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& FARMERS' WELFARE, GOVERNMENT OF KERALA



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Celebrating 62 Years of Research, Education and Extension

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Editorial

CTCRI @ 62 — ROOTING FOR FOOD AND NUTRITIONAL SECURITY

Established on July 1, 1963, in Thiruvananthapuram, the ICAR–Central Tuber Crops Research Institute (CTCRI) has been the world’s only research centre dedicated exclusively to tropical tuber crops. For over six decades, CTCRI has remained at the forefront of strengthening the value chain of cassava, sweet potato, yams, taro, and other tropical tubers—ensuring food, nutritional, and livelihood security for millions. As the institute celebrates its 62nd anniversary, Thiruvananthapuram once again becomes the global focal point by hosting the 20th International Symposium of the International Society for Tropical Root Crops (ISTRC) from November 17–21, 2025, marking a proud milestone for Kerala and India alike.

Tuber crops hold a unique place in Kerala’s agricultural history. Cassava, introduced in Travancore by Sri Visakhram Thirunal during a famine in the late 19th century, has since evolved from a food of necessity to a versatile crop contributing to food, feed, and industrial sectors. With their remarkable adaptability to marginal soils, resilience to climatic stress, and multiple industrial uses, tropical tubers have become pillars of

sustainable farming systems. Through dedicated research and farmer-oriented innovations, CTCRI has transformed these crops into vital instruments for income generation, food security, and rural prosperity.

In an era marked by climate change, soil degradation, and emerging pest and disease threats, CTCRI’s resilient and regenerative production and protection technologies offer sustainable pathways for the future. By integrating traditional wisdom with modern science, the institute has developed climate-smart varieties, eco-friendly management practices, and innovative planting material production systems that enhance productivity while restoring soil health and ecosystem balance. Its outreach and participatory initiatives ensure that technological advancements reach the farming community effectively.

With 62 years of research excellence and global recognition, CTCRI continues to lead India’s march toward a sustainable agricultural future. The upcoming ISTRC symposium in Thiruvananthapuram will once again bring together global experts, policymakers, and entrepreneurs to deliberate on strengthening the tropical tuber crop sector.



ICAR -
THIRUVANANTHAPURAM



G. BYJU
Director, ICAR-Central Tuber Crops Research Institute

REINVIGORATING TUBER CROPS CULTIVATION IN KERALA

TUBER TRENDS - FACTS & FIGURES

Historical records show that cassava, which originated in the southern Amazon forests of Brazil and was domesticated about 10,000 years ago, reached Africa in the 16th–17th centuries and eventually came to Malabar region in Kerala. It was introduced and popularised in Travancore during a famine between 1860–1880 by Sri Visakham Thirunal,

brother of the then King Sri Ayilyam Thirunal and a skilled botanist who was also the successor of Sri Ayilyam Thirunal and reigned Travancore during 1880–1885. Cassava use subsequently expanded beyond food to include animal feed and industrial products like starch, sago, alcohol, and sweeteners. Over the past 50 years, cassava cultivation spread to many countries like China, Thailand,

Indonesia, Lao PDR etc. By 2023, it was grown in 114 countries, covering 32.217 million hectares, producing 333.681 million tonnes of tuber. Tropical tuber crops include around 15 starch-rich crops like cassava, sweet potato, yams, taro, elephant foot yam, Chinese potato, arrowroot etc.—crops that have been cultivated for 5,000–10,000 years.

Trends in cassava cultivation in Kerala

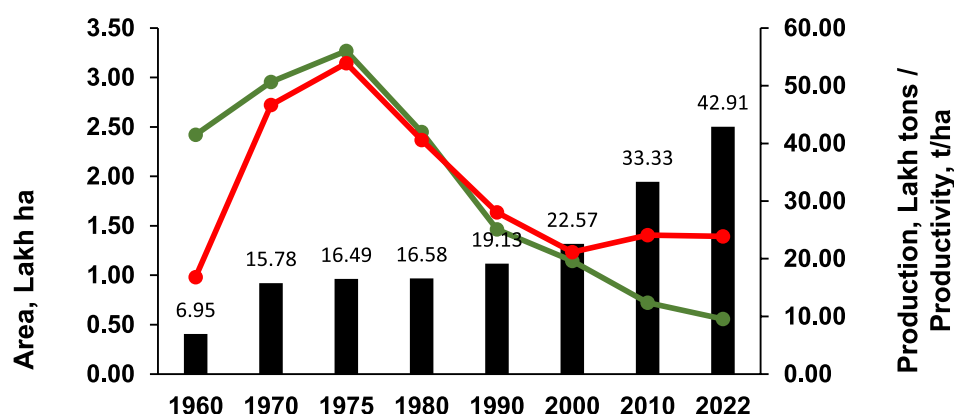


Figure 1. ■ Productivity ● Area — Production

Figure 1 shows the trends in area, production and productivity of cassava in Kerala over the past 63 years. From 2.42 lakh ha cultivation in 1960, it peaked at 3.27 lakh ha in 1975, but drastically dropped to 55,713 ha in 2022.

Cassava production rose to 53.90 lakh tonnes in 1975 from 16.83 lakh tonnes in 1960, but dropped to 23.90 lakh tonnes in 2022. Productivity increased from 6.95 t/ha in 1960 to 42.91 t/ha in 2022–3—an 8.2% annual growth

rate, a record among major crops in Kerala. This rise in productivity, despite reduced area, is mainly attributed to successful research, development, and extension efforts.



AREA, PRODUCTION AND PRODUCTIVITY OF TUBER CROPS IN KERALA (2022-23)

Crop	Area (hectare)	Production (tonnes)	Productivity (t/ha)
Cassava	55713	2390395	42.91
Taro	5185	58024	11.19
Elephant foot yam	4486	241000	53.73
Greater yam	1236	42210	30.00
Chinese potato	848	12720	15.00
Arrowroot	345	8625	25.00
Lesser yam	171	3078	18.00
Sweet potato	150	2133	14.22
Total	68134	2758185	

Table 1 presents the area, production and productivity of tuber crops in Kerala. Tuber crops were grown in 68134 ha with a total production of 27.58 lakh tonnes and a lion's share of it is cassava (23.90 lakh tonnes).

PROFITABILITY COMPARISON

Economics of production of tuber crops vis-à-vis other major food crops in Kerala

	Production Cost (Cost A) (Rs/hectare)	Value of Produce (Rs/hectare)	Profit (Rs/hectare)
Cassava	150000	450000	300000
Elephant foot yam	1000000	1750000	750000
Rice	75000-87500	112500-125000	37500
Banana	225000-250000	625000	375000-400000
Pepper	100000	250000	150000
Pineapple	250000	425000	175000
Vegetables/Spices	100000-200000	200000-450000	100000-250000
Coconut	100000	162500-175000	62500-75000

Table shows the total production cost, total income and net income from important tuber crops in comparison to a few other food crops in Kerala. Elephant foot yam and cassava are among the most remunerative crops along with a few other crops like banana and ginger. A net profit of at least Rs. 1 lakh/acre or Rs. 2.5 lakh/hectare is a minimum need and only a few crops give a net profit of above Rs. 1 lakh/acre and it is noteworthy that many tuber crops give net income more than Rs. 1 lakh/acre.



KEY CHALLENGES IN TUBER CROPS CULTIVATION

- ▶ DECLINE IN CULTIVATED AREA AND TOTAL PRODUCTION
- ▶ LOW PRODUCTIVITY IN SOME CROPS
- ▶ HIGH COST OF CULTIVATION
- ▶ LONG CROP DURATION

Vegetative propagation constraints

Lack of a formal seed system

Small and fragmented land holdings

Rising pests and diseases incidence

Market price volatility

Wild animal attacks

Post-harvest storage only for a short period

TECHNOLOGICAL INTERVENTIONS

Tuber crops research in Kerala began in 1942 and gained momentum with the establishment of ICAR-CTCRI on 01 July 1963. Since then, significant advancements have been made:

A. Development of Improved Varieties, Production and Protection Technologies

In 1971, ICAR-CTCRI released India's first high-yielding hybrid cassava varieties, H-97, H-165, and H-226. Since then, 77 improved varieties of tropical tuber crops have so far been released of which 22 are improved cassava varieties with specific desirable traits.

Notable varieties include:

1. Sree Jaya and Sree Vijaya (1998): Short-duration types suitable for paddy fields and coconut gardens.
2. Sree Shakti, Sree Suvarna, Sree Swarna: Virus-resistant varieties introduced to combat cassava mosaic disease.
3. Sree Raksha (drought-tolerant and cassava mosaic disease resistant) and Sree Pavithra (low potassium requirement) are now widely cultivated in Kerala.
4. In 2024, ICAR-CTCRI released Sree Annam and Sree Manna, two NPK use efficient, high yielding and high-quality cooking varieties.
5. Varieties like Kalpaka, Uthama, Vellayani Hraswa, and Nidhi were released by Kerala Agricultural University for specific agro-climatic zones.
6. Orange fleshed sweet potato (OFSP) and purple fleshed sweet potato (PFSP) from ICAR-CTCRI is very popular among farmers.

B. Impact Assessment of Research

ICAR-CTCRI conducted a study to assess the impact of improved varieties and agrotechniques of cassava and sweet potato developed and popularised in India during 1971-2018.

1. The impact analysis showed that ICAR-CTCRI's technologies yielded a direct benefit of 12,321 crores to producers and consumers. The benefit-cost ratio was 9.75 and internal rate of return (IRR) was 54%. Annual direct benefit from these technologies are valued at 197 crores.



2. Impact assessment by the author based on FAO cassava production statistics during 1960-2022 and value of output indicated that annual increase in production of cassava due to impact of technologies is to the tune of 200 crores per year. Another recent study by ICAR-CTCRI showed that cassava varieties developed by the institute are cultivated in 39% of cassava area in Tamil Nadu and 30% in Andhra Pradesh. Elephant foot yam varieties released by ICAR-CTCRI and All India Coordinated Research Project on Tuber Crops (AICRPTC) cover 100% of the elephant foot yam area in Andhra Pradesh.

3. Five multi-micronutrient liquid foliar formulations for different tuber crops developed by ICAR-CTCRI and licensed to M/s Linga Chemicals, Madurai resulted in an economic benefit of 21.23 crores to farmers over past five years.

Despite these advances, a study revealed that ICAR-CTCRI varieties are cultivated in only 14% of the cassava-growing area in Kerala, indicating the need for focused efforts in dissemination and adoption.

Yield Gap

Productivity of tropical tuber crops in Kerala and India in comparison to that of the average of world's five highest yielding countries and world's highest yielder is given in table 3.

Crop	Kerala	India	Average of worlds highest yielder	Worlds highest yield
			(t/ha)	
Cassava	42.91	35.77	32.91	41.41
Elephant foot yam	53.73	24.74	NA	NA
Taro	11.19	15.30	39.80	65.85
Greater yam	30.00	27.00	32.50	79.98
Sweet potato	14.22	11.72	36.34	45.52
Chinese potato	15.00	20.00	NA	NA
Arrowroot	25.00		NA	NA

Despite Kerala's top figures in cassava productivity, the current productivity is still only 40% of its potential yield (100 t/ha), suggesting considerable scope for further improvement

SCOPE FOR INCREASING PRODUCTION THROUGH TECHNOLOGY ADOPTION

To significantly boost tuber crops production in Kerala, increasing the rate of adoption of proven technologies is essential. Key proposals include:

A. Expand Area Under Cultivation – Focus on Cassava

Cassava, the most important tuber crop in Kerala, is declining in area. Currently grown in 55,713 hectares, a **target of 1 lakh hectares over the next five years is proposed.

B. Expand Area Under Cultivation – Focus on Sweet Potato

ICAR-CTCRI has developed a series of orange-fleshed sweet potato (OFSP)

for different climatic zones which need to be promoted to combat vitamin-A deficiency especially in children and women. Also, boiled or steamed OFSP has low to medium glycemic index (GI) (41-60). Antioxidant, anthocyanin rich purple fleshed sweet potato (PFSP) is also developed by ICAR-CTCRI.

Proposed action:

- Expand sweet potato cultivation to 10,000 ha.
- Scale up the successful 'Rainbow Diet Campaign' model developed by ICAR-CTCRI and recognised by FAO as a successful institutional innovation to a statewide programme in select locations. Currently a very successful programme is in implementation in Attappadi in collaboration with Kerala State Kudumbashree Mission.
- Create smart clusters of sweet

potato with complete value chain established.

- Promote sweet potato based diets developed by ICAR-CTCRI in anganwadis as part of the child nutrition programme.
- Develop village level processing facilities for value-added products and establish market linkages (local markets and supermarkets).

C. Expand Area of Other Tuber Crops

Designate district-specific tuber crop clusters:

- Focus districts for elephant foot yam, taro, greater yam, lesser yam are Pathanamthitta and Kollam
- Aliparamba panchayat in Malappuram and Manjaly in Ernakulam need special attention for elephant foot yam value chain improvement.



- c. Focus districts for Chinese Potato are Palakkad, Thrissur and Ernakulam.
- d. Focus districts for arrowroot are Thiruvananthapuram, Palakkad and Kollam.

D. Zone-Specific Production Technologies

- a. Agro-ecological unit (AEU) based package of practices recommendations for Kerala's 23 agro-ecological units.
- b. Smart micro-irrigation and fertigation.
- c. Computer model based site-specific nutrient management.
- d. AI, IoT and model-based e-Crop smart farming.
- e. Smart farming for cropping / farming systems involving tuber crops.
- f. Climate-resilient agriculture practices.
- g. Regenerative farming practices that will green the green revolution.

E. Pests and Diseases Management

Rising threat of pests/diseases:

- a. Cassava: Root and stem rot, mealybug, red spider mite
- b. Elephant foot yam: Collar rot, leaf and pseudostem rot
- c. Sweet potato: Sweet potato weevil
- d. Taro: Leaf blight
- e. Yams: Yam anthracnose

- f. Elephant foot yam, yams and Chinese potato: Root-knot nematodes

ICAR-CTCRI has developed integrated pests and diseases management (IPDM) protocols for all above major issues.

F. Value Addition and Agribusiness Promotion

ICAR-CTCRI has developed and disseminated technologies for micro- and industrial-scale products. To support entrepreneurship, we have a techno-incubation centre (TIC) to provide training and agri-business incubation (ABI) centre for handholding prospective entrepreneurs and startups in business development. Recent signing of a MoU to promote 36 farmer producer companies (FPC) under CISSA and another one with Kerala State Kudumbashree Mission to license 12 technologies for tuber crops value added products are creditable achievements of ICAR-CTCRI.

Development and licensing of the following technology products/ machinery are worth noting:

- a. Three bioactive molecules (Nanma, Menma and Shreya) from cassava crop residues
- b. Six multimicronutrient liquid foliar formulations for different tuber crops
- c. Super absorbent polymer from cassava starch

- d. Value added food products from tropical tuber crops
- e. Post harvest machinery

During 2006-2024, ICAR-CTCRI has signed MoU with 80 entrepreneurs and licensed 31 technologies grouped above. A comprehensive list of value addition technologies ready for commercialisation is available at ICAR-CTCRI.

