SUSTAINABLE PRODUCTION

GUIDE

COLEAD

DASHEEN AND MACABO

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1

INTRODUCTION TO THE CROP DASHEEN/ MACABO

1.1. DESCRIPTION OF THE PLANT

Taro (name derived from the Polynesian dalo) and macabo are monocotyledonous plants of the family *Araceae*, subfamily Aroideae (aroids), which includes several cultivated species whose underground parts, called corms, as well as the leaves are eaten. *Araceae* are also grown as ornamental plants. Table 1 gives the vernacular names of taro grown in different countries.

Table 1 — Common names of the main *araceae* cultivated by country

BOTANICAL SPECIES	COMMON NAMES BY COUNTRY	AREA OF ORIGIN
Colocasia esculenta (var *esculenta*)	**Taro or Dasheen** old cocoyam (anglophone Africa and Pacific), dalo, talo, kalo (Polynesian area), taro d'eau (New Caledonia), arouille (Mauritius), songe de Chine (Reunion), saonjo (Madagascar), madère (Guadeloupe), malanga (Cuba), chouchine or dachine (Martinique), yu-tao (China), arbi (India – Hindi), kolokasi (Cyprus), qolqas (Egypt), taro, inhame (Brazil), taro tru (Papua New Guinea), tayo (Haiti), mukhikachu (Bangladesh)	Southeast Asia, Melanesia
Colocasia esculenta (*var. antiquorum*), sometimes called simply *C. antiquorum*	**Eddoe,** taro japonais, petit taro, songe maurice (La Réunion) taro bourbon (New Caledonia), ñampi, chamol (Central America), taro do Egito, taro preto (Brazil), satoimo (Japan), Japanese taro	Asia
Xanthosoma sagittifolium	**Macabo or Cocoyam**, tannia, tania, yautia (Central America), ocumo (Venezuela), taioba (Brazil), choux-caraïbe (Martinique) tiquisque (Costa Rica), malanga (Cuba), taro de montagne (New Caledonia), songe (Reunion), taioba (Brazil), new cocoyam, American taro (Guam), dalo ni tan (Fiji), taro singapo (Papua New Guinea), mowlavi kachu (Bangladesh), dalo ni tana (Fiji)	North of South America.
Alocasia macrorrhiza	oreille d'éléphant, elephant ears, songe des caraïbes, taro géant, giant taro	South East Asia
Amorphophallus paeonifolius (syn.: *A. campanulatus*)	elephant foot yam, whitespot giant arum, telingo potato	Southeast Asia, Melanesia
Cyrtosperma merkusii	giant swamp taro, taro des atolls, swamp taro	North of Melanesia

This guide deals with the first 3 species, which will be distinguished, where relevant, respectively by the terms **taro/dasheen, eddoe or macabo**.

1.1.1. FOLIAGE

In *Colocasia* (taro/dasheen and eddoe), the leaves are peltate (the petiole attaches approximately to the middle of the blade), simple, heart-shaped, large (50-80 cm), more or less dark green, sometimes purplish with three main veins arranged in a spiral. The petiole, 0.5 to 1.5 m long, green or purple, is wider at its base where it emerges from the corm. There is a notable exception with "piko" type taros from the Hawaiian Islands, which have hastate and not peltate leaves. Young taro leaves are commonly eaten.

The macabo has larger leaves (up to 1.2 metres long), green in colour, hastate (or sagittate) with the petiole attaching to the edge of the blade in the extension of the central vein. This type of leaf represents the most distinctive criterium compared to *Colocasia* with peltate leaves (see above). The stout, fluted petiole can be over a metre long, with the entire plant reaching 2.5 m in height. Young macabo leaves are also eaten.

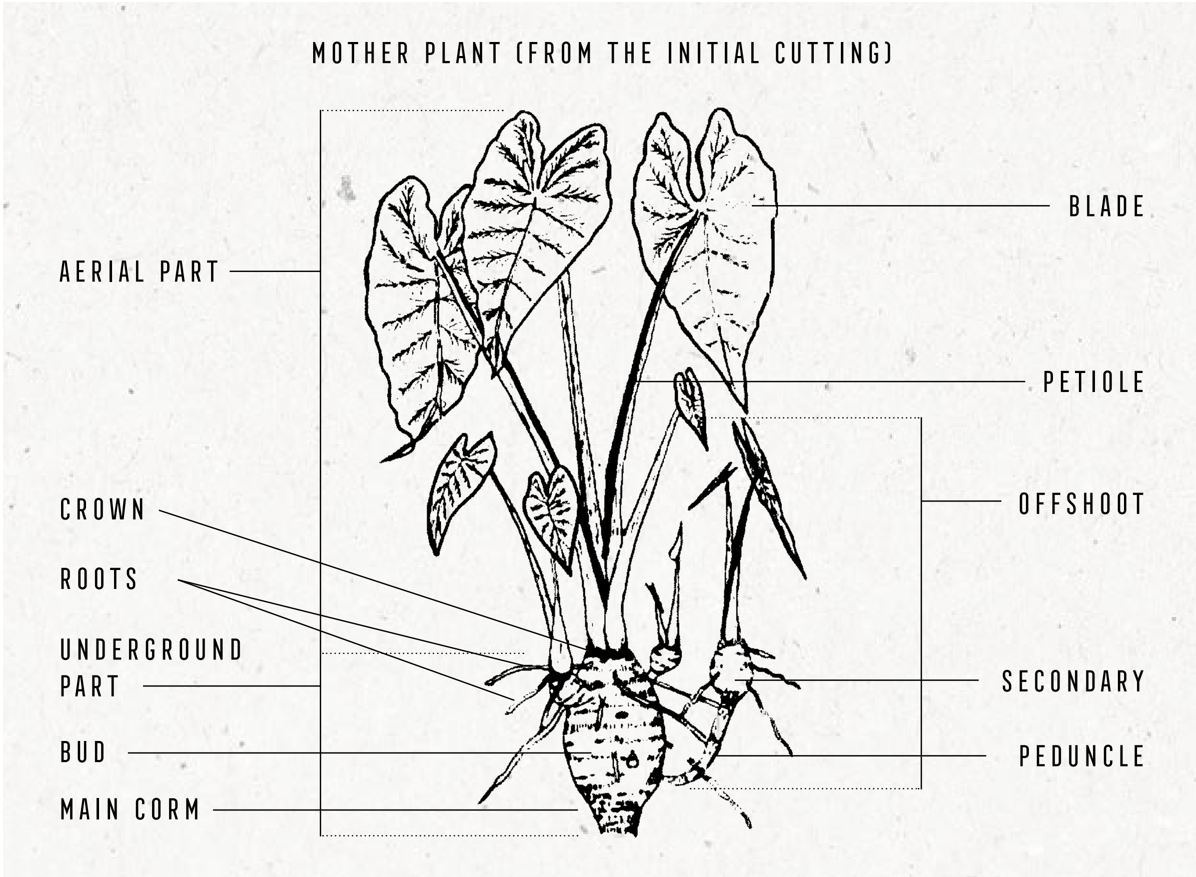

Figure 1 — Taro/dasheen plant (*C. esculenta*)
Source: Varin & Vernier, 1994 [ref 7] drawing by J. Brevart

Figure 2 — Peltate leaf of *C. esculenta*
Photo: P. Vernier

Figure 3 — Hastate/sagittate leaf of *X. sagittifolium*
Photo: P. Vernier

1.1.2. CORM AND ROOT SYSTEM

The underground apparatus consists of a corm, a tuberous underground stem. It is a more or less fibrous and starchy storage organ resembling a bulb, extended by a short swollen stem covered in scales. A superficial bundle of small roots starts from the surface of the corm, which provide food for the plant.

- **In the taro/dasheen,** the central corm (Figure 4) is round or oval in shape, more or less elongated and of a respectable size (1 to 3 kg), flanked by small lateral corms or cormels, which are generally not eaten. The colour of the flesh varies, according to the varieties, from white to dark purple through different shades of yellow, orange, pink and red or even combinations of white with purple or red spots.
- **In the eddoe,** the main corm is smaller but it is surrounded by several well-developed secondary corms (Figures 6 and 7) the size of a kiwi, called cormels. These have a thinner skin and are easy to peel, and are the parts eaten.
- **In the macabo,** the main corm, which is very bitter, is not edible. It bears a bundle (5 to 10) of elongated cormels, which are the edible parts, with white flesh more or less pigmented with red/violet depending on the variety.

Figure 5 — Taro/dasheen cormel
Photo: V. Lebot

Figure 5 — Macabo cormels
Photo: http://www.costafresh.co.cr/productos/tiquisque/

Figure 6 — Eddoe taro cormels
Photo: eddoe taro P. Vernier

Figure 7 — Corm surrounded by its cormels, eddoe taro
Photo: https://peerj.com/articles/10485/

1.1.3. INFLORESCENCE

- The inflorescences in *Colocasia* and *Xanthosoma* are monoecious (separate female and male flowers on the same plant), rare or even absent in certain cultivars. When they appear, these are spadixes, long *cylindrica*l tubes around 10 cm long enclosed in a greenish-white to yellowish spathe 12 to 15 cm long, which forms a closed spherical chamber at its base. This is the characteristic inflorescence of ornamental arums.
- The spadix, slightly longer than the spathe, bears flowers, female at the base, sterile in the middle part and male in the upper part.
- The fruits when they form are small green berries, sometimes yellow, orange or purple, grouped in a compact way at the top of the floral stem. There are about fifty very small seeds per berry (5,000 seeds equal 1 g).

Figure 8 — Dasheen flower (*C. esculenta*)
Source: https://www.cabidigitallibrary.org/doi/full/10.1079/cabicompendium.17221

Figure 9 — Macabo inflorescence (*X. sagittifolium*)
Photo: V. Lebot

1.2. CLASSIFICATION OF TAROS AND MACABO

Among taros of the *Colocasia esculenta* species, two morphological groups are commonly distinguished:

- **Dasheens** (or dachine), which like tropical wet or even flooded conditions. The plants are large, up to 2 metres tall in good conditions. Cultivars suitable for growing in flooded areas are generally separated from those grown in rainfed conditions. These taros have great importance in the traditional culture of Polynesian peoples from the Hawaiian Islands to New Zealand, and including Tahiti, Fiji, Samoa, Tonga and Wallis and Futuna.
- **Eddoes (Japanese taro),** whose plants are smaller (1 metre in height) and which tolerate cooler climates than dasheen.
- Some botanists consider these 2 groups as 2 botanical varieties of the species *Colocasia esculenta* (L.) Schott. As such, we refer to *C. esculenta var. esculenta* for dasheens and *C. esculenta var. antiquorum* for eddoe, sometimes also simply called *Colocasia antiquorum*.
- At the chromosomal level, the situation is complex in *C. esculenta*, the number of chromosomes varying from 14 to 56 depending on the cultivar (with x=14). The species is said to be polyploid. However, some cultivars are haploid (single chromosomes with n=14), others diploid, the most numerous (chromosomes grouped in pairs 2n=28), triploid (3n=42) and even tetraploid (4n=56). Dasheen cultivars are generally diploid (2n =28) and eddoes triploid (3n=42), although the number of chromosomes is not an absolute differentiating factor.

Macabo belongs to the genus *Xanthosoma*, native to northern South America, and includes several species close to *X. sagittifolium*, used for food and sometimes ornamental purposes (*X. brasiliense*, *X. atrovirens*, *X. violaceum*). Since the taxonomy of the genus *Xanthosoma* is still relatively uncertain, all cultivated *Xanthosoma* are generally classified under the name *X. sagittifolium*. These are diploid plants with 2x = 26.

1.3. GROWTH CYCLE OF THE PLANT

Taros and macabo have comparable development cycles, and each cycle requires replanting by vegetative propagation (cuttings) to obtain good quality corms. During its growth, the taro goes through three main phases (Figure 10):

- **Phase 1: Installation of the plant** (Week (W) 1 to W8): The plant establishes its first roots and its first leaves. At first, the leaves are rolled up into a tube, then they unfurl at the same time as the petiole lengthens. During this phase, it is important that the soil remains moist and weed-controlled.
- **Phase 2: Vegetative growth** (W9 to W20-24): The plant develops its superficial but vigorous root system within a radius of 1 to 2 m. It continuously produces new leaves to replace senescent leaves with a number of functional leaves that fluctuates (in dasheens) between 5 and 6. The water requirements are then at a maximum. Towards W25 the plant reaches its greatest height (1.5 to 2.5 m) with an accumulation of dry matter in the petioles and leaf blades, which become tougher. Ground cover is complete.
- **Phase 3: Growth of the corms** (W25-W40 and +): The growth of the aerial parts is slowed down. The starch accumulated in the aerial parts migrates to the corms and cormels, which grow vigorously until the plant reaches maturity at around the 40th week. At the same time, the aerial parts shrivel and yellow.

→ à After this period, if the plants are not harvested, they go into dormancy (vegetative rest) for one to two months before starting a new growth cycle. However, the quality of the corms from this new cycle is mediocre, which is why it is necessary to replant the taros each year to obtain good-quality production. In temperate or subtropical regions with a long cool season, dormancy can last more than 6 months with the complete disappearance of the aerial parts [ref 1].

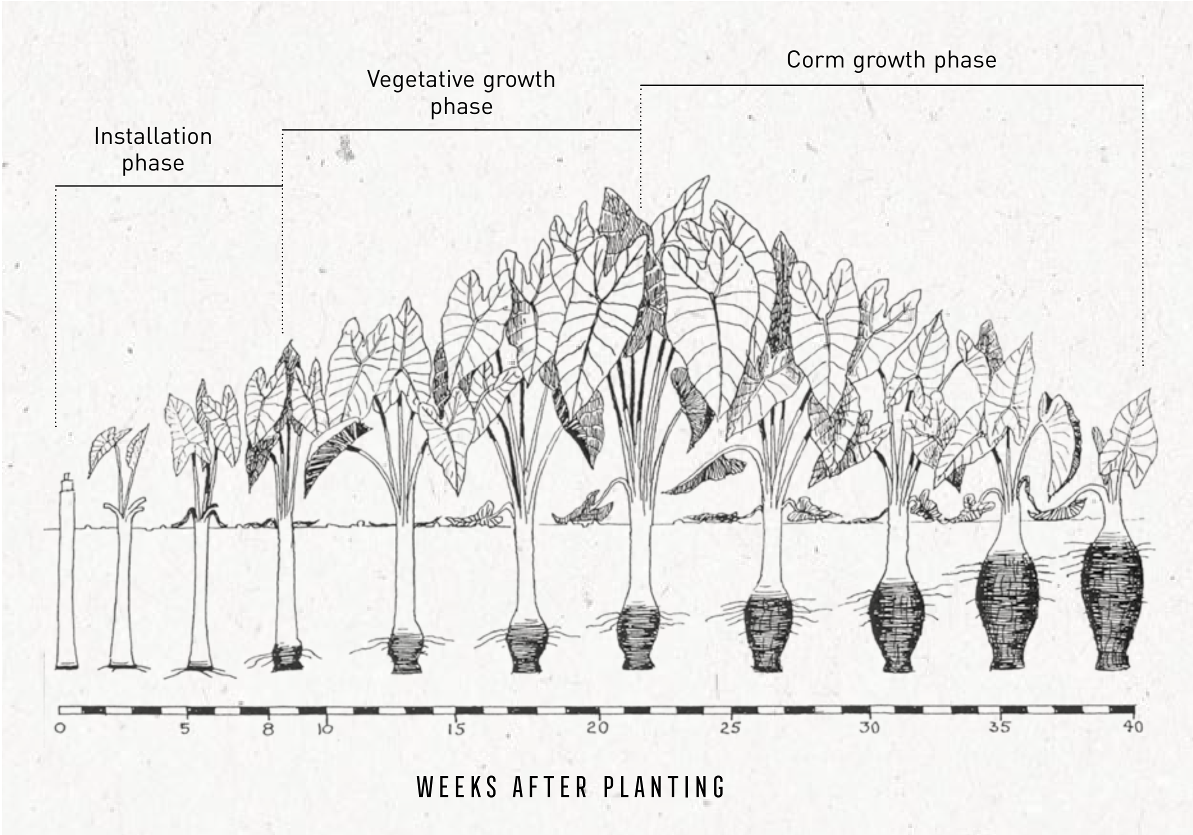

Figure 10 — Plant growth cycle
Source: according to Varin & Vernier, 1994 [ref 7]

INTRODUCTION TO THE CROP DASHEEN/MACABO

TAKEAWAYS FOR THE PLANT, ITS CYCLE AND THE TYPES OF TARO/MACABO

Taros and macabo belong to the *Araceae* family. They are grown for their corms, but also for their leaves. The 3 most cultivated species in the world and covered by this guide are:

— The **taro/dasheen** (*Colocasia esculenta*) native to South Asia and Melanesia. The leaves are peltate (the petiole attaches approximately to the middle of the blade). The central corm (1 to 3 kg) is harvested in a round or oval shape, the colour of the flesh varies from white to purple.

— The **eddoe taro** (*Colocasia antiquorum*) native to Asia. The leaves are peltate but smaller than in the dasheen. The main corm is surrounded by several secondary corms or cormels (20-150 g), which are the eaten parts.

— The **macabo or cocoyam** (*Xanthosoma sagittifolium*) native to Central America and northern South America. The leaves are very large (up to 1.2 meters long), hastate (or sagittate), with the petiole attaching to the edge of the blade in the extension of the central vein. The main, very bitter, corm bears a bundle of 5 to 10 elongated cormels, which are the edible parts.

THE TARO GROWTH CYCLE IS DIVIDED INTO 3 PHASES

— **Phase 1: Installation of the plant** (weeks 1 to 8): development of the roots and first leaves.

— **Phase 2: Vegetative growth** (week 9 to week 20-24): development of the root system and continuous production of leaves.

— **Phase 3: Growth of the corms** (week 25-40 and +): growth of the aerial parts is slowed. The starch migrates to the corms and cormels, which grow vigorously until maturity at around the 40^{th} week.

INTRODUCTION TO THE CROP DASHEEN/MACABO

Figure 11 — Taro/dasheen plants (*C. esculenta*)
Photo: V. Lebot

Figure 12 — Macabo plants (*X. sagittifolia*)
Photo: V. Lebot

2

CROP REQUIREMENTS

Taros and macabo are plants of tropical origin that need heat and a regular water supply to grow. The macabo tolerates semi-shaded exposures well but requires well-drained soils.

2.1. TEMPERATURE

Taros and macabo have optimal growth between 25 and 35°C. The rate of appearance and opening of leaves decreases when the temperature falls below this range. Similarly, the size of the corms decreases with the temperature, while the duration of the cycle lengthens. The corms go dormant below 15°C.

2.2. WATER REQUIREMENT

Taros and macabo are water-demanding plants due to their large leaf area, which is a source of high evapotranspiration. An overall water supply of 200 to 300 mm/month is required for optimal plant growth. The water requirement is higher during the first 5 months after planting, when the leaves are developing. After that, a more limited provision is possible for the rest of the cycle [ref 1]. In strict rainfed cultivation, rainfall of 2,500 mm/year is considered optimal, with at least 1,750 mm/year well distributed across the taro cycle. Below this rainfall level, supplementary irrigation is generally necessary [ref 6].

Dasheen-type taros tolerate hydromorphic conditions well and are often grown in flooded plots on heavy soil in what are then called taro fields, often in rotation with rice as is common in Asia and Madagascar. Taro plants, thanks to their spongy petioles, are able to transport oxygen from the leaves to the roots, allowing them to withstand waterlogged soil conditions.

However, this hydromorphic tolerance depends on the genotype, and some cultivars, conversely, require exposed situations like most **eddoe-type taros.**

Macabo (*Xanthosoma sagittifolium*) is more tolerant to the lack of water, but more sensitive to waterlogging. For this reason it is normally grown in an exposed situation, possibly with a supplementary watering system. [ref 36]

Since water availability often becomes a limiting factor with climate change, varietal improvement programmes are now oriented towards breeding varieties that are more resistant to water stress than the traditional varieties.

Taros and macabo are fairly tolerant to water salinity (cf. 2.5.11.).

2.3. TYPE OF SOIL

Taros and eddoe can be grown on a wide range of soils, but particularly like deep, well-drained, slightly acidic (pH 5.5-6.5) loamy soils. Stony soils should be avoided as they deform the corms and complicate harvesting. However, many varieties of the dasheen type develop well in flooded plots with clay soil provided that permanent water circulation is maintained to limit the water temperature, which promotes the development of algae and root rot when too high [ref 12].

Some taro/dasheen cultivars tolerate salinity well, and this aptitude is used in some countries, such as Japan and Egypt, to recover saline soils by cultivating taros as a break crop [ref 6].

A soil pH between 6.0 and 6.8 limits the risk of nutrient deficiencies. For high pH (7.5 and more) there may be iron deficiencies (see key to visual symptoms above), which can be corrected by foliar applications. For pH below 6, calcium deficiencies are possible, which can be corrected by adding a lime application (agricultural lime, gypsum etc.) [ref 11]. In general, taros appreciate soils rich in organic matter.

The macabo prefers sandy, loose soils with sufficient organic matter. The optimum pH is between 5.5 and 6.5 [ref 13]. The macabo requires well-drained soils to avoid root rot from *pythium*.

2.4. PHOTOPERIODISM – LIGHT REQUIREMENT

Taros are fairly insensitive to variations in day length and generally tolerate shady situations well thanks to good photosynthetic efficiency. In a situation of partial shade (50% natural light), the above-ground biomass is often even higher than would be obtained in conditions of full sunshine. The total corm yield does not seem to be affected by shade and the dry matter content even increases, which is a quality criterion [ref 14].

2.5. NUTRIENT REQUIREMENT

Taros are relatively nutrient-demanding plants and, in the event of a deficiency, quickly show visual symptoms on the leaf blades and eventually a reduction in corm yield. Nitrogen (N) and Potassium (K) are the 2 most important nutrients in leaves. Phenomena of toxicity appear with high concentrations of zinc (Zn) and manganese (Mn).

Table 2 specifies, for the main macro and micronutrients, the optimal concentrations at the blade level of the youngest fully developed leaves. The critical threshold for deficiency risks is the value below which the plant is in a situation of deficiency. The critical threshold for toxicity risks is the value beyond which these elements can become toxic for the plant.

Practically speaking, it is useful to know the visual symptoms that characterise the main deficiencies and toxicities observed on taros (see Figures 13 & 14). These symptoms are generally visible on the leaf blades, which under normal conditions are uniformly green. Deficiency symptoms appear on adult leaves if the plant is able to internally mobilise the nutrient from the oldest leaves. Otherwise these symptoms may appear on young leaves. The symptoms of toxicity generally appear on the adult leaves only because there must first be a certain level of accumulation of the nutrient in the tissues.

Table 2 — Physiological disorders of taros for the main nutrients

CRITICAL CONCENTRATION AND OPTIMAL CONTENT PER NUTRIENT MEASURED IN THE BLADE OF THE YOUNGEST DEVELOPED LEAVES		
PHYSIOLOGICAL DISORDER	CRITICAL CONCENTRATION THRESHOLD	OPTIMAL CONTENT
DEFICIENCY		
N (%)	3.7	3.9 – 5.0
P (%)	0.33	0.5 – 0.9
K (%)	4.60	5.0 – 6.0
Ca (%)	2.0	2.6 – 4.0
Mg (%)	0.15	0.17 – 0.25
S (%)	0.26	0.27 – 0.33
Fe (mg/kg)	56	68 – 130
B (mg/kg)	23	26 – 200
Mn (mg/kg)	21	26 – 500
Zn (mg/kg)	22	22 – 50
Cu (mg/kg)	3.8	5.8 – 35
TOXICITY		
Mn (mg/kg)	1100	26 – 500
Zn (mg/kg)	400	22 – 250

Source: Lebot (2020) according to O'Sullivan & al. (1996)

2.5.1. NITROGEN (N)

Nitrogen is one of the most consumed nutrients by taro plants and any deficit in its availability is detrimental to yield. Taros grow best when most of the nitrogen available in the soil is in the form of the nitrate ion (NO^{3-}) rather than the ammonium ion (NH^{4+}). Nitrogen-deficient taro plants have stunted roots and shoots. The yellowing of the leaf blades begins on older leaves and then spreads to all the foliage. Premature senescence of the older leaves reduces the active leaf area and ultimately decreases corm yield.

2.5.2. PHOSPHORUS (P)

Phosphorus-deficient taro plants exhibit stunted root and shoot growth. Older leaf blades may appear darker green due to a greater delay in leaf expansion in relation to the reduction of chlorophyll (green pigment). As the deficiency progresses, the leaf margins begin to yellow and then turn brown.

2.5.3. POTASSIUM (K)

Potassium-deficient taro plants have slower growth, a tendency to wilt, reduced leaf size, and a burnt appearance between the leaf veins and around the leaf margins. In some cultivars such as "Lehua maoli" in the Pacific, potassium deficiency manifests as irregularly shaped brown spots in the centre of the blades of the older leaves. As the deficiency progresses, the spots may coalesce, and the entire leaf turns yellow or brown. Potassium is important for regulating several metabolic processes and has a positive role in plant resistance to drought (Wang *et al.*, 2013).

2.5.4. CALCIUM (CA)

Calcium deficiency is characterised in taro by reduced root and shoot growth. If the deficiency is slight, the blades of the young leaves turn yellow between the veins. Under severe deficiency conditions, the leaf blades take on a cupped shape, with yellow areas between the veins and brown on the leaf margins.

2.5.5. MAGNESIUM (MG)

Magnesium deficiency is characterised by yellowing between the veins, especially on the older leaves. As the deficiency progresses, the leaf margins turn brown and become necrotic.

2.5.6. SULPHUR (S)

Taro plants deficient in sulphur present reduced root and shoot growth with reduced leaf size and a uniform yellowing of the leaf blades, especially in the young leaves.

2.5.7. IRON (FE)

Iron deficiency is initially manifested by yellowing between the veins of the young leaves and then by their uniform whitening. In addition, the formation of lateral roots is slowed.

2.5.8. MANGANESE (MN)

Taro deficient in manganese shows reduced growth. At first, there is a yellowing between the veins of the young leaves, then the entire leaf blade turns yellow.

Too much manganese in the soil can lead to toxicity, reducing root and shoot growth. It can also limit iron absorption, leading to symptoms similar to those of iron deficiency. Symptoms of manganese toxicity first appear on the oldest leaf blades, but vary between taro cultivars and growing conditions.

2.5.9. ZINC (ZN)

A taro plant deficient in zinc is stunted but often shows no other characteristic symptoms. Excessive zinc uptake can lead to toxicity characterised by necrotic spots between the leaf veins.

2.5.10. COPPER (CU)

Copper deficiency can occur in acidic sandy soils with a low total copper content, or in alkaline or organic-rich soils in which copper availability is low. Liming increases the risk of copper deficiency in these soils.

Copper deficiency causes localised deformations of young leaves without a noticeable reduction in their size, but if the deficiency is severe, the leaf size decreases causing the stunting of the plant.

Toxicity phenomena can occur in soils with a high copper content due to the excessive use of copper-based fertilisers or fungicides.

High concentrations of copper in the soil disrupts the growth of the roots, which become short and unbranched and eventually die. No specific symptoms appear on the aerial parts, apart from those attributable to root dysfunction.

2.5.11. SODIUM CHLORIDE (NACL)

Sodium chloride toxicity occurs when taro is grown in saline soil or if it is irrigated with water with a high salt concentration. At moderate levels of salt content, the margin of the leaves turns yellow. When the concentration increases, the blades curl and the margins of the leaves become necrotic until the plant dies due to the high salt concentration. Compared to other tropical crops such as cassava or sweet potato, taro (*Colocasia*) is considered moderately salt tolerant, with little impact on its size and morphology up to 100 mM (millimole per litre). It can survive up to a concentration of 200 mM NaCl from irrigation water. (Sea water has an NaCl concentration of around 500 mM). Salt concentration does not seem to increase the oxalate content of the corms either (5. Lloyd. *et al.*, 2021). There is, however, a genetic variation for salt tolerance of certain cultivars that tolerates higher salt concentrations than others.

2.5.12. BORON (B)

Taro deficiency symptoms are non-specific and manifest as the stunted growth of shoots and roots.

Excessive boron uptake can lead to toxicity characterised by depressed growth and yellowing or brown spots on the blades of the older leaves.

2.5.13. ALUMINIUM (AL)

When the soil pH is below 4, aluminium can become toxic to most plants. Taro seems relatively tolerant to high Al concentrations in soils, but with variations between varieties. When it occurs, toxicity leads to a reduction in root biomass. Liming the soil prevents this toxicity by precipitating the aluminium ions that can no longer be absorbed by the plants. Sensitivity to aluminium toxicity varies among cultivars and this could be a breeding objective for the taro breeding programme.

Figure 14 links variations in the appearance of leaves to the common deficiencies and toxicities. This determination key allows for an initial classification but should be supplemented by analyses (leaves and soil) in the laboratory and possibly field trials (for the correction of deficiencies) to confirm the elements responsible. As the key shows, the same symptom can have several causes and the same cause can produce different visible symptoms.

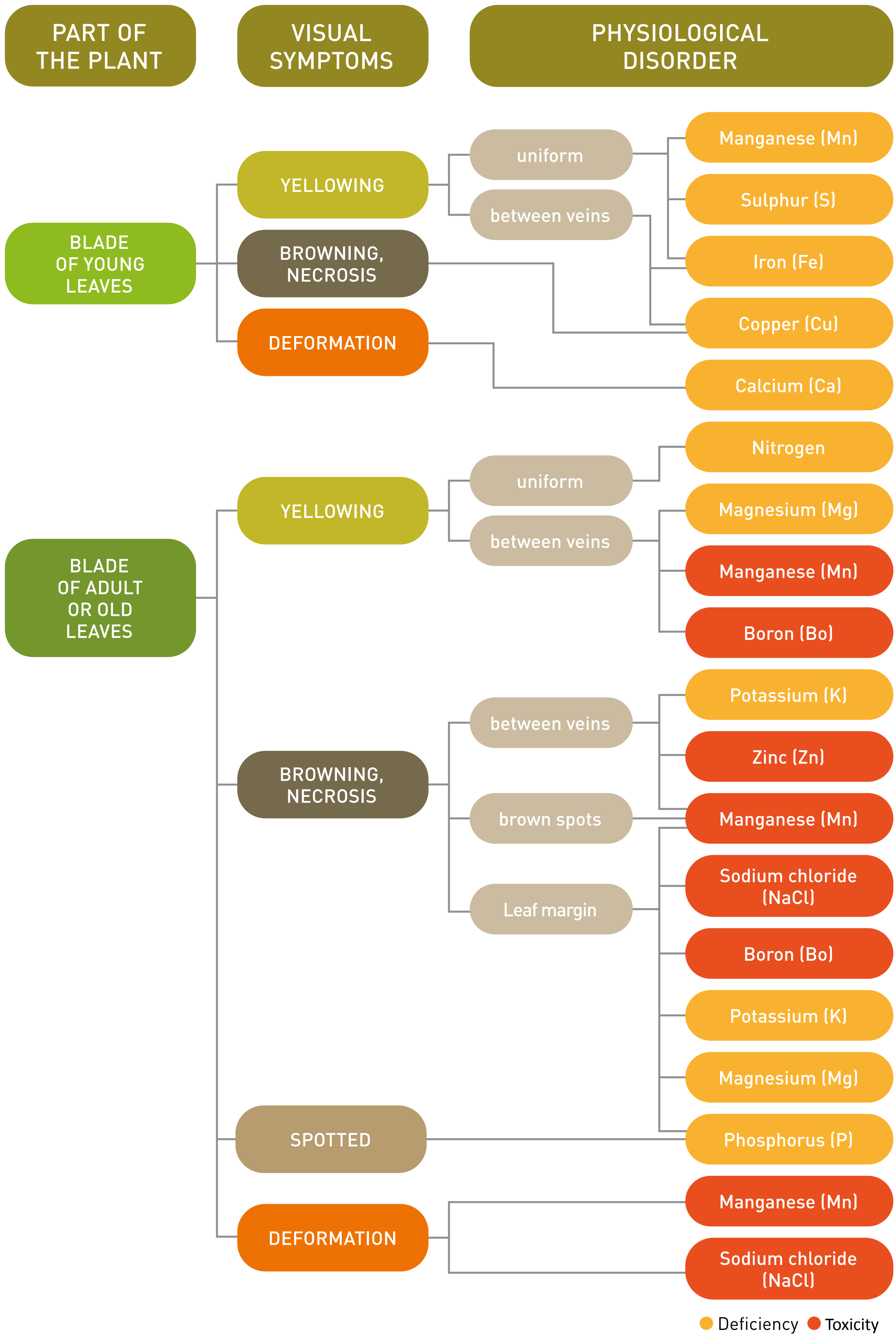

Figure 13 — Key for determining physiological disorders (deficiency and toxicity)
Source: S. Miyasaka *et al.*, 2002. CTARH, University of Hawai'i [ref 4]

N-deficient plant on the right (R), compared to a healthy plant on the left (L).

