AGROTECHNIQUES OF TROPICAL TUBER CROPS

Diamond Jubilee 60 Years ICAR-CTCRI

भाकृअनुप-केन्द्रीय कंद फसल अनुसंधान संस्थान

(भारतीय कृषि अनुसंधान परिषद्)

श्रीकार्यम, तिरुवनंतपुरम 695 017, केरल, भारत

ICAR-CENTRAL TUBER CROPS RESEARCH INSTITUTE

(Indian Council of Agricultural Research)

Sreekariyam, Thiruvananthapuram 695 017, Kerala, India

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ICAR-CENTRAL TUBER CROPS RESEARCH INSTITUTE
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Sreekariyam, Thiruvananthapuram 695 017, Kerala, India

Diamond Jubilee of ICAR-CTCRI

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

Published by
Dr. G. Byju
Director

Editors
Dr. S. Sunitha
Dr. G. Suja
Dr. D. Jaganathan

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

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ICAR-Central Tuber Crops Research Institute
Sreekariyam 695 017, Thiruvananthapuram, Kerala, India

Dr. G. Byju
Director

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

From the Director

Tropical tuber crops are the third most important food crops which contribute to food and nutritional security, income generation, employment, source of feed and provide raw materials for many industrial products. These crops are cultivated in an area of about 0.40 million ha with a total production of about 8.74 million tons contributing to 4.64% of the total vegetable production in India. Most of the root and tuber crops are rich in carbohydrates, minerals, vitamins, antioxidants, dietary fibre and have many medicinal properties. These crops are life sustaining crops and are able to cope with climate vagaries such as drought, high temperature and salinity which qualify them to be named as 'future smart crops'. The adaptability of tuber crops to marginal environments, their contribution to household food security as well as flexibility in mixed farming system make them important components of agrifood systems in our country. The significant increase in production and productivity of these crops have been mainly owing to the technological advancements and interventions by ICAR-CTCRI, AICRP TC centres and other developmental organizations in India.

The ICAR-CTCRI is the only research organization in the world dedicated solely to basic, strategic and applied research on 15 tropical root and tuber crops for catering to the needs of marginalized and tribal farmers as well as other stakeholders across the country. The Institute has made significant contributions through systematic research and extension programmes during the last six decades of service to the nation and celebrates its grammes have been the major achievements for empowering the farmers and other stakeholders. I take pride in publishing the scientific package of agrotechniques which are to be adopted by the stakeholders for realizing higher yield and sustainable income from tropical tuber crops, documented in the form of a technical bulletin.

I am sure that this technical bulletin will be a useful and handy reference material to the researchers, development professionals, FPOs, seed entrepreneurs, farmers, SHGs and other stakeholders for their utilization and scientific adoption of improved practices, thereby maximizing productivity and sustainable income from tropical tuber crops. I appreciate the Editors for their efforts in bringing out this publication covering all important aspects of cultivation of tropical tuber crops.

20 November 2023

G. Byju

CASSAVA (TAPIOCA)

Scientific Name: *Manihot esculenta* Crantz

Cassava is the most important tropical tuber crop cultivated in Kerala, Tamil Nadu, Andhra Pradesh, Maharashtra, Chhattisgarh and North Eastern states. Tubers are consumed as freshly cooked or for chips making or other snack foods. It is used as a component of animal and poultry feeds too. In industrial belts of Tamil Nadu and Andhra Pradesh, tubers are used for the extraction of starch.

Climate

It grows better in warm humid climate with well distributed rainfall. Though it performs well at lower altitudes, it is being grown up to an elevation of 2000 m. The most favourable conditions seem to be in climates with rainfall of 1500-2000 mm per year and maximum solar radiation. Ideal temperature for cassava cultivation is between 25°C to 32°C. It can tolerate drought, once it is established. It cannot withstand frost, as its growth is arrested at temperatures below 10°C. Shading causes stem elongation, wide internodes and poor tuber yield.

Soil

Cassava can be grown in a wide range of soil conditions. But saline, alkaline and ill-drained soils are not suitable. Cassava cannot thrive on waterlogged soils. A well-drained loamy soil is best suited for the crop. It can be grown successfully in acid soils of low pH. The optimum pH is 5-7.

Planting season

Cassava 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. If grown as an irrigated crop, December-January planting is better.

Improved varieties

Sl. No.	Name of variety	Duration (months)	Yield (t/ha)	Special features
1.	Sree Kaveri	9-10	40-50	▪ Tall, top-branching variety with silver grey stem and light green petiole ▪ Cylindrical tubers with cream skin, cream rind and white flesh colour ▪ Resistant to cassava mosaic disease. It also has high nutrient use efficiency and drought tolerance ▪ Starch content is 27-28% ▪ Recommended states: Tamil Nadu, Andhra Pradesh, Kerala

2.	Sree Sakthi	9-10	40-45	▪ Non-branching variety with dark brown stem, brownish green pubescent emerging leaves, dark green lanceolate leaves (7 lobed) and green petiole with brown tinge ▪ Long cylindrical tubers with brown skin, cream rind and white flesh colour ▪ Completely resistant to cassava mosaic disease caused by both Indian cassava mosaic virus and Sri Lankan cassava mosaic virus ▪ It is an industrial variety and starch content is 27-32% ▪ Recommended states: Tamil Nadu, Andhra Pradesh, Kerala, Maharashtra
3.	Sree Suvarna	7-8	35-40	▪ It is an erect top-branching variety with brown stem, dark purple petiole and light brown emerging leaves ▪ Conical to cylindrical tubers with brown skin, cream rind and white flesh colour ▪ Completely resistant to cassava mosaic disease ▪ Starch content is 25-27%, low cyanogen content ▪ Recommended states: Kerala, Tamil Nadu, Andhra Pradesh
4.	Sree Reksha	8-9	40-45	▪ It is a tall variety, non-branching with brown stem, dark purple petiole and light brown emerging leaf ▪ Tubers with brown skin, cream rind and white flesh colour ▪ Completely resistant to cassava mosaic disease and also tolerant to post-harvest physiological deterioration ▪ Starch content is 27-31% and low sugar content (1.10%) ▪ Recommended states: Kerala, Tamil Nadu
5.	Sree Pavithra	9-10	35-40	▪ Tall, top-branching variety with light brown stem and light purple emerging leaf ▪ Cylindrical tubers with brown skin, pink rind and white flesh colour ▪ It has high K efficiency (243.65 kg tuber/kg K absorbed). Suitable for soils which are inherently low to marginal in soil exchangeable K. Tubers have excellent cooking quality ▪ Starch content is 25-26% ▪ Recommended states: Kerala, Tamil Nadu

6.	Sree Swarna	7-8	35-40	▪ Tall, top-branching variety with orange stem, which turns brownish red on maturity. It has light purple emerging leaf and red petiole ▪ Cylindrical tubers with reddish brown skin, pink rind and light-yellow flesh ▪ Good cooking quality ▪ Starch content is 25.20% ▪ Recommended state: Kerala
7.	Sree Apoorva	10	35-40	▪ Tall, top-branching variety with stout stem, which is yellowish brown in colour, greenish purple emerging leaves, 7-9 lobed leaves thick and broad ▪ Long cylindrical tubers with brown skin, cream rind and white flesh ▪ Stable and high extractable starch content is 30.10% ▪ Recommended states: Tamil Nadu, Andhra Pradesh
8.	Sree Athulya	10	35-40	▪ 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 and white flesh ▪ Stable and high extractable starch content is 30.20% ▪ Recommended states: Irrigated plains of Tamil Nadu, Kerala
9.	Sree Padmanabha	9-10	29-30	▪ Tall, late-branching variety with greyish green stem and light green emerging leaves ▪ Resistant to cassava mosaic disease, shows cupping of leaves under drought conditions ▪ Starch content is 25-26% ▪ Recommended states: Rainfed areas of Kerala, Irrigated plains of Tamil Nadu
10.	Sree Prabha	9-10	35-40	▪ 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 ▪ Starch content is 26-29% ▪ Recommended states: Kerala, Tamil Nadu, Andhra Pradesh, Karnataka

11.	Sree Rekha	9-10	35-40	▪ 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 ▪ Starch content is 28-30% ▪ Recommended states: Kerala, Tamil Nadu, Andhra Pradesh, Karnataka
12.	Sree Vijaya	7	25-28	▪ 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 ▪ Starch content is 27-30% ▪ Recommended states: Kerala, Tamil Nadu
13.	Sree Jaya	6-7	26-30	▪ 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 ▪ Excellent cooking quality ▪ Starch content is 24-27% ▪ Recommended states: Kerala, Tamil Nadu
14.	Sree Harsha	10	35-40	▪ 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 ▪ Starch content is 38-41% ▪ Recommended states: Industrial areas of Kerala, Tamil Nadu
15.	Sree Prakash	7	30-35	▪ Erect, generally non-branching, rarely top branching variety with high leaf retention ▪ Cylindrical, short-necked, shallow bulking tubers with brown outer skin, cream rind and white tuber flesh ▪ Early maturing, suitable for lowland as a rotation crop ▪ Starch content is 30% ▪ Recommended state: Kerala

16.	Sree Visakham	10	35-38	▪ Tall, erect branching and flowering variety with dark sepia coloured mature stem, light brown emerging leaf, mature leaf broad with dark green petiole ▪ Light yellow tuber flesh colour ▪ Starch content is 26% ▪ Recommended states: Kerala, Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra, Assam, North eastern region
17.	Sree Sahya	10-11	35-40	▪ Semi-branching plant type ▪ Long necked (4.5-6.5 cm), medium long cylindrical tubers with occasional beading ▪ Starch content is 29-31% ▪ Recommended states: Kerala, Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra, Assam, North eastern region
18.	H-226	10	30-35	▪ Medium tall, erect branching with grey mature stem, green emerging leaf, mature leaf broad with green petiole ▪ Tubers cylindrical with tuber outer skin creamy with purplish patches, light pink tuber rind and white tuber flesh ▪ Starch content is 28-30% ▪ Recommended states: Tamil Nadu, Kerala, Andhra Pradesh, Karnataka
19.	H-165	8	33-38	▪ 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 ▪ Early maturing ▪ Starch content is 24% ▪ Recommended states: Tamil Nadu, Kerala, Andhra Pradesh, Karnataka
20.	H-97	10	25-35	▪ Erect and branching variety ▪ Cylindrical tubers ▪ Moderately resistant to *Cercospora* leaf spot, spider mite and scale insect ▪ Starch content is 27-31% ▪ Recommended states: Kerala, Tamil Nadu, Andhra Pradesh, Karnataka

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.

Method of planting

Various methods such as mounds, ridges and furrows and flat beds are followed for planting cassava. Planting in mounds is more common and mounds are prepared to 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 found suitable in sandy or sandy loam soils with good drainage facilities.

Planting material

Cassava is vegetatively propagated 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. Select planting materials from mature, healthy stems having 2-3 cm diameter. Discard the woody basal portion and tender top portion of the stem. Stakes of 15-20 cm length having 10-12 buds are ideal for planting.

Minisett technique for rapid multiplication

Stem pieces having two nodes is optimum to be used as minisetts for rapid production of planting material in cassava. 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 a period of 3-4 weeks. Two to three fully opened leaves stage is the optimum time for transplanting. Multiplication ratio using minisett technique is 1: 60 in place of 1: 10 under conventional system.

Planting and spacing

Plant the setts vertically to 5 cm depth. Avoid inverted planting of setts. The spacing of cassava depends upon the branching behaviour of the variety. Branching and semi-branching types require 90 x 90 cm, while non-branching types require 75 x 75 cm for optimum yield. Normally one sett is planted per mound. For transplanting minisetts, 60 x 45 cm or 45 x 45 cm is adopted. Planting material requirement per hectare is 3600 stems for the spacing of 75 x 75 cm and 2500 stems for the spacing of 90 x 90 cm.

Gap filling

At the time of planting of stakes in the main field, about 5% of the stakes may be planted

separately at a very close spacing of 5 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

Removal of excess sprouts from the planted setts, by nipping at the initial stage of establishment (10-15 days after sprouting) helps to prevent mutual shading and competition between plants. Retaining two healthy shoots per plant on opposite sides is ideal for the production of more number of tubers per plant.

Manures and fertilizers

1. Blanket recommendation

Major nutrients: Farmyard manure (FYM) 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 are recommended. Common fertilizers used for cassava is given in Table 1.

Table 1. Recommended chemical fertilizers (kg/ha)

Sl. No.	Fertilizers*	Basal dose	Top dressing 45-60 DAP
I	Urea	110	110
	Mussooriephos/Rajphos	250	0
	Muriate of potash	85	85
II	Urea	110	110
	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.

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

2. Site specific nutrient management (SSNM)

Customized fertilizer formulations: Custom-made mixed fertilizers according to the site specific nutrient management recommendations, are made available for each zone. Besides the

recommended N, P and K fertilizers, they can be fortified with secondary and micronutrients according to the soil fertility conditions in each zone as given in Table 2.

