# TARO


भाकृअनुप-केन्द्रीय कंद फसल अनुसंधान संस्थान
(भारतीय कृषि अनुसंधान परिषद्)
श्रीकार्यम, तिरुवनंतपुरम 695 017, केरल, भारत

**ICAR-CENTRAL TUBER CROPS RESEARCH INSTITUTE**
(Indian Council of Agricultural Research)
Sreekariyam, Thiruvananthapuram 695 017, Kerala, India

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Diamond Jubilee of ICAR-CTCRI

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**November 2023**

**Correct Citation**
Sunitha, S., Laxminarayana, K., Veena, S.S., Jyothi, A.N., Santhosh Mithra, V.S. and Kalidas Pati. 2023. Taro, Technical Bulletin No. **96**, ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, Kerala, India, 42 p.



**Design, Layout & Printing**
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## From the Director

**Taro** (*Colocasia esculenta* (L.) Schott) is an important tuber crop widely cultivated in tropical and subtropical regions. Taro is grown in 49 countries with a major share of production concentrated in Africa and the major producers are Nigeria, China, Cameroon and Ghana. It has considerable potential food value either in the fresh or processed form. It is a staple food in African, Oceanic and South Asian countries and plays a crucial role in food security, holding 9th position among world food crops. Taro is primarily grown as a vegetable for its edible starchy cormels, but its petiole and leaves are also used as vegetable for nutritional and medicinal purposes. Its cormels are rich in starch and essential nutrients such as thiamine, riboflavin, niacin and oxalic acid. Green leaves of taro are a rich source of protein, dietary fibre, folic acid, minerals and vitamins.

ICAR-CTCRI, established in the year 1963, is celebrating its 60 years of service to the nation. It is a research organization of global repute, dedicated to the R&D of 15 tropical root and tuber crops. A retrospection @ 60 indicates its rich legacy and contributions by way of 71 improved varieties, a number of potential technologies on production, protection, pre and post-harvest processing, value addition, smart farming etc in tuber crops. In India, taro is cultivated approximately in an area of 40,000 ha, in the states of Uttar Pradesh, Madhya Pradesh, Bihar, Andhra Pradesh, Telangana, Tamil Nadu, Kerala, Odisha, West Bengal and the North Eastern hilly areas. The average productivity of taro in India is 15.2 t/ha, much higher than the world average productivity of 6.9 t/ha, irrespective of the fact that it is cultivated in poor and marginal soils, often providing less attention. The higher productivity can be attributed to the technological interventions by ICAR-CTCRI, AICRP TC centres and other line departments working on taro in our country, along with the ideal climate.

Research efforts over the past six decades in taro has led to the development of ten improved varieties with different quality attributes, farmer-friendly agro-techniques, techniques for quality planting material production, protocols for integrated nutrient management, site specific nutrient management, organic management, water management, weed management, cropping systems, integrated pest and disease management and processing and value addition. Economics and utilization pattern and marketing aspects of taro have also been analysed. I take pride in presenting the scientific package of practices to be followed from farm to fork for realizing sustainable yield and income from taro, documented in the form of a technical bulletin titled 'Taro'.

I hope that this technical bulletin will serve as valuable reference material to the researchers, extension personnel, farmers, entrepreneurs and other stakeholders to uplift the status of taro from a neglected crop to a highly remunerative tuber crop. I appreciate the efforts of the team for bringing out this publication in high standard covering all the aspects of taro.

1 November 2023

**G. Byju**

# TARO

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

## Introduction

Taro, is an important tuber crop of tropical and subtropical regions. The crop is believed to have originated in South East or South Central Asia, perhaps, India or Malaysia. It is widely cultivated, mostly as a staple or subsistence crop, throughout the humid tropics to subtropics and in many warmer regions of the temperate zone. Taro is grown in 49 countries with an area of 1.89 million hectares with a production of 14.3 million tonnes, of which 77% production is concentrated in Africa and the major producers are Nigeria, China, Cameroon and Ghana. The average productivity of taro is the highest in Asia (16.12 t/ha) and the lowest in Africa (5.98 t/ha) and the world average productivity is reported as 6.91 t/ha. Taro can be grown in almost all the tropical regions of the world, and hence it can play a crucial role in food security, holding 9$^{th}$ position among world food crops.

In India, taro is mainly cultivated in the states of Uttar Pradesh, Madhya Pradesh, Bihar, Andhra Pradesh, Telangana, Tamil Nadu, Kerala, Odisha, West Bengal and the North Eastern hilly areas. Based on the data provided by AICRP on Tuber Crops centres and other published literature, the area comes to 40,000 ha with a total production of 0.606 mt, depicting an average productivity of 15.21 t/ha. In other places, it is cultivated on a limited scale as intercrop or homestead crop, but consumed as a routine vegetable or food crop by all sections of people.

### Importance

Taro (*Colocasia esculenta* (L.) Schott) is a vegetatively propagated tropical tuber crop and is used as staple food in tropical and subtropical countries. Its tubers are rich source of carbohydrates and the leaves are consumed as vegetables. Taro generates income, boosts food security and offers a natural ground cover where it is grown. It has high potential to combat food insecurity owing to its resilience and ability to grow and produce reliable yields in marginal areas where most other crops would fail. It is in fact classified as a neglected, an under-exploited crop, but with high economic potential. Bringing taro out of shadow into the main stream, would not only help to tackle the risk of climate change problems, but also would help to claim the region of marginal lands. It is an important vegetable grown throughout India and is sometimes called the "potato" of the humid tropics. Taro is adapted to shade and waterlogged conditions. It can be grown as a monocrop or intercropped with other crops or under plantation crops. Taro remains as food and nutrition security crop of tribals in north eastern India. An array of delicious cuisines is made from taro in India. The unique physico-chemical

properties of taro starch have great scope in food and other industries. Taro also fetches a good consumer market price compared to other root and tuber crops in Indian markets.

The important characteristics of taro are given in Table 1.

Table 1. Characteristics of taro

| | |
|---|---|
| Planting material (Propagule) | Mother corms/cormels |
| Growth period (months) | 5- 9 |
| Optimal rainfall (mm) | 700-1500 |
| Optimal temperature (°C) | 21-27 |
| Drought resistance | No |
| Waterlogging tolerance | Yes |
| Shade tolerance | Yes |
| Soil fertility requirements | Low to medium |
| Seasonality of crop cycle | No |
| In-ground storage life | Long |
| Post-harvest storage life (months) | 1-2 |
| Leaves used as food | Yes |

## Nutritional profile

Taro is used as a staple food or subsistence food by millions of people in the developing countries in Asia, Africa, Central America and the Pacific Islands. Even though all parts of the plant can be used for consumption, the most frequently eaten part of the taro plant is the cormels and corms. The cormels of taro are good sources of carbohydrates, proteins, minerals and vitamins (Table 2). Starch is the major component of dry matter and it ranges from 9.6-18.8% of fresh weight in taro. The lipid content is very low in the cormels. Taro cormels are good sources of minerals such as calcium, phosphorus, potassium, manganese and iron. Taro is one of the finest sources of dietary fibres, which help in gradual rise in blood sugar levels, together with slow digesting complex carbohydrates. Because of the small sizes of its starch granules (1.5 to 6.6 μm), taro starch is highly digestible and it also helps to increase the bioavailability of its nutrients due to efficiency of digestion and absorption. The cormels contain mucilage, which is a complex mixture of neutral polysaccharides, fibre and protein. Mucilage is important from the health point of view, imparting properties such as slow transit of food through upper GI tract, hold moisture to prevent constipation and lower blood cholesterol by binding bile.