Zero, moderate and severe P deficiency (L to R)

K deficiency producing necrotic lesions at vein endings

Interveinal chlorosis on an old leaf with moderate Mg deficiency

B toxicity:
Irregular V-shaped necrotic spots in the interveinal tissue in eddoe.

Stress due to NaCl salinity:
Necrosis rapidly spreading to all interveinal areas without prior chlorosis

Sulphur deficiency in macabo showing general chlorosis on the young leaf and interveinal chlorosis on the older leaf.

Ca deficiency:
ragged leaf after tearing of interveinal necrotic lesions

Fe deficiency:
reduction in the size of the blade
of the affected leaves with relative
elongation of the petioles

Severe stunting due
to zinc deficiency

Taros grown on soil without Al (L) and with a high Al content (100 µM/litre) (R)

Figure 14 — Symptoms of foliar deficiency and toxicity on taro/dasheen (unless otherwise *indica*ted)
photos: Jane O'Sullivan, University of Queensland

CROP REQUIRE-MENTS

TAKEAWAYS FOR TARO AND MACABO CROP REQUIREMENTS

TEMPERATURE AND WATER

- These are tropical plants that need heat and water to grow.
- Their growth is optimal between 25 and 35°C. Corms go dormant below 15°C. Macabo tolerates semi-shaded exposures well.
- A supply of 200 to 300 mm/month is necessary for optimal growth.
- Water requirements are higher in the first 5 months during leaf development.
- In rainfed cultivation, rainfall of 2,500 mm/year is optimal, with 1,750 mm/year well distributed across the cycle.

TYPES OF SOIL

- They can be grown on a wide range of soils but do well in deep, slightly acidic (pH 5.5-6.5) loamy soils. Stony soils should be avoided as they deform the corms and complicate harvesting.
- Many dasheen-type varieties are grown in flooded plots provided there is permanent water circulation to avoid overheating, as too high a temperature promotes the development of algae and root rot.
- A high pH (>7.5) causes iron deficiencies that can be corrected by foliar applications.
- If the pH is < 6, calcium deficiencies are possible which can be corrected by adding a lime amendment (agricultural lime, dolomite, gypsum etc.)
- They like soil rich in organic matter.
- Macabo is tolerant of a lack of water but requires well-drained, sandy and loose soils, rich in organic matter.

CROP REQUIRE-MENTS

NUTRITIONAL ELEMENTS

- Nutrient deficiencies and toxicities are manifested by visual symptoms on the leaf blades, which under normal conditions are uniformly green.
- Deficiency symptoms may appear at the start of the cycle on leaves that are still young.
- Toxicity symptoms appear on adult leaves after the accumulation of the nutrient in the tissues.

3

PRE-PLANTING CHOICES

3.1. CHOICE OF PLOT

Choosing a plot suitable for the type of taro you want to grow is a crucial preliminary stage for successful cultivation.

For **dasheen-type taros**, a distinction is made between:

1. cultivation in flooded conditions with a permanent layer of water;
2. cultivation in an exposed or rainy area, sometimes with supplementary irrigation.

Eddoe-type taros and macabo are always grown in an exposed situation, sometimes with additional watering.

The soil should have the characteristics mentioned in point 2.3.

3.1.1. TOPOGRAPHY

Flooded cultivation is possible when the water resource is sufficient to maintain a permanent layer of water on the plot throughout the crop cycle or at least during the periods when the needs of the plant are greatest. This method of cultivation is found on plains with abundant waterways or in areas of marshy lowlands.

Flooded cultivation is also practised on hillsides arranged as flat terraces liable to flooding thanks to a system of irrigation channels and bunds. The taro fields found on the east coast of New Caledonia or in Vanuatu are good examples. (Figure 16).

For rainfed/exposed cultivation, the topography is flexible. On the plain (Figure 15), areas prone to flooding should be avoided for eddoe taro and macabo, which are sensitive to soil hydromorphy. Cultivation on slopes is widely practised for all types of taro, but requires appropriate cultivation techniques to avoid erosion (plant cover, mulch etc.).

3.1.2. SHADE

While flooded cultivation is practised in an open environment and in full sun, rainfed cultivation is possible with different levels of shade. *Araceae* are in fact relatively shade-tolerant plants (see above) and adapt well to agroforestry systems, which are often more sustainable than open cultivation. (Figure 17).

Managing the level of shade in these systems through appropriate tree pruning and planting density can improve corm productivity and quality while reducing weed competition.

The shade tolerance of taro/dasheen, however, depends on the variety and it is important to choose the "right cultivars" for shade growing. In Hawaii, for example, the traditional "Taro Paepae" and improved "Samoa Hybrid" cultivars show very good behaviour in shady conditions. [ref 14]

Macabo is traditionally grown in Latin America in agroforestry systems.

3.2. CROP/COMBINATIONS ROTATION/SUCCESSION

3.2.1. FOR TARO/DASHEEN

In flooded cultivation, taro is generally planted as a pure crop, often several cycles in a row (Figure 15). In regions where rice is also produced, such as in Southeast Asia, it is cropped with this cereal. To limit phytosanitary problems, it is advisable not to repeat the cultivation of taro.

In traditional rainfed cultivation, taros, plants requiring high soil fertility, are often planted at the beginning of the rotation after clearing or long fallow. In the Pacific region, taros are one of the elements of major cropping systems, which often follow a model of itinerant slash-and-burn agriculture based on the vegetative propagation of root and tuber plants and banana trees [ref 18].

In Fiji, on slopes, taro is grown as single crop after ginger and before cassava. In the kava (*Piper methysticum*) growing area, it is used as a shade crop for young kava, which are planted once the taros are already well developed. [ref 6].

In Tonga, taro is traditionally combined with yam and plantain. In commercial production, it is cultivated as a single crop, sometimes following the production of squash (*Cucurbita maxima*), in order to benefit from the remains of fertiliser left by this intensive export crop.

In Papua New Guinea, taros are combined with other crops such as yams, sweet potato, groundnut, upland rice, beans etc. They can also be planted as an intercrop in oil palm or coconut plantations, for example. In Martinique, the "dachine" is very often combined with the cultivation of yams and/or vegetable plants.

Good agroecological practices recommend, in the absence of other crops, that an improved legume-based fallow (*mucuna*, *pueraria* etc.) is interposed between 2 taro cycles in order to ensure permanent soil cover and create mulch, in which the taro of the following cycle will be directly planted [ref 1]. This planting technique on plant cover can also be used for eddoe taro and macabo.

3.2.2. FOR EDDOE TARO

Eddoe-type taros are grown in an exposed situation and can be integrated into rotation with many crops. They can be grown in temperate or subtropical climates as long as you can have 5 to 6 months without frost, like in Japan or New Zealand [ref 16]. Yields vary between 12 and 15 t/ha [ref 10 &15].

3.2.3. FOR MACABO

Macabo is often grown in combination with other annual and perennial crops. In Cameroon, in Bamileke country, taros/dasheen and macabo are planted together after clearing, in combination with maize, groundnuts and beans, on sloping plots. Others dedicate themselves to coffee [ref 17]. In Cameroon, the combination of macabo with the plantain banana is not recommended by some because the uprooting of the taro corms at harvest weakens the roots of the banana trees, which then easily topple in strong winds.

Figure 15 — Irrigated taro/dasheen cultivation, Hawaii
Photo: W9JIM /Flick

Figure 16 — Flooded taro/dasheen cultivation, traditional taro field, Island of Santo-Vanuatu
Photo: V. Lebot

Figure 17 — Cultivation of taro/dasheen in an agroforestry system, Haiti
Photo: P. Vernier

3.3. TYPES OF PLANTING MATERIAL

Taros are cultivated by vegetative propagation using a fraction of the plant (cutting) to plant the next cycle. This method makes it possible to reproduce individuals identical from one generation to the next (cloning), but this can also transmit pests and diseases (viruses, fungi, bacteria, insects) if the selection of planting material is not done rigorously. It is therefore very important to take cuttings only from healthy plants and to remove those that show symptoms of pests or diseases.

3.3.1. FOR TARO/DASHEEN

Traditionally, 4 types of planting materials or seed tubers are used [ref 6]:

3. The **stem cuttings** (called *huli* in Hawaii) (Figure 18), which are prepared by taking the first 25-30 cm of the petiole from the plant at the time of harvest, leaving at its base a section of corm of 1 to 2 cm.
4. The **lateral offshoots or suckers** that develop around the mother plant. Sufficiently vigorous offshoots will be selected (5 cm in diameter, 40 cm long)
5. The **small unmarketable corms or cormels** (150-200 g)
6. **The corm pieces** produced from cutting up large corms (150-300g)

Stem cuttings provide a quick and vigorous start to vegetation. However, they cannot be stored for long and should only be used if they can be planted quickly after harvesting the mother plants from which they were taken.

The other 3 types of planting material make it easier to postpone planting after the preceding harvest. The material will then be placed in a nursery to initiate pre-germination (corm and cormels) or the resumption of the offshoots. Proper soil moisture must be maintained until replanting in the field.

3.3.2. FOR EDDOE TAROS

Planting is mainly based on secondary corms (Figure 19) by taking part of the harvest for replanting, but can also be done using offshoots. In Japan, cormels are pre-germinated and planted, rooted at the 2-leaf stage.

3.3.3. FOR MACABO

The same types of seed tuber as with taro/dasheen are used. Either pieces of the central corm (130 to 200 g) or whole secondary corms (Figure 20). Well-developed suckers (200-400g) or stem cuttings can also be planted.

3.3.4. FAST PROPAGATION METHODS

Several fast propagation methods for taro have been developed by agricultural research to increase the propagation rates of traditional techniques, which are in the order of 5 to 10. We can cite [according to ref 1 and ref 6]

— **The technique of mini-fragments (minisets)**: pieces of corm weighing 30-50g are germinated in the nursery and then transplanted into the ground. The resulting small corms and offshoots will serve as planting material in year 2 (Figure 22).

— **The production of runners with gibberellic acid** (GA3): the corms are soaked for 10 mins in a 500 ppm GA3 solution and then planted. This treatment induces the production of stolon (creeping stem which produces roots at each node) instead of the usual offshoots. The stolons are cut into fragments of a node, which will each produce a small taro plant. In 3 months, you can achieve a propagation rate of +130 to 1. This technique is notably used in Samoa within the context of large-scale taro propagation operations [ref 19].

— **In vitro meristem culture:** this consists in cultivating, on an appropriate and sterile growth medium, meristem cells taken from the seeds of mother plants (Figure 21), on which the absence of virus will have been checked beforehand by virological testing (PCR for example). In a few months, it is possible to produce several thousand small corms from a single mother plant to use as planting material. However, it is a sophisticated technology that should be reserved for laboratories specialising in the emerging seed production segment supporting commercial sectors. In vitro culture also allows for the international exchange of varieties of genetic material in observance of very strict international health rules, which require that the material exchanged be virus-free.

Figure 18 — Dasheen cuttings, "*Huli*, Vanuatu" method
Photo: V. Lebot

Figure 19 — Pregerminated eddoe taro cormel
Photo: P. Vernier

Figure 20 — Macabo seed tuber: cormel and corm piece (photo ref 13)

Figure 21 — In vitro meristem culture
Photo: Vernier/Vitropic

Figure 22 — Germinated dasheen mini-fragment
source: NARI/PNG

3.4. CHOICE OF VARIETIES

For taro and macabo, there are no universally grown varieties unlike other crops subject to significant international trade, such as the Hass and Fuerte varieties for avocados or Beauregard for sweet potato. The names of taro varieties are generally specific to a region, although some are found in several countries.

Varieties differ in a large number of morphological, agronomic and chemical composition characteristics.

For **taros/dasheens**, the most recognisable characteristics with which to distinguish between the varieties in a practical way are: (according to IPGRI 1999)

- Offshoots: numbers (1 to +20)
- Blade: shape, colour, appearance of margins, veins.
- Petiole: colour (white, green, pink, red, purple), with or without stripe
- Inflorescence: presence/absence; colour and shapes of spathe/spadix
- Corm: shape (conical, round, *cylindrica*l, elongated, forked), length, weight (0.5 to 4 kg), colour of cortex, flesh and flesh pigmentations (white, cream, yellow, orange, pink, red, purple); epidermis (smooth, fibrous, with scales)
- Cormels: numbers and same criteria as for corms.

For **eddoe and macabo,** the morphological characteristics making it possible to distinguish the varieties are the same, but those concerning the cormels are of course more important than those concerning the main corm, which is not eaten.

3.4.1. TARO/DASHEEN AND EDDOE VARIETIES

The genetic diversity of *Colocasia esculenta* is widely distributed throughout the tropical and subtropical zone, but the various studies on its genetic diversity do not allow for the determination of a single centre of origin for this species. Taros were probably domesticated in parallel in different places over an area stretching from India to southern China, Melanesia and northern Australia.

To date, approximately 6,000 accessions have been collected and described by research laboratories, but it is estimated that there are in fact more than 15,000 varieties of *C. esculenta* throughout the world [ref 1]. The most important genebanks are at the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria; the Philippine Root Crop Research and Training Center, Beybey, Philippines; the South Pacific Commission (SPC) Center for Pacific Crops and Trees (CePaCT) in Fiji; and the National Agricultural Research Institute (NARI), Bubia, Papua New Guinea.

3.4.2. MACABO VARIETIES

X. sagittifolium is native to the South American continent and was probably domesticated on the northern fringe of the Amazon basin. It is now widely distributed in the Pacific and in humid tropical Africa, where it tends to replace dasheen because it is more suitable for local culinary preparations (fufu) [ref1]. In Cuba, the Instituto de Investigaciones de Viandas Tropicales (INIVIT) holds an important collection of *X. sagittifolium* in Santo Domingo, Villa Clara Province. [ref 22]

Table 3 shows some of the taro varieties grown around the world.

Table 3 — Some cultivated varieties of *Colocasia*

COUNTRY	NAME OF THE VARIETY	TYPE	CROP SYSTEM	MORPHOLOGY	AGRONOMY
New Caledonia Ref 11	Kari	dasheen	Flooded and rainfed	Green petiole with stripes, pale yellow flesh with yellow fibres	3-5 offshoots far from the mother plant (easy to take cuttings from). Variety the most marketed in New Caledonia
	Matéo rose	dasheen	Flooded and rainfed	Pink petiole, corm with white flesh and yellow fibres	numerous offshoots (7 to 10)
					Corm is rot resistant
	Païta	dasheen	Flooded and rainfed	Pink petiole, pink flesh with mauve fibres	Sensitive to rot at the end of the cycle
	Wallis		Flooded and rainfed	Green petiole, corm with white flesh and mauve fibres, floury and fragrant flesh	numerous offshoots (7 to 10)
Mauritius	Arouille Carri	eddoe	rainfed	White flesh	
	Arouille Violette	dasheen	Flooded and rainfed	Purple flesh	

Hawaii (cultivar groups) Ref 21 (Figure 23).	Lehua Maoli	dasheen	Flooded and rainfed	yellowish green petiole with pink reflections, light lilac flesh with purplish fibres	High yield, early (8-12 months); excellent for the preparation of "poi"
	Bun Long	dasheen	rainfed	petiole is long, dark green tinged with red, flesh is white with large purple fibres	native to china, leaves are popular to eat
	Tsurunoko	eddoe	rainfed	petiole is long, light green with small brown to purple spots; cormels with white flesh and yellow fibre	early: 6-8 months; small and numerous cormels (up to 40 per plant)
	Kakakura-ula	dasheen	rainfed	Long red-purple petiole, white flesh with yellowish fibres	Cycle 9-12 months, also grown as an ornamental
Dominique and St. Vincent Ref 23	"Comme" or "Common"	dasheen	rainfed	petiole green at the base, red at the top; oval to round corm, bluish flesh after cooking	most grown and exported variety in Dominica
Guadeloupe Ref 25	White	dasheen	rainfed	petiole green at the base, yellow at the top, *cylindrical* corm, white flesh	most grown and exported variety in St Vincent
	Madère blanc	dasheen	rainfed	brown petiole, brown spot in the middle of the blade, dark brown corm, white flesh	
	Madère noir	dasheen	rainfed	idem	flesh of the madère noir takes on a purplish grey colour after cooking
Japan Ref 15	Ishikawa-wase	eddoe	rainfed	Corms with white flesh and smooth texture after cooking	Early (7-8 months)
	Dotare	eddoe	rainfed	oval cormels with soft, sticky flesh	Early, moderate tolerance to cold

Japon Ref 15	Hasubaimo	eddoe	rainfed	globular cormels with a slightly sticky texture after cooking, sweet taste	13 cormels/plant
	Akame	eddoe	rainfed	Reddish petiole and bud. Oval corms and cormels. Floury texture and sweet taste after cooking	Late
Nigeria (Anambra State) Ref 25	Kochuo	dasheen	rainfed	Green petiole, dark green blade Corm with purple flesh	
	Nwine	dasheen	rainfed	Yellow-green petiole, pale green blade, corm with pink flesh	
	Ogeriobosi	dasheen	rainfed	Purple petiole, dark green blade	
				Corm with cream flesh	
India CTCRI varieties Ref 26	Sree Kiran	eddoe	rainfed	Green petiole and leaf	Cycle 6-7 months
	Sree Pallavi	eddoe	rainfed	Green petiole and leaf	Cycle 6-7 months
				20-25 cormels/ plant	
	Sree Rashmi	eddoe	rainfed	Green petiole and leaf	Cycle 7-8 months
Vanuatu Ref 47 (Figure 24).	Sakius	dasheen	rainfed	dark green leaves, purple striped petiole, corm with pink flesh	8-month cycle, high dry matter content
	Tarapatan	dasheen	rainfed	dark green leaves, dark green petiole, white flesh	10-month cycle, high dry matter content
	Chapuis	dasheen	rainfed	light green leaves, light green and yellow striped petiole, light yellow flesh,	7-month cycle, high dry matter content

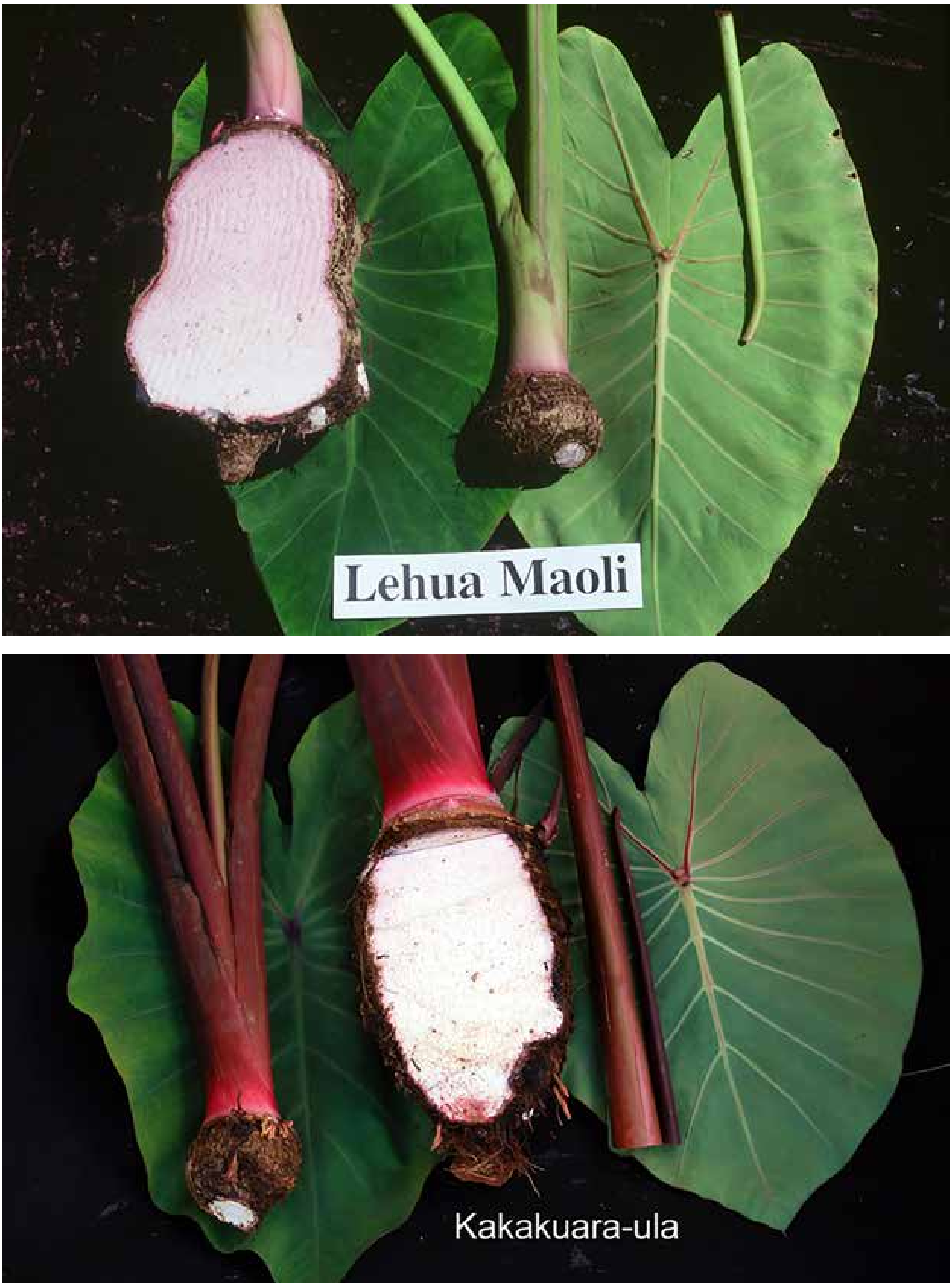

Figure 23 — 2 varieties of Hawaiian Lehua Maoli and Kakakura-ula
source: https://www.ctahr.hawaii.edu/Site/Taro.aspx

Figure 24 — Sakius variety of Vanuatu
Photo: V. Lebot

3.5. CROP CALENDAR

Taros and macabos can be planted all year round as long as the temperature is sufficiently high (20°C minimum) and the water supply can be ensured by rainfall or irrigation. In regions with a marked dry season, planting will take place at the start of the rainy season.

Table 4 gives, as an example for some production zones, the most favourable planting periods for taro/dasheen in rainfed cultivation (without irrigation) and at low altitude. In this instance, the crop cycle varies between 6 and 12 months and harvesting can be delayed up to 18 months after planting.

In rainfed cultivation, taro/dasheen mature earlier than in flooded cultivation, but their yield is lower. Thus in Hawaii, taro/dasheen in rainfed cultivation are harvested on average at 12 months, compared with 15 months in flooded cultivation. The yields of the former are overall half of those in flooded cultivation, which can reach 75/t/ha under good conditions [ref 6].

Table 4 — Some examples of planting calendars (in green) of taro/dasheen in rainfed cultivation

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JUL	AUG	SEPT	OCT	NOV	DEC
New Caledonia												
Tahiti												
Hawaii												

3.6. SUPPLEMENTARY IRRIGATION

In rainfed or exposed cultivation, it is sometimes necessary to provide supplementary irrigation in the event of insufficient rainfall to ensure optimal development of the taros. Several techniques are possible:

— **Furrow surface irrigation**: (Figure 25) The water is transported by gravity to the plot by a system of channels and gullies up to the entrance of the plots, where it is distributed into the open furrows in between the taro rows. Workers open up the soil at the head of several furrows to allow the water to reach the end of each row, then close them and move on to another group of rows - the watering cycle. This very old traditional technique requires flat plots with a slight slope to allow the water to flow by gravity. Traditionally in these systems, some of which date back to ancient times as in Egypt, the watering cycle is repeated every 15 days during the first 2 months (phase 1 of growth), then every 5-7 days until the 5th month (phase 2), and is then gradually reduced until being stopped completely 2 weeks before the planned harvest date. [ref 36].

— **Sprinkler irrigation**: (Figure 26) This is carried out using sprinklers distributed over the plot in such a way as to cover the entire planted surface area. This system has the advantage of being quite flexible. It does not require the flattening of the plots, it is fairly quick to install and it creates a humid atmosphere favourable to the growth of taro.

— **Micro-irrigation / Drip irrigation:** (Figure 27) This system saves the most water by bringing exactly the quantities needed as close as possible to the taro plants. The network of plastic pipes and ducts takes quite a long time to install on the surface or underground, but once in place does not require manipulation and the system can be programmed as needed for more frequent watering cycles without additional intervention. However, it can be troublesome for weeding and does not produce a humid atmosphere like sprinkling. Its use requires good technical skills and the installation of a water filtering system at the system intake point in order to avoid the risk of clogging of the ducts and drippers.

The recommendations on the quantities and frequencies of irrigation are covered in more detail in the chapter on "Water management and irrigation" (chapter VII).

Figure 25 — Gravity irrigation - Furrow surface irrigation
Photo: F. Molle@ flickr.com

Figure 26 — Sprinkler-irrigated taro field
Photo: https://fr.123rf.com #ID 15141698

Figure 27 — Micro-irrigation / Drip irrigation
Photo: COLEAD archives – Residue trials in the Dominican Republic – 2010

PRE-PLANTING CHOICES

TAKEAWAYS FOR PRE-PLANTING CHOICES

CHOICE OF PLOT (TOPOGRAPHY AND SHADE) IN (I) FLOODED AND (II) RAINFED OR EXPOSED CULTIVATION

- Flooded cultivation requires flat plots, a permanent layer of water and full sunshine.
- Rainfed cultivation is suited to all topographies provided that flood-prone soils are avoided and, in the event of a steep slope, the soil is protected from the risk of erosion by appropriate techniques (cover crop, mulch etc.).
- Taros and macabo tolerate shade well and can be grown in agroforestry systems.

CROP/COMBINATIONS ROTATION/SUCCESSION

- In flooded cultivation, taro/dasheen is often planted as a pure crop several cycles in a row. It can also enter into rotation with irrigated rice or non-flooded vegetable crops.
- In exposed cultivation, dasheens are often planted at the start of the rotation after clearing or long fallow. In the absence of other crops, it is recommended that an improved legume-based fallow is interposed between 2 taro cycles.
- Rainfed crops are planted either as a pure crop and in rotation with other crops, or in combination with other food crops or even as an intercrop in palm oil or coconut plantations.
- Eddoe taros are grown in an exposed situation. They can be grown in temperate or subtropical climates as long as you have 5 to 6 months without frost.
- Macabo is often grown in combination with other annual and perennial crops.

TYPES OF PLANTING MATERIAL

- Taros are cultivated by vegetative propagation using a fraction of the plant (cutting) to plant the next cycle.
- It is very important to take cuttings from healthy plants and to remove those that show symptoms of pests or diseases.

PRE-PLANTING CHOICES

— For taro/dasheen, 4 types of planting material can be used:

- Stem cuttings
- Lateral offshoots or suckers that develop around the mother plant
- Small unmarketable corms or cormels
- Pieces of large corms

— For eddoe taros, planting is based on cormels (secondary corms), by taking part of the harvest. The offshoots can also be used.

— For macabo, the same types of seed tuber as with taro/dasheen are used.

— Modern fast propagation methods can also be used:

- Mini-fragments (minisets)
- Production of stolons with gibberellic acid (GA3)
- In-vitro meristem culture

CHOICE OF VARIETIES

— There are no universally grown varieties. The names of taro varieties are usually specific to a region.

— Dasheen varieties differ in a large number of morphological, agronomic and chemical composition characteristics, in particular:

- Number of offshoots: 1 to +20
- Blade: shape, colour, appearance of margins, veins.
- Petiole: colour (white, green, pink, red, purple), with or without stripe
- Inflorescence: presence/absence; colour and shapes of spathe/spadix
- Corms and cormels: shape, length, weight, cortex and flesh colour, flesh pigmentations

— For eddoe and macabo, the morphological differentiation characteristics are the same but those concerning the cormels are more important.

PRE-PLANTING CHOICES

CROP CALENDAR

— Taros are planted all year round if the temperature is sufficiently high (20°C minimum) and water is available (rainfall and/or irrigation).

- In regions with a marked dry season, planting takes place at the start of the rainy season.
- For taro/dasheen in rainfed cultivation (without irrigation) and at low altitude, the crop cycle varies between 6 and 12 months and the harvest can be delayed up to 18 months.
- In rainfed cultivation, taro matures earlier (12 months in Hawaii) than in flooded cultivation (15 months), but the yield is half. (30-35 versus 70-75 t/ha).

SUPPLEMENTARY IRRIGATION

— For rainfed or exposed crops, supplementary irrigation is sometimes necessary. Several techniques are possible:

- Furrow surface irrigation
- Sprinkler irrigation
- Micro-irrigation / Drip irrigation

4

PREPARATION OF THE PLOT

4.1. PREPARATION OF THE SOIL

Tillage must be adapted to the crop system (flooded or rainfed), the type of soil and the topography of the plot (flat or sloping area).

4.1.1. IN FLOODED CULTIVATION

Water must be constantly available and the water level controllable. The soil of the plots, which must be clayey enough to retain the water, must be levelled and the plots surrounded by bunds.

The plots are flooded and left under water for a few days before preparation. Tillage aims to loosen the surface horizon and destroy weeds if necessary, with several passes of tools (hoe, disc, cutter, rotavator etc.).

If planting cannot be done immediately, a layer of water must be maintained (5 cm minimum) to prevent weeds from recolonising the plot. If water control is ensured at a constant height and with non-stagnant water, you can plant flat (Figure 28).

If, on the contrary, there is a risk of too much water or the stagnation of the water, it would be advisable to plant on beds or ridges (20-30 cm high) so that the young plants are not submerged or in contact with water that is too hot, which promotes root rot (Figure 29).

If, on the other hand, there is a risk of a lack of water at certain times, planting should be in hollows between the ridges.

Figure 28 — Taro/dasheen field in flat flooded cultivation
Photo: https://fr.123rf.com #ID 161247315

Figure 29 — Taro/dasheen ridge planting in irrigated cultivation
Photo: https://fr.123rf.com #ID 161247315

4.1.2. IN RAINFED CULTIVATION ("DRYLAND OR UPLAND CULTIVATION")

The plot is first cleaned manually by mowing the weeds, which are either burned or left as mulch (preferable). When the plot is on a steep slope, tillage must be limited and the soil must not be left bare to prevent erosion. Localised tillage and maintaining a mulch is favoured.

In mechanised cultivation on flat plots (Figure 30), conventional tillage includes ploughing and recovery by harrow or discs. If the soil is deep and loose, planting can be done flat; otherwise ridges should be created 70-100 cm apart and 30-50 cm high to increase the depth of soil available to plants and to avoid waterlogging.

An alternative is direct planting without tillage on plant cover or DMC (see below, chapter 9.2 - Plant cover). Here, mechanisation is limited to mowing the plant cover and possibly subsoiling or passing a chisel tine along the taro planting row.

