisha, West Bengal, Gujarat and North eastern hilly regions, whenever the crop is grown.

Symptoms

The infected leaves initiates as small chlorotic spots. As the disease advances, it enlarges and becomes necrotic and finally seen as blackened irregular spots. In severe cases, the leaves will dry and fall off. Normally, the symptom appears in the later stage of the crop in September month after 7 months of planting.


Initial stage


Advanced stage

Causal organism

Pseudocercospora contraria, the spores from debris of the previous crop are the major source of inoculum. This is commonly present in soil in debris which infects the next crop. The spores are formed enormously and air borne. They splashed by rain to adjacent plants.

The pathogen colonises injured plant tissues and forms an abundance of conidia. Conidia can spread over relatively short distances by rain splash or overhead irrigation. Only *D. alata* is highly susceptible. It infects some wild *Dioscorea* sp also.

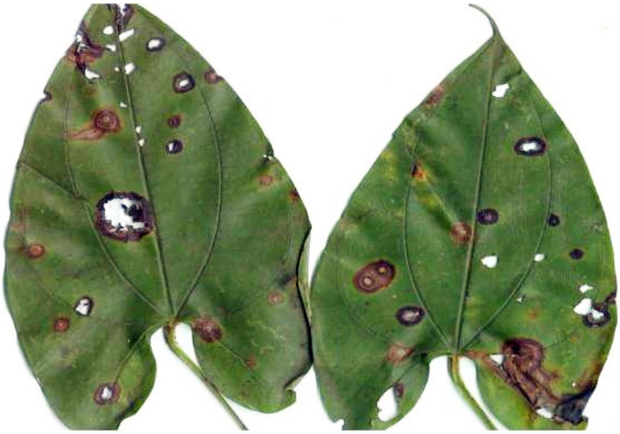
Management

- Removal of debris of previous crop.

- Ploughing immediately after harvest to destroy the spores.
- Spraying Mancozeb (0.2 %) or Carbendazim 0.05% when symptom initiates and spray for another five months first three at 15 days interval and rest monthly.

Other minor fungal diseases

Leaf spots are caused by *Curvularia lunata* var. *aeria*, *Pestalotiopsis* sp. and *Sclerotium rolfsii*. All are minor diseases occur in all greater yam growing areas of India. The infected leaves show black irregular necrotic spots and spots with dark brown margin and light coloured centre in *Curvularia* and *Petalotiopsis*, respectively. *Sclerotium rolfsii* cause black, circular, concentric spots which are between 5 and 10 mm in diameter, in the middle and bottom portion of the vines. As the disease advanced, the centre portion of the leaf spots dry and fall out, resulting in shot hole symptoms. The pathogen survives in leaf debris which infects the crop in the next season. Through rain water splash and air it spreads to the adjacent plants within the season. It is able to survive between growing seasons on crop debris which could infect the subsequent crop.



Greater yam leaves infected by *Sclerotium rolfsii*

Management

- Ploughing after harvest.
- Removal and destruction of crop debris.
- Follow crop rotation.
- Spraying Mancozeb (0.2%) or Carbendazim 0.05% when the symptom initiates and five sprays, first three at 15 days interval and rest monthly.

Yam mosaic disease

Symptoms

The prominent symptoms include, mosaic, green vein banding, green spotting or flecking, blistering and leaf mottling, vein yellowing and leaf deformation which infects all three cultivated species in India, greater yam (*D. alata*), Lesser yam (*D. esculenta*), and white yam (*D. rotundata*).

Greater yam White yam Lesser yam

Different kinds of mosaic symptoms in yams.

Causal organism

It is caused by three different viruses namely *Yam mosaic virus* (YMV) and *Yam mild mosaic virus* (YMMV) belonging to potyvirus group and *Yam chlorotic necrosis virus* (YCNV) belonging to Macluravirus group.

Management

- Selection of planting materials from healthy plants which are free from yam virus infection.
- Use of tubers obtained from meristem derived virus free plants.

Nematode management

Of the three major species of yams cultivated in India, white yam (*D. rotundata*) and greater yam (*D. alata*) are susceptible to nematodes. They cause extensive damage to tubers and render them unfit for marketing and consumption. Initially, they cause yellow necrotic lesions and later turn into dark brown discoloration in heavily infested tubers. Nematodes are field cum storage pest in yams. They cause around 20-30% reduction in weight during storage.