Table 2. Proximate composition and nutritional profile of taro cormels (per 100 g on fresh wt. basis)

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| Moisture (%) | 72.5-80.5 | Potassium (mg/100g) | 1100-2000 |
| Carbohydrates (%) | 13.0-29.0 | Calcium (mg/100g) | 292.5-391.0 |
| Starch (%) | 9.6-18.8 | Magnesium (mg/100g) | 47-73 |
| Sugar (%) | 0.63-1.12 | Iron (mg/100g) | 3.72-6.66 |
| Crude fibre (%) | 1.03-1.27 | Manganese (mg/100g) | 3.01-5.84 |
| Crude fat (%) | 0.10-0.14 | Zinc (mg/100g) | 3.22-9.94 |
| Crude protein (%) | 1.13-1.75 | Vitamin C (mg/100g) | 1.15-11.10 |
| Ash (%) | 1.95-2.27 | Total carotenes (mg/100g) | 0.11-3.10 |
| Phosphorus (mg/100g) | 230-400 | Phenols (mg/100g) | 1.45-5.32 |

The leaves of taro, which is widely consumed as a vegetable in many places are a rich source of protein, β-carotene, iron and folic acid. The leaves also contain minerals and vitamins such as calcium, phosphorus, iron, vitamin C, thiamine, riboflavin and niacin. The young tender leaves have significant levels of antioxidants such as β-carotenes and cryptoxanthin along with vitamin A (Table 3). Hundred grams of fresh taro leaves provide 4825 IU or 161% of RDA of vitamin A.

Table 3. Proximate composition and nutritional profile of taro leaves (per 100 g on fresh wt. basis)

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| Moisture (g) | 70.0-74.0 | Calcium (mg) | 55-118 |
| Carbohydrates (g) | 5.3-6.7 | Magnesium (mg) | 58-123 |
| Crude fibre (g) | 0.8-1.1 | Iron (mg) | 4-8.6 |
| Crude fat (g) | 0.05-0.07 | Manganese (mg) | 11.5-18.6 |
| Crude protein (g) | 3.79-5.88 | Zinc (mg) | 0.75-1.25 |
| Ash (g) | 1.65-1.85 | Ascorbic acid (mg) | 37-52 |
| Energy (kcal) | 42 | Thiamine (mg) | 0.209 |
| Phosphorus (mg) | 70-90 | Riboflavin (mg) | 0.456 |
| Potassium (mg) | 143-608 | Niacin (mg) | 1.51 |

## Anti-nutritional factor in taro

The edible parts of taro plant contain different anti-nutritional compounds which include oxalates, trypsin inhibitor, phytates, tannins and alkaloids, and the major one in the leaves and tubers of taro is calcium oxalate crystals, which causes an irritant effect known as acridity. Depending upon the variety, the total oxalate content in cormels varies. The acrid taro cultivars synthesize more oxalic acid and store mainly as calcium oxalate. However, the non-acrid cultivars have lower total oxalate content and the major portion of the stored oxalate is in the soluble form. The total oxalate content in the fresh taro corm/cormels of acrid varieties ranges from 165 to 232.5 mg/100g, whereas it ranges from 47.5-82.5 mg/100g for the non-acrid varieties. The tryspsin inhibitor content is in the range of 241.1-1907.1 TIU/g in the cormels.

# Varieties

Many local popular varieties are in cultivation in different parts of the country such as, Thamarakannan, Kannan chembu, Godavari local, vettu chembu etc. ICAR-CTCRI has released 10 improved varieties, in taro mostly through clonal selection. In addition, centres of AICRP on Tuber Crops evolved eleven varieties especially for the states of Bihar, Uttar Pradesh, Andhra Pradesh, Telangana, Chhattisgarh, West Bengal and North Eastern hilly areas.

Table 4. Distinguishing characters of taro varieties released by ICAR-CTCRI

| Sl. No. | Name of the variety | Particulars |
|---|---|---|
| 1. |  Sree Hira | • Year of release: 2022<br>• Duration (months): 6<br>• Average yield (t/ha): 18-20<br>• Important traits: Suitable for rainfed uplands and irrigated medium and low lands. More number (12-16) of long cormels measuring 14-18 cm length. Good cooking quality and low acridity. Tolerant to leaf blight disease.<br>• Recommended state: Odisha. |
| 2. |  Sree Telia | • Year of release: 2022<br>• Duration (months): 4<br>• Average yield (t/ha): 10-12<br>• Important traits: Can be planted during summer with protective irrigation. Produces 7-9 numbers of cormels per plant. Susceptible to leaf blight, but escapes leaf blight disease due to early harvest. Good cooking quality and low acridity.<br>• Recommended state: Odisha. |

| | | |
|---|---|---|
| 3. |  <br>Bhu Sree | • Year of release: 2017<br>• Duration (months): 6-7<br>• Average yield (t/ha): 11-12<br>• Important traits: Round corms and round to elliptic cormels. Good cooking quality. Tolerant to *Phytophthora* leaf blight and mid-season drought and salinity.<br>• Starch 15.6 - 17.3%, sugar 1.2 -1.5%<br>• Recommended state: Odisha. |
| 4. |  <br>Bhu Kripa | • Year of release: 2017<br>• Duration (months): 6-7<br>• Average yield (t/ha): 14-15<br>• Important traits: Round corms and round to elliptic cormels. Excellent cooking quality. Tolerant to *Phytopthora* leaf blight, submergence, drought and salinity stresses.<br>• Starch 12.3 - 14.2%, sugar 1.3 - 1.7%<br>• Recommended state: Odisha. |
| 5. |  <br>Pani Saru-I | • Year of release: 2005<br>• Duration (months): 6-7<br>• Average yield (t/ha): 12-15<br>• Important traits: Round corms and elliptic cormels. Good cooking quality and long keeping quality. Field tolerant to leaf blight and waterlogged condition.<br>• Starch 12%, sugar 3.3%, protein 2.5%<br>• Recommended state: Waterlogged /submerged conditions including coastal areas of Odisha. |
| 6. |  <br>Pani Saru-II | • Year of release: 2005<br>• Duration (months): 6-7<br>• Average yield (t/ha): 12-13<br>• Important traits: Round corms and round to elliptic cormels. Good cooking quality. Field tolerant to leaf blight and can be grown in water logged/ swampy condition.<br>• Starch 17%, sugar 2.8 %<br>• Recommended state: Odisha. |

| | | |
|---|---|---|
| 7. |  <br>Sree Kiran | • Year of release: 2004<br>• Duration (months): 6-7<br>• Average yield (t/ha): 17-18<br>• Important traits: 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.<br>• Recommended state: Kerala. |
| 8. |  <br>Muktakeshi | • Year of release: 2002<br>• Duration (months): 5-6<br>• Average yield (t/ha): 18-20<br>• Important traits: Round corms and cylindrical cormels. White flesh colour and excellent cooking quality. Resistant to *Phytophthora* leaf blight. Suitable for uplands and low lands.<br>• Starch 17.8%, sugar 2%, protein 2.8%<br>• Recommended states: Odisha, Chhattisgarh, Jharkhand, Kerala. |
| 9. |  <br>Sree Pallavi | • Year of release: 1987<br>• Duration (months): 7<br>• Average yield (t/ha): 15-17<br>• Important traits: 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.<br>• Starch 24.5%, protein 2.5%<br>• Recommended state: Kerala. |
| 10. |  <br>Sree Rashmi | • Year of release: 1987<br>• Duration (months): 7-8<br>• Average yield (t/ha): 18-20<br>• Important traits: 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.*<br>• Starch 14.5-15.5%, protein 2.3-2.7%<br>• Recommended state: Kerala. |

# Climate and soil

## Climate

Taro requires warm climate with plenty of moisture, which is available in the tropical and subtropical countries. It prefers moist conditions for better growth and yield. In natural habitat, it is commonly found growing near the water sources. It grows well in warm and humid conditions with mean temperature of 21-27°C and a well distributed rainfall of about 700-1500 mm during its growth period. In areas where rainfall is less, supplementary irrigation is required for successful production. It also survives at high altitudes on hills, 1200- 3000 m above MSL, if frost free conditions prevail during the cropping season.

## Soil

Taro comes up in all types of soils, but performs better in deep, well drained fertile loamy soils with pH range 5.5-7.0. In India, under low land conditions, it is grown in alluvial and fertile soil. The deep soils with good internal drainage, silt or clay textures, rich in organic matter and with slightly acidic or neutral pH are the most adequate for the crop. It can withstand waterlogged conditions in wet lands and reduced aeration conditions, because taro can transport $O_2$ from the leaves to the roots through aerenchyma tissues.