Future Research Prospects

To ensure the long-term sustainability and relevance of tuber crops in Kerala and beyond, focused research in the following areas is essential:

A. Protection of Indigenous Varieties

Many traditional tuber crop varieties in Kerala enjoy local popularity and these should be legally protected (e.g. under PPV&FRA). Currently, such protection is minimal in the tuber crops sector.

B. Development of nutritious, low Glycemic Index Cassava Varieties

Cassava, though widely consumed, has a high glycemic index, limiting its use for diabetics. Increasing amylose content in cassava starch from 20% (current average) to 27–30% could make it suitable for diabetic consumption. ICAR-CTCRI, the national active germplasm site (NAGS) of tropical tuber



crops holds 1,216 cassava germplasm accessions. Germplasms need to be screened to identify lines, if any, with high amylose content for use in marker assisted selection and development of low GI varieties. Modern tools like genome editing should also be employed in this direction. Modern laboratories and human resources need to be developed in using modern tools like speed breeding, phenomics, artificial Intelligence (AI) and model assisted predictive breeding.

C. Post-Harvest Shelf-Life Improvement

Cassava deteriorates within 1–2 days post-harvest. Our goal must be to develop varieties that can last at least 15 days without spoilage. Sweet potato has a bright future in products development for which the tubers will have to be stored for 3–4 months instead of the current possibility of 1–2 months. This will ensure reduced post-harvest losses for a longer duration and better market value, as well as smoother supply to processing units.

D. Nutritional Enhancement via Biofortification

Research needs to be focussed in improving the protein, vitamins and micronutrients in these crops without compromising yield, cooking quality, pests/diseases resistance and shorter duration.

E. Farming System Models Based on Agro-Ecological Units

Acropping intensity target of 150–175% in suitable AEUs using tuber crops as intercrops is one of the most important

possibilities for area expansion of tuber crops based sustainable production intensification.

F. Climate Change Adaptation and Mitigation

Climate resilient agriculture need to be developed for agro ecological units based on local issues. Village level climate contingency plan and climate risk management committees need to be developed based on local issues.

G. Urban and Peri-Urban Agriculture

Technologies for urban and peri urban farming such as sensor based smart nutrition gardens, soilless cultivation, hydroponics, aeroponics and controlled protected cultivation need to be developed.

H. Value Addition Research Areas

Promising areas for product development include:

- a. Animal feed sector (for fish, goat, pig, poultry)
- b. Ready-to-use infant and baby food, military food
- c. Bubble tea from cassava
- d. Meat analogues from elephant foot yam and taro
- e. Dietary supplements from sweet potato and Chinese potato
- f. Cassava starch-based edible films for controlled drug delivery (e.g., oral cancer)
- g. Scaling of ethanol production technology already developed by ICAR-CTCRI.

I. Mechanization to Reduce Cultivation Cost

A state wide plan is needed to implement this at scale through Farmer Producer Companies (FPC), Kerala State Kudumbashree Mission women's groups and establish 50–100 smart tuber crop clusters across Kerala.

Development and Extension Strategies – Key Recommendations

To enhance tuber crops production, profitability, and sustainability, the following institutional and policy-level interventions are recommended:

- A. Close Linkage Among Kerala State Department of Agriculture and Farmers' Welfare, Kerala Agricultural University and ICAR institutions as well as KVKs in Kerala

Agro climatic zone (5 zones) level bi-annual meetings for the following:

- a. Present technologies developed by KAU and ICAR institutions which need to be validated in different AEUs which will be done by Kerala State Department of Agriculture & Farmers Welfare and KVKs in Kerala.
- b. Present results of validation trials done by Kerala State Department of Agriculture & Farmers Welfare and KVKs in Kerala for approval and recommendation to package of practices.
- c. Prepare action plan to scale up the recommended packages for rapid adoption by farmers.
- d. Interaction with entrepreneurs for rapid licensing



and commercialisation of the recommended technologies that have commercial value.

B. Biannual conduct of state variety release committee meeting

State variety release committee meeting to be conducted biannually on a regular basis in January and July to consider approval of new varieties for release.

C. Annual Publication of Package of Practices

Kerala Agricultural University (KAU), ICAR institutes, and other research institutions should discuss and release new varieties and technologies every year. State variety release committee and package of practices recommendations meeting must happen every six months and publish an updated 'Package of Practices Recommendations Crops' annually. This is being ceremoniously practised in many states.

D. Formal Seed System and Seed Rolling Plan of Tuber Crops

A formal seed system to mass-produce planting materials of important tuber crops varieties for their faster spread among farmers. ICAR-CTCRI will supply nucleus seeds of quality planting materials of released varieties.

E. Focus on Sustainable Tuber Crop-Based Agribusiness

Promote sustainable agri-business and inclusive development centered on tuber crops. Explore export-oriented startup opportunities. Launch special programmes to support such ventures.

F. Impact Assessment of Technologies

Though many high-yielding varieties and technologies exist, their field-level adoption needs assessment. Identify commercially viable technologies and prepare them for industrial scaling. Scale up their technology readiness level (TRL) if commercialisation prospects exist.

10. Conclusion

Tuber crops, especially cassava, have historically supported Kerala during the famine of 1876-1880 and at many occasions including the COVID-19 lockdown (2020) in ensuring food security. Cassava is known for higher food energy production per unit area per unit time than other important staples, climate resilience, suitability for agroecological and sustainable farming as well as its multipurpose uses in human and animal food, and in the production of many value added industrial products. Other tuber crops are also a part of the culinary traditions of Kerala. A revitalisation of the production and value chain improvement of these crops that are very close to Malayalees will be an essential pillar of future food, nutrition and livelihood security.

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Climate-Resilient and Biofortified Tuber Crop Varieties

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Tuber crops are a group of crops which are known for its climate resilience, offering adaptability to marginal environments and withstand drought and other abiotic stresses like salinity. They are the future crops that can thrive in conditions where other crops struggle, thus contributing to the food security and offering a sustainable solution for agriculture in the face of climate change. Biofortification in tuber crops offers a sustainable, cost-effective way to combat micronutrient deficiencies, especially in the developing countries where these crops are a staple. In the biofortified crops, by increasing the levels of essential vitamins and minerals within the tuber, it enhances the nutritional value of the food source, thereby offering a direct and accessible solution to hidden hunger. Tuber crops like cassava, sweet potato, yam, taro, and others are vital staples for millions of people world over and particularly in the tropical regions, where they serve as a major source of carbohydrates.

Starch content of many of these tubers are utilized for various industrial applications and hold immense scope for these crops to be recognised as an economically valuable industrial commodity.

The ICAR-Central Tuber Crops Research Institute (CTCRI), a constituent entity of the Indian Council of Agricultural Research is an Institute dedicated solely to the improvement of these groups of future crops. The institute focuses on the conservation and improvement of tropical tuber crops, curating more than 5000 accessions of the major tropical tuber crops, and is recognised as the National Active Germplasm Site (NAGS) for tropical tuber crops. The Division of Crop Improvement has as its mandate collection, conservation, characterization, evaluation and utilization of these important set of crops through traditional breeding methods involving selection as

well as hybridization. This involves introgression of desirable traits to the plants of interest, viz., high yield, disease resistance, tolerance to biotic and abiotic stresses, and improved nutritional content. Non-conventional methods like omics and gene editing are also used in the improvement of these crops. The Division has released 77 high-yielding improved varieties, including climate-resilient, and bio-fortified varieties.

A total of 25 climate resilient and 10 bio-fortified varieties were released by the Institute. Further research has been initiated for enriching these crops with vitamins, minerals, and other micronutrients to address malnutrition and improve public health in regions where tubers are the dietary staples. The developed varieties cater to a wide range of categories viz., industrial, food, and fodder.

CLIMATE RESILIENT TUBER CROP VARIETIES DEVELOPED BY ICAR-CTCRI

A total of 25 climate resilient varieties of different tuber crops were developed by the Institute: cassava (5), sweet potato (10), greater yam (2), white yam (3), and taro (5).

CASSAVA

H-97: This is one the first cassava climate resilient variety developed in 1971 having a yield of 25-35 t ha⁻¹. This is an industrial variety with tubers having a starch content of 27-31%, cyanogen 180-200 ppm and good cooking quality, moderately resistant to *Cercospora* leaf spot, spider mite and scale insect.

Sree Sahya: This was released in 1977 having a yield of 35-40 t ha⁻¹. Tubers are long necked (4.5-6.5 cm) with medium long cylindrical tubers having 29-31% starch, 75-85 ppm cyanogens, good cooking quality and moderately resistant to *Cercospora* leaf spot.

Sree Harsha: This variety was developed in 1996 with a yield of 35-40 t ha⁻¹. It is a triploid industrial variety, with tubers having 38-41% starch, 40-55 ppm cyanogen and good cooking quality. It is field tolerant to *Cercospora* leaf spot, spider mite and scale insect and also drought tolerant.

Sree Pavithra: Released in 2015, the variety yields 35-45 t ha⁻¹. It's a clonal selection with 9-10 months duration with excellent cooking quality, high K efficiency (243.65 kg tuber/kg K absorbed), suitable for cultivation in Kerala soils which are inherently low to marginal in soil exchangeable K.

Sree Reksha: Released in 2017, the variety yields 45-50 t ha⁻¹. It is completely resistant to cassava mosaic disease caused by both Indian cassava mosaic virus and Sri Lankan cassava mosaic virus. It is also tolerant to postharvest physiological deterioration. It has medium starch (27-31%) and low sugar (1.10%) content. Suitable for planting in rainfed and irrigated conditions.

SWEET POTATO

Varsha: Released in 1983, it yields 17-22 t ha⁻¹ with a duration of 120 days duration, having good cooking quality, susceptible to sweet potato weevil (*Cylas formicarius*), drought tolerant and suitable for Konkan region of Maharashtra.

Sree Nandini: Released in 1987, the variety yield 20-25 t ha⁻¹. It has a duration of 100-105 days, with excellent cooking quality which cooks well and tastes sweet, susceptible to sweet potato weevil (*Cylas formicarius*), drought tolerant, suitable for paddy fallows as a catch crop and adopted to Kerala.

Gouri: Released in 1998, it yields 19 t ha⁻¹. A hybrid having 110-120 days maturity, with fair, non-mealy cooking quality, susceptible to sweet potato weevil (*Cylas formicarius*), with carotene content, can tolerate mid-season moisture stress, suitable for kharif and rabi seasons in the State of Odisha.

Sourin: Released in 2005, it yields 16.2 t ha⁻¹. It is a hybrid with 105-110 days duration, good cooking quality, slight hard, sweet and intermediate to moist in texture, Tolerant to weevil (*Cylas formicarius*), suitable for both rainfed and irrigated conditions, can withstand mid-season drought and can perform better in sandy loam soils, adapted to the state of Odisha.

Kishan: Released in 2005, it yields 17 t ha⁻¹. A hybrid having 110-120 days duration, with good cooking quality, sweet and mealy, Tolerant to weevil (*Cylas formicarius*), high yielding, with 18.2% extractable starch, suitable for food, fodder and starch, can withstand mid-season drought, perform better in sandy loam and black sandy soils, adapted to Orissa (coastal, plains and hilly areas) under both kharif and rabi season.

Bhu Kanti: Released in 2017, the variety yields 22-24 t ha⁻¹. It matures in 105-110 days having orange fleshed with good cooking quality, dry Matter: 24-26.6%, total starch: 16-18.8%, total sugar: 1.9-2.2%, β -carotene: 6.2-7.8mg/100g, suitable for Odisha.

Bhu Sona: Released in 2017, the variety yields 20-24 t ha⁻¹. It has a duration of 105-110 days, orange

fleshed with good cooking quality, dry Matter: 27-29%, total starch: 18.8-19.7%, total sugar: 2-2.4%, β -carotene: 13.2-14.4mg/100g, suitable for Odisha.

Bhu Ja: Released in 2017, the variety yields 20-22 t ha⁻¹. It has 100-110 days maturity, orange fleshed with good cooking quality, dry matter: 23.2-24.8%, Total starch: 16.6-17.2%, total sugar: 2.4-3%, β -carotene: 5.5-6.4mg/100g, suitable for Odisha.

Bhu Krishna: Released in the 2017, the variety yields 18-22 t ha⁻¹. It has a duration of 110-120 days, purple fleshed with fair cooking quality, dry Matter: 24-25.5%, total starch: 19.5%, total sugar: 1.9-2.2%, anthocyanin 85-90mg/100g, suitable for Odisha.

Bhu Swami: Released in 2017, the variety yields 20 t ha⁻¹. It has 105-110 days maturity, white fleshed variety with excellent cooking quality, dry matter: 27.4-29.7%, total starch: 20.8-21.2%, total sugar: 3-3.7%, suitable for Odisha.

GREATER YAM

Sree Keerthi: Released in 1987, the variety yields 25-30 t ha⁻¹. It has a duration of 9-10 months with good cooking quality, susceptible to anthracnose (*Colletotrichum gloeosporioides*) and leaf spot (*Cercospora* sp.), tolerant to scale insect in storage, high yielding, large sized tubers, suitable for intercropping in mature coconut gardens as well as with banana, adapted to coastal and interior plains of Kerala.

Sree Swathy: Released in 2014, the variety yields 30 t ha⁻¹. It has 9-10 months duration with tubers having good culinary and nutritive quality and moderately tolerant to anthracnose disease, withstands drought, suitable for Kerala.

WHITE YAM

Sree Shubra: Released in 1987, the variety yields 35 t ha⁻¹ having 9-10 months duration with excellent cooking quality, no virus or anthracnose symptoms observed, drought tolerant, having novel flavour, suitable for coastal and interior plains of Kerala.

Sree Priya: Released in 1987, the variety yields 35 t ha⁻¹. It has 9-10

months duration with excellent cooking quality, no virus or anthracnose symptoms observed, drought tolerant, has a novel flavour, suitable for intercropping in mature coconut gardens as well as with banana, suitable for coastal and interior plains of Kerala.

Sree Harita: Released in 2020, the variety yields 46 t ha⁻¹. The hybrid has 9-10 months maturity with excellent cooking quality and good flavour with medium size compact cylindrical tubers with smooth texture, brown skin and white flesh colour, suitable for Kerala.

TARO

Sree Rashmi: Released in 1987, the variety yields 18 t ha⁻¹. It has 7 months duration with very good cooking

quality, moderately susceptible to leaf blight (*Phytophthora colocasiae*), field tolerant to dasheen mosaic virus, having edible leaves, corms and cormels which are acid free, can give economic yield under low input levels also, suitable for Kerala.

Panisaruru 1: Released in 2005, it yields 15.7 t ha⁻¹ having a duration of 6-7 months with good cooking quality, field tolerant to leaf blight, can be grown in upland and low / submerged condition, having long shelf life of cormels (3 months), suitable for Odisha.

Panisaruru 2: Released in 2005, the variety yields 13 t ha⁻¹. It has 6-7 months duration with good cooking quality, field tolerant to leaf blight,

can be grown in upland and low land / waterlogged / swampy conditions, suitable for Odisha.

