# MINOR TUBER CROPS

**(Tannia, Chinese potato, Arrowroot and Yam bean)**


**भाकृअनुप-केन्द्रीय कंद फसल अनुसंधान संस्थान**

(भारतीय कृषि अनुसंधान परिषद्)

श्रीकार्यम, तिरुवनंतपुरम 695 017, केरल, भारत

**ICAR-CENTRAL TUBER CROPS RESEARCH INSTITUTE**

(Indian Council of Agricultural Research)

Sreekariyam, Thiruvananthapuram 695 017, Kerala, India

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Diamond Jubilee of ICAR-CTCRI

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## From the Director


Minor tuber crops hold immense potential for domestication and offer diverse advantages over other major tuber crops. These crops prove to be life-saving during times of food scarcity as they display tolerance towards biotic and abiotic stresses and thrive well in harsh environments. Recognizing the importance of their wild counterparts, the National Agricultural Research System has taken up initiatives for the collection and conservation of these species as part of their research and improvement programs. Despite being under-exploited, minor tuber crops possess excellent potential for utilization in food, nutrition and other purposes but are often hindered by adaptability issues and physiological constraints.

The potential under-utilized minor tuber crops are Tania (*Xanthosoma sagittifolium* (L.) Schott), Chinese potato (*Solenostemon rotundifolius* (Poir.) J. K. Morton; *Plectranthus rotundifolius* (Poir.) Spreng.), West Indian Arrowroot (*Maranta arundinacea* L.), Queensland Arrowroot (*Canna edulis* L.), East Indian Arrowroot or Tikhur (*Curcuma angustifolia* Roxb.), Insulin plant (*Costus igneus* Nak), Yam Bean (*Pachyrhizus erosus* (L.) Urb.), *Typhonium flagelliforme* (Lodd.) Blume, *Tacca leontopetaloides* (L.) Kuntze and *Vigna vexillata* (L.) A. Rich. Besides being a source of carbohydrate, these crops possess other uses also. Tannia is known for its edible tubers and leaves which are the sole source of vitamins and minerals. Chinese Potato tubers are known for their appealing aroma and iron content. Arrowroot is known for its varied attributes as functional food with nutritional potential and medicinal values. It occupies one of the rising markets both in the food and cosmetic industries. Yam Bean shows dual role as its elite tubers could be used raw or cooked and the seeds for pest control.

In the span of sixty years of extensive research and development, ICAR-CTCRI successfully introduced varieties in these under-utilized crops. From these crops, studies for releasing a variety in Arrowroot that harnesses its inherent capabilities for the global market is in progress. The synergy of ICAR-CTCRI had given farmer-friendly agro-techniques, techniques for quality planting material production, protocols for integrated nutrient management including site specific nutrient management, organic farming, water management, weed management, cropping systems, integrated pest and disease management, pre- and post-harvest machinery, processing and value addition. It is with great pleasure and honour that I present the technical bulletin titled 'Minor Tuber Crops' which offers recommended practices for farmers and other stakeholders to achieve increased yields and long-term sustainable income.

I look forward that this technical bulletin will equip the need as a valuable document for scientists, farmers, entrepreneurs, developmental professionals, policy makers and other stakeholders to enhance the production and profit from these potent crops. I appreciate the efforts of the Chief Editor and Editors in bringing out this publication.

**G. Byju**

15 November 2023

## Introduction

Minor tuber crops also known as underutilized tuber crops comprise a diverse group of tuber crops that play a crucial role in agricultural systems worldwide. These crops are often overlooked in the mainstream agricultural research and development, yet they hold immense potential for enhancing food security, nutrition and income generation particularly in the developing countries. These crops exhibit a remarkable diversity in their botanical characteristics, nutritional profiles and adaptation to different agro-ecological environments. They are found across various agro-climatic regions which signify their adaptability and resilience to adverse environmental conditions.

Minor tuber crops are rich sources of essential nutrients including carbohydrates, proteins, dietary fibre, vitamins and minerals. They are particularly valuable for their high content of complex carbohydrates which provide sustained energy and their abundance of vitamins and minerals which contribute to micronutrient deficiencies. It also plays a significant role in ensuring food security in resource-poor communities. Their ability to thrive in marginal environments and under low-input conditions makes them valuable assets for subsistence agriculture. The important minor tuber crops are the following:

| | |
|---|---|
| Tannia | *Xanthosoma sagittifolium* (L.) Schott |
| Chinese potato | *Plectranthus rotundifolius* (Poir.) Spreng |
| West Indian Arrowroot | *Maranta arundinacea* L. |
| Queensland Arrowroot | *Canna edulis* Ker Gawl. |
| East Indian Arrowroot | *Curcuma angustifolia* Roxb. |
| Insulin plant | *Costus igneus* N. E. Br. |
| Yam bean | *Pachyrhizus erosus* (L.) Urban |
| Fiji Arrowroot | *Tacca pinnatifida* J. R. Forst. & G. Forst |
| Wild Cowpea | *Vigna vexillata* (L.) A. Rich |

A total of 425 accessions of minor tuber crops comprising Tannia, Chinese potato, West Indian Arrowroot, East Indian Arrowroot (Tikhur), Queensland Arrowroot (Canna), Yam bean, Insulin plant and Fiji/ Polynesian Arrowroot are maintained in the field gene bank of ICAR-CTCRI HQ at Thiruvananthapuram (271 accessions) and in the Regional Station at Bhubaneswar (154 accessions). Thus, it is very important to concentrate research and development efforts on minor tuber crops to improve their yields, nutritional quality and resistance to pests and diseases.

Growing recognition of their nutritional values and adaptability to diverse environments is creating new opportunities for their promotion and utilization. Despite their immense potential, minor tuber crops face several challenges including limited research and development, inadequate market access and lack of awareness among consumers. Efforts are needed to promote market access for these crops and to create awareness among consumers of their nutritional value and culinary potential. By addressing these challenges and seizing the opportunities, minor tuber crops can play a more significant role in agriculture.

# 1. Tannia

Scientific Name: *Xanthosoma sagittifolium* (L.) Schott

## 1.1 Introduction

Tannia (*Xanthosoma sagittifolium* (L.) Schott) is an edible aroid known by many names like elephant ear, arrow leaf elephant ear, cocoyam *etc.* It is one of the most important edible corm and leafy crops for millions of people in the tropics and sub-tropics. It was originated in the tropical Americas and spread later to Southeast Asia, the Pacific Islands and Africa. It is a tall herbaceous plant growing to 1.5-2.7 m and has about 6 large outspreading hastate leaves in contrast to peltate leaves in taro. In India, the corms are the preferred edible part and are grown mainly in Maharashtra, Gujarat and Kerala. It is a rich source of carbohydrates, essential amino acids, vitamins and minerals for the human diet. The tubers are said to contain the irritant substance calcium oxalate and saponins which are mostly found in main corms. The cormels (small corms) which have a low percentage of irritants are used for cooking. The chromosome number of *X. sagittifolium* is 2n=26. Tannia cultivated in India lacks evident shoot diversity. Corm traits vary in size, shape and colour and flesh colour and cooked tuber palatability differ.

The crop is one of the most shade-tolerant terrestrial food crops. It grows up to 2 m tall and has a short stem producing large leaves at the top of the stem. A mother corm is produced at the base and is more or less cylindrical surrounded by cormels which develop from lateral buds adjacent to leaf scars on the underground corms. These are about 15-25 cm long and flask-shaped that get wider towards the tip. Leaves are large and the stalk joins to the edge of the leaf. The leaves stand erect on stout petioles or leaf stalks. There is a vein around the edge of the leaf. The leaf stalks can be 1 m long. The leaf blade is oval and 50-75 cm long. The leaf has triangular lobes at the bottom. The flowers are produced below the leaves. The large bract around the flower is pale green and about 20 cm long and the bases of this bract overlap. The closely arranged spike of


Tannia plant and tubers

flowers is about 15 cm long. The smaller female section is at the bottom of the spike and the larger male section toward the top.

### Nutritional profile of tannia

| Particulars | Tannia cormel | Tannia pseudostem | Tannia leaf |
|---|---|---|---|
| Proximate composition (FW) | | | |
| Moisture % (FW) | 75.88 | 76.56 | 72.49 |
| Energy (kJ/100g) | 98 | - | - |
| Crude protein (%) | 5.25 | 14.88 | 19.06 |
| Starch (%) | 14.6-16.05 | - | - |
| Sugar (%) | 0.74-1.33 | - | - |
| Polyphenol (%) | 2.29-2.42 | 0.73-0.78 | 0.63-0.66 |
| Dietary fibre (%) | 4 | - | - |
| Crude fibre (%) | 0.98 | 0.83 | 0.92 |
| Crude lipid (%) | 0.11 | 0.10 | 0.08 |
| Ash (%) | 1.89 | 1.94 | 1.75 |
| N & Minerals (DW) | | | |
| N (%) | 0.840-0.0883 | 2.038-2.58 | 3.05-3.37 |
| P (%) | 0.550-0.582 | 0.230-0.246 | 0.280-0.302 |
| K (%) | 0.74-0.793 | 1.43-1.552 | 1.710-1.573 |
| Ca (ppm) | 349-370 | 1970-2118 | 6756-7077 |
| Mg (ppm) | 336-367 | 6265-6627 | 8980-9454 |
| Fe (ppm) | 20.2-22.1 | 1377.6-1432.2 | 362.8-387.3 |
| Mn (ppm) | 3.8-4.07 | 290.4-311.8 | 382.4-401.8 |
| Zn (ppm) | 15.80-17.31 | 76.2-81.8 | 60.0-64.3 |
| Cu (ppm) | 2.2-2.36 | 19.2-20.6 | 25.0-26.6 |
| B (ppm) | 0.94 | - | - |
| Al (ppm) | 1.06-2.60 | - | - |
| Na (%) | 1.5 | - | - |

## 1.2 Variety

Balasaheb Sawant Konkan Krishi Vidyapeeth in Dapoli had released the variety Konkan Harit Parni, which is ideally suited for cultivation in the Konkan region of Maharashtra. This variety displays upright foliage adorned with deep green leaves, while its corms are compact and exhibit a rich brown hue. With an average yield ranging from 3-5 t/ha, it matures within 190-210 days. The cooking quality of the corms is good and the leaves

are edible. But local selections with corms having low acridity, good texture and leaves for vegetable use are also available.

## 1.3 Climate and soil

### (i) Climate

Tannia, a resilient tropical crop, which thrives under the warm and humid climate is typically found in the tropical regions worldwide. Its sustained growth and development are contingent upon an evenly distributed rainfall of approximately 1800-2000 mm. It exhibits a preference for drier conditions compared to other aroid plants but it does notgrow well in areas characterized by prolonged dry spells, cold climates or frost. The ideal cultivation environment for tannia is in regions, where the mean annual temperature ranges from 24-30°C with maximum temperature variations spanning from 13-29°C.

### (ii) Soil

The quality of soil determines the yield of tannia. This crop thrives in well-drained loamy soil with a slightly acidic pH range of 5.5-6.8. Particularly, it excels as an upland rain-fed crop in regions where rainfall is consistently distributed throughout the year.

## 1.4 Quality planting material production

Sprouted corms and suckers can be used in propagating tannia and are reported to give higher yields than the tubers. Damaged corms and planting material showing signs of decay should be discarded. Planting material should only be taken from healthy and vigorous plants. Disease-free planting material could now be produced by tissue culture, which results in even higher yields. Healthy cormels of 50-100 g weight and 20-25 cm long and corm weight of 150-200 g size are ideal as planting material. For planting one hectare 1.8-2.5 tons of corms or 0.6-1.0 tons of cormels are required. Usually the seed materials are planted 6-7 cm deep. While planting the cut pieces of the main corm or suckers, it is advisable to keep the apical portion above ground level.

### (i) Minisett technique

In the minisett technique, mother corms are selected from healthy plants at harvest. Such harvested mother corms are first cut into cylindrical pieces and then cut horizontally into minisetts of about 15 g weight. If minisetts are raised in a nursery, they could be transplanted in a month to the prepared main field. A major advantage of minisetts in tannia is that the cormels which are the economic part of the crop can be fully marketed. Corms which are less-edible would be used for minisett multiplication.

## 1.5 Agro-techniques

Tannia can be planted year-round and adequate water is necessary for its efficient growth. Planting usually coincides with the beginning of the rains i.e. May or June. The

crop is also planted in September and November in islands. Plants are normally spaced 60-90 cm along the ridges. Sprouted corms should be covered with 2 cm of soil while the tops and suckers are planted to a depth of 6-7 cm. A spacing of 90×90 cm is usually practised with a planting density of 12345 plants/ha and pits converted to mounds are the usual method of planting. Tannia is often intercropped with black-eyed peas, okra, pigeon peas and corn. The intercrop is normally planted after the crop.

To optimize tannia growth, it is advisable to turn the soil 2-3 months before planting. This preparatory step aids in the decomposition of previous crop residues and serves to reduce the population of nematodes and disease-causing pathogens in the soil. Generally, fields that have not been utilized for tannia cultivation in the last 2-3 years are favoured for its cultivation, while fields with high nematode populations are typically avoided.