# Quality planting material production

Cormels or corms constitute the planting/seed material of taro. The technology for raising the seed crop is similar to commercial cultivation. However, the crop should be disease free and fully mature. After harvesting, the cormels and corms should be cured for 10-15 days in shade by spreading them in single layer. Damaged corms and cormels should be removed and uniform sized corms and cormels should be stored in a shaded and ventilated place. The seed cormels can be safely stored for 2-3 months, however, mother corms may be planted at the earliest as the chances of rotting is more, especially when the temperatures are high.

## Conventional technique

Taro is a vegetatively propagated crop. Though cormels as well as mother corms are used as planting materials, cormels are found to be ideal for good yield. Traditionally farmers set apart a portion of their harvested corms and cormels as planting materials for the next planting. Taro exhibits a shorter period of dormancy, usually one to two months, during which sprouting does not occur in soil or in storage. Medium size cormels of about 35-45 g is standardized as the optimum size of planting material.

Mother corms of taro

Cormels of taro

## Minisett technique

Studies conducted at ICAR-CTCRI have revealed that the multiplication ratio in taro can be significantly enhanced by adopting minisett technique. Raising minisetts in nursery as in cassava is not required, since, it gets easily established while planting straight in the prepared field, provided there is availability of sufficient moisture. In minisett technique, mother corms are selected from healthy plants at harvest. Such selected mother corms are first cut into cylindrical pieces and then cut horizontally into minisetts of about 10 g weight. It is advisable to grow minisetts in nursery simultaneously, so that gap filling could be done effectively, if required. If minisetts are raised in nursery, they could be transplanted in a months' time to the prepared main field. A major advantage of minisetts in taro is that the cormels, which are the economic part, can be fully marketed since only corms would be required for minisett multiplication. Even if cormel is to be used as planting material in taro, only 1/4$^{th}$ of the conventional quantity needs to be stored as planting material.

Steps involved in minisett preparation

The minisetts are then directly planted in the main field in mounds formed over pits or on raised ridges at a spacing of 45 x 30 cm. Mulching is very essential for obtaining higher cormel yield. By adopting minisett technique, the multiplication ratio can be enhanced from 1:20 to 1:120 in taro.

## Micropropogation

The tissue culture or micropropagation technique provides a sustainable solution to the problems associated with conventional propagation by enabling rapid production of high quality, disease-free and uniform planting materials. The main benefit of tissue culturing taro previously screened for disease organisms, is the production of large numbers of uniform, disease–free plants. This provides the grower with the ability to plant new farms, fertilize efficiently and increase production. But, large-scale micro propagation success can be quite type-specific, *ie.*, different explants of the same species may react differently from one another. Before explanting and during the early stages of shoot proliferation, taro plant disease indexing is required. Other steps to prepare plantlets for field conditions include surface sterilization of stock material, nutrient medium requirements, induction of shoots, induction of rooting and acclimatization.

*In vitro* plant regeneration protocol has been developed by Regional Centre, ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI), Bhubaneswar, Odisha for taro varieties Muktakeshi and Sree Telia. Mother plant material is selected based on the following criteria: rapid growth of plants, leaves free from irregular patterns of yellowing or lesions with surrounding water-soaked yellow areas, free from burrowing pests in the tubers and from weeds, plants are mature, not too small or too close to harvest. Plants grown 3 to 6 months in the ground are the best. Plants need to be housed in greenhouses and irrigated using drip irrigation rather than overhead watering. Utilizing only the mother plant's shoot tip offers the strongest overall defence against disease propagation. This means that, only the bud from underneath the primary leaf stalk of large, central corms should be used for culture; side, smaller cormels and dormant buds are best avoided.

After 5 or 6 days of inoculation, each culture is carefully inspected for any contamination. After, shoot and root proliferation, the regenerated plants are taken to subculturing for increasing the plant numbers. The new plants are subjected to acclimatization before transferring the plants to field condition. Before collecting the plantlets for acclimatization, they should ideally be 2 to 3 inches tall and have some roots. They are planted in 3-inch pots with sterile potting soil. Prior to field planting, potted plantlets should be in 50% shade for 3 weeks, followed by one week in full sunlight. Plants are kept watered while in the shade house. Before transferring the plants to field condition, the plants should be 6 to 8 inches tall. It is highly recommended that such plants should be used as "seed" to produce many more clean plants. This technology for the mass propagation of high yielding taro planting materials by tissue culture can ensure disease-free planting materials for distribution and field planting.

Tissue culture technique in taro

## Seed certification standards

### General seed certification standards

All the general seed certification standards are to be followed together with the following specific standards. A seed field should be maintained separately, whose source and identity must be assured and approved by the certification agency.

### Land requirements

Land for seed production should be free from volunteer plants. Avoid swampy, low lying and over shady conditions. Avoid taro crop residues from other fields.

### Field inspection

A minimum of three inspections shall be made, the first and second at 60 and 90 days after planting and the third at 160 days after planting or prior to harvesting or at appropriate growth stage, depending upon the duration of the variety to check isolation, off-types and other relevant factors.

### Field standards

Provide a minimum isolation distance of 5 m for foundation seed and certified seed. The

isolation distance should be maintained from fields of other varieties as well as fields of the same variety, not conforming to varietal purity requirements for certification. Gaps in the seed field shall not be more than 10%. The details of maximum permissible limits of off-types, pest and disease for foundation seed and certified seed are as follows (Table 5).

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

| Factor | Maximum permitted (%) | |
|---|---|---|
| | Foundation seed | Certified seed |
| Off-types | 0.1 | 0.5 |
| Plants infected by *Dasheen mosaic virus* | 0.5 | 1.0 |
| Plants infected by fungus *Phytophthora colocasiae* | none | none |
| Plants infested with scale insects and mealybugs | none | none |

**Seed standards**

- For foundation and certified classes, seed standards for seed corms are 4-6 cm x 2.5- 3.5 cm with weight ranging between 20-40 g.
- In a seed lot, corms/cormels not conforming to specific size shall not exceed more than 5% by number.
- The seed material shall be reasonably clean, healthy, firm and shall conform to the characteristics of the variety. Those not conforming to the standards shall not exceed 0.1% and 0.5% by number, for foundation and certified seed classes respectively.
- Cut, bruised, cracked corms/cormels or those damaged by insects (other than mealybugs and scale insects), slugs or worms shall not exceed more than 1.0% by weight.
- There should not be any visible symptoms of scale insects or mealybugs infestation for foundation and certified seeds.

# Agro-techniques

## Planting season

Time of planting is not a major factor in tropical regions provided sunlight and moisture are adequate. When the crop is rainfed, planting should be timed to precede or coincide with the rainy season. Hence, under rainfed condition, planting during April to June is optimum. If grown as irrigated crop, it can be raised throughout the year. Mostly the irrigated crop is planted during January to March in different growing areas. The ideal time of planting taro in different states is as follows.

Table 6. Time of planting taro in different states

| State | Rainfed | Irrigated |
|---|---|---|
| Kerala | April-June | January-March |
| Andhra Pradesh | May-June | October-November |
| Bihar | June | February |
| Odisha | June-July | February-March, October-November |
| Jharkhand, Chhattisgarh | May-July | January-March |
| Uttar Pradesh | March-April, June-July | January-February |
| Tamil Nadu | June-July, September | February |
| Assam, West Bengal | March-April | January-February |
| North eastern states | March-April | -- |

## Land preparation

Land preparation involves proper ploughing and turning of soil till a fine tilth is created. It can be done either manually or by using animal drawn implements and tractors. Ploughing to a depth of 25-30 cm is good.

## Method of planting

According to soil type and management practices, different methods of planting 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. In general, ridge and furrow system is more common due to better soil moisture retention. Flat bed method can also be adopted in uplands having good drainage.

Flat bed method

Ridge and furrow method

Pit method

## Planting

Depth of planting does not make any marked effect on cormel yield. The cormels may be planted to a depth of 5-10 cm depending on the size of planting material. Very deep planting delays sprouting and there are chances of rotting.

In Odisha, certain varieties of taro (Panisaru-I and Panisaru-II) are transplanted in puddled field, like paddy. Seedlings are raised in nursery 20-30 days before transplanting. In case of delay in transplanting, leaves are clipped and seedlings with petiole are transplanted.