Table 2. Customized fertilizer formulation for cassava in different zones of Kerala (%)

*Agroecological units (AEU)	Production system	Yield target (t/ha)	N	P	K	Ca	Mg	Zn	B	Rate of application (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

*Agro ecological units of Kerala: 1. Southern Coastal Plain; 2. Northern Coastal Plain; 3. Onattukara Sandy Plain; 4. Kuttanad; 5. Pokkali Lands; 6. The Kole lands; 7. Kaippad Lands; 8. Southern Laterites; 9. South Central Laterites; 10. North Central Laterites; 11. Northern Laterites; 12. Southern and Central Foot Hills; 13. Northern Foot Hills; 14. Southern High Hills; 15. Northern High Hills; 16. Kumily High hills; 17. Marayur Hills; 18. Attappady Hills; 19. Attappady Dry Hills; 20. Wayanad Central Plateau; 21. Wayanad Eastern Plateau; 22. Palakkad Central Plain; 23. Palakkad Eastern Plain

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 i.e., 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.

Customized fertilizer (CF) mixture for cassava in 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 below (Table 3).

Table 3. Customized fertilizer (CF) mixture for Kerala

Sl. No.	Materials	Composition (%)	Quantity (g/kg or kg/ton)
1.	Urea	N-46	50.1
2.	Diammonium 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 (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.

3. 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 solubilizers (*Bacillus megaterium*) and K solubilizers (*Bacillus subtilis*) @ 5 g per plant after top dressing with chemical fertilizers. The secondary and micronutrients Mg, Zn and B can be applied based on soil status as shown in Table 4. These nutrients can be applied after top dressing of NK fertilizers around the mounds at an interval of 10 days.

Table 4. 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

Organic farming

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).

Irrigation

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. Sufficient moisture should be ensured in the field at initial stage i.e., the first 20 days after planting, for proper establishment of cassava stakes. Supplementary irrigation during drought period can result in higher yield. Drip irrigation @ 100% cumulative pan evaporation (CPE) gives maximum tuber yield in cassava. 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 the peak vegetative growth during summer months in Kerala.

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 for short duration varieties. For other varieties, fertigation may be given at the rate of 50% dose of nitrogen and potassium within 90 DAP, 30% within 150 DAP and 20% within 180 DAP. In Tamil Nadu, Andhra Pradesh and Gujarat, drip irrigation @ 100% CPE and fertilizer dose of 75% RDF may be adopted through fertigation.

Weeding and earthing-up

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 is proved to be efficient for weed control in addition to soil moisture conservation. Weed control ground cover, pre-emergence herbicide (oxyfluorfen at 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 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 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.

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 5.

Table 5. 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. Both the main crop and intercrop are to be separately and adequately manured in intercropping. Management practices which are to be followed are given in Table 6. Tuber crops like lesser yam, elephant foot yam etc. can also be grown in association with cassava.

Table 6. Management practices for intercrops in cassava

Name of the crop	Varieties	Duration (days)	Spacing (cm)	No. of rows	Seed rate (kg/ha)	NPK Fertilizer (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 x15	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, 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, 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; black gram variety Co-6 and cluster bean variety Gloria 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.

Crop protection

Cassava is affected by a few serious pests and diseases which can be managed by adopting integrated approaches as given below.

Pest management

1. Mealybug

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

Management

- Select pest free setts for planting.
- Burn the severely infected plants.
- Dip a small cotton ball in mild soap solution and swab on the infected area twice at 5 days interval, if the infestation is mild.
- 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 @ 25 g/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.

Preparation of spraying solution: Add 20 ml of neem oil and 2-5 ml of soap solution in a plastic bucket and make up to 1 L. Vigorously shake the solution till it looks milky white with foam. Dip the setts of cassava for 5 minutes in this solution, so larval stages of the mealybugs will be washed off and killed. Spray the same solution in mealybug infected cassava field also. Nozzle of the spray should be turned towards the lower side of the leaf and ensure full coverage by the spray fluid. A second spray after 15 days may ensure the death of residual population.

2. Spider mites

Symptoms: Occur during dry season from January–May, feed on leaf sap, causing blotching, curling and leaf shedding.

Management

- At the beginning of mite infestation, foliar application of urea (0.1%) followed by spraying water is effective.
- At peak infestation, spiromesifen 0.04% (22.9 SC @1.5-2 ml/l) or dicofol 0.05% (18.5 EC -2.5 ml/l) need to be sprayed at monthly intervals starting from January, whenever infestation occurs.

3. Scale insects

Infest the stems when stacked and occasionally in the field which causes drying.

Management

- Collect stems free of scale insects.
- Store stems in vertical position in shade to prevent multiplication of scale insects.
- As a prophylactic measure, spray the stems with 0.05% dimethoate 30 EC during storage.

Disease management

1. Cassava mosaic disease

Symptoms: Cassava mosaic disease is caused by *Indian cassava mosaic virus* (ICMV) and *Sri Lankan cassava mosaic virus* (SLCMV) (geminivirus). Among these, the latter one occurs predominantly in major areas and cause severe symptoms. Primary spread of this disease occurs through infected planting material and secondary spread in the field is through the insect vector whitefly (*Bemisia tabaci*). Chlorotic areas intermixing with normal green tissue gives mosaic patterns. In several cases, leaves are reduced in size, twisted and distorted, reducing chlorophyll content and photosynthetic area.

Management

- Use of healthy planting materials or meristem derived plants.
- Roguing and strict field sanitation.
- Growing field resistant varieties (eg. Sree Kaveri, Sree Sakthi, Sree Suvarna and Sree Reksha).
- 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.

2. Cassava tuber rot

Tuber rot is caused by *Phytophthora palmivora*. Infected tubers show brown discolouration of internal tissues, become rotten, emit foul smell and become unfit for consumption or marketing, causing heavy yield loss. The disease is severe in fields with poor drainage.

Management

- Deep ploughing through chisel plough up to 20” for free water percolation.
- Removal of infected plants from field.
- Ridge planting and proper drainage.

- Application of neem cake (200 g per plant) and *Trichoderma* enriched farmyard manure (mixing 2.5 kg *Trichoderma* with 100 kg of farmyard manure and then mixing with 12 t of FYM for one hectare) or 50 g of *Trichoderma* enriched manure (1 kg *Trichoderma* mixed with 100 kg of FYM or vermicompost).

3. Cassava stem and root rot

Symptoms: It is caused by *Fusarium* spp. and *Colletotrichum* sp. which cause yellowing and drooping of lower leaves, wilting, rotting of roots, tubers and stem collar region.

Management

- Removal and burning of highly infected plants.
- Avoid water stagnation and ensure good drainage in the field.
- Use only healthy setts for planting.
- Crop rotation with suitable crops once in two years.
- Application of lime @ 150 to 250 g per plant 10-15 days before planting, where pH of the soil is 4-5.
- Application of neem cake @ 20 g per plant and *Trichoderma asperellum* enriched FYM @ one kg per plant.
- Sett treatment with carbendazim 50% WP (0.1%) for 10 minutes and drenching with the same fungicides starting from planting three times at 15 days interval.

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.

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 35-40 t/ha, whereas short duration ones (6-7 months) yields 25-35 t/ha. In Tamil Nadu, under better management and irrigation, tuber yield of 40-60 t/ha can be obtained.

SWEET POTATO

Scientific Name: *Ipomoea batatas* (L.) Lam

Sweet potato is cultivated for human consumption and also for animal feed. Industries produce starch from sweet potato tubers.

Climate

It is a crop of tropical and sub-tropical regions having wide adaptability. The areas with an average day temperature of more than 24°C and an average annual rainfall of 750 mm or more are suitable for its cultivation. Short day with low light intensity promote root development, while excess of rainfall and long photoperiod encourages vine growth and reduces tuber yield.

Soil

Sweet potato performs well in well-drained, fertile, sandy loam soils having high organic matter. The optimum pH range of the soil is 5.2 to 6.7. Waterlogging is not good for its cultivation.

Planting season

Sweet potato is grown as a rainfed crop during *kharif* (June-August) and as an irrigated crop during *rabi* (October-December) in uplands or as a summer crop in lowlands.

Improved varieties

Sl. No.	Name of variety	Duration (days)	Yield (t/ha)	Special features
1.	Bhu Sona	105-110	20-24	▪ Spreading type, pubescent, purple vine with shallow grooves and green emerging leaf, leaf toothed with green petiole, profusely flowering ▪ Storage root round elliptic with yellow skin and dark orange flesh ▪ β carotene content is 13.2-14.4 mg/100 g fresh weight ▪ Recommended state: Odisha
2.	Bhu Swami	105-110	20	▪ Semi-compact plant type with green vine having purple spots and emerging leaf having purple vines on upper surface, toothed leaf, profusely flowering ▪ Storage root round with white skin and white flesh ▪ Suitable for food and processing and tolerant to mid-season drought. Excellent cooking quality ▪ Extractable starch is 21% ▪ Recommended state: Odisha
3.	Bhu Krishna	110-120	18-22	▪ Semi-compact plant type with green pubescent vine having purple nodes, emerging leaf bright green with purple edge, leaf triangular, sparse flowering ▪ Long elliptic tuber with dark purple skin and dark purple flesh ▪ Highly tolerant to sweet potato weevil and salt stress ▪ Anthocyanin content is 90 mg/100 g fresh weight ▪ Recommended state: Odisha

4.	Bhu Ja	100-110	20-22	▪ Semi-compact plant type with green vine and green emerging leaf, leaf toothed, profusely flowering ▪ Storage root round elliptic with pink skin and orange flesh ▪ Tolerant to salt stress ▪ β carotene content is 5.5-6.4 mg/100 g ▪ Recommended state: Odisha
5.	Bhu Kanti	105-110	22-24	▪ Spreading type, green vine with many purple spots and dark green emerging leaf, leaf triangular, profusely flowering ▪ Storage root elliptic with light yellow skin, orange flesh ▪ Field tolerant to weevil, mid-season drought and salt stress ▪ β carotene content is 6.5 mg/100 g fresh weight ▪ Recommended state: Odisha
6.	Kishan	110-120	17	▪ Semi compact with greenish purple vine and emerging leaf green with purple margin, leaf triangular having green petiole with purple near leaf base ▪ Storage root elliptic with reddish purple skin, white rind and creamy white flesh ▪ Suitable for food, fodder and starch. It can withstand mid-season drought, performs better in sandy loam and black sandy soils ▪ Extractable starch is 18.2% ▪ Recommended state: Medium to uplands and hilly areas of Odisha
7.	Sourin	105-110	16.2	▪ Spreading nature with mostly purple vine and purplish green emerging leaf, lobed leaf with green petiole having purple spot throughout ▪ Storage root round to elliptic with red skin, white rind and creamy white flesh ▪ Suitable for both *kharif* and *rabi* seasons ▪ Recommended state: Medium to uplands and hilly areas of Odisha
8.	Goutam	105-110	19	▪ Spreading plant type with mostly purple vine and light purple emerging leaf. Leaf shape triangular and petiole is green with purple spot at the leaf junction ▪ Storage root round to ovate with white skin and cream flesh ▪ Good cooking quality, soft, mealy and very sweet ▪ Tolerant to sweet potato weevil. Suitable for both *kharif* and *rabi* seasons ▪ Recommended state: Hilly and coastal areas of Odisha

9.	Sree Kanaka	75-85	10-15	▪ Compact with green vine and dark purple emerging leaf, leaf 3-5 lobed, very sparse flowering ▪ Storage root cylindrical, skin colour cream with reddish yellow tinge and dark orange flesh ▪ Short duration variety ▪ High β carotene of 8.4-10.6 mg/100 g fresh weight ▪ Recommended state: Kerala
10.	Kalinga	105-110	17	▪ Spreading type with green vine and green with purple-edged emerging leaf, leaves deeply lobed, moderate flowering ▪ Storage root round to elliptic with purple red skin and cream flesh ▪ Excellent cooking quality ▪ Recommended state: Odisha
11.	Sree Varun	90	20-28	▪ Spreading with green vine and slightly 5 lobed leaves, profuse flowering ▪ Fusiform short/spherical storage roots with cream skin and cream flesh ▪ Recommended state: Kerala (uplands)
12.	Sree Arun	90	20-28	▪ Spreading type, vine green with light brown emerging leaf, leaf cordate with green petiole, sparse flowering ▪ Storage roots fusiform short/spherical with very pale pink skin and cream flesh ▪ Recommended state: Kerala (uplands)
13.	Sankar	120	14	▪ Spreading type with green vine and green with purple-edged emerging leaf, hastate leaf. Petiole green with purple near leaf base, moderate flowering ▪ Elliptical storage root with red skin and pale-yellow flesh ▪ Medium duration variety with excellent cooking quality ▪ Recommended state: Odisha
14.	Gouri	110-120	19	▪ Semi-erect type with slightly purple vine and slightly purple emerging leaf. Leaf simple with 5-6 lobes, profusely flowering nature ▪ Storage root obovate to round elliptic with purple red and deep orange flesh ▪ Excellent cooking quality. Medium duration variety, can tolerate mid-season moisture stress. Suitable for *kharif* and *rabi* seasons ▪ β carotene content is 4.5 mg/100 g ▪ Recommended state: Odisha