Figure 30 — Taro/dasheen cultivation in exposed condition, Dominican Republic
Photo: COLEAD archives

4.2. AMENDMENTS

An amendment is a mineral or organic compound added to the soil of a plot with known chemical or physical imbalances in order to correct (or amend) them. Amendment therefore takes place before planting with the aim of correcting the imbalances in the long term or at least for several crop cycles. In this respect, it differs from ordinary fertilisation, which is applied to each crop cycle.

The main **mineral amendments** used are [ref 4]:

— Gypsum (natural calcium sulphate dihydrate with the formula $CaSO_4 - 2\ H_2O$) to correct problems of soil surface crusting and poor permeability in saline and sodic soils. Gypsum is also used to correct sulphur and calcium deficiencies (in non-acidic soil).

— Lime ($CaCO_3$), crushed limestone or dolomite ($Ca.Mg\ (CO_3)_2$) to raise the pH and correct problems related to soil acidity. Raising the pH helps in particular to correct the toxicity due to aluminium which can occur at a soil pH <5.0.

In Martinique, in rainfed taro/dasheen cultivation, it is recommended to add 1.5 to 3 t/ha of magnesium lime, dolomite or crushed limestone after ploughing, depending on the soil type. [ref 33]

In Hawaii, the following doses (Table 5) are recommended for the correction of acidic pH in flooded taro beds [according to Silva *et al.* 1998 [ref 46]:

Table 5 — Recommended addition for the correction of soil acidity in taro cultivation in Hawaii according to Silva *et al.* 1998 [ref 46]

SOIL PH	CA CONTENT (M.EQ/100 G)	$CACO_3$ ADDITION	GYPSUM ADDITION (22-24% CA, 18-20% S)
Over 5.8	Over 10	0	-
5.5 to 5.8	Below 10	1 t/ha	
Below 5.5	Below 10	2 t/ha	
Over 5.8	Below 10	-	1 t/ha

Note: Excessive liming can cause iron deficiencies and, in copper-poor soil, deficiencies in this element.

Soil can be enriched with **organic matter** using several techniques; for example: cultivate a green manure, add *azolla*, add compost or manure.

GREEN MANURE / PLANT COVER

The principle of green manure lies in sowing a crop with high biomass production before the taro crop (3 to 6 months before). Different species can be used for this purpose: The choice will depend on local conditions and constraints. Before planting the taro, it will be mowed, left on the soil for 2 to 3 weeks to initiate decomposition and then buried in the ground as a green manure.

The species most used for these purposes are mainly legumes, which enrich the soil by symbiotic fixation of nitrogen from the air. But plants from other botanical families are used too. Table 7 gives some species used in the tropics as green manure or cover crops before taro cultivation.

Table 6 — Some species used as green manure or cover crops in tropical zones

SPECIES	COMMON NAME	FAMILY
Centrosema pubescens	centro	Legumes (*Fabaceae*)
Crotalaria juncea	hemp (*sunn hemp*)	
Echinochloa sp.	Japanese millet	
Glycine max	soybean	
Lablab purpureus	hyacinth bean	
Macroptilium atropurpeum	siratro	
Mucuna sp.	velvet bean	
Pueraria phaseoloides	tropical kudzu	
Vigna unguiculata	cowpea	
Sorghum sp.	fodder *sorghum*	Grasses (*Poaceae*)
Chloris gayana	Rhodes grass	
Brachiaria mutica (*Urochloa mutica*)	para grass (buffalo grass)	
Brassica juncea	brown mustard	*Brassicas* (*Brassicaea*)

AZOLLA

Azolla filiculoides is a small aquatic fern (1-2 cm in diameter) living in symbiosis with a nitrogen-fixing cyanobacterium (*Anabaena azollae*), which develops spontaneously on the water surface. Easy to harvest because it floats, it is used as green manure in rice fields in many regions of Asia. In Hawaii, where it was introduced with some success in the 1980s, some farmers like to grow it in adjacent plots and then transfer it to the taro fields. [ref 6 and 32]

COMPOST AND MANURE

When available, these are good fertilisers. Their origin and the quantities applied are variable and depend on local resources. In Fiji, 10 t/ha of poultry manure is applied 2 weeks before planting. In other situations, it is introduced into the planting hole either once or twice, first at the time of planting then 2 to 3 months later. In Thailand, 300 to 500 g of manure is introduced per hole when planting; in Martinique 2 to 3 kg. (30-40 t/ha). In Papua New Guinea, coffee parchments are used as an organic amendment. [ref 32] It is always recommended to base your application based on analyses of the soil and amendments.

4.3. WEED CONTROL

Good crop weed management begins with land preparation. The most widespread practice is tillage prior to planting (see 4.1.). Other techniques that can be used are stubble cultivation, the creation of a plant cover to plant in or the use of broad-spectrum herbicides.

STUBBLE CULTIVATION

Before planting, the stubble cultivation technique can be used. To do this, the soil surface is tilled (10-15 cm) with a cultivator-type tine tool in order to lift the weeds, which will be destroyed by another passage of the tool a few weeks later.

If the schedule allows, this operation can be repeated a second time to complete the cleaning. Avoid using disc tools (*e.g.* cover-crop, disc tiller) which, conversely, favour the propagation of plants with stolon or rhizome (*e.g. Cyperus* spp., *Cynodon* spp., *Imperata cylindrica*, etc.).

PLANT COVER

Planting taro directly in a plant cover is an interesting agroecological technique for controlling weeds. For this, cover crops sown before taro cultivation (see 4.2.) are not buried but left on the surface after mowing or devitalisation with a broad-spectrum herbicide (*e.g.* glyphosate). The taros will then be planted directly in the mulch without any tillage other than digging the planting hole. This is the direct sowing on plant cover technique (DMC). (Figure 31).

Figure 31 — Taro/dasheen planting on *mucuna* mulch
Photo: V. Lebot

BROAD-SPECTRUM HERBICIDES

Before planting taro, it is technically possible to use a broad-spectrum herbicide to devitalise plant cover such as a fallow, green manure or a cover crop.

Effectiveness can be limited by the presence of resistant weed species. This resistance phenomenon appeared in 1996 following the massive use of this herbicide in certain regions of the United States. There are now around forty wild species around the world that have developed such resistance, such as: *Amaranthus palmeri*, *Bidens pilosa*, *Commelina benghalensis*, *Eleusine indica*, *Paspalum paniculatum*, [ref 39], which can be found in taro and macabo production areas.

Always consider local registration, authorisation for use of products and personal protection when using herbicides.

4.4. OTHER PRACTICES TO CONSIDER

— In agroforestry systems, the optimum level of shade should be managed by appropriate tree pruning and planting density.

— The planting of hedges/windbreaks and grassy strips improves the biodiversity of the operation and produces higher humidity favourable to the cultivation of taro and macabo.

— Installation of irrigation and drainage systems.

— Basic mineral fertilisation takes place when preparing the plot. The recommendations are given in Table 8 of Chapter VIII (Soil management and fertilisation).

PREPARATION OF THE PLOT

TAKEAWAYS FOR THE PREPARATION OF THE PLOT

IN FLOODED CULTIVATION

— Soil preparation aims to loosen the soil and destroy weeds before planting.

— If water control is assured, the crop can be planted flat.

— If there is a risk of too much water, beds or ridges should be created so that the young plants are not submerged.

— If there is a risk of a lack of water at certain times, planting should be in hollows between the ridges.

IN RAINFED CULTIVATION

— The plot is cleaned manually and the weeds are either burned or left as mulch (preferable), leaving only the planting holes to be dug.

— In mechanised cultivation, if the soil is deep and loose, planting is done flat.

— If the loose soil is minimal, ridges should be raised to increase the depth of soil available for the plants.

— Direct planting without tillage (apart from the planting row) on plant cover is a good alternative.

PREPARATION OF THE PLOT

A MINERAL OR ORGANIC AMENDMENT TO CORRECT CHEMICAL OR PHYSICAL IMBALANCES IS SOMETIMES NECESSARY SUCH AS

— Gypsum to correct poor permeability problems in saline and sodic soils.

— Lime amendments (lime, crushed limestone, dolomite) raise the pH and correct problems related to soil acidity.

— Green manure, *azolla* (aquatic fern), compost or manure to increase levels of organic matter.

WEED CONTROL BEFORE PLANTING: GOOD WEED MANAGEMENT BEGINS WITH PREPARING THE GROUND. SEVERAL TECHNIQUES CAN BE USED ALONE OR COMBINED

— Tillage,

— Stubble cultivation,

— Installation of a plant cover,

— Use of broad-spectrum herbicides.

5

PLANTING

5.1. PLANTING METHOD

5.1.1. IN FLOODED CULTIVATION (DASHEEN)

In flooded cultivation, planting is done traditionally by pushing the cutting by hand into the muddy soil (Figure 32). In mechanised systems, finger transplanters are used on drained soil with cuttings previously sized according to the machine. After planting, the plot is replenished with water and the water level raised as the taro grows so that the base of the young plants remains submerged. Care must be taken to maintain a constant flow of water to ensure good oxygenation and to limit the temperature of the water to prevent rotting of the taro roots.

5.1.2. IN RAINFED CULTIVATION (DASHEEN AND EDDOE)

In manual rainfed cultivation, fairly deep holes (20-40 cm) are dug with a spade or stick at the bottom of which the cuttings or seed tubers are placed. The holes are then filled with soil and possibly manure or compost. In mechanised cultivation, furrows spaced 50 to 100 cm apart are forged before planting, in which the cuttings or seed tubers will be placed by hand at regular intervals according to the desired density.

It is also possible to plant using a mechanical multi-row finger transplanter, which simultaneously digs the furrow, places the cuttings at the bottom of the furrow, closes the furrow and compacts the earth around the cuttings. It is sometimes useful to complete these operations with ridging 6 to 8 weeks after planting in order to protect the part of the corms that emerges above the ground and to consolidate the plants with a tendency to topple.

In New Caledonia, 8-900 cuttings are planted per hour with a 2-row transplanter handled by 3 operators (one driver and 2 planters). By hand, one person can plant 150 to 200 cuttings per hour. [ref 27].

For taro/eddoe, cormels can be planted mechanically using a mechanical transplanter similar to those used for potatoes (Figure 33).

When corm pieces are used as seed tubers, it is strongly advised to pre-germinate them in the nursery before planting in order to encourage their successful resumption. When using lateral offshoots as cuttings or small whole corms, it is also advisable to pre-germinate them if the time between harvest and planting is long enough. Germination in the nursery, which can be used with the different types of seed tube, can sometimes take several weeks, but it also has the advantage of eliminating seed tubers that are unable to germinate normally, thus avoiding the subsequent replanting of deficient plants in the field.

5.1.3. FOR MACABO

The planting techniques are quite similar to those of taro in rainfed cultivation. However, it is recommended that the seed tubers are planted more shallow (7-10 cm) in order to limit the propagation of offshoots, which are detrimental to the final yield.

5.2. PLANTING DENSITY

Planting density varies greatly depending on the situation. It depends on several factors such as the genotype, type of crop system, soil fertility and the size of corms sought by the market. It generally varies between 10,000 to more than 50,000 plants/ha as a pure crop. In combined cropping, it can fall to less than 5,000 in crop systems where taros cohabit with several other cultivated species. Traditional varieties with strong leaf development are more adapted to medium densities (15,000 to 20,000 plants/ha). The varieties which tolerate high densities well are those which have leaves with small, upright blades and long, erect petioles. [ref 28].

In Hawaii, the usual planting density for dasheen in flooded cultivation varies from 45 x 45 cm (approx. 1.5 x 1.5 feet), or 48,000 plants/ha, to 60 x 60 cm (2 x 2 feet), or 27,000 plants/ha. Yield increases with density but the unit weight of the corms decreases when density increases. Tests at the CTAHR have shown that with a 45 x 45 cm plantation, the yield is 6% higher and the weight of the corms 20% lower than with a spacing of 60 x 60 cm. In mechanised rainfed cultivation, the planting density among farmers ranges between 11,000 and 27,000 plants/ha. [ref 11].

Planting density affects the number of offshoots and the corm yield at harvest. In Papua New Guinea, trials in rainfed cultivation with the dasheen variety *Numkowec* have shown that when the density increases from 10,000 (1x1m) to 80,000 (0.5×0.25m) plants/ha, the number of offshoots per taro plant fell from 7 to 1 while the total yield increased by 80% (14.9 to 26.8 t/ha). The proportion of unmarketable corms (<250 g) increased slightly (5.3 to 6.7%). [ref 29]

Density also influences the dynamics of fungal pathogens. The lower the density, the better the aeration in taro fields and the lower the dispersal of spores of the *Phytophthora colocasiae* fungus responsible for taro leaf blight.

— **Eddoe taro** is often planted at a higher density than dasheens. In Japan, the planting density (interval between plants on the planting row x interval between rows) usually varies from 30 x 100 cm (33,333 plants/ha) to 30 x 75 cm (44,444 plants/ha). [ref 6]

— **For the macabo,** whose leaf development is greater, the planting densities are often lower. In Costa Rica, planting densities among producers average at 12,500 plants/ha (*e.g.* 50 x 160 cm). [ref 13]

PLANTING

TAKEWAYS FOR PLANTING

PLANTING METHOD

— In flooded cultivation (dasheen), planting is done by pushing the cutting by hand into the muddy soil.

- In mechanised systems, finger transplanters are used on drained soil with cuttings previously sized according to the machine.
- After planting, the plot is replenished with water, taking care to maintain a constant flow of water to ensure good oxygenation and limit the water temperature.

— In rainfed and manual cultivation (dasheen and eddoe), holes are dug 20-40 cm deep into which the cuttings or seed tubers are placed.

- In mechanised cultivation, planting is done in furrows spaced 50 to 100 cm apart. The seed tubers are placed by hand at regular intervals according to the desired density.
- It is also possible to use mechanical finger transplanters with several rows which simultaneously dig the furrow, place the cuttings and close the furrow.

Figure 32 — Taro/dasheen planting in flooded cultivation, China
Photo: https://en.123 #ID 33178572

PLANTING

— Pre-germination of seeds with:

- corm pieces pre-germination in the nursery is recommended to promote their optimal resumption.
- lateral offshoots or small whole corms, it is also advisable to pre-germinate them if the time between harvest and planting is long enough.

— For macabo, the planting techniques are similar to those of taro in rainfed cultivation, but the seed tubers are planted at a lesser depth (7-10 cm).

- The planting density depends on the variety, the crop system, the fertility of the soil and the size of the corms sought by the market.
  - It varies between 10,000 and 50,000 plants/ha as a pure crop.
  - In combined cropping, it can fall to less than 5,000 plants/ha.
  - Traditional varieties with strong leaf development are planted at medium densities (15,000 to 20,000 plants/ha).
  - Yield increases with density, but the unit weight of the corms and the number of offshoots decrease.
  - The lower the density, the better the aeration in taro fields and the lower the incidence of fungal diseases like taro leaf blight.
  - Eddoe taro is planted at a higher density than dasheens: between 30 x 100 cm (33,333 plants/ha) and 30 x 75 cm (44,444 plants/ha).
  - Macabo, with substantial leaf development, is planted at a lower density of between 10-15,000 plants/ha

Figure 33 — Eddoe taro mechanised planting, Hebei Province, China
Photo: https://en.123 #ID 178282490


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6

CROP MAINTENANCE

Crop maintenance requires good management of water, soil and fertilisation as well as weeds. These points are covered respectively in sub-chapters 6.1, 6.2 and 6.3. Good pest and disease management is also essential; this point is covered in detail in Chapter VIII.

The maintenance of the plot does not stop at the harvest. As soon as the crop has been harvested, the crop debris must be removed and composted or otherwise destroyed to prevent the maintenance and spread of pests and diseases. See point 8.1.4 for further information.

6.1. WATER AND IRRIGATION MANAGEMENT FOR CROP MAINTENANCE

6.1.1. FLOODED SYSTEMS

The most favourable situation is when irrigation water is constantly available and the water level is controllable. The plots are flooded just before or after planting. They are drained from time to time for 2 or 3 days to allow for the application of fertiliser and then re-flooded. [ref 36]. In these systems, taros (dasheens only) are generally grown as a pure crop for several years on the same fields before other rice or vegetable crops succeed them.

— Flooded systems with good water control (Figure 34) have certain advantages compared to production under rainfed conditions, but they also have constraints and limitations: [ref 6]

  - The crop can be grown practically all through the year, allowing farmers to stagger their production and therefore benefit from higher prices in the off-season.
  - Yields can exceed 80 t/ha compared with 15 to 30 t/ha under rainfed conditions.
  - On the other hand, flooded systems require significant initial investments in terms of infrastructure and generate higher operational costs (tillage, irrigation management in particular). The taro development cycle is also longer than in rainfed cultivation.
  - Due to the enormous volumes of water consumed, flooded cultivation systems, often combined with flooded rice cultivation, is only possible in situations where the resource is not a limiting factor. Ultimately, the sustainability of such systems will be problematic.

— Systems without complete water control or plot levelling are however seen frequently on the banks of rivers (Figure 35) or in marshy lowlands, and cultivation takes place with more extensive techniques. Yields in these contexts are barely half those obtained with good water control.

— Flooded cultivation is not suitable for eddoe taro and macabo that do not tolerate permanent soil hydromorphy.

6.1.2. RAINFED SYSTEMS (UPLAND/DRYLAND TARO)

Most of the world's taro production takes place under strict rainfed conditions and outside flooded areas. Water supply is ensured only by precipitation.

In a number of situations, farmers supplement rainwater with supplementary irrigation to compensate for rainfall deficits. These practices are essentially implemented within the context of commercial production, which makes them profitable.

Supplementary irrigation aims to maintain soil moisture at a sufficient level, close to the "field capacity", but without flooding, so that the plants do not experience water stress and have their growth stunted.

Watering also makes it possible to produce in the off-season, during the dry season, or to grow taro in semi-arid areas where taro is popular.

The irrigation methods that can be used are presented in point 3.6 of the chapter on pre-planting choices.

Applicable quantities: The quantities of water to provide will depend on local day-to-day conditions. They can be estimated by the difference between evapotranspiration (ETP) and precipitation. ETP can be measured using a standardised evaporation pan (class A type pan recommended by the World Meteorological Organization) or requested from local agricultural service providers. The effective water needs of the plants will be equal to the ETP weighted by a crop coefficient (Kc), which depends on the stage of the plant, minus the rainfall.

So: irrigation dose ID = ETP x KC - P

In New Caledonia we use empirically as Kc: 0.5 during growth phase 1 (weeks 1-8), 2 for phase 2 (weeks 9-24) and 1 during phase 3 (week 25 and +). [ref 37].

Thus with an ETP of 10 mm/day, a realistic Figure in hot, sunny and windy periods, the water needs of the taro will be 70 mm x 2 or 140 mm per week in phase 2 of the growth of the taro (where KC=2).

The irrigation needs will therefore be 140 mm after deducting the rainfall. If rainfall during this period reaches 70 mm, it will be necessary to provide 140 - 70 = 70 mm by watering, or 700 m^3 per hectare per week (10 mm or 10 104/ day). In practice, a "watering cycle" of 20 mm is carried out every 2 days.

The water provision method obviously influences the effectiveness of irrigation, which depends on many factors. Drip irrigation is unquestionably the technique ensuring the best use of water and can save more than 50% water for the same yield compared with gravity furrow irrigation [ref 79].

Figure 34 — Taro in flooded cultivation, Hawaii
photo: https://fr.123rf.com

Figure 35 — Traditional taro field without total water control, Tahiti
photo: https://www.tahitiheritage.pf/tarodiere-tautira

CROP MAINTENANCE

TAKEAWAYS FOR CROP MAINTENANCE

IN FLOODED SYSTEMS WITH GOOD WATER CONTROL

- Higher yields (around double)
- Better weed control.
- Flexibility for planting and production dates.
- Large initial investments and higher operational costs
- Low water efficiency, unsustainable in the long term if the water resource becomes a limiting factor
- Not suitable for eddoe taro and macabo

IN RAINFED (EXPOSED) SYSTEMS

- Water supply comes from rainfall
- In the event of a rainfall deficit, supplementary irrigation is sometimes practised, especially in commercial production for reasons of profitability.
- Water can be delivered to the furrow by gravity, by sprinkling or by drip system (the most efficient in terms of water consumption but the most technical).
- The irrigation dose (ID) to be provided over a given period is calculated by the formula: ID = (ETP x Kc - P) where ETP is the evapotranspiration, P is the precipitation and Kc the crop coefficient depending on the crop stage.
- The KC is estimated at 0.5 during growth phase 1 (weeks 1-8), 2 during phase 2 (weeks 9 to 24) and 1 during phase 3 (week 25 and +).

6.2. SOIL AND FERTILISATION MANAGEMENT IN CROP MAINTENANCE

6.2.1. INTEGRATED SOIL FERTILITY MANAGEMENT AND PRINCIPLES OF GOOD FERTILISER USE

It is recommended that the soil and fertilisation is managed following the **Integrated Soil Fertility Management** (ISFM) approach and the principles of the **4R concept.**

The **ISFM** is based on 4 main components, which are:

— The use of improved germplasm

— The use of mineral fertilisers

— The management of organic matter

— Adaptations to local conditions

This management is based on:

— The consideration of agroecological and socio-economic conditions

— Endogenous knowledge and experience of the producers (good agricultural practices)

— The participatory proposal and/or development of a set of technologies for organisational and socio-economic measures with gender inclusivity.

It must also contribute to:

A reduction in nutrient losses, which often takes place through:

— Soil preparation (clearing and ploughing)

— Erosion

— Leaching

— Volatilisation (N and S)

— Export of crop residues

TO LEARN MORE ABOUT ISFM AND SUSTAINABLE SOIL MANAGEMENT, SEE

https ://www.cariassociation.org/Publications/Manuel-de-gestion-integree-de-la-fertilite-des-sols

https://ifdc.org/wp-content/uploads/2019/07/FICHE-TECHNIQUE-1-GESTION-INTEGREE-DE-LA-FERTILITE-DES-SOLS-ET-PRINCIPES-DE-BASE-INTEGRATED-MANAGEMENT-OF-SOIL-FERTILITY-AND-BASIC-PRINCIPLES.pdf

https://cgspace.cgiar.org/handle/10568/76787

https://www.africmemoire.com/part.3-chapitre-i-principe-de-la-gestion-integre-de-la-fertilite-des-sols-gifs-730.html

https://www.africmemoire.com/part.4-chapitre-ii-gestion-integree-de-la-fertilite-des-sols-gifs-842.html

https://resources.colead.link/en/e-bibliotheque/sustainable-soil-management

The 4R concept emphasises the need to apply fertilisers from the right source, at the right rate, at the right time and in the right place. To this end, several methods of fertiliser application can be considered for taros such as fertigation, foliar sprays, full- or spot-application. This is the only way to ensure plants get the right nutrition.

PRINCIPLES OF THE 4RS

The 4R principles of nutrient management are the same all over the world, but how they are used locally will vary depending on the field and site characteristics, such as the soil, crop system, management techniques and the climate. The scientific principles of 4R are:

- **THE RIGHT SOURCE** - Ensure a balanced supply of essential nutrients taking into account both the naturally available sources and the characteristics of the specific products, in the forms available to the plants.
- **THE RIGHT RATE** - Evaluate and make decisions based on soil nutrient supply and plant demand.
- **THE RIGHT TIME** - Evaluate and make decisions based on the dynamics of crop uptake, soil supply, risks of nutrient loss and field operations logistics.
- **THE RIGHT PLACE** - Consider root-soil dynamics and nutrient movement.

FOR MORE INFORMATION ON THE 4RS, VISIT

The Fertiliser Institute website

http://www.ipni.net/4r

https://www.sprpn.org/issue-briefs

https://4rsolution.org/about/

https://www.yara.us/crop-nutrition/podcasts/4r-nutrient-stewardship/

6.2.2. FERTILISATION

Taros and macabo are plants that require relatively large amounts of nutrients to reach their potential. Their growth is stunted if the soil fertility does not meet their needs.

For sustainable taro production, the nutrient exports due to harvest must be compensated by new contributions to the plot. Table 6 [ref 30] gives, for the main nutrients, the concentration ranges in the corms and the corresponding nutrient export estimates based on two yield levels (average yield in the Pacific and potential yield).

The dry matter content of the corms generally varies between 25 and 30% at harvest. These data can help to estimate the needs for the restitution of nutrients to the soil and build a rational fertilisation programme. Actual plant needs and optimal nutrient supply, however, depend on many factors such as climate, soil type and the varieties grown.

The macroelements N (nitrogen), P (phosphorus) and K (potassium) are those that are most mobilised by taros. From Table 6, it can be estimated that macroelement exports for each tonne of corms harvested are in a ratio of NPK = 3:1:4.5. Other sources offer slightly different ratios such as Raju and Byju (2019) (re f31), who *indica*te a ratio of NPK = 4.7:1:6.4, but the orders of magnitude remain the same.

Additions to compensate for these exports can be made in different forms depending on local resources. They can be made using organic or mineral fertilisers. It is generally recommended that the additions are staggered to limit losses by leaching or evaporation. Additions are generally made twice, first during soil preparation or planting and then a second time after 3-4 months, when the corms are getting bigger.

Table 7 — Average nutrient content of corms (as a % of dry matter) and corresponding exports based on the fresh corm yield level

NUTRITIONAL ELEMENTS	CONTENT (% OF DRY MATTER)	EXPORT IN KG/HA BASED ON THE FRESH CORM YIELD	
		8 T/HA (AVERAGE YIELD IN THE PACIFIC)	65 T/HA (ESTIMATED POTENTIAL YIELD)
N	0.6–1.43%	14–34	117–280
P	0.17–0.47%	4.0–11.2	39–91
K	1.08–1.77%	25–42	210–345
Ca	0.04–0.13%	1.0–3.0	8.5–24.7
Mg	0.07–0.38%	1.6–9.2	13–75
S	0.03%	0.68	5.5
Fe	16–57mg/kg	0.038–0.14	0.31–1.11
Mn	11–16mg/kg	0.027–0.038	0.22–0.31
Cu	7–9mg/kg	0.016–0.019	0.13–0.16
Zn	40–120mg/kg	0.096–0.29	0.78–2.34
B	3.0 mg/kg	0.007	0.06

(According to Blamey, 1996)

6.2.2.1. ORGANIC FERTILISERS

Organic fertilisers, when available at reasonable cost, have several advantages over mineral fertilisers.

- They are more stable and release nutrients more slowly, limiting losses through runoff and leaching.
- They stimulate the biological activity of soils.
- They provide a number of nutrients, including micronutrients.
- They improve the structure of the soil and prevent compaction phenomena.

Different sources and techniques are possible for adding organic matter to taro crops in rainfed or flooded systems. These are green manures used in plant cover, the addition of *azolla*, compost and manure. The addition is generally made before planting. They are therefore described in the chapter "Preparation of the plot". However, care must be taken not to add an organic amendment too low in nitrogen, which could create a lack of nitrogen that is harmful to the crop. If the C/N (ratio of carbon content to nitrogen content) of the amendment is more than 25, there is too much carbon in relation to nitrogen.

The micro-organisms will draw on the reserves of the soil instead of releasing them. This is the phenomenon of "nitrogen starvation". Conversely, if the C/N is less than 25, the micro-organisms will release the excess nitrogen, which becomes available to the plants. [ref 80].

6.2.2.2. MINERAL FERTILISERS

While the majority of producers cultivate taro as a food crop and do not use mineral fertilisers, farmers geared towards commercial production generally use mineral fertilisers.

The quantities provided must take into account the natural fertility of the local soils, and must notably try to correct any deficiencies if they are known by prior soil analyses. They must also be calculated to compensate for estimated nutrient exports from harvests (see above) so as not to deplete the soil and to ensure sustainable production over time.

NPK macroelements must be added in larger quantities than other elements. Mineral nitrogen, which is easily soluble, must not be applied in excessive quantities at once at the risk of losses through leaching, environmental pollution and ultimately economic losses for the farmer.

The less mobile phosphorus should be added at the beginning of the cycle. Potassium requirements are high, especially during the growth phase of the corms.

In practice, it is often difficult for farmers to optimise the additions for each macronutrient separately. In fact, the fertilisers available are often NPK complex fertilisers which provide the 3 NPK macroelements in proportions that are not always optimal for the needs of the plants.

The needs for elements other than NPK should not be neglected, in particular calcium, magnesium and sulphur, which taros fix in significant quantities. For the other microelements whose quantitative requirements are less, we should remain attentive to possible symptoms of deficiency (cf. § 2.3) because their deficit can be highly detrimental to taro crops.

Studies in the Pacific region have *indica*ted that additions (kg/ha) of 40-80 N, 10 P and 40-80 K with staggered applications of N and K result in high yields for dasheen taros under rainfed conditions. [ref 30]. Table 8 gives examples of recommended fertilisation in a number of countries.

Table 8 — Examples of recommended/practised mineral fertilisation for taro

COUNTRY	ADDITION DATE 1	FERTILISER 1	DOSE 1 (KG/HA)	ADDITION 2+	FERTILISER 2	DOSE 2 (KG/HA)	TOTAL NPK (KG/HA)	CROP SYSTEM	
New Caledonia [ref 27]	On planting	NPK 13:13:21	400	60 days after planting	NPK 13:13:21	400	104-104-168	*Colocasia* Rainfed system	
Martinique [ref 33]	On planting	NPK 16:12:24 + 2 MgO	210	90 days after planting	NPK 16:12:24 + 2 MgO	210	65-50-100 + 8 MgO	*Colocasia* Rainfed system	after ploughing: 1.5 to 3 t/ha/year of magnesium lime, dolomite or limestone
Guam [ref 34]	On planting (37,000 plants/ ha)	NPK 16:16:16	370	70-105-140 days after planting	Sulphate NH^{4+} (21N:24S) + KCl (60K)	3 x 120 3 x 222	135-60-460 +86S	idem	No fertiliser after 150 days after planting
Costa Rica [ref 13]	60 days after planting	NPK 10:30:10	250	100 days after planting + 140 days after planting	NPK 18:5:15 + NPK 15:3:30	500 + 500	190-115-250	*Xanthosoma* Rainfed system	
Fiji [ref 6]	On planting	NPK 13:13:21	200	60-70 days after planting	NPK 13:13:21	200	52-52-84	*Colocasia* Rainfed system	
Tonga [ref 6]	Before 42 days after planting (18,500 plant/ha)	NPK 12:13:18	925 kg/ha	n/a	n/a	n/a	110-120-166	*Colocasia* Rainfed system	1 single addition of 50g/plant
Thailand [ref 6]	Before 30 days after planting	NPK 13:13:21	300 kg	60 to 90 days after planting	NPK 13:13:21	300	Approx. 80- 80-130		
India (Kerala & Andhra Pradesh) [ref 35]	30 days after planting (when young shoots appear)	100% P 50% N&K	40-25-50	60 days after planting	50% N&K	40-0-50	80-25-100		+ 10-12 t/ha of farm manure on planting

SOIL AND FERTILISATION MANAGEMENT

TAKEAWAYS FOR SOIL AND FERTILISATION MANAGEMENT

— The **Integrated Soil Fertility Management** (ISFM) approach is recommended for sustainable taro cultivation

— Taros are relatively demanding plants in terms of fertility to reach their potential.

— For sustainable production, nutrient additions must compensate for exports.

— One tonne of corms exports approximately (in kg) 3 to 4.7 N: 1.0 P: 4.5 to 6.4 K

— Base application rates on soil analyses

— Organic fertilisers have some advantages:

- they are more stable and release nutrients more slowly, limiting losses through runoff and leaching.
- they stimulate the biological activity of soils.
- they provide a number of nutrients, including micronutrients.
- they improve the soil structure and prevent compaction phenomena.

