CASSAVA

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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From the Director

Cassava (*Manihot esculenta* Crantz) is an important tropical tuber crop and ranks fourth in the world, after rice, wheat and maize, as a source of calories for human consumption. It is a major carbohydrate food for 800 million people in the world, and in Africa, it is the most important source of calories in the human diet. In India, it is mostly cultivated in Kerala, Tamil Nadu, Andhra Pradesh, Karnataka and north eastern states. It is consumed as freshly cooked tubers, and is also used in animal and poultry feed. Cassava is the source of raw material for a number of industrial products such as starch, flour and ethanol. It is a resilient crop and can thrive in diverse agro-ecological regions, especially in poor and marginal soils and low rainfall and high temperature zones. Among the tuber crops, cassava is a crop for adversity, food-cum-nutritional security and a future crop or climate-smart crop.

ICAR-CTCRI, established in the year 1963, is celebrating its 60 years of service to the nation. It is a research organization of global repute, dedicated to the R&D of 15 tropical root and tuber crops. A retrospection @ 60 indicates its rich legacy and contributions by way of 71 improved varieties, a number of potential technologies on production, protection, pre- and post-harvest processing, value addition, smart farming etc. In India, cassava is cultivated in an area of 1.83 lakh ha with a production of 69.40 lakh tonnes. It is important to note that though cassava area in India got reduced from 2.74 to 1.64 lakh ha, the total production increased from 2 to 7 million tons during the same period. The increase in cassava production is due to the technological interventions by ICAR-CTCRI, AICRP TC centres and other line departments working on cassava in our country.

Research and development over the past six decades in cassava has led to the development of 20 improved varieties with different quality traits, 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. Economics, utilization pattern and marketing aspects of cassava have also been analysed. I take pride in presenting the above scientific package of practices to be followed from farm to fork for realizing sustainable yield and income from cassava, documented in the form of a technical bulletin titled 'Cassava'.

I hope that this technical bulletin will serve as a valuable reference material to the researchers, extension personnel, farmers, entrepreneurs and other stakeholders for extending it to the field, thereby enhancing productivity and returns from cassava. I appreciate the efforts of the Chief Editor and Editors for bringing out this publication in high standard covering all aspects of cassava.

G. Byju

20 July 2023

Cassava (Tapioca)

Scientific Name: *Manihot esculenta* Crantz

Introduction

Four grains viz., rice, wheat, corn and soybeans-make up almost half of the daily calories of the average global diet. Estimates by McKinsey Global Institute in 2020 suggest a likelihood of an episode of climate stress causing a multiple-breadbasket failure of about 18% by 2030 and 34% by 2050. This highlights the vulnerability to climate change with negative impact on grain crops. In this changing climate scenario, root and tubers, especially cassava, come in handy as a crop for adversity, food-cum-nutritional security, future crop or climate-smart crop.

Cassava *(Manihot esculenta* Crantz*)* is one of the major tropical tuber crops and ranks fourth in the world, after rice, wheat and maize, as a source of calories for human consumption. It is a major carbohydrate food for 800 million people in the world, and in Africa, it is the most important source of calories in the human diet.

It is a native of Brazil in Latin America and was introduced to Kerala, India by the Portuguese merchants in the 17th century. Recognizing its nutritious and delicious character, it was popularized as a food crop by His Highness Sree Visakham Thirunal, the then Maharaja of the erstwhile Travancore princely state, who ruled the state during AD 1880-1885.

Cassava is popularly known as tapioca and is being cultivated mostly in Kerala, Tamil Nadu, Andhra Pradesh, Karnataka and north eastern states in India. It is consumed as freshly cooked tubers and is used in animal and poultry feed. Cassava can produce more calories per unit area and the drought tolerance is mainly due to its in-built mechanism to shed/drop the leaves under adverse soil moisture conditions to facilitate slowdown of all the vital activities of the plants. It can also be cultivated under wide

Cassava plant

Cassava tuber

range of soil conditions, and the ability to grow under a wide range of agroclimatic situations enhances the scope of extending the cultivation to non-traditional regions of the country like Maharashtra, Gujarat and Bihar.

Importance

Cassava is a farmer friendly crop owing to its heat and drought stress tolerance capability. As cassava performs well even under poor or low management conditions, it forms an important diet of small and marginal farmers. Cassava, thereby, is a climate resilient crop and a future crop to combat the varying climate. Under the 'One District One Product' (ODOP) scheme of Government of India, cassava is identified for Thiruvananthapuram and Kollam districts of Kerala and Salem district of Tamil Nadu.

Cassava is the source of raw materials for a number of industrial products such as starch, flour and ethanol. Cassava starch is superior to maize starch and this paves new market avenues for industrial cassava. Cassava can be processed into various secondary products, including modified starch, glucose syrup, extra neutral alcohol, noodles, pasta, bakery and confectionery items, meat and textile processing. It is also industrially processed as a raw material in the coating of pharmaceutical products, the manufacture of glues and adhesives and oil drilling starch. The important characteristics of cassava are given in Table 1.

Table 1. Characteristics of cassava

Planting material (Propagule)	Stems
Growth period (months)	8–36
Optimal rainfall (mm)	1000–1500
Optimal temperature (°C)	25–30
Drought resistance	Yes
Waterlogging tolerance	No
Shade tolerance	No
Soil fertility requirements	Low
Seasonality of crop cycle	No
In-ground storage life	Long
Post-harvest storage life	Very short
Leaves used for animal feed	Yes

Cassava has been globally recognized as a potential candidate for bio-ethanol production. Another industrial product of cassava starch is bio-degradable polymer. Thermoplastic starches form an economically viable alternative for traditional plastic packaging. Starch composite-based foams can be used in the preparation of disposable plates, cups and containers. The biodegradable polymers are used in controlled release of fertilizers. Release of pesticides and herbicides could be controlled by incorporating in natural polymer-based matrices. Hydrogels with slow water releasing properties can be used for water conservation and fertigation in agriculture fields.

While cassava continues to be a vital subsistence crop for small-scale farmers and tribal communities, its utilization pattern has changed dramatically in recent years largely due to its use as a primary raw material for starch, sago, adhesive, and animal feed industries as well as its potential for biofuel production.

Nutritional profile

Cassava tubers contain 24 to 40% starch on fresh weight basis. It contains very low level of sugars. The fat content ranges from 0.1 to 0.3% on fresh weight basis. Protein content ranges from 0.5 to 2.0% (fresh wt.). Cassava leaves contain 6-8% protein on fresh weight basis. Cassava tubers have calcium, iron, potassium, magnesium, copper, zinc, and manganese contents comparable to those of many legumes, with the exception of soybeans. The nutritional profile of cassava tuber, stem and leaf is given in Table 2.

Table 2. Nutritional profile of cassava tuber, stem and leaf

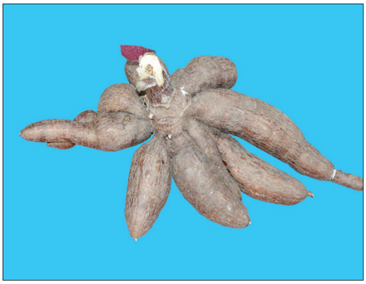
Parameters	Cassava tuber	Cassava stem	Cassava leaf
Proximate composition (FW)			
Moisture (%)	56.67-70.19	63.54-72.50	74.38-81.67
Energy (kJ/100g)	503-840	-	-
Crude protein (%)	2.58-6.43	4.90-12.43	19.86-35.66
Starch (%)	24.00-40.91	-	-
Sugar (%)	0.74-1.33	-	-
Polyphenol (%)	0.002-0.012	0.010-0.064	0.055-0.254
Dietary fibre (%)	1.43-1.57	-	-
Crude fibre (%)	0.08-0.385	2.49-5.02	1.02-2.91
Crude lipid (%)	0.15-0.37	1.05-2.95	1.25-2.05
Ash (%)	2.07-3.02	2.85-3.04	2.67-2.89

N & Minerals (DW)			
N (%)	0.413-0.973	0.784-1.988	3.178-5.705
P (%)	0.030-0.131	0.069-0.289	0.126-0.379
K (%)	0.327-1.087	0.433-1.411	0.571-1.618
Ca (ppm)	1083-1858	11025-18850	9035-18215
Mg (ppm)	540-895	2180-5220	2085-3940
S (%)	0.100-0.129	0.133-0.286	0.132-0.379
Fe (ppm)	68-248	77.80-194.60	179.80-280.00
Mn (ppm)	15.40-33.20	86.40-127.00	109-329
Zn (ppm)	15-28.20	38.80-57.00	54.20-129.00
Cu (ppm)	2.20-4.20	9.40-14.20	9.80-16.40
B (ppm)	4.12-7.62	9.23-19.24	18.26-47.93
Al (ppm)	1.06-2.60	-	-
Na (ppm)	6.20-8.10	-	-
Vitamins (mg/100g) (FW)			
Vitamin A	5-35	-	-
Thiamine	0.03-0.28	-	-
Riboflavin	0.03-0.06	-	-
Nicotinic acid	0.60	-	-
Pot. Nic. acid	0.07	-	-
Ascorbic acid	15-50	-	-
Dehydroascorbic acid	5.20	-	-
Vitamin C	14.90-36.00	-	-

Varieties

ICAR-CTCRI has released 20 high yielding varieties including hybrids with different quality traits suitable for cultivation in major cassava growing states of India. A brief description of the improved varieties and hybrids of cassava is given in Table 3.

Table 3. Distinguishing characters of elite varieties and hybrids of cassava

Sl. No.	Name of the variety	Particulars
1.	 Sree Kaveri	▪ Year of release: 2023 ▪ Duration (months): 9-10 ▪ Yield (t/ha): 40-50 ▪ Starch content (%): 27-28 ▪ Important traits: Resistant to cassava mosaic disease, high nutrient use efficiency and drought tolerance. ▪ Tall, top-branching variety with silver grey stem, light green petiole, cylindrical tubers with cream skin, cream rind and white flesh. ▪ Recommended states: Tamil Nadu, Andhra Pradesh, Kerala.
2.	 Sree Sakthi	▪ Year of release: 2018 ▪ Duration (months): 9-10 ▪ Yield (t/ha): 40-45 ▪ Starch content (%): 27-32 ▪ Important traits: Industrial variety and completely resistant to cassava mosaic disease caused by both Indian cassava mosaic virus and Sri Lankan cassava mosaic virus. Drought tolerant. ▪ Non-branching variety with dark brown stem, brownish green pubescent emerging leaves, dark green lanceolate leaves (7 lobed), green petiole with brown tinge. Long cylindrical tubers with brown skin, cream rind and white flesh colour. ▪ Recommended states: Tamil Nadu, Andhra Pradesh, Maharashtra and Kerala under irrigated/ rainfed upland conditions.

<table>
<tr><td>3.</td><td>
Sree Suvarna</td><td>

- Year of release: 2018
- Duration (months): 7-8
- Yield (t/ha): 35-40
- Starch content (%): 25-27
- Important traits: Completely resistant to cassava mosaic disease, low cyanogen content.
- Erect, top-branching variety with brown stem, dark purple petiole, light brown emerging leaves; conical to cylindrical tubers with brown skin, cream rind and white flesh colour.
- Recommended states: Kerala, Tamil Nadu, Andhra Pradesh.

</td></tr>
<tr><td>4.</td><td>
Sree Reksha</td><td>

- Year of release: 2017
- Duration (months): 8-9
- Yield (t/ha): 40-45
- Starch content (%): 27-31
- Important traits: Completely resistant to cassava mosaic disease and tolerant to post-harvest physiological deterioration. Low sugar (1.1%) content. Drought tolerant. Stable yield under organic management.
- Tall variety (275-325 cm), non-branching with brown stem, dark purple petiole and light brown emerging leaf. Tubers with brown skin, cream rind and white flesh colour.
- Recommended states: Kerala, Tamil Nadu.

</td></tr>
<tr><td>5.</td><td>
Sree Pavithra</td><td>

- Year of release: 2015
- Duration (months): 9-10
- Yield (t/ha): 35-40
- Starch content (%): 25-26
- Important traits: Excellent cooking quality. High K efficiency (243.65 kg tuber/kg K absorbed). Suitable for soils which are inherently low to marginal in soil exchangeable K.
- Tall, top-branching variety with light brown stem and light purple emerging leaf. Tubers are cylindrical with brown skin, pink rind and white flesh colour.
- Recommended states: Kerala, Tamil Nadu.

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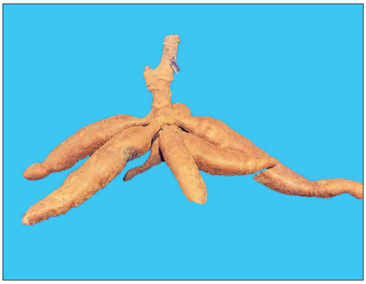
</table>

6.	 Sree Swarna	▪ Year of release: 2015 ▪ Duration (months): 7-8 ▪ Yield (t/ha): 35-40 ▪ Starch content (%): 25.20 ▪ Important traits: Good cooking quality, yellow flesh colour. ▪ Tall, top-branching variety with orange stem, which turns brownish red on maturity; light purple emerging leaf and red petiole. Tubers are cylindrical with reddish brown skin, pink rind and light-yellow flesh. ▪ Recommended state: Kerala.
7.	 Sree Apoorva	▪ Year of release: 2014 ▪ Duration (months): 10 ▪ Yield (t/ha): 35-40 ▪ Starch content (%): 30.10 ▪ Important traits: Triploid variety with stable and high extractable starch content. ▪ Tall, top-branching variety with stout stem, which is yellowish brown in colour; greenish purple emerging leaves; leaves thick and broad, 7-9 lobed. Tubers are long and cylindrical with brown skin, cream rind and white flesh. ▪ Recommended states: Tamil Nadu, Andhra Pradesh.
8.	 Sree Athulya	▪ Year of release: 2014 ▪ Duration (months): 10 ▪ Yield (t/ha): 35-40 ▪ Starch content (%): 30.20 ▪ Important traits: Triploid variety with stable and high extractable starch content. Drought tolerant. ▪ Tall, erect branching variety with greyish brown stout stem; emerging leaves purple, leaves thick, broad palmately lobed (7-9 lobes); long purple coloured petiole (26-35 cm) with green tinge. Long cylindrical tubers with brown skin, cream rind white flesh. ▪ Recommended states: Irrigated plains of Tamil Nadu, Kerala.

9.	 Sree Padmanabha	▪ Year of release: 2006 ▪ Duration (months): 9-10 ▪ Yield (t/ha): 29-30 ▪ Starch content (%): 25-26 ▪ Important traits: Resistant to cassava mosaic disease. ▪ Tall, late-branching variety with greyish green stem and light green emerging leaves; shows cupping of leaves under drought conditions. ▪ Recommended states: Rainfed areas of Kerala & irrigated plains of Tamil Nadu.
10.	 Sree Prabha	▪ Year of release: 2000 ▪ Duration (months): 9-10 ▪ Yield (t/ha): 35-40 ▪ Starch content (%): 26-29 ▪ Important traits: Medium height, semi-spreading flowering variety with light green stem and light sepia emerging leaves. Tubers are conical with brown tuber skin and light yellow tuber rind and flesh. Suitable for both lowland and upland conditions. ▪ Recommended states: Kerala, Tamil Nadu, Karnataka, Andhra Pradesh.
11.	 Sree Rekha	▪ Year of release: 2000 ▪ Duration (months): 9-10 ▪ Yield (t/ha): 35-40 ▪ Starch content (%): 28-30 ▪ Important traits: Erect, top-branching variety with brownish white mature stem, light sepia coloured emerging leaf, purple petiole. Long and conical tubers with light brown outer skin, cream rind and flesh. Suitable for both lowland and upland conditions. ▪ Recommended states: Kerala, Tamil Nadu, Karnataka, Andhra Pradesh.