When the crop is grown in the laterite soils of Kerala, interveinal chlorosis of the lower leaves characteristic of Mg deficiency was prevalent from 3$^{rd}$ month of growth causing complete devastation of the crop. As tannia is identified as an indicator plant for Mg deficiency, application of dolomite @1 t/ha during land preparation is advocated to prevent the problem in these soils. Crop can be harvested when older leaves start yellowing and drying usually during 9-11 months of planting. As the corms do not deteriorate if left unharvested, harvesting can be done from 6 months to 10-12 months. If mature corms are not harvested, most of them will sprout in rain and become watery making it less suitable for consumption. After harvesting, curing of the corms is done under sunlight for 4-5 days. They can also be stored by embedding them in dry soil or sand for 4-5 months in under-ventilated, dry and semi-dark conditions. Care should be taken to avoid injury to the corms and cormels while harvesting.

## 1.6 Nutrient management

### Integrated nutrient management

In the realm of nutrient management, several crucial steps should be taken to ensure optimal soil health and crop growth. One of these steps involves the application of dolomite as a soil amendment at a rate of 80-100 g/plant during the ploughing process, followed by allowing the land to remain untouched for a duration of two weeks.

Furthermore, adhering to integrated nutrient management (INM) recommendations is essential for achieving desirable results. This includes incorporating 25 tons of farmyard manure (FYM) per hectare in conjunction with the application of NPK fertilizers at a rate of 80:50:150 kg/ha. The practises also include applying FYM at a rate of 25 t/ha (equivalent to 2 kg/plant) into designated pits. Additionally, the application of phosphorus (P) at 50 kg/ha, utilizing Mussooriphos Rajphos at 250 kg/ha or 21 g/plant as a basal fertilizer is crucial for crop establishment.

For the cultivation of tannia, it is important to plant Pseudomonas-treated cormels after allowing them to shade dry for a period of 4-8 hours. In the interstitial spaces between tannia plants, it is recommended to sow green manure cowpea at a rate of 10 kg/ha immediately after tannia planting. Approximately 45-60 days after cowpea sowing, the green cowpea biomass should be ploughed into the soil to enrich its nutrient content.

To further enhance nutrient availability, it is advised to apply a nitrogen fixer at a rate of 10-20 g/plant within the first month of tannia planting. Following this, neem cake should be applied at a rate of 25-50 g/plant in designated pits one month after the nitrogen fixer application.

Integrated management also includes applying one-third of the nitrogen fertilizer (urea) at 2 g/plant and one-third of the potassium fertilizer (MOP) at 7 g/plant at intervals of 2, 4 and 6 months after planting (MAP).

The fertilization strategy involves applying the full dose of phosphorus and potash along with half of the required nitrogen as a basal dose at the time of ridge formation. The remaining half of the nitrogen is typically applied one month after planting coinciding with the earthing-up stage. Tannia generally requires medium to high levels of nitrogen, medium levels of phosphorus and medium doses of potash to thrive.

## 1.7 Organic farming

To commence organic tannia farming it is advisable to plant organically produced whole corms of sizes ranging from 50-80 g or utilize mother corm pieces weighing between 150-200 grams.

Soil enrichment using organic manures plays a pivotal role in this farming approach. At the time of planting, the application of farmyard manure (FYM) at a rate of 20 t/ha or 1.6 kg/pit is recommended. Additionally, neem cake should be applied at a rate of 1 t/ha or about 80-85 g/pit simultaneously with the planting process.

Furthermore, intercropping with green manure cowpea serves multiple purposes in organic tannia farming. Cowpeas can be inter-sown between pits at a seed rate of 20 kg/ha. After 45-60 days the green matter from the cowpea should be incorporated into the soil. This incorporation not only enhances soil structure but also contributes valuable nutrients, with an estimated addition of 15-20 t/ha of green matter.

To further enrich the soil and optimize nutrient availability, the application of ash at a rate of 2 t/ha or approximately 160-165 g/plant is recommended at the time of incorporating the green manure cowpea. This holistic approach to organic farming for tannia not only ensures a chemical-free cultivation process but also promotes soil health resulting in a sustainable and high-yielding crop.

## 1.8 Water management

Tannia exhibits a preference for upland rain-fed conditions over lowland conditions. However, sufficient irrigation is necessary to support optimal vegetative growth and leaf production particularly during periods when carbohydrates are stored. Under rain-fed conditions, the crop may face the risk of accelerated maturation due to short-term droughts. Therefore, it is essential to ensure adequate soil moisture at the time of planting. In cases where planting occurs in dry soil, immediate irrigation is warranted, with an additional irrigation session one week later to promote uniform corm sprouting.

Subsequent irrigation intervals, typically ranging from 12-15 days should be determined based on the soil's moisture retention capacity. Irrigation should cease approximately 3-4 weeks before the scheduled harvest to avoid excessive moisture content in the corms. In total, tannia cultivation usually necessitates 9-12 irrigations from planting to harvesting. In rain-fed crops, supplementary irrigation may be required to maintain adequate moisture levels during extended dry periods post-planting. Effective water management practices are indispensable for achieving the desired size of corms, underscoring the importance of water resources in optimizing tannia production.

## 1.9 Weed management

Perform weeding twice and earthing up the soil on the 30$^{th}$ and 60$^{th}$ days after planting. Using 3 kg/ha of herbicide dalapon after planting, but before sprouting also proves effective. When the crop is grown in a kitchen garden without applying any fertilizer, weeding is done especially at the early stage of plant growth. Lower leaves and petioles should be removed when they start drying.

## 1.10 Pest management

### (i) Aphids (*Aphis gossypii*)

Aphids are persistent sucking pests that extract cell sap from tender leaves, excreting honeydew-a sticky, sugary substance. The honeydew often attracts black sooty mould which disrupts photosynthesis in plants. Aphids also transmit viruses that lead to leaf yellowing and curling. Their primary infestation occurs during the early stages of crop growth, with high humidity and elevated temperatures favouring their presence.

**Management**

- Cultivate resistant varieties.
- Apply malathion 0.05% at 10-12 day intervals.

### (ii) Thrips (*Heliothrips indicus*)

Thrips are commonly observed between February and May. They suck cell sap, leaving behind white specks with black dots. Infected leaves turn brown and become distorted. Dry weather conditions promote the rapid multiplication of thrips.

**Management**

- Opt for resistant tannia varieties.
- Practice crop rotation with non-host crops.
- Remove and dispose of infected leaves.
- Apply phorate at 2 kg/ha in the soil.

### (iii) Root weevil (*Diaprepes abbreviatus*)

The root weevil is the most destructive tannia pest with both grubs and adults causing damage by tunnelling into corms and feeding on soft tissues. Damage occurs both in the field and during storage.

**Management**

- Maintain fallow fields.
- Implement long crop rotations with non-host crops.
- Utilize weevil-free corms and cormels for planting.
- Mound up soil on ridges 30 and 60 days after planting.
- Deploy sex pheromone traps.
- Apply fenthion or fenitrothion 0.05% at monthly intervals.
- Apply 2 kg phorate at intervals of 2, 6 and 10 weeks after planting.

### (iv) Root-knot nematodes (*Meloidoginy* spp.)

Root-knot nematodes are polyphagous and widely distributed, posing a significant threat in light sandy soils. Infection hinders the efficient utilization of soil nutrients and moisture by plants leading to stunted growth, chlorosis, wilting and plant death. Nematode infections also impact corm rotting in storage.

**Management**

- Practice long crop rotations with trap crops.
- Opt for nematode-resistant tannia varieties.
- Avoid planting nematode-infested corms.
- Apply high doses of potash fertilizer.
- Implement soil turning at 10 day intervals in summer.
- Sterilize nursery beds through soil solarization in hot summer months.
- Fumigate fields with Nemagon before planting sets.

- Add organic amendments to the soil, such as groundnut, neem, mahua or karanj cake.

### (v) Tannia beetle (*Ligrus ebenus*)

The tannia beetle is a highly destructive pest known for its leaf-feeding habits. It exhibits polyphagous behaviour and is particularly problematic in the states of Kerala, Maharashtra and Andhra Pradesh.

**Management**

- Apply Ridomil at 0.05% at 60day intervals after planting.
- Store only healthy corms in sand or sawdust.

## 1.11 Disease management

### (i) Root rot disease (*Pythium myriotylum*)

Root rot disease or leaf-burning disease is the most devastating disease in tannia at present and can cause a total loss of yield. The pathogen that seems to be the main causal agent is *Pythium myriotylum*.

**Economic Importance**

Root rot of tannia caused by *Pythium myriotylum* is the most devastating disease with yield reductions of up to 90%.

The above-ground symptoms of the disease are associated with rotting roots; hence, the descriptions for this disease indicate that the outer leaves of the plant gradually go yellow from margin to midrib and finally the leaf dies. The roots of the plant also die. Plant growth is stunted. The fungus primarily attacks roots, while above ground; leaves wither and turn pale yellow. Production of marketable corms is severely affected. The main sources of the inoculum are infected soil and infected planting material. The development of the disease is helped by poorly drained soils.

Damages on collar and leaf stalks due to corm rot

**Management**

- Cultural methods such as wide spacing, high mounds, proper timing of planting, drainage improvement, using disease-free planting material through meristem tip culture, planting on ridges, crop rotation and application of organic manures have been suggested to control the disease.
- To control root rot, the following cultural management practices are recommended: avoiding infected fields, planting on ridges using healthy and disease-free cuttings, maintaining high soil fertility, planting in well-drained soils and ensuring a prompt harvest.

### (ii) Dasheen mosaic virus (DMV)

Plants infected with DMV exhibit varied mosaic patterns and spots along the main veins causing reduced corm quantity and stunted growth. Severe cases may not recover, with visible symptoms of leaf distortion and vein chlorosis. DMV is transmitted rapidly by aphids, affecting plant growth and reducing yield, although it is not lethal.

Symptoms of DMV in tannia "Feathering" along the veins, leaf distortion, and stunted plant

**Management**

- Use virus-free seed stock.
- Isolate and protect plots (clearing).
- Destroy diseased plants by burning or burying them.
- Use cuttings from healthy mother plants.
- Use virus-free plants produced through meristem tip culture.

### (iii) Leaf blight

The disease is caused by the attack of *Phytophtor*a sps.

The disease plant shows brown to purple coloured water soaked lesions appear on its foliage and later results in defoliation.

**Management**

- To control the fungi, spraying copper fungicides like Dithane M-45 (0.25%) 3-4 times at fortnightly intervals. The efficiency of the fungicide is enhanced with sticking agents like teepol at the rate of 2-3 drops/litre.

## 1.12 Harvesting and yield

The crop typically reaches maturity after about 8-11 months from planting. Harvesting can be initiated when the older leaves start turning yellow and drying out, usually

occurring during the 9-11 month period post-planting. However, due to the corms and cormels capacity to stay in good condition even if not harvested, the harvesting window extends from 6 months after planting up to around 10-12 months.

Leaving mature corms unharvested, could lead to sprouting during rainy periods, causing them to become watery and less suitable for consumption. The smooth purple variety of tannia tends to mature later than the white variety. Following harvesting, it is advisable to wash the harvested corms. Since both corms and cormels are vulnerable to damage, handling them with care is crucial to minimize any potential post-harvest losses.

If the crop is grown for leaf purposes, the leaves can be harvested as and when they are fully expended and mature. A leaf size of 20-30 cm x 20-30 cm is ideal for making rolls. A clump of plants gives about 40-50 leaves during its entire growth period. The leaves to be ready for harvesting take 40-50 days after emergence in the field. The leaves are harvested along with their petioles. Petioles are usually used as a cooked vegetable. On an average, the yield of tannia corms and cormels is 20 t/ha.

### Storage of seed material

After harvest, the corms go through a curing process in sunlight for 4-5 days. Alternatively, they can be stored by embedding them within dry soil or sand for around 4-5 months. This storage should occur in conditions that are moderately dark, adequately ventilated and suitably dry.

When placed in well-ventilated structures at the prevailing room temperatures, the corms can be preserved for an extended period of up to 6 weeks. The corms can be stored for 4 months or even longer, if it is in refrigerators set at 7°C and maintain a humidity level of about 80-85%. However, it's important to note that storage at temperatures dipping below 5°C could lead to chilling injury which can negatively impact the quality and viability of the corms.

## 1.13 Processing and value addition

### (i) Curing for enhanced preservation

Post-harvest processing of tannia is a critical aspect of maintaining both its quality and quantity. When cormels (usually 4-10 in number) are removed, they create wounds on the tannia corm. Traditionally, curing has been achieved by exposing these corms to sunlight until the wounded surfaces dry out. Alternatively, curing can take place in naturally ventilated barns or other suitable storage structures. Research has demonstrated that curing tannia corms at 35°C and 95% relative humidity for 5 days effectively reduces sprouting and weight loss.

**(ii) Ventilated storage**

During storage in well-ventilated facilities at approximately 26°C and 76% relative humidity, tannia corms experience 1% weight loss per week, with sprouting becoming evident after 6 weeks. Remarkably, even after 9 weeks of storage the corms remain edible. However, storing corms in the dark at 24°C results in 30% decay within just 1-3 weeks. For optimal preservation, tannia corms can be stored at 7°C and 80% relative humidity maintaining their quality and eating characteristics for approximately 120-130 days.