— Mineral fertilisers are mostly used in commercial production. They mainly provide NPK macroelements. It is generally advantageous to combine organic and mineral fertilisers:

- The mineral fertilisers available are often NPK complexes which provide the 3 macroelements in ratios that are not always optimal for the needs of the plants.
- The addition of the highly soluble mineral nitrogen should be staggered or risk losses through leaching, environmental pollution and economic losses.
- The less mobile phosphorus must be available at the start of the cycle.
- Potassium requirements are high, especially during the growth phase of the corms.
- Ca, Mg and S fixed in notable quantities by the taros must not be neglected.
- Additions of 40-80 N, 10 P and 40-80 K (kg/ha) with staggered applications of N and K result in high yields for dasheen taros under rainfed conditions in the Pacific region.

6.3. WEED MANAGEMENT FOR CROP MAINTENANCE

Good agronomic management does not aim to totally eliminate weeds from cultivated plots, but to keep them at a low enough level so that they are not detrimental to the cultivated plant.

This management must be part of an integrated approach which begins before the establishment of the crop (cf. chapter IV on the preparation of the plot), by the prior management of cover crops and the possible establishment of cover plants or mulch in exposed systems, proper tillage and good water control in the case of flooded systems.

Weed control is crucial during the first 3-4 months of cultivation so that there is no harmful competition for taros for light, nutrients and soil water. After this time, the taro canopy closes and intercepts almost all the light, preventing the growth of weeds under the large taro leaves. [32]

6.3.1. IN FLOODED SYSTEMS

Weed control is first ensured by the permanent layer of water. The water level, initially low, is gradually increased as the taros grow so that the base of the plants always remains under water. A water depth of 4 to 8 cm during the vegetative growth period is generally sufficient to control weeds [36].

In some situations, aquatic weeds or freshwater algae may develop, like the so-called "limu" in Futuna, which often require several manual clearing campaigns. If not controlled in time, the biomass of these algae slows down the circulation of the water, which can heat up abnormally and promote rotting of the taro roots caused by *Pythium*.

There are no registered herbicides for flooded taro cultivation. Their use in these systems would be extremely harmful to aquatic fauna and the quality of water downstream of the taro fields.

6.3.2. IN EXPOSED OR RAINFED SYSTEMS

Controlling weeds in exposed conditions requires attention and an often considerable investment in labour. Several techniques can be used. The techniques that precede planting are described in chapter 4 "preparation of the plot". During crop maintenance the following techniques can be applied.

TILLAGE

- In traditional systems where taro is often combined with other crops, farmers generally do 2 or 3 manual weeding campaigns during the 8 to 10 months of the taro crop cycle.
- In more intensive systems, the weeding techniques are more extensive. Manual or mechanical weeding is carried out periodically between the taro rows. The first pass might be mounding to bring the earth back to the foot of the taros. Mechanical weeding often needs to be supplemented by manual hoeing on the planting row because the mechanical tools only work in the spaces between the rows.

ORGANIC MULCH

This involves bringing plant matter in from outside the cultivated plot, which will be spread at the foot of the taros and in the spaces between the rows in order to cover the soil and prevent weeds from growing. This mulch also helps maintain soil moisture by reducing evaporation and helps fertilise the soil as it decomposes. The nature of the mulch depends on local availability. The sources frequently used by taro producers include:

- Rice husk and straw.
- Stems and leaves of asteraceae (compositae): *Eupatorium* spp., *Chromolaena odorata*, *Mikania micrantha*.
- Coconut leaf, banana leaf, rush leaf (Figure 36).

Figure 36 — Taro/dasheen mulching with coconut leaf, Tahiti
photo: https://www.tahitiheritage.pf/legende-sirene-orovaru-rurutu/

PLASTIC MULCH

Mulching can be done using artificial materials such as plastic films commonly used in food growing (tomato, curcurbitaceae etc.). Two types are commonly used.

- Waterproof polyethylene film (black or white and opaque). Some are biodegradable. (Figure 37).
- Cloths of woven polypropylene fibres with the advantage of being water and air permeable.

The plastic mulches are installed after the tillage and the installation of the micro-irrigation network. They are pierced with a cutlass or a thermal torch at the point of the planting holes.

Figure 37 — Plastic mulch on ridge
source: Japan crops

Polypropylene weed cloths are used in Hawaii, as a total cover, to maintain a bare plot before growing the taro. Unlike single-use polyethylene films, weed cloth can be reused for several seasons. However, the purchase cost is quite high [11]. In Europe, the cost is around €1/m² (2022 prices). Also, consider the potential contribution to plastic pollution and waste.

HERBICIDES

The use of chemical herbicides may sometimes be necessary when other methods are not sufficient to control weeds. Their use must in all cases comply with local phytosanitary regulations and only duly authorised active substances and commercial formulations, at the recommended doses, must be applied to the fields.

Note: The description in this document of any method of using pesticides does not constitute an endorsement of the product or a recommendation to the exclusion of other suitable products. Before potentially using a product, it should be checked with the organisations that regulate plant protection products that its use is still authorised.

The use of chemical herbicides is only legal on taro in non-flooded crop systems. It is prohibited in flooded systems where the plots are in water.

Glyphosate is mainly used when preparing the plot ; but it is also used in rainfed cultivation to weed the taros during vegetation. Weeds that have already emerged should be sprayed only on the areas between the rows, using a cover and in calm weather so that the product does not touch the crop. Taro is very sensitive to glyphosate and contact with the herbicide can cause interveinal chlorosis, the deformation of young emerging leaves and even cause the death of plants in the event of high exposure [1].

SELECTIVE HERBICIDES

Taro-selective herbicides can be used in non-flooded cultivation and in the taro or macabo post-planting period. They destroy weeds without harming the crop, even if temporary phytotoxicity is sometimes observed.

Pre-emergent herbicides destroy weeds during their germination and should be sprayed on clean, non-grassy soil, in the spaces between the taro lines. For pre-emergent weed spraying, the nature of the soil must be taken into account and the doses reduced on light soil compared to those used on heavier substrate.

Post-emergent herbicides are applied during cultivation on already developed but young weeds. These herbicides are absorbed by the leaves of weeds, which are then destroyed.

Table 9 lists some herbicide solutions used in certain countries on taro crops. Formulations and doses should follow the recommendations of local agricultural advisory services and those of the plant protection product manufacturers.

Table 9 — Some selective herbicidal active substances used on taro (*Colocasia* spp.)

ACTIVE SUBSTANCE	USE ON TARO	EU APPROVED SUBSTANCE (2023)*	FORMULATION (CONCENTRATION A.S.)	EXAMPLES OF COUNTRIES USING THIS ON TARO
carfentrazone-ethyl	post-emergent application on weeds, using a cover, in the spaces between the taro rows	yes	Oily type emulsion at 60 g a.s. /litre	Hawaii [ref 38]
clethodim	post-emergent herbicide used on annual and perennial grasses	yes	Emulsifiable concentrate 120 to 240 g/litre	idem
pendimethalin	used on pre-emergent weeds	yes	Concentrated suspension 400 g/l	New Caledonia [ref 27]
isoproturon	used on pre-emergent weeds	no	Concentrated suspension 500 g/l	India [ref 35]
oxyfluorfen	used on pre-emergent and post-emergent young weeds	yes	Emulsifiable concentrate 240 g/litre	Hawaii [ref 38] Nigeria [ref 40]

* Information on GAP to meet EU and Codex Alimentarius MRLs is available in the COLEAD crop protection database

WEED MANAGEMENT

TAKEAWAYS FOR WEED MANAGEMENT

- Good weed management aims to keep weeds at levels low enough not to interfere with the crop rather than try to eliminate them completely.
- Weed control is crucial for the first 3-4 months of cultivation. The canopy of taro leaves then closes and limits the growth of weeds due to lack of light.
- In flooded systems, weed control is first ensured by the permanent layer of water. During the vegetative growth period of the taros, it must be 4 to 8 cm high.
- Aquatic weeds or algae must be controlled by clearing. Otherwise there is a risk of the water overheating and rotting the roots of the taro.
- In exposed systems, weed pressure is often greater and several techniques can be used to control them:
    - In manual cultivation, 2 or 3 weeding campaigns are often necessary during the 8 to 10 months of the taro crop cycle.
    - In mechanised cultivation, mechanical weeding between the rows and manual weeding along the row should be combined.
    - The sowing of cover crops before the taro and then the direct planting of the taro in their mulch (DMC) is a recommended agroecological technique.
    - Organic or plastic mulching is another technique for controlling weeds.
- Herbicides can be used in non-flooded systems (but not in flooded systems) in compliance with national legislation.
    - Broad-spectrum herbicides are used before planting the taro or are spot-applied in the spaces between the taro rows.
    - Taro-selective herbicides can be applied on pre-emergent and/or post-emergent young weeds.

7

LEAF AND PETIOLE PRODUCTION

Consumption of *Colocasia* taro leaves and petioles is widespread in Asia and the Pacific, as well as its corms and cormels. When the harvest of the leaves is large-scale, this harms the development of the underground parts and it is then preferable to devote certain plots, or part of these, to leaf production only by not harvesting the corms.

The objective of this production is to obtain tender and fine leaves. In an irrigated system, the leaves will be more tender in the cool season and, in rainfed crops, when the taros grow in shade. Strong exposure to sun and wind or water stress will produce thicker and tougher leaves that are difficult to cook. The tenderness of the leaves decreases with the age of the taro plants. [ref 11]

Generally, leaf-oriented production techniques are not that different from those intended for the harvesting of corms, with, however, a few specificities.

The leaves of some cultivars are more popular than others, like the Bun Long variety in Hawaii, which has however become susceptible to *Phytophthora*. Spots due to leaf diseases are obviously a handicap for this production.

Leaf harvesting can be done both in flooded and rainfed systems, but in the case of irrigation, gravity irrigation or micro-irrigation should be preferred to sprinklers, which will favour the occurrence of leaf diseases.

Leaf harvesting can begin around the 4th month, when they begin to reach a significant development, and takes place every 2 to 3 weeks in the hot season, with one further week in the cool season.

Leaf picking thins the canopy and promotes the growth of weeds, which receive more light. Weed control can then become a strong constraint, with the need to increase weeding as no chemical weeding is possible during cultivation. It is often necessary to add nitrogen to the cover to stimulate leaf production.

In India and sometimes on the English market, we find taro/dasheen leaves under the Indian name of "patra".

In Japan, where eddoe-type taros predominate, grown primarily in market gardening systems, production is primarily oriented towards the production of the leaves and petioles, the latter being a sought-after product locally called "zuiki". The production of corms and cormels has become secondary. [ref 6]

Young macabo leaves are also eaten, particularly in the Caribbean, where they are used in the preparation of "callaloo", a traditional dish made from the leaves of different plants, or in Cameroon and other West African countries. (Figure 38).

Figure 38 — Bunch of macabo leaves with petiole for marketing
http://www.alicepegie.com/fr/wp-content/uploads/2014/11/FEUILLES-DE-TARO.jpg

8

MANAGEMENT OF PESTS AND DISEASES

In integrated production, phytosanitary control is based on the "integrated" management of crop enemies (Integrated Pest Management or IPM). See COLEAD's "integrated pest management" training manual for more information on integrated production.

This part of the document first sets out the main principles of "integrated" management and then gives, for each pest and disease, useful information so as to best understand and control them.

Phytosanitary control falls within the general framework of "Good Agricultural Practices" (GAP), respecting the general requirements set out, for example, in the Global GAP Database.

The basis of Global GAP is Good Agricultural Practice, which is also the backbone of good agriculture. Replacing pesticides with biocontrol products will not improve crop protection if the farmer does not also adopt GAPs.

Without GAPs, crop damage can increase if pesticides are also reduced, as biocontrol products take longer to provide protection than conventional products. Even chemical controls will be less effective if GAPs are not followed.

GAPs can potentially reduce the need for chemical crop protection as it involves providing good growing conditions through optimal fertilisation and irrigation programmes, and good crop aeration in the root zone and canopy. Not only will the plant be less stressed and therefore less susceptible to pests and diseases, but the environment in the soil and the canopy will also be less favourable to the development of pests and diseases.

The ultimate objective is to provide a healthy and high-quality product (i.e. respecting Quality Standards) that's financially affordable. It is essential to combine the specific control methods that are recommended with all the available cultivation techniques (choice of varieties, rotation, staggered planting, tillage, rational fertilisation, etc.) to obtain optimal crop growth and protection, by paying close attention to the role and impact of agronomic and ecological factors.

The effect of the intervention(s) chosen must be evaluated in all its(their) aspects, making it possible to balance the "costs" and the "benefits" of the intervention(s):

- efficiency and profitability for the farmer,
- selectivity for the crop and non-target organisms.
- compliance with MRLs (consumer safety),
- side effects for the operator and domestic and wild animals,
- effects on the environment (soil, water, plants, air),
- effects on cultivation techniques,
- even resulting social consequences. (*e.g.* working time freed up if herbicides are used).

Grouping the different growing practices in a summary table makes it easier to see that certain practices help combat several pests and diseases at once. However, it is also useful for identifying cases where certain practices that are good for controlling one pest or disease can, on the other hand, promote other pests and diseases. For example, sprinkler irrigation reduces attacks by aphids and spider mites but risks promoting diseases such as anthracnose, rust and bacteriosis. Below is an example of a summary table for 10 pests and diseases.

Table 10 — Summary table of methods of controlling 10 pests and diseases

CONTROL METHOD	APHIDS	ROOT APHIDS	LEAFHOPPERS	SCARAB BEETLES	DEFOLIATING CATERPILLARS	ROOT-KNOT NEMATODES	*PHYTOPHTHORA*	*PYTHIUM*	*ATHELIA*	*ALOMAE/BOBONE*
PRELIMINARY CHOICES AND PREPARATION OF THE GROUND										
Resistant or tolerant varieties							√	√		√
Avoid planting near susceptible crops	√		√					√		
Use completely isolated ground							√			√
Avoid overly shaded plots									√	
Avoid the presence of host trees						√				
Practice crop rotation		√	√	√		√		√	√	
Cover crop (green manure) as a prior crop				√		√		√		
Light to heavy soil (no compacted and asphyxiating soil)								√		
Intensive (deep) tillage before planting								√	√	
High rate of well-decomposed organic matter						√		√	√	
Avoid potentially infected water						√		√		
Combination with other crops							√			
Presence of flower strips	√	√	√		√					
Presence of hedges	√	√	√		√	√				
Ground liming								√	√	
Flooding of ground before cultivation in floodplain						√				
Ensure soil drainage (raised beds)								√	√	

CONTROL METHOD	APHIDS	ROOT APHIDS	LEAFHOPPERS	SCARAB BEETLES	DEFOLIATING CATERPILLARS	ROOT-KNOT NEMATODES	*PHYTOPHTHORA*	*PYTHIUM*	*ATHELIA*	*ALOMAE/BOBONE*
PLANTING										
Cuttings taken from healthy plants		√	√			√	√	√		√
Proper preparation of cuttings (cleaning)		√	√			√	√	√		
Treatment of cuttings with hot water		√								
Avoid high densities							√		√	
Mulching							√			
MAINTENANCE										
No excessive irrigation								√	√	
Mulching							√			
Uprooting of severely affected organs or plants							√		√	√
Regular weeding of the plot and surroundings				√						
Irrigation by sprinklers	√									
Avoid excess nitrogen (balanced nitrogen fertilisation)									√	
HARVEST AND POST-HARVEST										
Avoid harvesting too late							√			
Destruction of crop residues							√			
Avoid injury to corms at harvest									√	
Sorting corms before storage								√	√	
Suitable storage conditions							√	√	√	

√ = practice favourable to the control of the pest or disease.

8.1. INTEGRATED PEST AND DISEASE MANAGEMENT

8.1.1. CONSIDERATION OF ENVIRONMENTAL CONDITIONS

A number of aspects relating to the environment, i.e. the environment in its broadest sense, significantly affect the relationships between crops and pests/diseases including, primarily, climatic parameters (possibly including the micro-climate created around a crop because of its behaviour or the fact that it is under shelter) such as temperature, relative humidity, sunlight, photoperiod, difference between daytime and night time temperatures etc.

For example, fungi such as *Pythium*, *Phytophthora colocasiae* and bacterial soft rot favour hot and humid weather, while *Cladosporium colocasiae* prefers wet but cool conditions. *Athelia rolfsii*, on the other hand, prefers hot but not overly humid conditions. Sucking/biting insects such as aphids, whiteflies and leafhoppers will thrive more in hot, dry weather.

The structure, texture, depth, pH, organic matter content, moisture and salinity of the soil can also play an important role in the development of crop pests and diseases, and more particularly those present in the soil. Soils with persistent high moisture levels are, for example, conducive to the development of fungal diseases such as *Pythium* and *Meloidogyne* nematodes. A clay-rich soil is favourable to *Pythium* but unfavourable to *Meloidogyne* nematodes and *Athelia rolfsii*. Soils poor in well-decomposed organic matter are favourable to several pests and diseases, such as *Meloidogyne* nematodes, *Pythium* and *Athelia rolfsii*.

8.1.2. IDENTIFICATION OF PESTS AND DISEASES AND MONITORING

It is important to identify as best possible the different pests and diseases present in a field in order to establish the most appropriate control. The description of the pests and diseases potentially present on taros is found in point 7.2. of this document. An identification key can be found in the Australian Taro Pest document available via https://www.aciar.gov.au/publication/books-and-manuals/taropest-illustrated-guide-pests-and-diseases-taro-south-pacific.

There are no methods specific to taros for monitoring pests and diseases. Reference should be made to existing general practices and principles, such as those listed below.

— The area to be observed should be as uniform as possible (slope and aspect of the field, variety of crop etc.). Too much variation will result in either overestimating or underestimating the number of pests or diseases. If necessary, divide the crop into sections if these are likely to have very different levels of pests and diseases.

— The maximum area forming a unit should be approximately one hectare, unless the plot is extremely uniform.

- Pests are used to moving on the crop at different times of the day. The unit should be examined at least once a week, ideally twice, preferably at the same time of day, so that pest and disease rates can be compared accurately. If the observation is not made at a more or less identical time of the week on the same field, the observer could conclude that the pests are decreasing, whereas they may have simply hidden or left the crop at that time.

8.1.3. USE AND PROMOTION OF NATURAL ENEMIES OF PESTS AND DISEASES

Biological control (or biocontrol) consists in controlling a pest by using or promoting its natural enemies, or a disease by favouring its antagonists. Biological control focuses mainly on pests (insects, mites and nematodes). Predatory, parasitoid and infectious organisms (entomophagous fungi, viruses) that limit the frequency and severity of outbreaks are considered the natural enemies of crop pests and diseases.

At the farm level, intervention strategies take various yet complementary forms.

PRESERVATION AND ENHANCEMENT OF THE ROLE OF INDIGENOUS AUXILIARY ORGANISMS

The development of intensive agricultural practices is generally unfavourable to respecting these regulation mechanisms. The transformation of natural ecosystems commonly results in a reduction in their biological diversity. Farms should be rationally designed to set aside refuge areas favourable to the maintenance of populations of auxiliary organisms (hedges, grassy areas, shelters, nectariferous plants). The use of unfavourable practices should be limited (*e.g.* uprooting hedges, elimination of fallowing, ploughing etc.), as well as phytosanitary treatments using non-selective products, on refuge areas, at the time of flowering etc. The life of useful organisms in the soil should also be preserved, notably by maintaining a good organic matter content and by disturbing the different layers of the soil as little as possible, by avoiding ploughing for example.

Integrated Pest Management involves the use of crop auxiliaries, such as predators and parasites.

The presence of parasitic wasps can be encouraged in a farm by the presence of flowers that provide the adults with useful nectar. To achieve this, it is recommended that flower strips and/or hedges are planted with a maximum 50 m spacing between them. Some umbelliferous plants (Apiaceae) such as dill and coriander are particularly useful. Several other families of plants are useful in encouraging the presence of auxiliaries such as hoverflies (predators of aphids). The plants of the Asteraceae family as well as the *Euphorbiaceae* family are also useful. Asteraceae found in tropical environments include: *Artemisia*, pyrethrum, *Tagetes*, joe-pye weed (*Eupatorium* spp.), *Bidens pilosa* (medicinal plant), sunflower etc. The presence of multi-tiered and species-diverse hedges. For more information, consult the COLEAD "biodiversity management" and "integrated pest management" training manuals.

EXPANDING THE ROLE OF AUXILIARY ORGANISMS THROUGH INUNDATIVE RELEASES

This strategy, which is based on the release of auxiliary organisms in large quantities at the right time and place, likens biological treatment to a conventional treatment. An example in taro cultivation is the release of the egg-predator mirid bug, *Cyrtorhinus fulvus*, which has successfully controlled *Tarophagus* spp. in many parts of the Pacific.

More information on biological control is found on page 15 of the COLEAD "integrated pest management" training manual.

8.1.4. ADAPTED GROWING PRACTICES

Different practices make it possible to limit pest populations and diseases. These are generally prophylactic practices aimed at preventing the appearance and spread of a pest or disease or the aggravation of damage. There are practices that make it possible to avoid the pest or disease, others that break the biological cycle of the pest or disease, others that allow plants to better defend themselves and even those that encourage the enemies of these pests and diseases.

For example, avoiding planting a crop near a plot with a host plant of a pest or disease can prevent the arrival of the pest in the plot or at least reduce and delay its appearance. This reduces the risk of the presence of leafhoppers, for example, and the transmission of viruses responsible for the *alomae*/*bobone* disease.

A long rotation with non-host crops breaks the biological cycle of a pest or disease; this is particularly true for soilborne diseases. Avoid growing crops in a field recently sown with aroids (a rotation of 3 years is considered a minimum; ideally rotations of at least 5 to 6 years are recommended for land infected by soil fungi or nematodes). For insect pests, shorter rotations may suffice, for example one year for root aphids and two years for scarab beetles.

Good crop maintenance (rational fertilisation, regular and appropriate irrigation etc.) allows plants to better defend themselves against most pests and diseases. The presence of hedges, flower strips and the practice of crop combination help promote the development of most natural enemies of pests and diseases.

The practices to be implemented can be categorised in 5 different groups: the choices prior to installing the crop; the preparation of the plot and its environment; planting, crop maintenance, harvest and post-harvest.

QUALITY OF PLANTING MATERIAL

With planting by cuttings, some pests and diseases can develop in the first season and transfer to the following crop.

On taros, many pests and diseases can pass over to the new crop by infested cuttings. For example: root aphids and leafhoppers, *Pythium*, *Athelia rolfsii*, *Phytophthora* fungi and viruses.

To avoid this transmission, always use cuttings taken from healthy plants. It is also advisable to remove all parts with defects from the cuttings and to treat them with fungicides, insecticides and/or hot water.

ADAPTED VARIETIES

Preference should be given to varieties that are resistant and/or tolerant to the main crop enemies in the production area. For taros, there is resistance/tolerance to viruses, *Phytophthora colocasiae* and *Pythium*.

IRRIGATION WATER QUALITY

Water can be contaminated with nematodes, bacteria and fungi capable of causing disease in taros. River water is the most contaminated source of irrigation water. Well water is the least contaminated source.

If possible, river water should be pumped into a holding tank to allow nematodes and microbes to settle on the bottom before pumping water from the upper layers. Ideally, the water can be filtered before use, but this requires a lot of energy and investment in equipment.

THE LOCATION OF THE CROP PLOT

It is always preferable, where possible, to grow taro in plots isolated from other *araceae* fields. This is especially important to avoid viruses such as *alomae*/*bobone*.

CROP COMBINATIONS

Combining taros with other crops can reduce the transmission of pests and diseases from plant to plant. For example, double rows of *sorghum* or millet to control *Phytophthora colocasiae*.

PREPARATION OF THE PLOT

Proper preparation of the plot and the design of its immediate environment will ensure good conditions for the growth of the crop (better defence of the plants against attacks). Avoid conditions favourable to the pest or disease, strengthen the action of antagonists and other natural enemies and impede the entry of certain pests. Two examples are given below.

DRAINAGE

Roots need air in the soil to breathe and grow properly. Excess water in the soil fills the air pockets and reduces root growth. This will not only affect yield but will also promote root infection by soilborne diseases such as *Pythium*.

SOIL PH

Athelia rolfsii develops more in acidic soils, its mycelial growth being optimal between pH 3 and 5 and the germination of sclerotia taking place between pH 2 and 5. The latter seems to be inhibited above pH 7.

Taros prefer slightly acidic soil (pH between 5.5 and 6.5). Lime should be applied to soil that is too acidic (pH below 5.5) to raise the pH. The rise in pH should also reduce the incidence of *Athelia rolfsii*.

FIELD PERIMETER

A clear field perimeter at least 1.5 m wide will prevent the risk of snail attacks.

PLANTING

At this stage, certain adapted practices establish good growth conditions for the plants, while allowing for easy PPP applications and avoiding conditions favourable to pests and diseases. Here are some examples of these practices.

PLANTING DENSITY AND DEPTH

The distance between plants affects not only the final yield per unit area, but also the length of time the leaves stay wet after rain or spraying. If the plants are close together, air circulation in the foliage is reduced and the leaves stay wet for longer. Long periods of leaf wetness favour leaf diseases such as *Phytophthora colocasiae*. A dense canopy also increases soil moisture. Increasing plant spacing can help reduce this moisture and reduce the development of *Athelia rolfsii*, for example.

Cuttings should be planted at the optimum depth based on the recommendations in point 5.1 Planting method.

MAINTENANCE

Good crop maintenance until the end of the harvest helps to avoid the excessive development of a number of pests and diseases. Some examples are given below.

IRRIGATION

The irrigation technique is really important for controlling pests and diseases. Not wetting the leaves for example (by using gravity or drip irrigation) reduces the risk of diseases that need water on the leaves to develop (*Phytophtora*, etc.). On the other hand, this promotes the development of other enemies (leafhoppers, whiteflies, aphids etc.). Gravity irrigation also has the drawback of transmitting enemies such as *Pythium* and *Meloidogyne* via the irrigation channels.

The highest risk of soilborne diseases will occur if the farmer does not control the amount of irrigation water applied to the crop. Furrow irrigation is the least controllable irrigation method and drip irrigation is the most controllable method.

Drip irrigation is the preferred irrigation method because it brings water closer to the roots and does not wet the aerial parts. Kits for small-scale farmers can be bought or made by the farmer. Rows of drippers should be placed with the holes facing upwards and aligned with the rows of plants.

Drip irrigation can also be used to apply biofertilisers, fertilisers and biopesticides directly to plant roots and is therefore a cost-effective system.

Sprinkler irrigation is a potential problem because unlike other watering methods, it wets the leaves and increases the risk of leaf diseases such as *Phytophthora colocasiae*. Sprinkler irrigation also splashes soil on the leaves and can increase infection by fungal spores in the soil.

FERTILISATION

If the crop does not receive enough or receives too much fertiliser, it will be stressed. Stressed plants will show nutrient deficiencies or toxicities and will not produce high yields. Crops that have received too much nitrogen fertiliser will be very attractive to sap-sucking pests such as aphids and whiteflies. Nitrogen-poor soils favour the development of *Athelia rolfsii*.

MULCHING

Mulching the soil can delay the onset and reduce the severity of diseases such as *Phytophthora colocasiae*. Scarab beetle attacks would also be reduced with mulching, for example with *Mucuna* or *Pueraria*. On the other hand, mulching can increase the incidence of diseases such as *Pythium* by increasing the soil moisture.

MANAGEMENT OF CROP WASTE

Crop waste contains the pest and disease history of the plant. Any pests or diseases that invaded the crop during growth will potentially be present on the waste remaining after harvest. The pest or disease may therefore continue to accumulate and create bigger problems for subsequent crops or crops planted nearby. Several measures can be taken to avoid this situation.

ELIMINATION OF PLANTS OR PARTS OF PLANTS INFECTED

During the growing season, if plants are severely infected with diseases such as *Athelia rolfsii*, *Phytophthora colocasiae*, *Alomae/Bobone* complex and *Maramellus* sp., they must be eliminated. This means pulling up the dying plant and putting it in a bag to carry it out of the field. If the dead plant is not carried in a bag, infected soil or plant material may spill into the field. Diseased plants should be properly composted or otherwise destroyed (deep burial in holes; fed to animals).

RAPID REMOVAL OF REMNANTS OF OLD CROPS

As soon as the crop has been harvested, crop residues should be removed and composted or otherwise destroyed.

It is therefore recommended that the old taro crop is completely eliminated, especially in fields where *Athelia rolfsii* is found. *Pythium* levels also increase when crop residues are left in the ground.

Producers who diligently remove taro from the field after harvest have less incidence of disease. Some producers pile this material away from the field in an area where runoff water does not flow into another field. The elimination of the host tissue necessary for the survival of the pathogen breaks the cycle of the disease. Removing taro waste is a difficult task, but it is an excellent practice in global disease management. (Janice Y. *et al.*, 2002).

COMPOSTING

Crop debris removed from the field is cut into small pieces before being heaped to a height of about one metre. In the heap, alternate layers of green plant matter (fresh taro leaves) and brown matter (dry grass, brown banana stalks etc.). A composting accelerator like *Trichoderma asperellum* can be applied. For more information on composting, see the COLEAD manuals on "soil management" and "organic farming" as well as the COLEAD technical brochure on composting techniques.

HARVEST

Overly late harvests should be avoided which, by leaving the plants too long in the field, favour the development of diseases such as *Athelia rolfsii* and *Pythium* on the corms.

You can minimise the rotting of corms or cormels in storage:

- by avoiding bruising them when harvesting;
- allowing the remains of petioles to dry completely before removal and storage to avoid open lesions;
- removing harvested corms or cormels that are infected with *A. rolfsii* or other diseases, especially those that show signs of mycelial infestation, before storing them.

POST-HARVEST

The way in which corms or cormels are stored after harvest strongly influences the development of corm diseases. For example, storing *Colocasia* corms in shallow, leaf-lined earth ditches reduces damage from *Pythium* and *Athelia rolfsii*. On the other hand, for *X. sagitttfolium*, less *Athelia rolfsii* rot is observed in cormels placed on raised and uncovered racks. This process creates an unfavourable microclimate of high humidity on the surface of the corms and air circulation accelerates the subsequent hardening of the flesh, which also acts as an obstacle to the pathogen.

8.1.5. RATIONAL USE OF PLANT PROTECTION PRODUCTS

Control using Plant Protection Products (PPPs) requires a certain balance to be maintained, which is often difficult to achieve, between pests and diseases and their natural enemies. In effect, it is important to remember that the complete eradication of a pest or disease on a plot will reduce the available resources for maintaining its natural enemies, which are a fundamental part of the system's resilience. As such, the objective is to "manage the control of harmful organisms to the point where natural predation operates in a balanced way and crop losses caused by pests are kept to an acceptable minimum level" (FAO).

The use of Plant Protection Products (conventional or biocontrol) should always be considered a last resort, when other measures taken have not sufficiently controlled the various pests and diseases.

The chosen products and their method of use must minimise the negative effects on human health and the environment.

PPP applications based on a pre-established treatment schedule should be avoided. It is preferable to act on the basis of regular observations to establish the phytosanitary state of the crop.

For pests and diseases where an intervention threshold (tolerance threshold, harmfulness threshold) is available, treatments will be carried out when this threshold is reached or exceeded, taking into account the presence of natural enemies. For pests and diseases that do not have a threshold, treatments are carried out when the risks are medium or high for the area in which the crop is located.

THE QUALITY OF PHYTOSANITARY APPLICATIONS IS KEY TO ENSURING EFFECTIVENESS

Sprayed PPPs must be applied in such a way as to best reach their targets. Many pests (whiteflies, aphids, leafhoppers etc.) are found on the underside of the leaves; the mixtures applied must therefore be able to reach the underside of the leaves. This is particularly true for substances which act by contact or ingestion and which are not systemic (case of practically all biocontrol products).

Because the taro leaves are waxy, the addition of a wetting agent to the mixture is essential to ensure the good distribution of the product on the taro leaves.

Proper calibration of sprayers is essential to apply the recommended dose of products per hectare and the optimal amount of spray.