12.	 Sree Vijaya	▪ Year of release: 1998 ▪ Duration (months): 7 ▪ Yield (t/ha): 25-28 ▪ Starch content (%): 27-30 ▪ Important traits: Erect, branching, early maturing type, tubers conical with brown outer skin, cream coloured rind and light-yellow tuber flesh. Suitable for lowland as a rotation crop. ▪ Recommended states: Kerala, Tamil Nadu.
13.	 Sree Jaya	▪ Year of release: 1998 ▪ Duration (months): 6-7 ▪ Yield (t/ha): 26-30 ▪ Starch content (%): 24-27 ▪ Important traits: Excellent cooking quality ▪ Erect, non-branching reddish brown mature stem; sepia coloured emerging leaf; mature leaves broad with light purple petiole. Tubers are conical with brown outer skin, purple rind and white tuber flesh. ▪ Recommended states: Kerala, Tamil Nadu.
14.	 Sree Harsha	▪ Year of release: 1996 ▪ Duration (months): 10 ▪ Yield (t/ha): 35-40 ▪ Starch content (%): 38-41 ▪ Important traits: Tall, erect, branching variety with stout stem and shy flowering nature with greyish mature stem; light purple emerging leaf; mature leaves thick and broad with acuminate tip having light purple petiole. Triploid variety with high extractable starch content. ▪ Recommended states: Industrial areas of Kerala and Tamil Nadu.

15.	 Sree Prakash	▪ Year of release: 1987 ▪ Duration (months): 7 ▪ Yield (t/ha): 30-35 ▪ Starch content (%): 30 ▪ Important traits: Early maturing, suitable for lowland as a rotation crop. Erect, generally non-branching, rarely top-branching variety with high leaf retention. Tubers are cylindrical, short-necked, shallow bulking with brown outer skin, cream rind and white tuber flesh. ▪ Recommended state: Kerala.
16.	 Sree Visakham	▪ Year of release: 1977 ▪ Duration (months): 10 ▪ Yield (t/ha): 35-38 ▪ Starch content (%): 26 ▪ Important traits: Tall, erect, branching variety with dark sepia coloured mature stem; light brown emerging leaf; dark green broad mature leaf with dark green petiole. Light yellow tuber flesh colour. ▪ Recommended states: Kerala, Tamil Nadu, Karnataka, Maharashtra, Assam, Andhra Pradesh and north eastern region.
17.	 Sree Sahya	▪ Year of release: 1977 ▪ Duration (months): 10-11 ▪ Yield (t/ha): 35-40 ▪ Starch content (%): 29-31 ▪ Important traits: Semi-branching plant type, long necked (4.5-6.5 cm) medium long cylindrical tubers with occasional beading. ▪ Recommended states: Kerala, Tamil Nadu, Karnataka, Maharashtra, Assam, Andhra Pradesh and north eastern region.

18.	 H-226	▪ Year of release: 1971 ▪ Duration (months): 10 ▪ Yield (t/ha): 30-35 ▪ Starch content (%): 28-30 ▪ Important traits: Medium tall, erect, branching with grey mature stem; green emerging leaf; mature leaf broad with green petiole. Tubers are cylindrical with outer skin creamy with purplish patches, light pink tuber rind and white tuber flesh. ▪ Recommended states: Tamil Nadu, Kerala, Andhra Pradesh, Karnataka.
19.	 H-165	▪ Year of release: 1971 ▪ Duration (months): 8 ▪ Yield (t/ha): 33-38 ▪ Starch content (%): 24 ▪ Important traits: Early maturing. Medium tall, non-branching with light grey mature stem, light brown emerging leaf and light green petiole. Tubers fusiform with good tuber shape, golden brown tuber skin, cream tuber rind and white tuber flesh colour. ▪ Recommended states: Tamil Nadu, Kerala, Andhra Pradesh, Karnataka.
20.	 H-97	▪ Year of release: 1971 ▪ Duration (months): 10 ▪ Yield (t/ha): 25-35 ▪ Starch content (%): 27-31 ▪ Important traits: Erect, branching with dark grey mature stem, light sepia emerging leaf and dark green petiole. Cylindrical tubers with light brown skin, cream rind and white flesh colour. Drought tolerant, Moderately resistant to *Cercospora* leaf spot, spider mite and scale insect. ▪ Recommended states: Kerala, Tamil Nadu, Karnataka, Andhra Pradesh.

Climate and soil

Climate

Cassava grows better in warm humid climate with well distributed rainfall. It is extensively cultivated in zones from latitude 30°N to 30°S. Though it performs well at lower altitudes, it is being grown up to an elevation of 2000 m. It can be cultivated successfully in areas with an annual rainfall ranging from 1000 to 2000 mm, but it can come up in lower rainfall also, if it is well distributed. The most favourable conditions seem to be in climate with 1500-2000 mm per year and maximum solar radiation. Ideal temperature for cassava cultivation is between 25°C to 32°C. Cassava can tolerate a temperature level of up to 40ºC, and thereafter the rate of photosynthesis decreases. It tolerates very hot climate, but critical point seems to exist between a daily temperature of 18-20°C, below which growth is reduced and yield declines rapidly. At reduced temperature, germination is delayed and leaf formation rate is slow. It cannot withstand frost, as its growth is arrested at temperatures below 10°C. It can tolerate drought, once it is established. Cassava has an inbuilt mechanism to cope with water scarcity by leaf drooping or folding, due to accumulation of epicuticular wax over leaf, leaf abscission and fine root system that can penetrate up to 2 m depth. The resilience to water stress and relative humidity variations are adapted by reducing stomatal conductance. Elevated CO_2 of up to 700 ppm has a strong positive influence on the rate of photosynthesis and yield of cassava and enhances the resilience of cassava to water stress and salinity. Shading causes stem elongation and wide internodes and poor tuber yield.

Soil

Cassava can be grown in a wide range of soil conditions. A well-drained loamy soil is best suited for the crop. Cassava cannot thrive on water-logged soils. It can be grown successfully in acid soils of low pH. The optimum pH is 5-7. Though saline, alkaline and ill-drained soils are not suitable, cassava can tolerate a salinity level of up to 150 mM and the younger plants can tolerate up to a level of 40 mM.

Quality planting material production

Conventional technique

Selection of planting material: Traditionally, cassava is propagated vegetatively through stem cuttings, usually called 'setts' or 'stakes', taken from the previous season crop and so the stems are often to be stored for two to three months. Sprouting is better when stakes are derived from stems stored with leaves intact. Fresh stakes from mature plants can also be used. Storing the stakes for a period of 15 days has been observed to give maximum sprouting (96%) as compared to planting fresh stakes (90%). Stems kept in vertical position give better sprouting as compared to those in horizontal position. Further, storing stems beyond 60 days result in loss of viability with lower sprouting of

75%. One practical way of knowing whether a stem is sufficiently mature is to determine the relationship between the diameter of the pith and stem cuttings. In a transversal cut, if the diameter of the pith is equal or little less than 50% of the diameter of the stem, it is sufficiently mature to be used for planting. Planting material from plants of 7-10 months maturity, free of pests and diseases, with a stem diameter of 2-3 cm is recommended.

Quality planting material preparation

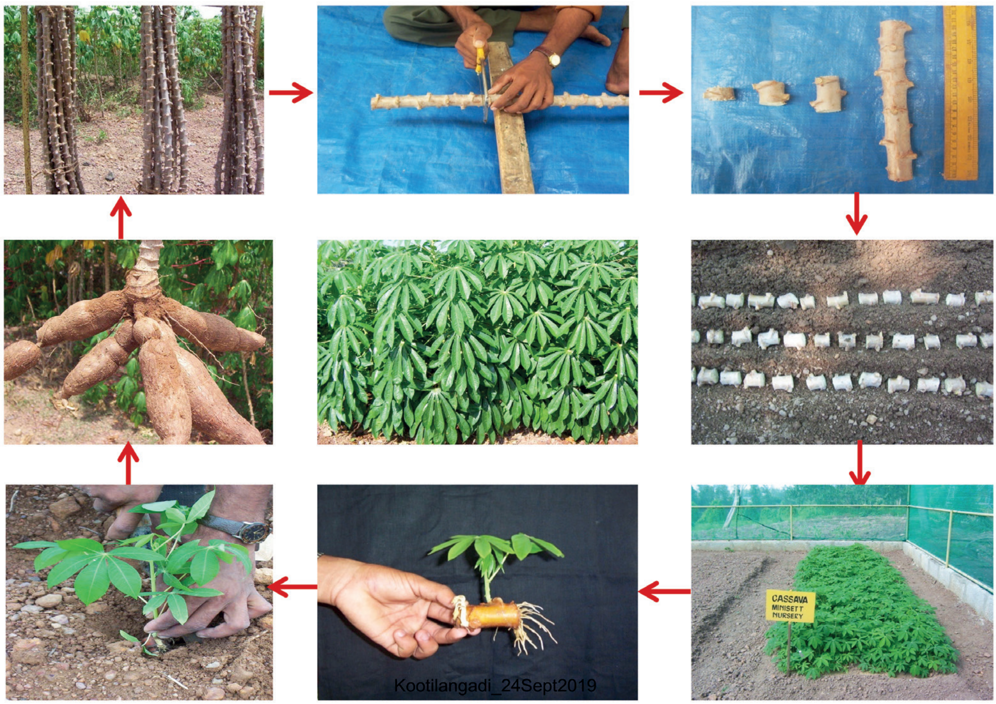
Preparation of setts: Setts are prepared by discarding 1/3 of the total length of the stem from the top and about 5 cm from the bottom. A sett length of 15-20 cm with 10-12 buds are ideal for planting. Smooth circular cut is preferred for preparing the setts rather than an irregular cut for uniform callus formation and tuber initiation.

Ideal setts and sett planted on mound

Minisett technique

Cut stem pieces of two nodes is optimum to be used as minisetts for rapid production of planting material in cassava. The protocol for minisett technique in cassava is given below.

Minisetts are planted in nursery beds in shade net house. A nursery area of 45 m^2 is required for producing minisetts for planting one hectare of main field. Furrows of 5 cm depth are made across the width of the bed with a khurpi or small hand hoe. Two node cuttings are then planted in the furrow, end to end horizontally, at a spacing of 5 cm. The minisetts would start sprouting in a week time. The minisetts will be ready for transplanting in the main field after 3-4 weeks. Two to three fully opened leaf stage is the optimum time for transplanting. Multiplication ratio using minisett technique is 1:60 instead of 1:10 in the conventional system.



Protocol for minisett technique in cassava

Seed certification standards

General seed certification standards

- All certified classes shall be produced from planting stakes (stem cuttings) cut from the seed field (field where cassava is cultivated for the purpose of planting material) whose source and identity may be assured and approved by the certification agency.

Land requirements

- Land shall be free from volunteer plants. Swampy and shaded conditions are to be avoided.
- Avoid cassava residue and drainage from other cassava fields.
- Well drained loamy soil is best suited. The optimum soil pH preferred is between 5-7.

Field inspection

- A minimum of four inspections (60, 120 and 180 days after planting (DAP) and at harvest) shall be made to verify the isolation, off-type plants, disease infected plants and other relevant factors.

Field standards

- Isolation distance: Seed fields shall maintain minimum isolation distance for foundation seed and certified seed as given in Table 4.

Table 4. Isolation distance

Contaminants	Minimum distance (m)	
	Foundation seed	Certified seed
Fields of other varieties	5	5
Fields of the same variety not conforming to varietal purity requirements for certificate	5	5

The details of maximum permissible limits of off types, pests and diseases (%) are given in Table 5.

Table 5. Permissible limits of off-types, pests and diseases

Factor	Maximum permitted (%)	
	Foundation seed	Certified seed
Off-types	0.10	0.20
Plants showing symptoms of cassava mosaic disease	0.10	0.50
Plants infested with scale insects, papaya mealybug, spiralling whitefly	None	None

Seed standards

Specifications in respect of size and age of the planting stakes for foundation and certified classes are given below.

- The planting stakes for foundation and certified classes shall be collected from a seed crop which is 6-7 months for short duration and 9-10 months for long duration.
- Approximate length of planting stake should be 15-20 cm with five numbers of nodes in the planting stake and diameter of the planting stake should be 2 to 3 cm.
- Pith area less than 50% of stem diameter, discard 1/3 top portion.
- Presence of latex at the cut end of the stake is the indication of good quality planting material.
- Keep the planting material upright side under shaded conditions.
- Proper care should be taken during the transport, not to damage nodes and to provide proper ventilation.

Decentralized seed multipliers (DSM) and seed villages

There are two avenues in the production of quality planting material open up for Startups, Farmer Producer Companies and progressive farmers by registering as DSM or commercial seed growers. The DSM system is conceptualized and being implemented since 2021. In this system, the seed material of pre-release varieties are multiplied with the help of progressive farmers so as to facilitate the distribution locally. The system is successful in Kerala, Tamil Nadu, Odisha and Andhra Pradesh, wherein, as of now, 43 cassava seed producers have been registered as DSM and is proposed to be expanded to the other states through Institute development programmes like SCSP, TSP, NEH progammes.

In addition, 22 seed villages have been established in 52 acres in the states of Kerala, Tamil Nadu, Odisha and Andhra Pradesh, which will also ensure availability of quality planting material to the needy farmers.

Agro-techniques

Planting season

Generally, in Kerala and Maharashtra, cassava planting coincides with the onset of rainy season. It is usually planted during May-June coinciding with South-West monsoon or September–October coinciding with the North-East monsoon. However, the crop can be planted at any time, if sufficient soil moisture is ensured by way of supplemental irrigation. The ideal time of planting in the different states are given in Table 6.

Table 6. Ideal time of planting of cassava

States/Region	Time of planting	
	Rainfed	Irrigated
Kerala, Maharashtra	May-June September-October	December-January
Andhra Pradesh, Assam Chhattisgarh	June	March
Tamil Nadu	June	September

Land preparation

The method of land preparation for cassava planting depends on the soil type, topography and farm size. In Kerala, most of the small-scale farmers prepare land by manual digging, while in Tamil Nadu, the usual practice is to provide 3-4 ploughings by animal drawn implements and tractors. Thus, ploughing or digging the field to a depth of 25-30 cm is required for planting cassava. When cassava is grown under monocropping system, immediately after the harvest, one ploughing is given to expose the land to sunshine as well as to absorb the soil moisture during summer showers. With the onset of pre-monsoon showers during April-May, land is again ploughed for planting cassava.

Land preparation

Method of planting

Various methods such as mounds, ridges and flat beds are followed for planting cassava. Planting in mounds is more common and mounds are prepared at a height of 25-30 cm. Mound method is preferred in poorly drained soils. Ridge method is followed in sloppy lands, across the slope/along the contour to a height of 25-30 cm. In plains, ridges are prepared for irrigated crop. Flat method of planting is suitable for sandy or sandy loam soils with good drainage facilities.

Mound method

Ridge and furrow method

Planting, spacing and gap filling

Planting: It is recommended to plant the setts vertically at 5 cm depth. Vertical planting results in a more uniform distribution of callus tissue all around the cut surface, which helps in the uniform distribution of tuber forming roots all around the base of the plant and ultimately uniform bulking of tubers. Avoid inverted planting of setts.

Spacing: The spacing of cassava depends upon the branching behaviour of the variety. Branching and semi-branching types require 90 cm x 90 cm, while non-branching types require 75 cm x 75 cm for optimum yield. Normally one sett is planted per mound. The recommended spacing in different states is given in Table 7. For transplanting minisetts, 60 x 45 cm or 45 x 45 cm spacing is to be adopted. Planting material requirement per ha is 3600 stems for the spacing of 75 x 75 cm and 2500 stems for the spacing of 90 x 90 cm.

Table 7. Recommended spacing in different states

States/Region	Spacing	
	Branching	Semi-branching/ non-branching
Kerala, Andhra Pradesh	90 x 90 cm	75 x 75 cm
Maharashtra, Gujarat, Chhattisgarh	90 x 75 cm	75 x 75cm
Tamil Nadu	90 x 75 cm	75 x 75 cm

Gap filling: At the time of planting of setts in the main field, about 5% of the setts may be planted separately at a very close spacing of 5 cm x 5 cm in a nursery. At the age of 15-20 days, the plants are uprooted from nursery and used for gap filling. Instead, longer setts of 40 cm length also may be used directly for gap filling after 15-20 days, without adversely affecting the tuber yield.