### Spacing

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 and also under protective irrigation during rabi/summer seasons. About one ton planting material is enough for planting one hectare land, at spacing of 60 x 45 cm; while higher planting density (45 x 30 cm) requires about 1.5-2.0 t/ ha. For minisetts, a closer spacing of 45 x 30 cm is followed.

### 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.

### Mulching

Planted corms/cormels take 20 to 45 days for sprouting. The planted corms need to be mulched with green or dry leaves. Green leaf mulching is found to have significant effect on increasing taro yield due to the enhanced level of available nutrients. Mulching helps to hasten sprouting, control weed growth, regulate soil temperature and retain soil moisture.

Mulching with dry leaves after planting

### Desuckering

Suckers/side shoot development is a common feature in taro. A large number of suckers per plant reduces the cormel size, hence only three suckers/plant should be retained at second earthing up. Cormel yield and size of good quality cormels per plant can be increased by desuckering the unhealthy suckers and retaining only the healthy suckers.

## Nutrient management

Taro is highly responsive to fertilizers. For an early vegetative growth, higher level of nitrogen is required. Response to phosphorus application is found to be inconsistent, whereas application of potassium revoked positive response on the growth and yield of taro.

### Nutrient uptake

A crop of taro producing 17 t/ha of cormel yield with a total dry biomass production of 6.2 t/ha removed 128 kg N, 19 kg P and 135 kg K. Studies on uptake of secondary and micronutrients indicated that for producing 17 t/ha of taro cormels, the crop removed 30.42 kg Ca, 15.87 kg Mg, 11.8 kg S, 10.25 kg Fe, 1.69 kg Mn, 647 g Zn, and 93 g Cu.

## Soil and plant sample collection for nutrient analysis

### Soil testing

To assess the soil nutrient status, soil samples may be collected randomly from the site at 30 cm depth, after removing any foreign debris. 'V' shaped cuts can be made with a spade and soil may be collected from exposed surface or an auger tube may be used for collection of soil. Such samples may be pooled and a representative sample may be taken for analysis, following quartering method. A basic soil test measures the soil pH and the plant-available levels of the nutrient elements, nitrogen, phosphorus, potassium, calcium, and magnesium. This information is used to determine which type of soil amendment might be needed and the quantity of fertilizers required to supplement nutrients in the soil to produce a good crop.

### Plant tissue analysis and critical levels

In taro, first fully expanded leaf at three months of planting is taken as the index leaf for analysis, *ie*., the "leaf number 2," the second leaf blade below the first, youngest expanded leaf blade with a new leaf beginning to emerge from its petiole. The critical nutrient levels in the index leaf tissues are as follows:

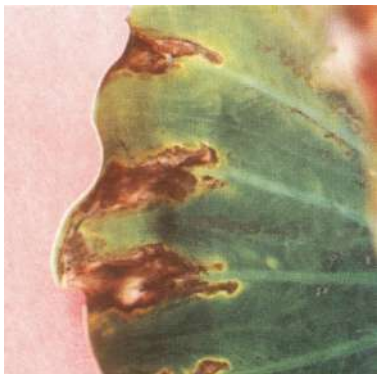
Table 7. Critical nutrient concentrations (CNC) in the index leaf of taro

| Nutrient | CNC |
|---|---|
| N (%) | 3.67 |
| P (%) | 0.36 |
| K (%) | 2.43 |
| Ca (%) | 0.75 |
| Mg (%) | 0.52 |
| Fe (µg / g) | 56.00 |
| Cu (µg / g) | 17.00 |
| Mn (µg / g | 675.0 |
| Zn (µg / g) | 48.00 |

## Nutrient deficiency symptoms

The commonly observed nutrient deficiency symptoms and their management measures are given in Table 8.

Table 8. Essential nutrients, deficiency symptoms and their management in taro

| Nutrient | Deficiency symptoms | Management |
|---|---|---|
|  Nitrogen | • Plants are stunted with small pale green leaves. Older leaves develop a pale, papery necrosis around the margins, particularly towards the tip. | • Application of organic manures and NPK fertilizers as per PoP (FYM @ 12 t/ha, NPK @ 80:25:100 kg/ha).<br>• If severe yellowing is noticed, foliar application of 0.1% urea to save the crop. |
|  Phosphorus | • The symptom is usually noticed on the older leaves. Gradual paling of the leaves followed by development of necrotic lesions on the oldest leaf, with water-soaked tissues around the edges of necrotic area. Necrosis usually follows a general or localized yellowing of the leaf. | • Application of organic manures and NPK fertilizers as per PoP (FYM @ 12 t/ha, NPK @ 80:25:100 kg/ha). |
|  Potassium | • Mild K deficiency results in reduced growth rates. Acute deficiency results in a series of necrotic lesions around the margins of the oldest leaves. Necrosis tend to spread inward rather than joining around the leaf margins. | • Application of organic manures and NPK fertilizers as per PoP. (FYM @ 12 t/ha, NPK @ 80:25:100 kg/ha).<br>• Split application of muriate of potash.<br>• Foliar application of sulphate of potash 0.5%. |

| | | |
|---|---|---|
|  Calcium | • The first sign of Ca deficiency is the appearance of pale, poorly developed interveinal tissue on new leaves. The tissue is pale green to white, forming a narrowing strip midway between major veins or a 'V' tapering from the margins and streaking into the surrounding tissue. Slower expansion of this tissue results in upward cupping or incomplete unrolling, or a puckered or corrugated leaf surface. | • Soil application of lime @ 0.5 to 1 t/ha as basal to avoid symptom manifestation.<br>• Foliar spray of $CaNO_3$ @ 0.5 to 1%. |
|  Magnesium | • Mg deficiency causes chlorosis of oldest leaves followed by interveinal and marginal necrosis. Necrotic tissue is pale in colour, dry and papery. The margins often curl upwards, but the leaves remain turgid until almost the entire leaf blade becomes necrotic. | • Basal application of dolomite @ 1-2 t/ha.<br>• Soil application $MgSO_4$ 10-40 kg/ha. |
|  Sulphur | • S deficiency results in stunting and general chlorosis of the whole plant. Older leaves develop light coloured papery marginal necrosis which tend to extend inward. Development of a very distinct yellow chlorosis extending from the centre along the major veins to about half way to the margin in the senescing leaves is common. | • Application of S containing fertilizers, gypsum or elemental S or ammonium sulphate or single super phosphate are recommended to control S deficiency. |

| | | |
|---|---|---|
|  Zinc | • Symptoms appear on new leaf blades as pale chlorosis in interveinal tissue, particularly near the midrib. Petiole length is reduced. Necrosis usually develop in the interveinal tissue immediately adjacent to the midrib. | • Soil application of $ZnSO_4$ based on soil test (10-50 kg/ha).<br>• Foliar application of $ZnSO_4$ @ 0.5% along with 0.25% lime. |

## Blanket fertilizer recommendations

The actual requirement of nutrients may slightly vary in different growing areas, depending on the soil conditions. Fertilizer recommendations available for taro are blanket recommendations in India based on the response of crop varieties to different doses of N, P, and K fertilizers and determining the fertilizer dose required for attaining economically profitable yield (Table 9). Standard recommendation is to 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. Different combinations of common fertilizers to meet the nutrient requirement of taro in Kerala are given in Table 10. Fertilizers N and K should be applied in split, while P fertilizer may be applied in full as basal. One-third dose of nitrogen and 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.

Table 9. Blanket fertilizer recommendations for taro in different states of India

| States | NPK (kg/ha) |
|---|---|
| Kerala, Andhra Pradesh, Meghalaya | 80:25:100 |
| Tamil Nadu | 40:60:120 |
| Odisha, Bihar, Assam, Jharkhand | 80:60:80 |
| Uttar Pradesh | 80:80:120 |
| West Bengal, Chhattisgarh, A&N Islands | 100:80:100 |
| Maharashtra | 120:60:120 |

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.