When using a manually-maintained pressure backpack sprayer (Figure 39), the farmer generally follows the advice on the label for the quantity of product to apply per 15-litre sprayer, which is the optimum concentration of the mixture (these doses are based on a theoretical spray volume of 1,000 litres per hectare on a crop in full vegetation). For backpack sprayers, the amount of spray mixture to be applied per hectare will normally depend on the stage of crop development to avoid unnecessarily spraying bare soil. The volume of mixture to be applied to young plants is significantly lower than that to be applied to plants in full development (less leaf area, therefore less product required). If the producer applies too large a volume of mixture per hectare, for a given growing area and at a given stage, they risk "over-applying" the product (risk of burns and economic loss due to over-consumption of product) or "under-applying" if the volume of mixture is insufficient (reduced effectiveness and economic loss due to the risk of pest and disease damage to the crop). It is therefore very important that the producer knows precisely the volumes of water needed per hectare at each crop stage. This can be determined by doing a blank test (water spray only).

The choice of the type of backpack sprayer is also important. In some cases it will be preferable to use powered sprayers (Figure 40) to ensure better penetration of the mixture into the foliage and better reach the underside of the leaves. The other advantage of a powered sprayer compared to a manually-maintained pressure sprayer is the speed of application of the product over large areas. This feature is important in areas of high rainfall where treatment must be completed quickly before the next rain.

Figure 39 — Manually-maintained pressure backpack sprayer
https://stihlusa-images.imgix.net/Product/581/CorpFull_2.png?w=710&h=532&fit=fill&auto=format,compress&fill=solid

Figure 40 — Powered sprayer
https://www.agriexpo.online/fr/prod/cifarelli/product-176151-20656.html (photo 3)

COMPLIANCE WITH NATIONAL REGULATIONS ON THE USE OF PPPS

In ACP countries, taro is mainly produced for the domestic market. If exported to the EU, importers have very specific directives on the PPPs that are authorised on the purchased production. The lists of PPPs approved by customers must be respected, but the producer can only use PPPs that have marketing authorisations in the country of production of the crop and must respect the authorised uses and the approved doses.

CONFORMITY OF PESTICIDE RESIDUES IN RELATION TO THE PRODUCTION DESTINATION MARKET

PPPs, which are used for taros or macabo, must be taken into account:

— the mandatory precautions for use (application period, pre-harvest interval, maximum authorised dose, existence or not of untreated areas, protective equipment) and any restrictions on use.

— The existence, on food, for the substance of a Maximum Residue Limit (MRL). The MRL in force in the country where the production will be distributed must be considered (national MRL, MRL harmonised at European level or even MRL established by the Codex Alimentarius). Note that the MRLs for corms are different from the MRLs for taro leaves.

Compliance with GAPs specific to each use allows the producer to comply with the MRL to be considered based on the end market of the production. The GAP includes the product dose, maximum number of applications, minimum application interval and pre-harvest interval (PHI). Any modification of one or more elements of these GAPs (for example: increase in dose, frequency of application and number of applications, and/or last application before harvest that fails to respect the pre-harvest interval (PHI)) might result in residues above the recommended MRL. These GAPs are not calendar treatments to be applied as such. In practice, the frequency of treatments must take into account the level of pest and disease attacks locally and the real risk of damage.

PPP labels should normally provide enough information to ensure the producer does not apply more product than necessary or authorised at a particular stage of growth. The label normally clearly *indica*tes which crops the product can be used on and what the PHI will be for each different crop. The PHI *indica*ted concerns the application MRL in the country for which the label is intended. For example, a product sold in Kenya would normally have a label approved by the country's pesticide approval system.

The label may also specify the stage of growth at which a product can be used. For example:

— use only before planting (*e.g.* some nematicides);

— use only post-harvest.

If the label places restrictions on the stage of growth at which a product can be used, it is very important that this information is followed to the letter - otherwise there is a very high risk that use of the product after this period will leave a residue above the authorised level.

THE COLEAD CROP PROTECTION DATABASE PROVIDES INFORMATION ON GOOD AGRICULTURAL PRACTICES

It went live in 2018 and is accessible to all its members and beneficiaries. To date, this is one of the only databases to provide information specifically designed to support the horticultural sector in ACP countries. Data on good agricultural practices (GAPs) are obtained from a variety of sources, including the COLEAD's field trials of PPPs, data from manufacturers of PPPs and scientific literature.

The crop protection database contains the MRLs established by the EU and the Codex Alimentarius for key horticultural crops in ACP countries. It also sets out good agricultural practices (doses, intervals between treatments, pre-harvest intervals etc.), which ensure that these MRLs are complied with. Additional information such as the type of pesticide, the authorisation status of the active substance in the EU and ACP countries, the classification recommended by the World Health Organisation (WHO) and the resistance group (FRAC code for fungicides, IRAC classification for insecticides) is also available[1].

COLEAD's crop protection database is available on our website: here.

RECOMMENDED SUBSTANCES

Appendix 3 lists the substances recommended to control the main pests and diseases. The list was established on the basis of a bibliographic search. We have only mentioned the substances that are authorised in the EU since this is a crop that can be exported to the EU https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/active-substances/?event=search.as; with the exception of substances considered biocontrol substances, which have nevertheless been listed.

The user must check whether products containing these substances are authorised in the country of production of the crop and whether these substances are authorised by the private standards of the crop buyers.

1 COLEAD also wants to highlight the importance of complying with the instructions on the labels of PPPs. Moreover, before using any product, you are recommended to consult the latest regulatory amendments in the EU database on pesticides and the Codex Alimentarius.

TRACEABILITY

As with other operations carried out in the cultivation process, it is very important to have complete documentation of the phytosanitary interventions, recording the following, as a minimum, for each treatment:

- the crop pest or disease to control,
- the date of application (+ number of days after sowing, + days before the planned harvest),
- the crop development stage,
- the product used (full name, supplier, formulation, batch number etc.),
- the dose actually used,
- the volume of spray mixture,
- the type of application (device, nozzle, volume/ha, working width, speed, wind etc.).

8.2. MAIN PESTS AND DISEASES

This section presents the main pests and diseases of taro and macabo in ACP countries. First, point 8.2.1 summarises the stages at which the different pests and diseases can cause damage and the potential scale of the damage; this is followed by the potential impact on crop yield and quality.

The main pests and diseases are then described individually; first insects, then nematodes, fungi, bacteria and viruses.

For each pest and disease, the following points are detailed:

— **Scientific name**

— **Life cycle**

Good knowledge of the biological cycle of the pest or disease makes it possible to better understand the different control methods to use and the conditions favourable to the pest or disease to be avoided.

— **Description/identification**

- Other host plants

  The list of other host plants of the pest or disease is not exhaustive. It is given as an *indica*tion for the main plants.

- Description of the pest or disease organism

  The description is given so that you can identify the insects yourself. The identification of nematodes, fungi and bacteria is often only possible by specialists and it is advisable to consult them for the correct identification.

- Crop stages affected

  This *indica*tes the level at which the main crop stages are potentially affected by the pest or disease. There are four possible levels:
  - 0 = generally not affected,
  - + = little affected,
  - ++ = moderately affected,
  - +++ = highly affected.

  "Affected" signifies the presence of the pest or disease and damage.

- Symptoms and damage

  These are described for the different plant organs affected.

- Impact on yield and quality

  This is described and explained for 3 types of impact: loss of plants, loss of yield per plant, reduction in quality of the harvest.

— **Quarantine organism**

If production is exported to the EU, it is important to know whether the organism is a quarantine organism, because control will have to completely eliminate the presence of the pest or disease on the harvested products (corms, cormels, leaves etc.).

European legislation on quarantine organisms is constantly evolving and it is important to check it regularly by consulting the site https://ec.europa.eu/food/plants/plant-health-and-biosecurity/legislation_en

The information given here was gathered from the site https://favv-afsca.be/fr/themes/plantes/sante-des-vegetaux/organismes-nuisibles-reglementes-des-vegetaux

— **Conditions conducive to infestation**

The main conditions (climate, meteorological conditions, season, soil (type, moisture etc.) conducive to the development of the pest or disease in a plot are given.

— **Monitoring**

This part outlines how to carry out monitoring.

— **Control through good growing practices**

The recommended actions are classified according to 4 types: preliminary choices, preparation of the plot, planting and crop maintenance. For each action, a reason and/or description and the expected effect is given. The expected effects are of 4 types: avoidance of the pest or disease, breaking of its life cycle, improvement of the plant's defence against the pest or disease and strengthening of the action of natural enemies.

— **Biological control**

There are two types of biological control: (i) the promotion and conservation of natural enemies present on the farm, (ii) the introduction of bred natural enemies. Recommendations are given for these two types of control when information is available.

— **Control using Plant Protection Products**

Information is given for the following different aspects of this control: periods, times of day and methods of application; resistance management; the choice of substances with an emphasis on biocontrol products.

The user should check whether there are approved products for the intended use in their country and whether the substances are authorised by the purchasers of the production (specifications).

Care should always be taken to alternate substances belonging to different resistance groups; consult the IRAC website for insecticides www.irac-online.org and the FRAC site for fungicides https://www.frac.info/.

— **Other control methods**

Specific control methods are presented.

8.2.1. SUMMARY OF THE MAIN PESTS AND DISEASES AFFECTING THE CROP

The main pests and diseases described in this document and their significance for taros and macabo are listed below.

Table 11 — Main pests and diseases and relative harmfulness* to taros and macabo as well as their presence in the 3 main production regions

PEST OR DISEASE	TAROS	MACABO	GEOGRAPHIC DISTRIBUTION**		
			AFRICA	AMERICA	ASIA PACIFIC
INSECTS					
Aphids (*Aphis gossypii*)	+	+	x	x	x
Root aphids (*Patchiella reaumuri*)	+++	0			x
Whiteflies (*Bemisia tabaci*, *Aleurodicus dispersus*)	+	+	x	x	x
Taro leafhoppers (*Tarophagus* spp.)	+++	0			x
Taro scarab beetles (*Papuana* spp.)	+++	++			x
Taro hornworms (*Hippotion celorio*)	+	0			x
Taro caterpillars (*Spodoptera litura*)	+	+	x***		x
NEMATODES					
Root-knot nematodes (*Meloidogyne* spp.)	+	+	x	x	x
Lesion nematodes (*Pratylenchus coffea*)	+	+	x	x	x
Reniform nematodes (*Rotylenchulus reniformis*)	+	+	x	x	x
FUNGI					
Leaf blight (*Phytophthora colocasiae*)	+++	0	x	x	x
Leaf mould (*Cladosporium colocasiae*)	+	0			x
Phyllosticta leaf spot (*Phyllosticta colocasiophila*)	+	0			x
Corm or cormel rot (*Pythium* spp.)	++	+++	x	x	x
Corm and root rot (*Marasmiellus stenophyllus*)	+	+		x	x
Athelia rot (*Athelia rolfsii*)	++	++	x	x	x

PEST OR DISEASE	TAROS	MACABO	GEOGRAPHIC DISTRIBUTION**		
			AFRICA	AMERICA	ASIA PACIFIC
BACTERIA					
Soft rot (*Pectobacterium carotovorum, Dickeya chrysanthemi*)	++	++	x	x	x
VIRUSES					
Alomae/Bobone (virus complex)	+++	0			x****
Taro Mosaic virus (*DsMV*)	+	+	x	x	x
MOLLUSCS					
Snail (*Lissachatina fulica*)	+	+	x	x	x

Legend: 0 = no impact; + = low impact; ++ = medium impact; +++ = significant impact;
x = presence of pest or disease
*the level of harmfulness may vary depending on the crop system, the area and the country of production
**Adapted from Table 27.1 in "Lebot V. 2009. Tropical root and tuber crops: cassava, sweet potato, yams and aroids. 1st edition. Section IV. Aroids: part 27 pp. 339 - 349. CABI"
*** reported in Ghana and the Central African Republic
**** limited to Solomon Islands and Papua New Guinea

The levels of impact at the different crop stages are given below.

Table 12 — Levels of impact* at the different crop stages of the main pests and diseases present on taros and macabo

PEST OR DISEASE	CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
INSECTS							
Aphids	+	+	++	++	+	0	0
Whiteflies	+	+	++	++	+	0	0
Scarab beetles	0	+	++	+++	+++	+++	0
Taro caterpillars	0	++	+++	+++	+	0	0
NEMATODES							
Root-knot nematodes	0	+	++	++	++	+	0
Lesion nematodes	0	+	++	++	++	+	0
Reniform nematodes	0	+	++	++	++	+	0

PEST OR DISEASE	CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
FUNGI							
Corm or cormel rot	++	++	+++	+++	+++	+++	+++
Corm and root rot	0	+	+	++	++	+	+
Athelia rot	+	++	+++	+++	++	++	++
BACTERIA							
Soft rot	+	++	+++	+++	+++	++	++
VIRUSES							
Taro Mosaic virus	+	+	++	++	+	0	0
MOLLUSCS							
Snails	0	+	++	++	+	0	0

Legend: 0 = no impact; + = low impact; ++ = medium impact; +++ = significant impact
*the level of impact may vary depending on the crop system, the area and the country of production

Table 13 — Levels of impact* at the different crop stages of the main pests and diseases present on taros only

PEST OR DISEASE	CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
INSECTS							
Root aphids	+	+++	+++	++	+	0	0
Taro leafhoppers	+	++	+++	+++	++	0	0
Taro hornworms	0	++	+++	+++	+	0	0
FUNGI							
Phytophthora	++	++	+++	+++	++	++	++
Taro leaf mould	0	+	++	++	+	0	0
Phyllosticta leaf spot	0	+	++	++	+	0	0
VIRUSES							
Alomae/Bobone	+	++	+++	+++	++	0	0

Legend: 0 = no impact; + = low impact; ++ = medium impact; +++ = significant impact
*the level of impact may vary depending on the crop system, the area and the country of production

Below are the types of impact on crop yield and quality.

Table 14 — Types and levels of impact on the yield and quality of the harvest of corms or cormels of the main pests and diseases of taros and macabo

PEST OR DISEASE	LOSS OF PLANTS	YIELD LOSS PER PLANT	REDUCTION IN QUALITY	EU QUARANTINE ORGANISM
INSECTS				
Aphids	0	+	0 (+**)	No
Whiteflies	0	+	0 (++**)	Yes for *Bemisia* spp.*
Scarab beetles	+	+++	+++	No
Taro caterpillars	+	++	0	Yes*
NEMATODES				
Root-knot nematodes	0	++	++	No
Lesion nematodes	0	++	++	No
Reniform nematodes	0	++	++	No
FUNGI				
Corm or cormel rot	++	+++	+++	No
Corm and root rot	+	+	+ (+**)	No
Athelia rot	++	++	++	No
BACTERIA				
Soft rot	++	++	++	No
Viruses				
Taro Mosaic virus	0	+	+ (+**)	No
MOLLUSCS				
Snails	+	++	0	No

* for the marketed leaves
Legend: 0 = no impact; + = low impact; ++ = medium impact; +++ = significant impact

Table 15 — Types and levels of impact on the yield and quality of the corm harvest of the main pests and diseases of taro only

PEST OR DISEASE	LOSS OF PLANTS	YIELD LOSS PER PLANT	REDUCTION IN QUALITY	EU QUARANTINE
INSECTS				
Root aphids	0	+++	0	No
Taro leafhoppers	+	++	0 (+**)	No
Taro hornworms	+	++	0	No
FUNGI				
Phytophthora	+	+++	++ (+++**)	No
Taro leaf mould	0	+	0 (++**)	No
Phyllosticta leaf spot	0	+	0 (++**)	No
VIRUSES				
Alomae/Bobone	++	+++	+ (++**)	Non

Legend: 0 = no impact; + = low impact; ++ = medium impact; +++ = significant impact

8.2.2. INSECTS

8.2.2.1. COTTON OR MELON APHIDS

SCIENTIFIC NAME

Aphis gossypii attacks taro (*Colocasia*) and macabo (*Xanthosoma*). It is part of the order Hemiptera and the family Aphididae.

LIFE CYCLE OF THE PEST

In hot climates, aphids multiply by parthenogenesis: reproduction takes place without fertilisation. The eggs are produced directly by the adult female. Females give birth to *larvae* after hatching from the egg inside the body. There are 4 larval stages.

Aphid colonies cluster around the growing points of plants, for example on the underside of preferably young and tender leaves, or the flower buds.

Aphids can grow quickly, since the entire cycle lasts around 11 days. A female can produce almost 150 to 200 offspring during her lifetime. Several generations can succeed each other in the year.

In the event of a swarm, the winged adults spread from one field to another.

DESCRIPTION/IDENTIFICATION

OTHER HOST PLANTS

They are extremely polyphagous. Plants of the families *Malvaceae*, *Solanaceae*, *Cucurbitaceae* and *Citrus* are notable hosts for this aphid.

DESCRIPTION OF THE INSECT

Adults are highly variable in colour ranging from light yellow to green, dark green, dark grey or black. They are 0.9 to 2.5 mm long and oval in shape. They can be winged or wingless. The winged aphids are generally darker. The antennae are shorter than the body, the cornicles are blackish, and the tail is dark. The head and thorax are dark grey, and the abdomen is mostly green.

The *larvae* look much like the adults but are smaller and always wingless. In the fourth stage they measure around 1 mm long.

Figure 41 — Colony of *Aphis gossypii* with a winged adult
https://bugwoodcloud.org/images/768x512/4387054.jpg

CROP STAGE(S) AFFECTED

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
+	+	++	++	+	0	0

SYMPTOMS AND DAMAGE

Aphids settle by preference on the underside of leaves, but the whole plant can be covered in the event of a major infestation.

LEAVES	Aphids are found on the underside of leaves. Attacks cause leaf blade blight and downward-facing curling. Leaves become senescent more quickly than normal in an aphid outbreak.
WHOLE PLANT	General weakening and wilting of the plant in the event of severe attacks.

Figure 42 — Aphid swarm on a taro leaf (together with ants)
https://upload.wikimedia.org/wikipedia/commons/thumb/3/3a/Taro_-_ants_and_aphids_32a84ab.jpg/800px-Taro_-_ants_and_aphids_32a84ab.jpg

IMPACT ON YIELD AND QUALITY

Indirect damage from aphids can be observed with the appearance of symptoms of viral diseases. The taro mosaic virus (*DsMV - Dasheen mosaic virus*) is potentially transmitted by aphids.

TYPE OF IMPACT	DESCRIPTION
Yield loss per plant	Reduction by weakening of the plants due to wilting and downward curling of the leaf blades. Indirect damage is caused by the accumulation of honeydew produced by the aphids. Honeydew serves as a substrate for sooty mould, which darkens the leaves, thus reducing photosynthesis and plant vigour.

QUARANTINE ORGANISM

It is not a quarantine organism in the EU.

CONDITIONS CONDUCIVE TO INFESTATION

TYPE	CONDUCIVE CONDITION	IMPACT / EXPLANATION
Weather conditions	Low humidity and high temperature.	Rapid development of populations. Generally, aphids do not survive in the field in extremely wet conditions.
Entomofauna	Aphids often live in symbiosis with ants.	The presence of ants promotes infestation by aphids.

MONITORING

Aphids are easily visible on plants. Detecting them as early as possible is essential to avoid heavy aphid infestations on the plant organs.

Look for infested leaves, which may appear wilted and curled downward. Older leaves become deformed and covered with honeydew, which promotes the growth of black mould. Ants sometimes deal with aphids and feed on the honeydew that the aphids excrete. But at the same time, they protect aphids from natural enemies. The presence of ants often *indica*tes the presence of aphids (although ants are also attracted to the honeydew of whiteflies and grasshoppers).

CONTROL THROUGH GROWING PRACTICES

The practices mentioned below help to control the pest.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
Prior choices		
Choice of plot location	Avoid plots close to and downwind of old taro plantations or other crops carrying aphids hosted by taro.	Avoidance of the arrival of winged aphids.
PREPARATION OF THE PLOT		
Installation of grass strips or flowering hedges	The installation of hedges and flower borders provides refuge and food for useful fauna. See biological control through conservation below	Control by auxiliaries is strengthened.
Installation of windbreak hedges	Hedges to limit the movement of aphids from one crop to another	Avoidance of the arrival of winged aphids.
CROP MAINTENANCE		
Rational irrigation	In dry weather, regular overhead spray watering disturbs aphid populations	The population decreases.
Removal of heavily affected leaves	Their removal must be followed immediately by the destruction of the foliage (deep burial, burning or food for animals).	Elimination of sources of infestation

BIOLOGICAL CONTROL

THROUGH CONSERVATION OF THE AUXILIARIES PRESENT

Several natural enemies of aphids occur naturally on farms. These include parasitic wasps, for example those of the genera *Aphidius* and *Aphelinus*, hoverflies, lacewings, anthocoridae and ladybirds.

The presence of parasitic wasps can be encouraged on a farm by the presence of flowers which bring useful nectar to the adults. See point 8.1.3.

It is also useful to control ants in a field as they will disrupt the activities of natural enemies.

Entomopathogenic fungi of the genus *Metarhizium* are naturally present in aphid colonies. However, its development is often too late to allow satisfactory aphid control; the damage to the crop is already done.

CONTROL USING PLANT PROTECTION PRODUCTS

It is rarely necessary to use PPPs to control aphids on taro. Populations are normally well controlled by predators - ladybirds, hoverflies and lacewings in particular. If it is necessary to use PPPs, seeking advice from a local agricultural advisory agent is recommended. If ants are present, the best solution may be to destroy the ant colony so that predators and parasites can continue their beneficial activities unhindered.

During foliar treatments, take care to spray the underside of the leaves where most aphids are located. A wetting agent is essential to ensure the good distribution of the product on the taro leaves.

RESISTANCE MANAGEMENT

Aphids can become resistant to chemical PPPs if they are used repeatedly without alternating substances belonging to different resistance groups. For example, resistance to pyrethroids has been detected.

SUBSTANCES

Find out about the harmfulness of PPPs on the auxiliaries of the crop because these must be conserved as best possible. For example, a pyrethroid can kill up to 75% of the natural enemies of aphids and this harmful effect can persist for up to 10 weeks after application. The least harmful PPPs should therefore be preferred, even if their cost of use per hectare is higher.

Substances recommended for aphid control are listed in Appendix 3.

Many biocontrol products can be used against aphids. These include the following substances: fatty acid, maltodextrin, azadirachtin, oxymatrin, pyrethrin, *Beauveria bassiana*, *Metarhizium anisopliae*, *Paecilomyces fumosoroseus*, *Verticilium lecanii*, paraffin oil, orange essential oil, *citri*c acid. However, only azadirachtin is mentioned in the literature as being usable on taro.

OTHER CONTROL METHODS

No information available.

8.2.2.2. TARO ROOT APHIDS

SCIENTIFIC NAME

Patchiella reaumuri: present mainly in the Pacific on taro and only in the Solomon Islands in ACP.

It is part of the order Hemiptera and the family Aphididae.

LIFE CYCLE OF THE PEST

In hot climates, aphids multiply by parthenogenesis: reproduction takes place without fertilisation. The eggs are produced directly by the adult female. Females give birth to *larvae* after hatching from the egg inside the body. In tropical regions, there are no winged adults. Ants allow this aphid to spread. Infected cuttings also enable their spread.

DESCRIPTION/IDENTIFICATION

OTHER HOST PLANTS

In tropical regions, its hosts are plants of the family *Araceae*.

DESCRIPTION OF THE INSECT

The adult is very dark green or brown, the plump body is about 3.5 mm long. The *larvae*, which initially cluster on and around the adult, are green. As they mature, they develop tufts of wax along the sides of the abdomen.

Figure 43 — Dark coloured adult with green *larvae* clustered around it
https://influencepoints.com/Images/Patchiella_reaumuri_fundatrix_with_nymphs_c2017-05-10_17-46-02ew.jpg

Figure 44 — *Larvae* with thick wax
https://www.reabic.net/journals/bir/2022/1/BIR_2022_Firake_etal.pdf

CROP STAGE(S) AFFECTED

The effect of the root aphid is greater on young plants than on mature plants. A taro crop planted with infested cuttings will never get off to a good start, and subsequent yield will not reach adequate levels.

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
+	+++	+++	++	+	0	0

SYMPTOMS AND DAMAGE

ROOTS	The infestation is manifested by a white waxy deposit on the fibrous roots. The affected roots rot.
LEAVES	Attacks cause small leaves and yellowing. When populations are very high, this aphid can be found on the leaf petioles.
WHOLE PLANT	General weakening of the plant in the case of severe attacks.

Figure 45 — Attack on roots
https://www.reabic.net/journals/bir/2022/1/BIR_2022_Firake_etal.pdf

Figure 46 — Infestation of taro root aphids on the petiole and sheath of taro leaves
https://www.ctahr.hawaii.edu/oc/freepubs/pdf/IP-1.pdf

IMPACT ON YIELD AND QUALITY

This is one of the most destructive insect pests of taro in rainfed/exposed cultivation.

TYPE OF IMPACT	DESCRIPTION
Yield loss per plant	Reduction by weakening of plants. Losses of up to 75% have been observed for some varieties.

QUARANTINE ORGANISM

It is not a quarantine organism in the EU.

However, it is in other parts of the world. The transport of plant material from the island of Hawaii to other Hawaiian islands, for example, is subject to quarantine. (Carmichael A., *et al.*, 2008)

CONDITIONS CONDUCIVE TO INFESTATION

TYPE	CONDUCIVE CONDITION	IMPACT / EXPLANATION
Weather conditions	Drought period	Aggravation of plant weakening.
Entomofauna	Aphids often live in symbiosis with ants.	The presence of ants promotes infestation by aphids.

MONITORING

Because the aphid is found on the roots, it may not be detected until symptoms appear on the surface. The base of the petioles, the corm and the roots should be inspected to see if masses of white, cottony, waxy threads are present (these cover the insects). The presence of ants on the ground and lower parts of the taro (and sometimes on the leaves when aphid numbers are high) can be an *indica*tion that the plants are infested. (Carmichael A., *et al.*, 2008)

CONTROL THROUGH GROWING PRACTICES

The practices mentioned below help to control the pest.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
PRIOR CHOICES		
Choice of plot location	Avoid plots that have been previously attacked	Avoidance of source of infestation
PREPARATION OF THE PLOT		
Installation of grass strips or flowering hedges	The installation of hedges and flower borders provides refuge and food for useful fauna. See biological control through conservation below	Control by auxiliaries is strengthened.
PLANTING		
Use healthy cuttings	Ensure cuttings come from an uninfested area or are disinfected	Avoidance of a source of infestation from the start of cultivation
CROP MAINTENANCE		
Crop destruction	It is recommended, in the case of heavy infestations over a small area, that the crop is harvested and destroyed. Then deep plough the land and leave fallow for at least a year or plant with another non-susceptible crop. (Carmichael A., *et al.*, 2008)	Breaking the pest cycle and destruction of ants

THROUGH CONSERVATION OF THE AUXILIARIES PRESENT

Several natural enemies of aphids occur naturally on farms. These include parasitic wasps, for example those of the genera *Aphidius* and *Aphelinus*, hoverflies, lacewings, anthocoridae and ladybirds.

Ants should be controlled in the field as they will disrupt the activities of natural enemies and cause the spread of the root aphid.

Figure 47 — Ants tending to aphids
https://influencepoints.com/Images/Patchiella_reaumuri_fundatrix_attended_by_Lasius_niger_c2017-05-10_17-23-01ew.jpg

Entomopathogenic fungi of the genus *Metarhizium* are naturally present in aphid colonies. However, its development is often too late to allow satisfactory aphid control; the damage to the crop is already done.

CONTROL USING PLANT PROTECTION PRODUCTS

Aphids on roots are difficult to reach with insecticides. They also secrete a wax that protects them.

APPLICATION PERIOD

If an insecticide is available, it will be most useful when applied during the early growth phase of the taro crop.

RESISTANCE MANAGEMENT

Aphids can become resistant to chemical PPPs if they are used repeatedly without alternating substances belonging to different resistance groups. For example, resistance to pyrethroids has been detected.

SUBSTANCES

Find out about the harmfulness of PPPs on the auxiliaries of the crop because these must be conserved as best possible. For example, a pyrethroid can kill up to 75% of the natural enemies of aphids and this harmful effect can persist for up to 10 weeks after application. The least harmful PPPs should therefore be preferred, even if their cost of use per hectare is higher.

Substances recommended for root aphid control are listed in Appendix 3.

There are no biocontrol products known to be effective against root aphid on taro.

OTHER CONTROL METHODS

A hot water immersion treatment can disinfect taro cuttings with root aphids without adverse effects on the cuttings. This involves soaking the cuttings for 6 minutes in 49°C water, followed by immersion in cold water. (Carmichael A., *et al.*, 2008)

8.2.2.3. WHITEFLIES (OR *ALEURODE*)

SCIENTIFIC NAME

Two main species of whitefly are found on taros and macabo.

- Sweet potato/cotton/tobacco whitefly: *Bemisia tabaci*
- Spiralling whitefly: *Aleurodicus dispersus*

They are part of the order Hemiptera and the family Aleyrodidae.

LIFE CYCLE OF THE PEST

The cycle of these two pests is very short so a population can grow quickly if nothing hinders their survival. *Bemisia tabaci* and *Aleurodicus dispersus* have similar cycles and control techniques will be the same for both species.

STAGE	DESCRIPTION
Egg	The eggs are laid in groups on the underside of the leaf, and are attached to the leaf by a peduncle.
Larva	There are 4 larval stages. *Bemisia tabaci*: After hatching, the first larval stage moves a very short distance from the egg. The next three larval stages do not move. *Aleurodicus dispersus*: After hatching, the first larval stage moves to find a suitable leaf vein to feed on, where it settles. As they mature, the *larvae* develop waxy tufts. The first stages are motile, while the last three stages are permanently attached to the leaf.
Puparium	It does not feed during this stage. About a week later, the adult whitefly emerges from the puparium. The hatching usually occurs in the morning.
Adult	Although adults can fly up to 15 metres in a 24-hour period, most stay 2.5-3 metres from their hatching location. Dispersal over long distances is ensured by the wind. The adults are very active and are easily disturbed during the day. They feed on the lower surface of the leaves, where they lay their eggs, but they can also settle on other areas of the host plant. The adult is inactive when it rains.