Thinning

The sprouts emerging from the top buds are more vigorous than those emerging from the lower nodes of the setts. Removal of excess sprouts by nipping at the initial stage of establishment (10-15 days after sprouting) and retaining two per plant at opposite sides helps to prevent mutual shading and competition between plants resulting in more number of tubers per plant.

Nutrient management

Nutrient uptake

It is generally considered that cassava exhausts the soil and removes large amounts of N and K. In addition to varietal variations, factors like levels of fertilizer application, water management and the cropping system influence the nutrient uptake in cassava. A crop of cassava capable of producing 30 tonnes fresh tubers per hectare removes 180-200 kg N, 15-22 kg P and 140-160 kg K. Thus, for the production of one tonne of tuber dry matter, cassava removes 6.45 kg N, 1.23 kg P and 8.5 kg K.

Plant and soil sample collection for analysis

Plant analysis: Proper sampling is the key to obtain reliable plant analysis results. To monitor plant nutrient status most effectively, sample is taken during the recommended growth stage for cassava. The index leaf for tissue analysis in cassava is the youngest fully expanded leaf (YFEL) blade without petiole at the third month. However, to identify a specific plant growth problem, take samples whenever a problem is suspected.

Critical nutrient concentration (CNC) indicates the nutrient demand of the crop. The CNC in the index leaves of cassava is 5.3% for N, 0.4% for P and 1.5% for K, below which the crop should be adequately fertilized.

Soil analysis: Soil testing is a chemical method for estimating the nutrient supplying power of a soil. Compared to plant analysis, the primary advantage of soil testing is its ability to determine the nutrient status of soil before the crop is planted. Composite soil samples collected from a depth of 0-15 cm, air dried and sieved (2 mm), is normally used for the estimation of nutrients in cassava.

Essential nutrients and deficiency symptoms

The commonly observed nutrient deficiencies in cassava and their management are given in Table 8.

Table 8. Essential nutrients, deficiency symptoms and their management

Nutrient	Deficiency symptoms	Management
 Nitrogen	▪ General stunted growth and yellowing, affecting mostly the lower leaves. ▪ In severe cases, necrosis and drying of the older leaves and incidentally the whole plant.	▪ Application of organic manures and NPK fertilizers as per the recommended PoP (FYM @ 12.5 t/ha + NPK @ 100:50:100 kg/ha). ▪ If severe yellowing is noticed and if there is no moisture in the soil, foliar application of 0.1% urea can be done to save the crop.
 Potassium	▪ Symptoms appear in the older lower leaves as drying of the margins and tips. ▪ In severe cases, complete drying of the lower leaves resulting in general low vigour and retarded growth of the plant.	▪ Application of organic manures and NPK fertilizers as per the recommended PoP. ▪ In the case of symptom initiation only, apply muriate of potash in the soil and ensure there is sufficient moisture. ▪ In later stages of symptom manifestation, foliar application of sulphate of potash (SOP) @ 0.5-1% can be done.

 Calcium	▪ Symptoms appear only in younger leaves as Ca is immobile in the plant. ▪ The tip of leaves from middle to top turn round in appearance with slight curling of the leaflets depending upon the variety.	▪ Application of lime/dolomite in acid soils @ 1-2 t/ha as a precaution to avoid the symptoms to manifest. ▪ If symptoms appear, apply calcium nitrate ($CaNO_3$) as foliar spray @ 0.5-1%.
 Magnesium	▪ Interveinal chlorosis of the lower older leaves. Yellow discolouration of the laminar area between veins with dark green colour of the veins. ▪ In severe cases, the margins and tips of the leaves turn necrotic and dry.	▪ Basal soil application of dolomite @ 1-2 t/ha or magnesium sulphate ($MgSO_4 2H_2O$) @ 20 kg/ha after top dressing. ▪ In severe cases of symptom manifestation, foliar application of $MgSO_4 2H_2O$ @ 0.5-1% can be done depending upon the sensitivity of the crop to sulphate injury.

<table>
<tr>
<td>Potassium and magnesium
(Lime induced)


Lime induced K


Lime induced Mg</td>
<td>▪ Usually seen in alkaline soils of high pH.

▪ The antagonistic interaction of Ca with K and Mg due to high Ca in alkaline soils can cause the deficiency of K and Mg.

▪ K deficiency is manifested as marginal and tip drying of the lower leaves with slight chlorotic appearance and in severe cases, the plant will dry and die.

▪ Lime induced Mg deficiency appear as interveinal chlorosis of the lower leaves.</td>
<td>▪ Manage the alkalinity of the soil through application of S @ 10-20 kg/ha as elemental sulphur or gypsum or use of sulphur containing fertilizers like ammonium sulphate, single super phosphate or potassium sulphate.

▪ Soil application of Muriate of potash @ 100 kg//ha.

▪ In severe K deficient plants, foliar application of SOP @ 0.5-1% can rectify the emerging leaves from manifesting the same.

▪ In the case of Mg deficiency, soil application of $MgSO_4$ $2H_2O$ @ 20 kg/ha as basal or after top dressing can be done.

▪ In case of symptom expression, foliar application of 0.5-1% $MgSO_4$ $2H_2O$ is recommended.</td>
</tr>
</table>

 Boron	▪ Boron being immobile, its deficiency symptom manifestation is on the growing tip portion. ▪ Appear as rosette look with small sprouts in clusters or bunches with reduced/crinkled leaves/distorted appearance affecting the normal growth of the plant. Cracking of tubers in advanced stages.	▪ Soil application of either borax or boric acid based on soil test data (general recommendation of borax @ 10 kg/ha). ▪ After the appearance of symptom, foliar application of $CaNO_3$ (0.5%) along with solubor (0.05-0.1%) (combined) at fortnightly intervals, till the plant recoup.
 Zinc	▪ Usually seen in alkaline soils with high pH. Interveinal chlorosis of the middle to upper leaves. Leaflets droop and the petiole become horizontal with widening of the angle between petiole and main stem.	▪ Basal soil application of $ZnSO_4$ $7H_2O$@ 12.5 kg/ha to prevent the occurrence. Foliar application of 0.5-1% $ZnSO_4$ $7H_2O$ is recommended.

 Iron (Lime induced)	▪ Usually seen in alkaline soils with high pH (above 8). ▪ Uniform chlorosis of the entire leaves of the plant with stunted growth and drying in severe cases. ▪ Extreme situations result in complete devastation of the crop.	▪ Spraying a mixture of 1% ferrous sulphate ($FeSO_4$) + 1% zinc sulphate ($ZnSO_4$ $7H_2O$). ▪ Application of sulphur (S) @ 10-20 kg/ha as elemental sulphur or gypsum or use of sulphur containing fertilizers like ammonium sulphate, single super phosphate or potassium sulphate as basal can prevent the manifestation of the same in alkaline soils.
 Imbalanced nutrient application, higher levels of N and P without K	▪ Shedding of healthy leaves at the middle of the plant and drooping down of the leaves with petioles bending down in severe cases, leaves above the middle may become yellow, dry and fall down. ▪ In severe cases, leaves above the middle may become yellow, dry and fall down.	▪ Balanced application of NPK as per PoP or soil test data. ▪ Soil application of Muriate of Potash at the initial stages of symptom manifestation. ▪ Foliar application of sulphate of potash @ 0.5-1% to save the new emerging leaves.

1. Blanket recommendation

Major nutrients: For Kerala, farmyard manure may be applied and incorporated @ 12.5 t/ha at the time of land preparation. Apply NPK fertilizers @ 100:50:100 kg/ha, full P, half N and K as basal and the remaining half N and K at 45-60 DAP along with weeding and intercultural operations. Different combinations of common fertilizers are given in Table 9.

Table 9. Recommended chemical fertilizers (kg/ha)

Sl.No.	Fertilizers*	Basal dose	Top dressing 45-60 DAP
I.	Urea	100	110
	Mussooriephos/Rajphos	250	0
	Muriate of potash	85	85
II.	Urea	100	100
	Single super phosphate	300	0
	Muriate of potash	85	85
III.	Urea	65	110
	Diammonium phosphate	110	0
	Muriate of potash	85	85
IV.	Urea	0	110
	Ammonium phosphate/Factomphos (20:20)	250	0
	Muriate of potash	85	85

*For M4 and other local varieties, apply half of the above recommended dose

Phosphorus application can be skipped for 4 years if the available P status of the soil is high. Thereafter, a maintenance dose of 50% may be applied. Fertilizer recommendation for the different states is given in Table 10.

Table 10. Fertilizer recommendation for different states

Sl. No.	State	NPK (kg/ha)
1.	Kerala	100:50:100
2.	Tamil Nadu Rainfed Irrigated	 50:65:125 90:90:240
3.	Andhra Pradesh	60:60:60
4.	Chhattisgarh	75:50:75
5.	Gujarat, Maharashtra	100:50:100

Secondary and micronutrients: In case of deficiency of Mg, Zn and B, applications of $MgSO_4$ $2H_2O$ (20 kg/ha), $ZnSO_4$ $7H_2O$ (12.5 kg/ha) and borax (10 kg/ha) respectively are recommended.

2. Soil test based recommendation

For FYM, N, P and K: In the case of FYM, the organic C status of the soil is considered. If the organic C status is 0.5, 0.5-0.75, 0.75-1.0, 1.0-1.5 and > 1.5%, the

FYM recommendation is 12.5, 10, 7.5, 5.0 and 2.5 t/ha respectively. In the case of N, P, K, the nine class system suggested by Aiyer and Nair (1985), is followed, which is a modification of the existing blanket recommendation (package of practices (PoP) recommendation), as per soil testing, as percentage of N, P and K (Table 11).

Table 11. Fertilizer recommendation based on soil test values followed in Kerala

Soil fertility class No.	Organic C (%)		Recommendation of N, as % to GR*	Available P (kg/ha)	Exchangeable K (kg/ha)	Recommendation of P & K, as % to GR*
	Sandy	Clayey/ loamy				
0	0.00-0.10	0.00-0.16	128	0.0-3.0	0-35	128
1	0.11-0.20	0.17-0.33	117	3.1-6.5	36-75	117
2	0.21-0.30	0.34-0.50	106	6.6-10.0	76-115	106
3	0.31-0.45	0.51-0.75	97	10.1-13.5	116-155	94
4	0.46-0.60	0.76-1.00	91	13.6-17.0	156-195	83
5	0.61-0.75	1.01-1.25	84	17.1-20.5	196-235	71
6	0.76-0.90	1.26-1.50	78	20.6-24.0	236-275	60
7	0.91-1.10	1.51-1.83	71	24.1-27.5	276-315	48
8	1.11-1.30	1.84-2.16	63	27.6-31.0	316-355	37
9	1.31-1.50	2.17-2.50	54	31.1-34.5	356-395	25

*GR = General recommendation as per the PoP recommendations of KAU

(For N, maximum recommendation is 133% of GR and minimum is 50% of GR; 100% of GR is for 0.3% organic C in sandy soil and 0.5% organic C in clay/loam. For P and K, maximum recommendation is 133% of GR and minimum has not been fixed; 100% is for 10 kg P per ha and 115 kg K per ha, respectively).

For Mg, Zn and B: The continuous application of blanket recommendation would result in buildup of these nutrients above their critical levels, without increase in tuber yield, the rate of application of these nutrients can be modified based on soil test as shown in Table 12.

Table 12. Ready reckoner for application of Mg, Zn and B based on soil status

Soil Mg status (cmol/kg)	Rate of application of $MgSO_4\ 2H_2O$ (kg/ha)	Soil Zn status (ppm)	Rate of application of $ZnSO_4\ 7H_2O$ (kg/ha)	Soil B Status (ppm)	Rate of application of borax (kg/ha)
0–0.25	20	< 0.2	12.5	< 0.2	10
0.25–0.50	15	0.2–0.3	10	0.2–0.5	7.5
0.50–0.75	10	0.3–0.4	7.5	0.5–1.0	5.0
0.75–1.00	5	0.4–0.6	5	1–2	2.5
>1.00	2.5	> 0.6	2.5	> 2	0

Application of Zn based on soil testing will result in a significant reduction in tuber cyanogen and increase in starch content in addition to increase in tuber yield.

3. Integrated nutrient management (INM)

The INM practices involving organic manures, chemical fertilizers and biofertilizers are gaining popularity due to energy crisis and escalating prices of fertilizers. Among these three components, organic manures are important to improve the soil physical properties, especially in tuber crops as the economic produce is formed inside the soil. Since the nutrient requirement of cassava is very high owing to its high productivity of 20-50 t/ha, the replenishment of the soil nutrient status through chemical fertilizers, including major, secondary and micronutrients are very important. Nutrient use efficient biofertilizers like N fixers, P solubilizers and K solubilizers also can substitute the NPK fertilizers to a great extent.

Organic manure sources

The commonly used organic manure is FYM @ 12.5 t/ha. Alternate sources like green manuring *in situ* with cowpea, residue of the crop itself, vermicompost and coir pith compost can also be used as good organic manure sources for cassava.

Green manuring *in situ* with cowpea: In this practice, cowpea seeds are sown @ 25 kg/ha during middle of April with the availability of pre-monsoon showers. Apply half N, full P and half K of the recommended NPK to cassava while sowing cowpea. If there are drizzles/light rains during the crop growth period, a good vegetative biomass of 25 t/ha can be obtained within a period 45-60 days. Before flowering of cowpea, the crop can be trashed, ploughed and incorporated, while taking mounds for cassava. The N fixing capacity of the cowpea coupled with the high N content in the leaf and vines (3-4%) contributes greatly to the soil fertility in this practice of green manuring *in situ* with cowpea.

Crop residue incorporation: In the practice of crop residue incorporation, the stems after preserving for planting material purpose will be cut into small pieces or shred with the help of a shredder and spread in the field along with the retained leaves at harvest stage. At the time of land preparation and planting after about 30-60 days, the incorporated residue might have decomposed well and mixed thoroughly with the soil. Cassava is a leaf shedding crop and during its life span it produces 2.5-4 t/ha of dry leaf biomass. It is estimated that the mean crop residue contribution (in terms of leaves and stems including the fallen leaf dry matter) is 3-7 t/ha and this is supposed to add total N to the extent of approximately 195 kg/ha. This is because of the nutrient content of cassava leaves viz., N, P, K, Ca, Mg, Fe, Cu, Mn and Zn as 4.41, 0.28, 1.25, 0.21, 0.321, 0.016, 0.0008, 0.0154 and 0.0064 % respectively.

Wood ash: The traditional common practice before the advent of chemical fertilizers was application of FYM, bone meal and wood ash as sources of major nutrients viz., N, P, K respectively. Ash application results in better quality tubers with low cyanogen and good starch content. Wood ash contain nutrients like K, Ca and Mg, which play a moderating effect on the action of the linamarase enzyme responsible for the synthesis of cyanogenic glucoside, resulting in reduction in cyanogen content of tubers. Similarly, K imparts a favourable effect on starch synthatase enzyme responsible for the synthesis of starch, resulting in greater starch content in cassava tubers. Though the yield realized from organic manures like wood ash and FYM is low due to poor nutrient contents in these sources, it can result in better quality tubers with low cyanogen and high starch. Hence, when cassava is grown in homesteads for subsistence farming, use of ash @ 2.75 t/ha along with other organic manures like FYM can be a good practice for the production of tubers with low bitterness and higher starch.

Vermicompost and coir pith compost: Vermicompost @ 3.9 t/ha or coirpith compost @ 4.60 t/ha can serve as substitutes to FYM with tuber production similar to FYM. However, from the economic point of view, among all the different alternate sources, green manuring is the most cost-effective and farmer friendly practice.

Half the recommended dose of FYM: When cassava is grown continuously in the same field for more than 7-10 years, the rate of application of FYM can be reduced to half (6.25 t/ha). The innate physiological mechanism of cassava plant in shedding its leaves, which being easily decomposable can form a part of the soil organic matter and become a good source of N.

Thippi compost: Thippi compost can serve as an alternative to FYM, green manuring *in situ* with cowpea, crop residue incorporation, vermicompost, coir pith compost, NPK up to 50%, $MgSO_4$ $2H_2O$ @ 2.5 kg/ha and $ZnSO_4$ $7H_2O$ @ 2.5 kg/ha. There is an improvement in the tuber quality parameters, with enhancement in starch content and decrease in HCN content, when thippi compost is applied or thippi compost is combined with chemical fertilizers.