Bhu Kripa: Released in 2017, the variety yields 15-20 t ha⁻¹. It has a duration of 6-7 months with excellent cooking quality, dry matter: 23.5-24.6%, total starch: 12.3-14.2%, total sugar: 1.3-1.7%, biotic and abiotic stress tolerant, suitable for Odisha.

Bhu Sree: Released in 2017, this variety yields 15-20 t ha⁻¹. It has a duration of 6-7 months with excellent cooking quality, dry matter: 23-24.8%, total starch: 15.6-17.3%, total sugar: 1.2-1.5%, biotic and abiotic stress tolerance, suitable for Odisha.

CLIMATE-RESILIENT CASSAVA VARIETIES



H-97



Sree Harsha



Sree Sahya



Sree Pavithra



Sree Reksha

SWEET POTATO VARIETIES



Varsha



Sourin



Kishan



Gouri



Sree Nandhini



Bhu Kanti



Bhu Sona



Bhu Ja



Bhu Kripa



Bhu Swami

GREATER YAM VARIETIES



Sree Keerthi



Sree Swathy



Sree Shubra



Sree Priya



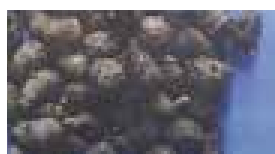
Sree Harita

WHITE YAM VARIETIES

CLIMATE-RESILIENT TARO VARIETIES



Panisaru 1



Panisaru 2



Sree Rashmi



Bhu Kripa



Bhu Sree

BIOFORTIFIED TUBER CROPS VARIETIES DEVELOPED BY ICAR-CTCRI

Biofortification is of great importance as it addresses nutritional security of the nation. Biofortified crops are those which are naturally fortified with important vitamins, minerals, etc. They fetch a better price in the market. The Institute has developed 10 naturally biofortified tuber crop varieties in cassava (3), sweet potato (6), and greater yam (1).

CASSAVA

Sree Visakhham: Released in 1977, the variety yields 35-38 t ha⁻¹. Tubers have 25-27% starch, 466 IU/100g carotene, 35-40 ppm cyanogen having good cooking quality. Field tolerant to *Cercospora* leaf spot.

Sree Vijaya: Released in the year 1998, the variety yields 25-28 t ha⁻¹. It is an early maturing variety (6-7 months) with 40-60 ppm cyanogen having excellent cooking quality. Field tolerant to *Cercospora* leaf spot.

Sree Swarna: Released in 2015, the variety yields 35-40 t ha⁻¹. It is an early bulking (7 months) variety with good culinary quality, yellow flesh colour and tolerant to cassava mosaic disease, suitable for Kerala.

SWEET POTATO

Sree Kanaka: Released in 2004, this variety yielded 10-15 t ha⁻¹. It has a duration of 75-85 days with good cooking quality and soft texture, with 8.8-10.0 mg/100g fresh weight of β -carotene, having early maturity and

suitable for Kerala

Apart from these, Gouri, Bhu Kanti, Bhu Sona, Bhu Ja and Bhu Krishna are also biofortified with orange and purple flesh colour.

GREATER YAM

Sree Neelima: Released in the year 2014, the variety yields 35 t ha⁻¹. It has a duration of 9-10 months with tubers having good culinary and nutritive quality (high protein and micronutrients) and flesh colour is light purple, suitable for Kerala. Along with the germplasm line Da-340, this variety was dedicated to the Nation by the Hon'ble PM along with 15 other biofortified varieties during the eve of the 75th Anniversary of the Food and Agriculture Organization (FAO).

BIOFORTIFIED VARIETIES



Sree Visakhham



Sree Vijaya



Sree Swarna



Sree Neelima



Sree Kanaka



Gouri



Bhu Sona



Bhu Kanti



Bhu Ja



Bhu Krishna

SUMMARY

The popular article summarises the climate resilient and biofortified improved varieties of tuber crops released by ICAR-CTCRI. The notable varieties include Sree Reksha (CMD resistant), Sree Vijaya (short duration), and Sree Swarna (yellow fleshed) in

cassava; Sree Kanaka, Bhu Sona and Bhu Ja (Orange fleshed), Bhu Krishna (purple fleshed) in sweet potato; Sree Neelima (purple fleshed) in greater yam with high protein and micronutrient content and Sree Rashmi (no acidity) in taro. The sweet potato varieties,

Gouri and Bhu Kanti, Bhu Sona, Bhu Ja and Bhu Krishna are both climate resilient as well as biofortified. These results highlight the persistent efforts made by ICAR-CTCRI to improve the nutritional security of the nation.

Current Status and Export potential of Tropical Tuber Crops in India

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Tropical tuber crops, including cassava, sweet potato, yam, elephant foot yam, taro and tannia play pivotal roles in the food sector, particularly in supporting the well-being of people in developing nations. Additionally, minor tubers such as Chinese potato, yam bean and arrowroot contribute to food security and nutrition. The two most important tropical tuber crops viz., cassava and sweet potato rank 5th and 7th among the top ten food crops in the world in terms of volume of production. According to FAOSTAT (2023), these crops are grown in 52.83 million hectares of land globally, producing about 534.97 million tonnes annually. In recent years, the cultivation of tuber crops has

garnered increasing attention due to their adaptability, nutritional value and resilience to changing environment. Globally, these crops are cultivated across diverse regions, contributing significantly to food security, income generation and rural livelihoods.

The production landscape of tuber crops exhibits noteworthy trends with countries like Nigeria, China and India emerging as key players in cultivation and trade. Cassava, with its wider cultivation across Africa, Asia and the Americas, stands out as one of the most widely grown tuber crops globally. Similarly, sweet potato, predominantly cultivated in Africa and Asia, play a pivotal

role in addressing nutritional deficiencies and enhancing food security in these regions. Elephant foot yam, though less widespread, has witnessed significant growth in cultivation in countries like India, contributing to both dietary diversity and economic prosperity. The trade dynamics of tuber crops further underscore their significance in the global agricultural landscape. India, for instance, emerges as a notable exporter of tuber crops, including cassava, sweet potato, yams, taro and arrow root catering to diverse international markets. Conversely, the country also engages in imports particularly cassava starch, with minimum quantity, to meet domestic demand and other uses.



CURRENT STATUS OF TUBER CROPS PRODUCTION IN THE WORLD

Tropical tuber crops are grown in 126 out of 195 countries and are widely grown and consumed as subsistence staples in many parts of Africa, Asia, Latin America and the Pacific Islands. Cassava is the most important tropical tuber crop with 60.99% of the total world tropical tuber crops production followed by yams (20.08%). Sweet potato constitutes another 14.33% and tannia constitute only 4.60% of the total world production.

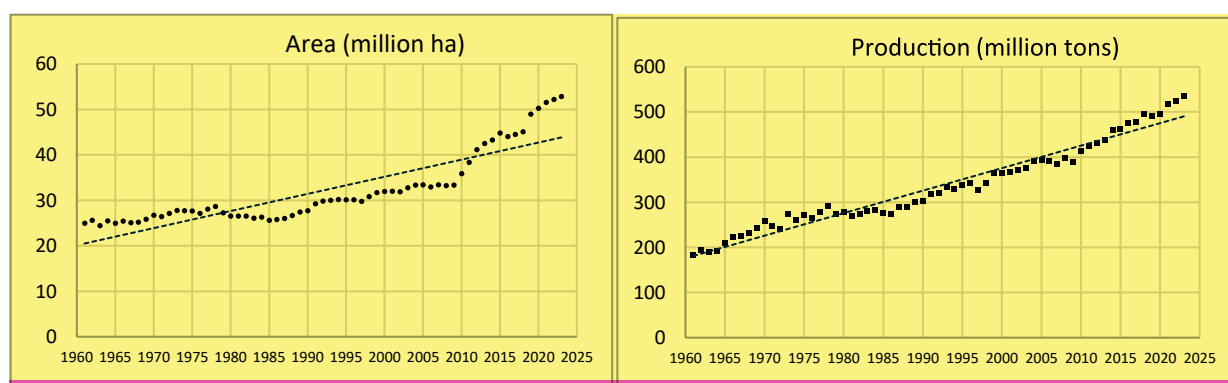
Global area, production and productivity of major tropical tuber crops (2023)

Crop	Area (million ha)	Production (million tons)	Productivity (t/ha)
Cassava	32.22	333.68	10.35
Sweet potato	7.57	93.52	12.35
Yams	10.61	89.34	8.42
Taro	2.40	18.07	7.52
Tannia	0.03	0.37	12.42
Total	52.83	534.97	10.21

Source: FAOSTAT (2023)

The trend in area and production of tropical tuber crops over the past 63 years (1961-2023) shows a consistent increase. Regression analysis of the long-term data indicates a linear upward trend in both area and production, with an average annual increase of 0.37 million ha ($R^2=0.763$) and 4.98 million tons

($R^2=0.957$) respectively. The compound growth rate was 1.09% for area and 1.52% for production. Overall, the area and production of tropical tuber crops increased by 112% and 193% respectively in 2023 compared to 1961.



Global trend in area (million ha) and production (million tons) of tropical tuber crops during 1961-2023 (www.fao.org/faostat)

Current status of tuber crops production in India

Tropical tuber crops are the source of sustenance and livelihood security of about 200 million people across different states of India, namely Kerala, Tamil Nadu, Andhra Pradesh, Odisha, West Bengal, Bihar, Uttar Pradesh, Chhattisgarh, Gujarat, Goa, Maharashtra, Madhya Pradesh, Jharkhand, Andaman and Nicobar Islands, Jammu and Kashmir and Telangana, Karnataka, Rajasthan, north-eastern states. The total tropical tuber crops production such as cassava, sweet potato and elephant foot yam in our country is about 8.55 million tons, with a present market value of more than Rs. 200 billion.

Area, production and productivity of important tropical tuber crops in India (2023-2024)

Crop	Area(lakh ha)	Production(lakh tons)	Productivity (t/ha)
Cassava	1.780	62.729	35.24
Sweet potato	1.107	13.061	11.80
Elephant foot yam	0.396	9.794	24.74
Total	3.283	85.584	23.93

Source: Indiatatagri (2024)

CASSAVA

Cassava is an important crop in India, especially in Kerala, Tamil Nadu, Andhra Pradesh and parts of north eastern states. It is cultivated in 12 states. Tamil Nadu is the leading state in India for cassava cultivation, (55.30% of the total area and producing 57.27% of the country) followed by Kerala (31.77% of the area and 37.14% of the production), Andhra Pradesh (2.92% of the area and 2.07% of the production), Nagaland (2.74% of the area and 1.21% of the

production) and Meghalaya (3.08% of the area and 0.59% of the production) during 2023-2024. The compound growth rate showed a negative trend in area harvested (-0.95), but a positive trend in production (+1.05) and yield (+2.02) from 1961-2023.

SWEET POTATO

Sweet potato is an important crop in India especially in states like Odisha, Uttar Pradesh, West Bengal, Madhya

Pradesh, Karnataka, Assam, Meghalaya and Chhattisgarh. It is cultivated in 22 states. Odisha is the leading state with the largest area under sweet potato cultivation, contributing 31.22% of the harvested area and 25.68% of the country sweet potato output, followed by Uttar Pradesh (17.44% of the area and 20.10% of the production), West Bengal (14.74% of the area and 13.43% of the production), Madhya Pradesh (6.43% of the area and 8.56 of the production), Karnataka (5.89% of the

area and 7.88 of the production), Assam (4.52% of the area and 2.17% of the production), Meghalaya (4.49% of the area and 1.38% of the production) and Chhattisgarh (4.11% of the area and 4.10% of the production) during 2023-2024. The compound growth showed a negative trend in area harvested (-1.13) and production (-0.30), but a positive trend in yield (+0.84) from 1961-2023.

ELEPHANT FOOT YAM

Elephant foot yam is cultivated in 12 states across India. The crop witnessed significant growth in both area harvested (+13.79%) and production (+9.77), despite a slight decline in yield per hectare (-3.53) from 2013-2014 to 2023-2024. West Bengal is the leading state in elephant foot yam cultivation contributing 41.26% of the harvested

area and 34.65% of the country's output followed by Tamil Nadu (11.42% of the area and 14.62% of the production), Kerala (10.94% of the area and 18.38% of the production), Chhattisgarh (8.97% of the area and 4.26% of production), Bihar (8.41% of the area and 5.95% of the production), Andhra Pradesh (7.60% of the area and 11.44% of the production) and Jharkhand (5.20% of the area and 5.94% of the production) during 2023-2024.

STATUS OF EXPORTS AND IMPORTS OF TUBER CROPS BY INDIA

The below table shows the commodity-wise export and import performance of major tuber crops by India during 2024, based on the data from the International

Trade Centre (ITC) Trademap. The total quantity of tuber crops exported stood at 13,654 tons, valued at US\$ 10.65 million, while imports were minimal, about 51 tons with a value of US\$ 0.14 million, indicating India's strong self-sufficiency and export orientation in this sector. Among the commodities, yams (HS 071430) recorded the highest export volume (6,614 tons) and value (US\$ 4.62 million), followed by manioc starch (HS 110814) with 3,619 tons and US\$ 3.49 million, and sweet potato (HS 071420) with 1,218 tons and US\$ 0.42 million. Taro (HS 071440) and arrowroot (HS 071490) also contributed modestly to exports. Imports were negligible across all commodities, with only minor quantities of manioc starch (50 tons) and taro (1 ton) imported, primarily to meet niche industrial or consumer needs.

Commodity wise export and import of tuber crops by India (2024)

Commodities	Export qty (tons)	Import qty (tons)	Export value (US 1000 USD)	Import value (US 1000 USD)
Manioc Starch (HS 110814)	3619	50	3489	136
Sweet potato (HS 071420)	1218	-	416	-
Yams (HS 071430)	6614	-	4620	-
Taro (HS 071440)	1074	1	832	3
Tannia (HS 071450)	1	-	2	-
Arrowroot (HS 071490)	564	-	647	-
Arrowroot (HS 07149010):Sago Pith	225	-	224	-
Arrowroot (HS 07149090):Other edible roots and tubers containing high starch/insulin	339	-	424	-
Total	13654	51	10654	139

Source: ITCTrademap (<https://www.trademap.org/Index.aspx>)

Country wise export of tuber crops by India (2024)

The below table shows the country-wise distribution of India’s tuber crop exports during 2024, highlighting the key international markets for each commodity. The data reveal that India’s exports are strongly concentrated in a few major destinations, primarily in Asia, the Middle East, and North America. The United States of America was the largest market for manioc starch (54.85%), while Nepal dominated imports of sweet potato (68.72%) from India. The United Arab Emirates (UAE) was the leading destination for several tuber crops accounting for 87.60% of yam, 41.72% of taro, 32.45% of arrowroot, and 53.78% of other starch-rich edible roots and tubers exports. Other significant importers included Canada, United Kingdom, Australia, Qatar and Bangladesh, reflecting India’s diversified yet regionally focused export profile in tuber commodities.