**(iii) Value addition through starch and syrup production**

Tannia starch is distinguished by relatively large granules with an average diameter of 17-20 µm, making it versatile for various applications. Among these, starch from tannia along with other aroids can be processed into high fructose-enriched syrups (HFES). These syrups serve as desirable, cost-effective and easy-to-use sweeteners ideal for applications such as canning, jams, jellies and soft drinks. The nutritional value of HFES is comparable to that of sucrose.

**(iv) Utilizing aroid gums**

Tannia contain a gum-like substance that can swell in water and become hydrated. This gum holds promise as an emulsifying, thickening and smoothing agent for various food preparations including creams and suspensions. Extracting this gum not only enhances the properties of aroid products but also reduces stickiness and viscosity.

**(v) Biodegradable plastics and packaging**

Starch from tannia, being biodegradable, has the potential to contribute to the production of environmentally friendly plastics. When incorporated into plastic formulations, tannia starch accelerates the biodegradability of the parent polymer, without excluding the possibility of recycling the majority of plastic composition. Tannia starch's small granule size further enhances its suitability for biodegradable plastics especially in addressing the increasing demand for sustainable waste management solutions.

**(vi) Aroid-based edible films for bodified atmosphere packaging (MAP)**

Tannia starch exhibits low gas permeability, making it an excellent candidate for developing modified atmosphere packaging (MAP) technologies. These technologies are particularly valuable in regions where root crops, including tannia, are a significant part of agricultural production. Starch-filled polyethylene films with higher starch content demonstrate decreased gas permeability, an effect attributed to the high degree of crystallinity in the starch filler material.

## Dishes on tannia

The starchy corms occupy an important place in the diet of many tropical countries. The main corms are usually acrid. These are boiled, baked or parboiled and fried in oil. The tannia leaves can be boiled and used as a vegetable, similar to spinach.

### (a) Tannia flour

The dried peeled corms can be processed to make flour that is as tasty as cassava flour. About 10 kg of tannia will yield 3 kg of flour. For the making of noodles, tannia flour can be supplemented with soya and wheat flour. Starch is occasionally made from the grated tannia corms.

### (b) Tannia parotta

Cook the tannia well, peel and mash into a soft consistency. Grind the onions, chillies and ginger together. Add this and salt to the mashed product. Squeeze the lemon into this and mix well. Knead the wheat flour with enough water to form a soft dough. Spread the dough into chappathis. Roll the chappathis and make them into a circle of concentric rings. Spread a little flour over each chappathi and spread again into chappathis. Fry the chappathis on a frying pan with little oil spread over it.

### (c) Tannia fritters

Make the besan into a thick batter with a little water. Add turmeric powder and a little salt to this batter. Keep aside. Cook the tannia corms with water for 15-20 min (Do not overcook). Peel the corms and slice into half-inch thick flat pieces (corms should not be overcooked). Dip the pieces in the batter and deep fry in oil till golden brown. Serve hot with tomato sauce.

## 1.14 Conclusion

Tannia, scientifically known as *Xanthosoma sagittifolium*, holds a significant place in the agricultural landscape of the Caribbean, particularly in the islands of Dominica, St Vincent and the Grenadines, St Lucia and Grenada. Originating from the American Tropics, this versatile crop is cherished for both its leaves and subterranean corms and cormals although the latter is the preferred part for consumption.

While tannia corms contain irritants such as calcium oxalate and saponins, these compounds are effectively neutralized through cooking, making the crop a valuable and safe source of sustenance. Beyond its cultural significance, tannia also finds its way into international markets notably in the United Kingdom and North America, catering to the needs of diverse ethnic communities. Moreover, tannia has been associated with various health benefits including antihyperglycemic, antihypertensive, hypoglycemic and prebiotic effects. The functional properties of its components, particularly starch, mucilage and powders have paved the way for their incorporation into a range of food products including baked goods, food pastes and beverages, as thickening and gelling agents.

In the regions where it thrives, tannia contributes significantly to easing poverty and food security, serving as a staple in the diets of local populations. As we continue to explore the potential of this versatile crop and its various applications, it reaffirms its role as a source of nourishment and as a valuable resource for improving health and promoting economic sustainability. Journey of tannia from the American Tropics to international markets shows its adaptability and resilience, ensuring its continued importance in the years to come.

# 2. Chinese potato

Scientific name: *Plectranthus rotundifolius* (Poir.) Spreng

## 2.1 Introduction

Chinese potato (*Plectranthus rotundifolius* (Poir.) Spreng) is a lesser-known tuber crop in India coms under the Lamiaceae family comprising over 300 plant varieties. It's believed to have originated in Kenya or Ethiopia in East Africa. This annual herb, grown from cuttings thrives well in tropical regions like India, Indonesia, Malaysia, Sri Lanka and Africa. It's a monsoon crop taking 4-5 months to grow with lush stems and fragrant leaves that bloom extensively from September to November. The flowers don't produce seeds due to the absence of viable pollen grains. This small herb has low-lying or slightly upward stems, producing oval tubers up to 4-8 cm long in clusters of 3-7 at the stem base or nodes beneath the soil. Harvesting begins around 150-200 days after planting, once flowering occurs and above-ground parts wither. Tubers are around 2.5-4 cm long with the weight spanning up to 480 g.

In India, Chinese potato is mostly grown in laterite and coastal sandy soils of Kerala (Thrissur, Palakkad, Idukki, Kasaragod and Kannur), Tamil Nadu (Tirunelveli, Tenkasi, Tuticorin, Virudhunagar and Kanyakumari) and in tribal settlements throughout the country. Its popularity as an aromatic tuber vegetable has led to its cultivation in commercial fields, even on black soils in Tamil Nadu and its expansion has seen more than 500 ha dedicated in South Tamil Nadu.

The main variability is in the tuber shape and size rather than their appearance. These tubers, known for their appealing aroma and iron content and are embraced as a vegetable for various dishes in Kerala. This crop is commonly grown in homestead gardens in Kerala and Tamil Nadu. In Kerala, it is known as Koorka or Cheevakizhangu.

### Importance

This plant reaches a stature ranging from 15-30 cm and has unique and distinct aroma due to the volatile oils contained within the glands or sacs found in its leaves. The leaves are used as wound-healers and antiseptics. Within the plant volatile oils, sesquiterpenes and diterpenes are present. Currently, several researchers are engaged in the extraction of numerous bioactive components from the leaves, stems and tubers. Among these components are γ–muurolene (21%), α-humolene (12.5%), ε-caryophyllene (5.67%), n-dodecane (5.55%) and 1-octene-3-ol (4.63%). Epi-α-cardinol (15.52%), sesquiceneole (9.36%), cyperene (making up 4.88%), epi-α-bisabolol (3.0%) and α-santalene (25%) are also isolated from the leaves.

These compounds have shown antibacterial activity against specific bacteria, such as *Pseudomonas aeruginosa, Escherichia coli* and *Staphylococcus aureus.* Tubers also

contains a significant array of secondary metabolites contributing to the enhancement of the body's immune system and its ability to fend off diseases.

Chinese potato field view and tubers of various shapes

### Nutritional profile of Chinese potato (Sree Dhara)

| Particulars | Chinese Potato tuber | Chinese potato stem | Chinese potato leaf |
|---|---|---|---|
| Moisture % (FW) | 70.13 | 82.6 | 72.35 |
| Crude protein (%) | 7.56 | 6.38 | 17.06 |
| Starch (%) | 17.3-18.23 | - | - |
| Polyphenol (%) | 4.21-4.39 | 3.74-3.92 | 4.21-4.39 |
| Crude fibre (%) | 1.27 | 1.05 | 0.96 |
| Crude lipid (%) | 0.09 | 0.05 | 0.06 |
| Ash (%) | 2.36 | 2.33 | 1.97 |
| N (%) | 1.21-1.285 | 1.02-1.10 | 2.73-2.91 |
| P (%) | 0.036-0.381 | 0.46-0.487 | 0.57-0.611 |
| K (%) | 1.51-1.522 | 2.44-2.618 | 1.83-1.912 |
| Ca (ppm) | 3015-3211 | 3110-3284 | 2428-2560 |
| Mg (ppm) | 2180-2283 | 9115-9593 | 1650-1775 |
| Fe (ppm) | 57.8-62.6 | 583.8-620.4 | 338.4-362.5 |
| Mn (ppm) | 20.8-22.34 | 133.6-142.0 | 135.6-145.0 |
| Zn (ppm) | 39.6 | 94.2-101.5 | 60.8-65.4 |
| Cu (ppm) | 3.2-3.42 | 31.4-34.2 | 25.1-27.3 |
| B (ppm) | 1.81-1.94 | - | - |

## 2.2 Varieties

Chinese potato tubers exhibit a wide array of variations encompassing their shapes, sizes and colours. There are three traditional varieties categorized by their outer skin colours. These include the black variant, referred to as var. nigra A. Chev., the reddish-grey or reddish-yellow type known as var. rubra A. Chev. and the white variety known as var.

alba A. Chev. Despite the diversity in tuber colours across these three varieties, the inner flesh colour of the tuber remains consistent as white. However, there are reports of alternative flesh colours such as dark-brown, reddish-yellow and light-grey.

### (i) Sree Dhara

The variety of Chinese potato known as Sree Dhara was officially released in 1993 by ICAR-CTCRI for cultivation in the states of Kerala and Tamil Nadu. It was developed through the clonal selection process from indigenous germplasm and is particularly well-suited for cultivation during the kharif season. This variety exhibits spreading growth habit and features green, round to ovate leaves.

Sree Dhara is characterized by its round tubers measuring 2-5 cm in diameter. The skin of the tubers is dark brown, while the flesh colour is cream. In terms of its composition, the tubers have a dry matter content ranging from 25-29% with total starch content falling within the range of 16-20%. Additionally, the variety contains approximately 0.6-0.8% sugar content which makes it suit for cooking.

Sree Dhara demonstrates adaptability to both lowland and upland conditions and exhibits a positive response to applied agricultural inputs. Its maturity period spans approximately 5-8 months from planting to harvest. On an average, this variety yields around 25 t/ha with the potential yields of up to 28 t/ha under optimal conditions. The tubers have a shelf life of 1-2 months. Growers should be aware and manage appropriately to maximize yields and crop health as the variety is very susceptible to root-knot infection.

Sree Dhara: tubers and fielf view

### (ii) CO1

The variety CO1 was introduced by the AICRP-TC in the year 1991. This variety was meticulously chosen through clonal selection and was proven to be exceptionally well-suited as a Kharif crop particularly in the state of Tamil Nadu.

CO1 exhibits several important characteristics, making it a valuable addition to the agricultural landscape. It is the first known variety of Chinese potato havind with a spreading plant growth pattern with distinctive ovate leaves and profuse flowering. The tubers produced by CO1 are generally round to oval in shape, featuring brown skin and creamy white flesh. These tubers possess a dry matter content ranging from 28-30% and their starch content is measured at 21.5% rendering them suitable for culinary purposes as they emit minimal soil odour upon cooking.

CO1 grows in red sandy loam soil types. The maturity period for this variety spans approximately 180-190 days from the date of planting to harvest. Growers can expect an average yield of 31.93 t/ha with the potential to reach yields as high as 35.85 t/ha under favourable conditions. The tubers of CO1 have a shelf life lasting between 1-2 months after harvest.

## 2.3 Climate and soil

### (i) Climate

Chinese potato grows well in hot-humid climate. A comparatively lower temperature in night than day time favours better tuber development. It grows well in subtropical and hot temperate areas where there is no incidence of frost. The crop requires a reasonably good evenly distributed rainfall and it cannot withstand drought conditions.

### (ii) Soil

A fertile, well drained, sandy loam to alluvial soil, rich in organic matter is ideal for the crop. Heavy clay soils are not suitable. The crop cannot withstand water logging or flooded soil conditions as excess soil moisture reduces tuber yield considerably. For this reason it is desirable to grow the crop on ridges than flat cultivation. The best soil pH requirement ranges between slightly acidic to neutral (6.5-7.0).

## 2.4 Quality planting material production

The primary method of propagation of Chinese potato is through the use of suckers or stem cuttings since it does not produce seeds. The quantity of suckers required depends on the chosen planting method.

To obtain sufficient quantity of suckers for planting, it is necessary to allocate approximately 0.2 ha of land to nursery beds. Healthy tubers harvested in the previous season serve as the source material for raising these suckers. Tubers are planted in well-manured nursery beds, typically 15 cm in height and 0.9-1.0 m wide, with variable lengths for convenience. They are placed in rows with a spacing of 5x15 cm and planted at a depth of 4 cm. Within about 15 days, these tubers begin to sprout which give raise to multiple sprouts, which can reach a height of 15-20 cm in 3-6 weeks. These sprouts are then ready for transplanting into the field. Although stem cuttings from these sprouts

can also be used as planting material, direct planting of suckers is preferred for better establishment.