Conjoint use of biofertilizers

Integrated use of biofertilizers (*Azospirillum* + *Phosphobacterium*) with the recommended dose of FYM and K and 50% of N and P (FYM @ 12.5 t/ha, NPK @ 50:25:100 kg/ha) is a good practice to save N and P fertilizers by 50%, besides comparable tuber production.

Nutrient use efficient (NUE) variety

The concept of NUE cultivars is basically to reduce or substitute chemical fertilizers, through its ability to produce high yield in a soil, which is limiting in that particular nutrient by acquiring nutrients from the growth medium and by incorporating or utilizing them in the production of root or shoot biomass or utilizable plant material. Sree Pavithra is the first K efficient variety. It is also proven as NPK efficient and by growing Sree Pavithra it is possible to save 75% of NPK as there is need to apply only 25% of the present nutrient recommendation (NPK @ 25:12.5:25 kg/ha) for up to five years.

Polyhalite/polysulphate application

Polysulphate, a natural mineral product containing 18.5% S, 13.5% K_2O, 5.5% MgO and 16.5% CaO, is a good soil amendment for realizing higher tuber yield (+17%), better tuber quality and improved soil physico-chemical properties. Polysulphate @ 1-2 t/ha need to be applied along with half lime and half dolomite as per lime requirement. Polysulphate results in bulking of tubers, better quality in terms of cooking, improvement of starch and lowering of bitterness. There can be substantial improvement in exchangeable soil K, Ca, Mg and S with an increase of 80.93, 91, 2.54 and 59.84% over initial status of these nutrients.

4. Site specific nutrient management (SSNM)

Site specific nutrient management (SSNM) is an approach of supplying plants with nutrients to optimally match their inherent spatial and temporal needs for supplemental nutrients. The SSNM approach aims to enable farmers to dynamically adjust their fertilizer use to optimally fill the deficit between the nutrient needs of a high yielding crop and the nutrient supply from naturally occurring indigenous sources such as soil, crop residues, organic inputs and irrigation water. The SSNM approach aims to apply nutrients at optimal rates and times to achieve high profit for farmers, with high efficiency of nutrient use by crops across spatial and temporal scales; thereby preventing loss of excess nutrient to the environment.

Zone-specific SSNM recommendations: While the SSNM is definitely more efficient in fertilizer use and may increase yield, it is not practical to make site-specific recommendations for each cassava field as soil and plant tissue testing facilities are not always available and the service is too expensive for farmers. The short-term aim is to produce zone NPK recommendation maps of the main cassava growing areas showing zones with the same SSNM fertilizer recommendations based mainly on existing soil test data, yield data and general crop management practices (rainfed or irrigated), and for a certain target yield. Specific SSNM-based fertilizer recommendations are now available for each zone. SSNM fertilizer recommendation charts that show recommendations for the application rates of N, P and K for cassava based on soil testing results, for particular cassava growing areas and different management practices and yield targets are shown in Tables 13, 14, 15 & 16.

Table 13. General SSNM recommendations

Region	FYM (t/ha)	N	P_2O_5	K_2O
		(kg/ha)		
Kerala-Rainfed	12.5	100	20	100
Kerala-Irrigated	12.5	160	30	160
Tamil Nadu-Rainfed	12.5	100	50	100
Tamil Nadu-Irrigated	12.5	160	60	160
Andhra Pradesh-Rainfed	12.5	100	50	100
Maharashtra-Irrigated	12.5	160	60	160

Table 14. Zone specific SSNM recommendations for Kerala (kg/ha)

AEU No.	Production system	Yield target (t/ha)	N	P	K	Ca	Mg	Zn	B
1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 20, 21, 22, 23	Rainfed	30	100	20	100	40	20	2.5	1
1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 20, 21, 22, 23	Irrigated	40	160	30	160	40	20	2.5	1
17	Rainfed	30	100	20	50	40	20	2.5	1
17	Irrigated	40	160	30	80	40	20	2.5	1
4, 14	Rainfed	30	50	20	100	40	20	2.5	1
4, 14	Irrigated	40	80	30	160	40	20	2.5	1
16	Rainfed	30	50	20	50	40	20	2.5	1
16	Irrigated	40	80	30	80	40	20	2.5	1
18, 19	Rainfed	30	200	20	50	40	20	2.5	1
18, 19	Irrigated	40	240	30	80	40	20	2.5	1

Table 15. Zone specific SSNM recommendations for Tamil Nadu (kg/ha)

District	Production system	Yield target (t/ha)	N	P	K	Fe	Mn	Zn	B
Salem, Namakkal, Dharmapuri	Rainfed	30	100	50	100	5	2.5	2.5	1
	Irrigated	40	160	60	160	5	2.5	2.5	1
Salem, Namakkal	Rainfed	40	150	50	100	5	2.5	2.5	1
	Rainfed	50	240	80	160	5	2.5	2.5	1
	Irrigated	50	200	60	160	5	2.5	2.5	1
Dharmapuri	Rainfed	40	150	50	50	5	2.5	2.5	1
	Rainfed	50	240	80	240	5	2.5	2.5	1
	Irrigated	50	200	60	80	5	2.5	2.5	1

Table 16. Zone specific SSNM recommendations for Andhra Pradesh (kg/ha)

District	Production system	Yield target (t/ha)	N	P	K	Ca	Mg	Zn	B
East Godavari West Godavari	Rainfed	30	100	50	100	40	20	2.5	1
	Rainfed	40	200	75	200	40	20	2.5	1
Srikakulam Vijayanagaram Visakhapatnam	Rainfed	30	100	25	100	40	20	2.5	1

Customized fertilizer formulations: In addition, custom-made mixed fertilizers prepared according to the specific SSNM recommendations, can be made available for each zone. Besides the recommended N, P and K balance in these fertilizers, they can be fortified with Mg, Zn and B according to the soil fertility conditions in each zone as given in Tables 17, 18 & 19.

Table 17. Customized fertilizer formulations for cassava in Kerala (%)

AEU No.	Production system	Yield target (t/ha)	N	P	K	Ca	Mg	Zn	B	Rate (kg/ha)
1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 20, 21, 22, 23	Rainfed	30	16	3.0	16	6	3	0.4	0.2	600
1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 20, 21, 22, 23	Irrigated	40	18	3.0	18	4	2	0.3	0.1	900
17	Rainfed	30	19	3.0	9	8	4	0.5	0.2	500
17	Irrigated	40	21	3.5	10	6	3	0.3	0.1	750
4, 14	Rainfed	30	10	3.0	20	8	4	0.5	0.2	500
4, 14	Irrigated	40	11	4.0	22	6	3	0.3	0.1	700
16	Rainfed	30	12	5.0	12	8	4	0.6	0.2	400
16	Irrigated	40	13	5.0	13	6	3	0.4	0.2	600
18, 19	Rainfed	30	26	3.0	7	5	2.5	0.3	0.1	750
18, 19	Irrigated	40	25	3.0	9	4	2	0.3	0.1	950

Table 18. Customized fertilizer formulations for cassava in Tamil Nadu (%)

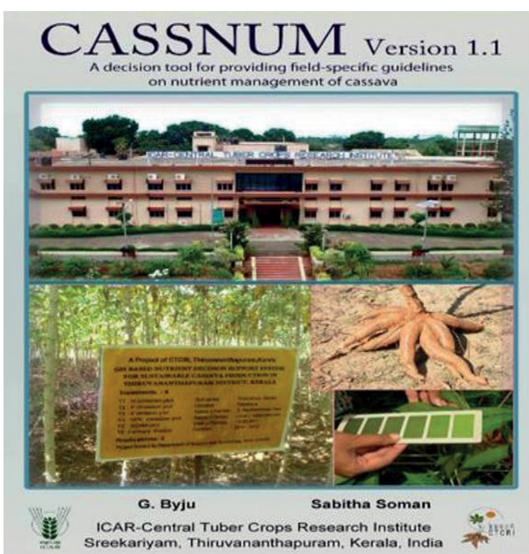
District	Production system	Yield target (t/ha)	N	P	K	Fe	Mn	Zn	B	Rate (kg/ha)
Salem Namakkal Dharmapuri	Rainfed	30	20	9	20	1	0.5	0.5	0.2	500
	Irrigated	40	21	8	21	0.7	0.3	0.3	0.1	750
Salem Namakkal	Rainfed	40	24	8	16	0.8	0.4	0.4	0.2	600
	Rainfed	50	25	8	17	0.5	0.3	0.3	0.1	950
	Irrigated	50	24	7	19	0.6	0.3	0.3	0.1	800
Dharmapuri	Rainfed	40	28	9	9	1	0.5	0.5	0.2	550
	Rainfed	50	22	7	22	0.5	0.2	0.2	0.1	1100
	Irrigated	50	28	8	11	0.7	0.4	0.4	0.1	700

Table 19. Customized fertilizer formulations for cassava in Andhra Pradesh (%)

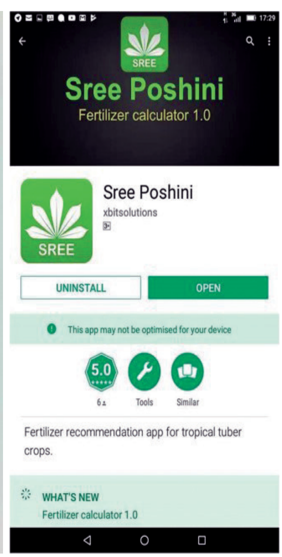
District	Production system	Yield target (t/ha)	N	P	K	Ca	Mg	Zn	B	Rate (kg/ha)
East Godavari	Rainfed	30	17	9	17	7	3.5	0.4	0.2	600
West Godavari	Rainfed	40	15	6	15	3	1.5	0.2	0.1	1300
Srikakulam Vijayanagaram Visakhapatnam	Rainfed	30	18	5	18	8	4	0.5	0.2	550

CASSNUM 1.1: (Nutrient decision support system): In order to popularize the SSNM technology for cassava among farmers, ICAR-CTCRI has developed CASSNUM (CAssava Site Specific NUtrient Management) version 1.0, which is a nutrient decision support system (NuDSS) available in the website of ICAR-CTCRI, which will help the farmers and extension personnel to calculate SSNM recommendations besides providing solutions to nutrient related issues of cassava cultivation (www.ctcri.in). A newer version of the NuDSS, CASSNUM version 1.1 is available in a CD and is distributed among farmers and extension personnel in India.

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



CASSNUM version 1.1



Sree Poshini, a mobile app

Foliar liquid micronutrient formulations: ICAR-CTCRI has developed a microfood formulation containing all the micronutrients essential for cassava. This customized liquid micronutrient formulation, commercially available in the market as ‘Micronol Cassava’ for acid soils and ‘Micronol Tapioca’ for neutral and alkaline soils may be applied as foliar spray ie., Micronol Cassava @ 5 ml per litre and Micronol Tapioca @ 5-10 ml per litre, thrice at 2, 3 and 4 months after planting. One litre of the formulation in 200 litres of water is required for spraying in one acre.

Two microfood formulations commercialized for cassava

Customized fertilizer (CF) mixture for AEUs of Kerala

These are fertilizer mixtures specific to crops and soils which can enhance the crop yield and can take care of the nutritional disorders, if any, as it contains primary, secondary and micronutrients, which is arrived based on soil nutrient status and crop requirement. The CF grade suitable for cassava is N: P_2O_5: K_2O: Mg: Zn: B @ 7: 12: 24: 3.5: 1.25: 0.4. This can be prepared by mixing the following fertilizers as given in Table 20.

Table 20. Customized fertilizer (CF) mixture for Kerala

Sl.No.	Materials	Composition (%)	Quantity (g/kg or kg/ton)
1.	Urea	N-46	50.1
2.	Di ammonium phosphate (DAP)	N-18 P_2O_5-46	260.9
3.	Muriate of potash (MOP)	K_2O-60	400
4.	Magnesium sulphate ($MgSO_4$)	Mg-16	156.3
5.	Zinc sulphate (Mono) ($ZnSO_4$)	Zn-33	37.9
6.	Borax	B-10.5	38.1
7.	Filler (Lime/dolomite/any inert material)		56.7

If DAP is not available, mix 103 g or 103 kg urea (in addition to 50.1g/50.1 kg urea) and

600 g or 600 kg Mussooriephos/Rajphos for each kg or ton of the CF mixture. This can be applied @ 500 kg/ha or 41g/plant at 30-45 days after planting. Top dressing with urea and MOP may be done @ 27 and 15 g/plant, respectively within 30-45 days after first application. This is suitable for agro-ecological units (AEU) 3, 8 and 9 and validated in all AEUs of Kerala.

4. Low input management

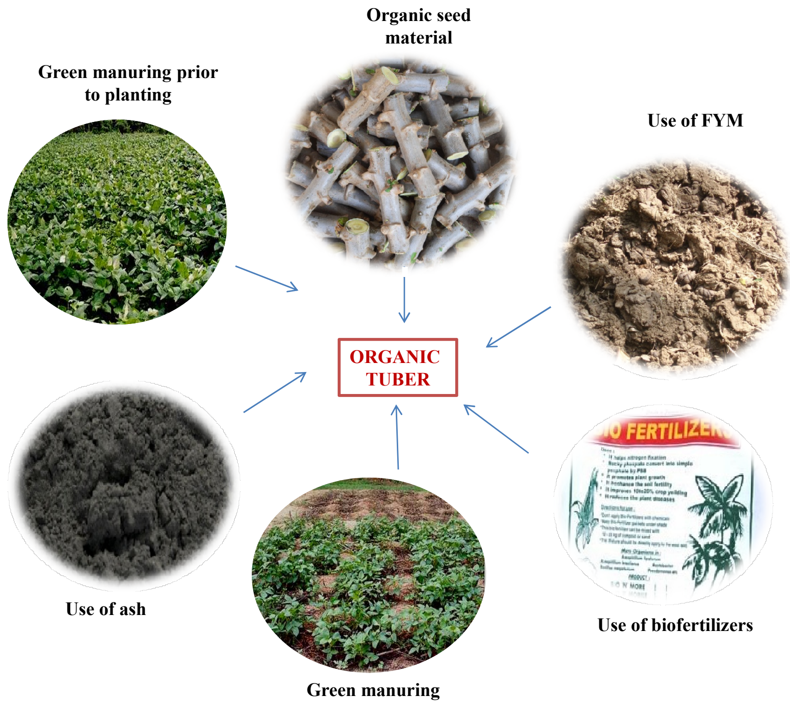
Cassava being mostly grown as a homestead crop in Kerala without using much of chemical fertilizers, a low input nutrient management strategy can also be recommended. The package consists of using nutrient use efficient (NUE) variety like Sree Pavithra and other NUE genotypes, green manuring *in situ* with cowpea as organic manure source in place of FYM, application of N, P, K, Mg, Zn, B fertilizers based on soil test and nutrient use efficient biofertilizers containing N fixers (*Bacillus cereus*), P soubilizers (*Bacillus megaterium*) and K solubilizers (*Bacillus subtilis*) @ 5 g per plant after top dressing with chemical fertilizers. The secondary and micronutrients viz., Zn and B can be applied based on soil status as shown in Table 12. These nutrients can be applied after top dressing of NK fertilizers around the mounds at an interval of 10 days.

Organic farming

The necessity for environmental conservation coupled with the desire for safe foods has made organic farming one of the fastest-growing agricultural enterprises. There is a great demand for organically-produced foods due to the considerable concern regarding food safety and security, environmental protection, biodiversity and human well-being. The protocols for organic production of cassava are briefed below.

Organic package for cassava

Incorporate cassava crop residue @ 7-9 t/ha (generates dry biomass @ 2-3 t/ha) (fresh cassava leaves and stem @ 550 g/plant). It is preferable to grow cassava mosaic disease resistant variety, Sree Reksha. Use of pest-and disease-free healthy planting materials of Sree Pavithra and Sree Vijaya is also recommended. All these varieties respond well to organic management. Plant setts of 15-20 cm length from organically produced stems of cassava. Apply FYM @ 12.5 t/ha (1 kg/plant) at the time of planting. Apply biofertilizers, *Azospirillum* @ 3 kg/ha, phosphobacteria @ 3 kg/ha and K solubilizer @ 3 kg/ha (20 g of each of these biofertilizers per plant) at the time of planting. Inter-sow green manure cowpea (seed rate @ 20 kg/ha) between mounds after planting cassava and incorporate green matter at 45-60 days. The green matter addition from the green manure is 10-15 t/ha (800-1200 g/plant). Major components of organic cassava production are given below.