Causal organism

There are two major nematode species infesting yams, root knot nematode, *Meloidogyne incognita* and yam nematode, *Scutellonema bradys* while, the latter causes the dry rot of yams.

Spread

Primary spread is through infected planting materials. Secondary spread is through irrigation from infected field, use of farm implements and movement of animals from infected fields to healthier fields.

Symptoms

The common above ground symptoms associated with nematode damage are yellowing of leaves, day wilting and stunting of plants. The below ground symptoms are longitudinal cracking of tubers, knots on roots, malformed and distorted tubers, brown discoloration of tissues and tuber rot.

Management

- Deep ploughing during hot summer months to expose the nematode and eggs to sunlight.
- Fallowing for a season (if feasible).
- Selection of healthy, nematode free planting materials.
- Changing the place of cultivation each time within the farm.
- Following crop rotation with non-host crops like cereals.
- Growing of trap crops *viz*., Sree Bhadra (sweet potato cultivar), wherein the nematodes are attracted but gets killed within the roots.
- Growing of nematode antagonistic crop, marigold.
- Burning and destruction of severely infested tubers and plants.
- Treatment of tubers with *Trichoderma* enriched cowdung slurry @ 5g kg^{-1} tuber before planting.

Brown discolorations on tuber

Longitudinal cracking of tuber

- Use of *Trichoderma* enriched farm yard manure @12 tonnes ha^{-1}.
- Use of newer nematicides, Fluensulfone 2% GR @ 1g $plant^{-1}$ and Fluopyram 34.48% SC @ 0.5 ml $plant^{-1}$.

Processing and value addition

Yam tubers are playing an important role in dietary habits due to high energy and nutritional values. In addition, yam tubers are good sources of starch, protein, fiber, and minerals, and ascorbic acid (vitamin C). Presence of good amounts of vitamin C in yam tubers helps in fighting infections such as cold and flu and quick healing. Roots of yams provide a beneficial fiber known as glucomannan, which is thought to help in weight loss. Moreover, yam tubers are loaded with various nutrients such as phosphorus, magnesium, sodium, potassium, iron, calcium and traceable amounts of vitamin A, thiamine, riboflavin and nicotinic acid. The difference in chemical composition of different yam species are mainly due to genetic and environmental factors. However, yam tubers comprised anti nutritional factors (calcium oxalates) that affect both human and animals when ingested, despite their high nutritional values. Hence, traditional processing methods like boiling or sun drying of yam tubers are commonly followed to remove the anti-nutritional factors. Further, yam flour is considered as a fibre rich than refined wheat flour and potato flour, which helps in slow down of sugar absorption in the blood. In addition, yam tubers are loaded with bioactive compounds such as phenolic acids, organic acids, flavonoids, and color pigments. Therefore, yam tubers have immense potential as functional foods and nutraceutical ingredients help in disease risk reduction by promoting overall wellness. Importantly yam tuber production requires minimum inputs and processing and preservation of these tubers is not hard. Hence, yam tubers play a vital role in providing food and nutritional security in different parts of world.

Value added food products

Fresh yams are peeled and boiled or roasted or fried to prepare the most common dishes often consumed in many parts of the world. In addition to the traditional dishes, there are many commercially available food products prepared using *Dioscorea* yams. Cleaning, chipping followed by sun drying and milling of yam tubers results in yam flour and flakes. Yam dried chips and flakes are having good national and international market for preparation of various food products including fried snack products, bakery food products, functional pasta products and confectionaries. Snack foods prepared from yams are rich in nutrition and energy (Table 9). Moreover, yam dried chips and flakes greatly reduce the deterioration and wastage during post-harvest storage. These dried chips and flakes are used widely for making flour, which are an important food ingredients for preparation of different food products.