Country wise export of tuber crops by India (2024)

Rank	Manioc Starch (HS 110814)	Sweet potato (HS 071420)	Yams (HS 071430)	Taro (HS 071440)	Arrowroot (HS 071490)	Arrowroot (HS 07149010): Sago Pith	Arrowroot (HS 07149090): Others
I	United States of America (54.85%)	Nepal (68.72%)	United Arab Emirates (87.60%)	United Arab Emirates (41.72%)	United Arab Emirates (32.45%)	Canada (37.62%)	United Arab Emirates (53.78%)
II	Nepal (27.96%)	Maldives (13.05%)	Qatar (5.40%)	United Kingdom (13.97%)	Canada (15.43%)	United States of America (12.94%)	United States of America (16.77%)
III	Kuwait (5.42%)	Bhutan (8.62%)	United States of America (1.38%)	Bangladesh (9.59%)	United States of America (15.25%)	Mauritius (10.03%)	United Kingdom (13.21%)
IV	Sri Lanka (2.71%)	Bangladesh (3.28%)	Maldives (1.19%)	Saudi Arabia (5.59%)	United Kingdom (10.64%)	Australia (9.01%)	Australia (5.38%)
V	United Arab Emirates (2.54%)	United Arab Emirates (2.71%)	Kuwait (1.07%)	Qatar (5.12%)	Australia (6.91%)	United Kingdom (6.91%)	Qatar (3.18%)

Source: ITC Trademap (<https://www.trademap.org/Index.aspx>)

CONCLUSION AND WAY FORWARD

Tropical tuber crops play an indispensable role in global and national food systems, contributing significantly to food and nutritional security, income generation and climate-resilient agriculture. The global production trends highlight a consistent increase in both area and yield over the past six decades, with cassava, yam and sweet potato emerging as the leading contributors. In India, these crops form an integral component of rural livelihoods, particularly in southern, eastern and north-eastern states, providing food, feed and industrial raw materials. Despite a decline in the area under cultivation for certain crops such as cassava and

sweet potato, productivity gains have offset the reduction, resulting in overall positive growth in production. Elephant foot yam, in particular, has shown remarkable expansion in area and output, reflecting growing commercial and nutritional importance. India's position as a net exporter of tuber crops shows its comparative advantage and self-sufficiency in this sector. Major export commodities such as yams, manioc starch and sweet potato are finding strong markets in Asia, Middle East and North America, with countries like the UAE, USA and Nepal emerging as key trading partners. The minimal level of imports further indicates India's strong domestic production base. Strengthening value chains, improving processing and storage facilities and climate resilient high yielding varieties can further enhance the productivity,

profitability and global competitiveness of India's tuber crop sector.

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Resilient and regenerative production and protection technologies of tuber crops for a sustainable future



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Tuber crops such as cassava, sweet potato, yams, and taro are vital staples for millions of people across tropical, subtropical, and temperate regions. They serve as critical sources of carbohydrates, dietary fibre, vitamins, and minerals, contributing significantly to global food and nutrition security. Tuber crops also support livestock feed, industrial starch production, and diverse value-added products, making them integral to rural livelihoods and agro-based economies. However, their production faces multiple challenges. Climate change is intensifying abiotic stresses such as drought, flooding, and heat waves, which threaten yield stability and quality. Pest and disease pressures, including emerging pathogens and invasive insect species, continue to erode productivity and increase the need for timely, sustainable protection measures. Soil degradation, declining organic matter, and nutrient imbalances further undermine the long-term viability of tuber crop systems.

In this context, the principles of resilience and regeneration offer a transformative pathway. Resilience in agricultural systems refers to the capacity to absorb shocks, adapt to change, and recover rapidly without loss of function or productivity. Regeneration focuses on restoring and enhancing the natural resource base, soil health, biodiversity, and ecosystem services, so that production systems not only sustain themselves but also improve over time. Integrating these concepts into tuber crop farming requires a blend of traditional knowledge, cutting edge science, and farmer led innovation. Tuber crops in general, have inherently resilient traits such as deep rooting systems and adaptability to marginal soils. This article explores the latest resilient and regenerative production and protection technologies tailored to tuber crops, developed by ICAR-CTCRI.

PRODUCTION TECHNOLOGIES

Nutrient use efficient varieties

ICAR-CTCRI has released three nutrient use efficient varieties in cassava. Sree Pavithra with excellent cooking quality is a potassium efficient variety, which can give optimum and comparable tuber yield even in soils of low potassium content. Upto 50% of recommended potassium can be saved by growing this variety. Similarly recently released varieties viz., Sree Annam and Sree Manna are found to be NPK efficient varieties in cassava and can be grown with 25% recommended dose of fertilizer nutrients for an optimum tuber yield. Identification of such nutrient efficient genotypes can help to reduce the usage of chemical fertilizers and ensure maximum resource use efficiency.

Crop diversification

Crop diversification is recognized as one of the most feasible, cost-effective and rational ways of developing resilience to the changing climate. Tuber crops are ideal choice in most of the common cropping systems. These are mostly grown in association with plantation, fruit or tree crops like coconut, arecanut, coffee, rubber, banana, mango, sapota etc under agri-horti or agri-silviculture system, especially in small and medium sized land holdings. In small farms, pulses and legumes like groundnut, cowpea, black gram, green gram and vegetables such as French bean, amaranthus, onion, coriander and okra are ideal for integrating with tubers. Short-duration cassava varieties, Sree Vijaya, Sree Jaya, Vellayani Hraswa and Kalpaka hold promise as component crops in rice based cropping system. Rice-black gram-short-duration cassava, rice-short-duration cassava+black gram, Rice-short-duration cassava+cluster bean are certain productive, profitable and energy efficient cropping systems.

There is a possibility to save upto half FYM and nitrogen and full P in these crop combinations.

Yam varieties such as Sree Latha, Sree Keerthi and Sree Priya are suited for intercropping. Yams intercropping with Nendran/ Robusta banana is an ideal combination. Intercropping dwarf white yam (var. Sree Dhanya) with green gram or soybean is another productive and profitable model. Yams when intercropped with maize, maize stalks after harvest can be used for trailing yam vines.

Elephant foot yam is ideal as an intercrop as well as main crop in different cropping systems. During early stages of growth, there is possibility of growing bushy short-duration vegetables, or short-duration pulses in the interspaces. After harvest, haulms could be reused as mulch or incorporated in soil, while earthing up. Elephant foot yam can be intercropped profitably in coconut, arecanut, rubber, banana and robusta coffee plantations. Intercropping elephant foot yam with pulses like black gram or soybean is productive and profitable. Vegetable crops like amaranthus and cucumber can also be intercropped in elephant foot yam with higher yield and profit following organic methods.

Taro is found to fit well under different cropping systems. During initial growth stages of taro, different short duration crops can be raised as intercrops such as vegetables (chilli, tomato), leafy vegetables (amaranthus, spinach, coriander), cowpea, onion, pulses etc. In Kerala, taro is recommended as intercrop in banana/coconut/ arecanut. Integrating multiple cropping strategies from intercropping and crop diversification to agroforestry and traditional polyculture systems creates habitat complexity, nurtures beneficial microbial and faunal communities, and fortifies ecosystem services like



pollination, pest regulation, soil protection, and nutrient cycling. Adoption of crop diversification can help to increase the income of small landholder farmers, conservation of natural resources, many agronomic benefits in pest management by breaking insect habitats and disease cycles, reducing weeds and soil erosion, and conserving soil moisture.

Precision water and nutrient management

ICAR-CTCRI has made significant advances in precision water and nutrient management of tuber crops. Water requirement of tuber crops have been worked out, drip irrigation schedules have been developed to meet the actual crop needs at different growth stages in crops like cassava, sweet potato, elephant foot yam, taro and chinese potato. Drip irrigation, which has emerged as a highly efficient irrigation method, delivering water directly to the root zone could save irrigation water to the tune of 100- 200%, compared to furrow irrigation, commonly followed. Fertigation technique, which combines the application of water and nutrients is also perfected for tuber crops like cassava, elephant foot yam, greater yam and taro and schedules have been developed based crop demand and stages of growth. Fertigation techniques could save the nutrient requirement to the tune of 25% of nitrogen and potassium, in addition to increase in nutrient use efficiency by 30-40%. It is also found possible to reduce the irrigation water usage by suitably employing water saving technologies like, porous ground cover mulching, soil application of super absorbent polymers such as Pusa hydrogel, SAP from cassava starch, crop residue mulching etc which can save up to 50% of irrigation water.

Site-specific nutrient management (SSNM) and fertilizer best management practices (FBMP) using a 4R nutrient

stewardship framework—right source, correct rate, right time, and proper placement—for tuber crops across diverse agroecological zones has been standardized by ICAR-CTCRI. Custom-made mixed fertilizers made according to the site specific nutrient management recommendations, is made available for each agroecological zone. Besides the recommended N, P and K balance in these fertilizers, they can be fortified with Mg, Zn and B according to the soil fertility conditions in each zone and recommendations have been made. Calibrated QUEFTS models have generated nutrient recommendations for cassava, sweet potato, elephant foot yam, yams, and taro, resulting in yield increases of 13–28%, improved nutrient-use efficiency, reduced fertilizer inputs, enhanced benefit - cost ratios, and better soil health. To support implementation, the mobile app 'Sree Poshini' delivers soil-test-based fertilizer recommendations, while CASSNUM v1.1 serves as a decision support tool. The institute also has developed microfood formulations containing all the micronutrients essential for different tuber crops such as cassava, sweet potato, yams, elephant foot yam, taro and chinese potato. These customized liquid micronutrient formulations are commercially available in the market as 'Micronol' and a yield increase of 20-30% is recorded with foliar application of these formulations. These precision tools ensure increased crop yield, reduction in synthetic fertilizer use, helpful for improving soil quality, and mitigating greenhouse gas emissions.

Organic farming technologies

As per FAO reports, CO₂ emission from organic farming is reported to be 48 to 66% lower than in conventional system due to the reduced reliance on synthetic fertilizers and pesticides, which are energy-intensive to produce and contribute to greenhouse gas emissions.



Organic farming technologies have been standardized for all the tuber crops, which can fully avoid the use of chemical fertilizers or pesticides. The package including the incorporation of organic manures, crop residues, green manuring in situ and green leaf manures, ash, biofertilizers, biopesticides etc, based on nutrient requirement of each crop, enrich the organic matter content and overall quality of soils. The yield levels of tuber crops under organic technologies are found increasing or comparable with that under inorganic cultivation. The tuber quality also is found enhanced along with extended storage life under organic farming.

Organic practices have shown to increase soil organic carbon and have the potential to sequester more carbon than is currently emitted, contributing toward reversing climate change trends. Crop residue recycling enhances organic carbon sequestration, improves soil structure and nutrient retention, and strengthens overall soil health with positive residual effects on subsequent crops. This cost-effective practice serves to reduce reliance on external inputs while sustaining productivity. They become a reservoir of organic matter that fosters microbial activity, enhances moisture retention, and provides slow-releasing nutrients vital for tuber growth and soil regeneration. Such strategies are especially pertinent for tuber systems, where root systems and organic-rich residues can help build and maintain fertile, resilient soil.

Low input management/ Integrated nutrient management

Cassava being mostly grown as a homestead crop in Kerala without using much of chemical fertilizers, a low input nutrient management strategy can also be recommended. The package consists of using nutrient use efficient variety like Sree Pavithra and other NUE genotypes,

green manuring in situ with cowpea as organic manure source in place of FYM, soil test based application of nutrients and biofertilizers. Integrated nutrient management (INM) practices can replace 25 to 75% of chemical fertilizers by suitably integrating organic nutrient sources, like green manuring, crop residue recycling, composting, cover cropping etc thereby enhancing the soil organic matter content and carbon enrichment of soil in the long run.

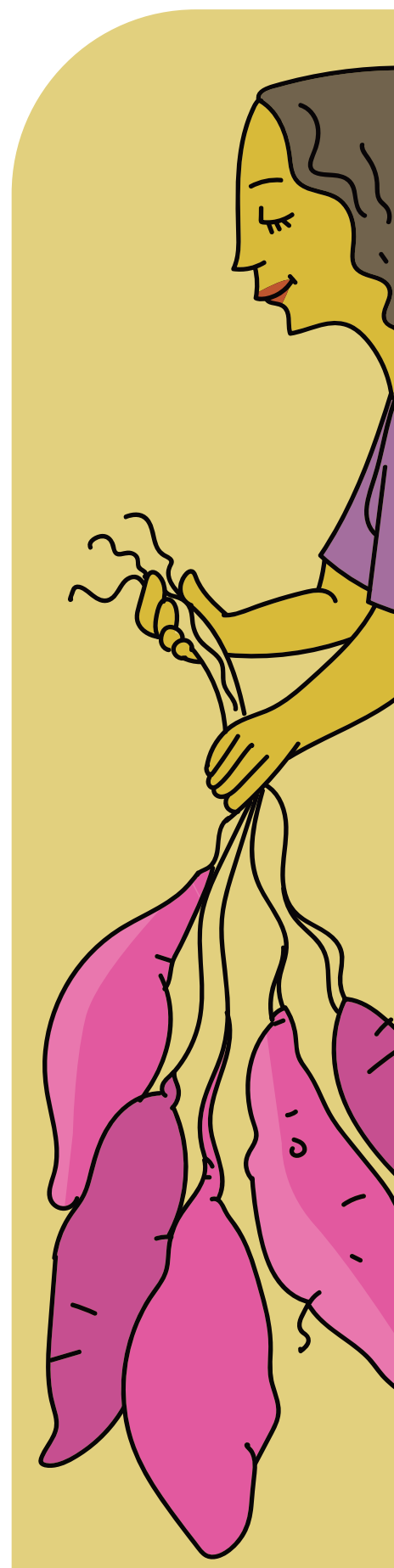
These organic amendments enhance organic carbon sequestration, improve soil structure and nutrient retention, and strengthen overall soil health with positive residual effects on subsequent crops. This cost-effective practice serves to reduce reliance on external inputs while sustaining productivity. They also become a reservoir of organic matter that fosters microbial activity, enhances moisture retention, and provides slow-releasing nutrients vital for tuber growth and soil regeneration. Such strategies are pertinent for tuber production systems, where root systems and organic rich residues can help to build and maintain fertile, resilient soil.

PROTECTION TECHNOLOGIES

Tuber crops face serious threats from pests and diseases. Due to the mounting concern over the deleterious effect of synthetic chemicals, modern protection technologies are now focusing on resilience and regeneration. This approach is eco-friendly, reduces chemical pesticide use, protects beneficial organisms, improves soil health, and provides long-term, sustainable crop protection.

Integrated Pest and Disease Management (IPDM)

The strategy integrates cultural practices, resistant varieties, biological control agents and need-based chemical use to



minimize crop losses while protecting beneficial organisms. Cultural practices reduce pest and disease risk by creating unfavorable conditions for harmful organisms. It includes use of healthy planting material, crop rotation & intercropping, field sanitation, soil & water management, mulching, application of organic manures etc. As tuber crops are clonally propagated, the use of healthy and pest-free planting material plays a crucial role in ensuring crop health. Resistant varieties serve as the first and most cost-effective line of protection against pests and diseases. ICAR-CTCRI has developed cassava varieties such as Sree Reksha, Sree Shakthi, Sree Suvarna, and Sree Kaveri, which can completely resist the virus causing cassava mosaic disease, the most common and destructive disease of cassava. Similarly, taro varieties released by the institute, Muktakeshi, Bhu Kripa, and Bhu Sree, are resistant to taro leaf blight, while yam varieties Sree Karthika and Sree Keerthi show resistance to anthracnose.