Essential components of organic cassava production

Organic package for cassava-groundnut system

Organic production of cassava-groundnut system will enable diversification of the food basket, year round safe food production, maintenance of soil health and environmental protection. The package of practices is given in Table 21.

Cassava

Groundnut

Cassava-groundnut system

Table 21. Package of practices for organic production of cassava-groundnut system

Crop	Variety	Planting season	Nutrient management	Pest management
Cassava	Sree Vijaya	May-June	FYM @ 12.5 t/ha + Green manure @ 10 t/ha + Biofertilizers viz., *Azospirillum*, Phosphobacteria and K solubilizer @ 3.0 kg/ha each	Use of cassava mosaic disease resistant variety, botanicals and neem based pesticides
Groundnut	CO-7	January-February	FYM @ 3.0 t/ha + Biofertilizers viz., Phosphobacteria and K solubilizer @ 3.0 kg/ha each + P_2O_5 @ 40 kg/ha as Mussoorie rock phosphate (200 kg/ha) + Wood ash @ 0.75 t/ha + *Panchagavya* 3% @ 15 l/ha, twice at 30 and 60 days after sowing + Vermi wash 10% @ 50 l/ha, twice at 30 and 60 days after sowing	Bordeaux mixture (1%) before flowering to manage Tikka leaf spot

Integrated organic farming system (IOFS) model

Establishment of an integrated organic farming system model involving tuber crops, especially cassava and animal components in 75 cents involving cropping systems of horticulture crops and food crops like cassava + vegetable cowpea/amaranthus (7% area), banana + elephant foot yam (13%), taro + maize (13%), vegetables (okra, amaranthus, cucumber, cluster beans)-pulses (green gram, black gram, soybean) (20%), vegetables-oilseeds (groundnut) (7%), pineapple, moringa, agathi (as hedge crops) (13%), hybrid napier grass (for fodder) (7%), dairy unit (7 cows & 3 calves) (13%), lemon grass and vermicompost unit will enable net returns of ₹ 1,71,277. The marketable equivalent yield (MEY) of 20.14 tons can be realized from such a system.


Cassava + amaranthus

Vegetable cowpea


Banana + cucumber


Hedge rows of pineapple, agathi & moringa


General view of IOFS


Dairy unit


Hybrid napier fodder grass


Vermicompost unit

Field view of IOFS

Products from IOFS: From the IOFS unit, there is a regular production and supply of organic inputs viz., liquid organic manures (*Panchagavya, Jeevamrit, Bheejamrit, Ghanajeevamrit,* cow urine, vermiwash) and vermicompost (*Sree Amrutham*).

Water management

In India, cassava is grown under irrigation only in parts of Tamil Nadu, Andhra Pradesh and in some other non-traditional areas, where cassava cultivation is spreading in the recent past. Usually, one irrigation is given on the day of planting, followed by two irrigations at an interval of 3-5 days till the plants establish. Thus, sufficient moisture should be ensured in the field during the initial stage i.e., first 20 days after planting, for proper establishment of cassava. Supplementary irrigation during drought period can result in higher yield. Drip irrigation @ 100% cumulative pan evaporation (CPE) gives the highest tuber yield in cassava. The water requirement of cassava is 3 mm/day and the water productivity is 8.2 kg/m^3. Quantity of irrigation water is decided by the local weather and soil conditions and stage of the crop. Approximately, 100 to 150 litres of water is required for an area of 40 m^2 (one cent) per day during peak vegetative growth during summer months in Kerala.

Drip irrigation in cassava

Drip fertigation

Fertigation is practiced along with drip irrigation in cassava. For fertigation, 50% dose of nitrogen and potassium may be applied within 45-60 DAP, 30% during 60-90 days and the rest 20% within 120 DAP is ideal. The detailed fertigation schedule is given in Table 22. In Tamil Nadu, Andhra Pradesh and Gujarat, drip irrigation @ 100% CPE and fertilizer dose of 75% recommended dose of fertilizers (RDF) may be adopted through fertigation.

Table 22. Fertigation schedule in cassava (kg/ha)

Weeks after planting	N	K	Weeks after planting	N	K
Short-duration varieties					
2	6	6	10	7.5	7.5
3	6	6	11	7.5	7.5
4	6	6	12	7.5	7.5
5	6	6	13	7.5	7.5
6	6	6	14	5	5
7	6	6	15	5	5
8	7	7	16	5	5
9	7	7	17	5	5
Long-duration varieties					
2	4	4	14	5	5
3	4	4	15	5	5
4	4	4	16	5	5
5	4	4	17	5	5
6	4	4	18	4	4
7	4	4	19	4	4
8	4	4	20	4	4
9	4	4	21	4	4
10	5	5	22	3	3
11	5	5	23	3	3
12	5	5	24	3	3
13	5	5	25	3	3

Weed management

The first weeding and earthing up is undertaken at 30-45 days after planting and the second, a month later. Pre-emergence herbicides viz., Oxyflourfen @ 0.850 l/ha or Alachlor @ 1.5 l/ha or Pendimethalin @ 1.3 l/ha is recommended on the day of planting till 3-5 days after planting with sufficient soil moisture. In Tamil Nadu, first weeding is done at 20 days after planting and subsequent weeding once in a month up to 5 months depending upon the weed density. Weed control ground cover proved to be efficient for weed control in addition to soil moisture conservation. Weed control ground cover, pre-emergence herbicide (Oxyfluorfen @ 0.2 kg a.i. per ha on the day of planting), and biomass mulching using crop residues and green manuring can be components of integrated weed management in cassava.

Cropping systems

Cassava as an intercrop in perennials

Cassava is mostly grown in association with plantation/fruit/tree crops like coconut, arecanut, coffee, rubber, banana, mango, sapota and litchi under agri-horti or agri-silviculture system. Intercropping cassava both at the immature and mature phases of these perennial crops is a common practice, especially in small and medium sized land holdings. This will help to augment the net income and employment opportunities, serve as an insurance crop against risk and natural calamities, enhance the resource use efficiency and ensure food security. In such farms, the produce from the perennials generates cash income, while the starchy tubers of cassava partially meet the food requirements of the farm family and the feed needs of farm animals.

Coconut + cassava

Mango + cassava

Cassava as an intercrop

Cassava can be intercropped during early stages (< 8 years) and mature stages (> 25 years) of coconut garden with yield reduction to the extent of 33%. Experimental evidences indicate that yield is promoted by 5-15% in coconut under intercropping.

Management practices to be followed under intercropping in coconut gardens are given in Table 23. Socio-economic analysis of the integration indicated that an additional tuber yield of 10-12 t/ha, added profit of ₹ 1,00,000-1,25,000 per ha, and employment opportunities of 150-200 man-days per ha could be generated apart from sustainable livelihoods.

Table 23. Management practices for cassava intercropped in coconut gardens

Time of planting	Suitable variety	Method of planting, spacing and plant population per ha	Nutrients		Duration (months)
			FYM (t/ha)	NPK (kg/ha)	
May-June	Sree Vijaya Sree Reksha Sree Pavithra	Mound 90 x 90 cm (9000 plants)	9	50:50:100	6-7 8-9 9-10

Cropping systems involving cereals, vegetables, pulses and oilseeds in cassava

In small farms, legumes like groundnut, cowpea, black gram, green gram and vegetables like French bean, amaranthus, onion, coriander and okra are ideal for intercropping in cassava in south India. Management practices to be followed are given in Table 24. Tuber crops like lesser yam, elephant foot yam etc. can also be grown in association with cassava.

Table 24. Management practices for intercrops in cassava

Name of the crop	Varieties	Duration (days)	Spacing (cm)	No. of rows	Seed rate (kg/ha)	NPK (kg/ha)	Yield (kg/ha)
Groundnut	TMV-2 TMV-7 Pollachi-2	100	30 x 20	2	40-45 (kernel)	10:20:20	1200 (dry pod)
French bean	Contender	70	30 x 20	2	40	20:30:40	2000
Cowpea (grain)	S-488	90	30 x 15	2	20	10:15:10	800
Cowpea (vegetable)	B-61 (Arka Garima) Anaswara	65	90 x 20	1	8	10:15:10	3000

Cassava can be grown as sequential crop in rice fallows. Short-duration cassava varieties viz., Sree Vijaya, Sree Jaya, Vellayani Hraswa and Kalpaka hold promise as component crops in rice based cropping system. Nutrient management based on soil test data is appropriate for these varieties, which results in saving of 10% N, full P and

15% K. Thus NPK recommendation will be @ 90:0:85 kg/ha. Sequential cropping of vegetable cowpea with short-duration cassava is another feasible option as it enables saving of nutrients and additional income. Rice-black gram-short-duration cassava,

Cassava + vegetable cowpea

Cassava + groundnut

First crop of rice

Second crop: Green gram (Co-Gg-7)

Second crop: Black gram (Co-6)

Third crop: Short-duration cassava

Rice-pulse-short duration cassava

Rice-short duration cassava + pulse crop
Cropping systems involving cassava

rice-short-duration cassava+black gram, Rice-short-duration cassava+cluster bean are certain productive, profitable and energy efficient cropping systems. Cassava varieties, Vellayani Hraswa and Sree Vijaya are suitable for such systems. There is a possibility to save half FYM and N and full P to short-duration cassava. Thus, FYM @ 6.25 t/ha and NPK @ 50:0:100 kg/ha is sufficient for cassava in this system.

e-Crop based smart farming (e-CBSF)

Adoption of improved technologies and other inputs helps in achieving higher productivity and profitability in farming. However, there exists a huge gap between technologies generated and technologies adopted in the field due to various constraints. One of the major constraints is lack of knowledge on technologies and its optimum use for realizing potential yield. ICT tools can play a major role in bridging the gap and enhancing the technology utilization in farming. ICAR-CTCRI has developed novel tools for application in tuber crops.

e-Crop-is an IoT device that calculates N, P and K and water requirement at a daily time scale aiming at minimizing the yield gap, thereby achieving yields nearer to potential yields at reduced input applications. The device collects weather and soil data at 15 minutes interval, which are uploaded in the website. e-Crop scheduler is installed in the local machine, which automatically downloads the weather data from the website, runs the simulation model and computes the dry matter produced by the crop at that time and calculates the potential yield the crop can achieve based on crop growth till date. It also calculates the amount of water and nutrients, which should be applied to achieve the recalculated potential

e-Crop for cassava

yield. All these information will be sent to the mobile of the cassava farmer in the form of advisory.

One e-Crop is sufficient to give real time agro-advisories to 10-20 km^2 area. One device can be adapted for different field crops, if crop models are integrated. The yield gap of 52% recorded in traditional farming of cassava can be reduced to 5% in e-CBSF and B:C ratio increased to 4.38 in e-CBSF in comparison to 3.38 in traditional farming.

Pest management

The major insect pests are sucking pests, which desap the plant and also function as predisposing factors for various viral and fungal diseases.

Mealybugs

Mealybugs cause considerable yield loss in cassava. In India, there are three major types of mealybugs that infest the crop. They are papaya mealybug (*Paracoccus marginatus* Williams and Granara de Willink), two-tailed mealybug (*Ferrisia virgata* Cockerell) and cassava mealybug (*Phenacoccus manihoti* Matile-Ferrero). They are white and soft bodied insects, covered with mealy or waxy secretions.

Symptoms: They affect all aerial parts of the plant and while sucking the sap, they inject a toxic substance into the feeding point, causing deformation of terminal shoots, reduction of internodal length, stunted growth and subsequently development of

Papaya mealybug

Two-tailed mealybug

Cassava mealybug

Symptoms of mealybug damage in cassava

'bunchy tops'. Honey dew excretion and associated black sooty mold formation impair photosynthetic efficiency of the affected plants that often leads to heavy yield loss to the extent of 60-80%.

Management

Cultural and mechanical methods

- Monitor and scout to detect the infestation.
- Prune and burn the infested branches.
- Remove weeds/alternate host plants in and around cassava fields.
- Avoid planting materials from infested cassava fields.
- Destroy ant colonies to prevent spread of mealybugs.
- Maintain field hygiene and sanitize farm equipment.

Biological methods

- Conserve natural enemies like hymenopteran parasitoid, *Acerophagus papayae, Anagyrus lopezi* and lady beetle predators like *Cryptolaemus montrouzieri, Scymnus* sp. etc., lacewings and hover flies.

Biopesticides/Chemical methods

- Soak cassava setts in Dimethoate 30 EC @ 1% (10 ml/litre) for one hour before planting and after the infestation starts.
- Spray neem oil-soap solution (7:3) @ 1 to 1.5% twice at weekly intervals or fish oil rosin soap @ 25g/litre of water.
- Spray either Thiamethoxam 25 WG @ 0.6 g/litre or Imidacloprid 17.8 SL @ 0.6 ml/litre to cover lower surface of the leaves/infested portions of the plants.
- Drench Chlorpyrifos 20 EC @ 2 ml/litre for the destruction of ant colonies, which are notorious for the insect spread.

Cassava whitefly (*Bemisia tabaci*)

Whitefly is a polyphagous sap sucking insect which feeds more than 900 host plant species and is also a vector of 111 plant viruses according to Global Invasive Species Database (2022). Whiteflies are insect pests of significant economic importance affecting agricultural crops, including cassava. Cassava mosaic disease, the viral disease affecting cassava cultivation is caused by cassava mosaic virus (*Indian cassava mosaic virus* and *Sri Lankan cassava mosaic virus*) and spread by the vector *B. tabaci*. Higher

Cassava whitefly

productive potential, broad host range and resistance to insecticides are some of the constraints facing their management.

Management

Cultural and mechanical methods

- Proper field sanitation.
- Cultivate resistant varieties.
- Remove crop residues and rogue infested plants to check the risk of carryover population.
- Install yellow sticky traps or sticky cum light traps to be operated between 4 to 6 am to attract adults, which are very effective.

Biological methods

- Natural enemies provide satisfactory control over this noxious pest and several potential parasitoids can suppress its population.
- Among them, *Encarsia* sp. and *Erectmocerus* sp. are very common in India.
- It is also parasitized by an aphelinid parasitoid *Prospaltella flava*.

Chemical method: Imidacloprid 17.8 SL @ 1ml/3 litres is effective in its management.

Spiralling whitefly (*Aleurodicus dispersus*)

Spiralling whitefly is a small (1-2 mm long) insect just like other whiteflies and eggs are laid, along with deposits of waxy secretions, in a spiralling pattern, under leaves. Adult *A. dispersus* are white and coated with a fine dust-like waxy secretion. Similar to mealybug, this pest is also a predisposing agent for 'sooty mold' fungal growth in the plants, because of the production of honeydew.

Spiralling whitefly

Management

- Yellow sticky traps can be effectively used for controlling this pest.
- Neem oil and cotton seed oil at 1% (10 ml/litre) can cause considerable mortality of the different stages of the pest.

- Fish oil insecticidal soap at 2.5% (25 g/litre) also deter the adults of the spiralling whitefly.
- Among chemical insecticides, Dimethoate 30 EC and Profenofos 50 EC at 2 ml/litre are very effective.
- Coccinellid predators, *Nephaspis oculatus, N. bicolor* and *Encarsia haitiensis* are effective in suppressing the whitefly population.

Cassava scale/White mussel scale (*Aonidomytilus albus*)

This is a hard scale, oval shaped and like a mussel. The male is winged. The eggs are laid in the scales. They hatch within 4 days. Nymphs are active and move along the stems, spreading into new areas of new stems. They settle close together, feed on sap, and become mature in 20 to 25 days. Pest is distributed through movement of crawlers, winged males and infested stems. This has not been noticed as a serious problem in the field, but cassava stems under storage are severely infested by this pest. Infestation is common on stem, branch or even on leaf petiole and it occurs in dry seasons and aggravates during prolonged moisture stress.