Earthing up after fertilizer application in mounds

Earthing up after fertilizer application in ridges

Table 10. Requirement of common fertilizers for taro (kg/ha) in Kerala

| Sl. No. | Fertilizers | 2 weeks after sprouting | 1 month after first dose | 2 months after first dose |
|---|---|---|---|---|
| I | Urea | 58 | 58 | 58 |
| | Mussoorie phosphate/Rajphos | 125 | - | - |
| | Muriate of potash (MOP) | 56 | 56 | 56 |
| | | | | |
| II | Urea | 58 | 58 | 58 |
| | Single super phosphate | 155 | - | - |
| | Muriate of potash (MOP) | 56 | 56 | 56 |
| | | | | |
| III | Urea | 37 | 58 | 58 |
| | Diammonium phosphate | 54 | - | - |
| | Muriate of potash (MOP) | 56 | 56 | 56 |
| | | | | |
| IV | Urea | - | 60 | 60 |
| | Ammonium phosphate/Factomphos (20:20) | 125 | - | |
| | Muriate of potash (MOP) | 56 | 56 | 56 |
| | | | | |

## Integrated nutrient management

Traditionally taro is cultivated with plenty of organic manure, especially FYM, to supplement the nutrient requirement. Mulching with green leaves also is found to

increase the soil nutrients and soil aggregation, which subsequently enhanced the yield and yield attributes. Application of 12.5 t of FYM along with nitrogen @ 80 kg and green leaves @ 12 t/ha results in comparatively good yield. Studies at Regional Station, ICAR-CTCRI revealed that conjunctive use of organic manure and soil test based inorganic fertilizers enhanced the taro productivity and its biochemical constituents and improved biochemical and microbiological activities and soil physico-chemical properties. Inoculation of Vesicular Arbuscular Mycorriza (VAM) *Glomus microcarpum*, combined with half the recommended dose of NPK *ie*., 40:30:40 kg/ha and FYM @ 12.5 t/ha resulted in 39% increase in yield compared to half NPK alone. Addition of lime along with FYM @ 12.5 t/ha, half the recommended dose of NPK (40:30:40 kg/ha) and micro nutrients $ZnSO_4$ @ 10 kg/ha and $MgSO_4$ @ 25 kg/ha, showed a significant rise in cormel yield over unlimed plots. INM package involving application of FYM @ 10 t, vermicompost @ 1t/ha along with 50 to 75% recommended dose of NPK is found ideal for better cormel yield in taro in different states of India.

## Site specific nutrient management

Taro yield in many parts of the world is stagnant mainly due to conventional blanket recommendation of fertilizers, lower nutrient use efficiency and imbalance in the use of nutrients. The Quantitative Evaluation of Fertility of Tropical Soils (QUEFTS) model was used for determining zone-specific balanced NPK uptake requirements and recommendations for a target yield of taro. The constants for minimum and maximum accumulation (kg cormel/kg nutrient) of N (33 and 177), P (212 and 606) and K (25 and 127) were derived as standard model parameters. The results showed that taro requires N, P and K accumulation of 12.97, 2.75 and 17.47 kg/t of cormel yield, suggesting an average NPK ratio in the plant dry matter of about 4.7:1:6.4. Based on this calibrated QUEFTS model, the NPK fertilizer requirements for different potential yield situations were calculated. These results were validated in six agroclimatic zones in India, namely eastern Himalayan region (Assam), eastern plateau and hills region (Odisha, West Bengal), middle gangetic plains region (Bihar), southern plateau and hills region (Telangana) and west coast plain and hill region (Kerala). Based on these results, following SSNM fertilizer calculation chart was prepared for different taro growing regions (Table 11). 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 at the rate of 600 kg/ha is recommended for a target yield of 20 t/ha.

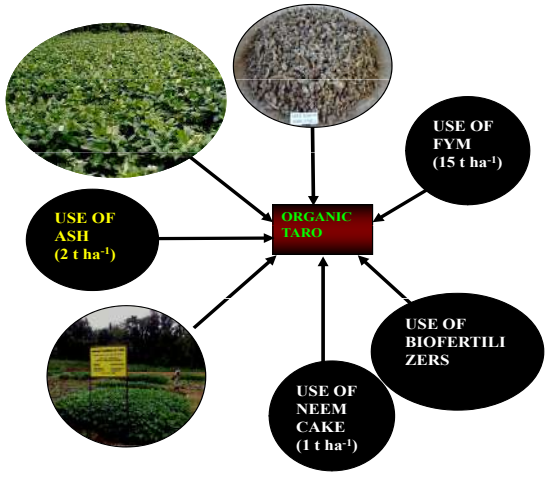
Table 11. SSNM recommendations for taro in India based on calibrated QUEFTS model

| O.C (%) | Yield target(t/ha) | | | | Available P(kg/ha) | Yield target(t/ha) | | | | Available K(kg/ha) | Yield target(t/ha) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | | 10 | 20 | 30 | 40 | | 10 | 20 | 30 | 40 |
| | N rate (kg/ha) | | | | | $P_2O_5$ rate (kg/ha) | | | | | $K_2O$ rate (kg/ha) | | | |
| Below 0.5 | 80 | 120 | - | - | Below 10 | 25 | 40 | - | - | Below 180 | 100 | 150 | - | - |
| 0.5 – 0.8 | 60 | 80 | 120 | - | 10-20 | 15 | 25 | 40 | - | 180-280 | 50 | 100 | 150 | - |
| 0.8 – 1.2 | 40 | 60 | 80 | 120 | 20-30 | 15 | 15 | 25 | 40 | 280-360 | 25 | 50 | 100 | 150 |
| Above 1.2 | 25 | 40 | 60 | 80 | Above 30 | - | 10 | 15 | 25 | Above 360 | 15 | 25 | 50 | 100 |

## Organic farming

Organic farming in taro has been proved to be an eco-friendly alternative to conventional farming for stable yield and quality cormels as well as for maintaining soil health. ICAR-CTCRI has standardized the following practices for organic production of taro.

- Use organically grown planting material.
- Treat cormels of 20-25 g with slurry containing cowdung, neem cake and *Pseudomonas fluorescens* (5 g 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 @ one t/ha (25-30 g per pit) at the time of planting.
- Apply biofertilizers, *Azospirillum* @ 3 kg/ha, mycorriza @ 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.




Essential components of organic production of taro

- Apply ash @ 2 t/ha (60 g per plant) at the time of incorporation of green manure cowpea.
- To manage taro leaf blight, plant TLB resistant variety Muktakeshi, treat the cormels in cowdung slurry enriched with *Trichoderma asperellum* (5 g 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 upto 4 months.

## Water management

There are two main production systems used in taro cultivation: upland irrigated or rainfed conditions and the wet land or low land flooded conditions. Under rainfed conditions, supplementary irrigation by sprinkler or surface irrigation may be given during the dry spell for attaining high yield. It is essential to maintain soil moisture at field capacity, which when falls, should be supplemented with irrigation. Moisture may not be limiting, when cultivated in paddy lands or swampy conditions. However, under rainfed or upland conditions, irrigation should be assured. After planting in any season, 2-8 irrigations may be required depending upon the onset and distribution of monsoon. Usually furrow or flood irrigation is followed. Summer crop requires more frequent irrigation at 10 days interval. Corm bulking stage of taro occurs between 4$^{th}$ and 6$^{th}$ month period, which is considered as the most critical period of water deficit stress. About 5-8 surface irrigations are required under summer conditions of Bihar, whereas 8-10 irrigations are required for Andhra Pradesh.

Taro under furrow irrigation

Taro under sprinkler irrigation

Drip irrigation is found economic during summer season, and taro requires continuous irrigation upto six months during summer and drip irrigation at 100% cumulative pan evaporation (CPE) is found optimum. On an average, the crop requires 130 to 175 litre

of water per day for one cent of its cultivation. The optimum water requirement of upland taro was observed as 610 to 628 mm for a period of six months, with a water productivity of 3.5 kg/m$^3$. The requirement varies with crop stages as 68-72 mm/month during first two months, 118-126 mm during 3-5 months, 110-112 mm during 6$^{th}$ month. *ie*., 90-96 litre/cent during the initial period, 156 to 168 litre during the peak vegetative phase and 146 to 150 litre nearing maturity of the crop. A dry spell of 2-3 weeks towards the end hastens maturity and stop further vegetative growth or sprouting of mature cormels.

Taro under drip irrigation

Use of suitable mulching materials can reduce the water requirement of the crop. Mulching with green/dry leaves during the initial stages will retain soil moisture and enhances sprouting and can reduce the frequency of irrigation. It is found that drip irrigation along with mulching with ground cover mat or crop residues can reduce the water requirement of the crop to half, thereby saving 50% of irrigation water.