15.	Sree Bhadra	90	20-22	▪ Semi-spreading with greenish brown vine and dark brown emerging leaf. Leaves broad cordate. Profusely flowering type ▪ Storage root spherical with light pink skin and cream flesh ▪ Excellent cooking quality. Useful as a trap crop for root knot nematode (*Meloidogyne incognita*) ▪ β carotene content is 0.48-0.60 mg/100 g ▪ Recommended states: Kerala, Maharashtra, Bihar, Madhya Pradesh
16.	Sree Rethna	90-105	20-22	▪ Spreading with light greenish brown vine and brown emerging leaf, light green shouldered leaves, profusely flowering type ▪ Storage root spherical with purple skin and orange flesh ▪ Excellent cooking quality ▪ β carotene content is 1.92-2.10 mg/100 g ▪ Recommended state: Kerala
17.	Sree Vardhini	100-105	20-25	▪ Semi-spreading, green vine with pink tinge, emerging leaf light brown, leaf simple with 3-4 lobes, profusely flowering type ▪ Storage root is short, fusiform with purple skin and yellow flesh ▪ β carotene content is 0.72 mg/100 g ▪ Recommended state: Kerala
18.	Sree Nandini	100-105	20-25	▪ Drought tolerant, spreading, green vine with light green emerging leaf, leaf unifoliate with entire margin, moderate flowering ▪ Storage root fusiform with cream skin and yellow flesh ▪ Excellent cooking quality and sweet, suitable for rice fallows as a catch crop ▪ Recommended state: Kerala
19.	Varsha	120	17-22	▪ Semi-spreading, dark green vine with simple 3-5 lobed leaves, shy flowering ▪ Tubers fusiform with reddish purple skin and light yellow flesh ▪ Drought tolerant ▪ Recommended state: Konkan region of Maharashtra
20.	H-42	120	22-25	▪ Semi-spreading, vine greenish with pink tinge, emerging leaf light purple, unifoliate leaf with toothed margin, petiole greenish with purple tinge, profusely flowering ▪ Storage root fusiform with pink skin and cream flesh ▪ Recommended states: Kerala, Tamil Nadu, Karnataka

21.	H-41	120	20-25	▪ Semi-spreading, green vine with unifoliate leaf, profusely flowering ▪ Storage root fusiform, with white flesh ▪ Excellent cooking quality ▪ Recommended states: Kerala, Tamil Nadu, Karnataka

Planting material

Vine cuttings obtained from harvested plants or from nursery are used for field planting. Vines of 20-30 cm length with at least 3-4 nodes are ideal as planting material. The cuttings obtained from the apical and middle portion of vines are preferable to get higher sprouting percentages and better tuber yields. The cuttings with intact leaves are stored under shade for two days before planting in the main field to promote better root initiation, early establishment and higher yield. If tubers are used, nursery is raised in two stages-primary nursery and secondary nursery for getting enough vine cuttings.

Primary nursery

The nursery is prepared about 3 months before planting in main field. About 100 m^2 primary nursery area and 100 kg of medium-sized weevil free seed tubers, weighing 125-150 g each, are enough for planting one hectare of land. The tubers are planted 25 cm apart on ridges formed at a spacing of 60 cm. Urea may be applied 15 days after planting @ 1.5 kg urea/100 m^2 to ensure quick growth of vines and the nursery may be irrigated on every alternate day for the first 10 days and thrice a week thereafter. The vines are clipped off to a length of 20-30 cm after 40-45 days of planting, for replanting in the secondary nursery.

Secondary nursery

The vines obtained from the primary nursery are further multiplied in secondary nursery area of 500 m^2, which produces enough planting material to plant one hectare of land. About 500 kg FYM or compost may be applied at the time of preparation of the nursery. The vines, obtained from primary nursery are planted at a spacing of 20 cm on ridges formed 60 cm apart. Urea @ 1 kg/100 m^2 may be applied in two split doses at 15^{th} and 30^{th} day after planting. After 45 days, vines are ready for planting in the main field.

Method of planting

The different planting methods, which are practiced in sweet potato are mound, ridge and furrow, bed and flat method. Among the different methods, ridge and furrow method is mostly practiced, which gives better yield. Make ridges at 60 cm apart having 25-30 cm height and plant the vine cuttings at 20 cm spacing on the ridges. Plant the cuttings horizontally and only the middle portion of the vine with two to three nodes is buried in soil at 5-10 cm depth keeping both the ends exposed.

Manures and fertilizers

1. Blanket recommendation

Major nutrients: Apply FYM @ 5 t/ha at the time of field preparation. Apply fertilizers @ 50 kg N, 25 kg P_2O_5, 50 kg K_2O/ha. Full dose of P_2O_5 and K_2O and half dose of nitrogen should be given at the time of planting, whereas remaining half dose of nitrogen should be applied one month after planting along with first weeding and earthing up.

For this, apply urea (55 kg) or ammonium sulphate (125 kg), rock phosphate (125 kg) and muriate of potash (85 kg) per hectare at the time of planting and top dress with 55 kg urea or 125 kg ammonium sulphate along the side of the ridges, a month after planting.

Secondary and micronutrient management in sweet potato

- The soil pH is found as an important factor affecting tuberization in sweet potato. In acid soils of Kerala, where the soil pH ranges from 4.5-5.5, liming is essential to raise the pH. The rate of application of lime can be as follows: (pH: 3.5, 4.0, 4.5, 5.0, 5.5, 6, 6.5-lime/dolomite: 8, 7, 6, 5, 4, 3, 2 t/ha respectively).
- If the soil status of Mg is low (below the critical level of 1 meq/100g or 120 ppm), soil application of $MgSO_4$ @ 80 kg/ha may be done.
- Apply $ZnSO_4$ @ 20 kg/ha, if the soil status of Zn is low (below the critical level of 0.6 ppm).
- In the case of B, if the soil status is low (below the critical level of 0.5 ppm), apply borax/solubor @ 10 kg/ha.
- If all these nutrients are needed as per soil test, an interval of 5-10 days shall be given between applications and can be applied after 45 days of planting of sweet potato.
- If the soil test values of these nutrients are above the soil critical level, the rate can be limited to one half or one fourth (as per soil test) as a maintenance dose.
- Foliar application of 0.1% solubor, 0.1% Zn EDTA and 0.5% $MgSO_4$ independently depending upon the requirement as per soil test or on the occurrence of the symptom manifestation.
- Foliar application can be done as one spray during the peak vegetative growth stage of the crop (45-60 DAP) and two sprays at an interval of 15-20 days during the tuber bulking stage (75-95 DAP).
- For combined application along with major nutrients, foliar application of 19:19:19 (1%) + Zn EDTA (1%) @ 625 litres per ha during the peak vegetative growth stage and 1% KNO_3 along with 0.1% solubor (together @ 625 litres per ha) twice at tuber bulking stage at an interval of 15-20 days is recommended.

Management of tuber cracking due to Boron (B) deficiency in sweet potato

- Liming the soil either with lime or dolomite (refer the lime/dolomite rate as per pH given in the previous section) 15 days prior to land preparation so as to raise the soil pH and increase the Ca content of the soil.
- Follow balanced application of NPK @ 50:25:50 kg/ha along with FYM @ 5 t/ha.
- Apply borax/solubor @ 5 kg/ha by mixing with sand or soil in the ridge/mound at the time of planting with irrigation.
- After top dressing, apply sand/soil mixed solubor 5 kg/ha in the soil at 50-60 DAP.
- Apply solubor 0.1% as foliar spray @ 650 litres/ha at maximum vegetative growth stage (55-60 DAP) and at tuber bulking stage twice (70-80 DAP and 80-90 DAP).

- After continuing this recommendation for three seasons, further soil and foliar application of B may be done based on the occurrence/non-occurrence of the symptom and soil B status at that time.
- Care must be taken to strictly adhere to the maximum concentration of B for foliar application as 0.1%.

2. Site specific nutrient management (SSNM)

Customized fertilizer formulations: The SSNM recommendations developed for sweet potato is given in Table 7. In soils with medium NPK fertility status, application of customized fertilizer formulation with the composition of 11: 7: 11: 6: 3: 0.4: 0.1 of N: P: K: Ca: Mg: Zn: B at the rate of 650 kg/ha is recommended for a target yield of 20 t/ha.

Table 7. SSNM recommendations for sweet potato in India

Organic C (%)	Yield target (t/ha)				Available P (kg/ha)	Yield target (t/ha)				Available K (kg/ha)	Yield target (t/ha)			
	30	40	50	60		30	40	50	60		30	40	50	60
	N rate (kg/ha)					P_2O_5 rate (kg/ha)					K_2O rate (kg/ha)			
Below 0.5	75	100	-	-	Below 10	50	60	-	-	Below 180	75	100	-	-
0.5 – 0.8	50	75	100	-	10-20	35	50	60	-	180-280	50	75	100	-
0.8 – 1.2	35	50	75	100	20-30	25	35	50	60	280-360	35	50	75	100
Above 1.2	25	35	50	75	Above 30	-	25	35	50	Above 360	25	35	50	75

Foliar liquid micronutrient formulations: ICAR-CTCRI has developed a microfood formulation containing Zn, Cu, B, Fe and Mn at 2, 0.6, 0.2, 0.5 and 0.25% concentrations prepared based on crop requirements for sweet potato. This customized liquid micronutrient formulation, commercially available in the market as 'Micronol Sweet Potato' may be applied as foliar spray @ 5 ml per litre thrice at 15, 30 and 45 days after planting. One litre of the formulation in 200 litres of water is required for spraying in one acre.

Organic farming

It is preferable to grow sweet potato variety, that has great demand in market. Use of pest and disease-free healthy vine cuttings of orange-fleshed sweet potato variety, Bhu Sona is recommended. Plant vine cuttings of 20-30 cm length from organically grown sweet potato.

Organic manures need to be applied based on N requirements. The total N requirement is calculated by considering N content in 5 t FYM + 50 kg fertilizer N. Nutrient content of organic manures should be analyzed before application. *Azospirillum*, *Azotobacter*, phosphorus solubilizing bacteria and *Trichoderma* combinations can be used as biofertilizers applied into the soil @ 5 kg/ha each. The different options in the use of commonly available manures for organic sweet potato production are as follows.

***Trichoderma* enriched FYM**: FYM enriched with *Trichoderma* can be applied in organic farming. For enriching FYM with *Trichoderma*, 1 kg of *Trichoderma* formulation should be mixed with one ton of FYM and sprinkled with water, and then it is covered with polythene sheet after heaping. The heap is to be turned once in 10 days and sprinkled with water. The enriched FYM can be used after a month. For FYM based organic farming, FYM @ 15 t/ha and *Trichoderma* @ 15 kg/ha is required.

Green leaf manuring/vermicompost: Alternative organic manures like green leaf manures or vermicompost can also be used in the place of FYM, depending on availability. Green leaves of *Gliricidia sepium* @ 17 t/ha can be incorporated at 10-15 days before planting of sweet potato vines. Use of vermicompost @ 4 t/ha at the time of planting is also suggested for comparable tuber production.

Organic manures inoculated with biofertilizers: Inoculation of biofertilizers (*Azospirillum, Azotobacter,* phosphorus solubilizing bacteria and *Trichoderma*) with the commonly used organic manures will help to reduce the dose of FYM, green leaf manure and vermicompost to half. This will help to increase soil enzyme activities, microbial population and microbial biomass carbon. Thus, FYM @ 7.5 t/ha + biofertilizers @ 5 kg/ha (or) green leaf manure @ 8.5 t/ha + biofertilizers @ 5 kg/ha (or) vermicompost @ 2 t/ha + biofertilizers can also be used. It is advisable to follow neem-based plant protection measures in organic farming of sweet potato.

Irrigation

A light irrigation after planting, to maintain sufficient moisture, gives proper establishment of the crop. If there is insufficient moisture, irrigation should be given at 10-15 days interval. In Kerala, sweet potato is cultivated in summer rice fallow using residual moisture and supplementary irrigation. Irrigation is required if the crop is raised during summer in uplands.

Drip irrigation @ 100% cumulative pan evaporation (CPE) gives maximum tuber yield in sweet potato. Quantity of irrigation water is decided by the local weather and soil conditions and stage of the crop. Approximately, 300 to 500 ml of water is required per plant per day during the peak vegetative growth during summer months in Kerala.