Yam chips-0.1 % citric acid+0.1 % NaCl

Yam chips-0.1 % acetic acid+0.1 % NaCl

Crisps

Sweet fries

Pakkavada

Sweet diamonds

Nutrichips

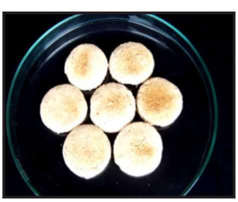
Hot sticks

Salty fries

Muruku

Masala chips

Boonthi

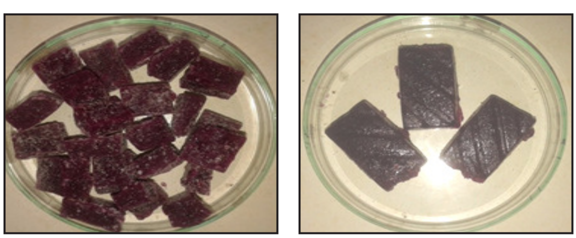


Biscuits

Burfi

Cookies

Purple yam cookies



Anthocyanin rich candy from purple yam

Table 9. Nutritional profile of yam snack foods

Type of value-added product	Dry matter (%)	Starch (%)	Sugar (%)	Fat (%)	Protein (%)	Energy (kcal/100g)
Murukku	97.89	54.71	7.38	19.73	7.97	461
Masala chips	96.27	51.07	6.65	24.00	10.60	493
Boonthi	95.05	21.82	34.48	31.38	5.95	529
Cookies	98.37	35.29	24.22	28.82	7.35	527
Biscuits	97.56	45.45	14.84	25.53	8.58	507

Functional pasta products

Pasta is a widely consumed food which is described as a healthy and convenient food worldwide. At ICAR-CTCRI much effort had been taken into improving the nutritional value of pasta by inclusion of nonconventional ingredients such as tuber crop flours due to the demand by health-conscious consumers for functional foods. In this context, high fibre rich pasta using yam flour and oatmeal, protein rich pasta using yam-whey protein concentrate, and fish flavour pasta using yam-fish meal were developed. Fortification of yam flour with fibre sources such as oat bran, wheat bran, and rice bran resulted in products having slow and progressive starch digestibility and very high percentage of starch remained undigested (RS) after 2 h of digestion under *in vitro* conditions. Increasing the level of fibre from 10 to 20 % decreased the swelling index and cooking loss, which resulted in high-protein levels in the 20 % fortified pasta due to formation of firmer protein-starch network. The slow digestibility of the fibre-enriched yam pasta coupled with the high level of residual undigested starch makes these pastas ideal food for diabetic and obese people.

Yam-oatmeal based functional pasta

Yam-whey protein concentrate based functional pasta

Yam-fish meal based functional pasta

Functional yam-based pasta products

Economics and Marketing

In India, yams are grown in an area of about 30,000 hectares, producing 8.10 lakh tones annually. On an average, the price of one kg of yam is sold at ₹ 30 and the total value of yam in India is ₹ 24,300 million. From farm to fork, yam provides opportunity for

As yams are mainly used for edible purpose, the price varies from ₹ 15 to 60 per kg of tubers depending on the demand and supply and consumer preferences. Gross income that could be realized from one ha is ₹ 4.05 to 16.20 lakhs.

The major yam production and marketing centres in India are listed below. The tubers are marketed at local places and also to various states in the country *viz*., Kerala, Tamil Nadu, Mumbai, Hyderabad, Bengaluru, New Delhi, Madhya Pradesh and Punjab (Table 10). Some quantities are exported to Gulf and European countries.

Table 10. Major production and marketing centres of yam in India

States	Production centres	Marketing centres
Kerala	Kollam, Pathanamthitta and Idukki districts	Local sales
Gujarat	Rajkot, Junagarh, Surat and Valsad districts	Mumbai Azadpur Punjab Local sales
Uttar Pradesh	Jhansi district	Gujarat Azadpur Madhya Pradesh Local sales
Andhra Pradesh	East Godavari, West Godavari, Krishna and Guntur districts	Mumbai Odisha Local sales
Odisha	Ganjam, Koraput, Keonjhar and Baripada districts	Azadpur Local sales

Conclusion

Yams can grow well in marginal soil, with low input and it is adaptable to the environment. Importantly yam tuber production requires minimum processing and the preservation of these tubers is not difficult. The crop management is also easy as compared to other crops. It can be grown as intercrop and suits well with the cropping system. Yam tubers showed immense potential as functional foods and nutraceutical ingredients which lead to disease risk reduction by promoting overall wellness. Hence, yam tubers play a vital role in providing food and nutritional security in different parts of the world.

Yams for Food, Health, Wealth and Prosperity

ICAR-Central Tuber Crops Research Institute
Sreekariyam, Thiruvananthapuram 695 017, Kerala, India
Phone: (91) (471) 2598551 to 2598554
E-mail: director.ctcri@icar.gov.in; Website: https://www.ctcri.org