Mulching with ground cover mat

Crop residue mulching

## Drip fertigation

Wherever drip irrigation is followed, fertigation can be combined, especially for nitrogen and potassium fertilizers, which are regularly required for growth and tuberization.

Fertigation results in a saving of 25% each of both the nutrients. In place of the standard recommendation of 80:25:100, a lower nutrient dose of 60:25:75 kg N, $P_2O_5$ and $K_2O$ is sufficient per hectare, if drip fertigation is adopted. Full phosphorus is applied as basal application. Fifty percent of nitrogen and potassium may be applied during the first three months, 25% during the fourth month and the rest 25% during the fifth month through fertigation (Table 12).

Fertigation units for small and big areas

Taro under drip fertigation

Table 12. Fertigation schedule for taro

| Weeks after planting | Nutrients (kg/ha) | | Fertilizers (kg/ha) | |
|---|---|---|---|---|
| | Nitrogen | Potassium | N as urea | K as MOP |
| 3 | 2 | 2 | 4.4 | 3.5 |
| 4 | 2 | 3 | 4.4 | 5 |
| 5 | 3 | 3 | 6.5 | 5 |
| 6 | 3 | 3 | 6.5 | 5 |
| 7 | 3 | 3 | 6.5 | 5 |
| 8 | 3 | 3 | 6.5 | 5 |
| 9 | 3 | 4 | 6.5 | 6.7 |
| 10 | 3 | 4 | 6.5 | 6.7 |
| 11 | 4 | 5 | 8.7 | 8.3 |
| 12 | 4 | 5 | 8.7 | 8.3 |
| 13 | 4 | 5 | 8.7 | 8.3 |
| 14 | 4 | 5 | 8.7 | 8.3 |
| 15 | 4 | 5 | 8.7 | 8.3 |
| 16 | 4 | 5 | 8.7 | 8.3 |
| 17 | 4 | 5 | 8.7 | 8.3 |
| 18 | 4 | 5 | 8.7 | 8.3 |
| 19 | 3 | 5 | 6.5 | 8.3 |
| 20 | 3 | 5 | 6.5 | 8.3 |

## Weed management

Taro is very susceptible to weed competition, especially during its early growth period. Initial slow growth and development coupled with wider spacing and congenial soil moisture, make conditions favourable for early establishment of weeds. It is found that weed infestation throughout the crop, reduces yield by 60%. Clean and weed free field during initial periods of crop growth facilitate better crop growth. Generally, two to three manual weeding along with earthing up has been recommended for better growth and tuberization in taro. 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 are effective for weed control during the initial stages of growth.

Mulching with crop residues, paddy straw, peanut hull etc is commonly followed, but mulching alone was not found adequate compared to three hand weedings at 30, 60 and 90 days after planting (DAP). Biointensive live mulching with sunhemp, daincha, and cowpea suppressed the weeds considerably and increased yield than weedy check. Application of pre-emergence herbicide followed by mulching with porous ground cover weed mat (120 GSM) is best for weed management in taro. Hand weeding thrice, at 30, 60 and 90 DAP is more economical where labour is cheap. Paddy straw mulching is another alternative for weed control.

Heavily weed infested field

Porous ground cover mat

Paddy straw mulching

## Cropping systems

Taro is found to fit under different cropping systems. During initial growing stages, different short duration crops can be raised as intercrops such as vegetables (chilli, tomato etc), leafy vegetables (amaranthus, spinach, coriander etc), cowpea, onion etc. In Kerala, taro is recommended as intercrop in banana, coconut and arecanut. Taro and turmeric combination is found to be ideal for getting higher yield of both the crops.

Taro var. Sree Kiran intercropped with green gram or black gram at the reduced fertility level produced higher tuber equivalent yield (12.34 and 11.89 t/ha), production efficiency (68.55 and 66.03 kg/ha/day), equivalent energy (45.66 and 44.69 x $10^3$ MJ/ha

respectively), net income (₹ 2,90,508 and ₹ 2,78,362 per ha), B:C ratio (2.72 and 2.59) and added profit (₹ 2,24,152 and ₹ 2,12,006 per ha) over sole taro. Nutrient saving in taro to the extent of half FYM and N and full P was possible. Thus, FYM @ 6.25 t/ ha, NPK @ 40:0:100 kg/ha is sufficient for taro when intercropped with these pulses.

Field experiment conducted at Bhubaneswar, India revealed that intercropping five rows of taro with one or two rows of maize or pigeonpea on replacement series was a biologically efficient system and taro + pigeonpea (5:1) had higher B:C ratio of 2.35. Taro when intercropped with vegetables in the ratio of 1:1, resulted in the highest taro equivalent yield and net income by taro + vegetable cowpea, followed by cluster bean and then okra.

Intercropping taro with green gram & black gram

Intercropping with turmeric

Taro as intercrop in coconut garden

Intercropping with maize

## Integrated farming system

Tuber crops in general are ideal components for integrated farming system, with other seasonal, horticultural and silvicultural crops, either in mixed/intercropping or sequential cropping and utilizing tubers and leaves for livestock either fresh or processed form. Among tuber crops, taro is capable of utilizing the available resources more efficiently, especially the partial sunlight. Great flexibility in planting and harvesting are the additional advantages with this crop which is aptly suitable to fit in farming systems. Taro is an essential component of integrated farming, for additional income to the tribal farmers of eastern, north eastern states and A&N islands providing a net income of ₹ 20,000 to ₹ 50,000 per ha with a B:C ratio of 1.74 to 2.86 in different places.

# Pest management

## Aphids

There are two types of aphids damaging taro and can be controlled by the same management measures.

**Cotton/Melon aphid** (*Aphis gossypii*)

Cotton aphids feed on the underside of leaves, or on growing tip of veins, sucking nutrients from the plant. The foliage become chlorotic and dies prematurely. Feeding also causes distortion and leaf curling.

**Banana aphid** (*Pentalonia nigronervosa*)

Banana aphids are mainly found in the lower region of the leaf along mid rib. Damage is caused by both nymphs and adults by sucking cell sap. Dry condition favours population flair up. Honeydew is produced by both the aphids and it serves as a substrate for sooty molds, which blacken the leaves, reducing photosynthesis and plant vigour. Aphids are vectors of *Dasheen mosaic virus*.

***Management***

- Avoid planting of taro close to alternate hosts such as melon, cotton, cucumber, or other cucurbits.
- Provide hedges to limit movements of aphids from a crop to another and to encourage natural enemies.
- Sprinkler irrigation or sustained rain can reduce infestation.
- Control ants in the field, as these will disrupt natural enemy activities.
- Destruction of infested leaves after harvesting.
- Treatment with neem oil/neem-based formulation (7 ml/l), Imidacloprid 17.8 SL (0.3 ml/l).

## Taro corm borer (*Aplosonyx chalybaeus*)

Corm borer causes 20-30% damage to the foliage and 80-90% to the corms, resulting in severe loss to the tribal farmers of North Eastern India.

***Management***

- Manual picking and destruction (farmers practice).
- Intercropping with ginger, sweet potato, yam and maize.
- Use of *Beauveria bassiana* and Entomo-pathogenic nematodes (EPN).

## Tobacco caterpillar (*Spodoptera litura*)

The early larval stages remain together initially, later radiates out from the egg mass, stripping the interveinal leaf surface and skeletonising the leaves as they advance. Later stages eat all parts of the leaf, including the petioles. Older larvae are night feeders. Armyworms chew large areas of the leaf and, when numerous, can defoliate a crop.


***Management***

- Remove and burn heavily infested leaves. Most taro growers manually smash cluster caterpillars with their hands when infestations are light.
- Two round spraying with 5% aqueous yam bean seed extract starting from 50% flowering stage at 15 days interval.
- Pesticides are seldom necessary. One application of Malathion (0.05%) is recommended when there is heavy infestation.

## Whitefly (*Bemisia tabaci*)

Both the adults and nymphs suck the plant sap and reduce the vigor of the plant. When the populations are high, they secrete large quantities of honeydew, which favours the growth of sooty mold.