Weeding and earthing-up

During the initial stage, because of wider spacing, weeds grow and cause yield loss. Hence, weeding cum earthing-up at 30 days after planting is required. The second weeding cum earthing-up should be done 60 days after planting. Pre-emergence herbicide isoproturon @1.0 kg/ha mixed with dry sand applied by broadcasting prevents the weed growth up to 30 days. It may be followed by one hand weeding at 60 days after planting.

Cropping systems

Sweet potato has been found to grow under different cropping sequences in eastern and southern region of India. In Kerala, sequential cropping of rice- rice- sweet potato and rice- sweet potato-fallow are common.

Crop protection

1. Sweet potato weevil (*Cylas formicarius*)

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

Integrated management

- Dip the vine cuttings in dimethoate 30 EC @ 0.05% solution for 10 minutes before planting.

- Earth up the crop two months after planting.
- Install synthetic sex pheromone traps @ 1 trap/100 m^2 area to collect and kill the male weevils.
- Destroy the crop residues after harvest by burning.
- Spray imidacloprid 17.8 SL @ 0.005% at fortnightly intervals.

2. Sweet potato feathery mottle virus (SPFMV)

Among the 12 virus symptoms recorded, feathery mottle (SPFMV) is widely occuring. The primary spread is through planting material. The disease results in 50% crop loss in other countries. However, in India the loss in farmers' field is negligible. The disease can be managed through planting field tolerant varieties *viz*., Sree Vardhini, use of virus free planting materials as well as meristem derived plants.

Harvesting

The crop matures in 100-135 days after planting depending on the variety and environmental conditions. Light irrigation during 2-3 days before harvesting of tubers make digging easier. Early cultivars can be harvested 90-105 days after planting, whereas, medium and late maturing cultivars at 110 and 120 days after planting, respectively. Remove the vines and dig out the tubers without injuring them. After harvest, tubers must be spread in partial shade for 5-6 days, for proper healing and curing and then can be stored in well-ventilated rooms.

Yield

Yield of sweet potato vary from 10-20 t/ha depending on the varieties and cultural practices adopted.

YAMS

Scientific Name: *Dioscorea* spp.

Yams are tropical tuber crops which prefer long moist growing season. In India, they are cultivated largely in southern, eastern and north eastern states. There are three main species of yams grown in our country, which are edible viz., greater yam (*Dioscorea alata*); lesser yam (*Dioscorea esculenta*); white yam (*Dioscorea rotundata*). While greater yam and lesser yam are quite popular since ancient items, white yam is an introduction from Africa. Yams are normally consumed as staple food, vegetable, either boiled, baked or fried.

Climate

Yams grow well in warm and humid conditions. Warm climate, with a temperature of 25-30°C and adequate moisture, with a well distributed annual rainfall of 1200-2000 mm are ideal for vegetative growth and tuber bulking. Yams cannot tolerate frost and growth is affected at a temperature below 20°C.

Soil

Yams require deep well drained fertile soil containing good amount of organic matter and do not come up well under waterlogged conditions. A pH of 5-7 is ideal for growing yams.

Planting season

March-April is the ideal time for planting yams.

Improved varieties

Sl. No.	Name of variety	Duration (months)	Yield (t/ha)	Special features
Greater yam				
1.	Sree Hima	7-8	35-45	▪ Cylindrical moderately hairy tubers with rough tuber surface texture, brown skin, pink rind and white flesh colour ▪ Good cooking quality. Field tolerant to anthracnose disease ▪ Recommended state: Kerala
2.	Sree Nidhi	7-8	35-45	▪ Cylindrical tubers with light pink cortex and white flesh colour without browning. It has optimum tuber size with very little apical portion ▪ Good culinary quality. It has field tolerant to anthracnose disease ▪ Tubers with medium dry matter (32%), starch (23.2% FW) and crude protein (2.5% FW) content ▪ Recommended state: Kerala
3.	Sree Neelima	8-9	30-40	▪ Conical tuber with dark brown skin, dark purple cortex and light purple flesh colour ▪ Good cooking and nutritional quality ▪ Tubers with medium dry matter (24.6%), low starch (18.1% FW), medium crude protein (3.28% FW) content ▪ Recommended state: Kerala

4.	Sree Swathy	9-10	35-45	▪ Medium conical to irregular tuber with dark brown skin, yellowish cortex and white flesh colour without browning ▪ Good cooking and nutritional quality. Field tolerant to anthracnose disease caused by *Colletotrichum gloeosporioides* and drought tolerant ▪ Tubers with medium starch (20.02%), high protein (16.94% DW) and ascorbic acid (6.9 mg/100 g DW) content ▪ Recommended state: Kerala
5.	Bhu Swar	6-7	20-25	▪ Long cylindrical to irregular tuber with brown skin, yellow cortex, cream flesh ▪ Good cooking quality ▪ Tubers have low starch (18-20%) and sugar (1.0-1.5%) content ▪ Recommended state: Odisha
6.	Orissa Elite	9	22-25	▪ Good cooking quality ▪ Recommended state: Rainfed/irrigated conditions of Odisha
7.	Sree Karthika	9	28-30	▪ High yielding selection with good cooking quality and shelf life ▪ Field tolerant to anthracnose disease ▪ Recommended state: Kerala
8.	Sree Shilpa	8	25-28	▪ Tubers are swollen, oval and smooth, with black skin, yellow cortex and white flesh colour ▪ Good cooking quality ▪ Starch content is 17-19% ▪ Recommended state: Kerala
9.	Sree Roopa	9-10	25-30	▪ Tubers are digitate in shape with black skin and white flesh ▪ Tubers have good cooking quality and taste ▪ Starch content is 17-19% and protein 1-2% ▪ Recommended state: Kerala
10.	Sree Keerthi	9-10	25-30	▪ Tubers are conical in shape with brown skin and white flesh ▪ Tubers have good cooking quality and excellent taste ▪ Field tolerant to anthracnose disease ▪ Starch content is 20-22% ▪ Recommended state: Kerala
			Lesser yam	
1.	Sree Kala	8-9	20-25	▪ Tubers are round and smooth with good cooking quality. The cooked tuber is sweet in taste and without fibre ▪ Recommended state: Kerala
2.	Sree Latha	8-9	20-25	▪ Tubers are oblong to fusiform in shape with greyish brown skin covered with thin hairs and creamy white flesh ▪ Tubers have good cooking quality and flavour ▪ Starch content is 18.4% ▪ Recommended states: Kerala, Bihar, Maharashtra, Andhra Pradesh, Assam, West Bengal
			White yam	
1.	Sree Swetha	8-9	25-30	▪ Dwarf/bushy variety with 30-50 cm height that does not require staking and can be accommodated at closer spacing (60 x 60 cm) ▪ Cylindrical tubers with brown skin and white flesh colour ▪ It has medium starch (22.02%) and medium protein (3.8%) content ▪ Recommended state: Kerala

2.	Sree Haritha	9-10	45-50	▪ Medium size compact cylindrical tubers with smooth texture, brown skin and white flesh colour ▪ Good cooking quality and drought tolerant ▪ It has medium starch (24.02%) and crude protein (3.2%) content ▪ Recommended state: Kerala
3.	Sree Dhanya	9	15-20	▪ Dwarf type which is bushy in appearance and staking is not required. The height of the plant is about 30 cm and each plant forms a bush of about 50-60 cm in diameter. It has spineless stems ▪ Starch content is 23.3% ▪ Recommended state: Kerala
4.	Sree Priya	9-10	35-40	▪ Tubers have smooth surface with good cooking quality and taste ▪ Starch content is 20-21% and protein is 2-3% ▪ Recommended state: Kerala
5.	Sree Subhra	9-10	35-40	▪ Tubers are cylindrical in shape with brown partially hairy skin and white flesh ▪ Possesses excellent cooking quality ▪ Starch content is 21-23% ▪ Recommended state: Kerala

Planting material

Yams are propagated vegetatively through either small whole tubers or tuber pieces. In the case of greater yam and white yam, tuber pieces of 200-300 g size can be used as planting material whereas, 100-150 g is ideal for lesser yam.

Minisett technique

In minisett technique, tubers are cut into cylindrical pieces and then transversely into small pieces of 30 g size with periderm intact. It can be planted initially in the nursery at a spacing of 5 cm with cut surface facing upwards in the nursery bed. The plants may be transplanted after sprouting in the main field with proper mulching at a spacing of 60 x 45 cm. In the minisett technique, multiplication ratio could be enhanced to 1: 24 from 1: 6 in the conventional method.

Land preparation and planting

Yams are planted by various methods in different places depending on soil types. Plough or dig the land to a depth of 15-20 cm. Open pits of 45 x 45 x 45 cm size for planting greater yam and white yam at a spacing of 90 x 90 cm. Fill up three-fourth of the pit with top soil and FYM and reform into a mound. Plant seed tubers of greater yam/white yam on reformed mounds. About 3000-3700 kg of seed material is required to cover one hectare.

For raising lesser yam, mounds may be formed at a spacing of 75 x 75 cm after broadcasting FYM. Plant whole tubers of lesser yam on mounds. Approximately 1800-2700 kg of seed materials are required to plant one hectare. In loose sandy type of soils, they can be planted in flat beds and in mild sloppy land, the ridges are prepared to conserve soil. After planting the tubers, completely cover them with soil. Mulching hastens sprouting, control weed growth, regulate soil temperature and retain soil moisture.

Manures and fertilizers

1. Blanket recommendation

Apply FYM or compost @10 t/ha at the time of land preparation. In addition to organic manure, apply N: P: K @ 80: 60: 80 kg/ha for *D. esculenta* and *D. alata* and N: P: K @ 100: 50: 100 kg/ha

for *D. rotundata*. Apply half dose of nitrogen (87 kg of urea or 200 kg of ammonium sulphate), full dose of phosphorus (300 kg rock phosphate) and half dose of potash (67 kg of muriate of potash) within a week after sprouting. The remaining nitrogen and potash may be applied one month after the first application. Top dressing of fertilizers should be followed by weeding and earthing up.

Management of B deficiency in yams

- Application of lime @ 2 t/ha
- Soil application of B as borax @ 25 kg/ha, half each as basal on mounds before planting and at 3-4 MAP
- Foliar application of solubor @ 0.5% thrice at maximum vegetative growth (3-4 MAP) and tuber bulking stages (5-6 MAP) and (7-8 MAP) @ 625 litres/ha

2. Site specific nutrient management (SSNM)

Customized fertilizer formulations: Conventional blanket recommendation of fertilizers lead to yield stagnation, lower nutrient use efficiency and imbalance in the use of nutrients. Custom-made mixed fertilizers according to the site specific nutrient management recommendations are available. In soils with medium NPK fertility status, application of customized fertilizer formulation with the composition of 11: 8: 11: 2.5: 0.3: 0.1 of N: P: K: Mg: Zn: B @ 600 kg/ha is recommended for a target yield of 20 t/ha.

Customized fertilizer (CF) mixture for Kerala

- The CF grade suitable for yams is N: P_2O_5: K_2O: Mg: Zn: B @ 8: 11: 21: 3.84: 0.84: 0.315.
- The rate of application is 625 kg/ha, @ 51g/plant at 45-60 days after planting followed by top dressing with urea and MoP @ 36 and 18 g/plant respectively within 30-45 days after first application. This can be used in all AEUs of Kerala.

Foliar liquid micronutrient formulations: ICAR-CTCRI has developed a Microfood formulation 'Micronol Yam' containing all the micronutrients essential for yams. This customized liquid micronutrient formulation may be applied as foliar spray at the rate of 5 ml per litre, three times at 2, 3 and 4 months after planting. One litre of the formulation in 200 litres of water is required for one acre.

Organic farming

Plant anthracnose disease resistant varieties of greater yam like Sree Keerthi, Sree Swathy or tolerant varieties like Sree Nidhi and Sree Karthika. Plant organically produced tuber pieces of 250-300 g for white yam and greater yam and medium sized tuber of 100-150 g for lesser yam. Apply FYM @ 15 t/ha (1.2 kg per plant) in pits at the time of planting. Apply neem cake @ 1 t/ ha (80-85 g per pit) in pits at the time of planting. Apply biofertilizers, *Azospirillum* @ 3 kg/ha, mycorrhiza @ 5 kg/ha and phosphobacteria @ 3 kg/ha for trailing genotypes of white yam, greater yam and lesser yam and *Azospirillum* @ 3 kg/ha and mycorrhiza @ 5 kg/ha for dwarf white yam at the time of planting. Inter-sow green manure cowpea (seed rate @ 20 kg/ha) between yam mounds and incorporate green matter at 45-60 days. The green matter addition from the green manure will be @ 15-20 t/ha. Apply ash @ 1.5 t/ha (120 g per plant) at the time of incorporation of green manure.

Irrigation

Yams are relatively tolerant to drought, but it gives better tuber yield with supplementary

irrigation, when there is a long dry spell. Yams should be irrigated immediately after planting to ensure quick and uniform sprouting. The crop is sensitive to waterlogging.