Cassava scale

Management

- Store the stem cuttings in hygienic conditions.
- Dip the setts in Dimethoate (0.05%) for 10 minutes before planting.
- Spray ICAR-CTCRI developed *Nanma* (7ml/l) and Imidacloprid 17.8 SL @ 1ml/3 litres.
- These scale insects are heavily preyed upon by coccinellids (*Chilochorus nigritus* and *Menochilus sexmaculatus*) and parasitized by two hymenopteran parasitoids *Aspidiophagus* sp. and *Signiphora* sp.

Spider mites (*Tetranychid* mites)

In India, four species of mites viz., *Tetranychus telarius*, *T. noecaledonichus*, *Eutetranychus orientalis* and *Oligonychus biharensis* infesting on cassava are reported. *Tetranychus telarius* and *T. noecaledonichus,* commonly called as red mites, feed on under surface of the leaves. Hot, dry conditions are often associated with population build-up of spider mites. Infestation starts from mature lower leaf. Symptoms of the infested leaf shows yellow specks along the main leaf vein and during severe infestation leaf withers off. Feeding by the mite on the lower surface of the leaves causes characteristic blotching.


Spider mite

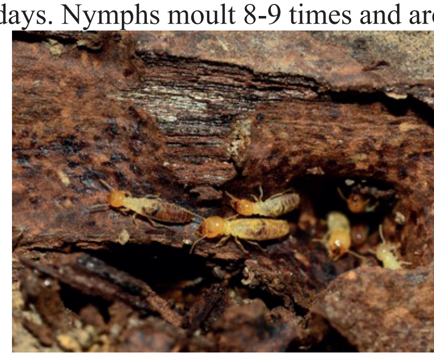

Symptoms of spider mites

Management

- Foliar application of urea (0.1 %) (1 g/l) followed by spraying water at the beginning of mite infestation.
- Spray acaricides, Spiromesifen 22.9 SC @ 1.5-2 ml/litre or Dicofol 18.5 EC @ 2.5 ml/litre at the peak period of infestation.

Termite (*Odontotermes* spp.)

Eggs are dull, kidney shaped and hatch in 30-90 days. Nymphs moult 8-9 times and are full grown in 6-12 months and adults are cream-coloured, tiny insects resembling ants with a dark-coloured head. They infest the setts and young seedlings; eat away the bark and tunnel the pith. Affected stem cuttings grow poorly, die and rot. This weakens the stems and makes them easy to break. Termite damage occurs primarily during the dry season and 20-40% plant mortality is observed.


Odontotermes spp. infestation in cassava

Management

- Chlorpyriphos 20 EC @ 2.5ml/litre can be used for soil drenching.
- The biological control of termites through entomopathogenic nematodes (EPN) like, *Steinernema* and *Heterorhabditis* is also possible. The infective juveniles of EPN emerge from cadaver, search for termites, infect, kill and again multiply and remain in the moist soil. EPN can be produced even at farmer level using either *Galleri*a or *Corcyra* as a host.

Bandicoot rats

Greater bandicoot rat (*Bandicota indica*): This is the largest domestic rat, which is also seen in the field. This can be considered both as domestic and field rat. Fur is coarse and tail length is almost equal to the body length. Body weight ranges from 750 to 1000 g. It damages all tuber crops.

Lesser bandicoot rat (*Bandicota bengalensis*): It is a short-tailed mole rat and tail length is only 70% of the body length. Fur is short and coarse and it is seen in areas where tubers are cultivated. Average yield loss caused by rodents in tubers is about 10%.

Management

- Sanitation of field.
- Use traps like automatic traps, glues, pot traps, snap traps, kerosene tin trap etc.
- Use Bromadiolone (Mortein, Roban), yellow phosphorus (Ratol).
- Fumigate live burrows with Aluminium phosphide (1 tablet/m^3) and poison baiting using Zinc phosphide (2%).
- Place cotton ball soaked in jaggery (100 g jaggery in 100 ml water) at the side of the burrows.
- Plant *Plumbago indica* (Indian Leadwort) *Chethikoduveli* along the border.
- Plant turmeric along the border.

Wild boar (*Sus scrofa*)

They are one of the biggest threats in tuber cultivation and can destroy hectares of crop area by eating away the tubers after uprooting. As of now, up to 16 subspecies are recognized. The wild boar has a long history of association with humans, having been the ancestor of most domestic pig breeds and a big-game animal for millennia. Boars have also re-hybridized in recent decades with feral pigs; these boar–pig hybrids have become a serious wild animal pest. They are mostly active at night time.

Management: Integrated management practices utilizing various mechanical, organic and chemical methods are recommended.

- Install solar fences/electric fences (12 volts) all around the field.
- Make bio-fences using thorny shrubs.
- Erect fences with honey bee hives or fishing nets (4 feet high).
- Erect physical barriers like barbed wire fencing or galvanized iron fencing.
- Prepare trenches all around the field.
- Build pucca stone walls around the fields.
- Produce sound using crackers at uniform intervals with the help of automatic cracker station.
- Soak ropes in Ecodon @ 1 l/ha for 6 hours and tie the ropes all around the field at 0.5 feet height.
- Use olfactory repellents like Borep developed by Kerala Agricultural University at 3 week intervals (2 kg/acre).
- Tie Borep @ 25 g per cotton ball at 0.5 feet height and 3 m spacing all around the field.

Storage pests

Cassava chips borer or coffee bean weevil (*Araecerus fasciculatus*)*:* It is a polyphagous stored product pest. Adult beetle is greyish brown in colour, with antenna having three apical segments, forming a long loose antennal club. It is 3 to 4.5 mm long with a life cycle of about 50 days. Female lays on an average 50 eggs and adults live for 70 days. Adults and grubs feed on the cassava chips and convert them into powdery mass. Infestation causes weight loss and quality loss.

Cigarette beetle (*Lasioderma serricorne*): It is a small oval or globular beetle, 2 to 2.5 mm long with prothorax covering the deflexed head. Elytra cover the abdomen. Antenna is serrate. Adult lives for about 2 weeks and the life cycle is completed in 40 days. It damages cassava chips and flour that leads to weight loss and quality loss of the products.


Coffee bean weevil


Cigaratte beetle


Red flour beetle

Red flour beetle (*Tribolium castaneum*): Adult is red-brown and medium size (3-4 mm). The larvae are cream or pale brown and are very active. Adults live up to six months. Population growth is very rapid. Adults and grubs feed on the flour and also chips damaged by other pests.

Management

- Drying cassava chips to a moisture level below 10% is recommended to reduce insect infestation.
- The chips should be stored using suitable packing material, which can prevent reabsorption of moisture. Polythene impregnated jute bag, closely woven plastic bags; metalbins etc. can be used for long time storage. The store should be cleaned before storing chips.
- Infested cassava should be fumigated for disinfestation before storing. Methyl bromide and Aluminum phosphide (0.6 g/50 kg) are the fumigants most widely accepted for effective and safe disinfestation. Impregnating the bags using Malathion (0.5%), Fenvalerate (0.1%) or Nimbicidin (2%) before storing the chips also reduces insect infestation.
- Admixture of salt @ 3 to 5 g/100g chips before drying reduces insect infestation considerably during storage.

Disease management

Cassava mosaic disease

Cassava mosaic disease (CMD) is one of the main biotic constraints in cassava production, limiting the productivity of cassava and thereby becoming the most important threat to food security worldwide in all cassava growing areas, especially in Africa and Asia. In India, this disease causes yield loss up to 88%.

Causal organism: Cassava mosaic disease is caused by *Indian cassava mosaic virus* (ICMV) and *Sri Lankan cassava mosaic virus* (SLCMV). Among these, the later one occurs predominantly in major areas and cause severe symptoms.

Spread: Primary spread of this disease occurs through infected planting material and secondary spread in the field is through the insect vector whitefly (*Bemisia tabaci*).

Symptoms: Cassava plants infected with cassava mosaic virus express wide range of symptoms. The most typical symptoms consist of yellow or pale green chlorotic mosaic on leaves, commonly accompanied by distortion and crumpling. Affected leaves are reduced in size, deformed, twisted and distorted to give shoe string appearance. In severely infected plants, the deformed plants result in stunting with bushy appearance.

Symptoms of cassava mosaic disease

Management

- Cultivate resistant varieties like Sree Kaveri, Sree Reksha, Sree Suvarna and Sree Sakthi.
- Use disease-free planting material obtained from healthy plants.
- Remove infected plants and maintain strict field sanitation.
- Spray Imidacloprid 17.8 SL (0.3 ml/l) or Thiamethoxam 25 WG (0.3-0.4 g/l) at 14 days interval for vector control.

Cassava tuber rot

Cassava tuber rot disease is a problem in cassava growing areas of Tamil Nadu, which cause 50% yield loss and in severely affected fields under conducive conditions of high rainfall and poor drainage, it may cause total loss.

Causal organism: *Phytophthora palmivora*

Spread: The pathogen survives in the infected tubers and soil. Under water logged conditions the pathogen produce lot of sporangia in soil and infect the tubers.

Symptoms: The disease is characterized by the appearance of dark coloured round to irregular shaped water-soaked lesions on mature tubers in the field. White mycelial mats of the fungus develop around these lesions. On advancement of infection, the lesions enlarge causing internal browning, oozing of internal fluids and rotting of the tubers. The infected tubers emit a characteristic foul smell and rot within 5-7 days depending on the soil conditions. However, the leaves and stems of infected plants show no apparent symptoms.

Cassava tubers infested with tuber rot disease

Deep ploughing to break hard pan as cultural measure in tuber rot infested field

Management

- Avoid water stagnation in the field by providing proper drainage.
- Rotate with other crops, which are non-hosts for *Phytophthora.*
- Deep plough using chisel plough up to 50 cm to enhance water percolation.
- Plant in ridges to avoid exposure of tubers to excess water.
- Add organic amendments (neem cake @ 250 kg/ha) to improve the soil structure and enhance the growth of native microbes antagonistic to *Phytophthora*.
- Incorporate biocontrol agent *Trichoderma asperellum* (prepared by mixing 2.5 kg of *Trichodema* with 250 kg farmyard manure, incubated under shade by covering

with polythene sheet). This should be mixed with FYM @ 12.5 t/ha. *Trichoderma asperellum* enriched FYM should be applied @ one kg per plant at the time of planting.

- Remove diseased plants from the field, after harvest, if any

Cassava stem and root rot

Cassava cultivated in wetlands of Kerala only have been so far infected with the disease, which is up to 100% incidence, resulting in entire tuber loss based on the weather factors and soil moisture.

Causal organisms: *Fusarium* spp. and *Colletotrichum* sp.

Symptoms: The crop will succumb to the disease at any time from planting till harvest. Setts and the collar region will first degrade after planting before rooting. The mature plants show yellowing and drooping of old leaves, as well as stem and tuber rotting and finally wilting occur as it advances. The rotten stem close to the soil turns dark and displays fungus pustules with white mycelia.

Symptoms of cassava stem and root rot

Management

- Remove and burn highly infected plants.
- Avoid water stagnation and ensure good drainage in the field.
- Use healthy setts and avoid setts from infected fields for planting.

- Sett treatment with Carbendazim 0.05% (5 g per 10 litre) for 10 minutes.
- Crop rotation with suitable crops once in two years.
- Apply lime @ 150 to 250 g per plant 10-15 days before planting, where pH of the soil is 4-5 (ensure soil moisture during application).
- Apply neem cake @ 20 g per plant and *Trichoderma asperellum* enriched FYM @ one kg per plant at the time of planting.
- Drench the soil with Carbendazim 0.05% (5g per 10 litre) starting from planting, thrice at 15 days intervals.

Cassava brown leaf spot

Brown leaf spot is a major fungal disease in high rainfall areas. It causes considerable premature defoliation and loss in tuber yield up to 30 % in susceptible variety like Malayan-4 (M-4).

Causal organism: *Cercospora henningsii*

Spread: Warm, humid conditions favour the initiation and spread of *C. henningsii*. The pathogen spreads to new plants by rain splash. The fungus survives during the dry season in old lesions, often on fallen leaves.

Symptoms: Small brown spots with dark borders appear on both sides of the leaves. Spots on the lower surface have less distinct margins and appear greyish in the centre because of the presence of fruiting bodies of the fungus. The spots expand and become irregular and angular in shape as they are limited by leaf margins and veins. An indefinite halo appears round the lesions. As the disease advances, the infected leaves turn yellow, become dry and fall off.

Symptoms of cassava brown leaf spot

Management

- Plant at a wider spacing to reduce the humidity within the stand of cassava and reduce the incidence.
- Adjust the time of planting in such a way that the most susceptible growth stage (over 5 months old) does not coincide with the wet season.
- Cultivate resistant varieties viz., Sree Prakash, Sree Visakham.
- Spray Copper oxychloride @ 0.15% (1.5 g per litre).

Cassava anthracnose disease (CAD)

Anthracnose disease is widespread in most of the cassava growing regions. It is estimated that the disease causes yield loss of about 30% in susceptible cultivars, when the conditions are favourable for the pathogen. The disease affects both leaf and stem portions, thus reduces yield and can affect the availability of planting materials for the next season.

Causal organism: *Colletotrichum gloeosporioides* f. sp. *Manihotis*

Spread: The disease usually starts with the onset of rains and worsens as the wet season progresses. The pathogen spreads by wind or by planting stem cuttings with the disease. Dead cassava stems and leaves with the fungus also serve as sources of the disease if they are not destroyed properly.

Symptoms: Cankers on stems, leaf spots, leaf drying and tip die-backs, wilting, shoot death and easy breaking by wind action. Sprouting of new twigs from axillary buds below the necrotic area, which shows bunchy appearance.

Symptoms of anthracnose disease

Management

- Avoid planting of stem cuttings with cankers.
- Remove and destroy crop debris after harvest from the infected fields.
- Spray Carbendazim 0.05% (5 g in 10 litres) thrice at fortnightly intervals starting from the appearance of symptoms.

Harvesting and yield

Harvesting

Normally, short duration cultivars can be harvested at 6-7 months, while long-duration ones can be harvested at 9-11 months after planting. Maturity indices are yellowing, drying and shedding of leaves. The soil near the base show cracking. The plants are uprooted by lifting the stems. Tractor operated cassava harvester developed by TNAU is also getting momentum among the farmers due to shortage of labourers.

Harvesting

Harvested tubers

Yield

Yield of cassava depends on the cultivars, management conditions and stage of harvesting. High yielding varieties of long-duration cassava (10-11 months) yield 35-50 t/ha, whereas short duration ones (6-7 months) yield 25-35 t/ha. In Tamil Nadu, under better management and irrigation, tuber yield of 40-60 t/ha can be obtained.

Pre and post-harvest machinery

Harvesting tools

The conventional method of harvesting cassava by lifting the tubers from the soil is quite strenuous and slow process. Cassava uprooting tools based on the principle of lever reduce the effort of lifting of the tubers. The first order lever type harvesting tool has a mechanical advantage of 4.0 and its total weight is 14 kg. Second order lever type harvester has a mechanical advantage of 3.4, total weight of 8 kg and overall length of 2.1m.

First order lever type harvester

Second order lever type harvester

Post-harvest machines

Cassava chipping machines

Conventional method of chipping cassava tubers by hand-knives produces about 10-40 kg/h, with chip thickness varying from 2.7 to 12.5 mm. The chipping machines developed by ICAR-CTCRI have the following advantages: Higher output, low operational cost, moderate initial cost, accommodates all sizes of tubers, easy to operate, requires no special skill to operate, production of uniform chips, adjustable chip thickness, convenience of feeding the tubers into the machine.

The basic parts of these machines are two concentric mild steel drums, the annular space between which is divided into compartments for feeding the tubers. A rotating disc at the bottom of the drum carries the knives assembly. Thickness of chips can be changed by introducing spacing washers between the disc and the blade. Tubers are fed into the compartments from the top and the chips are collected at the bottom. In the hand operated chipping machine, a pair of H.S.S. bevel gears is provided to operate the machine manually with a crank arm. The pedal operated chipping machine is a modified version of the earlier prototype with additional provision of a pivoted pedal for transmitting the power to the cutting disc through suitable belt and pulley drive mechanism. The motorised chipper developed is run with a 0.5 hp single phase motor through suitable belt drive.