In biological control, beneficial organisms such as fungi, bacteria, natural enemies of insect pests, and entomopathogenic nematodes (EPNs) are used to suppress harmful pests and diseases. ICAR-CTCRI has developed solid, liquid, and biocapsule formulations of *Trichoderma* and *Bacillus* for managing major diseases, including tuber rot and cassava stem and root rot, yam anthracnose, taro leaf blight, and collar rot and postharvest rot in elephant foot yam. Three biopesticides developed by ICAR-CTCRI, Nanma, Menma and Sreya, serve as effective tools to reduce crop losses caused by sucking pests. These biopesticides are effective against pests of tuber crops, banana, vegetables, and even storage pests.

Climate Smart Protection

Early warning systems and pest forecasts alert growers in advance about

the possible occurrence of pests and diseases, enabling them to take timely preventive measures. This approach not only reduces crop losses but also prevents the indiscriminate use of pesticides. ICAR-CTCRI has developed models to predict mealybug infestation in cassava and taro leaf blight incidence. Both models are in the final phase of testing before being released for farmer use. Similarly, AI-powered diagnostic apps, remote sensing, and IoT-based pest monitoring systems enable early detection and targeted control measures, reducing pesticide misuse and cost.

Soil Health Centric Approaches

The focus is on keeping the soil alive and healthy, improving its structure, fertility, and biodiversity so crops grow better and naturally resist pests and diseases. Practices such as applying organic amendments, using cover crops, and bio-priming planting material promote beneficial microbes that compete with or suppress pathogens.

Safe And Judicious Pesticide Use

Applying pesticides in a controlled and responsible way helps minimize risks to humans, beneficial organisms, and the environment while effectively managing pests and diseases. Many growers confuse fungicides, insecticides, and weedicides, leading to indiscriminate use that often wastes time and money. Educating growers before pesticide distribution is essential. When chemicals are necessary, newer molecules with low environmental impact should be preferred, and applications should strictly follow residue limits and waiting period guidelines to ensure food safety and protect soil and water.

Postharvest Pest Management

The carbohydrate-rich tubers/corms harbor pests and pathogens, leading to reduced quantity and quality, carry-over of propagules to the next crop, and poor



crop stand. ICAR-CTCRI has developed organic and integrated management practices for mitigating postharvest rot in yams and colocasia, emphasizing the importance of cleaning and timely application of bioagents or pesticides.

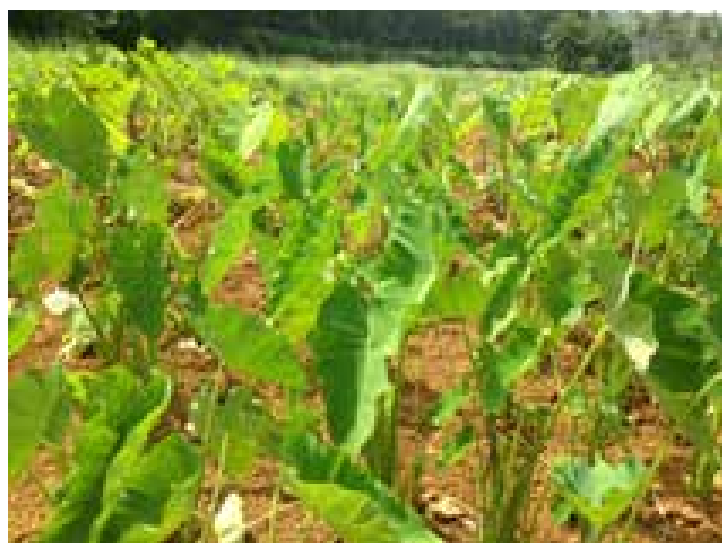
Climate resilience and regeneration techniques involve strategies to mitigate climate change impacts and restore ecosystems. Climate-smart varietal development and microbiome-enabled agronomic practices to harden crops against biotic and abiotic stresses and regenerative practices like crop diversification, precision resource management, residue recycling, organic amendments, , improve soil function and carbon stocks, Continued warming due climate change is inevitable, but the severity of future impacts can be significantly reduced through concerted action to curb greenhouse gas emissions.



Cassava Intercropped With Green Gram



Cassava Under Drip Irrigation



Muktakeshi- Resistant To Taro Leaf Blight



Biocapsules Released From Icar-Ctcric

Innovative approaches for quality planting material production in tuber crops

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INTRODUCTION

Quality seed is a key input for agriculture, with a direct impact on agricultural production and productivity. The Food and Agriculture Organization (FAO) emphasizes that access to quality seeds is a vital element of food security and sustainable development. This holds particular significance for food security crops like tropical tuber crops. The section discusses special features of tuber crop seed materials and various innovative methods available for the production of quality planting material.

FEATURES OF TUBER SEED MATERIAL

- Tuber crops are mostly propagated through vegetative means (via. tuber, root, stem, vine etc.). Hence vulnerable to build up of viruses or other pathogens and ultimately leading to seed degeneration when the same planting material is used repeatedly seed degeneration results in repeated use of the material

- Bulkiness and perishability are limitations during storage and transport and lead to high cost of seed material.

- Low multiplication rate -while in case of grain crops (propagated through true seeds), the rate of multiplication is as high as 1:100 or more whereas in the tuber crops its very low typically 1: 5 to 1: 10

- Usually long crop cycle (about 9 months except for sweet potato) and dormancy or bud development periods in case of elephant foot yams and yams (2-3 months).

- Since, seed material and edible part are same in most of the tubers, there is competition between Ware tuber and

Seed tubers. As a result, often left over material is used as seed.

- Lack of private companies in seed production

- Total dependence on public institutions and their lack of capacity to meet the entire demand.

All these attributes to shortage of quality seed/planting material which in turn has become main bottleneck in expanding production of tuber crops. Hence, various innovative methods available for rapid multiplication of quality planting materials of tuber crops are discussed here.

1. CASSAVA MINISSETT TECHNIQUE

ICAR-CTCRI, Thiruvananthapuram has developed a novel method for quality planting materials production of tuber crops called minisett techniques. Rapid multiplication of planting material by minisett method involves the following steps:

Selection of mother plant: In the minisett technique, first select the mature plant, disease free stems (preferably those obtained from meristem culture), Minisett are prepared from healthy stems. Presence of latex at the cut end of the planting stake is the indication of good quality planting material.

Preparation of minisett: Two nodes was found as optimum size for rapid production of planting material in cassava. Two node cuttings are prepared by cutting the stem using a sharp hack saw blade. In conventional method, top one-third portion is usually discarded,

however in minisett technique, the whole stem is used. When tip cuttings are taken, it is recommended to quickly 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 prepared instead of two as the latter may dry up very fast. During the minisett preparation, sufficient care should be taken such that no damage is caused to the axillary buds.

Planting minisett in nursery bed:

Since the nursery plants raised from minisett ought to be free of any diseases and pests, it is essential to grow them in a protected environment. 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 30 x 7 m dimension with frame with GI Pipe and shade net of 35% percent shade, preferably near water source is ideal. Make raised beds 20 cm height of soil and sand, mixed in the ratio of 1:1. A nursery area of 45 m² is required for producing minisett for planting one hectare of land, or 18 m² of nursery area of planting 1 acre. 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. Minisett 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 5 x 5 cm.

Plate: Cassava minisett technique



Planting miniset in potray: Alternative to field nursery, the miniset could be raised in 50 cavity pottrays filled with potting mixture of soil: cocopeat: sand in 1:1:1 ratio. Raising the miniset in potray has many advantages such as easy to uproot, less damage to root portion, easy to handle and transport to far distances etc.

Nursery management of miniset: The miniset would start 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). Further, if any infected plant is found, it should be immediately uprooted and destroyed. Transplanting miniset to main field: The mini set 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 miniset 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 45 cm between the ridges. Uprooted miniset are then carefully planted on the ridge at spacing 45 cm. About the 50,000 miniset could be transplanted in 1 ha of land.

Management of transplanted miniset: management practices are same as that of general cultivation. It is advised to spray dimethoate (0.05%) at fortnightly intervals as a prophylactic measure against pests like white fly. The miniset crop would mature in about 8-9 months.

2. SWEET POTATO

Sweet potato is propagated by means of vine cuttings. To obtain vines cuttings, a nursery is raised either from stored tuber or from vines of the freshly harvested crop. Vines obtained from nursery are found to be healthy and vigorous resulting in maximum tuber production.

Primary nursery: The nursery is prepared about 3 months before planting in the main field. In order to produce vines for planting one hectare of land, about 100 m² primary nursery area and 100 kg of medium sized (125-150g), weevil free tuber are required. The tubers are planted on slanting position at a spacing of 25 cm apart on ridges formed at a spacing of 60 cm. To ensure quick growth of vines, top dressing with 1.5 kg urea/100 m² at 15 days after planting is recommended. The nursery is irrigated on alternate days for the first 10 days and once in three days thereafter. After 45 days of growth, the vines are cut to a length of 20-30 cm for further multiplication in the secondary nursery.

Secondary nursery: Vines obtained from the primary nursery are further multiplied in the secondary nursery in an area of 500 m² to produce enough vines for planting one hectare of land. About 500 kg farm yard manure (FYM) or compost may be applied at the time of preparation of the nursery. The vines obtained from primary nursery are

planted at a spacing of 20 cm on ridges formed 60 cm apart. To ensure enough vegetative growth 5 kg of urea is applied in two splits at 15th day and 30th days after planting. After 45 days, vines are ready for planting in the main field.

The apical cuttings are found to be the best to secure high yields from sweet potato. A vine length of 20-40 cm with at least 3-5 nodes is found to be optimum for tuber production in different parts of India. The cut vines with intact leaves when stored under shade for two days prior to planting in main field promote better root initiation, early establishment of vines and high tuber yield. The leaves can be removed where the vines are to be transported to distant places to reduce the bulk. To enable rapid multiplication, single node cuttings are planted directly in the secondary nursery bed or pottrays. 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.

3. YAMS

a. Miniset technique

Steps to be followed for miniset propagation of yams is as follows

Selection of planting material

- Tubers should be clean, healthy, conforming to variety characters. In a lot, the tuber not conforming to size should not be more than 5% (by number). Tubers not conforming to variety character should be less than 0.1%

- Cut, bruised, irregular shape, cracked or tubers damaged by insects, slugs,

worms shall not exceed 1%, by weight

- There should not be any visible symptom of infestation by scale insects/nematodes/rotting

Preparation of minisets

- In traditional method, tuber /tuber pieces of 250-300g size is used as planting material with a spacing of 90x90cm where as in miniset method 20g sett size is used

- First, the whole tuber is made into cylindrical pieces of 5 cm thickness. Then, it is radially cut to have 20g pieces ensuring that each piece have a portion of outer skin to enable sprouting

- This may be raised in nursery or in pottrays filled with potting mixture. Pottrays are beneficial in uniform germination as well as easy for handling and transportation. Treating the minisets with biofertilizers during planting was found to improve percent germination and uniformity in plants. In case of pottrays the sprouted minisets could be transplanted easily. But when nursery bed is used for germination, the plants are to be uprooted carefully without damage to roots using khurpi

- Multiplication ratio is 1:40 against 1:6 in conventional method. Further selling as seed tuber fetches more returns compared to ware tuber selling





Whole seed tuber



Preparation of minisett



Various stages of sprouting



Minisett plants ready for field planting

Transplanting of minisett plants:

Transplanting should be done after receipt of rains and ensuring proper moisture content in the soil. After field preparation ridges are to be made 60 cm apart. Closer spacing of 60 x 45cm is sufficient for minisett in which up to 37,000 plants could be accommodated in one hectare which will increase the total yield.

Management of transplanted yam minisett plants:

Immediately after establishment, the vines need to be trailed and it is found that trailing of vines enhances tuber yield by about 20%. To meet the nutritional requirement, apply well rotten FYM @10 t/ha at the time of field preparation. Chemical fertilizers should be applied @100:50:100 kg/ha. Of these, 50% of N and K, full P are

applied as basal dose within a week after establishment (15 days after planting). The remaining N and K must be applied one month after application of basal dose. Weeding and earthing up are to be carried out during manuring. Mean size of harvested tubers from 1 -2 kg with 20 g minisett plants

b. Propagation by vine cutting

Use of vine cuttings ensures rapid multiplication of planting material while sparing edible tubers. Rooted vine cuttings of two node length produced tubers of average 400g size with high multiplication ratio of 1: 500 plants from a single mother plant of 6 months age. Hence, it is evident that use of vine cuttings is a viable option for yam seed tuber production and hence rapid multiplication in vivo.

Rooting of vine cuttings in low tunnel system



Rooted cuttings at 21 DAP



4. ELEPHANT FOOT YAM

Elephant foot yam (*Amorphophallus* sp.), is relatively less amenable to rapid multiplication through conventional methods. However, studies at ICAR-CTCRI revealed that the low multiplication rate could be overcome to a great extent by adopting minisett technique.

MINISSETT METHOD

Selection of seed corm

- In seed lot, tubers not conforming to size should not exceed 5% (by number)
- Clean, healthy and conform to variety characteristics. Those not conforming to character of variety shall not exceed 0.1% for certified seed
- Cut, bruised, irregular, cracked tuber or tubers damaged by insects (other than scale insects) shall not exceed more than 1%
- There should not be any visible

symptom of tuber infested with scale insects/nematodes for use as planting material

Preparation of minisett

- In conventional method 750 g size setts are used for planting whereas in minisett method 100 g size sett is used.
- As the buds are located as a ring around the central portion, care must be taken to ensure a portion of this in each sett while cutting. Otherwise it will not sprout.
- The setts are dipped in cow dung slurry treated with *Trichoderma* and shade dried for 1 day before planting. This treatment is effective against collar rot by *Sclerotium rolfsii* as well as for better sprouting.
- It is recommended to plant the minisett directly to field and provide mulching. At the same time, planting some minisett in nursery bed/bags w

Whole seed corm



Method of preparing minisett



Establishment in field:

EFY minisett is directly planted in field instead of nursery because mortality is more in case of transplanted plants. The field is prepared by through digging or ploughing and pits are taken at a reduced spacing of 60 cm x 45 cm instead of conventional 90 cm x 90 cm. Total population of 37000 plants could be accommodated per hectare instead of 12345 plants under conventional method.

The pits could be of 30 cm deep, and the top soil used to fill the pit after mixing of well rotten and Trichoderma enriched FYM @ 2 kg/pit. The minisett is planted at the centre of the pit with bud portion facing up. A small layer of soil is packed over the minisett and then mulched with dry or green leaves. If minisett are to be transplanted, it should be ensured that sufficient moisture is available in the field till their establishment so as to prevent drying up. If seed crop is raised under irrigation, then planting could be advanced to make seed material available for off season planting.