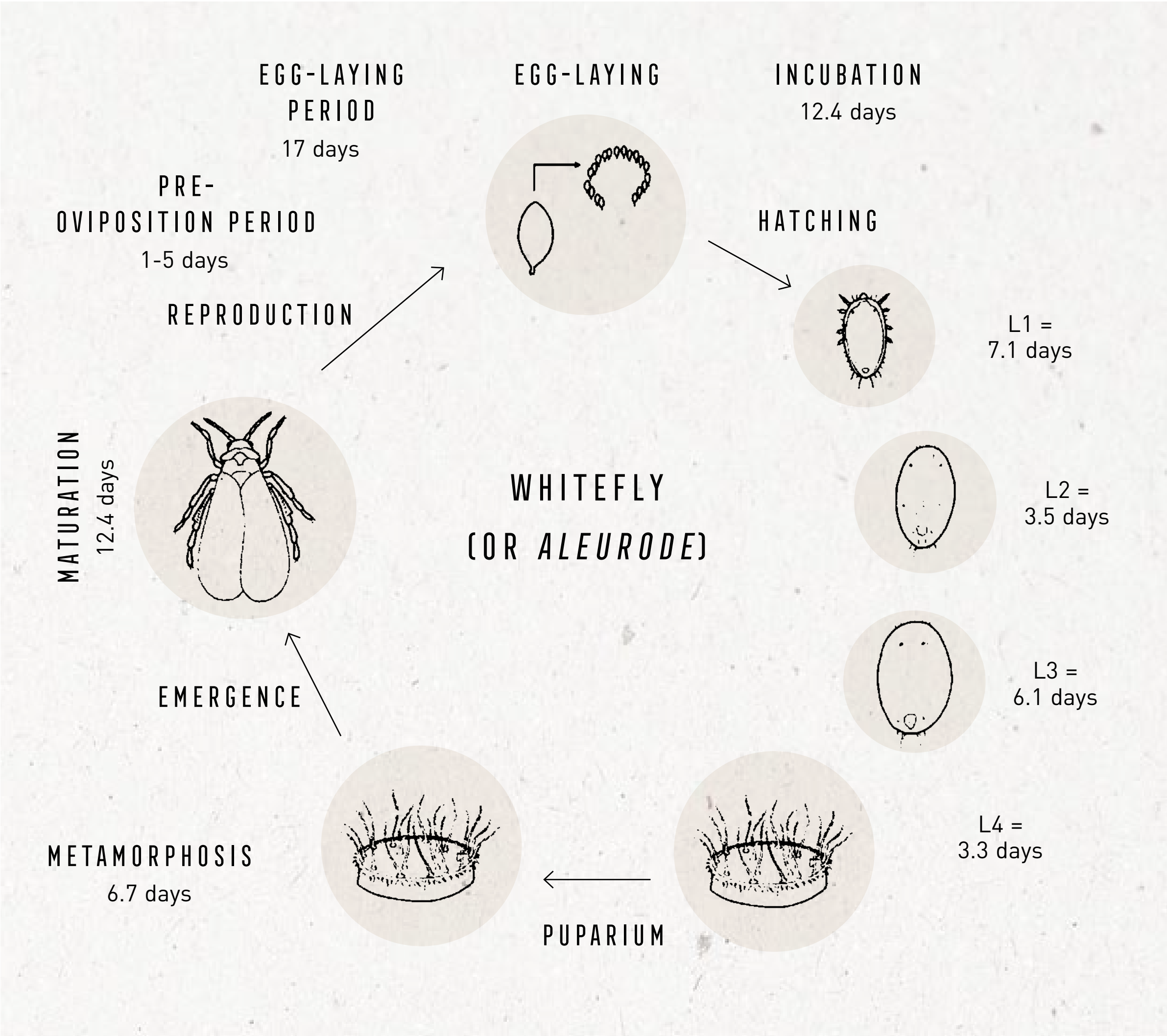

Figure 48 — Duration of development stages of *Bemicia tabaci* on tomato at 20°C. J Poidatz (Koppert). (2015)
http://ephytia.inra.fr/fr/C/19694/Biocontrol-Biologie

DESCRIPTION/IDENTIFICATION

OTHER HOST PLANTS

The tobacco whitefly has a vast choice of host plants and attacks many crops worldwide. The pest attacks, for example, the following families: *Brassicaceae*, *Cucurbitaceae*, *Fabaceae*, *Malvaeaceae*, *Solanaceae*. It is also abundant on cassava, sweet potato and *citrus*.

Aleurodicus dispersus has a wide range of hosts, especially tree or shrub plants (such as banana, guava and palm). This allows it to spread quickly from one crop to another in tropical areas.

DESCRIPTION OF THE INSECT

STAGE	DESCRIPTION
Egg	*Bemisia tabaci*: The eggs, which are white, gradually turn brown, are held in place by a thin peduncle produced by the female. Mature whitefly eggs are grey in colour. *Aleurodicus dispersus*: The eggs are smooth, yellow to tan, oval in shape and 0.3 mm long. *Bemisia tabaci* tend to lay their eggs randomly on the leaf surface, while *Aleurodicus dispersus* lay their eggs spirally, which are associated with streaks of white wax.
Larva	*Bemisia tabaci*: The *larvae* are cream to light green in colour, flat and oval in shape. *Aleurodicus dispersus*: The first larval stage is tiny (0.3 mm long) and mobile when feeding. The second and third larval stages are between 0.5 and 0.65 mm long and secrete waxy tufts or rods on their backs.
Puparium	For *Bemisia tabaci*, L4 changes shape to become almost round (about 0.8 mm long and 0.6 mm wide). The puparium sometimes has an irregular, lobed outline, depending on the length of the hairs and the structure of the leaf of the host plant. At this stage, the red eyes of the insect can be clearly distinguished. As the cuticle of the puparium is transparent, you can see the yellow colour of the whitefly. We can see the white wings developing laterally. In *Aleurodicus dispersus*, large quantities of white, fluffy, flocculent wax extending from the back are secreted by the pupae, more so than in the larval stages. The puparium measures 0.67mm long and 0.43mm wide. The young nymphs are almost flat dorsally and flat ventrally. Mature pupae (1.06 mm long and 0.34 mm wide) have a swollen ventral surface and are surrounded by a band of wax. Waxy growths can be up to 8mm long. The nymphs are colourless or yellowish, almost oval.
Adult	*Bemisia tabaci*: The adults of the insect are between 0.8 and 1 mm long with a wingspan of 2.5 mm, the male being smaller than the female. The antennae are short. The two pairs of wings are white, rounded and folded over the back in the form of a roof. The body is white or pale yellow. The wings as well as the body are covered in a white mealy wax. *Aleurodicus dispersus*: Male adults are around 2.2 mm long, while females are smaller (1.7 mm). The forewings have two characteristic dark spots.

Figure 49 — Eggs of *Aleurodicus* laid in a spiral pattern
https://gms.ctahr.hawaii.edu/gs/handler/getmedia.ashx?moid=61814&dt=2&g=14

Figure 50 — *Bemisai tabaci larvae*
INRA-Versailles, Institut National de la Recherche Agronomique, Bugwood.org

Figure 51 — *Aleurodicus dispersus larvae*
https://ephytia.inra.fr/fr/I/42767/Aleurodicus-dispersus-larves

Figure 52 — *Bemisia tabaci* puparium
Central Science Laboratory, Harpenden, British Crown, Bugwood.org

Figure 53 — *Aleurodicus* disperus puparium on the left
https://nrcb.icar.gov.in/album/Spiralling%20whitefly%2C%20Aleurodicus%20dispersus/slides/spw5.jpg

Figure 54 — Adult *Aleurodicus dispersus*
https://bugwoodcloud.org/images/1536x1024/2131041.jpg

Figure 55 — Adult *Bemisia tabaci*
https://gd.eppo.int/media/data/taxon/B/BEMITA/pics/1024x0/285.jpg

CROP STAGE(S) AFFECTED

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
+	+	++	++	+	0	0

SYMPTOMS AND DAMAGE

Whiteflies settle by preference on the underside of the leaves, but the whole plant can be covered in the event of a major infestation.

LEAVES	Presence of *larvae*, puparium and adults mainly on the underside. Attacks can cause wilting or yellowing of the leaf blade and downward-facing curling. Sooty mould rarely develops on taro.
WHOLE PLANT	General weakening of the plant (and even wilting) in the event of severe attacks and drought.

IMPACT ON YIELD AND QUALITY

TYPE OF IMPACT	DESCRIPTION
Yield loss per plant	Reduction by weakening of plants due to wilting and downward curling of leaf blades
Reduction in quality	Leaves infected with honeydew or sooty mould are devalued for marketing.

Bemisia tabaci is not known to transmit taro viruses.

QUARANTINE ORGANISM

Bemisia tabaci is considered a quarantine organism by the EU, which means it cannot be imported on products destined for the EU. This mainly concerns the leaf trade as the corms do not harbour whiteflies.

Aleurodicus dispersus is not a quarantine organism in the EU.

CONDITIONS CONDUCIVE TO INFESTATION

TYPE	CONDUCIVE CONDITION	IMPACT / EXPLANATION
Weather conditions	Low humidity and high temperature.	Rapid development of populations. Generally, whiteflies do not survive in the field in extremely wet conditions.

MONITORING

Whiteflies are usually detected by examining the underside of leaves and looking for attached larval stages. *Larvae* are also occasionally found on the upper side of leaves and may be scattered or form dense groups. Shaking the plant can disturb the adults, which quickly fly off and resettle.

The spirally arranged eggs and the presence of white waxy material, which covers the immature and adult stages on the underside of the leaves, is visible and distinctive for *Aleurodicus dispersus*. Note that other whitefly species also lay spiral eggs. (Carmichael A., *et al.*, 2008)

Identification can be made from the fourth morphological stage, which requires glass plate mounted specimens and taxonomic keys. (Carmichael A., *et al.*, 2008)

BY TRAPPING

You can also monitor populations with traps to observe general trends in pest populations present in the fields. Since adult whiteflies are strongly attracted to yellow, sticky traps can be made using yellow plastic covered in glue or other sticky substances, such as grease. However, these traps should not be used regularly and in large quantities as they also catch and kill beneficial insects, such as *Encarsia*, which prey on whiteflies. These sticky traps should only be used for monitoring and not for control. Yellow sticky traps also attract thrips, aphids and leaf miners to varying degrees.

CONTROL THROUGH GROWING PRACTICES

The practices mentioned below help to control the pest. Crop rotation is difficult to achieve given the high number of hosts for these insects.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
PRIOR CHOICES		
Choice of plot location	It is advisable that new crops are planted in the opposite wind direction in relation to older crops.	This will reduce migration of adults from the older crops to the young crops in the direction of the wind.
PREPARATION OF THE PLOT		
Planting windbreaks between plots	Windbreaks reduce the movement of whiteflies from one plot to another.	New infestations are reduced.
Installation of grass strips or flowering hedges	See biological control through conservation below.	Control by auxiliaries is strengthened.
CROP MAINTENANCE		
Rational irrigation	In dry weather, regular overhead spray watering disturbs whitefly populations.	The population decreases.
Removal of plants that have reached the end of production	The crop residues removed should be quickly ploughed into the ground, fed to livestock or burned to prevent the spread of whiteflies.	Elimination of sources of infestation for neighbouring crops

BIOLOGICAL CONTROL

THROUGH CONSERVATION OF THE AUXILIARIES PRESENT

Biological control is ensured in most cases by auxiliaries.

There are several natural enemies of whiteflies that are present on farms. These include parasitic wasps such as *Eretmocerus* spp. and *Encarsia* spp. (eg *Encarsia haitiensis*), predatory mites such as *Amblyseius* spp. and *Typhlodromus* spp., predatory thrips, lacewings, rove beetles and ladybirds (*e.g. Clitostethus arcuatus*).

Their presence must be conserved by using PPPs compatible with the crop auxiliaries.

The presence of parasitic wasps can be encouraged on a farm by the presence of flowers which bring useful nectar to the adults. See point 8.1.3.

BY RELEASES OF AUXILIARIES

For example, after first being reported in Hawaii in 1978, the spiralling whitefly was controlled by the introduction of five natural enemies to Hawaii from the Caribbean. One of the three coccinellids, *Nephaspis oculatus* (formerly *N. amnicola*), has been shown to be effective in controlling high whitefly population densities. Although the majority of prey are nymphs, this beetle feeds on all stages of whiteflies. Two parasitic wasps, one of which is the *Encarsia haitiensis*, were the most effective, especially against low whitefly population densities. Predators introduced to control other pests can also help reduce populations of spiralling whiteflies, particularly the coccinellid beetles *Delphastus* (formerly *Nephaspis*) *pusillus* and *N. bicolor*, which also attack other species of whiteflies as well as many mealybugs and aphids. (James L. Martin Kessing *et al.*, 1993).

CONTROL USING PLANT PROTECTION PRODUCTS (PPP)

The use of PPPs is not a recommended method to manage this pest on taro crops as attack levels are generally low.

SUBSTANCES

Recommended substances are listed in Appendix 3.

The control of *Bemisia* is sensible if taro leaves are exported to the EU. Several biocontrol products could be used but their effectiveness on taro crops is not known. The substances include the following: *Metarhizium anisopliae*, *Beauveria bassiana*, *Paecilomyces fumosoroseus*, *Verticilium lecanii*, azadirachtin and extracts of neem, pyrethrins, sweet orange essential oil, oxymatrine, *Chromobacterium subtsugae* strain PRAA4-1, fatty acids and horticultural oils.

OTHER CONTROL METHODS

No information available.

8.2.2.4. TARO LEAFHOPPERS

SCIENTIFIC NAME

The leafhopper *Tarophagus proserpina* develops only on taro (*Colocasia*). Present only in Oceania and Hawaii.

Other taro leafhoppers are: *Tarophagus colocasiae* (present in several countries in Asia and Oceania and in the United States, Cuba and Hawaii) and *T. persephone* (present in several countries in Asia and Oceania).

It is part of the order Homoptera and the family Delphacidae.

LIFE CYCLE OF THE PEST

STAGE	DESCRIPTION
Egg	Eggs are laid in holes made by female taro leafhoppers in the midvein of the underside of the leaf and at the base of leaf petioles or stems.
Larva	There are five larval stages, which last about 19 days, depending on weather conditions.
Adult	Jumping insect, on leaves (lower and upper sides) and stems.

Larvae and adults concentrate on the underside of the leaves and suck the sap.

DESCRIPTION/IDENTIFICATION

OTHER HOST PLANTS

Taro leafhoppers feed mainly on taro, although they have been observed on *Alocasia* spp. and *Cyrtosperma* spp.

DESCRIPTION OF THE INSECT

STAGE	DESCRIPTION
Egg	The eggs are not visible because the females lay them inside the leaf veins.
Larva	Young *larvae* are creamy white, and the third to fifth larval stages are mostly black or brownish with white markings.
Adult	The adults, 3 to 5 mm long, have a black or blackish-brown body with a whitish longitudinal stripe on their back. Adults are of two types: they are either short-winged for most of the year or long-winged for cooler periods, when the plant is maturing and beginning to die. Taro leafhoppers normally move laterally, but *larvae* and adults jump easily if disturbed.

Figure 56 — Sap oozing from oviposition bites made by the leafhopper on a taro petiole. Photograph by Alexander Tasi, University of Florida
https://entnemdept.ufl.edu/creatures/images/Tarophagus_colocasiae03.jpg

Figure 57 — Mature *larvae*
https://apps.lucidcentral.org/pppw_v10/images/entities/taro_planthopper_041/thumbs/tarophagus_wingless_sml.jpg

Figure 58 — Winged adult
https://apps.lucidcentral.org/pppw_v10/images/entities/taro_planthopper_041/thumbs/tarophaguswinged_sml.jpg

CROP STAGE(S) AFFECTED

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
+	++	+++	+++	++	0	0

SYMPTOMS AND DAMAGE

LEAVES	The *larvae*, like the adults, cluster together on the undersides of the leaves and suck the sap which, as it flows, causes a reddish crust on the leaf blade and brown/black spots on the petioles. In the event of a major attack, the leaves can die prematurely.
WHOLE PLANT	Wilting in the event of a major attack and dry period.

Figure 59 — *Tarophagus* leafhoppers prefer sites on the plant where humidity is highest, either inside the rolled leaf, on the petioles below the leaf blade, or between the petioles at the base of the plant
https://apps.lucidcentral.org/pppw_v10/images/entities/taro_planthopper_041/thumbs/tarophagusonpetiole3_sml.jpg

Figure 60 — Severe leafhopper infestation
https://apps.lucidcentral.org/pppw_v10/images/entities/taro_planthopper_041/thumbs/img_8092_sml.jpg

IMPACT ON YIELD AND QUALITY

Leafhoppers are serious pests, damaging plants directly by feeding on them and indirectly by spreading viruses.

TYPE OF IMPACT	DESCRIPTION
Loss of plants	In heavy infestations, the plants may die.
Yield loss per plant	Reduction by weakening of plants due to wilting of the leaves.
Reduction in quality	Reduction in quality of marketed leaves.

The pest is a vector of the *Alomae Bobone* viral complex.

QUARANTINE ORGANISM

It is not a quarantine organism in the EU.

CONDITIONS CONDUCIVE TO INFESTATION

TYPE	CONDUCIVE CONDITION	IMPACT / EXPLANATION
Climate	Dry season	Heavy rains reduce leafhopper populations. The youngest nymphs are particularly susceptible to drowning in the water that collects between the bases of the petioles. (Helen Tsatsia *et al.*, 2021).

MONITORING

Taro leafhoppers are easily found on the underside of leaves, inside leaves that are just beginning to unfurl, and at the base of young petioles. Older petioles appear dirty as sap oozes from the perforated cells and dries to form a brown crust.
(Carmichael A., *et al.*, 2008)

CONTROL THROUGH GOOD GROWING PRACTICES

The practices mentioned below help to control the pest.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
PRIOR CHOICES		
Choice of plot location	It is advisable to avoid growing on land with a severely infested prior crop or near a severely infested crop. As *Tarophagus* spp. are generally brachypterous and therefore limited in their ability to disperse, infestation of new plantings is avoided if healthy cuttings are planted away from old infested plantings.	Avoidance of the arrival of new adults.
PREPARATION OF THE PLOT		
Installation of grass strips or flowering hedges	See biological control through conservation below.	Control by auxiliaries is strengthened.
PLANTING		
Cutting preparation	Remove the base of the petiole on cuttings as they often contain hidden leafhopper eggs.	A considerable reduction in *Tarophagus* infestation is achieved by planting healthy cuttings only.
CROP MAINTENANCE		
Destruction of leaves after harvest	Collect and burn or bury all old leaves discarded during harvesting.	Spread is avoided by breaking the cycle.

BIOLOGICAL CONTROL

THROUGH CONSERVATION OF THE AUXILIARIES PRESENT

Several species of auxiliaries parasitise the eggs and nymphs. Spiders and ladybird *larvae* also feed on them. However, ants raise leafhoppers, most likely attracted by the honeydew produced when they suck the sap from the leaves. In this case, they can protect them from parasitoids and predators.

BY RELEASES OF AUXILIARIES

The *Cyrtorhinus fulvus* egg-sucking mirid bug has successfully controlled *Tarophagus* spp. in many parts of the Pacific, but *C. fulvus* is unlikely to reduce populations enough to prevent the spread of *alomae* and *bobone* virus diseases. (Carmichael A., *et al.*, 2008)

CONTROL USING PLANT PROTECTION PRODUCTS

PERIODS AND METHODS OF APPLICATION

An insecticide can be applied preventively to the cuttings by soaking them for 10 to 15 minutes in an insecticide solution (*e.g.* malathion).

After planting, you can also apply a systemic insecticide by watering the base of the plants.

If the pest is detected on the plant in the field, an insecticide can also be applied by spraying.

During foliar treatments, take care to spray the underside of the leaves where most of the leafhoppers are located. A wetting agent is essential to ensure the good distribution of the product on the taro leaves.

SUBSTANCES

Recommended active substances are listed in the table in Appendix 3. Azadirachtin is the only biocontrol substance that could be used.

OTHER CONTROL METHODS

No information available.

8.2.2.5. SCARAB BEETLES

SCIENTIFIC NAME

Several species of the genus *Papuana* attack taro: *P. woodlarkiana*, *P. biroi*, *P. ininermis*, *P. huebneri*, *P. szentivanyi*, *P. trinodosa* and *P. uninodis*.

Eucopidocaulus ssp. scarab beetles also attack taro.

The macabo is also secondarily attacked by these beetles.

This pest, present in Indonesia and in the countries of Melanesia, has a considerable impact on the cultivation of water taro in Papua New Guinea, the Solomon Islands and Vanuatu. It is not present in Africa.

These beetles are part of the order Coleoptera and the family Scarabaeidae.

LIFE CYCLE OF THE PEST

These insects have a life cycle that takes place on two types of host plants, main and secondary. The main hosts, attacked by the adults, are primarily taros but other *araceae* and cultivated plants are susceptible too. The secondary hosts on which the *larvae* develop are primarily grasses. This multiplicity of host plants makes taro scarab beetles even more destructive, and controlling these insects is all the more difficult.

STAGE	DESCRIPTION
Egg	Eggs are laid 5-15 cm below the ground near a host plant.
Larva	The *larvae* hatch from the eggs in 11 to 16 days. The larva feeds on the plant roots and dead organic matter at the base of host plants. The larva moults about three times during its 3-4 month life cycle, then turns into a pupa.
Pupa	After around two weeks, the adults develop from the pupa.
Adult	Adult beetles fly from breeding sites to the taro field and tunnel into the ground just at the base of the corm. They then feed on the growing corm. The adult lives for 4 to 8 months. After feeding for about two months on the taros, the female flies off to the surrounding vegetation to lay her eggs.

DESCRIPTION/IDENTIFICATION

OTHER HOST PLANTS

The main hosts, attacked by the adults, are mainly *Colocasia* taros (dasheen and eddoe), but also other *Araceae*, like the macabo (*Xanthosoma sagittifolium*), and various cultivated plants (sugar cane, banana tree, sweet potato, yam etc.).

The secondary hosts on which the *larvae* develop are mainly grasses, like *Sorghum verticilliflorum*, *Pennisetum purpureum*, *Imperata cylindrica* and *Phragmites karka*. (Anonymous, 2022).

DESCRIPTION OF THE INSECT

STAGE	DESCRIPTION
Egg	The eggs are *cylindrica*l and brown or white in colour.
Larva	*Larvae* are translucent when hatched and take on the colour of surrounding debris when they begin to feed.
Pupa	Fully developed *larvae* develop into pre-pupae and pupae, creating pupal chambers at the breeding sites.
Adult	The beetles are 15 to 25 mm long and half as wide. For most species, the males have a horn on their head and a bulge at their base. The females sometimes have these attributes but on a smaller scale. The body is dark brown and very shiny during the first months.

Figure 61 — Adult
https://apps.lucidcentral.org/pppw_v10/images/entities/taro_papuana_beetle_030/taro_beetle_new.jpg

Figure 62 — Different stages of development.
Guide to good phytosanitary practices for growing taro and macabo in ACP countries. (April 2011) COLEAD

CROP STAGE(S) AFFECTED

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
0	+	++	+++	+++	+++	0

SYMPTOMS AND DAMAGE

CORM	The damage is caused by the adults which dig galleries in the corms up to the terminal bud.
WHOLE PLANT	Young plants wilt and die, but older plants generally recover.

Figure 63 — Significant and typical damage caused by taro scarab beetle, *Papuana* sp., in taro corms. These corms are unsaleable
https://apps.lucidcentral.org/pppw_v10/images/entities/taro_papuana_beetle_030/oldin1.jpg

IMPACT ON YIELD AND QUALITY

TYPE OF IMPACT	DESCRIPTION
Loss of plants	Young plants can be killed when the beetle invades the shoot.
Yield loss per plant	Decreased weight of corms or cormels as plants grow more slowly and some or all leaves wilt.
Reduction in quality	Devaluation by presence of galleries. Export markets do not tolerate any damage and damage of more than 15% makes the crop unacceptable for local markets. The damage may be such that the corms cannot be used for domestic consumption or livestock feed. (Carmichael A. *et al.*, 2008) In addition, the wounds they create while feeding promote the attack of organisms responsible for rot.

QUARANTINE ORGANISM

These species are not quarantine organisms in the EU.

Internationally, strict quarantine measures must be observed to prevent the spread of the taro beetle to new areas within countries where it is already present, and to countries where it is not present. The planting material, soil, taro and alternative hosts of the beetle should not be moved from infested to uninfested areas. (Carmichael A. *et al.*, 2008)

CONDITIONS CONDUCIVE TO INFESTATION

TYPE	CONDUCIVE CONDITION	IMPACT / EXPLANATION
Soil	Wet soil	More attractive to scarab beetles.

MONITORING

There are three methods of early detection in an area.

- Dig up taro plants that are wilting or appear weak and examine them for symptoms of scarab beetle damage.
- Use a light trap at night, especially on moonless and rainy nights, to catch the beetle.
- Sample other plant species and materials for the beetle: banana trees, sugarcane, rotting logs, compost and sawdust heaps, grasslands where *Paspalum* spp. and *Brachiaria mutica* are dominant, especially along river banks. (Carmichael A. *et al.*, 2008)

CONTROL THROUGH GOOD GROWING PRACTICES

The practices mentioned below help to control the pest.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
PRIOR CHOICES		
Choice of plot location	It is advisable to avoid growing on land with a severely infested prior crop.	Avoidance of the arrival of new adults.
Choice of plot location	Avoid proximity to areas favourable to scarab beetle reproduction: forest clearing, proximity to river banks, tree stumps.	Avoidance of the arrival of new adults.
Make a sanitary vacuum on the farm	Cleaning fallow based on *Glycine wightii* (perennial soybean) for 2 years.	Decline in populations by breaking the cycle.
Combination with a cover crop	Planting taro in a mulch formed by a legume cover crop keeps the taro relatively safe from *Papuana* beetles. The *Mucuna* legume is the cover crop with the greatest potential because it grows vigorously and is an annual. But *Pueraria phasioloides* and other legumes can be just as effective. (Helen Tsatsia *et al.*, 2022).	Avoidance of the arrival of new adults. It is unclear whether this is a physical barrier or whether there is some other reason.
CROP MAINTENANCE		
Ensure regular weeding of the land and surrounding areas	It is recommended that host weeds growing in and along cultivated fields are destroyed.	Decrease in sources of reinfestation.

BIOLOGICAL CONTROL

THROUGH CONSERVATION OF THE AUXILIARIES PRESENT

Several natural enemies have been recorded, including the *Metarhizium* fungus, a tachinid fly and the cane toad, but none is considered effective in controlling populations well enough to stop corm damage.

Other natural enemies include the bacterium *Bacillus popilliae* and the protozoa *Vavraia*.

CONTROL USING PLANT PROTECTION PRODUCTS

This control must be done in combination with other control methods (agronomic, prophylactic and biological), since no single method alone can control this pest. However, the use of PPPs can be effective and economical in large-scale commercial production systems where corms or cormels are produced for the urban or export market. (Carmichael A. *et al.*, 2008)

PERIODS AND METHODS OF APPLICATION

Scarab beetles can be controlled by applying insecticide in the planting holes and then, 3 months after planting, by watering at the base of the plants. (Helen Tsatsia *et al.*, 2022).

SUBSTANCES

Recommended active substances are listed in the table in Appendix 3. The entomopathogenic fungus *Metarhizium anisopliae* is a biocontrol substance.

OTHER CONTROL METHODS

No information available.

8.2.2.6. DEFOLIATING CATERPILLARS

SCIENTIFIC NAME

The following 2 main defoliating caterpillars are found on taro and macabo.

SCIENTIFIC NAME	COMMON NAME	DISTRIBUTION	FAMILY
Hippotion celorio	Taro hornworms	Tropical Africa, South Asia, Australia, Oceania, Arabia, Europe, especially hot regions.	*Sphingidae*
Spodoptera litura	Armyworm	In Asia and the Pacific. In Africa, reported in Ghana and the Central African Republic. In Hawaii.	*Noctuidae*

LIFE CYCLE OF THE PEST

HIPPOTION CELORIO

STAGE	DESCRIPTION
Egg	Eggs are laid individually on the upper and undersides of leaves and on petioles.
Caterpillar	The caterpillars moult four times.
Chrysalis	At the mature stage, the caterpillars move towards the ground, form a cocoon or cell in the leaf litter or just under the ground and turn into a chrysalis.
Adult	The moths are able to fly long distances and are attracted to light.

SPODOPTERA LITURA

STAGE	DESCRIPTION
Egg	The eggs are deposited in clusters on the leaf blades.
Caterpillar	The initial larval stages are gregarious with radial progression from the hatching site. The caterpillars then become solitary. The eat all parts of the blade and can cut the petioles down to ground level. Armyworms destroy large areas of the leaf and, when numerous, can completely defoliate a crop. In this case, the *larvae* migrate in large groups from field to field in search of food.
Chrysalis	Pupation takes place in the ground, near the plants.
Adult	After the emergence of the adults, the peak of egg-laying takes place on the second night. Females mate three or four times in their lifetime, while males mate up to 10 times.

OTHER HOST PLANTS

— *Hippotion celorio*

Most plants of the taro family (*araceae*) but also, for example, sweet potato and ornamental plants.

— *Spodoptera litura*

Other major crop species attacked by *S. litura* in the tropics include cotton, flax, groundnut, jute, alfalfa, maize, rice, soybean, tea, tobacco, vegetables (aubergines, *Brassica*, *Capsicum*, Cucurbits, *Phaseolus*, potatoes, sweet Potatoes and *Vigna* species). Other hosts are ornamental plants, wild plants, weeds and shade trees (*e.g. Leucaena leucocephala*).

DESCRIPTION OF THE INSECT

— *Hippotion celorio*

STAGE	DESCRIPTION
Egg	The eggs vary in size and shape, from nearly spherical (1 mm) to oval, and are clear to bluish-green. Before emergence, they become greenish-yellow.
Larva (caterpillar)	The *larvae* have a red sting on the posterior part of the abdomen. Measuring around only 4 mm on hatching with a pale yellow body, they take on a shiny green colour with age and then dark brown or remain green, at the end of growth, reaching 8 to 9 cm before transforming into a chrysalis. In the second stage, two spots appear on the first and second abdominal segments, resembling eyes. In the third stage, a dorso-lateral yellow line appears, extending from thoracic segment 3 to the base of the horn, and the eyespots take on their final colouration.
Nymph (chrysalis)	Chrysalises are grey-brown, 45-50 mm long, with dark brown spots.
Adult (moth)	Their wingspan is between 4 and 9 cm. They are streamlined and robust in flight, with a conspicuous head and large eyes.

Figure 64 — Egg
http://www.pyrgus.de/Hippotion_celerio_en.html#

Figure 65 — Caterpillar
https://upload.wikimedia.org/wikipedia/commons/thumb/7/70/Hippotion_celerio_larva.jpg/240px-Hippotion_celerio_larva.jpg

Figure 66 — Chrysalis
Photo Serge Wambeke https://www.lepinet.fr/especes/photos/CELERIO-P-20050913-1.jpg

Figure 67 — Dorsal side of the female moth
https://upload.wikimedia.org/wikipedia/commons/thumb/a/a3/Hippotion_celerio_MHNT_CUT_2010_0_73_Malaysia_female_dorsal.jpg/260px-Hippotion_celerio_MHNT_CUT_2010_0_73_Malaysia_female_dorsal.jpg

— *Spodoptera litura*

STAGE	DESCRIPTION
Egg	Egg masses are usually 4 to 7 mm in diameter and cream to golden brown in colour.
Larva (caterpillar)	Young caterpillars (2-10 mm) are pale green and turn dark green to brown when fully grown. They have characteristic bright yellow longitudinal stripes on the back.
Nymph (chrysalis)	The chrysalis is 15-20 mm long, red-brown in colour; the end of the abdomen bears two small spines.
Adult (moth)	The nocturnal moth has a brown-green body 15 to 20 mm long with a wingspan of 30 to 40 mm. The forewings are grey to reddish-brown, with a strongly variegated pattern and paler lines along the veins. The hindwings are greyish-white with grey edges.

Figure 68 — *Spodoptera* egg mass
https://plantwiseplusknowledgebank.org/doi/full/10.1079/pwkb.species.44520

Figure 69 — Last larval stage
https://plantwiseplusknowledgebank.org/doi/full/10.1079/pwkb.species.44520

Figure 70 — Moth
https://plantwiseplusknowledgebank.org/doi/full/10.1079/pwkb.species.44520

CROP STAGE(S) AFFECTED

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
0	++	+++	+++	+	0	0

SYMPTOMS AND DAMAGE

YOUNG PLANT	They can be cut to the ground by *Spodoptera litura*.
LEAVES	The caterpillars devour the leaf blade.

Figure 71 — Severe damage to the taro; the leaves have been eaten, only the petioles remain
https://apps.lucidcentral.org/pppw_v11/pdf/web_full/taro_hornworm_032.pdf

Figure 72 — A caterpillar eating a leaf and leaving only the veins
https://apps.lucidcentral.org/ppp_v9/images/entities/taro_hornworm_032/2310_taro_hornworm_4a.jpg

IMPACT ON YIELD AND QUALITY

TYPE OF IMPACT	DESCRIPTION
Loss of plants	Young plants can disappear if severely attacked or if the stem is cut.
Yield loss per plant	Yield losses can be observed following significant defoliation.

QUARANTINE ORGANISM

HIPPOTION CELORIO

It is not a quarantine organism in the EU.