Nursery has to be raised approximately one and half months prior to planting. An area of 500 $m^2$ (12.5 cents) is required to produce stem cuttings for planting in one ha of land. Farm yard manure or compost has to be applied @1 kg/$m^2$ and ridges/mounds are to be prepared at a close spacing of 45 or 60 cm. Healthy tubers that weigh about 15-20 g are planted on the ridges/mounds so as to accommodate 75-100 kg tubers in 500 $m^2$ area. Top dressing with urea @5 kg is done at three weeks after planting to get good stem growth. At about 45 days after planting clip off the terminal portion of the stem devoid of roots to a length of 10-15 cm for use as planting material. To enable rapid multiplication, single node cuttings are planted directly in the secondary nursery. Such single node cuttings produce auxiliary shoots within a week.

### Seed village programme (SVP) for chinese potato

The quality of seed is to be maintained by various good agricultural practices at all levels in the supply chain. The availability of quality seed at the proper time determines agriculture growth through accelerated productivity. Seed village programme aims at improving the quality of farm-saved seeds. A village, where in a trained group of farmers are involved in seed production of various crops and serve the essentials of themselves, fellow farmers of the village and farmers of the neighbouring village at an appropriate time and an economical cost is called a seed village. Seed villages for Chinese potato were established by ICAR-CTCRI, Thiruvananthapuram as lead institute with the help of Department of Horticulture, Govt. of Tamil Nadu/KVK, Tirunelveli and Chinese potato growers.

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

A total of 60 farmers were selected during 2018-2019 to 2021-2022 and improved variety of Chinese potato Sree Dhara was supplied to the farmers to prove its technical feasibility and economic viability. Demonstrations under SVP were conducted by a multidisciplinary team from ICAR-CTCRI comprising scientists and technical staff. Quality planting materials and critical inputs were supplied to the farmers for establishing demonstration plots under SVP.

## 2.5 Agro-techniques

### (i) Planting season

The planting is done from July to November depending upon the irrigation facilities. The planting in September has resulted in the production of fairly big tubers. In most parts of the country, it is cultivated in the rainy season as a monsoon crop. The standard plant density is 74000 plants/ha.

### (ii) Land preparation and planting

The soil is ploughed to a depth of 20-25 cm using a mould board plough, repeating this procedure two to three times. Subsequently, this is followed by ploughing with a desiplough, combined with planking. This comprehensive process effectively pulverizes the soil, levels it and conserves moisture content. Before the ultimate ploughing stage, it is essential to broadcast 10 tons of farmyard manure (FYM) or compost per hectare.

The crop is raised both under upland and lowland situations, where there is no water logging. Soil is deeply ploughed to a depth of 15-20 cm so that the soil gets pulverized and levelled. Prepare ridges of 15-30 cm height at a spacing of 45 cm. Plant the stem cuttings of 10-15 cm at a spacing of 30 cm on the ridges either in a vertical or horizontal position. Horizontal planting of stem cuttings to a depth of 4-5 cm and exposing the terminal bud ensures quick establishment and promotes tuber yield. In loose soils having good drainage, planting can also be done on flat beds with proper drainage.

Irrigation is given immediately after planting to ensure adequate soil moisture for establishment of suckers. If sufficient rain is not received supplementary irrigations are to be given for proper growth and development.

## 2.6 Nutrient management

Application of FYM @10 t/ha and NPK @ 30:60:50 kg/ha and incorporate into the soil at the time of land preparation. Top dressing with 30 kg N and 50 kg $K_2O$ at 45 days after planting is recommended to promote good vegetative growth and tuber formation. This is followed by intercultural operations and earthing up of the soil. In case, the soil is very loose and a chance for eroding from the base of the plant, one more earthing up has to be given to promote tuber formation.

The application of these nutrients should be strategically timed to maximize their effectiveness. The entire dose of phosphorus and potash, along with half of the required nitrogenous fertilizer, should be applied as a basal dose. This application should coincide with the final ploughing or ridge preparation ensuring that the nutrients are well-integrated into the soil before planting.

The remaining nitrogen requirement should be applied as a top dressing approximately 45 days after the initial planting, typically during the earthing-up stage. This carefully planned nutrient management strategy contributes to the healthy growth and development of Chinese potato plants, ultimately leading to a successful yield.

### Earthing-up

Another pivotal cultural operation in Chinese potato cultivation is the earthing-up. This practice involves the careful mounding of soil around the root zone, serving multiple purposes. Firstly, earthing-up ensures ample space for the developing tubers, safeguarding them from potential damage caused by rodents and insect pests. Secondly, this operation is typically performed 45 days after planting, coinciding with the top-dressing of nitrogenous fertilizers. It involves covering a portion of the vine with soil facilitating tuber formation and subsequent development. Moreover, earthing-up indirectly contributes to weed control there by enhancing the overall health and yield potential of the crop.

## 2.7 Organic farming

To enhance the organic cultivation of Chinese potato, several key steps can be undertaken. First, it is advisable to raise green manure cowpeas with a seed rate of 20 kg/ha before planting Chinese potato. After 45-60 days, the green matter, approximately 10-15 t/ha should be incorporated into the soil. This not only enriches the soil with organic matter but also enhances its overall fertility.

Opt for organically produced vines of 10-15 cm in length to ensure a healthy start for the crop. Additionally, organic soil enrichment is paramount. At the time of planting, apply well-rotten farmyard manure (FYM) at a rate of 10 t/ha to infuse the soil with essential nutrients. Incorporate neem cake at a rate of 1 t/ha in the ridges during planting for further fortification. These organic practices not only nurture the soil but also contribute to healthier crop development.

At the time of planting the crop consider the application of biofertilizers such as *Azospirillum*, P solubilizer and K solubilizer each at a rate of 3 kg/ha. These biofertilizers enhances nutrient availability in the soil, fostering sustainable growth and minimizing the reliance on synthetic alternatives.

## 2.8 Water management

The irrigation schedule for Chinese potato cultivation is contingent upon both the soil type and the prevailing climatic conditions within the growing area. The crop exhibits a favourable response to consistent and well-managed irrigation particularly during dry seasons. In the nursery, irrigation should be applied immediately after planting and subsequently it is imperative to maintain consistent moisture levels to facilitate optimal growth of the planting material.

In the field, the initial irrigation should be administered either before planting or shortly after planting. This practice significantly contributes to the successful establishment of the crop. In cases where rainfall is sporadic or insufficient, it becomes necessary to irrigate the crop at regular intervals to uphold the ideal moisture content in the field.It is essential to exercise caution, as the plants are vulnerable to waterlogging. Therefore, excessive irrigation should be avoided to prevent waterloggingrelated issues. Moreover, in excessively wet conditions the tubers are susceptible to deformities such as branching which can complicate the peeling process and increase susceptibility to tuber rots. In general the crop typically require irrigation at intervals of 7 to 10 days to maintain the optimal soil moisture levels.

## 2.9 Weed management

Maintaining a weed-free environment in Chinese potato field during the early stages of crop growth is imperative. At this stage, the young plants may struggle to compete with weeds, given their relatively slower growth rate. Therefore, it is essential to undertake a minimum of two shallow hoeings and hand-weeding sessions. These interventions serve the dual purpose of suppressing weed growth and creating an optimal soil environment for tuber development. It is worth noting that as the crop matures into its later stages, the need for weeding diminishes. The robust canopy formed by the mature plants effectively suppresses weed growth. Additionally, the application of light mulch, comprising dried ground leaves, compost or grass proves beneficial in further inhibiting weed proliferation while conserving soil moisture.

## 2.10 Pest management

### (i) Root-knot nematode (*Meloidogyne incognita)*

Root knot nematode is a serious pest of Chinese potato and the infested plants exhibit serious swellings or galls in the roots resulting in suppressed roots, yellowing of leaves, stunted growth, wilting of plants, tuber rot and malformed/small tubers. The nematodes are tiny worms less than one mm long which enter the plant roots when the plant is most vulnerable. Hence, selection of the seed tubers free from nematodes is the foremost step in plant health management. Deep summer ploughing of the field immediately after harvest exposes the soil and kills the nematodes. Cultivation of the sweet potato variety ‘Sree Bhadra’ as a preceding crop in the month of May-June enables the trapping of root-knot nematodes in the soil.

**Management**

- Soil solarisation of nursery beds.
- Selection of nematode-free planting material.
- Burning and destruction of severely infested tubers and plants.
- Use of nematode antagonistic trap crop, marigold and Sree Bhadra (sweet potato variety).
- Use of *Trichoderma* enriched farmyard manure @12 t/ha.
- Use of nematicides like Fluensulfone 2% GR @1 g/plant and Fluopyram 34.48% SC @0.5 ml or Fluensulfone 2% GR per plant.
- Dipping the stem cuttings in insecticide solution *viz.*, Dimethoate or Rogar 30 EC @1.7 ml/l for 10 minutes before planting helps kill the insects.
- Spraying of insecticides is recommended using Fenthion/Fenitrothion 50 EC @1 ml/l for severe damages.

Root-knot nematode attack in Chinese potato

### (ii) The leaf folder (*Spoladea recurvalis*)

This is the most important pest in Chinese pototo, and caterpillars cause significant shoot damage in the crop.

**Management**

- Weed control is the most important requirement for pest management.
- Bacteria, *Bacillus thuringiensis kurstaki* and fungus, *Paecilomyces* can be effectively used for leaf and shoot folder management.
- *Nanma* or neem oil (1%) spray is also very effective.

The leaf folder attack in Chinese potato

### (iii) Aphids (*Myzus persicae*)

Aphids are polyphagous insects that inflict damage on Chinese potato plants by feeding on cell sap from tender parts causing the spread of viral diseases. Severe infestations result in yellowing of the leaves, distortion and formation of necrotic spots. Aphids also excrete a sticky honeydew-like substance that promotes the growth of black sooty mould and other fungal diseases.

**Management**

- Consider using resistant varieties if available.
- Employ silver-coloured plastic mulch to deter aphid feeding.
- In the early stages of infestation, remove infected plant parts or rogue out entire infected plants.
- Apply crop sprays such as 4% neem extract, Malathion 0.1%, monocrotophos 0.04% or methyl demeton 0.025%.
- Encourage natural aphid predators like ladybugs or release parasitoid wasps.

### (iv) Cutworm (*Agrotis spp.*)

Cutworm larvae, typically 2.5-5.0 cm long, attack Chinese potato seedlings at the soil line, causing damage by chewing through stems. At later stages of infestation, irregular holes appear on plant surfaces. These larvae are nocturnal and hide in the soil or plant debris during the day.

**Management**

- Remove all crop residues from the field after harvest or at least two weeks before planting.
- Protect plant stems 7 cm above the soil line with plastic or foil collars extending into the soil.
- Introduce natural predators like ground beetles or parasitic nematodes.
- Physically remove and destroy cutworm larvae after dark.
- Drench the soil with chlorpyrifos 0.1%.

### (v) Thrips (*Frankliniella occidentalis*)

Thrips are small, slender insects that distort leaves and coarse stippling due to their feeding habits. This leads to silvery leaves speckled with black faeces.

**Management**

- Avoid planting the crop near onion, garlic or cereal crops.
- Use reflective mulches in the early growing season to deter thrips.
- Apply crop sprays like Confidor 0.03-0.05%, Regent 0.2% or dimethoate 0.2%.
- Release predatory thrips or lacewings that feed on thrips.

### (vi) Two-spotted spider mite (*Tetranychus urticae*)

Spider mites, appearing as tiny moving dots, damage leaves by mottling and bronzing. Water-stressed plants are more susceptible to their attack.

**Management**

- Rogue out the infected plants from the field.

- Maintain proper irrigation to avoid water stress.
- Introduce natural predators like predatory mites.
- Dust the crop with sulfur at 20–25 kg/ha.
- Apply crop sprays like 0.25% detergent suspension, 4% neem extract, cypermethrin 0.1%, dimethoate 0.2%, quinolphos 0.03% or monocrotophos 0.05%.

### (vii) Leaf-folding caterpillars (*Hymenia recurvalis*)

Caterpillars cause damage by feeding on leaves and folding them, resulting in reduced leaf area and hindering photosynthesis.

**Management**

- Maintain good field hygiene and remove crop debris promptly.
- Implement crop rotation to disrupt the life cycle of caterpillars.
- Apply crop sprays like 5% neem seed kernel extract, 0.03% dimethoate, or 0.04% monocrotophos at recommended intervals.

### (viii) Vine borer (*Nupserha vexator*)

Vine borer grubs bore into stems, disrupting nutrient flow and causing yellowing and drying of leaves.

**Management**

- Employ crop rotation and clean planting material.
- Remove and destroy infested vines and tubers from the field.
- Apply crop sprays like 5% neem seed kernel extract, 0.03% dimethoate or 0.04% monocrotophos at recommended intervals.

### (ix) Tinged bug (*Monanthia globulifera)*

Female-tinged bugs cause damage by sap-sucking, resulting in yellow patches, browning, shrivelling and leaf drying.

**Management**

- Promote natural predators and maintain a diverse ecosystem in the field.
- Apply foliar sprays of acephate, carbaryl, methyl parathion, or phenthoate at 0.05% at recommended intervals.

### (x) Spike borer (*Helicoverpa armigera*)

Spike borer larvae bore into spikes and buds causing damage.

**Management**

- Monitor and scout for early signs of infestation.
- Maintain proper field sanitation.

- Apply two or three sprays of Endosulfan, methyl parathion or Etofenprox at 0.07% at 15-day intervals.