The outturn of the hand-operated cassava chipping machine is 40-120 kg/h with chip thickness ranging from 2.3 to 6.9 mm. The capacity of the pedal operated machine is 80-770 kg/h with chip thickness ranging from 0.9 to 6.9 mm. The output of the motorized machine has been found to be 290, 655 and 1090 kg/h for chip thicknesses of 2.5, 5.3 and 9.9 mm, respectively.

Hand operated
Output: 40-120 kg/h for chip thickness 2.3-6.9 mm

Pedal operated
Output: 80-770 kg/h for chip thickness 0.9 -6.9 mm

Motorized
Output: 290-1100 kg/h for chip thickness 2.5-10 mm

Cassava chipping machines

Mobile starch extraction unit

The major components of the machine are hopper to feed the tubers, crushing disc or cylinder with nail punched protrusions rotating inside crushing chamber to crush the tubers, sieving tray to remove the fibrous and other cellulosic materials, stainless steel or plastic tanks to collect the sieved starch suspension, tuber storage chamber, handle and wheels for easy transportation from place to place and a frame to support these components. Addition of water during the processing can be controlled through a water pipe with holes fixed inside the hopper along its length and during sieving by a shower attachment connected to the water line. An electric motor (0.75 hp) or a generator (kerosene–petrol) attached to the frame can be used as the energy source to operate the machine. The recovery of starch by using this machine is 84.2 for cassava with the crushing capacity of 200 kg/h for the above tubers. Rasping effect of the machine ranged from 61.10 to 40.32% and the energy consumption to crush 100 kg tubers is 0.24-0.44 kWh.

Mobile starch extraction unit
Output: 200 kg/h

Cassava rasper

The rasper consists of a crushing drum made up of a mild steel pipe with power hacksaw blades fixed on its circumference. The crushing drum is fixed on a shaft, power to which is provided by an electric motor with belt and pulley. The drum is rotated inside the crushing chamber which is made up of two halves, the upper half acts as hopper and the bottom half portion acts as outlet for the crushed mash to flow.

Gap between the blade set and crushing chamber is adjusted to minimum. A changeable sieve plate is provided at the bottom half to filter the starch pulp without any bigger pieces. Capacity of the machine is 800-1000 kg/h.

Cassava rasper

Feed granulator

The low palatability of the cassava based feed due to the powdery nature of flour gave way for the particle size upgradation by the process of pelleting, granulation or globulation. Development of a centrifugal granulator for feed preparation based on cassava flour offers better scope for the *in situ* consumption and farm scale processing of tubers. A drum type centrifugal granulator consists of a cylindrical drum mounted horizontally on a shaft installed on a trapezoidal angle iron frame work. Provision is also made to spray water using a knapsack sprayer through one side of the drum while the granulator is in operation. A rectangular slot is provided at the down slope of the drum for feeding the materials and to take out the granulated feeds. The machine can be operated manually and also by an electric motor (0.75 hp). Flours of different feed formulations are fed to the granulator, granulation is done by rotating the machine, simultaneously spraying the water using a knapsack sprayer and the resulting granules are dried. Feed granules of optimum properties can be obtained by adjusting the moisture content, rotational speed and time. The capacity of the machine is 20 kg/h.

Feed granulator

Wax coating of cassava tubers for enhanced shelf-life

Cassava tubers are highly perishable in nature and cannot be stored for more than 24-48 hours. The shelf-life of fresh cassava roots can be enhanced by applying wax coating. The process involves cleaning the harvested roots, dipping them in chlorinated water, and allowing them to dry. The roots are then immersed in molten paraffin wax or a suitable alternative, ensuring a uniform coating. This wax treatment acts as a barrier against the exchange of gases, such as oxygen, carbon dioxide, and water vapor, effectively preserving the freshness of roots for up to a month or two. This surface coating method is cost-effective, easy to implement, and significantly reduces post-harvest deterioration. It enables processors and traders to store, transport, and sell fresh cassava roots over long distances without compromising quality, thereby increasing profitability.

Wax coating of cassava tubers

Processing and value addition

Cassava, though branded as poor man's crop in rural areas, has considerable unrealized potential for processing into high end products for food, feed and industrial uses. Agro-industrial transformation of cassava by linking improved production and processing technologies, marketing techniques and institutional innovation in processing technologies ensure food security, rural employment and adequate remuneration to the producers. ICAR-CTCRI has developed an array of novel value added products from cassava suited to food and industrial sectors.

Cassava-based food products

Fried and baked snack foods

Variety of snack foods having good texture and taste can be prepared from cassava based composite flour containing refined wheat flour, Bengal gram flour, rice flour, salt, chilli powder, asafoetida, baking soda and oil. The ingredients are thoroughly mixed and made into dough with hot water, proofed for one hour and then extruded through hand extruder or snack food making machine with suitable dies into hot oil. The ready to eat fried snack foods include cassava pakkavada, sweet fries, nutrichips, crisps, salty dimons, hot sticks, salty fries, sweet dimon, murukku etc.

Crisps

Nutrichips

Sweet fries

Pakkavada

Excellent quality fried chips can be made from cassava tubers by soaking the chips in acetic acid-brine solution for one hour, parboiling for 3-5 minutes, surface drying and deep frying in oil. This facilitates in the removal of excess starch and sugars from the cassava slices, with the result that light yellow crispy chips can be obtained, having soft mouth feel and good texture.

Cassava 'chitchore' is produced from wet cassava paste, which is mixed with ingredients like refined wheat flour, cheese, salt, sugar, baking powder and white pepper. The dough, after proofing for one hour, is spread into sheets and cut into small discs of one cm diameter and deep fried in oil.

Chips

Popups

High protein minipapds

Bakery products viz., biscuits, cookies, muffins, rusks, bread etc. can be prepared from cassava-refined wheat flour based composite flours by using the conventional baking methods. Micronutrient rich products can also be prepared by adding millet flour in the composite mix.

Cassava based papad

Mini-papads can be developed from cassava flour by adding functional ingredients viz., fibre sources (wheat bran, oat meal, rice bran and cassava fibrous residue) or protein sources (cheese, defatted soy flour, prawn powder and whey protein concentrate). The fibre/protein sources are added to gelatinized cassava slurry and mixed thoroughly. The spicy condiments are also added and spread on plastic sheets, which are then dried in the sun for 36 h. The papads are peeled off from the sheets and packed. The deep fried products have soft and crisp texture. Papads can also be produced from the dough of dry cassava flour by adding gram flour/maida/sago flour in different proportions. The dough is made into sheets and cut into round shapes and dried.

Functional pasta/Spaghetti

Pasta being a food rich in complex carbohydrates with low glycaemic index is gaining wide acceptance in the recent years. Pasta products, largely consumed all over the world, are traditionally manufactured from durum wheat semolina. ICAR-CTCRI has developed an array of pasta products from tuber based composite flours with high functional value coupled with low starch digestibility. Technology for making protein rich pasta from cassava through fortification with protein sources like whey protein concentrate, defatted soy flour and fish powder has been standardized. They have excellent cooking quality and high protein content (10-15%). Hydrocolloid fortified pasta is prepared by incorporating guar gum, xanthan gum and locust bean gum at 1% level in cassava-maida blends. *In vitro* starch digestibility is slow and progressive over a period of two hours for the control as well as the gum fortified pasta, with a high retention of resistant starch after the digestion. Rice analogue can be prepared by the cold extrusion process from the composite flour containing cassava flour

Pasta

Noodles

(45-60%), rice flour/maida (25-40%), guar gum (0-0.5g), gelatinized starch (5%) and whey protein concentrate (10%). The rice analogue made from cassava-maida-whey protein concentrate-guar gum composite flour is more acceptable by sensory evaluation.

Extruded products

Extrusion cooking is a high temperature short time cooking process designed for processing of starchy as well as proteinaceous materials. Being the treasure house of starches with complex physico-chemical properties, cassava flours/starches can be extruded to obtain a variety of nutritionally enriched, ready-to-eat/cook products. Tubers after washing, peeling and slicing into chips are dried and powdered in a hammer mill. The dry flour after conditioning to 12-15% moisture content is extruded by maintaining appropriate temperatures at different sections of the barrel and die of the food extruder. Cassava, being rich in carbohydrates and lacking in protein content, addition of low-cost protein sources like wheat, finger millet, soy flour etc. gives more nutritional and market value products.

Extruded snack

Quick cooking dehydrated tubers (QCDT)

Quick cooking dehydrated tubers (QCDT) with longer shelf life have tremendous potential to be used as a rehydrated product or as an ingredient in vegetable mix with minimum cooking time of 3-5 minutes. Also, instant cooking dehydrated tubers is an alternative for frozen tubers to reduce the high cost involved in storage, packaging and transport during the distribution chain, both in domestic and export market. The parboiled and dried chips popularly known as *'vattukappa'* have longer cooking time and hard/woody texture upon cooking, which is a main bottleneck for their widespread use. However, freezing and thawing of the pre-cooked tubers and drying processes produce porous end products on drying, which improves the rehydration characteristics of the dehydrated products resulting in a reduced cooking time.

Quick cooking dehydrated cassava

The tubers after peeling are thoroughly washed and made into thin slices of round (1-1.5 cm thick) or square shape (1-2 cm) and is cooked in boiling water. The cooking time may vary depending upon the variety and generally takes about 15-25 minutes. The uniformly cooked tubers after draining the water, is allowed for cooling for 15-20 min. They are frozen at -20°C for about 18 h in a deep freezer. After freezing, the tubers are allowed to thaw for 2-3 h depending upon the ambient conditions. The thawed samples are dried in tray drier at 55-60°C till it attains the moisture content of 10-12%. Being the ethnic food products, the dehydrated tubers of cassava with less cooking time of 3-5 minutes will have great demand in both domestic and export market.

High quality cassava flour

Cassava flour is a basic raw material for many value added products. The food grade cassava flour is prepared by peeling the tubers, washing, slicing and drying. The drying time may vary from 12 to 48 hours depending upon the drying methods. For mechanical drying of the tuber slices, the drying temperature may be kept at 45-55°C in the initial period and may be increased to 65°C at the later stages to avoid gelatinization of the high moist tubers, which affects the quality of the flour. High quality cassava flour can also be prepared by partial removal of moisture by pressing the tuber slices or mashes followed by mechanical or sun drying, by which the drying time can be reduced and quality can be increased.

Cassava flour

Cassava starch, sago and wafers

The process of extraction of starch consists of peeling the tubers, rasping, screening, settling and drying. Peeled tubers of cassava are disintegrated into pulp by a rasper, which releases the starch granules from the fibrous matrix. The resulting slurry is pumped onto a series of vibratory screens and the fibrous waste (thippi) is retained on them and the starch milk passing through the sieves are channeled into sedimentation tanks. After at least 8 hours of settling, the supernatant liquor is decanted out and the starch cake settled at the bottom is scooped up for sun drying on a cement floor. Sago *(Saboo dana)* is manufactured from the partially dehydrated (35-40% moisture content) starch cake. The lumps are broken in a spike mill and then globulated on a gyratory shaker. The globules are graded according to size and then partially gelatinized by roasting on shallow metal pans or by steaming. Finally, the sago pearls are dried in the sun on cement floor. The agglomerates are separated by means of a spike beater and polished before bagging. Wafers are made by arranging the wet granules in suitable dies and steaming. The steamed granules take the shape of the die and after drying, it can be separated out from the dies and packed.

Sago

Sago wafers

Cassava based industrial products

Starch based adhesives

Gums

Liquid adhesives and gum pastes can be made from cassava starch using simple low cost technologies. Starch is cooked with water, cooled and preservatives like formaldehyde or copper sulphate are added. The shelf life of the gums can be improved by adding borax, urea, glycerol, carboxymethyl cellulose etc. The process for the preparation of a multipurpose binding paste based on cassava starch as a multipurpose adhesive and ready-to-mix two-part adhesive, which can be used for book binding, sticking labels on bottles, making envelops and paper pouches etc has been developed. Bench-scale technologies are developed for corrugating adhesive with oxidized cassava starch as the carrier phase; single phase corrugating adhesive with acid thinned cassava starch; moisture resistant corrugating adhesive based on native cassava starch and alkali free corrugating adhesive dry mix based on cassava starch.

Starch graft-co-polymers

The process for the preparation of different graft-copolymers of cassava starch viz., starch-graft-poly (acrylamide), starch-graft-poly (acrylonitrile) and starch-g-poly (methacrylamide) copolymers have been standardized. The grafted starches of poly (acrylamide) and poly (methacrylamide) have cold swelling nature, high viscosity, water absorption capacity and thermal stability. The graft copolymers with acrylonitrile are water insoluble and do not undergo gelatinization even at 95ºC and exhibit excellent thermal stability. It can be used in oil drilling, in sizing and printing of cotton fabrics, water treatment for the removal of heavy metal ions, and as flocculating agent.

Starch graft copolymer

Superabsorbent polymers (SAP)

Cassava starch can be modified as superabsorbent polymers (SAP) through free radical graft copolymerization with vinyl monomers and subsequent alkali saponification. A bench-scale process was developed for the production of a superabsorbent polymer by the alkali saponification of grafted cassava starch. It has slow absorption and desorption of water and equilibrium absorbency (<350-400 g/g of the dry sample) is reached in 2 hours. It improves soil properties such as porosity, water holding capacity and nutrient status. The polymer is effective in soil moisture retention, reduces frequency of irrigation of plants, especially in pots.

Super absorbent polymer

Starch based nanocomposites

Cassava starch/montmorillonite nanocomposites prepared using citric acid activated MMT are appropriate matrices for incorporating therapeutic drugs (Theophylline) to attain sustained release properties. Starch-konjac glucomannan blend films are developed for the sustained release of drugs. Water soluble curcumin incorporated in octenyl succinate cassava starch nanoparticles can be prepared by a wet grinding process. The nanocurcumin exhibits aqueous solubility, enhanced cellular uptake and anti-cancer potential. As revealed by pharmacokinetic studies in Wistar albino rats, the nanocurcumin formulation increased the curcumin bioavailability by 71.27%.

Resistant starch

Cassava starch is subjected to different chemical and physical modification techniques to develop RS3, RS4 and RS5 type resistant starches with fairly high content of slowly digestible starch (SDS) and medium glycaemic index. These resistant starches are beneficial in formulating low-calorie food and diabetic food and it can act as a pre-biotic. These can be used to improve the nutritional value of various food products.

Biodegradable films and edible coating

Biodegradable film can be developed from cassava starch modified by etherification, esterification, double cross linking and enzymatic treatments by film casting method. Eco-friendly biodegradable composite films based on chitosan and konjac glucomannan can be prepared for food wrapping application with incorporation of granular cassava starch to enhance the barrier properties and mechanical properties. Nanosilver has been incorporated into the films to achieve antimicrobial properties.

Biofilms

Cassava starch-konjac glucomannan blend has been prepared and successfully used for edible surface coating of carrot slices to increase the shelf life. Coating significantly maintains the visual quality of carrot compared to uncoated samples throughout the storage period at low temperature. At room temperature, there is no significant change in the colour of coated samples until 21 days of storage and thereafter a gradual change is observed. Coated samples have less microbial growth on storage.

Modified cassava starch

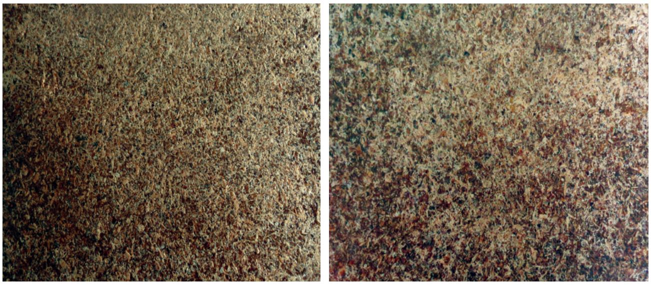
The processes for the preparation of an array of physically and chemically modified starches of cassava have been standardized. Chemically modified starches include: cross-linked starch, starch succinate, octenyl succinate starch, starch citrate, hydroxypropylated starch, oxidized starch, starch phosphate. The physical modifications include heat-moisture treatment, annealing and pre-gelatinization. The modified starches have got wide application in food, pharmaceutical and other industries as food ingredient in salad dressings, frozen foods, canned foods and puddings, thickener and viscosity modifier in soups, jellies, fruit pastes, surgical dusting powders, carriers, absorbents and ion exchange resins, paper and adhesive industries, tablet disintegrant, instant binder etc.