SPODOPTERA LITURA

Considered a quarantine organism in the EU (Annex II, part A of Regulation (EU) 2019/2072). This means it cannot be imported on products destined for the EU. This mainly concerns the trade in leaves, since corms or cormels do not harbour this caterpillar.

CONDITIONS CONDUCIVE TO INFESTATION

There are no particular conditions to report.

MONITORING

HIPPOTION CELORIO

Larvae can be found on leaves during the day, often on the underside. Leaves should be inspected for damage and to detect larval stages, and specimens should be compared with photographs. If in doubt, caterpillars can be raised to maturity and the adult stage identified. It is advisable to raise a number of caterpillars as some may be parasitised. (Carmichael A. *et al.*, 2008)

SPODOPTERA LITURA

Egg masses are relatively easy to see against the dark green of the leaves. The presence of newly hatched *larvae* can be detected by the "scratch marks" they make on the surface of the leaves. (Carmichael A. *et al.*, 2008)

CONTROL THROUGH GOOD GROWING PRACTICES

The practices mentioned below help to control the pest.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
PREPARATION OF THE PLOT		
Installation of grass strips or flowering hedges	See biological control through conservation below.	Control by auxiliaries is strengthened.
Installation of hedges	Provides shelter for many beneficial insects and insectivorous birds	Control by auxiliaries is strengthened.
CROP MAINTENANCE		
Destruction of leaves after harvest	This prevents caterpillars from turning into chrysalises and then into moths.	Breaks the cycle.

BIOLOGICAL CONTROL

THROUGH CONSERVATION OF THE AUXILIARIES PRESENT

Many native natural enemies have adapted to these pests. The most common parasitoids include the Braconidae Hymenoptera and the Tachinidae Diptera. Predators frequently attack the eggs and small *larvae*; among the most important are the Anthocoridae, the Geocoridae and the Nabidae. The nymphs are subject to attacks, especially by ants. Significant mortality factors vary across crops and geographic regions.

Spraying insecticides can harm the natural enemies. Replacing broad-spectrum PPPs with selective biopesticides, such as Bt, to control these and other pests can allow for the early establishment of natural enemies.

Spodoptera litura is generally well controlled by auxiliaries, although invasions do occur occasionally, especially following cyclones or in isolated areas recently cleared. (Carmichael A. *et al.*, 2008)

CONTROL USING PLANT PROTECTION PRODUCTS

HIPPOTION CELORIO

Insecticides are not normally recommended for the control of caterpillars of this moth on taro. They are only necessary when the natural enemies have been destroyed by cyclones, droughts, or when the plantations are in isolated places. In these situations, insecticide applications can help control populations of this pest. Synthetic pyrethroids are probably effective, but they also kill natural enemies. (Helen Tsatsia *et al.*, 2022).

SPODOPTERA LITURA

Insecticides may be necessary where biological control of *Spodoptera litura* is insufficient, but they should be used with caution so as not to upset the established balance between natural enemies and this pest - otherwise they may do more harm than good. Only products non-toxic to beneficial auxiliaries should be considered.

RESISTANCE MANAGEMENT

Resistance to insecticides has been observed for this pest, so an anti-resistance strategy will have to be implemented by alternating insecticides belonging to different resistance classes.

SUBSTANCES

Recommended active substances are listed in the table in Appendix 3. Biocontrol substances include the following:

- *Bacillus thuringiensis*.
- Azadirachtin.
- *Spodoptera Nuclear Polyhydrosis* Virus for *Spodoptera litura*.

OTHER CONTROL METHODS

Because armyworm caterpillars are large (8-10 cm), they can be easily removed by hand on small areas.

Removal and destruction of leaves infested with egg masses or young *larvae* will help reduce *Spodoptera litura* populations.

8.2.3. NEMATODES

8.2.3.1. ROOT-KNOT, LESION AND RENIFORM NEMATODES

SCIENTIFIC NAME

The 3 main types of nematodes that attack taros are as follows.

- Root-knot nematodes: *Meloidogyne* spp. Mainly *M. incognita*, *M. javanica* and *M. arenaria*. These are part of the order Tylenchida and the family *Heteroderoîdae*.
- Lesion nematodes: *Pratylenchus coffea*. These are part of the order Tylenchida and the family *Pratylenchidae*.
- Reniform nematodes: *Rotylenchulus reniformis* (pantropical on taro and macabo).

These are part of the order Tylenchida and the family *Hoplolaimidae*.

Meloidogyne nematodes are especially damaging, and it is primarily these that will be discussed here.

LIFE CYCLE OF THE PEST

ROOT-KNOT NEMATODES

Meloidogyne is a sedentary endoparasitic nematode, which means that it does not travel very far in the soil and must live inside a plant.

STAGE	DESCRIPTION
Egg	A mass of eggs (500 to 1000) protected by a mucilaginous coating is produced by a large female found inside each of the galls on the roots. The egg mass is released outside the gall.
Juvenile *larvae*	The juveniles hatch from the eggs. This is the free-living stage, where it travels very short distances through the soil to infect new roots. It can only live two weeks outside
Larvae	the roots, seeking a new host plant. Juvenile nematodes die if they do not find a new host within two weeks.
Adult	Juvenile nematodes penetrate the tips of the roots and stay in one place in the root for their entire life. Males and females are differentiated inside the root. Males are rare.
Conservation	*Meloidogyne*s persist for several years in the soil in the form of egg masses protected by a mucilaginous coating, but also thanks to a large number of plants, whether cultivated or not, which ensure their multiplication and conservation.
Spread	Passive spread of eggs and *larvae* occurs through runoff, drainage and irrigation water. *Larvae* actively move short distances in moist soils. Spreading is possible via soil dust, contaminated plants, tillage tools and agricultural machinery.

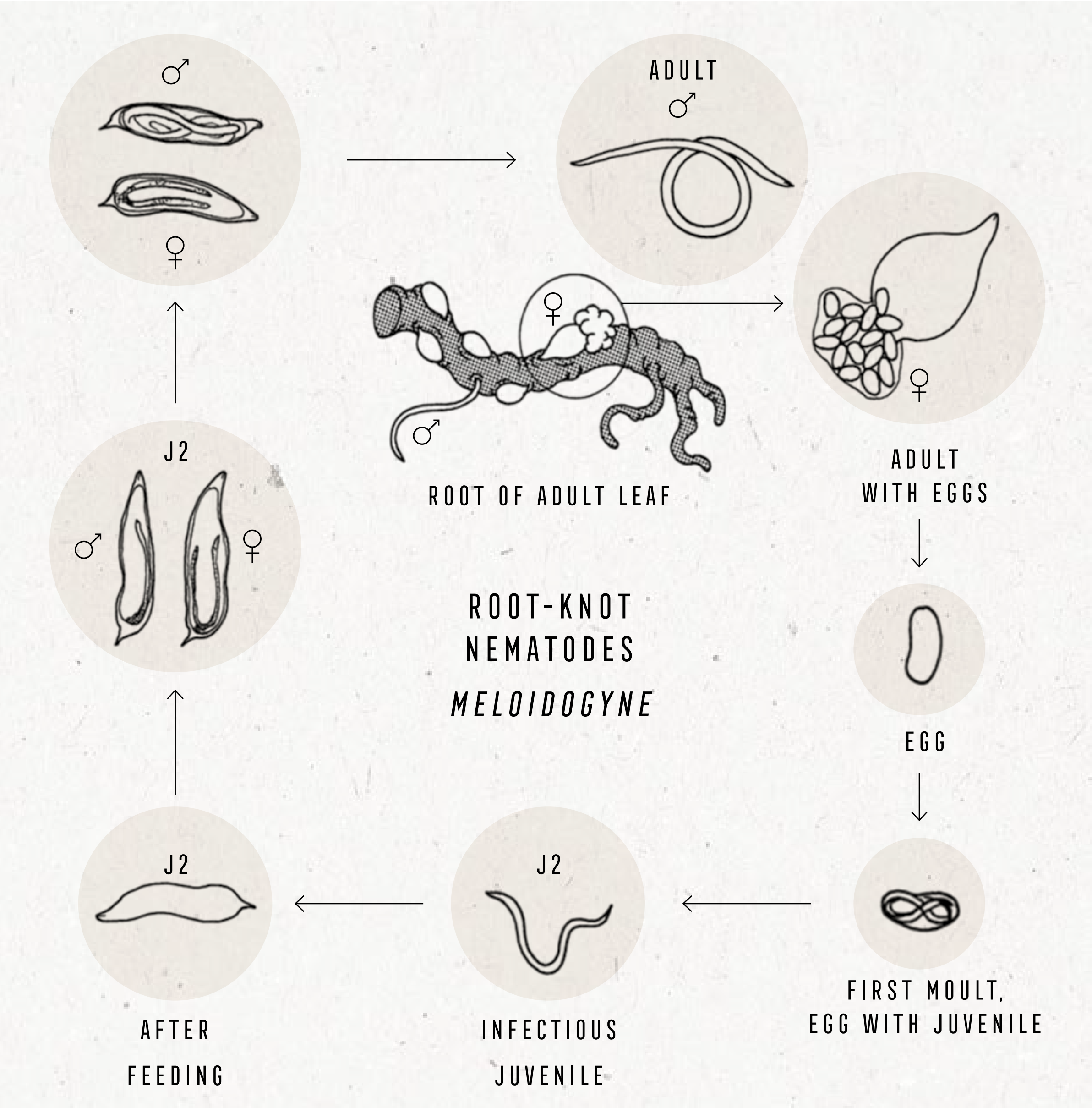

Figure 73 — Root-knot nematode life cycle (2016)
https://www.promusa.org/Root-knot nematodes

OTHER HOST PLANTS

Many crops are hosts to *Meloidogyne*, such as: *Arachis hypogaea* (groundnut), *Musa* spp. (banana), *Oryza sativa* (rice), *Solanum tuberosum* (potato), *Lycopersicon esculentum* (tomato) and almost all vegetable crops except onion, mint, strawberry, garlic and leeks.

Depending on the species, the host plants differ greatly in the genus *Meloidogyne*. In general, plants of the family *Malvaceae*, *Solanaceae*, *Cucurbitaceae*, *Fabaceae*, Apiaceae and Asteraceae are hosts for *Meloidogyne* spp. and are prior crops unfavourable to the cultivation of taro. Banana and papaya are also important host plants.

The root-knot nematode is very cosmopolitan and polyphagous.

DESCRIPTION OF THE PEST

The root-knot nematode is a very small worm, invisible to the naked eye. It "diverts" nutrients from the plant to create large swellings in the roots, where it lives and feeds. These swellings are the characteristic "galls" of the roots, hence its name in French.

CROP STAGE(S) AFFECTED

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
0	+	++	++	++	+	0

SYMPTOMS AND DAMAGE

ROOTS	*Meloidogyne* spp.: In general, the roots are slightly swollen and present no galls. Swollen and deformed roots with galls are very rarely reported. The lesion nematode causes necrosis on the roots.
CORM	*Meloidogyne* cause fairly mild symptoms in taro with limited root swellings and generally minor galls. The lesion nematode causes necrosis on the corms.
WHOLE PLANT	In the field, lesion nematode attacks are often localised on the rows or specific areas where plants show symptoms of wilting and major reductions in growth compared with unaffected areas. Plants attacked sometimes die.

Figure 74 — Symptoms of *Meloidogyne* on corm.
Guide to good phytosanitary practices for growing taro and macabo in ACP countries. (April 2011) COLEAD

Figure 75 — Root necrosis caused by lesion nematode.
Guide to good phytosanitary practices for growing taro and macabo in ACP countries. (April 2011) COLEAD

Figure 76 — Irregular growth due to lesion nematode.
Guide to good phytosanitary practices for growing taro and macabo in ACP countries. (April 2011) COLEAD

IMPACT ON YIELD AND QUALITY

The reduction of the root system and metabolic disorders resulting from the presence of nematodes result in poor plant development and a gradual fall in yields (smaller and fewer corms).

In addition, a reduction in the commercial value of the corms has been observed due to deformations or symptoms.

An attack by root-knot nematodes (*Meloidogyne* spp.) can sometimes cause considerable losses, but generally the degree of damage is small. Root-knot nematodes are particularly serious on eddoe and taro/dasheen type taro in exposed cultivation. *Meloidogyne* populations can be suppressed when taro is grown in very wet or flooded conditions.

Colocasia and *Xanthosoma* are said to be more tolerant to *Meloidogyne incognita* than other crops, and high populations of the nematode must be present in the soil of the field prior to planting for damage to occur. (Carmichael A. *et al.*, 2008)

QUARANTINE ORGANISM

These nematodes are not quarantine organisms in the EU for corms and cormels.

CONDITIONS CONDUCIVE TO INFESTATION

ROOT-KNOT NEMATODES

TYPE	CONDUCIVE CONDITION	IMPACT / EXPLANATION
Weather conditions	Warm period, with cardinal temperatures of 14°C-28°C-32°C). Optimum soil temperatures of 26 to 28°C. The activity would be blocked above 38°C.	At very high temperatures (over 29°C) the cycle takes approximately 3 weeks, but at low temperatures it can take as long as 3 months.
Soil moisture	Saturating irrigation promotes the spread of root-knot nematodes.	Juveniles need free water to move around and infect the roots.
Soil	Sandy, light, low in organic matter and clay.	Juveniles move more easily in this type of soil and attacks are therefore more severe. The migration of juveniles decreases when the clay content in the soil increases.
Soil	Compacted or low moisture, nutritional deficiency.	Increased damage severity.

MONITORING

MELOIDOGYNE SPP.

The presence of *Meloidogyne* spp. in infested soils can be determined by extracting second stage juveniles using a standard procedure for the extraction of free-living nematodes. External symptoms on corms are only evident in heavy infestations. When the presence of the nematode is suspected, but the numbers are low or the infection is in its early stages, cleaning, staining and microscopic examination should be carried out. (Carmichael A. *et al.*, 2008)

LESION NEMATODE

The lesion nematode can be detected by extraction of root and corm tissue, using standard methods, and by high magnification examination. Symptoms are unlikely to be seen on the plant except for the localised necrosis of feeder roots. (Carmichael A. *et al.*, 2008)

CONTROL THROUGH GOOD GROWING PRACTICES

Using crop control methods to manage nematodes is the most environmentally sustainable and potentially the most effective way to limit damage.

The practices listed below help to control root-knot nematodes.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
PRIOR CHOICES		
Choice of plot location	It is recommended that planting in a field that has previously had severe nematode infestations is avoided.	Avoidance of a source of infestation.
Management of irrigation water source	Use borehole water for irrigation in preference to river water, as river water can carry a large number of nematodes. If this is not possible, decant the river water into a tank before using it and let the nematodes sink to the bottom of the tank. Use a floating pump to extract water only from the upper part of the water volume - where there are fewer nematodes.	Avoidance of a source of infestation.
Avoid susceptible prior crops	The following plants are considered tolerant to *Meloidogyne*: *Brassica*s, peppers, radishes, sweet potatoes and turnips. Resistant plants are: cassava, garlic, leeks, maize, millet, onions, shallots, *sorghum* and grasses. *Brassica* crops are not a host for root-knot nematode and can be used in rotation with legumes Additionally, *brassica* crop residues contain a substance similar to certain nematicides, which is released into the soil when it decomposes. If *brassica* crop waste is chopped, dried for two days and then incorporated into the soil, it will reduce the level of nematodes in the soil. This is known as biofumigation. Other good prior crops for taro are fodder crops such as *Paspalum notatum*, *Eragrostis curvula*, *Panicum maximum*, *Chloris gayana*, *Sorghum sudanense* and *Digitaria decumbens*.	Disruption in successive cycles.
Grow prior crops with a nematode-repellent/ nematicide effect	Plant service plants as prior crops with a nematode-repellent/nematicide effect, making it possible to reduce the populations of nematodes in the soil. A certain number of plant species with a nematicidal effect can be recommended but must be validated locally because their antagonistic action is often limited to certain species of nematodes (*Meloidogyne* or *Pratylenchus*), and their effectiveness also depends on the variety of plant species used. Cover crops have the added benefit of stabilising topsoil and improving soil quality. For examples of plants see the table below.	This practice reduces soil infestation
Choose land that is flooded in the rainy season. rains or deliberately flood the land	The ground should be flooded for several months.	Asphyxiation of *larvae*

ACTION	REASON AND/OR DESCRIPTION	EFFECT
Avoid the presence of host trees and shrubs of *Meloidogyne*	Windbreaks that might be hosts (*Euphorbia*, *Prosopis*) and combinations with other host plants with different cycles (papaya, etc.) should be avoided.	Avoidance of a source of infestation.
PREPARATION OF THE PLOT		
Cleaning of agricultural equipment	Equipment used in the fields (ploughs etc.) can move nematodes into the field and should be cleaned, for example with water, after and before use.	Avoidance of a source of infestation.
Rational use of organic matter	Apply compost or manure to restrict the movement of juveniles and strengthen the action of natural enemies and humic acid on nematodes	Physical barrier around the roots. Control by antagonists is strength-ened.
Installation of hedges	Hedges reduce the risk of rainwater runoff, which is a mode of movement of juvenile nematodes.	Barrier to new sources of soil infestation.
PLANTING		
Choice and sanitation of cuttings	Avoid those coming from infested plots, wash them well to avoid transporting soil that might bring in nematodes. To control *Meloidogyne*, the plant material to be planted is treated with 50°C water for 40 minutes. (Jeri J. Ooka) To prevent lesion nematode, necrotic tissue should be removed from cuttings (around 40 cm of the petiole and 1-2 cm of the corm) and suckers, which should then be washed under running water and left to dry before being planted. (Carmichael A. *et al.*, 2008)	Avoidance of a source of infestation
ENTRETIEN DE LA CULTURE		
Uprooting plants that have reached the end of production and destroying them	Remove and destroy waste from the field immediately after harvest to avoid increasing populations in the field	Reduction of inoculum in the soil.
Tillage at the end of cultivation	It is possible to eliminate root nematodes by drying out the soil using discing operations (depth of 30 cm) after removal of the infested crop. Part of the root nematode egg deposits, which had remained in the soil after the removal from the crop, will be killed by desiccation.	Disruption in successive cycles.

Table 16 — Examples of species available as prior crops with nematode-repellent action

SCIENTIFIC NAME	FRENCH/ENGLISH NAME	OBSERVATIONS
1. *Tagetes erecta* 2. *T. patula* 3. *T. minuta*	1. Tagète africaine/African marigold 2. Oeillet d'Inde/ French marigold 3. Tagète des parfumeurs / Mexican marigold *	Service plant used as prior or combined crop. * in particular the Nemanon® variety
Arachis hypogea	Arachide/groundnut	Crop
Cajanus cajan	Pois d'angole/pigeon pea	Crop
Calopogonium sp.		Service plant, legume
Crotalaria juncea	Crotalaire/*Crotalaria*	Service plant Strong action against *Pratylenchus coffea* as a previous crop or as combined crops
Macroptilium atropurpureus	Siratro	Service plant Legume, antagonist of *Meloidogyne* sp.
Mucuna atterrima (syn. *Styzolobium atterrimum*)	*Mucuna* noire/black *mucuna*	Service plant
Panicum maximum var. trichoglume	Herbe de Guinée/Guinea or Buffalo grass	
Sesamia indica	Sésame/sesame	Crop
Vigna unguiculata	Niébé/cowpea	Crop

Source: Guide to good phytosanitary practices for growing taro (*Colocasia esculenta*) and macabo (*Xanthosoma sagittifolium*) in ACP countries. COLEAD (2011).

Service plants can be used as fallow grown in a mixture (cocktail) or as a pure crop. The cocktail has the advantage of having a broader spectrum anti-nematode effect. Its disadvantage is that it is more difficult to avoid natural re-sowing by seeds, since the different species have different cycles. Pure crops avoid these drawbacks if mowing is done before seed production, but the spectrum of antagonistic action on nematode species is narrower. The crop should be mowed before seed production and ploughed into the ground.

BIOLOGICAL CONTROL

Various organisms present in the soil attack nematodes. Predatory fungi (*Arthrobotrys* spp.) trap nematodes and feed on them. Other fungi (*Paecilomyces* spp. and *Verticilium* spp.) kill nematode eggs. Nematodes can also be parasitised by various fungi with adhesive spores. Mycorrhizae, fungi associated with the roots of plants, protect the plant against nematodes. Bacteria (*Pasteuria penetrans*) also parasitise nematodes. Other microorganisms produce nematicidal toxins.

It is therefore necessary to take all possible measures to avoid stopping the action of this natural activity, which is a decisive, if not essential, element in the regulation of crop pest populations.

Maintaining a high organic matter content in the soil plays an important role in supporting beneficial microflora.

CONTROL USING PLANT PROTECTION PRODUCTS

The use of nematicides is not considered economical for taro cultivation. It is advisable to use nematicides only in the case of multiplication plots not intended for consumption.

OTHER CONTROL METHODS

SOLARISATION

Ploughing with solarisation (sterilisation of the soil under the effect of solar radiation) under transparent plastic tarpaulin, disinfection of the soil with steam can, over limited surfaces, be a suitable solution to limiting populations of nematodes in the plots.

8.2.4. FUNGAL DISEASES

8.2.4.1. TARO LEAF BLIGHT

SCIENTIFIC NAMES

The pathogen is *Phytophthora colocasiae*: on taros (*Colocasia*), macabo (*Xanthosoma*) is not attacked.

It is part of the oomycetes lineage.

It is reported in many countries of Asia and Oceania as well as in Africa (Cameroon, Equatorial Guinea, Ethiopia, Ghana, Nigeria and Seychelles), Hawaii and the Dominican Republic.

In some countries/territories, taro leaf blight is present but causes relatively minor economic damage. This is true of the Philippines, Thailand and Hawaii. In other cases, such as Samoa and American Samoa, the disease can be devastating. This situation has given rise to speculation that there are various strains of *Phytophthora colocasiae*, and that in Southeast Asia in particular, some of these strains have evolved concurrently with taro cultivation and are less virulent. This factor is in addition to differences in the genetic heritage and genetic diversity of taro cultivation in each country. (Anonymous, 2022).

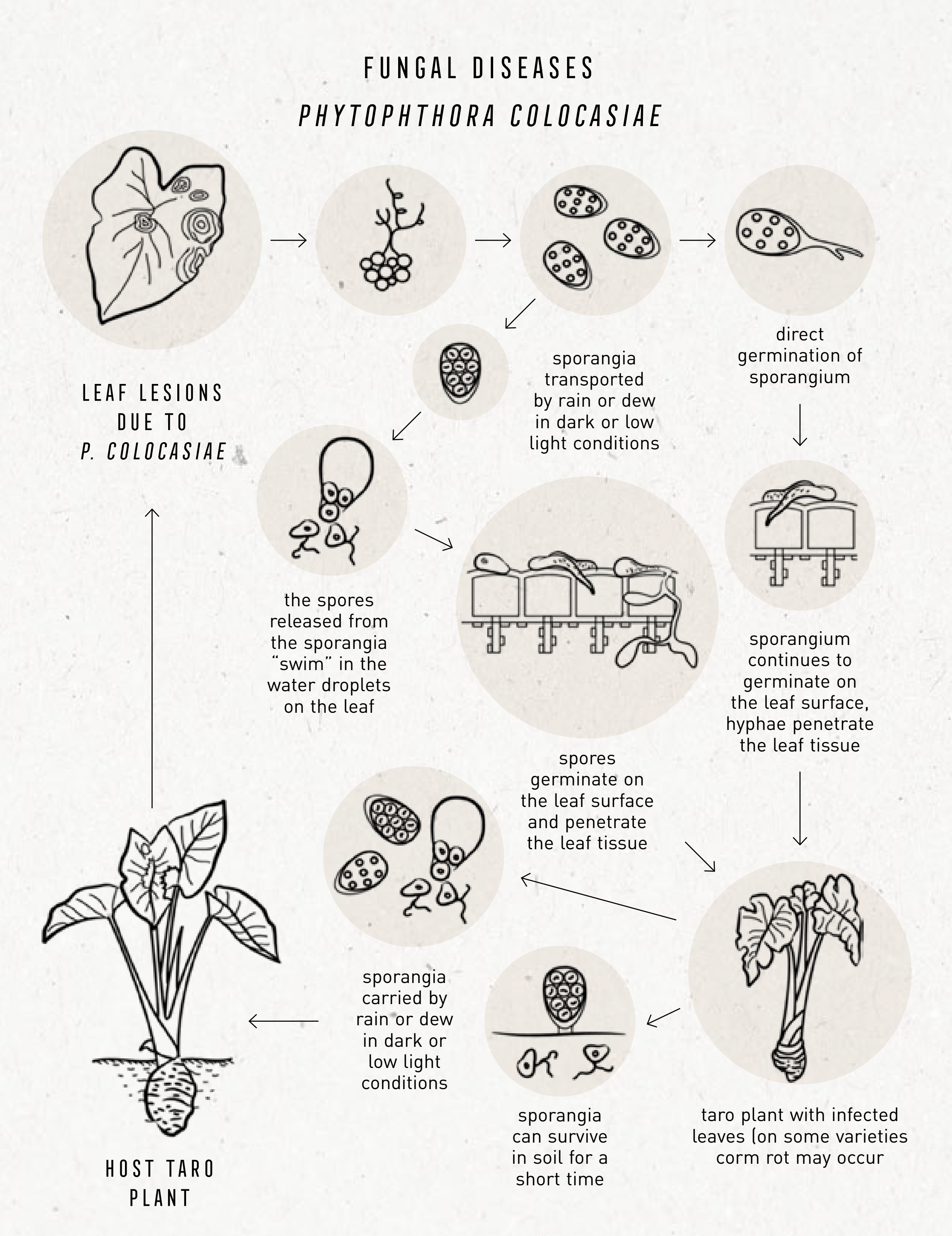

Figure 77 — *Phytophthora colocasiae* cycle
Guide to good phytosanitary practices for growing taro and macabo in ACP countries. (April 2011) COLEAD

DESCRIPTION/IDENTIFICATION

OTHER HOST PLANTS

The disease also attacks *Alocasia macrorrhiza*, a commonly grown aroid in the Pacific region, but symptoms and yield losses are less severe.

CROP STAGE(S) AFFECTED

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
++	++	+++	+++	++	++	++

SYMPTOMS AND DAMAGE

PETIOLE	The disease does not usually attack the petioles, which die back later as the leaf blade deteriorates. In American Samoa and Samoa, where taro varieties are very susceptible to the disease, the infection frequently affects the petioles. (Carmichael A., *et al.*, 2008).
LEAVES	Small, circular, dry-looking, light brown spots on the upper side of the leaves and wet-looking, purple to brown, on the underside are the first visible symptoms of this fungus. The spots usually start on the parts of the blade where the water collects. The spots then grow in an irregular shape and become dark brown with yellow margins. The leaf blade can be completely destroyed in 10 to 20 days. (Anonymous, 2022). In the morning, you can see the sporiferous zones around the spots from which light yellow or red droplets seep. These harden as they dry in the form of dark brown granules. This is a characteristic aspect of the disease. Spores can be trapped in the granules. The spots that initially appeared give rise to secondary infections and, soon after, the leaf blade collapses and dies.
CORM	The fungus can also cause post-harvest corm rot but this is difficult to detect unless the corms are split open. The rotten parts are hard and light brown in colour.

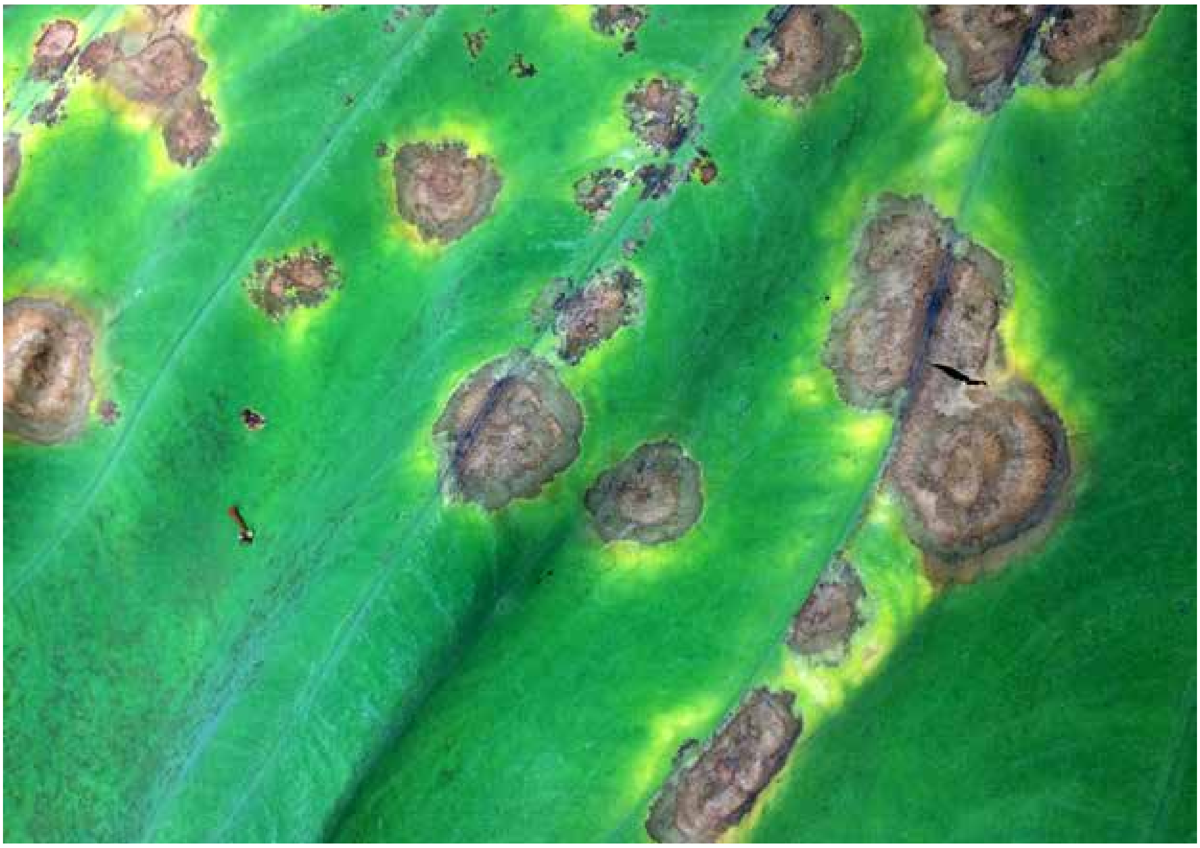

Figure 78 — Spots on leaf
Public domain - Released by Scot Nelson/via Flickr

Figure 79 — Marginal necrosis
Photo: Philippe Vernier

Figure 80 — Droplets associated with taro leaf blight form on the underside of the leaf and harden into balls when they dry. Leaf spots of other taro-infecting fungi do not
https://apps.lucidcentral.org/pppw_v10/images/entities/taro_leaf_blight_014/thumbs/dropletstaroleaf_sml.jpg

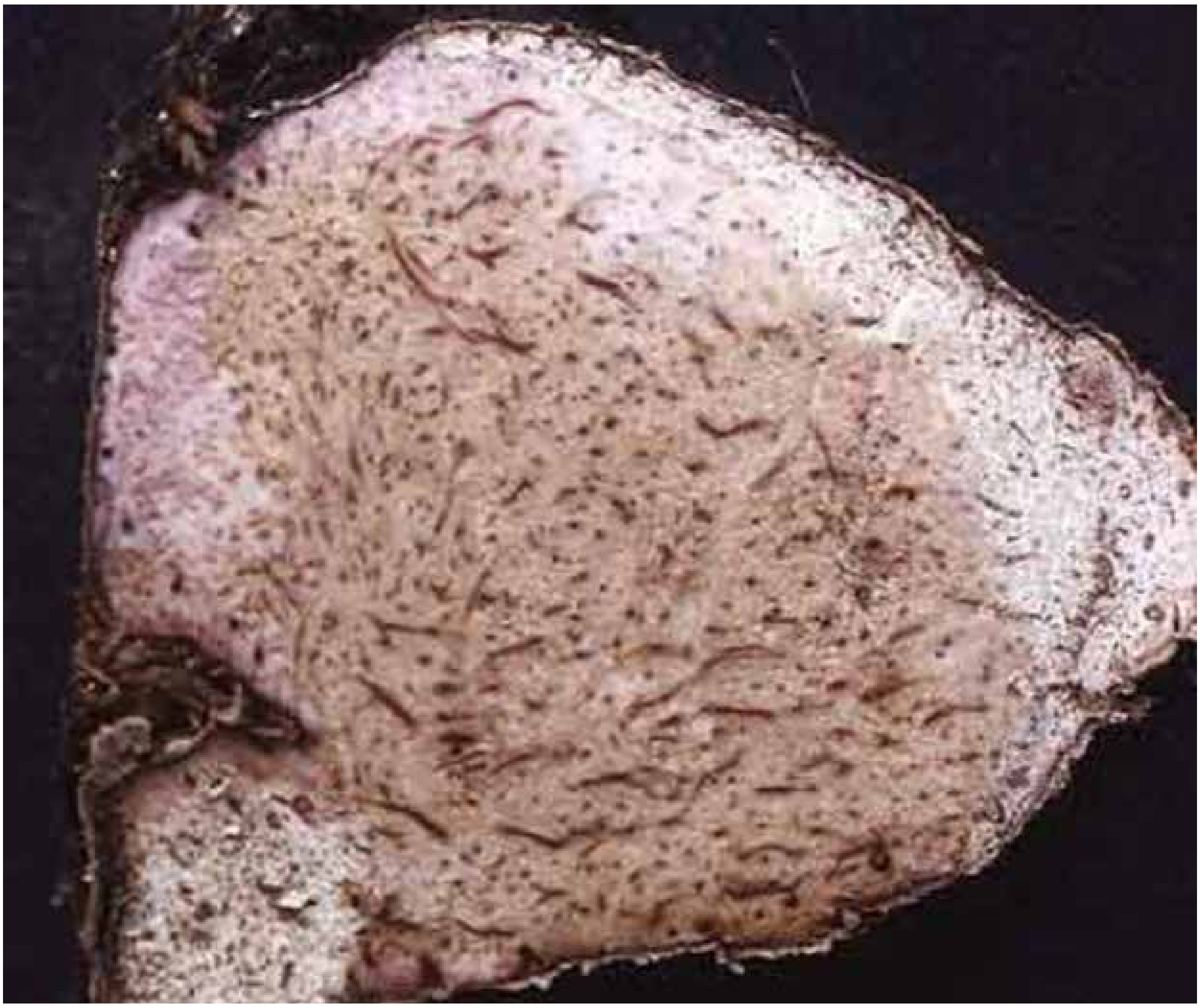

Figure 81 — Firm light brown rot in a corm
https://apps.lucidcentral.org/pppw_v10/images/entities/taro_corm_rots postharvest_179/thumbs/pcolrot_sml.jpg

IMPACT ON YIELD AND QUALITY

This is the most damaging disease to taro, especially in the Pacific, where it has caused considerable losses, *e.g.* in the Solomon Islands, where cultivation had to be partly replaced by sweet potato.