On sprouting the newly developed roots would start drawing plant nutrients from the soil and not from the mother corm. Basal application of nutrients could be done when 50 percent of the planted minisett sprout. Chemical fertilizers @ 100:50:100 kg/ha NPK is recommended for the crop. N and K applied in two splits and P in single dose along with weeding and earthing up. If collar rot is prevalent in the area, it is advised to drench the soil at the base of plants with Bavistin @ 4g per litre. Size of harvested corm range between 600

g to 1.5 kg per plant and average yield expected is 40-50 t per ha. These could be further multiplied as minisett or used for commercial planting material production. Rate of multiplication is 1:15 in minisett method against 1:4 in normal method.

5. TARO AND TANNIA

Though cormels as well as mother corms could be used as planting materials, cormels are found to be ideal. In taro, cormels weighing 20-25 g are used as planting material, where as in tannia, cormels of 60g size is used. The cormels are directly planted in field provided sufficient moisture is ensured. Nursery raising is required especially when the rain fall is scarce and field moisture is not sufficient for direct sown cormels to sprout.

The storage life /viability of taro is too low and it less than a fortnight whereas tannia can be stored up to one month. Taro and tannia have inherently high multiplication ratio as compared to yams and EFY, ie., 1:20 and 1:10 respectively.

Taro exhibits a very short storage life and viability, typically less than two weeks, whereas tannia can be stored for up to one month. Both taro and tannia possess inherently higher multiplication ratios compared to yams and elephant foot yam, with ratios of approximately 1:20 and 1:10, respectively.

Minisett method

Studies at ICAR-CTCRI revealed that, the multiplication ratio could be considerably increased by adopting minisett technique. The cormel is

cut into cylindrical pieces and then diagonally into minisett of about 10g and 15 g for taro and tannia respectively. The minisett could be raised in nursery or in portrays. If minisett are raised in nursery, they could be transplanted in a month's time to the prepared main field. In this way requirement of cormels for planting material could be reduced and a higher proportion is available for marketing or consumption.



Plate: Steps in preparation of minisett in taro/tannia

Field management:

The soil has to be thoroughly ploughed and brought to a fine tilth. The minisett are then directly planted in the main field in mounds formed over pits or on raised ridges at a spacing of 45x30 cm for taro and 45x45 cm for tannia. Application of FYM @ 12 t/ha prior

to planting and fertilizers as NPK @ 80:25:100 kg/ha is found sufficient. N and K should be applied in two equal splits along with the intercultural operations, the first soon after sprouting and the second one month later. Mulching is very important and essential to get higher cormel yield.

By adopting minisett technique, the multiplication ratio could be enhanced to 1:120 in taro and to 1:80 in tannia.

Table 1: Comparison of conventional method and minisett technique in production of planting materials of tuber crops

Particulars	Cassava		Elephant foot yam Y		am	
	Conventional	M inisett method	Conventional	M inisett method	Conventional	M inisett method
Planting material	20 cm long sett	Stem sett with 2 bud	500-750 g size corm/corm piece	Corm piece of 100g size	Tuber piece of 250-300g	Tuber piece of 20g size
Plant density/ Spacing	12345/ 90x90	37000/ 60x45	12345/ 90x90cm	37000/ 60x45cm	12345/ 90x90cm	37000/ 60x45cm
Rate of multiplication	1:6	1:60	1:4	1:15	1:4	1:50

Protected Cultivation for Clean Seed Production

Protected cultivation could be successfully employed for rapid multiplication of clean seed material in tuber crops. In sweet potato, planting material free of sweet potato weevil and virus diseases could be multiplied at a faster rate of 10 times in protected cultivation compared to open field cultivation. Successful cormel production in *Colocasia* grown under NFT hydroponics system was achieved by 90 days. Further, direct

microtuber formation in hydroponics system and enhanced growth of taro (*Colocasia esculenta*) was found during acclimatization of in vitro plant lets. The survival rate, plant height, number of leaves and microtuber were high in soilless system than in conventional soil media. The superior performance was continued in field also.

In yams, rooting of vine cuttings of yam (*Dioscorea alata* and *D. rotundata*) was achieved within two weeks in aeroponic culture. Minituber upto 110 g could be harvested in 10 months.

Seed yam production through drip system hydroponics (DSH) in the inert substrate media.

In vitro cassava plants adapted in green house for 6 days and treated with fungicide and transferred to hydroponic system resulted in high survival rate



Plate: Protected cultivation of sweet potato and yams in soilless system

Micro Propagation/Tissue Culture

Despite the technical sophistication and specialized skills required, micropropagation remains a highly effective method for the rapid multiplication of disease-free planting material in vegetatively propagated crops, including tuber crops. Tuber crops for which micropropagation protocols are developed are described below.

Taro: In vitro propagation method for mass and rapid production of dasheen

taro plantlets through direct somatic embryogenesis and organogenesis using axillary meristem explants. Microcorm induction technique were used for the rapid propagation of taro plants. Large scale production of microcorms of taro could be achieved using thin layer culture.

Cassava: Rapid multiplication of planting material in cassava through tissue culture techniques using apical node as explant was developed. Potential number of planting material production from one nodal explant using micropropagation techniques was estimated to be ranging from 16,000 to

17,000 in one year period.

Elephant foot yam: Plants which are directly raised from apical and axillary buds produced 50-300 mg tubers in field. Successful in vitro seed germination was achieved in MS medium without any plant hormones.

Yams: A simple, reproducible and efficient micropropagation protocol was developed for greater yam (*Dioscorea alata* L.) using nodal segments for axillary shoot proliferation

Sweet potato: An efficient and reproducible plant regeneration protocol for sweet potato (*Ipomoea batatas* L.) was developed.

Plate: Elephant foot yam micropropagation



Key biotic stresses affecting tuber crops



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CASSAVA DISEASES CASSAVA MOSAIC DISEASE

Cassava mosaic disease (CMD) is one of the most serious problems faced by cassava farmers. It can cause up to 88% yield loss. The disease is caused by two viruses, Indian cassava mosaic virus (ICMV) and Sri Lankan cassava mosaic virus (SLCMV). Of these, SLCMV is more common in India and causes severe damage. The disease spreads mainly through infected stem cuttings used for planting, and later it is carried from plant to plant by the tiny insect whitefly (*Bemisia tabaci*).

SYMPTOMS

Leaves show pale green or yellow patches (mosaic pattern), the affected leaves become smaller, twisted, and deformed, sometimes looking like shoe-strings. In severely affected plants, growth becomes stunted and bushy, with very poor yield.

Green or yellow patches due to CMD



MANAGEMENT

a. Grow resistant varieties like Sree Reksha, Sree Suvarna, Sree Kaveri, and Sree Sakthi, which can tolerate the disease better

b. Select healthy cuttings for planting, always taken from disease-free fields

c. Remove and destroy affected plants from the field to prevent the virus from spreading

d. Control whiteflies by spraying imidacloprid (17.8 SL @ 0.3 ml per litre of water) or thiamethoxam (25 WG @ 0.3–0.4 g per litre of water) once in 14 days.

Cassava Tuber Rot

Cassava tuber rot is a major challenge.

In many fields, it reduces yield by about half, and in places with heavy rains and poor drainage, farmers may even lose the entire crop. The disease is caused by a fungus called *Phytophthora palmivora*. This fungus lives in infected tubers and soil, and under waterlogged conditions it produces large numbers of spores that attack the cassava roots.

Symptoms

The disease first starts as dark, water-soaked spots on mature tuber. Soon, white fungal growth can be seen on these spots. As the infection spreads, the tuber turns brown inside, becomes soft, oozes liquid, and starts to rot. Within 5–7 days, the roots may completely decay and give out a bad smell. The leaves and stems usually look normal, so the problem is noticed only when the tubers are dug up.



Tuber rot due to *Phytophthora*

MANAGEMENT

a. Farmers can reduce the damage from tuber rot by following these practices

b. Rotate cassava with crops that are not affected by this fungus

c. Plough the field deeply (about 20 inches) using a chisel plough to improve drainage

d. Plant cassava on ridges so that tubers

are not exposed to standing water

e. Apply neem cake at 250 kg per hectare to improve soil health and encourage helpful microbes that fight the fungus.

Cassava Brown Leaf Spot

Brown leaf spot is a common fungal

disease of cassava in high-rainfall areas. It causes early leaf fall and can reduce

tuber yield by up to 30% in susceptible varieties like Malayan-4 (M-4). The disease is most often seen in crops that

are older than five months. It is caused by the fungus *Cercospora henningsii*, which spreads easily in warm and humid weather. Rain splash helps the fungus move from one plant to another, and it survives on fallen leaves and old lesions during the dry season.

Symptoms

The disease first shows up as small brown spots with dark edges on both sides of the leaves. The centres of the spots turn grey because of fungal fruiting bodies. As infection advances,

the spots increase in size, become irregular in shape, and often develop a yellow halo. Later, the affected leaves turn yellow, dry up, and fall off from the plant.



Brown spot symptoms in cassava

MANAGEMENT

- a. Maintain wider spacing between plants to reduce humidity inside the field and thereby minimize the disease
- b. Adjust the time of planting so that the crop is not older than five months during the rainy season, when the disease is most severe
- c. Grow resistant varieties such as Sree Prakash and Sree Visakham

- d. Apply copper oxychloride at 0.15% (1.5 g per litre of water) to suppress the fungus

Cassava stem and root rot

Cassava stem and root rot is caused in cassava which is planted in wet land of Kerala and cause upto 100% incidence. Cassava is affected by the disease at any stages of crop growth from planting to harvest. The causal organisms of this disease are *Fusarium* spp. and *Colletotrichum* sp. The pathogen is present in the soil and infects the collar

region, and further spreads to stem and root.

Symptoms

The setts near the collar area first degrade after planting before rooting. The mature plants display yellowing and drooping of their old leaves, rotting of stem in collar region and tuber, and finally wilting of the plant. The rotten stem close to the soil turns dark and displays white fungus mat.



Wilt, stem and root rot in cassava

MANAGEMENT

- a. Remove and burn highly infected plants
- b. Avoid water stagnation and maintenance of good drainage in the field
- c. Use healthy setts collected from disease free areas
- d. Crop rotation with non host crops once in two years
- e. Apply lime @ 150-250 g/plant 10-15 days before planting, where pH of the soil is 4-5 and apply neem cake @ 20g/plant and *Trichoderma asperellum* enriched FYM @ 1kg/plant

- f. Sett treatment with solution of carbendazim (0.05% treating for 10 min).

- g. Drenching with the same fungicide starting from planting-three times at 15 days intervals

Anthracnose disease

Anthracnose is a common disease found in most cassava-growing regions. Under favourable conditions, it can cause yield losses of up to 30 percent in susceptible varieties. The disease attacks both leaves and stems, reducing plant growth and also the availability of healthy stem cuttings for the next season. It is caused by the fungus *Colletotrichum gloeosporioides* f.sp. *manihotis*. The

problem usually begins with the onset of rains and becomes more severe as the wet season continues. The fungus spreads either by wind or through planting stem cuttings taken from infected plants. Dead stems and fallen leaves carrying the fungus also act as a source of infection if they are not removed from the field.

Symptoms

The disease produces cankers on stems, spots on leaves, drying of leaves, tip dieback, wilting, and in severe cases complete shoot death. When new twigs sprout from the buds below the diseased area, the plant shows a bunchy top appearance.

Cankers on stems due to anthracnose

MANAGEMENT

a. Use stem cuttings from the plants noting show cankers or disease symptoms for planting

b. After harvest, remove and destroy infected crop residues from the field to reduce the source of infection

c. Spray carbendazim at 0.05% three times at 15-day intervals, starting as soon as the first symptoms are observed.

PESTS

1. Mealybugs

Mealybugs cause considerable yield loss in cassava. There are three major types of mealybugs found infesting cassava in India. They are Papaya mealybug, *Paracoccus marginatus*, two-tailed mealybug, *Ferrisia virgata* and cassava mealybug, *Phenacoccus manihoti*.

a. Papaya mealybug, *Paracoccus marginatus* Williams and Granara de Willink

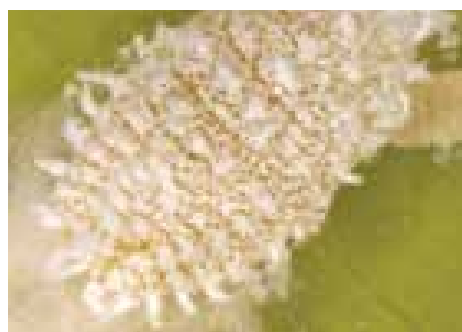
A native of Central America/ Mexico, it infests more than 60 species of plants spread over 50 countries. In India, it was first reported from Tamil Nadu in 2008, infesting papaya, cassava and a wide list of agricultural and horticultural crops. In the cassava growing area, particularly in Tamil Nadu and Andhra Pradesh, management of this pest by chemical measures poses a challenge; however, its menace could successfully be managed by releasing the parasitoid *Acerophagus papaya* which was imported by ICAR-NBAIR, Bengaluru, from Puerto Rico.

b. Striped mealybug, *Ferrisia virgata* Cockerell

One of the most highly polyphagous mealybugs known, attacking plant species belonging to some 203 genera in 77 families, preferably on the host species belongs to the families, Fabaceae and Euphorbiaceae. The striped mealybug has also achieved economic significance as a pest of several agricultural crops, including cassava.

c. **Cassava mealybug, *Phenacoccus manihoti* Matile-Ferrero** Recognized as the most noxious pests of cassava in the world. It was first reported in Asia from Thailand in the year 2008, since then there has ever been an aggressive spread of this pest throughout Thailand's cassava-growing region and adjoining countries. Several non-preferred host species support *P. manihoti* reproduction, but only cassava is known to experience significant damage by this insect. In India the pest was first reported by ICAR-NBAIR in May, 2020 from Thrissur, Kerala and subsequently from Salem, Tamil Nadu.

Mealybugs are white and soft bodied insects, and are covered with mealy or waxy secretions. Mealybug affects all the aerial parts of the cassava plant and while sucking the sap, they inject a toxic substance into the feeding point, causing the deformation of terminal shoots, reduction of internodal length, stunted growth and subsequently the development of 'bunchy tops'. Honey dew excretion and the associated black sooty mold formation impair photosynthetic efficiency of the affected plants that often leads to heavy yield loss to a tune of 60-80 per cent.



Papaya mealybug



Two-tailed mealybug



Cassava mealybug

MANAGEMENT PRACTICES

a. Cultural and Mechanical methods

It includes strategies like, monitoring and scouting to detect the infestation, pruning and burning of infested branches, removal of weeds/alternate host plants from in and around cassava fields, avoiding the use of planting materials from infested cassava

fields, destruction of ant colonies to prevent the spread of mealybugs and maintenance of field hygiene and sanitization of farm equipment.

b. Biological method

Conservation of natural enemies like hymenopteran parasitoid, *Acerophagus papayae*, *Apoanagyrus lopezi* and lady

beetle predators like *Cryptolaemus montrouzieri*, *Scymnus* sp. etc., lacewings and hover flies.

c. Biopesticides/Chemical methods

Soak cassava setts in Dimethoate 30 EC @ 1% for one hour before planting and after the onset of infestation, spray neem oil-soap solution (7:3) @ 1 to

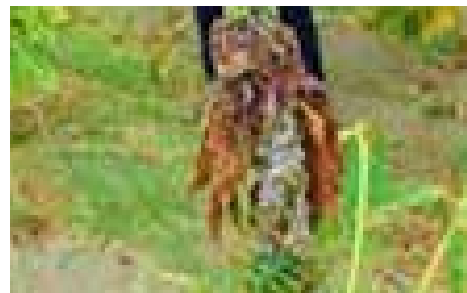
1.5% twice at weekly intervals or Fish Oil Rosin Soap @ 25g/litre of water. Among chemical insecticides, spray either Thiamethoxam 25 WG @ 0.6 g/litre or Imidacloprid 17.8 SL @ 0.6 ml/liter to cover lower surface of the leaves/ infested portions of the plants. Drenching of Chlorpyrifos 20 EC @ 2 ml/litre may be done for the destruction of ant colonies-which are notorious for the insect spread.