### (xii) Grasshopper (*Chrotogonus sp.*)

Grasshoppers feed during the day, causing irregular holes in leaves and cutting tender shoots.

**Management**

- Apply malathion at 0.1% or carbaryl at 0.2% sprays.
- Utilize 2% neem oil as an eco-friendly alternative.

### (xiii) Mealybug (*Orthezia insignis*)

Mealybugs feed on plant juices by piercing the plant, leading to wilting and reduced growth.

**Management**

- Promote natural enemies like ladybugs and parasitic wasps.
- Use diluted rubbing alcohol or insecticidal soap.
- Apply chemical insecticides when infestations are severe.

## 2.11 Disease management

### (i) Wilt (*Fusarium chlamydosporum)*

In the field, infected plants displayed gradual yellowing, marginal necrosis, and withering of leaves, leading to loss of vigour and premature death. The roots of these plants showed discolouration and complete decay of the tap and lateral root system with the bark peeling off easily. Severe root and collar rot ultimately caused death of the affected plants. The infected tubers exhibited rotting and emitted a foul odour.

Symptoms of *Fusarium* wilt of Chinese potato

**Management**

- Water stagnation in fields may lead to severe infections; therefore, water stagnation in the planted fields should be avoided.
- Neem cake reduces the percent disease index (40-60%) and increases the root yield of the crop.
- Dipping the cuttings in Carbendazim solution (1 g/l) before planting protects the crop from fungal pathogens.
- Chemical fungicides (Benomyl or Carbendazim 0.1%) reduce the disease incidence caused by *Fusarium chlamydosporum* in the crop.
- Inoculation with *Trichoderma* gave the best result in controlling the disease and also resulted in maximum growth and yield of crop.

- *Pseudomonas fluorescens+Trichoderma* combination which reduces the disease incidence by 25-30%.

### (ii) Downy mildew (*Peronospora belbahrii*)

Downy mildew manifests as numerous yellow spots on the upper leaf surface. As the disease progresses, a fuzzy growth forms on the underside of the leaves with infected areas enlarging and developing a tan to light brown papery texture at their centres. Severe infestations result in the yellowing and death of all leaves.

**Management**

- Utilize resistant varieties, if available.
- Implement long crop rotation with cereal crops.
- Opt for disease-free, healthy planting material.
- Maintain wider spacing in well-drained soil.
- Apply crop sprays containing 0.25% Dithane M-45 or Dithane Z-78.

### (iii) Leaf spot (*Colletotrichum* spp.)

Leaf spot symptoms include brown to black spots or patches on leaves, with small clusters of dark fruiting bodies developing as the infection progresses. Infected leaves take on a yellowish-brown hue. Wet conditions intensify disease spread.

**Management**

- Practice field sanitation to prevent disease occurrence.
- Collect and incinerate infected plant debris.
- Employ crop sprays with carbendazim 0.05% or hexaconazole 0.05% at 7-10 day intervals.

### (iv) Rust (*Puccinia sp.*)

Rust, primarily windborne, affects leaves and above-ground plant parts. It presents as small, dusty, bright orange, yellow, or brown pustules on the undersides of leaves, which later wither and detach. Emerging shoots become pale and distorted with large areas of leaf tissue dying and leaves potentially falling.

**Management**

- Adhere to 2-3 years of crop rotation with non-host crops.
- Cultivate resistant cultivars when available.
- Utilize disease-free planting material.
- Subject planting material to hot water treatment at 44°C for 10 minutes.
- Maintain effective field sanitation by eradicating diseased debris and weeds.
- Apply crop sprays with Dithane M-45 0.2% or Bayleton 0.05% at 10-12 day intervals.

## 2.12 Harvesting and yield

Harvesting is done when the leaves and shoots of the plants dry up at 5-8 months after planting. The plant may be uprooted after loosening the base with a pick axe/spade/ hand hoe or any other sharp implements. Harvesting cannot be delayed as the mature tubers deteriorate rapidly if left in the soil, but they can be stored successfully in dry sand or a cool, well-ventilated shed. The tuber may be separated from the plant and the crop residues may be recycled in the field. Tubers resemble potatoes but are smaller in

Chinese potato field

Chinese potato tubers

Harvesting of Chinese potato tubers

size and have an aromatic sweetish flavour. The tuber yield ranges from 20-25 t/ha. The tubers can be used as a potato substitute and are usually cooked in a curry and eaten with rice, but they can also be boiled, baked or fried similar as potato chips.

## 2.13 Post-harvest processing and value addition

Following the harvest of Chinese potatoes and subsequent trimming, it is crucial to undertake a series of steps to ensure the preservation and quality of the tubers. Initially, the removal of soil particles adhering to the tubers is accomplished through thorough washing. Subsequently, non-tuberous components are meticulously separated from the harvested produce.

To enhance the post-harvest quality of Chinese potato tubers, a curing process is employed, typically conducted under shade. This curing period serves the dual purpose of reducing moisture content and facilitating the healing of any injuries or wounds sustained during harvesting and handling.

However, it's important to note that the storage potential of Chinese potato tubers is limited due to the susceptibility to decay caused by pathogenic organisms or enzymatic

deterioration. In traditional farmstead settings, various storage methods have been devised to address this challenge. One effective method involves storing the tubers in sand within well-ventilated sheds or on the ground beneath trees, where cooler conditions prevail compared to open storage. This approach allows the preservation of tuber quality for approximately 2 months without significant deterioration.

Alternatively, sealed earthen vessels or sacks can be employed for tuber storage, using straw as a cushioning material. While this method can extend the storage duration, it may be less effective in regions with hotter climates, where the risk of deterioration increases over time. Careful consideration of these post-harvest management practices is essential to maintain the quality and longevity of harvested Chinese potato tubers.

## 2.14 Post harvest machinery

### Power-operated size based on Chinese potato grader

Grading to uniform sizes will increase the market value both in domestic and export markets. Chinese potato tubers are now graded manually at the farm level. The manual grading process requires more labour as well as more time and expense. As a result, the study was designed to develop a power-operated size-based Chinese potato grader to boost market value and address the concerns identified. A grader for Chinese potato tubers with a capacity of 1 t/hr has been developed by ICAR-CTCRI. The developed Chinese potato grader has three laser-cut rotating drums with holes of various diameters and runs at an optimized speed of 10 rpm. The grader is mainly made up of five parts: a feeding chute, a grading drum, guiding rollers, a collection chute and a power transmission system. The overall dimension of the unit is 1650x600x1200 mm. Chinese

Power operated size based Chinese potato grader

Harvested tubers and different grades of Chinese potato

potato tubers are sorted into four sizes namely small (<20 mm), medium (20.1-30 mm), large (30.1-40 mm) and very large (>40 mm) by the developed grader. The oversized Chinese potato tubers that are greater than 40 mm in size are collected at the other end of the grading drum whereas, the other three grades are collected through the cushioned outlets positioned below the grading drum. It is driven by a 1 HP single-phase electric motor, which includes a 0.5 HP single-phase motor for operating the guiding rollers which rotate at 1100 rpm and are situated in between the rollers to prevent tuber breaking.

The grading efficiency of the developed Chinese potato grader was found to be 96%. Depending on the size of the tuber, the rotating drum can be changed. The developed size-based power-operated Chinese potato grader reduces the drudgery of human labour needed in grading the tubers. The total weight of the machine is 200 kg. The cost required to separate one tonne of Chinese potato tubers was calculated to be Rs.150/- including labour and electricity charges. Thus, it shows that mechanical grading of Chinese potato tubers is ten times cheaper than manual grading that saves money, time and manpower.

## 2.15 Conclusion

Chinese potato is an important minor tuber crop cultivated in India that plays a pivotal role in addressing the challenges of poverty, hunger and food security among farm families. Despite its limited scale this crop has made significant contributions alleviating these pressing issues. To fully harness its quantitative and qualitative yield potential, concerted research efforts aimed at resolving agronomic and storage-health challenges are imperative. This will not only enhance the crop's productivity but also further its role in supporting the food security initiatives. The crop's adaptability to varying soil types and its acceptance as a flavorful tuber vegetable in regions like Kerala and Tamil Nadu has led to its expansion in both laterite and black soils, with irrigation enabling its emergence as a viable commercial crop. The correlation between tuber yield and well-distributed rainfall underscores the importance of climate considerations in its cultivation, emphasizing the need for judicious water management practices to optimize tuber development. In summary, Chinese potato stands as a crop with immense potential to contribute significantly to agricultural sustainability and food security, provided that ongoing research endeavours continue to address its unique challenges and opportunities.

# 3. Arrowroot

Scientific name: *Maranta arundinacea* L.

## 3.1 Introduction

Arrowroot (*Maranta arundinacea* L.) is a perennial plant belonging to the Marantaceae family which grows up to 2 m high with large, fleshy underground rhizomes. The stem is erect. There are 4-8 leaves near the base and 1-8 leaves on the stem. It has large leaves on long stalks near the base. These stalks can be 3.5-20.0 cm long. The leaf blade is 12 cm long and the leaf stalk clasps the stem. The flowers are small and white. There can be several on each leafy shoot. They occur on the ends of branches. There are 1-2 bracts under each 2-3 flowers. The rhizomes can be 20 cm long and about 3 cm wide. They are covered with fleshy scales. The fruits are capsules which are green with a red-brown tinge. They are oval and 7-8 mm long by 4-5 mm wide. The seeds are brown. The valorisation of arrowroot starch is quite widespread, but little explained. The three forms of peroxidises *viz*., SoPOD, IoPOD and CoPOD existed in the arrowroot leaves contributing to the disease and pest-resistant nature of the plant. Arrowroot is considered a rustic, easy-to-grow and low-cost crop. These characteristics occur when the cultivation is handled on a horticulture scale with a less technology.

It is a promising industrial crop fetching fair income to the farmers. The differential importance of arrowroot with starches extracted from other raw materials is connected to its special characteristics, allowing it to reach higher prices in the international market compared with similar starches, which increases the interest of the industrial sector in its production. Popular tradition suggests a great variety of uses for arrowroot starch, which is recommended as a food for convalescent or weak people because of its high digestibility. The fresh rhizome of arrowroot contains about 20% starch, higher than the content observed for sweet potato (14.72%) and lower than that of cassava (31.09%). However, during the starch extraction, whether in industry or the laboratory, the soluble components are lost in the water, leaving the starch with only 1% to 2% of residual amounts of these components. In addition to the starch content other important compounds like lipids and phosphorus are present in the starch of arrowroot so it can be considered a special food ingredient.

Arrowroot field view and tubers

### Nutritional profile of arrowroot

| Particulars | Arrowroot tuber | Arrowroot stem | Arrowroot leaf |
|---|---|---|---|
| Proximate composition (FW) | | | |
| Moisture % (FW) | 72.80 | 82.60 | 72.35 |
| Crude protein (%) | 6.06 | 6.75 | 18.50 |
| Starch (%) | 15.6-18.8 | - | - |
| Polyphenol (%) | 3.26-3.53 | 1.98-2.26 | 2.35-2.56 |
| Crude fibre (%) | 2.31 | 1.88 | 1.72 |
| Crude lipid (%) | 0.08 | 0.06 | 0.05 |
| Ash (%) | 1.86 | 1.74 | 1.68 |
| N & Minerals (DW) | | | |
| N (%) | 1.21-1.285 | 1.02-1.11 | 2.73-2.91 |
| P (%) | 0.42-0.446 | 0.21-0.224 | 0.20-0.214 |
| K (%) | 1.24-1.229 | 1.20-1.313 | 2.03-2.192 |
| Ca (ppm) | 3240-3269 | 4980-5265 | 9760-10191 |
| Mg (ppm) | 3620-2718 | 5670-5931 | 8705-9137 |
| Fe (ppm) | 47.8-51.4 | 133.6-144.9 | 391.8-410.3 |
| Mn (ppm) | 34.2-36.31 | 185.6-192.3 | 249.2-263.9 |
| Zn (ppm) | 44.1 | 78.1-83.5 | 47.4-50.2 |
| Cu (ppm) | 3.2-3.44 | 19.4-20.9 | 23.0-24.7 |
| B (ppm) | 1.81-1.94 | - | - |

## 3.2 Climate and soil

### (i) Climate

Arrowroot cultivation is primarily concentrated in tropical regions across multiple places in India including Uttar Pradesh, Bihar, Orissa, West Bengal, Assam and Kerala. However, it thrives particularly well in Kerala due to its preference for a tropical climate. Arrowroot is characterized by its perennial fibrous starchy rhizome, which produces numerous fusiform fleshy, scaly tubers from its crown. The fleshy rhizome typically white and cylindrical, is covered with regular scale leaves measuring approximately 2.5-5.0 cm in thickness and 20-45 cm in height.

The successful adaptation of this crop is closely linked to hot and humid climatic conditions with optimal growth occurring within a temperature range of 20-30°C and an annual rainfall of 95-150 cm. The consistent moisture supply facilitated by evenly distributed rainfall and brief dry spell periods are essential for achieving a high yield. Arrowroot cultivation thrives in slightly acidic, fertile, deep, sandy loam to loamy soils,

provided proper drainage conditions are met. Partial shade, especially when grown on light soils, is considered ideal for its growth.