Weeding and earthing-up

In the initial stage, after a week of sprouting, weeding and earthing-up should be done sufficiently deep for the better growth of vines. The second weeding and earthing up should be done one month after the first one.

Trailing/Staking

Trailing is necessary to expose the leaves to sunlight. It is done within 15 days after sprouting by coir rope attached to artificial supports in the open area or to the trees where it is raised as an intercrop. Plants of *D. alata* and *D. rotundata* need to be trailed to a height of 3-4 m, whereas *D. esculenta* requires comparatively lesser height of staking.

Cropping systems

Yams as intercrops in plantation crops and fruit crops

Yams can be raised as intercrops in coconut, arecanut, banana, rubber and robusta coffee. In the case of rubber and coffee, intercropping should be restricted during the initial 3-4 years. About 9000 plants can be accommodated at a spacing of 90 x 90 cm in one ha of coconut plantation, leaving 2 m radius from the base of the palms. Both the main crop as well as intercrop should be separately and adequately manured. Yam varieties such as Sree Latha, Sree Keerthi and Sree Priya are suited for intercropping.

Yams can also be intercropped in Nendran and Robusta varieties of banana. In the interspaces of 2 rows of Nendran banana spaced at 3.6 x 1.8 m (1500 plants/ha), 3 rows of yams can be planted to accommodate 8000 plants/ha. It was also found that the levels of FYM, N and P to the intercrop as well as main crop could be reduced to half, with full potash. Robusta banana can be planted at 2.4 x 1.8 m to accommodate 2300 suckers. In between 2 rows of banana, 2 rows of yams can be planted to accommodate 6000 plants/ha. In Robusta banana+*Dioscorea* system, banana should be manured at the full recommended dosage and for yams, manuring at the 2/3rd recommended level is sufficient.

In young rubber plantations, during the initial 3-4 years, yams can be intercropped. It is possible to accommodate about 6000 yam plants in one ha of rubber plantation after leaving 1.5 m radius from the base of the rubber plants. But manuring at the full dose should be done for both the crops.

When yams are intercropped in arecanut garden, about 7000 yams can be accommodated at a spacing of 90 x 90 cm, leaving 1 m radius from the base of the palms.

Intercropping system involving dwarf white yam and pulse crops

Intercropping dwarf white yam (var. Sree Dhanya) with green gram (var. Co-Gg-7) or soybean (var. NRC-37) is productive and profitable. There is a possibility to save half FYM and N and full P to white yam in the system. Thus, FYM @ 5 t/ha and NPK @ 50:0:100 kg/ha is sufficient for dwarf white yam in this system.

Crop protection

1. Yam scale

Yam scale is found to occur on the tubers both under field and storage conditions. As a prophylactic measure, dip the planting material in monocrotophos @ 0.05%. Use scale free seed tuber for planting.

2. Anthracnose (Die-back)

It is caused by *Colletotrichum gloeosporiodes* Penz. Among various *Dioscorea* species, *D. alata* is very susceptible to anthracnose, followed by *D. esculenta*, whereas *D. rotundata* is tolerant. The disease appears as brown pinhead like spots on the leaves and stems. These spots become enlarged as the leaves approach full size and they may develop pale yellow margins. Sometimes the leaf spots run together to form large irregular blotches, the centers of which may fallout giving a shot hole effect. Infected leaves usually fall off. The production of toxin by the fungus cause die-back symptoms due to drying of vines.

This can be managed by adopting crop rotation, fallowing, removal of crop debris, use of healthy planting material and destruction of infected plants. Ploughing immediately after harvest also helps to reduce the inoculum. Spraying carbendazim (0.025%) seven times starting from the appearance of the first symptom, thrice once in 15 days, followed by four times at monthly intervals will manage the disease.

3. Leaf spot

The disease is distributed worldwide in all species of yams. Several *Cercospora* spp. are recorded as causal agents of leaf spots on yams. The fungus survives on crop debris. Conidia are produced on both surfaces of infected leaves and spread by rain. The symptom starts as chlorotic spots, which turns into dark brown to black necrotic spots with regular margin.

The disease is more common during warm and wet weather. Though the symptoms are severe, since it occurs in the later stages of the crop the yield loss is negligible. The disease can be managed by spraying copper oxychloride @ 0.15% (1.5 g per litre).

4. Nematodes

There are two major nematode species infesting yam, *Scutellonema bradys* and *Meloidogyne incognita.* Symptoms appear as yellowing of leaves, cracking of tubers, malformed tubers, brown discoloration of tissues and tuber rot.

Management

- Selection of nematode free planting material.
- Following crop rotation with non-host crops.
- Burning and destruction of severely infested tubers and plants.
- Treatment of tubers with *Trichoderma* enriched cowdung slurry @ 5 g/kg tuber (or)
- Use of *Trichoderma* enriched farmyard manure @ 12 t/ha
- Use of newer nematicides, fluensulfone 2% GR @ 1g/plant and fluopyram 34.48% SC @ 0.5 ml/plant.

Harvesting

Yams are generally harvested at 7-10 months after planting, depending on the species and varieties. Yellowing of leaves and complete drying up of the vines indicate the maturity of crop. Greater yam and white yam become ready for harvest by 9-10 months after planting. Lesser yam takes 8-9 months for attaining maturity. The tubers are dug out carefully without causing injury.

ELEPHANT FOOT YAM

Scientific Name: *Amorphophallus paeoniifolius* (Dennst.) Nicolson

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

Climate

Amorphophallus is a tropical/sub-tropical crop and hence thrives well under warm humid climate with a mean annual temperature of 30-35°C and a well distributed rainfall of 1000-1500 mm spread over a period of 6-8 months.

Soil

A well-drained, well-aerated, fertile, sandy loam to sandy clay loam soil with a pH of 6 to 7, rich in organic matter is ideal for the crop. The growth of corms in heavy soil reduces the yield greatly. Waterlogging is harmful at any stage of the crop.

Planting season

Elephant foot yam undergoes a dormancy period of 45-60 days before sprouting. February-March is ideal time for planting the crop in Kerala so that the corms sprout with the pre-monsoon showers during April. In Tamil Nadu, planting is taken up during February-March, June-July and September. In Andhra Pradesh, it is grown as a *kharif* crop, which is planted during April-June and harvested during December-January. During *rabi* season also, it is planted in November-December and harvested in May-June.

Varieties

A selection (AM-IS) from the indigenous germplasm collection of elephant foot yam with an average yield of 42 t/ha has been released under the name 'Sree Padma' for general cultivation in Kerala. 'Sree Athira' is a genetically improved variety with good cooking quality and high yield (40 t/ha), which matures in 9 months.

Planting material

Elephant foot yam is propagated vegetatively by using either whole corms or cut corms. Small whole corms are preferred over cut corms for early and uniform sprouting. Whole or cut corms weighing 750-1000 g are used for commercial cultivation, 500 g is ideal for economic returns. Care should be taken while cutting to see that each cut piece bears a portion of the central bud. To enhance the sprouting, planting materials should be dipped in thick cow dung slurry and then dried in shaded place. The corm pieces treated with cow dung slurry mixed with mancozeb @ 0.2% or *Trichoderma* @ 5 g/kg and dried under shade for 30 minutes before planting is effective in reducing corm rot and enhancing germination.

Minisett technique for rapid multiplication

In minisett technique, corm pieces of 100-200 g may be used as planting material. A portion of the central bud should be present in the cut pieces. It can be planted at a spacing of 60 x 45 cm

directly in the main field with proper mulching. It is possible to produce seed corms weighing between 500 and 750 g at harvest. Multiplication ratio by minisett technique could be enhanced to 1:15 from the conventional method of 1: 4.

Method of planting

A good soil turning followed by pit formation is the traditional method of land preparation for elephant foot yam. The pit size should be 60 x 60 x 45 cm. The top soil is then mixed with farm yard manure or compost (2.5 kg/pit) in the pit prior to planting. The planting material is placed vertically in the pits and then covered with soil and compacted lightly. Elephant foot yam is planted shallow as deep planting would interfere with harvest operations, besides, most of its feeder roots are found on the surface. Spacing and seed rate depends on the size of planting material. A comparatively wider spacing of 90 x 90 cm is recommended. A seed rate of 6-12 tonnes is required as planting material, depending upon the size and spacing adopted for planting.

Mulching

Mulching the pits with organic materials, immediately after planting, results in better sprouting, moisture conservation, suppression of weeds and reduction of the temperature around the corms.

Manures and fertilizers

1. Blanket recommendation

Major nutrients: Apply FYM/compost @ 25 t/ha (2-2.5 kg/pit) at the time of planting. In Kerala, NPK @ 100: 50: 150 kg/ha is recommended, half the dose of N and K is applied after 50% sprouting of corms and the rest one month after first application along with weeding and earthing up.

Secondary and micronutrient management

- Application of lime/dolomite @ 2 t/ha as basal dose.
- Soil application of $MgSO_4$, $ZnSO_4$ and borax/solubor @ 60-90, 20-30, 10-15 kg/ha respectively depending upon the soil status of these nutrients.
- Foliar application of Zn EDTA (0.5%), Solubor (0.1%) and $MgSO_4$ (1%) independently or together depending upon its requirement based on soil status or on the occurrence of deficiency symptoms twice at an interval of one month during peak vegetative growth stage and tuber bulking stage @ 625 litres/ha.

2. Site specific nutrient management (SSNM)

Customized fertilizer formulations: Custom-made mixed fertilizers according to the site specific nutrient management recommendations, is made available for each zone. Besides the recommended N, P and K fertilizers, they can be fortified with secondary and micronutrients according to the soil fertility conditions in each zone as given in Table 8.

Table 8. Customized fertilizer formulations for elephant foot yam in Kerala (%)

AEU No.	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	40	12	4	18	6	3	0.4	0.2	650
17	40	13	4	20	5	2.5	0.3	0.1	750
4, 14	40	16	4	12	6	3	0.4	0.2	600
16	40	8	4	23	6	3	0.4	0.2	600
18, 19	40	10	4	17	8	4	0.5	0.2	500

Customized fertilizer (CF) mixture for Kerala

- The CF grade suitable for elephant foot yam is N: P_2O_5: K_2O: Mg: Zn: B @ 6: 3: 30: 3.5: 0.8: 0.3.
- The rate of application is 625 kg/ha @ 51g/plant at 45-60 days after planting, followed by top dressing with urea and MoP @ 33 and 21 g/plant respectively within 30-45 days after first application. This can be used in all AEUs of Kerala.

Foliar liquid micronutrient formulations: ICAR-CTCRI has developed a Microfood formulation containing all the micronutrients essential for elephant foot yam. This customized liquid micronutrient formulation may be applied as foliar spray @ 5ml per litre, thrice at 2, 3 and 4 months after planting. One litre of the formulation is required in 200 litres of water for one acre.

Organic farming

Raise green manure cowpea (seed rate @ 20 kg/ha) prior to elephant foot yam and incorporate green matter at 45-60 days. Use organically produced planting material. Treat corm pieces of 500-750 g with slurry containing cowdung, neem cake and *Trichoderma* (5 g per kg seed) and dry under shade before planting. Apply *Trichoderma* enriched FYM @ 36 t/ha (3 kg per pit) in pits at the time of planting (FYM: neem cake mixture (10:1) inoculated with *Trichoderma* @ 2.5 kg per tonne of FYM-neem cake mixture. *Trichoderma* can be multiplied in FYM alone but it will take 15 days to form sufficient inoculum as against 7-8 days if neem cake is also used along with FYM). This is effective against collar rot caused by *Sclerotium rolfsii*. Apply neem cake @ 1 t/ha (80-85 g per pit) in pits at the time of planting. Inter-sow green manure cowpea (seed rate @ 20 kg/ha) between elephant foot yam pits and incorporate green matter in pits at 45-60 days. The green matter addition from the two green manure crops should be 20-25 t/ha. Apply ash @ 3 t/ha (250 g per pit) at the time of incorporation of green manure in pits. Apply *Trichoderma* enriched vermicompost @ 150 g per plant twice after weeding and interculturing as a precaution to avoid collar rot infection. Remove the collar rot infected plants and apply *Trichoderma* enriched vermicompost @ 150 g per plant in the collar region of the adjoining healthy plants.

Irrigation

It is mostly raised as a rainfed crop. Wherever the crop is raised under irrigated conditions, a light irrigation immediately after planting should be done to get uniform sprouting; subsequent irrigations should be given depending on the requirement of plants. Waterlogging should be

avoided. Enough soil moisture should be ensured at 4-6 months after planting, coinciding with corm bulking phase, the most critical stage in elephant foot yam, to reduce yield loss. However, a dry spell towards later stages helps in maturity of corms. On an average, the crop requires 150 to 200 litres of water per 40 m^2 per day depending on the local weather and soil conditions.