***Management***

- Removal of crop residues and rouging of infested plants to check the risk of carryover population.

- Install sticky cum light trap and operate between 4 to 6 am to attract adults.
- Use insecticide, Imidacloprid 17.8 SL@ 1ml/3l.

## Mealybug (*Formicococcus polysperes*)

Mealybugs occur on the undersurface of the leaves, on and between the petioles, and on the roots and corms. Direct feeding results in distorted foliage, yellowing, stunting, and wilting accompanied with underdeveloped rhizomes which eventually dried prematurely. Indirectly, mealybugs cause a build-up of sooty mold fungi, which grows on the honeydew excreted as they feed.

***Management***

- Burn the severely infested plants.
- Use a mixture of neem oil and soap solution for spraying.
- Use of ICAR-CTCRI developed bio-formulations *'Shreya'* (7 ml/l) followed by *'Nanma'* (7 ml/l) after one week.
- Use one of the insecticides *viz*., Imidacloprid 17.8 SL@ 1ml/3l; Profenophos 50 EC @ 2 ml/l; Chlopyriphos 20 EC @ 4 ml/l; Dimethoate 30 EC @ 2 ml/l if really needed.

## Leaf thrips (*Thrips* sp.)

Thrips feed on base of the leaves; give plants a distorted appearance. When the weather is warm, the life cycle from egg to adult may be completed in as short a time as 2 weeks.

***Management***

The management practices followed against mealybugs are found to be effective against thrips also.

## Banana lacewing bug (*Stephanitis typicus*)

Adults and nymphs feed on the lower leaf surface, mostly in the region of the midrib. Feeding causes small white spots on the upper leaf surface opposite to the feeding site; chlorotic spots and dark excreta marks are left on the lower leaf surface.

***Management***

- The management practices followed against mealybugs are found to be effective against lacewing bugs also.

### Silver striped hawk moth (*Hippotion celerio*)

Small-to-large holes on the leaf margin are typical damage symptom. The larvae may be green, yellowish green or brown in colour and feed voraciously, leading to severe defoliation. The larvae also feed on young succulent stems and the newly sprouted shoots. Infested plants have large areas of leaf missing and the leaf appears ragged.

***Management***

- The larvae are large and relatively seen easily; they can be picked off the plants by hand. In small taro plantings, this is the best means of control.
- In case of severe infestation, spray Indoxacab 14.5 S @ 0.5 ml/l, Spinosad 45% SC @ 0.2 ml/l, Bt @ $10^8$cfu.

### White spotted flea beetle (*Monolepta signata*)

Adults make large holes in leaves by feeding leaf tissues. Adults are commonly found on leaves. The beetle lay minute eggs and are laid in soil cracks around the base of the host plant. Minute worm-like larvae live in the soil and feed on small plant roots and root hairs.

***Management***

- Spray Carbaryl 50 WP @ 3 g/l.

## Disease management

### Taro leaf blight (*Phytophthora colocasiae*)

Taro leaf blight (TLB) is the most destructive disease of taro and causes 25-50% yield loss. The pathogen attacks foliage, petioles and cormels of taro. 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. Lesions develop on petioles of susceptible varieties and the infection causes the plants to collapse. Infected corm tissue is brown, firm, and rotting develops rapidly after harvest.

***Management***

- Cultivation of 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 any one of the fungicides, *viz*., Metalaxyl 4% and Mancozeb 64% (68% WP) (1g/l), Mancozeb 75% WP (2g/l) or potassium phosphonate (3ml/l) as prophylactic/protective measure at 45 days after planting and again three sprays at 15 days intervals once the symptom appears.
- For organic cultivation, dip the cormels in *Trichoderma* enriched cowdung slurry (mix *Trichoderma* in the cowdung slurry at the rate of 5 g/kg of cormel) for 10-15 min. Apply *Trichoderma* enriched vermicompost at the rate of 100 g/ plant at the time of planting and again during intercultural operations.

## Taro mosaic disease (*Dasheen mosaic virus,* DsMV)

The disease is 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. The virus infection may reduce corm size and quality, with yield losses up to 20%. Transmission of the virus is through planting material (cormels) and aphids.

***Management***

- Selection of planting material from healthy plants, which are free from DsMV infection.
- Roguing, periodic physical removal of infected plants.
- Intercropping of non-host plants with taro may check the spread of the virus.

### Ghost leaf spot (*Cladosporium colocasiae*)

Ghost leaf spot has probably the widest distribution, and is likely to be present wherever the crop is grown. Since not causing severe damage, it is considered as minor disease. Irregular reddish-brown with light brown centres coalesce and seen as patches, not penetrating to the undersurface. Since it is a minor disease and the symptoms are superficial, management practices are not needed.

## Harvesting and storage

### Harvesting

Taro is ready for harvesting when most of the leaves begin to turn yellow. Duration of the crop varies with cultivars and methods of cultivation. Crop will be ready for harvest within 5-8 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.

### Yield

Taro yield depends on the type of cultivar as well as the management conditions. The yield highly varies from 10 to 25 t/ha depending upon the variety, spacing, water availability and soil fertility conditions. Under water limited conditions, there is a tendency to produce more mother corms with a corm to cormel ratio of 1:1-1.2. Under stress free conditions, cormel yield will be more and the corm to cormel ratio can be 1:3 or more. Mother corms if planted fresh with adequate soil moisture (not during heavy rains) can give yields, comparable with healthy cormel planting.

## Storage

The harvested corms and cormels are to be stored for marketing or for planting. The duration of storage may vary depending upon the purpose. At the time of harvesting, damaged tubers must be removed to prevent rotting during storage. The tubers should be dried for a day under shade by spreading on ground and the soil adhering to the tubers should be removed. Cormels of certain cultivars possess some degree of dormancy. Usually taro cormels can be stored upto 2-3 months under warm moist tropical ambient storage conditions. In general, farmers select healthy cormels during October-December and store for 3-4 months in shady places for planting in the next season. The harvested materials must be stored in a well ventilated storage shed, facilitating diffused light. Poor storage conditions causes yield reduction mainly due to weight loss, loss of viability, rotting and pests and diseases. Traditional method of storage include above ground storage in raised shelters at the prevailing RH of 85-90% and cool temperatures, or in a cool domestic store room in a heap covered with cloth or straw or in a shallow pit near the field buried in different combinations of sand, soil and straw. However, mother corms have poor storability due to high moisture content and cannot be used for planting in the next planting season. Small quantities of cormels for planting, can be stored in cloth or jute bags with minimum physiological loss in weight and retaining the maximum viability. Treating with suitable fungicide (Carbendazim 12%+ Mancozeb 63% WP 1g/l) reduces the chances of rotting and secondary infections. Treating cormels with *Trichderma viridae* also reduces rotting.

Cormels stored on floor

Mother corms stored on floor

Storage in ventilated place

## Processing and value addition

The main economic parts of the taro plant are the corms and cormels, and the leaves. Fresh corms or cormels are boiled, baked, roasted or fried and consumed in combination with fish, coconut preparations, etc. Taro leaves are used for human food in most producing countries. The leaves are usually boiled or prepared in various ways mixed with other condiments. The high protein content of the leaves favourably complements the high carbohydrate content of the corm which goes with it. The leaves and rhizomes of taro are eaten depending on the cultivar and the culture.

The reduction in oxalate content can be achieved through various processing techniques such as washing, peeling, dicing, soaking, boiling, cooking, blanching, and drying.

Heat treatments such as boiling, blanching, steaming, frying and pressure cooking are effective in minimizing the anti-nutritional factors in taro cormels and leaves. Soaking of the taro chips in 2% w/v sodium bicarbonate solution at ratio 1:4 (w/v) for 20 minutes at ambient temperature, followed by boiling is an effective method to reduce the calcium oxalate levels. Pre-soaking of chips with calcium carbonate at 90°C for one hour as well as baking of the chips pre-treated with calcium carbonate are also effective methods to eliminate acridity. Baking and flour preparation are highly efficient methods to reduce the trypsin inhibitor levels significantly in the cormels.