### (ii) Soil

Arrowroot cultivation demands specific soil conditions to flourish. Well-drained, slightly acidic loam soils with a pH range of 5.5-6.5 are deemed most suitable for its growth. It can also thrive in sandy soils, provided they possess good water-holding capacity and maintain adequate soil moisture without waterlogging. On the other hand, clayey soils are generally avoided for arrowroot cultivation as they hinder rhizome development resulting in deformities that may cause breakage during harvesting.

## 3.3 Quality planting material production

Arrowroot doesn't set seeds and normally propagates from small pieces of rhizomes 4-7 cm with 2-4 nodes on them known as bits. The 'bits' are sometimes treated with smoke to aid germination. Suckers are also used occasionally for propagation. If suckers are used, preparation of planting material should actually start at the time of harvest of the crop. Suckers are separated from the clump and planted 30-45 cm apart in the nursery during off season. These suckers give rise to new plants which are uprooted and the canopy cut off to retain 10 cm of the shoot intact with roots. Thus the planting material becomes ready. Plant two clumps at a distance of 45 cm. The requirement of planting material is about 3 t/ha which is quite high.

## 3.4 Agro-techniques

Planting usually starts at the beginning of the rainy season, after the soil has been thoroughly ploughed and harrowed to obtain fine filth (forking may be necessary on steep terrain where mechanisation is not possible). Raised flat beds of 15-20 cm in height and convenient length and breadth of 50x50 cm, prepared in the last week of May or in early June depending on the onset of rains, is the ideal one. The bits/suckers each weighing around 25 g are planted 30 cm apart at a depth of 5.0-7.5 cm and covered with soil. An ideal spacing would be 30x15 cm (to accommodate 220000 plants/ha) for obtaining high tuber dry biomass yields to the tune of 13.9 tonnes. Holes about 8-15 cm deep are made and the pieces of tuber are dropped in and covered with soil. The crop must be kept clean-weeded during the first 3 or 4 months and the flowers removed as they appear. Pre-emergence applications of 2,4-D, MCPA, monuron and diuron at the rate of 1.7 kg/ha have been recommended for weed control.

## 3.5 Nutrient management

Arrowroot is a heavy feeder and replenishment of the soil with adequate amounts of organic manures and inorganic fertilizers is inevitable. Application of 10 t/ha of FYM or compost at the time of land preparation is recommended for arrowroot cultivation. Field experiments at ICAR-CTCRI indicated that arrowroot responds to NPK fertilizers

and application of N:$P_2O_5$:$K_2O$ @50:25:75 kg/ha is necessary to produce a higher yield. A full dose of phosphorus is to be applied at the time of planting. Half the dose of nitrogen and potassium should be given one month after planting and the remaining doses of nitrogen and potassium should be given one month later.

### 3.6 Organic farming

A crucial step in organic cultivation of arrowroot involves raising green manure cowpea with a recommended seed rate of 20 kg/ha. The green matter obtained from these cowpea plants approximately 45-60 days after sowing and in quantities ranging from 10-15 t/ha should be incorporated into the soil. This process not only enriches the soil with organic matter but also contributes to improved nutrient availability.

For organic arrowroot cultivation, it is essential to use organically produced rhizome pieces weighing between 20-25 grams. These tuber pieces serve as the foundation for a sustainable arrowroot crop, ensuring that the cultivation process aligns with organic farming principles. To further enhance soil fertility and nutrient availability, organic farming practices recommend the application of biofertilizers at the time of planting. Specifically, *Azospirillum*, P solubilizer and K solubilizer should be applied at the rate of 3 kg/ha each. Additionally, the incorporation of organic amendments is vital for organic arrowroot cultivation. This includes the application of farmyard manure (FYM) @10 t/ha and the use of neem cake at the rate of 1 t/ha in the ridges during planting. These organic inputs not only provide nutrients but also contribute to pest management, aligning arrowroot cultivation with the principles of sustainable and organic farming.

### 3.7 Weed management

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

### 3.8 Pest management

#### (i) Rugose spiralling whitefly (*Aleurodicus rugioperculatus*)

It is a small sap-sucking insect belonging to the order Hemiptera. The adults look like very small moth and have a body length of about 2.5 mm relatively larger than common

Rugose spiralling whitefly attack in arrowroot

Adult of Spiralling whitefly

whiteflies. Adults have a pair of irregular light brown bands across the wings with greyish eyes. The males are slightly smaller than females and have elongated claspers at the distal end of the abdomen. The spiralling of waxy material is the feature from which its common name spiralling whitefly is derived.

Feeding by this pest not only causes stress to its host plant, but the excessive production of wax and honeydew creates an enormous nuisance in infested areas. The presence of honeydew results in the growth of fungi called sooty mold, which then turns everything in the vicinity covered with honeydew black with mold.

**Management**

- Yellow sticky traps can be effectively used for controlling this pest.
- Neem oil and cotton seed oil at 1% (10 ml/l) can cause considerable mortality in the different stages of the pest.
- Imidacloprid 17.8 SL @1 ml/3 l) and Dimethoate 30 EC @ 2 ml/l are very effective as chemical insecticides.

### (ii) Arrowroot leaf spot (*Cercospora apii*)

Arrowroot leaf spot is characterized by the appearance of small, circular irregular spots on the leaves of arrowroot plants. The spots may initially be light brown but can darken over time, turning dark brown or black. Severe infections can lead to extensive defoliation and reduced plant vigour.

**Management**

- Sanitation: Remove and destroy infected plant debris to reduce the source of inoculum and prevent the spread of the disease.
- Crop rotation: Avoid planting arrowroot or related crops in the same area for consecutive seasons to minimize disease build-up in the soil.
- Proper irrigation: Avoid overwatering and maintain good drainage to prevent conditions favourable for disease development.
- Fungicide application: In severe cases, the use of triazole fungicides can help control leaf spot disease.

## 3.9 Harvesting and yield

The tubers become ready for harvesting 10-11 months after planting. Plants are dug up manually and tuber are separated from the plants. The yield of tuber ranges from 12-31 t/ha and the normal commercial yield of starch is 8-16%. Tuber yield of 35.7-40.7 t/ha was reported in Kerala. The low production is a consequence of lack of the latest agro techniques with producers. As there is no seed setting reported in the crop, the possibilities of the presence of natural hybrid and propagation of the hybrid varieties

are practically absent. Intercropping arrowroot in coconut, arecanut and rubber also augments the net income from these plantations.

### Storage

A tuber that is fleshy, cylindrical and covered with regular scales is the main product and grows to approximately 2.5 cm thick and 20-45 cm long. Rhizomes are ready for harvesting when the leaves wilt and die down. At this stage, the plants are usually dug up by hand using some hand tools and the rhizomes are separated from the leafy stem. Once harvested, deterioration is rapid and the rhizome must be processed within 2 days.

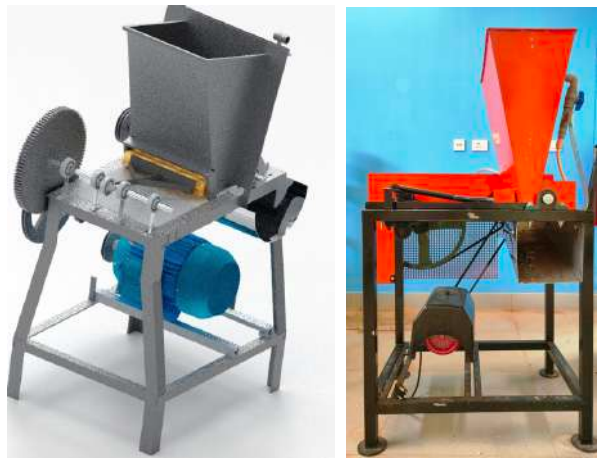
## 3.10 Processing and value addition

The tuber are used for the production of a very fine, easily digested starch, which appears on world markets as a dry white powder known as arrowroot starch. It is valued as a foodstuff, particularly for infants and invalids and is used in biscuits, cakes and puddings. Arrowroot tuber are eaten as a secondary staple or vegetable after boiling or baking. The leaves are occasionally used as local packing material.

Arrowroot starch is one of the purest forms of natural carbohydrate with a high viscosity that is hampered by the salinity of the processing water. Arrowroot starch is a commercially underutilised tuber starch with potential digestive and medicinal properties. Arrowroot starch possesses demulcent properties and is used in the treatment of disorders of the intestine. The starch is mostly utilised as a functional food. Local farmers consume arrowroot starch dissolved in milk or warm water for instant energy during diarrhoea and other stomach ailments. It may also be employed in the manufacture of tablets where rapid disintegration is desirable. The starch is also used as a base for talcum powders, in the preparation of certain specialised glues and, more recently, in the manufacture of carbonless paper for computers. Starch can be produced from arrowroot tuber either on a small or large scale.

**(i)Small-scale processing**

At present, in Odisha, only arrowroots are used for processing into starch. In this process, the tubers are washed and the skin scales are carefully peeled from the white fleshy core, otherwise, they impart a bitter taste to the final product. The peeled rhizomes are washed again and grated into a coarse pulp using an arrowroot starch extractor developed by ICAR-CTCRI. The rasping efficiency of the machine is



Arrowroot starch extractors

25 kg/hr, whereas in the traditional method it is 1 kg/hr. The starch recovery is 20% compared to 10-12% for the traditional method. Apart from reducing drudgery, the machine is used to produce good-quality starch. The pulp is mixed with a large quantity of clean water and the mixture is passed over a series of sieves to separate the fiber. The liquid is allowed to stand and the starch to settle out on long tables. The starch is removed from the tables mixed with more water and resettled overnight. The lumps of starch are placed on racks to air-dry, a process which can take from 3-4 days according to the weather; slow drying can result in the material becoming discoloured. After drying, the lumps of starch are pulverised and prepared for marketing in different grades according to viscosity ratings. The pulverised fine starch is stored in moisture-proof bags.

**(ii) Large scale processing**

In this process, on arrival at the factory, the rhizomes are first thoroughly washed in special tanks. They are then cut into small pieces, rasped and crushed into a pulp using an arrowroot starch extractor developed by ICAR-CTCRI. The pulp is passed in a continuous flow of water into a series of three vibratory sieves. The starch milk then passes to the separator. The residues remaining on the sieves are crushed and sieved twice more to effect the maximum extraction of starch. The resultant starch milk is passed to the separator. The separator divides the starch from the water within 4 min and it is next mixed with fresh water, passed through a fine sieve of 120 mesh wire cloth and re-centrifuged. The starch is then mixed with fresh water and fed into settling tanks. After the starch has settled, the supernatant liquid is run off and the upper layers of sediment are washed away by vigorous hosing to remove as much as possible of the residual fibrous tissue. The starch is then mechanically dried at 55-60°C for 2-3 hrs to a moisture content of 14%. To be commercially marketed in India, arrowroot starch must comply with IS 1006:1984. The fibrous material left over after arrowroot starch extraction, known as *thippi*, can be utilised as cattle feed or manure.

Arrowroot starch

Arrowroot starch in granular form

**(iii) Arrowroot extrudate**

Extrusion cooking is now employed for the manufacturing of a wide range of food products, from simple extended snacks to highly processed meat analogues. Extrusion cooking is accompanied by the breaking of intermolecular hydrogen bonds, which results in starch gelatinization. It significantly increases water absorption, including starch granule

Arrowroot extrudate

breakdown. Arrowroot starch extrudate can be produced using a twin-screw food extruder by varying the moisture content from 12-16% and extrusion temperatures from 140-190°C. The physical and functional properties of arrowroot starch extrudate found that the expansion index of the product varied from 3.22-6.09%. The water absorption index ranged from 6.52-8.85 g. $g^{-1}$ the solubility index from 15.92-41.31% and the oil absorption index from 0.50-1.70 g. $g^{-1}$. The hardness and toughness of the extrudates were higher at higher feed moisture and lower extrusion temperature; whereas increased snap force and energy were obtained at lower feed moisture and temperature. The percentage digestibility of arrowroot starch extrudates varied from 25.27-30.56%.

## 3.11 Economics and marketing

Due to its rich nutritional content, it is given to babies as a substitute for breast milk or as a nutritional supplement after weaning. Arrowroot is available in the market in the form of flour and tubers. Both food and non-food industries are dependent on the market. The arrowroot market is traded in the food, medicinal, nutritional and beauty sectors, both conventionally and organically. Arrowroot flour is used as a raw material of many medicines and beauty supplements, which has many medicinal properties. It also comes with Arrowroot flour as the main ingredient used for the production of cakes, puddings, fruit preserves and jams. Mainly the medicinal value increases the marketability of Arrowroot species. As the health conscious population prefers nutritious food items, the market for gluten free arrowroot starch continues to grow. Hence, research in this crop is gaining importance. The arrowroot market is expected to grow at a rate of 3.5% to reach a market size of $3.62 billion by 2032.

## 3.12 Conclusion

Arrowroot, with its diverse varieties and myriad applications, is a botanical treasure with immense economic significance. From its culinary uses to its medicinal properties and beyond, this unassuming plant has the potential to impact various industries and improve lives worldwide. Its resilience against pests and diseases, coupled with its adaptability to different climates, underscores its value as a sustainable crop. Arrowroot may play a vital role in our diets, our health and our industries, offering us an arrow pointing towards a more sustainable and prosperous future.