2. MITES

Mites cause considerable yield loss in cassava. Attacks are usually seen in dry weather. These are the most destructive pests that attack cassava leaves. Infestation starts from mature

lower leaves. There are two types of eight-legged mites that occur in the underside and the top of leaves. Attacks by *Tetranychus cinnabarinus* and *Tetranychus neocaledonicus*, in the underside of the leaves, can cause the leaves to appear discolored, weak, and dry and fall off. *Eutetranychus orientalis* and *Oligonychus biharensis* attack the upper part of the leaves. As a result of their bout, the leaves lose their green color, get rusted and look like leather and gradually curl up and dry. Webbing also often seen in the shoots. Spider mite prefers the hot, dry weather of the summer and fall months, but can occur year-round

Symptoms of mealybug damage in cassava



Mite

◀ infestation in cassava

MANAGEMENT STRATEGIES

a. Cultural and mechanical methods: monitoring and scouting to detect the infestation, pruning and burning of infested branches, removal of weeds/ alternate host plants from in and around cassava fields, avoid the use of planting materials from infested cassava fields, maintenance of field hygiene and sanitization of farm equipment, fallowing of land and crop rotation and spray heavily with water at the beginning of the infestation, followed by a 1% magnesium sulfate spray on the leaves.

b. Biopesticides/chemical methods: spray ICAR-CTCRI developed biopesticide Nanma @ 1 % two times at five days interval or Neem oil @1 to 1.5 % mixed with soap solution 0.5 % in five days interval

c. Spray any of the entomopathogenic fungi *Hirsutella* or *Lecanicillium* at the rate of 20 grams per liter of water (minimum 108 cfu)

d. During heavy attack, spray entire field with spiromesifen 22.9 SC @ one ml/liter of water

SWEET POTATO

Diseases

Sweet Potato Feathery Mottle Disease

Feathery mottle is one of the most serious virus diseases of sweet potato in India. When this virus occurs together with other sweet potato viruses, yield losses can reach 50–80 percent. The disease is caused by the Sweet potato feathery mottle virus (SPFMV). The

virus spreads mainly through infected planting material such as tubers and vine cuttings, while aphids act as the main insect carriers that transmit the disease from plant to plant.

Symptoms

The disease shows different types of symptoms depending on the variety. Common signs include pinkish ring spots with a green or yellow centre, feather-like streaks, small yellow specks, mosaic patterns, and leaf puckering. These symptoms are seen more clearly in broad-leaved varieties, especially during the active growth stage of 45–60 days. They are usually more noticeable on the lower leaves of the plant.



Ring spots due to SPFMV

MANAGEMENT

- a. Always plant vine cuttings that are free from disease
- b. Choose resistant varieties such as Sree Nandini and Sree Vardhini
- c. Use vine cuttings produced through meristem culture to ensure they are virus-free
- d. Remove and destroy infected plants in

the field and maintain strict sanitation practices.

PESTS

1. Sweetpotato weevil (*Cylas formicarius Fabricius*)

Sweet potato weevil is often considered to be the most serious pest of sweet potato, with reports of losses ranging from five to 97% in areas where the weevil occurs.

Symptoms include thickening and malformation of vines and often cracking of the tissue, discoloration, cracking, or wilting of damaged vines, an infested tuber is often riddled with cavities or tunnels, attacked tubers become spongy, brownish to blackish in appearance start rotting from the top and develop an unpleasant smell and a bitter taste unfit for human consumption.

MANAGEMENT STRATEGIES

- a. Before planting, vines should be treated/ dipped in 0.2% chlorpyrifos for 10 minutes insecticides for effective management of the pest at early stage, the weevil can be better managed when is rotated with rice, yam, cowpea, maize and ginger and also inter-cropping with rice and cowpea was found effective
- b. Mulching (straw or plastic), planting on ridges with sufficient irrigation (at 10 days interval) can also decrease the pest damage
- c. Earthing up of soil around the base of the sweet potato at 30 and 60 days after planting which prevents the entry of the weevils by reduced chance of cracks and crevices in the soil.

d. Destroy the crop residues after the harvest by flooding on the field, which results in the rotting of left-over residues and kills the larvae and adult weevils, which are the carry over population to the next season

e. The trap with synthetic pheromone lure together with ethyl acetate is usually placed at ground level to facilitate the entrance of adult weevils. Traps have to be installed at one trap per 100 sq. m for mass trapping of males. Trap the weevil by placing cut tubers (100 g) from 50-80 DAP at 10 days interval and the trapped weevils should be destroyed.

f. Timely harvesting at 105-110 days after planting reduces the infestation.

g. At fortnightly intervals, drench the

collar portion of the plant (part close to the soil) thoroughly and spray with Imidacloprid 17.8 SL @1 mL per litre, after one month of planting.

2. Sweet potato vine borer

Vine borer, *Omphisa anastomosalis* is a serious emerging pest of sweet potato, which found to reduce the crop yield substantially for the past few years in several parts of India. As a result of the attack by larvae in collar region of the vines, bore holes become visible and they form tunnels inside the vines. Severe attack causes withering and killing of the plants.



Fig. 7. Vine borer larva

MANAGEMENT PRACTICES

Before planting, vines should be treated/ dipped in 0.2% chlorpyrifos for 10 minutes insecticides for effective management of the pest at early stage.

a. Crop rotation/ inter or mixed cropping: The vine borer can be better managed when is rotated with crops like rice, yam, cowpea, maize, ginger etc.

b. Sanitation: The crop residues harbouring the pest is the reason for higher infestation in next season. Hence, the crop be destroyed after the harvest by flooding on the field, which results in the rotting of left-over residues and kills the larvae and adult insects, which are the carry over population to the next season

c. Entomopathogenic organisms: Entomopathogenic fungus, *Metarhizium anisopliae* and *Beauveria bassiana* found effective against vine borer.

d. Insecticide spray: At fortnightly intervals, drench the collar portion of the plant (part close to the soil) thoroughly and spray with Imidacloprid 17.8 SL @0.5-1 mL per litre, after one month of planting.

3. Sweet potato leaf miner

Sweet potato leaves found heavily infested by a new emerging pest, *Bedellia somnulentella* (Leaf miner). They attack sweet potato leaves in between upper and lower leaf surfaces, eat away leaf tissues, leaves become transparent and cause on an average 30 % leaf damage.

As leaf miners can become a potential pest in later crop stages, it is important to manage them early. Since pupation of the pest is in soil, clean cultivation and weeding are important. Ploughing the field and raking of soil around the vines can kill the pupae. Mulching using plastic sheet is an effective management strategy against the pest. Also, application of spinosad 45% SC @0.3 ml/L at fortnightly intervals found to be very effective in its control.



Sweet potato leaf miner adult



Leaf miner attack in leaves

GREATER YAM

Diseases

1. ANTHRACNOSE

Anthracnose is a major disease of greater yam (*Dioscorea alata*) which can cause 30–60% yield loss. The problem becomes worse during long rainy periods because the fungus spreads through splashing rainwater. Young leaves are more vulnerable to infection. The disease is caused by the fungus *Colletotrichum gloeosporioides*. The fungus does not live in the soil for long but survives on infected crop residues

and also infects other crops and weeds, which act as a source of infection. Wet and humid weather favours its spread and multiplication.

Symptoms

The disease shows different symptoms depending on the variety and growing area. It usually begins as small dark brown to black spots on leaves, petioles, and vines. These spots may be surrounded by a yellow halo and can grow larger or join together, leading to drying and death of leaves. Infected leaves often curl upward (cupping) due

to damage on the lower surface, which restricts leaf growth. As the disease worsens, leaves dry up, vines die back, and the whole plant looks scorched. For this reason, it is sometimes called “scorch disease” of yam.



Leaf spot and die back due to greater yam anthracnose

MANAGEMENT

a. Remove all crop residues from the field after harvest, as they act as a source of the fungus.

b. Carry out summer ploughing to expose fungal bodies in the soil to the sun and destroy them.

c. Use only healthy, disease-free planting material for new crops.

d. Treat the soil with *Trichoderma* (50 g of 10^7 cfu/g formulation per plant) and dip seed tubers in a slurry made with 5 g *Trichoderma* mixed in fresh cow dung per kg of tuber.

e. Spray carbendazim at 0.05% on foliage about 7 times during crop growth. After symptoms appear, apply carbendazim at 0.1% three times at 15-day intervals, followed by four sprays at monthly intervals.

2. LEAF SPOT

Leaf spot is a common disease of greater yam and occurs in almost all yam-

growing regions of the world. All species of greater yam can get this disease. It is caused by several fungi belonging to the genus *Cercospora*, with *Cercospora contraria* being the most common one. The disease develops mostly in warm and wet weather. Although the spots look severe at later stages of crop growth, the effect on yield is negligible.

Symptoms

Initially the disease shows up as light yellow (chlorotic) spots on the leaves. Later, these spots turn into dark brown to black patches with clear margins. The fungus produces spores on both sides of infected leaves, which spread to nearby plants mainly through rain splash. The fungus can also survive on old crop debris in the field.

MANAGEMENT

a. Spray copper oxychloride at 0.15% (1.5 g per litre of water) to manage the disease.

b. Remove and destroy infected crop residues after harvest to reduce the source of infection.



light yellow and dark spots due to *Cercospora*



ELEPHANT FOOT YAM

Diseases

1. Collar Rot

Collar rot is the most serious and widespread disease of elephant foot yam. It can attack the crop at any stage of growth and is a major cause of yield loss. The same fungus can also damage stored corms after harvest when conditions are favourable. The disease is caused by the fungus *Sclerotium rolfsii*. The fungus survives on corms in the form of small round bodies called sclerotia and also through live fungal threads. It grows well in warm, wet,

and humid conditions, with the best temperature for its spread being 27–30°C. Poor drainage, injuries caused during field operations, and insect attack make the crop more prone to this disease.

Symptoms

The fungus attacks the collar region of the plant, just above the soil line, and produces water-soaked patches on the pseudostem. The tips of the leaves first turn yellow, and this yellowing gradually spreads until the whole leaf becomes dry. As the infection progresses, the pseudostem rots and shrinks, and

the entire plant may collapse. Under favourable conditions, the disease can cause sudden death of plants. The white fungal mycelium and mustard like sclerotia could be seen



Mycelium and sclerotia due to collar rot

MANAGEMENT

a. Always use healthy, disease-free corms for planting and remove infected plants from the field

b. Improve drainage and plough the field deeply to destroy or bury the fungus in the soil

c. Rotate with non-host crops and mulch the plants with paddy straw or other organic material to reduce disease spread

d. Before planting, treat corms (3 days in advance) with a fungicide mix of mancozeb (2 g per litre of water) + carbendazim (1 g per litre)

e. After intercultural operations, drench the soil around plants with the same fungicide mixture to protect them

f. Remove diseased plants carefully and drench the nearby healthy plants with fungicide to stop spread

g. Treat seed corms with Trichoderma by dipping them in a slurry made of cow

dung mixed with 5 g of Trichoderma per kg of corm

h. Apply Trichoderma-enriched farmyard manure (FYM) at 5 g per kg of corm three days before planting, place 2.0–2.5 kg FYM in each pit at planting time, and apply 150 g around the collar region of plants immediately after intercultural operations

2. POST-HARVEST ROT

Elephant foot yam corms get easily spoiled after harvest because they contain a lot of water and starch. These rots not only damage seed corms but also reduce sprouting and later cause field problems when planted. Wounds during harvest, nematode attack, high moisture in corms, and infections that start in the field but remain hidden are the main reasons for post-harvest rot. Many fungi and even a bacterium can cause this problem. The major ones are *Sclerotium rolfsii*, *Lasiodiplodia theobromae*, *Fusarium* species, *Colletotrichum gloeosporioides*, and *Erwinia carotovora*. Often, pathogens that infect plants in the field continue

to spread on corms during storage if conditions are favourable.

Symptoms

The affected corms become soft, rotten, and discoloured. At first, small rotten patches may appear on the surface and later spread inside, turning the flesh brown to black. These small patches often join together to form large irregular rotted areas. In some cases, the inner part of the corm also decays and becomes dark brown or black. Sometimes a brown or chocolate-coloured liquid oozes from the lesions, and in severe cases, a white fungal growth is seen on the rotten portions.



Rotten patches in elephant foot yam tuber

MANAGEMENT

a. Handle corms carefully during harvest, transport, and storage to avoid injuries

b. Remove infected portions of corms before storage and keep them in a well-ventilated place

c. Dip corms in a fungicide mix of mancozeb + carbendazim (0.2%) for 10 minutes, then shade-dry for 2–3 days before storing in a ventilated area

d. Treat corms with Trichoderma mixed in cow dung slurry (5 g per kg of corm) or dip in Nanma (ICAR-CTCRI bio-formulation, 0.7%) for 10 minutes, then shade-dry for 2–3 days before storage

3. MOSAIC DISEASE

Mosaic disease is found in all major elephant foot yam growing areas and can reduce the yield by up to 38%. The

affected plants show many types of leaf changes. The leaves may have light and dark green patches (mottling or mosaic), become wrinkled or curled, look cup-shaped, or turn narrow and thin like a shoe string. Sometimes the leaves also become thick and distorted. These symptoms are usually seen clearly on young leaves.

This disease is caused by Dasheen mosaic virus (DsMV), which belongs to the Potyvirus group. The virus mainly spreads through infected planting material. In the field, it is also carried from one plant to another by small sucking insects like aphids (*Myzus persicae* and *Aphis gossypii*).

MANAGEMENT

a. Always use healthy and disease-free planting material

b. Plant vines or corms produced through meristem tip culture to ensure virus-free plants

c. Remove and destroy infected leaves and also self-grown yam or taro plants that may act as sources of infection

d. To control the insect carriers (aphids), spray imidacloprid 17.8 SL @ 0.3 ml/litre or thiamethoxam 25 WG @ 0.3–0.4 g/litre once every 14 days



Light and dark green patches due to DsMV

PESTS

1. AMORPHOPHALLUS

DEFOLIATOR

For the last 2–3 years, amorphophallus shoots found attacked by the chrysomelid beetle, *Sphenoraia hopei* in many parts of Kerala, India. They feed on the shoots and also found bore in them. If attack is severe the whole plant will be dried off. The pest can reduce the crop yield substantially in

the future, and can become a headache for farmers.