Mulching with porous ground cover mat in the interspaces of elephant foot yam helps in soil moisture conservation and reduce the irrigation water requirement to 50%.

Weeding and earthing up

Proper mulching at planting helps in suppression of weeds to a large extent. Two manual weeding, 45 DAP and then after one month, followed by earthing up with the application of fertilizers results in better growth and tuberization.

In Kerala, West Bengal and Andhra Pradesh, application of straw mulch @ 2 kg/m^2 at the time of planting of elephant foot yam has been recommended for management of weeds in the crop. Pre-emergence application of butachlor @ 5 l/ha or fluchloralin or pendimethalin @ 2.5 l/ha, after planting corms is also recommended. Application of pendimethalin followed by glyphosate twice, 45 and 90 DAP is also good for weed management. Spreading ground cover mat is another feasible option for weed control in elephant foot yam, which can be reused for 3-5 seasons.

Cropping systems

Elephant foot yam is ideal as an intercrop as well as main crop in different cropping systems. During early stages of growth, there is a possibility of growing bushy short-duration vegetables, or short-duration pulses in the interspaces. After harvest, haulms could be reused as mulch or incorporated in soil, while earthing up.

Intercropping elephant foot yam (var. Gajendra) with pulses like black gram (var. Co-6) or soybean (var. JS-95-60) is productive and profitable. Both the crops should be fertilized adequately and separately in the system. Vegetable crops like amaranthus and cucumber can also be intercropped in elephant foot yam with higher yield and profit following organic methods.

Elephant foot yam can be intercropped profitably in coconut, arecanut, rubber, banana and robusta coffee plantations. About 9000 plants can be accommodated at a spacing of 90 x 90 cm in 1 ha of coconut garden, leaving 2 m radius from the base of the palms. Half the quantity of FYM (12.5 t/ha) and one third of the NPK dosage (27: 20: 33 kg/ha) will be sufficient for an intercrop of elephant foot yam in coconut garden.

For intercropping elephant foot yam in Nendran banana, banana should be planted at 3.6 x 1.8 m spacing to accommodate 1500 plants/ha. In between 2 rows of banana, 3 rows of elephant foot yam can be grown at a spacing of 90 x 90 cm to accommodate 8000 plants/ha, leaving 45 cm from the base of banana. For both the crops FYM, N and P can be reduced to half, whereas the entire quantity of K should be applied. Care should be taken to manure both the main crop as well as the intercrop separately and adequately while intercropping elephant foot yam with arecanut, rubber and robusta coffee.

Crop protection

1. Collar rot

The disease is caused by a soil borne fungus *Sclerotium rolfsii*. The pathogen invades the collar region resulting in development of water-soaked lesions on the pseudostem just above the soil surface. The leaves turn yellow from the tip, which steadily extends to the other portions causing

complete chlorosis of the plant. Finally, the pseudostem shrinks and the plant collapses due to rotting of the collar region. The pathogen is capable of causing sudden death of the plant under favourable conditions. Warm and humid weather, poor drainage and mechanical injuries caused during intercultural operations and by insect attack are the major predisposing factors for disease incidence.

Management

- Use disease free corms and remove infected plants from the field.
- Improve drainage in field and plough deeply to bury or kill sclerotia and hyphae of the pathogen in the field.
- Rotate with non-host crops and mulch with paddy straw or any other organic wastes.
- Treat the corms three days before planting with combination fungicide, mancozeb + carbendazim @ 2 g/litre. Drench the plants immediately after intercultural operations with the above fungicide @ 2 g/litre. Remove infected plants carefully and give an additional drenching with the fungicide to the nearby plants.
- Treat the corms with *Trichoderma* enriched cowdung slurry, three days before planting, mix *Trichoderma* in cowdung slurry @ 5 g/kg corm. Apply *Trichoderma* enriched FYM @ 2.0-2.5 kg/pit at the time of planting and same to the collar region @ 150 g/plant immediately after intercultural operations. Remove infected plants carefully and give an additional application of *Trichoderma* enriched vermicompost to the nearby plants.

2. Post-harvest rot

The corms are prone to several post-harvest diseases due to their high moisture content and starch. Besides damaging seed corms, these pathogens inhibit sprouting and make the plants more prone to field diseases. Pre-harvest infection in the field, infected soil adhering to the corms, nematode damage and high moisture content of the corms stimulates microbiological spoilage. Thirteen fungi and a bacterium cause the rot. The major ones are *Sclerotium rolfsii, Lasiodiplodia theobromae, Fusarium* spp*., Colletotrichum gloeosporioides* and *Erwinia carotovora.* Many field disease pathogens continue to attack the corms in storage also. Pre-harvest infection in the field is enhanced with the favourable conditions at storage.

The affected corms show discoloration, softening of the tissue and rotting. External symptoms may or may not be there. The symptom varies with the organism (s) involved with the rotting. In some cases, white powdery appearance will be seen on the outer surface of the corm. Many a times, the surface of the tuber becomes completely rotten. Inside tissues show brown/black colour spots and the adjoining spots coalesce and form bigger irregular patches. In some cases, inner portion of the corms show putrefaction of the tissue with brown to black discolouration. Chocolate brown to brown colour oozing from the lesions can also be observed. Affected portion may turn to powdery mass of tissue.

Management

- Minimise injury to corms during harvesting, transportation and storage.
- Remove infected portion from the corm and store in a ventilated place.
- Dip the corms in combination fungicide, mancozeb + carbendazim (0.2%) for 10 minutes, shade dry for 2-3 days and store in a ventilated place (or)
- Treat the corms with *Trichoderma* enriched cowdung slurry (@ 5 g/kg corm) or 0.7%

ICAR-CTCRI developed bio-formulation *Nanma* for 10 minutes, dry in shade for 2-3 days and store in a ventilated place.

3. Mosaic disease

This disease occurs in all major elephant foot yam growing areas and cause yield loss up to 38%. The disease is caused by *Dasheen mosaic virus* (*DsMV*) which belongs to potyvirus group. This disease is mainly transmitted through infected planting material and in field through aphids (*Myzus persicae* or *Aphis gossypii*). Various types of symptoms like mild mottling, mosaic, leaf puckering, cupping, filiformy, leaf thickening and narrowing like shoestring are observed on elephant foot yam plants.

Management

- Select planting material from healthy plants, which are free from DsMV infection.
- Grow plants obtained through meristem tip culture.
- Rogue infected leaves, self-sown elephant foot yam or taro plants.
- Vector control by spraying imidacloprid 17.8 SL (0.3 ml/litre) or thiamethoxam 25 WG (0.3-0.4 g/litre) at 14 days interval.

4. Nematodes

There are two major nematode species infesting elephant foot yam, *Meloidogyne incognita* and *Pratylenchus coffeae.* Symptoms appear as yellowing of leaves, day-wilting of plants, knots/galls on corms and cormels and brown discoloration of tissues.

Management

- Select nematode free planting material.
- Follow crop rotation with non-host crops.
- Burn and destroy severely infested tubers and plants.
- Treat corms with *Trichoderma* enriched cowdung slurry @ 5g/kg corm three days prior to planting.
- Apply *Trichoderma* enriched FYM @ 2.0-2.5 kg/pit at the time of planting.
- Use of newer nematicides, fluensulfone 2% GR @ 1g per plant and fluopyram 34.48% SC@ 0.5 ml per plant.

Harvesting and post-harvest management

The crop can be harvested from 6-9 months after planting, depending upon market demand. Yellowing and drooping of the leaves is considered as maturity indices of the crop. When corms are used for vegetable purpose, the crop is harvested early. For seed purpose, the crop is left in the field for total senescence or even later for maturity. Early harvesting considerably reduces the yield of corms, which can be compensated by higher market price. Harvested corms are cleaned and spread under shade for 2-3 days which helps in healing of injuries or bruises on corms. Then corms are stored in well-ventilated rooms with buds facing down.

Yield

The corm yield is greatly influenced by variety, size of planting material and stage of harvesting and management options. Normally corm yield ranges from 30-50 t/ha but it can go in the range of 50-100 t/ha also.

TARO

Scientific Name: *Colocasia esculenta* (L.) Schott

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

Climate

It grows well in warm and humid conditions with a mean temperature of 21-27°C and a well distributed rainfall of about 1000 mm during the growth period. In areas where rainfall is less, supplementary irrigation is required for successful production.

Soil

Taro comes up in all types of soils, but performs better in well drained fertile loamy soils with pH range of 5.5-7.0.

Planting season

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

Improved varieties

Sl. No.	Name of variety	Duration (months)	Yield (t/ha)	Special features
1.	Sree Hira	6	18	▪ More number (12-16) of long cormels measuring 14-18 cm length. Good cooking quality and low acridity ▪ Tolerant to leaf blight. Suitable for rainfed upland and irrigated medium and low land ▪ Recommended state: Odisha
2.	Sree Telia	4	10-12	▪ Produces 7-9 numbers of cormels per plant. Good cooking quality and low acridity ▪ Susceptible to leaf blight, but escapes leaf blight disease due to early harvest. Can be planted during summer with protective irrigation ▪ Recommended state: Odisha
3.	Bhu Sree	6-7	12	▪ Round corms and round to elliptic cormels. Good cooking quality ▪ Tolerant to *Phytophthora* leaf blight and mid-season drought and salinity ▪ Starch content is 15.6-17.3% and sugar content is 1.2-1.5% ▪ Recommended state: Odisha
4.	Bhu Kripa	6-7	15	▪ Round corms and round to elliptic cormels. Excellent cooking quality ▪ Tolerant to *Phytophthora* leaf blight, submergence, drought and salinity stresses ▪ Starch content is 12.3-14.2% and sugar content is 1.3-1.7% ▪ Recommended state: Odisha

5.	Pani Saru-I	6-7	12-15	▪ Round corms and elliptic cormels, good cooking quality and long keeping quality ▪ Field tolerant to leaf blight and waterlogged condition ▪ Starch content is 12%, sugar content is 3.3% and protein content is 2.5% ▪ Recommended state: Waterlogged/submerged conditions including coastal areas of Odisha
6.	Pani Saru -II	6-7	13	▪ Round corms and round to elliptic cormels. Good cooking quality ▪ Field tolerant to leaf blight and can be grown in waterlogged/swampy condition ▪ Starch content is 17% and sugar content is 2.8% ▪ Recommended state: Odisha
7.	Sree Kiran	6-7	17-18	▪ First hybrid taro variety in India (C-303 x C-383). Oval shaped corms and round to oval cormels ▪ Good cooking quality and long keeping quality ▪ Recommended state: Kerala
8.	Muktakeshi	5-6	20	▪ Round corms and cylindrical cormels. White flesh colour and excellent cooking quality ▪ Resistant to *Phytophthora* leaf blight. Suitable for uplands and lowlands ▪ Starch content is 17.8%, sugar content is 2% and protein content is 2.8%. ▪ Recommended states: Odisha, Chhattisgarh, Jharkhand and Kerala
9.	Sree Pallavi	7	16	▪ Relatively big and conical corms and club shaped small and numerous cormels. White flesh colour and good cooking quality ▪ Field tolerant to *Dasheen mosaic virus* and leaf blight ▪ Starch content is 24.5% and protein content is 2.5% ▪ Recommended state: Kerala
10.	Sree Rashmi	7-8	18	▪ Non-acrid leaves, petiole, corm and cormels. Big and cylindrical corms and conical and medium size cormels. White flesh colour and good cooking quality ▪ Moderately susceptible to leaf blight, but field tolerant to *Dasheen mosaic virus* ▪ Starch content is 14.5-15.5% and protein content is 2.3-2.7% ▪ Recommended state: Kerala

Planting material

Taro is propagated vegetatively either by mother corms or cormels, but cormels are ideal for good yield. Cormels weighing about 20-25 g are ideal planting material.

Method of planting

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

cormels at a spacing of 60 x 45 cm. Higher planting density at a distance of 45 x 30 cm is also adopted on marginal land. About one ton planting material is enough for planting one hectare land, at a spacing of 60 x 45 cm, while higher planting density (45 x 30 cm) requires about 1.5-2.0 t/ha. The cormels may be planted to a depth of 5-10 cm depending on the size of planting material.

Mulching

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

Gap filling

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

Manures and fertilizers

1. Blanket recommendation

Apply 12 tons of FYM per hectare and mix it with the soil prior to planting. Taro requires a fertilizer dose of 80 kg N, 25 kg P_2O_5 and 100 kg K_2O/ha in two or three split doses. One-third dose of nitrogen (60 kg of urea or 135 kg of ammonium sulphate), 125 kg of rock phosphate and one-third dose of potash (55 kg of muriate of potash) are to be applied at two weeks after sprouting. The remaining dose of nitrogen and potash may be applied in two equal split doses at monthly intervals after the first application of fertilizers.