# 4. Yam bean

Scientific name: *Pachyrhizus erosus* (L.) Urban

## 4.1 Introduction

Yam bean (*Pachyrhizus erosus* (L.) Urban) is a legume cultivated for its large tuberous roots. The yam bean appears to have originated in Mexico and northern South America, in the hot moist region of the Amazon and was cultivated there in pre-Columbian days. It is also called 'Potato bean' in English though the name yam bean is quite common. The most popular name in Hindi is 'Mishrikand'. It is commonly called 'Sank alu' or `Sankehalu' in West Bengal, Assam and Orissa. Yam bean is a starchy root crop with comparatively high sugar content and a moderately good source of ascorbic acid. It is a hairy twining herbaceous plant woody at the base trailing or climbing to about 6 m. The leaves are alternate, trifoliate with petioles 3-18 cm long and ovate or rhomboidal leaflets which are toothed or lobed, about as broad as long, usually large, in the range of 4-20 cm. The flowers are in long axillary racemes, 1-5 borne in each of several clusters along the peduncle; the petals are violet or white, 1.5-2 cm long and broad. The pods are 7.5-15 cm long and about 1.5 cm broad, flattened, almost smooth at maturity, containing 4-12 seeds which are yellow, brown or red, almost square and flattened, 5-10 mm in diameter. Tuberous roots, frequently turnip-shaped are borne at the base of the stem and may be solitary or several, simple or compound, normally they are about 10-15 cm in diameter. The pods are toxic when mature but can be used as a vegetable when young. The plant is a climbing vine with flat, kidney-shaped seeds and the tubers range in weight from 0.5-2.5 kg. Its white/blue flowers are often removed (a process known as reproductive pruning) to increase the yield and biomass of the tubers.

In India, tender tubers resembls Chinese water chestnut in taste. Juvenile tubers are crisp, juicy and sweet, while older ones turn fibrous and unsuitable for consumption. Tubers hold over 72% water, 5% protein, 19% starch and 5-6% sugar. It is used in salads for dieters due to their high water content, low calories and bulkiness. They are consumed raw or cooked, such as pickles or chutney in Latin America. China employs dried mature tubers to cool feverish individuals. In many nations, young pods serve as vegetables. Tough, fibrous stems craft fish nets in Fiji. India consumes young tubers with unexploited potential for other uses. Seeds contain ample alkaloids and insecticidal traits making them natural insecticide for cultivation.

Flowering twig and tubers of Yam bean

### Nutritional profile of Yam bean

| Particulars | Yam bean tuber | Yam bean stem | Yam bean leaf |
|---|---|---|---|
| Proximate composition (FW) | | | |
| Moisture % (FW) | 72.88 | 79.03 | 60.15 |
| Energy (kJ/100g) | 158.992 | - | - |
| Crude protein (%) | 4.88 | 9.88 | 28.81 |
| Starch (%) | 17.2-18.51 | - | - |
| Polyphenol (%) | 3.26-3.53 | 1.98-2.24 | 3.26-3.53 |
| Crude fibre (%) | 1.76 | 1.62 | 1.57 |
| Crude lipid (%) | 0.08 | 0.04 | 0.05 |
| Ash (%) | 1.92 | 1.84 | 1.82 |
| N & Minerals (DW) | | | |
| N (%) | 0.78-0.842 | 1.58-1.7 | 4.61-4.92 |
| P (%) | 0.13-0.139 | 0.30-0.324 | 0.46-0.482 |
| K (%) | 0.55-0.97 | 1.80-1.936 | 1.45-1.564 |
| Ca (ppm) | 2940-2998 | 6800-7226 | 3650-3902 |
| Mg (ppm) | 1330-1400 | 5085-5269 | 9485-9900 |
| Fe (ppm) | 81.8-87.9 | 198.2-211.7 | 363.8-395.2 |
| Mn (ppm) | 20.2-21.63 | 84.4-85.2 | 209.4-225.7 |
| Zn (ppm) | 19.4 | 66.4-70.7 | 72.8-78.1 |
| Cu (ppm) | 59.6-62.82 | 22.8-24.0 | 23.0-24.7 |
| B (ppm) | 2.46-2.67 | - | - |

## 4.2 Varieties

Edible tuberous roots of yam bean are napiform i.e. turnip shaped and are borne singly or in clusters of 3-4 at the base of the stem. The Mexican types are larger and attain a diameter of 10-15 cm and weigh up to 1.5-2.0 kg/tuber. But they tend to crack off the skin and are less sweet. Due to these reasons, Mexican cultivars are not preferred in the Indian market. The local cultivars have smaller sizes, moderate to high sweetness, less fibre, conical shape, white flesh and are soft with creamy skin.

### Rajendra Mishrikand-1 (RM-1)

The variety known as Rajendra Mishrikand-1 is a significant achievement in the yam bean variety generation. It was introduced in 1992 as the first variety for commercial cultivation by Rajendra Agricultural University, Bihar as part of the All India Coordinated Research Project (AICRP) on Tuber Crops. This variety which was a seedling selection from the Mexican line-29 is well-suited for kharif crop cultivation in regions such as

North Bihar and West Bengal. The plant is characterized by its sprawling vines decked with yellowish-green leaves. This variety has a maturity period of 120-135 days producing shallow-rooted, fleshy and juicy tubers. These tubers have a spherical upper part that swells along with a sharply tapering lower section and typically produce 2-3 tubers per plant. Individual tubers weigh approximately 0.6-0.7 kg each and stand out for their enhanced sweetness and resistance to cracking. They possess smooth, cream-coloured skin, and their napiform shape adds to their visual appeal. The pleasant white flesh within further enhances their desirability.

The tubers themselves are notable for their round conical shape, white colour, and remarkable combination of sweetness, taste, and low fiber content. The pods are suitable for consumption in their raw state and also serve as a source of seeds used in biopesticide formulations to combat leaf-feeding pests due to their rotenone content in mature stage. It offers an impressive yield potential, averaging between 30-35 t/ha of marketable tubers. This yield is double that of indigenous cultivars and it can reach up to 45 t/ha. Furthermore, it has a shelf life of 8-10 days.

In terms of pest resistance crops grown for tuber purposes with this variety are generally free from infestations or only with mild mosaic symptoms. Additionally, RM-1 is well-suited for intercropping with kharif maize and arhar providing opportunities for diversified agricultural practices. In North Bihar, this variety has gained significant popularity and is preferred over local cultivars due to its exceptional attributes and productivity.

## 4.3 Climate and soil

### (i) Climate

Yam bean requires a hot humid climate and it adapts well in subtropical and hot temperate zones. The basic requirement is frost-free condition during the growth period. It grows up to an altitude of 1000 m. It has been observed that thermoperiodism has a definite effect on tuberisation. Though yam bean requires 14-15 hours of photoperiod for good vegetative growth, shorter days are required for better tuberisation. Hot days and cooler nights are suited for good tuberisation. A well-distributed rainfall during the growth period is required for optimum tuber yield. Excessive rain is harmful to the crop. Cool climate during the early growth period adversely affects the initiation of tuberization and also results in a prolonged vegetative phase.

### (ii) Soil

Cultivating yam bean thrives in fertile sandy loam soil, although it can adapt to loamy and clay loam soil types, especially if they have good drainage and humus content. Water logging can have adverse effects on yam bean growth. The ideal soil pH ranges from 6-7.

## 4.4 Quality planting material production

Yam beans are typically cultivated from seeds, and the required seed rate is contingent upon the chosen spacing configuration, which, in turn, is determined by the intended purpose of cultivation. Under normal circumstances, the recommended seed rate falls within the range of 20-60 kg/ha, contingent on factors such as the timing of seed sowing, the selected spacing, and the cultivation objectives. Alternatively, yam beans can be propagated from sprouted roots of previously grown crops, a method employed to preserve specific plant characteristics. However, it's important to note that yam beans, belonging to the Papilionaceae family, often undergo self-pollination, although the practice of cultivating them from sprouted roots is not common in our country.

For optimal growth, yam bean seeds can be sown on mounds, typically at a rate of 3-5 seeds/hill. It is crucial to utilize disease-free seed materials for planting, and rigorous field sanitation practices should be observed to eliminate infected or self-grown plants, which should be promptly incinerated. Additionally, an effective insect control strategy is advised, with the application of suitable pesticides such as Profenophos 50 EC@ 2 ml/l, Dichlorvos 76 EC @2 ml/l, Acephate 75 SP @2g/l, Chlorpyriphos 20 EC @2ml/l, Imidacloprid 17.8 SL 0.5 ml/l, Thiamethoxam 25 WDG @0.5 g/l at 15 days interval for control of insect.

## 4.5 Agro-techniques

Yam bean is typically planted between June and July when the monsoon rains commence. Harvesting usually takes place from December to January with the peak harvest period occurring from late January to February. The timing of seed sowing varies from June to September depending on the intended purpose of the crop. For seed production, the recommended sowing time is June-July with a planting spacing of 30x30 cm. Alternatively, for obtaining smaller tubers which align with current market preferences sowing can be carried out in August-September with closer spacing options of 30x15 cm or even 15x15 cm

The seeds are normally sown at the beginning of the rains, either on the flat or in ridges, the latter gives better results. Usually, 2-3 seeds are placed in each hole and the plants are thinned out as necessary or the seeds may be planted singly by the drill. The provision of bamboo trellises about 2.5 m high to support the vines has been found beneficial but is not essential. The crop is kept free from weeds and is often mulched to help conserve soil moisture and prevent weed growth. Sometimes the plants are stopped or pruned to encourage vegetative growth and the removal of the flowers is reported to increase tuber yields and improve their flavour. Field spacing-recommended seed spacing for India is 15 cm along rows 50 cm apart, a spacing of 10 cm in rows 15-20 cm apart is common practice, although it has been shown experimentally that the yield of roots doubled when a spacing of 15x15 cm was used. In India, a higher seed rate of 50-70 kg/ha is practiced depending on the time of sowing of seed, spacing and the purpose.

The crop normally reaches maturity in 5-8 months, although in the warmer areas, a commercial crop is obtained in about 3 months. Late sowing of the crop in September and subsequent harvesting in December-January results in a comparatively lower yield due to the smaller size of the tubers. However, these tubers are devoid of cracking and are well-suited for integration into various multiple cropping systems, due to their shorter growth cycle.

Inflorescence, tubers and seeds of Yam Bean

### Intercultural operations

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

The flowering stage in yam bean typically commences around 75 days after sowing. To optimize tuber yield, it is advisable to remove the flowers and prevent the plant from bearing pods. This practice is supported by a significant negative correlation between tuber yield and the duration of flowering and pod formation. Manual removal of buds is the conventional method; however, an alternative approach involves the application of 2,4-D (at 50ppm) during the flower initiation stage, which induces flower dehiscence and leads to improved tuber yield. The cost associated with manual deflowering is approximately 1.5-2 times higher than that of using 2, 4-D.

## 4.6 Nutrient management

Yam bean plants exhibit a preference for soil with moderate fertility levels, as soil rich in nitrogen can lead to excessive vegetative growth, while insufficient potassium levels can adversely affect tuber growth and quality. To optimize the soil conditions for successful yam bean cultivation, it is recommended to incorporate well-decomposed farmyard manure at a rate of 10-20 t/ha during the land preparation phase. Additionally, a balanced application of essential nutrients is crucial. Specifically, nitrogen should be applied at a rate of 40 kg/ha, phosphorus at 40 kg/ha and potash at 80 kg/ha. It is important to note that the entire dose of phosphorus and potash, along with half of the nitrogen fertilizer, should be thoroughly integrated into the soil before sowing the yam

bean seeds. The remaining half of the nitrogen should be provided as a top dressing approximately 40-45 days after sowing to ensure optimal growth and development.

### 4.7 Water management

The specific water requirements of a crop are contingent upon the prevailing soil type and climatic conditions within its cultivation region. When planting seeds in arid soil, it is crucial to initiate the first irrigation immediately after sowing to induce growth. Once the crop has taken root and it becomes imperative to maintain optimal soil moisture levels. Caution should be exercised to avoid over-irrigation, as an excess of soil moisture can make the crop susceptible to fungal infections. However, for crops sown in September it becomes essential to implement a regular irrigation schedule to ensure the soil maintains sufficient moisture levels for the proper development of tubers. Mulching the crop is an additional measure to conserve soil moisture.

### 4.8 Weed management

Early-stage weed control is crucial to mitigate competition for nutrients, moisture, space, and sunlight between yam bean and weeds. Manual weeding should be conducted at least twice within the first couple of months. Furthermore, the practice of mounting up soil on both sides of the ridges is essential to provide adequate space for tuber growth and protection from rodents and insect pests. This operation indirectly aids in weed control within the yam bean field. Another vital intercultural operation is reproductive pruning, aimed at maximizing yam bean yield by reducing excessive flowering. The efficacy of this operation varies with cultivar, season and climate with some regions opting for not only the removal of reproductive shoots but also pruning the top half of the vegetative part. In most cultivars two rounds of reproductive pruning suffice to ensure a favourable yield.