## Taro dried chips and flour

The corms and cormels can be processed into chips and flour. Flour is prepared by peeling and slicing the corms and cormels followed by washing and soaking overnight in water. The slices are then immersed for 3 hours in 0.25% sodium/potassium bisulphite solution followed by blanching (4-5 minutes), draining, drying and powdering. The flour is a good source of carbohydrate and production of weaning food and diabetes. The taro flour can be used with wheat or other flours in the preparation of composite flours.

## Taro starch

Taro starch, extracted from the cormels after removal of fibre is very peculiar in its properties. It is a very fine starch with small granules and easily digestible; hence it can be used in baby foods, weaning food and the diets of people allergic to cereals and children sensitive to milk. Taro starch, in view of its small granule size, has also been used for industrial applications such as filler in cosmetic powders.

## Taro based food products

Taro is an important vegetable in Odisha, West Bengal and Kerala cuisines. Dhalma is a special dish in Odisha which contains taro. The fried chips prepared from taro is a popular snack food in all these states. The most widespread processed, storable forms of taro are taro chips for human consumption. They are usually made by peeling the cormels, washing, slicing into thin pieces and blanching. The pieces are then fried in vegetable oil, allowed to cool and drain, and then packaged. ICAR-CTCRI has standardized the preparation process for taro chips, taro leaf pakoda etc. The tribal communities in North Eastern states of India prepare several traditional cuisines from taro leaves and tubers. Some of them include *pan irambo, pan thongba, uti curry, uti chutney, shingzu, Balkan, monglok curry, teang, fluo curry, Anishi etc.* In Andaman and Nicobar Islands, taro leaf paste, taro chips and taro cake are prepared. *Aluchefadafade* is a traditional food made from taro leaves in Maharashtra.

The taro flour can find use in food formulations such as taro bread, taro cookies, baby food, pasta, or as a thickener for soups and other preparations. Gluten free cookies are made from combinations of taro flour, rice flour, and sorghum flour.

Taro fried chips

Taro cookies

## Economics and marketing

### Economics

In India, taro is grown in an area of about 40000 hectares, producing 6.10 lakh tones annually. On an average, the price of one kg of taro is sold at ₹ 20 and the total value of taro in India is ₹ 12,200 million. From farm to fork, taro provides opportunity for employment generation to the extent of 247 man-days per ha. Thus, the total employment generation is 9.88 million man days from the taro sector in our country.

The cost of cultivation of taro for one hectare is estimated to be ₹ 0.80 to 1.0 lakh. As taro is mainly used for edible purpose, the price varies from ₹ 15 to 30 per kg of cormels depending on the demand and supply and consumer preferences. Gross income that could be realized from one ha is ₹ 2.28 to 4.57 lakhs. In addition, taro cormels are roasted, boiled or baked and leaves could be used for producing snack food.

### Utilization pattern

For centuries, taro has been consumed as a staple food. Taro is utilized as a routine vegetable in all parts of the country. It has an important place in Indian cuisines and an array of recipes from taro has been well documented. Taro plays an important role in the food and nutrition security of tribal population in NE India, where they use all parts of the plant, in fresh, processed, fermented or dried forms during all seasons including the lean season. Though the potential of taro for the extraction of starch, flour, feed for cattle, poultry, pigs and its medicinal values are documented, India is still in the premature stages of exploitation of the industrial potential of this crop. The exact data regarding its utilization in different forms is also not available.

## Marketing

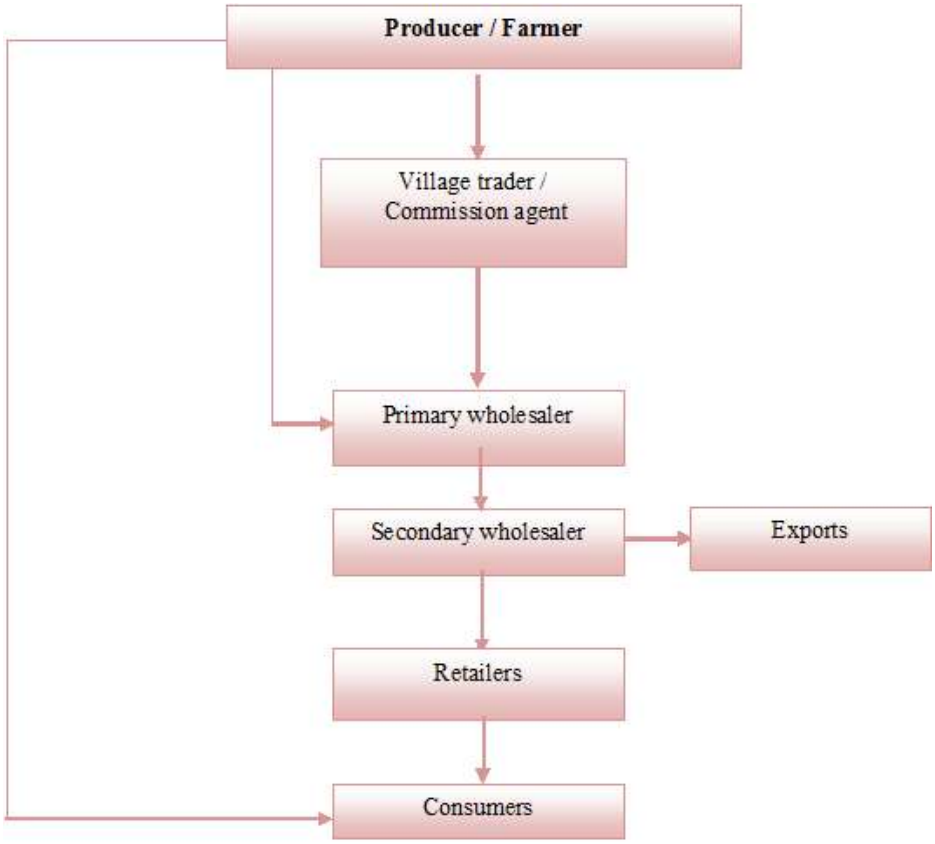
Different production and marketing centres of taro identified in India are listed in Table 13. The states *viz*., Uttar Pradesh, Madhya Pradesh, Andhra Pradesh, Odisha, Chhattisgarh and Kerala are the potential production and marketing centres in India. Few quantities of taro are exported to United Kingdom, United Arab Emirates, United States of America, Dubai etc.

Table 13. Major production and marketing centres of taro in India

| State | Production centre | Marketing centre |
|---|---|---|
| Uttar Pradesh | Baruvasagar (Jhansi)<br>Bisholi (Kanpur, Farookhabad) | Azadpur market<br>Local sales in Uttar Pradesh |
| Madhya Pradesh | Kumti (Indore-Khandwa) | Pandhana and Khandwa APMCs for local sales in M.P<br>New Delhi |
| Andhra Pradesh | Pithapuram (East Godawari dist.)<br>Perakalapudi (Guntur dist.)<br>Venkatagiri (Chittoor dist.) | Local sales<br>Odisha<br>Chennai |
| Odisha | Birdihi (Nagagarh dist.) | Uttar Pradesh<br>Azadpur market<br>Local sales in Odisha |
| Chhattisgarh | Raipur, Bilaspur | Local sales in Chhattisgarh |
| Kerala | Kollam, Pathanamthitta, Kasaragod | Local sales in Kerala |

### Market channels for taro

Identified market channel for taro is presented below. Primary wholesaler collects the produce from farmer through village trader/commission agent for further distribution to consumer through secondary wholesaler/commission agent and retailer. Farmer, trader, commission agent, wholesaler, retailer and consumer are the different market functionaries involved in marketing of taro in India.




Market channel for taro in India

## Conclusion

Despite its food, nutritional, health, industrial, animal feed and pharmaceutical importance, taro has not gained enough attention from researchers. As taro fetches high price in markets compared to other vegetables, it has vast scope of improvement. Taro has great genetic diversity, which needs to be tapped for crop improvement. Tolerance to submergence and shade, photo insensitivity, response to inputs and short duration varieties make it a suitable component in many of the cropping/farming systems with bonus yield and income. A small portion of the produce is now being exported also, which gives scope for further expansion in area. The industrial potential of the crop has to be exploited and the technologies for value addition are to be upscaled, popularised and commercialized to recognize taro as a remunerative future crop.

Taro for Food, Health, Wealth and Prosperity

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