2. Site specific nutrient management (SSNM)

Customized fertilizer formulations: Taro yield remains stagnant mainly due to conventional blanket recommendation of fertilizers, lower nutrient use efficiency and imbalance in the use of nutrients. In soils with medium NPK fertility status, application of customized fertilizer formulation with the composition of 13: 4: 17: 3: 0.4: 0.2 of N: P: K: Mg: Zn: B @ 600 kg/ha is recommended for a target yield of 20 t/ha.

Intercultural operations

The weeding and earthing up operations are to be done along with the application of fertilizers. Small, inefficient suckers from the mother plant have to be removed along with second weeding and earthing up operation.

Organic farming

Use organically grown planting material. Treat cormels of 20-25 g with slurry containing cowdung, neem cake and *Pseudomonas fluorescens* (5g per kg seed) and dry under shade before planting. Apply FYM @ 15 t/ha (400 g per pit) at the time of planting. Apply neem cake @ 1 t/ha (25-30 g per pit) at the time of planting. Apply biofertilizers, *Azospirillum* @ 3 kg/ha, mycorrhiza @ 5 kg/ha and phosphobacteria @ 3 kg/ha at the time of planting. Inter-sow green manure cowpea (seed rate @ 20 kg/ha) between pits and incorporate green matter at 45-60 days. The green matter addition from the green manure will be 15-20 t/ha. Apply ash @ 2 t/ha (60 g per plant) at the time of incorporation of green manure cowpea. To manage taro leaf blight

(TLB), plant TLB resistant variety Muktakeshi, treat the cormels in cowdung slurry enriched with *Trichoderma asperellum* (5g per kg of seed) and apply vermicompost @ 100 g per plant. As a prophylactic measure against TLB, spray vermiwash @ 100 ml per litre of water and repeat at fortnightly intervals, especially during rainy season or akomin @ 3 ml per litre from one month after planting at fortnightly intervals up to 4 months.

Irrigation

Taro grows well under moist situations. Hence, whenever there is less rainfall, it should be supplemented with adequate irrigation. During summer season, taro requires continuous irrigation upto six months and drip irrigation at 100% CPE is found optimum. On an average the crop requires 130 to 175 litres of water per day for 40 m^2 (one cent) of its cultivation.

Weeding and earthing-up

Clean and weed-free field during initial periods of crop growth facilitate better crop growth. Generally, two manual weeding along with earthing up has been recommended for better growth and tuberization. The first weeding along with earthing up is done after 7-8 days of sprouting and second a month later. Several herbicides have been recommended for weed control in taro field. Pre-emergence application of isoproturon, atrazine or nitrofen @ 1.0 kg/ha is effective for weed control.

Desuckering

A large number of suckers per plant reduces the tuber size, hence only 3 suckers/plant should be retained at second earthing up.

Cropping system

Taro is found to fit well under different cropping systems. During initial growth stages, different short duration crops can be raised as intercrops such as vegetables (chilli, tomato), leafy vegetables (amaranthus, spinach, coriander), cowpea, onion etc. In Kerala, taro is recommended as intercrop in banana/coconut/arecanut. Intercropping taro (var. Sree Kiran) with pulses like green gram (var. Co-Gg-7) or black gram (var. Co-6) is productive and profitable. There is a possibility to save half FYM and N and full P to taro in the system. Thus, FYM @ 6.25 t/ha and NPK @ 40: 0: 100 kg/ha is sufficient for taro in this system.

Crop protection

1. Pests

Aphids and worms are important pests attacking the leaves. The other pests include spider mites, thrips, grasshoppers, scale insects and mealybugs. These can be controlled by using quinalphos or dimethoate @ 0.05% spray. Mealybugs and scale insects damage cormels and corms and hence select cormels free of these pests for planting. If infested, the seed cormels should be dipped in dimethoate @ 0.05% solution for 10 minutes before planting.

2. Taro leaf blight

The disease is caused by the fungus *Phytophthora colocasiae*. Heavy incidence causes up to 50% crop loss. Cormels and other plant parts left in the field after harvest can also act as an inoculum sources for newly planted taro. The pathogen spreads to long distances through infected planting material.

Small, water-soaked light brown spots appear on the leaf surface. The spots enlarge rapidly, increase in size and number, coalesce and lead to complete destruction of leaf lamina. Bright orange or reddish-brown exudates, oozing from the affected portion is another common symptom and they become hard globules later. When there is high relative humidity, whitish ring formed by mass accumulation of sporangia is seen around the edge of the lesions. Lesions develop on petioles of susceptible varieties and the brown exudates are seen oozing out from the petiole and the petiole infection causes the plants to collapse. Infected corm tissue is brown, firm and rotting develops rapidly after harvest.

Management

- Cultivate resistant varieties like Muktakeshi, Bhu Sree and Bhu Kripa.
- Use disease-free cormels for planting and remove infected leaves and other plant parts from the field.
- Crop rotation and intercropping with non-host crops like okra.
- Mulch with paddy straw or any other ground mulch.
- Spray metalaxyl-mancozeb (0.1%)/mancozeb (0.2%)/potassium phosphonate (3 ml/ litre) as prophylactic/protective measure at 45 days after planting and again at 15 days intervals when significant disease incidence is observed (or)
- Treat the cormels with *Trichoderma* enriched cowdung slurry. Mix *Trichoderma* in the cowdung slurry @ 5 g/kg of cormel. Apply *Trichoderma* enriched vermicompost @100 g/plant at the time of planting and once again during intercultural operation.

3. Taro mosaic

Characterized by interveinal yellowing along the major veins and veinlets. In severely infected plants, leaf distortion symptoms like cupping, curling and shoestring appearance are observed. Transmission is through planting material (cormels) and aphids. Selection of planting material from healthy plants, which are free from *DsMV* infection is recommended.

Harvesting

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

TANNIA

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

Tannia is popular in Kerala, Maharashtra, Chhattisgarh and North Eastern areas. It can be grown as a pure crop as well as an intercrop in coconut, banana, rubber and other plantations.

Climate

The crop prefers a warm humid climate with high rainfall. It can be grown under a wide range of temperature (13-29°C) and in areas of 1000-2000 mm rainfall, provided it is evenly distributed. It is less tolerant to drought and cannot withstand waterlogging.

Soil

It requires a deep well drained, fertile loamy soil, preferably with a pH of 5.5 to 6.5 with a mean soil temperature above 20°C.

Planting season

As a rainfed crop, it is planted during February-March to November-December. As an irrigated crop, it can be planted throughout the year.

Varieties

Konkan Haritparni is the only variety released in tannia adapted to Konkan and adjoining areas as rainfed crop. It matures within 190-210 days producing good cooking quality tubers and edible leaves. Local varieties having tubers with less acridity, good texture and leaves suitable for use as vegetable are also available.

Planting material

Healthy cormels of 50-100 g size and 20-25 cm long and cut corms of 150-200 g size are commonly used. For planting one hectare, 1.8 to 2.5 tons of corms or 0.6-1.0 ton of cormels are required.

Method of planting

Planting on ridges or mounds is often recommended since the tuber formation is improved when adequate drainage is provided. A spacing of 90 x 90 cm is usually practiced and pits reformed into mounds is the usual method of planting.

Mulching

As the crop responds well to mulching, after planting, green leaf mulching @ 15 t/ha is beneficial for getting higher tuber yield.

Manures and fertilizers

FYM @ 25 t/ha and dolomite @ 1 t/ha is recommended for its cultivation. Dolomite should be applied during first land preparation at least 15 days before planting. FYM and P are to be applied as basal. NPK @ 80: 50: 150 kg/ha is recommended as N and K in spilt doses at 2, 4 and 6 months after planting.

Integrated nutrient management (INM) in tannia

- Apply dolomite as soil amendment @ 1 t/ha (80-100 g/plant) during ploughing and keep the land as such for 2 weeks.

- Apply FYM @ 25 t/ha (2 kg/plant) in pits and P @ 50 kg/ha (Musooriephos/Rajphos @ 250 kg/ha or 20 g/plant) as basal.
- Plant the *Pseudomonas* treated cormels/corms.
- Sow green manure cowpea @ 10 kg/ha immediately after planting tannia in the interspaces and plough and incorporate into the soil at 45-60 days after sowing of cowpea
- Apply N fixer (@ 10-20 g/plant) within one month of planting tannia.
- Apply neem cake (25-50 g/plant) in pits after one month of N fixer application.
- Apply 1/3 fertilizer N (urea @ 2 g/plant) and 1/3 fertilizer K (MOP @ 7g/plant) each at 2, 4, 6 MAP (months after planting)

The following points need to be taken care in the cultivation of tannia in the major tuber crops growing soils of Kerala viz., laterite and sandy loam soils

- Ensure 25-50% shade (plant under coconut, arecanut, banana).
- Apply dolomite @ 100 g per plant as basal in the pits.
- Ensure good aeration with proper moisture in the root zone.
- Avoid using more of urea. Apply 25% of the recommended dose of N (ie., 20 kg/ha) as urea and remaining as organic manures in the form of FYM, neem cake, green manuring *in situ* with leguminous crops, N use efficient biofertilizers.
- Apply the recommended dose of P @ 50 kg/ha.
- Avoid cultivating tannia in the same land year after year. After one crop of tannia, avoid the land for growing tannia for the next 1-2 seasons.

Organic farming

Plant organically produced whole cormels of size 50-80 g or mother corm pieces of 150-200 g. Apply FYM @ 20 t/ha (1.6 kg per pit) in pits at the time of planting. Apply neem cake @ 1 t/ha (80-85 g per pit) in pits at the time of planting. Inter-sow green manure cowpea (seed rate @ 20 kg/ha) between pits and incorporate green matter at 45-60 days. The green matter addition from the green manure will be @ 15-20 t/ha.

Weeding and earthing up

Weeding and earthing up should be done twice at one and two months after planting. Lower leaves and petiole should be removed when they start drying.

Irrigation

During summer and drought months, it is essential to give 5-6 shallow irrigations to maintain soil moisture. Maintenance of adequate soil moisture and proper shade to sustain a humid microclimate and avoiding full exposure to sunlight is a must for good crop growth, better tuber and leaf yield.

Crop protection

Dasheen mosaic virus is found to a small extent and is usually manifested as a secondary

infection when nutritional disorders such as Mg deficiency becomes severe. Use of disease-free planting materials can avoid the incidence of this problem.

Nutritional disorders

Tannia is identified as an indicator plant for Mg deficiency, manifested as interveinal chlorosis of the lower leaves from third month, causing complete devastation of the crop. Application of dolomite @ 1 t/ha is recommended during land preparation as a prophylactic measure to prevent the problem.

Harvesting

Crop can be harvested when the older leaves start yellowing and drying, usually 9-11 months after planting. After harvesting, curing of corms and cormels is done under sunlight for 4-5 days. Care should be taken to avoid injury while harvesting. They can be stored by embedding in dry soil or sand for a period of 4-5 months under ventilated dry or semi dark conditions.

CHINESE POTATO

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

Chinese potato is known by different names as Hausa potato, country potato, Sudan potato, Kafir potato, etc. It is a native of tropical Africa. Locally known as *Koorka/Cheevakizhangu*, it is a seasonal crop cultivated for its edible tubers in Sri Lanka, Malaysia, Indonesia, South Korea, China, India and parts of Africa. The tubers that resemble potato in appearance, are consumed as vegetable after cooking. The tubers have an aromatic flavour on cooking and has a delicious taste.

It is a bushy herbaceous annual with succulent stems and aromatic leaves. The plant bears a cluster of dark-brown aromatic tubers at the base and lower parts of the stem. It is cultivated on a commercial scale in Tirunelveli, Tenkasi, Tuticorin and Virudhunagar districts (Tamil Nadu) and to a large extent in Northern districts of Kerala *viz*., Thrissur, Palakkad and Malappuram. The crop is also grown in the tribal settlements throughout India.

Climate

It comes up well in hot-humid regions. A comparatively lower temperature at night than day time favours better tuber development. It requires an evenly distributed rainfall for its cultivation and withstand neither drought nor frost conditions.

Soil

A medium fertile well-drained, sandy loam to alluvial soil with adequate organic matter is ideally suited for its cultivation. Waterlogging reduces tuber yield considerably. The best soil pH requirement ranges between 6.5-7.0. High content of clay in the soil restricts tuber development.

Planting season

Planting is done from the month of July to October. Planting in September results in the production of fairly big tubers. It can be planted in January and September as an irrigated crop.

Improved variety

A promising selection has been released as Sree Dhara for cultivation in the state of Kerala. It has an yield potential of 25 t/ha and duration of 150 days. Tuber shape is round (2-5 cm diameter), tuber skin colour is dark brown, tuber flesh colour is cream. It is tolerant to root knot nematode. The dry matter is about 28.5% and the starch content is 19.5%. It is suitable for Tamil Nadu and Kerala states.