To effectively combat weeds, it is recommended to initiate the first interculturing process approximately 40 days after sowing. During this operation, the remaining half of the nitrogen dose should also be administered and earthing up should be carried out as needed. A second weeding session is advisable 30 days following the first one, ensuring that the field remains devoid of weeds.

### 4.9 Pest management

#### (i) Spotted pod borer (*Maruca vitrata*)

The Spotted pod bzorer, known as *Maruca vitrata*, poses a significant threat to yam bean and is recognized as a serious pest in tropical regions. Its destructive impact is primarily directed towards various parts of the yam bean plant.

The larvae of this pest exhibit a voracious appetite for flowers, buds, and young pods, often weaving webs around them. They penetrate the pods and consume the young immature seeds. Indicators of their presence include the presence of small holes in flower buds, flowers and pods which can result in yield losses ranging from 20% to a staggering 80%.

**Management**

- Damaged pod and larvae removal: It is essential to promptly collect and destroy pods and larvae that have been damaged by the spotted pod borer.
- Chemical control: To minimize the population of the borer, the crop can be sprayed with either dimethoate at a concentration of 0.05%, tobacco decoction at 3%, Yam bean seed extract (YBSE) (5%) or neem oil at 3%.
- Biological control: Nuclear polyhedrosis virus (NPV) belonging Baculoviridae is used to infect the larvae making it fragile by losing its appetite. Dead larvae hang from the top of plant and called "Treetop Disease" phenomenon.

### (ii) Hairy Caterpillar (*Ascotis imparata* and *Spilosoma obliqua*)

Hairy caterpillars, specifically *Ascotis imparata* and *Spilosoma obliqua*, lay their eggs in clusters on the leaf surfaces. During their early gregarious stage these caterpillars feed on the green portions of the leaves often resulting in skeletonization. In severe cases this feeding can lead to defoliation significantly impacting overall plant growth.

**Management**

- Early larvae removal: Timely action involves collecting and eliminating the larvae during the early stages of crop growth.
- Chemical control: Crop spraying is recommended with pesticides such as Quinolphos at 0.05% Endosulfan at 0.2%, Monocrotophos at 0.15%, or Fenvalerate at 0.05% with intervals of 10-12 days between applications.

### (iii) Root knot nematode (*Meloidogyne arenaria*)

Root-knot nematodes particularly *Meloidogyne arenaria*, are widely distributed and polyphagous pests in the country. Infected yam bean tubers often exhibit wart formation and acquire a bitter taste. This nematode infestation leads to reductions in both tuber yield and quality, ultimately affecting marketable yield. Above-ground symptoms include foliage discolouration, dwarfing of plants and wilting.

**Management**

- Crop rotation: Implement a rigorous crop rotation plan with non-host crop species.
- Neem cake application: Apply neem cake in conjunction with recommended fertilizers.
- Nematicide use: Consider soil application of nematicides such as Furadon at 20 kg/ha or Cadusafos at 1% as part of the nematode control strategy.

### (iv) Rose beetle (*Adoretus versutus*)

The adult beetle feeds the leaflets and causes depressions in the feeding area. This causes tarnished leaves and reduces the yield.

**Management**

Cultural methods: Damage from beetles could be prevented by putting structural barriers such as coconut fronds or bamboo fences around the plant at least as high as the plant. Handpicking adult beetles under lantern light is also done, which would reduce the chances of transversing the soil surface and attacking the host plant.

## 4.10 Disease management

### (i) Rust (*Phakopsora pachyrhizi*)

Rust caused by *Phakopsora pachyrhizi*, is a highly concerning disease with symptoms predominantly appearing on the leaves and other above-ground parts of the yam bean plant. Infected leaves exhibit the formation of small, round reddish-brown rust pustules on their lower surfaces which eventually lead to wilting and shedding.

**Management**

- Crop rotation: Implement a rotation strategy with non-host crops spanning at least 3-4 years, to break the disease cycle.
- Early maturing cultivars: Opt for early maturing cultivars that can potentially avoid rust infestations until the harvesting stage.
- Field sanitation: Maintain excellent field hygiene by promptly disposing of diseased debris and managing weed growth.
- Chemical control: Employ regular crop spraying with Dithane M-45 at 0.2% and Bayleton at 0.05% adhering to 10-12 day intervals.

### (ii) Sincama mosaic virus

Sincama mosaic virus is the most severe viral ailment affecting yam bean. Symptoms include irregular chlorosis on leaves, increased brittleness in young shoots, and a reduction in seed set due to diminished pollen fertility. This viral infection significantly impacts both tuber yield and quality. Disease transmission is primarily attributed to mechanical wounding and insect attack, with aphids and potentially spider mites serving as vectors.

**Management**

- Plant removal: Eliminate all infected yam bean plants and weeds from the field to prevent disease spread.
- Granule application: Apply Disulfotan or Phorate 10G granules at 1.5 kg/ha during the seed sowing stage.
- Vector control: Implement regular crop spraying with Monocrotophos at 0.05% or dimethoate at 0.05% at intervals of 10–12 days to manage disease-transmitting vectors.

### (iii) Witches' broom disease

Witches' broom disease is likely caused by mycoplasma-like organisms and manifests through excessive branching, dwarfed leaves and flower deformities. Although transmission via sap inoculations is unknown there are evidences suggesting possible transmission by sucking insects such as whiteflies *(Orosius argentatus*), aphids and mealybugs.

**Management**

- Soil treatment: Apply Carbofuran, Fensulfothion, or Disulfotan at 1.5 kg a.i/ha in the soil during sowing.
- Plant removal: Promptly remove infected plants upon detection.
- Vector control: Employ regular crop spraying with Monocrotophos at 0.05% or dimethoate at 0.05% at 10-12 day intervals.

### (iv) Yam bean mosaic virus (YBMV)

Yam bean mosaic virus (YBMV) primarily spreads through aphids, acting as vectors that transmit the virus from infected to healthy plants. YBMV can cause substantial harm to yam bean crops, resulting in reduced yield and quality. Symptoms include mosaic patterns on leaves with light and dark green patches, yellowing, distortion, stunted growth and reduced yield.

**Management**

- Use virus-free planting material: Commence yam bean cultivation with certified virus-free seeds or cuttings to prevent virus introduction.
- Aphid control: Implement strategies to control aphid populations, such as insecticide use, physical barriers like mesh netting or companion planting with aphid-repellent plants.
- Sanitation: Remove and destroy infected plants to eliminate virus sources and aphids. Address nearby weed hosts that can harbour both the virus and aphids.
- Crop Rotation: Practice crop rotation to disrupt the disease cycle, avoiding consecutive plantings of yam beans or susceptible crops in the same area.

Yam bean mosaic virus (YBMV) infection in leaves

## 4.11 Harvesting and yield

Yam bean will be ready for harvest 150 days after sowing. It can be harvested early according to demand in the market to get smaller-sized tubers. If harvesting is delayed, then the chances of cracking of tubers are more. This in turn results in the deterioration of tuber quality and thereby affects market value. Give a shallow irrigation just before digging the tubers manually. Remove or trim the above-ground portions and dig out the tubers. Harvested tubers can be stored for 2-32 days without any deterioration. If the tubers are stored for a longer period, the creamy colour of the skin changes to purplish brown and loses water which causes weight reduction. To delay the harvesting leave the crop in the soil without removing the top portion. The seed crop is usually harvested 240 days after sowing i.e. during March-April. Harvest the seed pods when they start drying and thrash them by beating them with sticks. The average yield of local cultivars is 18-20 t/ha while that of improved varieties like Rajendra Mishrikand-1 is 36-40 t/ha. With improved cultivation practices it is possible to get a yield of 40-45 t/ha and a net profit of Rs. 12000-15000/ha.

In the post-harvest phase of yam bean cultivation, a series of essential operations are performed to ensure the quality and preservation of the harvested tubers. These operations includes washing, trimming (which involves the removal of the non-tuberous portion of the root and the basal part of the stem) and immersion in a high-concentration chlorine solution. This chlorine treatment serves a dual purpose by sterilizing and imparting a bleaching effect to the tubers.

Once the tubers have been meticulously cleaned of adhered soil particles and subjected to curing in the shade, they are packed in sturdy jute sacks. It is worth noting that these tubers can be stored for duration of 1-2 months, ideally maintaining a temperature range of 12-16°C. It is imperative to avoid subjecting the tubers to colder temperatures, as this can result in damage. Refrigeration should be strictly avoided. It is important to check the tubers in storage periods as they can lead to an alteration in the starch-to-sugar ratio within the tubers. Over time, there is a shift from higher starch content to increased sugar content, which may impact the desired quality of the yam bean tubers.

## 4.12 Processing and value addition

*P. erosus* presents possibilities for various industrial applications, such as the development of processed tuber products and snacks, provided methods to preserve their crisp texture are developed. In India, Yam bean tubers are used to produce high-quality flour. While rotenone is mainly used in flea powders, plant protective agent and in the treatment of eutrophic lakes need further exploration. As a cost-effective crop protection measure, it holds promise for producers in developing countries.

The yam bean flour has remarkably low moisture content, a critical attribute that ensures an extended and dependable shelf-life for the product. In addition to its moisture content,

the low-fat content of this flour plays a pivotal role in mitigating the risk of oxidation, effectively preventing the development of off-flavours stemming from rancidity. The low moisture and fat content makesyam bean flour an ideal choice for health-conscious individuals. Furthermore, the notable high protein content of yam bean flour renders it exceptionally suitable for incorporation into weaning foods for infants, while its high sugar content, lower pasting characteristics, and exceptional water-holding capacity make it a superior choice for the production of infant supplement foods. These highly desirable attributes collectively make this flour a versatile ingredient, apt for either partial or complete substitution of traditional flours in the creation of various flour-based food products.

The utilization of processed yam bean roots, primarily in canned form, is steadily gaining popularity both as a standalone starchy food and as a viable alternative to Chinese water chestnuts. When considering the suitability of yam beanroots for processing, it is important to note that very large tubers tend to possess a woody texture and are unsuitable for culinary applications. Instead, roots with approximately 10 cm in diameter and a weight of around 1 kg are the preferred choice. Thick layers of fibrous material that prove difficult to remove through mechanical means. However, a practical solution exists in the form of immersion peeling, which involves soaking the roots for approximately 10 minutes in an 18 percent sodium hydroxide solution heated to a range of 95-99°C. This method effectively addresses the fibrous material, albeit with a side effect of surface discolouration on the peeled roots can be remedied through a subsequent bleaching process with hydrogen peroxide.

*Pachyrhizus,* like other legumes forms a beneficial symbiotic relationship with nitrogen-fixing bacteria such as *Rhizobium* and *Bradyrhizobium*. These bacteria provide a natural source of nitrogen for the plants, reducing the need for additional nitrogen fertilizers. Moreover, a significant portion of the fixed nitrogen is returned to the soil when the vegetative aboveground parts of the plant are left in the field. This characteristic makes *Pachyrhizus* an integral component of sustainable land-use systems, both ecologically and socioeconomically. Research efforts have focused on enhancing biological nitrogen fixation by selecting *Pachyrhizus* genotypes and bacterial strains with high nitrogen-fixing potential particularly for use by farmers in developing countries.

Studies have quantified the amount of nitrogen fixed by various *Pachyrhizus* species. For instance, field tests conducted by Castellanos *et al*. found that *P. erosus* fixed 162-215 kg N/ha. In the case of *P. erosus,* approximately 50% of the harvested nitrogen, approximately 130 kg/ha, accumulated in the tuberous roots, equivalent to nearly 800 kg of protein/ha. This quantity rivals or surpasses the protein yield of grain legumes. Furthermore, the residue (hay) of *P. erosus* contained 120-150 kg/ha of nitrogen higher than most grain legumes. It's worth noting that both species were reproductively pruned in these trials.

Another common characteristic of *Pachyrhizus* species is the presence of rotenone which is an insecticidal compound primarily found in mature seeds. However, the tuber and other parts of the plant do not contain toxic levels of rotenone. The insecticidal properties of yam bean seeds, pods, stems and leaves have been extensively studied, with the potential for commercial or local use as insecticides. Additionally, rotenone and rotenoids in seeds and leaves may serve as protective compounds against insect predators, offering ecological advantages. Recent studies have explored the extraction of rotenone and rotenoid from callus cultures indicating the potential for renewed interest in exploiting the insecticidal properties of yam bean seed.

## 4.13 Conclusion

Yam bean's carbohydrate content, encompassing sugar, starch and dietary fiber, makes it a substantial energy source. Moreover, it has an array of essential nutrients, including potassium, vitamin C, calcium, iron, niacin, riboflavin and thiamine while maintaining low levels of protein, lipids, saturated fat, cholesterol and sodium. The unique sweet and starchy flavour attributed to the presence of oligofructose inulin (fructo-oligosaccharides), not only adds to its palatability but also serves as a prebiotic, fostering the growth of probiotics in the digestive system. These healthful qualities, combined with its abundant dietary fiber and mineral content, contribute to a range of potential health benefits, including weight management, enhanced immunity and improved digestive, circulatory and nervous system functions. In essence, yam bean stands as a versatile and nutritious addition to the diet offering both culinary enjoyment and potential wellness advantages.

Minor Tuber Crops for Food, Health, Wealth and Prosperity

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