Like other pests, weeding and clean cultivation are important in its management. Study shows that, spraying and drenching of quinalphos 25% EC @ 2 ml/Litre can control the pest.

Shoot attack by
Amorphophallus defoliator



Chrysomelid beetle



2. WIREWORMS

In the last few years, wire worms/ click beetles found attacking amorphophallus cultivation by boring in to collar region and tubers. It can drastically reduce crop yield and also market value. Ploughing the field before planting and adequate irrigation can provide the desired effect against the pest. In the

field where the wireworms once came, further pest attack can be prevented by flooding the field for one week before planting. Drenching with Fipronil 5% @ 1.5 ml/Litre or Chlorpyrifos 20% EC @ 2 ml/litre can manage the pest.

Attack by wireworms in amorphophallus ▶



3. NEMATODES

Root knot nematode, *Meloidogyne* spp. and lesion nematode, *Pratylenchus* spp. are the two most devastating nematodes and cause economic damage on elephant foot yam.

Because of their endoparasitic nature, they cause severe root damage. The aerial symptoms of nematode damage are generally not apparent. Most of the nematode damage in tubers is noticed only after harvesting. *Meloidogyne* spp. produces typical galls on the roots. In corms and cormels, infestation leads to irregular projections. Under severe infestation, the tuber tissue gets discoloured and in corms the infested area dries up. The root knot nematode

multiplies in the tuber after harvest during transport and in storage, causing more economic damage. Infestation by lesion nematode change tuber colour to black with cracks on the surface.

For the management of nematodes, if possible, field can be kept as fallow for some time. Deep summer ploughing during hot summer months is very effective against the pest. Other strategies can be follow crop rotation, change the place of cultivation, grow trap crop Sree Bhadra (Sweet potato) or marigold in the field, incorporation of cassava leaves in soil, apply farm yard manure (20-25 tonne/ hectare) & neem cake enriched with *Trichoderma* (one tonne/ hectare).



Nematode attack in amorphophallus

TARO

Diseases

LEAF BLIGHT OF TARO

It is caused by *Phytophthora colocasiae* is the most destructive disease of taro causing 25- 50 percent yield loss . This disease is common in areas with high humidity and frequent rain, but less in warm, dry regions. The fungus spreads through sporangia, which are carried by rain splash, wind, or washed into the soil to infect corms. Continuous wet weather for 3 days helps the disease spread fast, sometimes affecting the whole field. Leftover corms in the soil and infected planting materials also act as sources of infection, so using

tolerant varieties is important. Taro leaf blight is more common in areas with high humidity and frequent rainfall, while it is less severe in warmer places with less rain. The fungus spreads through sporangia, which are carried by rain splash and wind, and can infect leaves, stalks, and corms. When weather conditions are wet and humid for 2-3 days, the disease spreads very fast and can damage the entire field. Infected planting material, corm pieces, or plant parts left in the field after harvest also help the disease spread to new crops and even long distances

SYMPTOMS

The disease starts as small, water-soaked, light brown spots on the leaves. These spots quickly enlarge, join together, and can destroy the whole leaf. In some varieties, the centre of the spots dries up, becomes papery, breaks, and looks like a 'shot hole'. Under humid conditions, a white ring of fungus can be seen around the spots, while in tolerant varieties the spots remain small with a yellow border. In severe cases, spots also appear on the leaf stalks (petioles), from where brown gum-like fluid oozes out, and this can cause the plant to collapse. The corms of infected plants turn brown, firm, and start rotting quickly after harvest

MANAGEMENT

IDM

- a. Use tolerant varieties like Muktakeshi, Bhu Sree, and Bhu Kripa
- b. Always plant disease-free cormels
- c. Remove and destroy infected leaves and plant parts from the field
- d. Follow crop rotation or intercrop with non-host crops like bhindi
- e. Apply mulch (paddy straw or any other material) to reduce disease spread
- f. Adjust planting time so that the most

sensitive growth stage does not coincide with peak disease-favourable weather

- g. Spray one of the following chemicals (start 45 days after planting and repeat every 15 days if disease appears)

- h. Metalaxyl + Mancozeb @ 0.1% / Mancozeb @ 0.2% / Potassium phosphonate @ 3 ml/l

Organic management options

- a. Use resistant varieties and follow the cultural practices above

- b. Treat cormels with 10% vermiwash before planting, apply 100 g vermicompost per plant, and spray or drench with 10% vermiwash before monsoon and at 15-day intervals during rainy season.

- c. Treat cormels with *Trichoderma* enriched cowdung slurry (5 g *Trichoderma*/kg cormel). Apply *Trichoderma* enriched vermicompost @ 100 g/plant at planting and again during intercultural operations.

Value Addition in Tuber Crops: Pathways for Entrepreneurial Development

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Tropical tuber crops viz., cassava, sweet potato, yams, aroids, arrowroot, coleus, yam bean etc., are used as staple or supplementary food in many of the tropical and sub tropical countries. 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 systems. 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 these problems, processing, value addition and product diversification of the tubers in the production catchment itself is recommended, enabling the promotion of micro, small and medium agro based industries besides ensuring food security.



SNACK FOODS

Fried chips with light yellow crispy texture can be made from cassava, sweet potato, yams, taro and Amorphophallus tubers by suitable pretreatment with acetic acid/citric acid/potassium metabisulphite solution and deep frying in oil. Variety of snack foods having good texture and taste can be prepared from tuber based composite flour containing maida, bengal gram flour, rice flour and spices and condiments by cold extrusion using hand extruder or snack food making machine with suitable dies into hot oil. The ready to eat fried snack foods include cassava pakkavada, sweet fries, nutrichips, crisps, salty dimons, hot sticks, salty fries, sweet dimon, murukku etc. Vacuum fried chips were developed from orange and purple-fleshed sweet potato tubers with less oil content and high retention of carotenoids / anthocyanins.



BAKERY PRODUCTS

Protein and fiber enriched gluten free functional cookies from orange and purple fleshed sweet potato were developed using whey protein concentrate, fructo-oligosaccharide, maltodextrin and sucralose. The bread made from orange fleshed sweet potato

with whey protein concentrate and psyllium husk has 17.72% protein. Taro flour based gluten free cookies were produced with rice flour, sorghum flour and cassava flour. Protein rich sweet potato based muffins with 7.5% protein and 2.5% crude fiber was developed using sweet potato flour, whey protein concentrate and wheat

flour. The beta-carotene rich cake made from orange fleshed sweet potato flour and refined wheat flour is an excellent source of beta-carotene and it fulfils the RDA of children and adolescent. The anthocyanin rich cake made from purple fleshed sweet potato flour and refined wheat flour is a good source of antioxidants containing about 39 mg/100g anthocyanin. The sweet potato based protein enriched nutri bar containing sweet potato, sweeteners (honey and jaggery), along with oats, puffed rice, Bengal gram, dhal and nuts was found to be the best combination..



PROTEIN AND FIBRE ENRICHED FUNCTIONAL FOODS

Pasta as a food rich in complex carbohydrates with low glycaemic index is gaining wide acceptance in the recent years. ICAR-CTCRI developed an array of pasta products from tuber based composite flours with high functional value coupled with low starch digestibility. Technology for making

protein rich pasta from the tuber based composite through fortification with protein sources like whey protein concentrate, defatted soy flour and fish powder was standardized at ICAR-CTCRI. They have excellent cooking quality and high protein content (10-15%). Tuber flour based pasta rich in dietary fiber was made at ICAR-CTCRI using dietary fiber sources like oat bran, wheat bran, and rice bran, with the objective of enhancing the functional value as a prophylactic/therapeutic diet. The slow digestibility of the fiber enriched sweet potato pasta coupled with the high level of



residual undigested starch make these pastas ideal foods for diabetic and obese people. Addition of edible gums at 1% level in cassava-maida pasta have slow and progressive starch digestibility with a high retention of resistant starch after the digestion. Low glycaemic spaghetti could be developed by fortification of sweet potato flour with banana and legume starches as well as sweet potato starch; sweet potato: maida flour blended with commercial (edible) gum; sweet potato with black gram (urad dhal), chickpea (basan) and green gram (mung bean) and also using the resistant starch source, NUTRIOSE.



Gluten-free pasta from sweet potato flour-rice flour blends were developed along with additives such as whey protein concentrate and guar gum.



‘READY TO EAT’ 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. Several cereal based extruded products are available commercially. But tuber crop based extruded snack product is 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.

“READY TO USE” FOOD MIXES

The ready to use paratha mix was prepared from sweet potato flour-50%, millet flour-15%, multigrain flour-30% and dried spices-5%. Ready to use sweet potato laddu mix made from purple fleshed sweet potato flour (50%) +Bengal gram flour (50%) + sugar (20%) with addition of cardamom is a good source of anthocyanin. The ready to use weaning food mixes made from composite of sweet potato flour (25%), Arrowroot flour (10%), Chuda powder (20%), malted ragi flour (20%), rice flour (10%), sugar (6%), skim milk powder (8%) and starch (1%) is good source of all the micronutrients

ELEPHANT FOOD YAM BASED PRODUCTS

Ready to fry nutri-shreds from elephant foot yam was prepared which can be used after frying with seasonings, curry and coriander leaves. It is rich in omega-3 fatty acids,

micronutrients and is a healthy snacks for all age group. Ready to fry papad was prepared from elephant foot yam flour (30%) + black gram flour (40%) +green gram flour (30%). It have an expansion of 16.50% and contain protein (18.36g) and fibre (3.51g). Ready to cook healthy pasta was made from elephant foot yam flour (35%), suji (45%) and finger millet (20%), It is a healthy breakfast for children, diabetic and obese person and a good source of protein (14.63%), iron (3.45mg/100g) and calcium (336mg/100g). Process technology for the production of shelf stable dehydrated quick cooking tubers with short cooking time by parboiling-freezing-drying had been standardised. The technology for ready to cook flakes from Amorphophallus tubers for making ada pradhanam having comparable quality in taste and texture of the rice based flakes (ada) will have great demand in both domestic and export market.



BIOFORTIFIED SWEET POTATO BASED PRODUCTS

Synbiotic sweet potato ice cream were developed from purple fleshed sweet potato with rich in anthocyanin content (12.20 mg 100 g⁻¹), dietary fiber (3 g), protein content (4.18%) and abundant with beneficial probiotic bacteria (4.0×10⁸ CFU ml⁻¹ and from beta carotene rich sweet potato which contains good amounts of vitamin A (455 mcg RAE), dietary fiber (3 g), protein (4.28%) and abundant with beneficial probiotic bacteria (4.0×10⁸ CFU ml⁻¹ at end of the three month storage. Anthocyanin rich sweet potato gummy confections contain anthocyanin content of 3.13 mg 100 g⁻¹. Beta carotene rich sweet potato

gummy confections contain good amounts of vitamin A (204 mcg RAE). Anthocyanin rich sweet potato kulfi contains anthocyanin content of 12.45 mg 100 g⁻¹ and protein content of 3.94 %. Beta carotene rich sweet potato kulfi contains good amounts of vitamin A (487 mcg RAE) and protein content of 4.22 %. Naturally orange colored sweet potato muffins contain good amounts of vitamin A (270 mcg RAE), protein content of 4.28% and dietary fiber of 1%. Low-fat, anthocyanin and beta carotene rich vacuum-fried chips made from orange and purple fleshed sweet potato tubers.



CASSAVA STARCH BASED INDUSTRIAL PRODUCTS

Cassava starch is extracted from the tubers by rasping-sieving-settling and drying process. Sago (Saboo dana) is manufactured from the partially dehydrated (35-40% m.c) starch cake by globulation and roasting/steaming followed by drying. Wafers are made

by arranging the wet sago granules in suitable dies and steaming followed by drying.

Cassava and sweet potato starches were subjected to different chemical and physical modification techniques

to develop resistant starches with fairly high content of slowly digestible starch and medium glyceamic index. These resistant starches are beneficial in formulating low-calorie food and diabetic food and it can act as a pre-biotic.



Cassava resistant starch

Starch forms an important ingredient for the development of biopolymer based environment friendly packaging materials. Studies have been carried out to develop biodegradable film from cassava starch modified by etherification, esterification, double cross linking and enzymatic treatments by film casting method. Eco-friendly biodegradable composite films based on chitosan and konjac glucomannan were

prepared for food wrapping application with incorporation of granular cassava starch to enhance the barrier properties and mechanical properties, further addition of nanosilver induced antimicrobial properties. Cassava starch-konjac glucomannan blend based edible surface coating of carrot slices enhanced the shelf life with less microbial growth on storage.



Starch based food wrapping film

Cassava starch either in native or modified form can be used for making liquid adhesives, gum pastes, multipurpose binding paste, corrugating adhesive, single phase corrugating adhesive, moisture resistant corrugating adhesive and alkali free corrugating adhesive. Graft-copolymers of cassava starch with cold swelling nature, high viscosity, water absorption capacity and thermal stability can be used in oil drilling, in sizing and printing of cotton fabrics, water treatment for the removal of heavy metal ions, and as flocculating

agent. Cassava starch can be modified as superabsorbent polymers through free radical graft copolymerization with vinyl monomers and subsequent alkali saponification and the resulting product has slow absorption and desorption of water and equilibrium absorbency (<350-400 g/g of the dry sample) is reached in 2 hours.

Cassava starch/montmorillonite nanocomposites, starch-konjac glucomannan blend films, water soluble curcumin incorporated in octenyl succinate cassava starch nanoparticles

are found to be appropriate matrices for the sustained release of drugs.

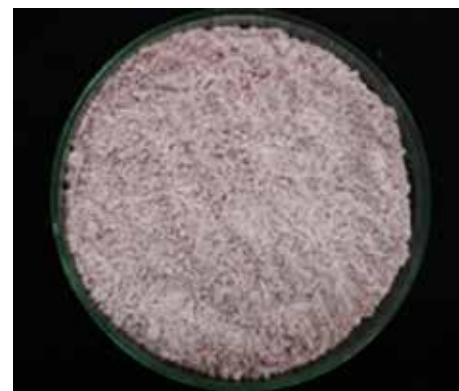


Nanostarch incorporated soluble curcumin

Anthocyanin extracted from purple yam and sweet potato tubers/leaves have high antioxidant activity and can be used as natural colourant. Capsules

filled with coated/encapsulated anthocyanins were also developed as nutritional supplement

Sweet potato anthocyanins as natural colourant



Cassava with its high carbohydrate content and ability to grow under low management conditions, degraded soils and wide range of edaphoclimatic conditions has been globally recognized as a potential candidate for bioethanol production. Fresh cassava tubers, dry chips/flour or starch can be used for the

production of ethanol. The processes for the preparation of an array of physically and chemically modified starches of cassava have been standardized which have got wide application in food, pharmaceutical and other industries as food ingredient in salad dressings, frozen foods, canned foods and

puddings, thickener and viscosity modifier in soups, jellies, fruit pastes, surgical dusting powders, carriers, absorbents and ion exchange resins, paper and adhesive industries, tablet disintegrant, instant binder etc.



Modified cassava starch as gelling agent and emulsifier for food products



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17-21 November 2025

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