Planting material

It is vegetatively propagated through suckers raised from healthy tubers of previous harvest or stem cuttings. A nursery is raised, approximately one and half months prior to planting. An area of 500 m² is required to produce vines for planting one hectare of land. Cattle manure or compost may be applied @ 1 kg/m² and ridges/mounds may be prepared at a closer spacing (45/60 cm). Healthy tubers that weigh about 15-20 g may be planted on the ridges/mounds so as to accommodate 75-100 kg tubers in 500 m² area. Top dress with urea (5 kg/500 m²) at about three weeks after planting to encourage good vine growth. Clip off the terminal portion of the vines devoid of roots to a length of 10-15 cm at about 45 days after planting. To enable rapid multiplication of the planting material, single node cuttings can be planted directly in the

secondary nursery. Such single node cuttings produce axillary shoots within one week.

Land preparation and planting

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

Irrigation

It is essential to give irrigation immediately after planting to ensure adequate soil moisture for proper establishment of stem cuttings. During the tuber development phase, proper moisture must be maintained to encourage better growth and tuber development.

Manures and fertilizers

About 10 tonnes of FYM or compost are to be added at the time of field preparation. In addition to FYM, 60 kg N, 60 kg P_2O_5 and 100 kg K_2O are applied for one hectare of land. Half the dose of N and K along with full dose of P are to be applied at the time of planting. The remaining half dose of N and K are to be applied along with second earthing up (45 days after planting).

Fertilizer schedule

Fertilizer	Basal (kg)	Top dressing (kg)
Urea	66	66
Rajphos	300	-
Muriate of potash	83	83

Customized fertilizer formulations: Custom-made mixed fertilizers are made according to the site-specific nutrient management recommendations. Besides, the recommended N, P and K fertilizers, these can be fortified with secondary and micronutrients according to the soil fertility conditions.

Foliar liquid micronutrient formulations: ICAR-CTCRI has developed a microfood formulation containing all the micronutrients essential for Chinese potato. This customized liquid micronutrient formulation, commercially available in the market as 'Micronol Chinese potato' may be applied as foliar spray ie., Micronol Chinese potato @ 5 ml per litre twice at 45 days and 75 days after planting. One litre of the formulation in 200 litres of water is required for spraying in one acre.

Organic farming

Raise green manure cowpea (seeds @ 20 kg/ha) prior to planting and incorporate @ 10-15 t/ha of green matter thus generated. Apply FYM @ 10 t/ha at the time of planting. Apply neem cake @ 1 t/ha in the ridges at the time of planting. Apply biofertilizers, *Azospirillum*, P solubilizer and K solubilizer each @ 3 kg/ha, at the time of planting. Plant organically produced vines of 10-15 cm length at a spacing of 45 x 30 cm on ridges.

Weeding and earthing up

A weeding along with earthing up and top dressing of fertilizers is done at about 3 weeks after

planting to cover a portion of the stem with soil and to improve the physical conditions of soil, and promote better tuberization and tuber development. The second weeding and earthing up should be done at about 6 weeks after planting.

Crop protection

1. Leaf folding caterpillars and vine borers

Dipping the vines in insecticide solution (dimethoate 30 EC @ 1.7 ml/litre) for 10 minutes prior to planting is helpful to manage the pest. In case of severe damage, spraying malathion 50 EC @ 1 ml/litre may be done.

2. Nematode

Root-knot nematode, *Meloidogyne incognita* is the major nematode species inflicting damage to Chinese potato. Symptoms appear as yellowing of leaves, day-wilting of plants, knots on tubers and malformed or distorted tubers, discoloration of tissues and hollowness of heavily infested tubers.

Management

- Soil solarization of nursery beds.
- Select nematode free planting material.
- Burn and destroy severely infested tubers and plants.
- Use of nematode antagonistic trap crop, marigold and Sree Bhadra (sweet potato variety).
- Use of *Trichoderma* enriched FYM @ 12 t/ha
- Use of newer nematicides, fluensulfone 2% GR @ 1 g/plant and fluopyram 34.48% SC @ 0.5 ml/plant.

Harvesting

Harvest the crop when the vines dry up at 4-5 months after planting. Pull out the plants and dig out the left-over tubers in the field. Separate the tubers from the plant and recycle the crop residues by ploughing into the soil.

The tuber yield varies from 10-20 t/ha depending on the management practices. Tubers can be stored in well-ventilated room after curing for 2-3 days under shade condition.

ARROWROOT

Scientific Name: *Maranta arundinacea* L.

Arrowroot commonly known as 'West Indian arrowroot' is an erect herbaceous plant belonging to the family Marantaceae. Arrowroot is primarily grown for its quality starch, which is valued as food stuff particularly for infants and invalids.

The starch is often used as a thickener in all kinds of foods, dressings, soups, sauces, candies, cookies and desserts like puddings and ice-creams. Industrially, processed rhizome pulp is applied in the manufacture of paper, cardboard, cushions and wallboards and the starch as basic ingredient of powders, glues and soap.

Arrowroot starch possesses demulcent properties and is used in the treatment of disorders of the intestine. It may also be employed in the preparation of barium meals and in the manufacture of tablets, where rapid disintegration is desirable. The starch is also used as a base for face powders, in the preparation of certain specialised glues and, more recently, in the manufacture of carbonless paper for computers. The rhizomes are also a good substitute for maize in broiler rations. The fibrous debris after starch extraction, is used as feed and manure. The crop is a native of tropical America. In India, it is grown in North Eastern States, West Bengal, Assam and in South India mostly in Kerala as a rainfed crop. It is an ideal intercrop in coconut gardens.

Cimate

Arrowroot grows best under warm humid conditions, preferring temperatures of 25-30^{o} C and average annual rainfall of 1500-2000 mm or more, but with 1-2 dry months. Partial shade is ideal for crop growth.

Soil

Slightly acidic, fertile, deep well drained sandy loam soils are preferred for active growth and good yield. It cannot withstand waterlogging.

Planting season

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

Planting material

Arrowroot does not set seeds and is normally propagated vegetatively from rhizome apices (bits) about 2-4 nodes long and not too thin. Suckers 30 cm tall can also be used, but should be planted immediately after removal. If suckers are used, preparation of planting material should actually start at the time of harvest of the crop. Suckers are separated from the clump and planted 30 to 45 cm apart in the nursery during the off-season. These suckers give rise to new plants, which are uprooted, and the canopy cut off to retain 10 cm of the shoot intact with roots. The requirement of planting material is about 5.5 t/ha.

Method of planting

Plough the land to obtain a fine tilth. Prepare raised beds of 15-20 cm height and convenient length and 1 m breadth made 50 cm apart. Plant rhizome bits 30 cm apart at a depth of 5.0-7.5 cm and cover with soil. Planting at a spacing of 30 x 15 cm produces higher tuber yield. If clumps are used, plant two clumps at a distance of 45 cm. Mulching using locally available plant materials viz., green leaves, dried leaves or coconut fronds immediately after planting

is beneficial for realizing significantly higher rhizome yields and enhances yield by 60-65%. Shoots come up within 15-20 days.

Manures and fertilizers

Application of FYM @ 10 t/ha is suitable for arrowroot cultivation. Application of 50 kg N, 25 kg P_2O_5 and 75 kg K_2O per ha is required to get higher yields. Full dose of phosphorus, is to be applied at the time of planting. Half the dose of N and K should be given one month after planting and the remaining doses of N and K should be given one month later.

Organic farming

Raise green manure cowpea (seed rate @ 20 kg/ha) prior to arrowroot and incorporate green matter at 45-60 days (green matter @ 10-15 t/ha). Apply FYM @ 10 t/ha at the time of planting. Apply biofertilizers (*Azospirillum*, P solubilizer and K solubilizer) @ 3 kg/ha each. Plant organically produced rhizome pieces of 20-25 g.

Irrigation, weeding and intercultural operation

The crop is grown mainly as a rainfed crop. However, if dry spells occur during the initial 3-4 months, supplementary irrigation at weekly intervals becomes necessary. Optimum moisture in the field throughout the growth period gives higher yield and starch content.

It is essential to keep the field clean and free of weeds during the first 3-4 months. Earthing up should be done along with weeding. Flowers are to be nipped off as they appear.

Plant protection

No major pests and diseases are noted, except field rats, which tunnel and damage the roots. Poison baits using zinc phosphide is recommended to control rats.

Harvesting and yield

The crop attains maturity in 10-11 months after planting. Maturity is indicated by yellowing, wilting and drying up of the leaves. At this stage, the plants are dug out and the rhizomes are separated. The average rhizome yield is 12 t/ha and under favourable conditions yield of 20-25 t/ha can also be obtained.

YAM BEAN

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

Yam bean belongs to the family Leguminosae and sub family Fabaceae. It is popularly known as *Mishrikand* in Hindi. Yam bean is a starchy root crop with comparatively high sugar content and moderate ascorbic acid. In India, tender tubers are consumed as a vegetable. Young tubers are crisp, succulent and sweet and are highly preferred for salad making. The mature seeds have high content of alkaloids and insecticidal properties.

In many developed countries the tubers are processed, canned and many sweet preparations are made. The crop has been cultivated in Mexico and South America from pre-colombian period and has originated from hot moist region of the river Amazon. The crop is now being cultivated in Philippines, China, Indonesia, Nepal, Bhutan, Burma and India. In India, it is grown in parts of West Bengal, Bihar, Odisha and Assam.

Climate

Yam bean requires a hot humid climate (25° C-30° C) and it adapts well in subtropical and hot temperate frost-free zones. Cool night temperature of 18-20° C along with dry sunny days is required for tuber bulking and development. Yam bean requires about 14-15 hours of photoperiod for good vegetative growth, however, shorter days are required for better tuberization. Cool climate during early growth period adversely affects the initiation of tuberization and also results in a prolonged vegetative phase. A well-distributed rainfall during the growth period is required for optimum tuber yield.

Soil

Fertile, well-drained and sandy loam soil is best suited for cultivation of yam bean. Waterlogging is deleterious for yam bean cultivation. Optimum soil pH requirement is 6.0-7.0. It can do well in loamy and clay loam soil with good drainage and adequate humus content.

Planting season

Traditionally yam bean is sown during June-July with the onset of rain in North-Eastern India and is usually harvested in December-January. For late sowing, August-September is ideal for sowing.

Planting material

Yam bean is usually propagated by seed. The mature pods have about 8-10 brownish-yellow to red seeds, which contain a toxic substance 'rotenone' and are harmful for grazing cattles. The seed rate varies according to the spacing adopted. Normal seed rate is 20-60 kg/ha.

Method of planting

Deep ploughing of land followed by planking pulverizes the soil as well as conserve moisture. Yam bean seeds can be sown on mounds at the rate of 3-5 seeds per hill. Prepare mounds at a spacing of 0.75-1.00 m with 15 cm height. Planting the seeds on ridges results in better yield. In ridge planting, usually 2-3 seeds are placed on ridges made at a distance of 30 cm to a depth of 2 cm. For timely sown crop, spacing is 30 x 30 cm and late sown crop, 30 x 15 cm or 15 x 15 cm is recommended. Closer spacing gives higher yield, but small tubers, which are free from cracks.

Irrigation

Rainfed crop, sown in June-July does not require irrigation. In case, there is scarcity of rains, irrigation is essential, as yam bean requires lot of moisture. Wherever the planting is done in the month of August-September, crop requires supplementary irrigation.

Manures and fertilizers

FYM or compost @ 15-20 t/ha should be applied at the time of land preparation. In addition to this, a fertilizer dose of N: P: K @ 80: 40: 80 kg/ha is recommended for getting optimum yield. Entire dose of P and K has to be applied at the time of planting along with half the dose of N. The remaining quantity of N is top dressed at 40-50 days after sowing along with interculturing and earthing up.

Weeding and earthing up

Weed infestation is maximum in June-July sown crops compared to September sown crop. One weeding is essential at the initial stage to check the weeds and promote the crop growth. First weeding at 40 days, along with nutrient management results in better growth and tuberization. Second weeding may be done one month later, if required. Earthing up is not much effective in increasing tuber yield, but a light earthing-up around the stem gives better results.

Deflowering

Normally yam bean starts flowering at 75 days after sowing. It is desirable to remove the flowers for getting better tuber yield. There is significant negative correlation between tuber yield and pod formation. The flowers are manually removed or the flowering can be successfully prevented at bud initiation stage (60-70 days). It has been observed that spraying 2,4-D (50 ppm) at flower initiation stage causes dehiscence of flowers and results in better yield of tubers.

Harvesting

Yam bean will be ready for harvest at 150 days after sowing. It can be harvested early or late according to the market demand. Delay in harvesting leads to the fibrous flesh along with cracked tubers. Harvested tubers can be stored for 2-3 days without any deterioration. The average yield of local cultivars is 18-20 t/ha, while improved varieties like Rajendra Mishrikand-1 and 2, yield 35-40 t/ha. The seed crops should be harvested after 240 days during March-April.

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