Bioethanol from cassava

Cassava has been globally recognized as a potential candidate for bioethanol production. Fresh cassava tubers, dry chips/flour or starch can be used for the production of ethanol. The process consists of three steps viz., liquefaction, saccharification and fermentation. The process yields up to 115-120 litres of ethanol per ton of fresh tuber or 450 litres of ethanol per ton of starch. Nevertheless, the process is highly energy-intensive due to the varying temperatures and pH as well as time consuming (total of 122 h). Hence the process technology was modified and essentially is now a single step conversion of cassava starch to ethanol, except for a 30 min thinning step, which requires 90ºC. The entire saccharification-fermentation reaction can be performed at room temperature (30±1ºC) in presence of the new enzyme and yeast. The whole process duration takes only 48 h and 30 minutes. The ethanol yield (from laboratory level batch process) is approximately 150-180 l/ton of fresh tuber or 680 l/ton of starch.

Cassava stem and leaf-based products

Particle boards can be developed from cassava stem using synthetic resins urea formaldehyde, phenol formaldehyde and melamine formaldehyde and the properties of the boards obtained are in conformity with that of BIS values. Native and modified cassava starch as bioadhesive can be used to prepare green particle board from cassava stem.



Particle boards

Cassava leaf protein concentrate (CLPC)

Cassava leaf, after detoxifying for its cyanogen content can be a promising protein source in the feed sector. Fresh cassava leaves yield about 6% leaf protein concentrate by alkaline extraction and thermo-coagulation method. Cassava leaf protein concentrate has a protein content of 52%, cyanogen 4.9 µg/g, phenol 1.6 mg/100 mg and amino acid 0.7 mg/100g. The cyanogen level being less than 10g/g is in the safe level as recommended by WHO and FAO. The product is non toxic and have good appearance too. Cassava leaf protein concentrates could replace the fish meal component in feed for Black molly (*Poecilia sphenops*) without deleterious effects and the optimum performance is for 20% replacement of fish feed by CLPC. Nutritive evaluation of cassava leaf meal, prepared from the powdered, shade dried upper leafy portion of cassava stems in animal feed using goats as an experimental model indicates that replacement of concentrated feed with 30% leaf meal results in the highest weight gain in goats.

Biochar production from cassava residue

Biochar can be produced from tuber crop residues, like cassava stems and other residues through slow pyrolysis. The resulted biochar is processed into a powdered form and enriched with nutrients and beneficial microorganisms. This enriched biochar serves as a soil amendment for improving soil quality, nutrient retention, and microbial activity. The biochar production capacity can range from small-scale systems for household use to large-scale commercial operations, catering to various waste management and soil improvement needs. With its carbon-positive and climate-smart characteristics, biochar offers a promising solution for soil quality improvement and sustainable crop production.

Bioactive molecules from cassava

In cassava cultivation, after the harvest of tubers, leaves and tender stems are usually thrown as waste and based on the study conducted at ICAR-CTCRI, these have now been identified as an important source to extract the bioactive molecules with insecticidal action. With the technical support of Vikram Sarabhai Space Centre (ISRO) and financial support of Central and State Governments, Bioformulation Extraction and Formulation Units were designed and installed at the Bioformulation Laboratory of ICAR-CTCRI. The three bioformulations named as *Nanma*, *Menma* and *Shreya* have now been widely accepted by the farmers to manage a spectrum of insect pests of agricultural crops of national importance.

1. *Nanma* to be used as a prophylactic measure against banana pseudostem weevil (*Odoiporus longicollis*) and to manage sucking pests like aphids, thrips, scale insects and mealybugs in vegetable crops. 2. *Menma* to manage the borer pests like

Bioformulation extraction plant

Bioformulations *Nanma*, *Menma* and *Shreya* pseudostem weevil and rhizome weevil (*Cosmopolites sordidus*) in banana. 3. *Shreya* to manage mealybugs. Pest activity profile of ICAR-CTCRI developed bioformulations is given in Table 25.

Table 25. Pest activity profile of ICAR-CTCRI developed bioformulations

Bioformulations	Target pests	Dose and schedule
Nanma	Aphids Thrips	7-10 ml/l
	Early-stage caterpillars	10 ml/l
	Pseudostem weevil of banana	50 ml/l Spray on the pseudostem and last leaf axils Spray schedule: Two sprays at 4th & 5th month after planting
	Rhizome weevil of banana	Make cow dung slurry @ 1 kg/l. Add 200 ml of *Nanma* and mix thoroughly. Smear a thin layer of the slurry on the rhizome and dry it under shade for 3 days. A fortnight after planting, drench its base with *Nanma* @ 20 ml/l
Menma	Pseudostem weevil of banana	Pseudostem injection: Draw *Menm*a in a 20 ml specially designed syringe. Insert the needle approximately 1-2 cm below the infestation point. Press the piston gently and release the bioformulation. Withdraw the syringe for about 1 cm and again release the solution. Continue this until the needle is removed out from the pseudostem. Give one application through the feeding hole also. Give similar injections at two opposite sides of the pseudostem.
	Borer pests like Red palm weevil Rhinoceros beetle Mango stem borer etc.	Plug all the bore holes in stem after pouring *Menma*
Shreya	Mealybugs Whiteflies	Spray *Shreya* 7-10 ml/l After one week, spray *Nanma* at 5-7 ml/l

Thippi compost

In Tamil Nadu, cassava is used as an industrial crop for the production of starch. After starch extraction, there is voluminous accumulation of the solid residue called thippi. It is acidic in nature (pH: 3.6) with very poor plant nutrient contents viz., N, P, K, Ca, Mg, Fe, Cu, Mn and Zn to the extent of 0.38%, 0.07%, 0.05%, 0.04, 0.06 %, 60, 4.3, 7.8 and 7.5 ppm respectively with very high C:N ratio (82:1). Thippi can be converted into a nutrient rich organic manure, by the cheap and traditional way of composting using earthworms, within a period of 45-60 days. Thippi compost has lower C:N ratio of 8:1 with N, P, K, Ca and Mg, Fe, Mn, Cu and Zn contents as 1.32, 3.82, 0.40, 2.18, 0.96, 1.11, 0.08%, 11.23 and 89.93 ppm respectively, which is 3.5, 49,7, 32.5, 8, 185, 100, 2.5 and 12 times compared to raw thippi. The maximum nutrient release is during 5-7 months.


Thippi


Composting of thippi


Thippi compost

Economics and marketing

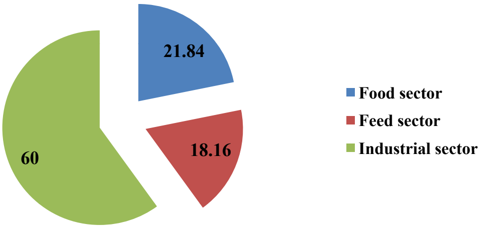
Economics

In India, cassava is cultivated in an area of 1.83 lakh ha with a production of 69.4 lakh tonnes. On an average, the price of one kg of raw cassava tubers is ₹ 17 and the total value of cassava in India is ₹ 1,179, 97 million. From farm to fork, cassava provides opportunity for employment generation to the extent of 220 man-days per ha and enables sustainable livelihood in our country. Thus the total employment generation is 40.26 million man-days from the cassava sector in our country.

The cost of cultivation of cassava for one hectare is estimated to be ₹ 1.5 to 2.0 lakhs. As cassava is mainly used for edible and industrial purposes, the price varies from ₹ 5 to 40 per kg of tubers depending on the demand and supply and consumer preferences. Gross income that could be realized from one ha is ₹ 1.75 to 14.0 lakhs. In addition, cassava leaves and other crop residues could be used for producing bioformulations, compost etc.

Utilization pattern

Cassava finds a place in the home front as well as in the industrial front. In the home front, it is consumed as cooked or baked tubers in culinary preparations and in making papads. In Kerala and north eastern states, the maximum production is utilized for human consumption. The total production of cassava in India is 6.94 m tonnes. The consumption of cassava in

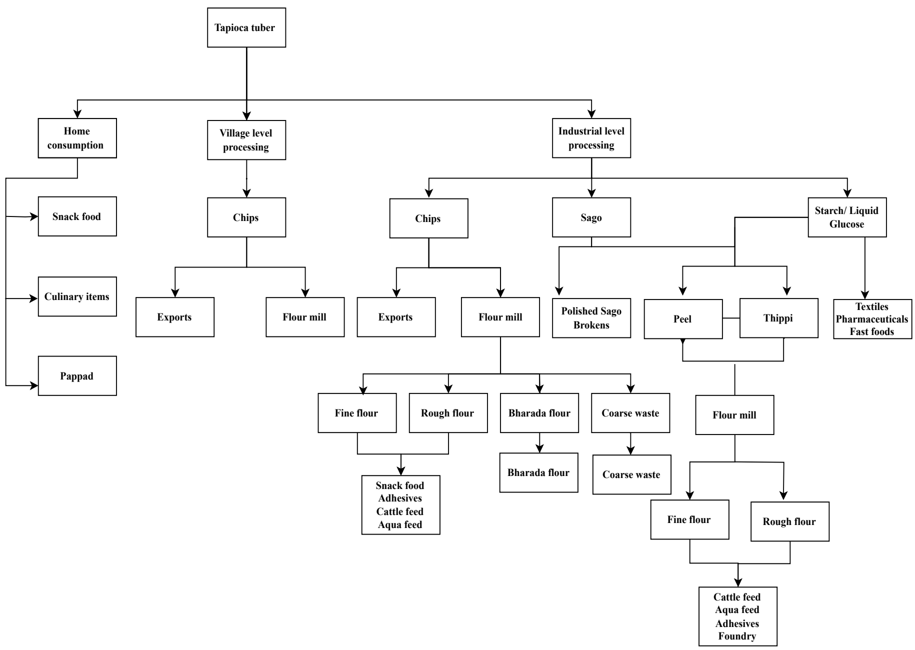


Utilization pattern of cassava

India is for food sector (1.52 mt, 21.84%), feed sector (1.26 mt, 18.16%) and industrial sector (4.16 mt, 60%).

Consumption pattern of cassava in India

Cassava and fish consumed together, form a good combination of dietary carbohydrate and protein. Now-a-days cassava dishes are seen in big hotels and restaurants. In a limited quantity, it is consumed as baked tubers in Tamil Nadu and Andhra Pradesh during harvesting season. Cassava fried chips is another form of utilization observed in Tamil Nadu and Kerala at cottage industries level. In the industrial front, it has wide applications. Many value added products are prepared from cassava viz., starch, sago, flour, chips etc. Cassava starch has wide industrial applications. The consumption pattern of cassava in India is given below.



Consumption pattern of cassava in India

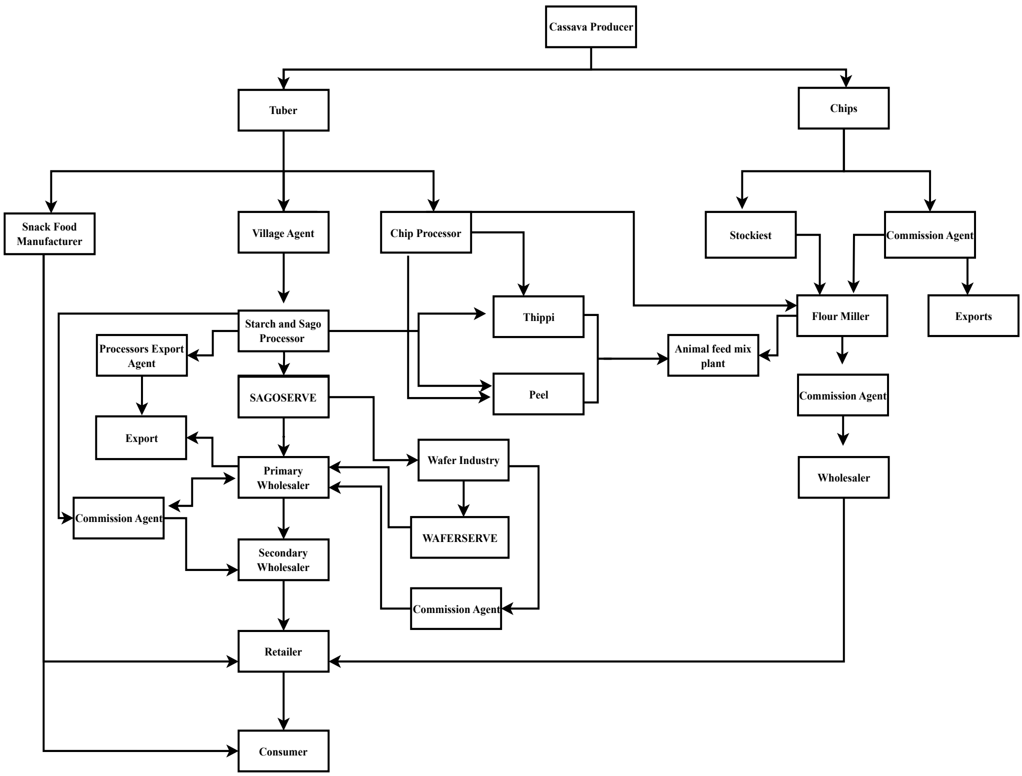
It is used in textile industries as sizing agent, in pharmaceutical industries, making adhesives, dextrin manufacturing, paper industry, laundry and in many fast-food preparations. A sizeable quantity of cassava produced in Tamil Nadu and Andhra Pradesh is processed in the industrial sector. Flour is made from cassava dried chips and this finds applications in gum industry, in making *kumkum* (vermillion) and in making colours applied to faces, during celebrations, festivals etc. Thippi (fibrous waste from starch and sago industries) and peel (waste from chip industries) are used as an ingredient in poultry and cattle feed preparations.

Marketing

Though cassava production centres are concentrated in southern India, the marketing centres are distributed throughout the country for different value added products produced from cassava (Table 26). Cassava is consumed either directly as cooked tubers or as products prepared from cassava. The schematic diagram of the marketing channels for cassava and its value added products in India is given below.

Table 26. Production, marketing and consumption centres of cassava and its value added products

Sl. No.	Cassava product	Major production states	Consumption purpose	Marketing centres
1.	Sago: *Moti dana* & *Medium dana*	Tamil Nadu & Andhra Pradesh	Human consumption	West Bengal, Maharashtra, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, Assam, Tripura, Tamil Nadu & North India
	Nylon sago, Sago waste	Tamil Nadu & Andhra Pradesh	For sizing in textile industry	Maharashtra, West Bengal
2.	Starch	Tamil Nadu & Andhra Pradesh	Textile industry Adhesive manufacturers Liquid glucose Dextrin manufacturers Confectionery Foundry Laundry Pharmaceuticals	Gujarat, Maharashtra, West Bengal
3.	Chips & Flour	Andhra Pradesh & Kerala	Gum manufacturers Sizing clothes Animal feed industry Snack food manufacturers	Maharashtra, Andhra Pradesh
4.	Wafers, Chips & Papad	Tamil Nadu	Human Consumption	Gujarat, Delhi, Maharashtra, Tamil Nadu, Kerala
5.	Raw tubers	Kerala	Human Consumption	Kerala, Tamil Nadu



Schematic diagram of marketing channels for cassava and its value added products in India

Conclusion

A climate-ready crop, cassava is adapted to marginal environments, low input management, adverse soil and climatic conditions, particularly drought and acidic soil conditions and thus exhibits a great phenotypic plasticity to thrive under different systems. It is a potential crop for integration in agri-food systems for higher productivity, profitability and resilience. The protocols to be followed from farm to fork described above will be definitely useful to various end users or stakeholders and help to transform its role from the status of a subsistence crop to a commercial crop to improve their livelihoods.

Cassava for Food, Health, Wealth and Prosperity

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