Plants infected with the disease have fewer leaves than others. In a healthy plant, the leaves last up to around forty days, while those infected with the fungus die after ten to twenty days. Instead of six to seven leaves each, infected plants bear only three or four. The disease can also cause a reduction in the size of the planting material, which, in turn, has an effect on the yield of the corm or cormel. (M.G.V.H.Jackson., 2001).

TYPE OF IMPACT	DESCRIPTION
Loss of plants	Possible destruction of plants
Yield loss per plant	Reduction if severe attack and non-resistant variety. This disease can cause yield losses of 30 to 50%. (Anonymous, 2022).
Reduction in quality	Possible corm rot. Rots that develop during storage destroy the corms within 5 to 10 days after harvest. Taro leaves intended for human consumption are rendered unsaleable.

QUARANTINE ORGANISM

It is not a quarantine organism in the EU.

At the international level, strict phytosanitary control measures must be implemented to prevent the disease from spreading to countries that are free from it. Any movement of plant material from one country to another should be limited to sending sterile seedlings from tissue culture media. These seedlings should also be tested for virus detection. (M.G.V.H.Jackson., 2001).

CONDITIONS CONDUCIVE TO INFESTATION

TYPE	CONDUCIVE CONDITION	IMPACT / EXPLANATION
Weather conditions	Temperature of 25-28°C and humidity of 60-70% during the day, cool nights (20-22°C) and very humid. Light rain or heavy dew in the morning favours dispersal. The very delicate spores wither and die in two to three hours in sunny weather as the humidity drops. (M.G.V.H.Jackson, 2001)	Ideal conditions for the production and germination of spores.
Climate	Rainfall above 2,500 mm and rainfall regularly distributed throughout the year. (M.G.V.H.Jackson., 2001)	Particularly high incidence of the disease.

MONITORING

The plants should be inspected at least twice a week. It is extremely important you do this also within 3-4 days following heavy rain, gusty winds or cyclones. (M.G.V.H.Jackson, 2001)

On the leaves, spots caused by *Phytophthora colocasiae* are visible to the naked eye. Microscopic examination of spore masses is necessary to identify them. (Carmichael A., *et al.*, 2008)

Taro leaf blight should not be confused with pitting which is a disease caused by species of the *Phoma* group. Brown spots bordered with yellow up to three centimetres in diameter form on the surface of the leaves. At first, they look like blight spots on taro leaves. They then stop growing and only rarely join up. Eventually, they burst in the centre and give the leaf the riddled appearance of a bullet hole, characteristic of the pitting disease. (M.G.V.H.Jackson, 2001)

Corms can carry spores on the surface (undetectable) and mycelium in post-harvest rot. Corms must be opened to detect rot. (Carmichael A., *et al.*, 2008).

CONTROL THROUGH GOOD GROWING PRACTICES

The practices mentioned below help to control the disease.

Crop rotation is not an effective control method since the fungus is not carried in the soil.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
PRIOR CHOICES		
Use resistant cultivars	Taros originating from the Federated States of Micronesia and Palau are more resistant than those grown in other islands of the Pacific. Varieties with disease resistance characteristics have been obtained in Papua New Guinea, Samoa and the Solomon Islands. (M.G.V.H.Jackson, 2001) Resistant material can be obtained in particular from the Regional Germplasm Center of the Pacific Community based in Fiji. For any international exchange of genetic material, it is mandatory to respect the international rules for the protection of genetic resources governed by the International Treaty on Plant Genetic Resources for Food and Agriculture of the FAO, see: https://www.fao.org/plant-treaty/en/	Less or no effect of the disease on plant growth.
Choice of plots	Isolated, far from other taro fields, surrounded by tall vegetation (forest clearing etc.). When the plots are close by, synchronise the taro planting dates as much as possible. This avoids contaminating young plantations from affected plots which constitute a large stock of inoculum. Plantations near the sea seem to be less prone to infection, perhaps due to the drying effect of offshore winds. (M.G.V.H.Jackson, 2001)	This prevents the fungus from being introduced into a healthy site.
Crop combinations	This helps reduce plant-to-plant transmission. Combinations with double rows of *sorghum* or millet would be effective in reducing the incidence of the disease. (S.K. Sugha *et al.*, 2022).	Reduces the conditions conducive to infestation.
Period and place of planting	Grow taro during dry periods or when grown in low altitude regions where hot and dry conditions are unfavourable to the development of mildew.	Reduces the conditions conducive to infestation.

PLANTING		
Adapt the planting density	A wide spacing between plants can help reduce the incidence of the disease but, more often than not, this precaution is futile if the conditions are particularly favourable to the development of the fungus. (M.G.V.H.Jackson, 2001)	Reduces the conditions conducive to infestation.
Choice of cuttings	Use cuttings from disease-free plants.	This prevents the fungus from being introduced into a healthy site.
Mulching	Mulch crops with *eupatorium*, neem, eucalyptus or cereal straw.	Delays the onset of disease by 5 to 9 days and reduces the severity of the disease.
CROP MAINTENANCE		
Eliminate diseased leaves	Diseased leaves (or just the infected part) must be removed as soon as they are detected and then eliminated them by burning them. This requires inspecting the plots regularly and especially 3 to 4 days after heavy rains or in the event of morning dew.	Prevents the spread of spores to healthy leaves.
Destruction of leaves after harvest	Cela évite que le champignon ne persiste dans le milieu.	Breaks the cycle.
POST-HARVEST		
Storage of corms	The disease can be prevented by placing harvested corms, which have a petiole length of around 30 cm remaining, in polythene bags. Stored like this, the taro continues to grow while its envelope prevents the penetration of fungi and bacteria that cause rot. If spots continue to develop, the corms can be treated with a dilute bleach solution (1% sodium hypochloride) for two minutes then dried before being placed in polythene bags. (M.G.V.H.Jackson, 2001)	Reduces the conditions conducive to infestation.

BIOLOGICAL CONTROL

Trichoderma sp. and *Pseudomonas fluorescens* are antagonists of *Phytophthora colocasiae*, which are naturally present in soils.

CONTROL USING PLANT PROTECTION PRODUCTS

The disease is partially controlled by using fungicides, but the treatments are tedious and expensive. Applications may also prove to be insufficiently effective in periods that are very conducive to the disease. An integrated pest management approach, combining growing methods and the application of fungicides, seems to be the best option at present. If rainfall is high, fungicides are likely to be needed to control the disease. However, sprays are not effective when applied just before or during frequent periods of heavy rain.

PERIODS AND METHODS OF APPLICATION

Spray treatment of the foliage as soon as the symptoms appear, on at least 5 to 10% of the plants, followed by elimination of the attacked leaves. Alternatively, applications can begin 60 days after planting. Then, make applications at 7 to 14 day intervals, alternating the active substances until the stage of complete foliar coverage, two or three weeks before harvest.

Applications can be made using a power sprayer or a manually-maintained pressure backpack sprayer. The advantage of a power sprayer compared to a hydraulic backpack sprayer is the speed at which the product is applied over large areas. This feature is important in areas of high rainfall. For both types of application, a wetting agent must be added to the fungicide in order to increase the dispersion of the product on the foliar surface treated.

A preventive post-harvest treatment can be carried out if there has been infection in the field. The best way to control corm rot is to soak them for 2 minutes in a 1% solution of bleach (sodium hypochlorite) and store them in polythene bags. The corms must be thoroughly dried before being placed in a polythene bag.

SUBSTANCES

Contact and systemic fungicides can be used. Recommended active substances are listed in the table in Appendix 3.

Biocontrol substances include the following:

- Azadirachtin
- *Ocinum sanctum* extract
- *Trichoderma asperellum*
- *Trichoderma viride*

OTHER CONTROL METHODS

No information available.

8.2.4.2. TARO LEAF MOULD

SCIENTIFIC NAME

Cladosporium colocasia.

This is part of the ascomycetes group.

A fungus widespread in Asia, Southeast Asia and Oceania, it is now observed in all the taro production areas of the inter-tropical belt. Mainly present on water taro (*Colocasia esculenta*), and more rarely on taro of the genus *Alocassia*, it does not seem to affect taro of the genus *Xanthosoma*. (A Berton *et al.*, 2021).

LIFE CYCLE OF THE FUNGUS

The fungus persists in crop residues and attacked plants. From the first lesions, conidia are produced which are disseminated by the wind to infect other plants.

DESCRIPTION/IDENTIFICATION

OTHER HOST PLANTS

All *Colocasia* spp.

CROP STAGE(S) AFFECTED

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
++	++	+++	+++	++	++	++

SYMPTOMS AND DAMAGE

LEAVES	Attacks mostly occur on older leaves, but during severe attacks, the young mature leaves may show symptoms of the disease. This fungus causes circular brown spots on older leaves, but less marked on the opposing side. The centre of the spots is lighter than the very black borders. The spots are often small but can reach a diameter of 15 mm. On older leaves, it is often associated with another fungus (*Pseudocercospora colocasiae* or white leaf spot), which causes similar symptoms. *Neojohnstonia colocasiae* (orange leaf spot) also causes very similar symptoms.

Figure 82 — *Cladosporium colocasiae*. Early symptoms, brown or ghost leaf spots.
Some spots present a slight darker border
https://apps.lucidcentral.org/pppw_v12/text/web_full/entities/taro_minor_leaf_spots_094.htm photo 1

Figure 83 — *Cladosporium colocasiae*. Old leaf with brown leaf spot
https://apps.lucidcentral.org/pppw_v12/text/web_full/entities/taro_minor_leaf_spots_094.htm photo 2

Figure 84 — *Pseudocercospora colocasiae*. White leaf spots on the upper side of the taro leaf
https://apps.lucidcentral.org/pppw_v12/text/web_full/entities/taro_minor_leaf_spots_094.htm photo 6

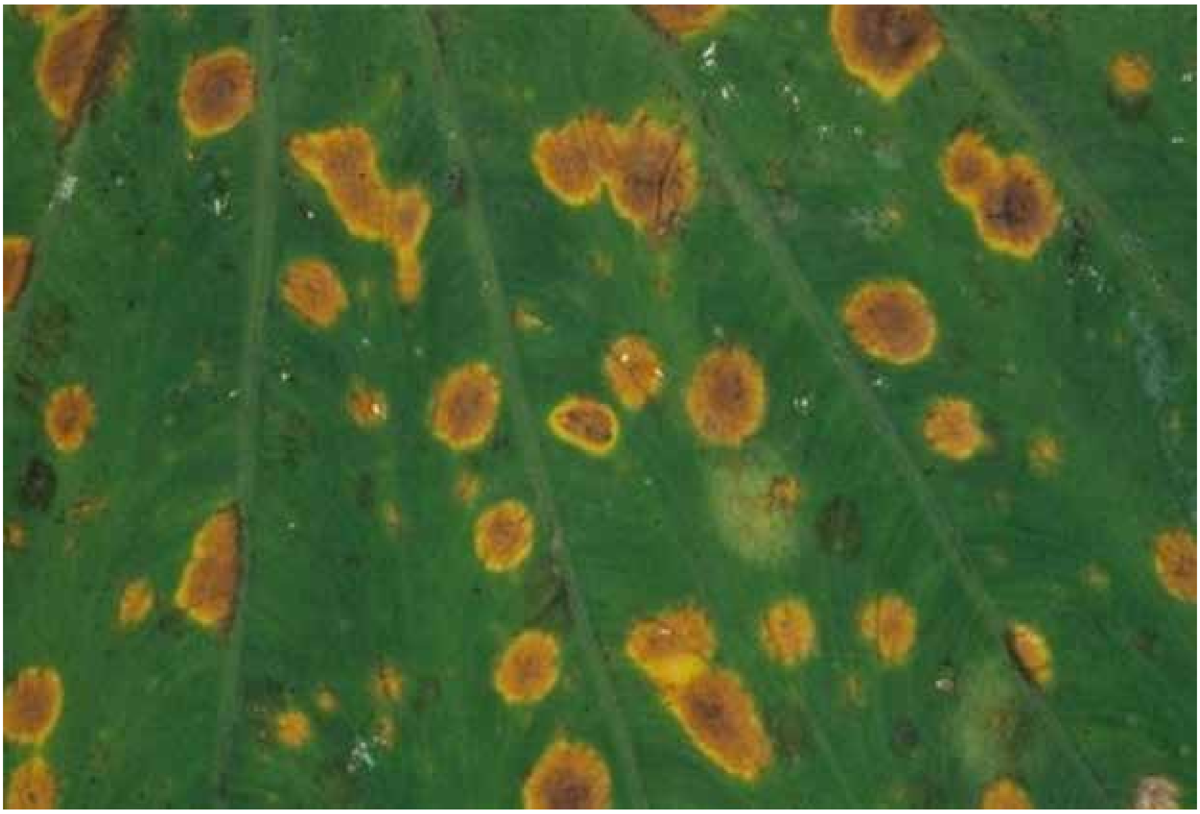

Figure 85 — *Neojohnstonia colocasiae*. Upper surface of the leaf with orange leaf spots
https://apps.lucidcentral.org/pppw_v12/text/web_full/entities/taro_minor_leaf_spots_094.htm photo 4

IMPACT ON YIELD AND QUALITY

TYPE OF IMPACT	DESCRIPTION
Yield loss per plant	This disease can cause significant defoliation but does not, in principle, affect corm yields.
Reduction in quality	Affected leaves are unsaleable.

QUARANTINE ORGANISM

It is not a quarantine organism in the EU.

CONDITIONS CONDUCIVE TO INFESTATION

TYPE	CONDUCIVE CONDITION	IMPACT / EXPLANATION
Weather conditions	Humidity and cool temperatures (below 18°C).	Ideal conditions for spore germination.

MONITORING

Microscopic examination is necessary for identification. The spores can be peeled off the leaf by using a scalpel to scrape the surface, or by using clear tape, gently pressing a piece onto the spot and peeling it off the surface of the leaf. The spores can then be mounted in a drop of water on a microscope slide for identification under a compound microscope. Conidiophores (spore-bearing stems) are straight or curved, with spores (conidia) forming on swellings at the tip. The spores are *cylindrica*l to oblong, rounded at the end, often narrowed in the middle, with up to three transverse walls. (Carmichael A., *et al.*, 2008)

CONTROL THROUGH GOOD GROWING PRACTICES

The practices mentioned below help to control the disease.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
CROP MAINTENANCE		
Removal of heavily infested leaves	Elimination by burning leaves with severe symptoms.	Less dispersal and infection.
Destruction of leaves after harvest	This prevents the fungus from persisting in the medium.	Breaks the cycle.

BIOLOGICAL CONTROL

No information available.

CONTROL USING PLANT PROTECTION PRODUCTS

The application of fungicides is generally not essential.

OTHER CONTROL METHODS

No information available.

8.2.4.3. *PHYLLOSTICTA* LEAF SPOT

SCIENTIFIC NAME

Phyllosticta colocasiophila, affects taro in the Pacific only.

LIFE CYCLE OF THE FUNGUS

The life cycle of *cladosporiosis* is generally as follows.

CONSERVATION	On plant debris, thanks to their mycelium, their spores and the mycelial stroma they form, and whose viability is several months. They persist in the crop environment, probably on various cultivated or wild plant species.
INFECTION	Germination of spores on the surface of the plant organs and penetration of germ tubes into the tissues through the stomata.
DEVELOPMENT, SPORULATION	The mycelium invades the tissues. Compartmentalised brown conidiophores are then produced, bearing more or less elongated and compartmentalised hyaline conidia depending on the species.
SPREAD	Via spores carried by the wind over long distances, by water splashes following rain and sprinkler irrigation, by workers and agricultural tools.

DESCRIPTION/IDENTIFICATION

OTHER HOST PLANTS

None.

CROP STAGE(S) AFFECTED

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
0	+	++	++	+	0	0

SYMPTOMS AND DAMAGE

LEAVES	The spots on the leaves vary from 8 mm to 25 mm or more and are oval or irregular in shape. Young spots are tan to reddish brown in colour. Older spots are dark brown with a chlorotic region surrounding the lesion. The centre of the infected area frequently rots to produce a holey lesion. *Phyllosticta* spots generally resemble those caused by *Phytophthora colocasiae* except for the absence of sporangia produced on the *Phytophthora colocasiae* lesions.

IMPACT ON YIELD AND QUALITY

Attacks by the fungus can be dramatic and take on significant proportions in single-varietal plots.

TYPE OF IMPACT	DESCRIPTION
Yield loss per plant	This disease does not, in principle, affect corm yields.
Reduction in quality	Affected leaves are unsaleable.

QUARANTINE ORGANISM

It is not a quarantine organism in the EU.

CONDITIONS CONDUCIVE TO INFESTATION

TYPE	CONDUCIVE CONDITION	IMPACT / EXPLANATION
Weather conditions	Prolonged rainy weather (2 to 3 weeks) with cool temperatures.	Ideal conditions for spore germination.

MONITORING

Does not generally require monitoring.

CONTROL THROUGH GOOD GROWING PRACTICES

The practices mentioned below help to control the disease.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
CROP MAINTENANCE		
Removal of heavily infested leaves	Elimination by burning leaves with severe symptoms	Less dispersal and infection.
Destruction of leaves after harvest	This prevents the fungus from persisting in the medium.	Breaks the cycle.

BIOLOGICAL CONTROL

No information available.

CONTROL USING PLANT PROTECTION PRODUCTS

No use of fungicides is generally recommended unless the disease is continuously present and causing significant defoliation.

OTHER CONTROL METHODS

No information available.

8.2.4.4. CORM OR CORMEL ROT

SCIENTIFIC NAME

Pythium spp., primarily *Pythium myriotylum* but also *Pythium splendens*. Mainly on macabo but also on taro/dasheen (flooded and rainfed) and eddoe. It is part of the oomycetes lineage.

LIFE CYCLE OF THE FUNGUS

Oomycetes produce oospores, sexual spores that serve as a dormant structure and a means of survival in adverse conditions.

CONSERVATION	Oospores are the primary survival structures: they are resistant to desiccation and can survive in soils for long periods (11 months) in the absence of an adequate host or organic substrate that enables them to survive as saprophytes. If conditions are not right for infection, zoospores encyst and as long as soil moisture and temperature are adequate, they remain in the soil for at least 7 years.
SOURCE OF INOCULUM	In the presence of certain nutrients and for high relative humidities, the sporangia are stimulated to produce motile zoospores, the main infectious agents.
INFECTION	The oospores germinate directly or form sporangia. The sporangia can also germinate directly, but can also produce spores in swarms, the zoospores. In the presence of free water, the zoospores are attracted to the seeds and roots, which they penetrate. The zoospores germinate and infect the seedling, often at the boundary between the soil and the air.
DEVELOPMENT, SPORULATION	Long hyphae pierce the epidermis of the plant. The fungus can produce new sporangia within a few days. The plant cells are killed by the substances excreted by the mould, causing rotting.
SPREAD	The pathogen is dispersed when infected plant debris is transported to uninfested areas and when soil moisture is sufficient to allow zoospores to swim freely.

DESCRIPTION/IDENTIFICATION

OTHER HOST PLANTS

*Pythium*s like a wide variety of host plants, including cucumbers, cereals, varieties of cabbage, beans, tomatoes, peanuts, aubergines and potatoes.

CROP STAGE(S) AFFECTED

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
++	++	+++	+++	+++	+++	+++

SYMPTOMS AND DAMAGE

ROOTS	Healthy roots are cream or pink in colour and very turgid, while diseased roots are dark and flabby before complete necrosis.
LEAVES	On the aerial parts, you can see the wilting and stunting of leaves in the field, with a shortening of the petioles and chlorosis of the blade (green-yellow colour).
CORM (OR CORMEL)	They exhibit rot that ranges in colour from whitish-yellow to dark purple through shades of grey and blue. Usually the rot begins at the base of the corm or cormel and progresses upward until the entire organ is affected. Sometimes, the disease begins on the side of the corm or cormel, 5-7 cm above the base. The skin of the diseased corm softens and usually remains intact until the interior of the corm has completely disintegrated, then the skin disintegrates too. When an affected corm or cormel is cut open, the diseased parts are discoloured and soft with a marked separation from the healthy areas, which remain white or coloured depending on the cultivar. (Carmichael A., *et al.*, 2008). The rots are wet, and often smelly.
WHOLE PLANT	When infected, the entire plant becomes stunted: leaf stalks are shortened, leaf blades are curled or crinkled, and instead of being a deep, healthy green, they are yellowish and mottled.

Figure 86 — *Pythium* infection on macabo. After uprooting the plants and washing the roots, we see that the root system has been destroyed. Many large roots are black, and the lateral (fine) roots are absent https://apps.lucidcentral.org/pppw_v10/images/entities/taro_root_rot_044/thumbs/kktarorotfield_sml.jpg

Figure 87 — Damage to crown and base of petioles.
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Figure 88 — Onset of symptoms, showing the early death of the older leaves caused by *Pythium* sp.
https://apps.lucidcentral.org/pppw_v10/images/entities/taro_root_rot_044/thumbs/kktaroplant_sml.jpg

Figure 89 — *Pythium* infection on taro shows the plants looking weak with two or three leaves at most, and the new leaves shrivelled and partially curled
https://apps.lucidcentral.org/pppw_v10/images/entities/taro_root_rot_044/thumbs/samataiutapythium2398_sml.jpg

IMPACT ON YIELD AND QUALITY

TYPE OF IMPACT	DESCRIPTION
Loss of plants	Young plants may die from infestation.
Yield loss per plant	Size and number of corms reduced following the weakening of the plant.
Reduction in quality	Corms are stunted if not destroyed. Conservation is low. Flesh is soft and smelly.

QUARANTINE ORGANISM

It is not a quarantine organism in the EU.

CONDITIONS CONDUCIVE TO INFESTATION

TYPE	CONDUCIVE CONDITION	IMPACT / EXPLANATION
Soil	Hydromorphy	This fungus attacks the roots, especially in hydromorphic soil conditions
Temperature	For taros, high temperatures and very moist soils.	Promotes the development of the fungus

MONITORING

Generally, rot is evident on the corms as it develops from the base. However, if it is an early infection, lesions may be seen on the surface of the corm. If found, the corm should be opened to see what is underneath. Although few other species of fungi cause rots in the field, there are others that cause rots after harvest. It is therefore necessary to isolate the pathogen and identify it by microscopy. (Carmichael A., *et al.*, 2008).

CONTROL THROUGH GOOD GROWING PRACTICES

The practices mentioned below help to control the disease.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
PRIOR CHOICES		
Choice of land	Avoid waterlogged or poorly drained soils.	Avoidance of disease-promoting conditions.
Choice of land	Do not plant taro or macabo in land downhill from where root rot has previously occurred. If you do, *Pythium* spores will spread through soil or surface water during rains. (Helen Tsatsia *et al.*, 2021).	Avoidance of contamination of healthy ground.
Choice of soil type	Preferably avoid heavy clay soils. If there are soil types where the disease is rare, use them. It has been found in West Africa that certain soil types produce healthy crops, while crops in other soil types are still affected. It is likely that there are microorganisms antagonistic to *Pythium* in beneficial soils, (Helen Tsatsia *et al.*, 2021).	Avoidance of disease-promoting conditions.
Avoid susceptible prior crops	Banana as a prior crop, favourable to disease control. Before planting taro, grow a legume such as *Mucuna* or *Pueraria*. The accumulation of organic matter in the soil can favour the presence of microbes antagonistic to *Pythium*. (Helen Tsatsia *et al.*, 2021).	Reduction of inoculum in the soil.
Choice of plant material	Choice of offshoots (no visible rot).	Avoidance of contamination of healthy ground.
Choice of varieties	In Samoa, the following varieties have shown resistance: Tusi Tusi, Talo Vale, Pute Mu and Pula Sama Sama. The Hawaiian taro varieties Pa'lehua, Maui Lehua, Pa'akala and Pauakea are all considered resistant to *Pythium* rot. (Carmichael A., *et al.*, 2008).	Lower or no incidence of attacks.
PREPARATION OF THE PLOT		
Enrich the soil with calcium	Apply lime some time before replanting taro. The use of white coral sand has been suggested in Samoa. (Helen Tsatsia *et al.*, 2021).	Better plant defence.
Tillage	Ploughing and exposure of the plot to the sun.	Reduction of inoculum in the soil.
Ridges and drainage	In heavy soil, make drains around plots or plant taro/macabo on raised beds or mounds to facilitate drainage.	Avoidance of disease-promoting conditions.

CROP MAINTENANCE		
No excessive irrigation	The presence of abundant and permanent free water favours the dispersal of zoospores.	Less dispersal and infection.
HARVEST		
Harvest at the right time	Avoid overly late harvests by leaving the plants too long in the field.	Lower incidence of attacks.
Uproot visibly diseased plants	Removal of diseased plant material from the field at harvest time.	Reduction of inoculum in the soil.

BIOLOGICAL CONTROL

Good agricultural practices and the addition of organic matter to the soil increase the natural presence of *Trichoderma* and other microorganisms in the soil that are *Pythium* antagonists.

CONTROL USING PLANT PROTECTION PRODUCTS

In addition to growing methods, fungicide applications can be made at different crop stages.

— The cuttings from selected offshoots should be well cleaned and can be treated before planting by soaking in a fungicide, for example based on fosetyl-al or metalaxyl-M.

— Young plants can be sprayed with a fungicide after planting at the foot of the plants.

— The best way to control *Pythium* during storage is to soak the corms for 2 minutes in a 1% solution of bleach (sodium hypochlorite) and then store them in polythene bags. The corms must be thoroughly dried before being placed in a polythene bag.

ACTIVE SUBSTANCES

Recommended active substances are listed in the table in Appendix 3.

OTHER CONTROL METHODS

In the Solomon Islands, storage in shallow earth pits dug into the ground and lined with leaves has been shown to reduce damage. (Carmichael A., *et al.*, 2008).

8.2.4.5. CORM AND ROOT ROT

SCIENTIFIC NAME

Marasmiellus stenophyllus.

It is part of the agaricomycetes.

LIFE CYCLE OF THE FUNGUS

INFECTION	*Marasmiellus stenophyllus* infects the base of the plant.
DEVELOPMENT, SPORULATION	The mycelium attacks the crown. Carpophores are commonly produced on the destroyed parts of the plant.
SPREAD	By the spores produced by the carpophores.

Figure 90 — Carpophore at the foot of an affected plant.
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DESCRIPTION/IDENTIFICATION

OTHER HOST PLANTS

Several host plants including sugar cane.

CROP STAGE(S) AFFECTED

This fungus is generally found at the end of the crop cycle.

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
0	+	+	++	++	+	+

SYMPTOMS AND DAMAGE

A white felt often colonises the affected areas.

ROOTS	The fungus kills the roots, which remain attached to soil particles.
LEAVES	The leaves dissolve under the effect of the development of large brown rots. They often remain clumped together due to the development of a mycelial net.
CORM	Rot dries the corms, which become inedible and, even at an early stage of decomposition, can be unsightly with the growth of mycelium causing small "pocket" rots. However, the incidence of infection is low
WHOLE PLANT	Dead plants appear mummified.

Figure 91 — Mummified appearance of a plant.
Guide to good phytosanitary practices for growing taro and macabo in ACP countries. (April 2011) COLEAD

IMPACT ON YIELD AND QUALITY

TYPE OF IMPACT	DESCRIPTION
Loss of plants	Death of the plant following desiccation of the organs.
Yield loss per plant	Reduction by weakening of the plant
Reduction in quality	Attacked corms and leaves are unsaleable.

QUARANTINE ORGANISM

It is not a quarantine organism in the EU.

CONDITIONS CONDUCIVE TO INFESTATION

No information available.

MONITORING

If plants are wilting or growing slowly compared to others, check for carpophores growing from dead or dying petioles. The roots will look dirty and debris will cling to them in clumps that cannot be removed even after gentle washing. *Marasmiellus stenophyllus* is quite distinct on taro, but can be confused with *Athelia rolfsii* on completely dead plants. The two can be distinguished by looking for the presence of carpophores for *M. stenophyllus* and sclerotia for *A. rolfsii*. (Carmichael A., *et al.*, 2008).

CONTROL THROUGH GOOD GROWING PRACTICES

The practices mentioned below help to control the disease. These are essentially prophylactic measures.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
PRIOR CHOICES		
Choice of plant material	Choice of offshoots (no visible rot).	Avoidance of contamination of healthy ground.
CROP MAINTENANCE		
Uproot visibly diseased plants	Removal and destruction of infected plants by burning is helpful in controlling the fungus.	Reduction of inoculum in the soil.
HARVEST		
Harvest at the right time	Avoid overly late harvests by leaving the plants too long in the field.	Lower incidence of attacks.

BIOLOGICAL CONTROL

No information available.

CONTROL USING PLANT PROTECTION PRODUCTS

The application of fungicides is generally not essential.

OTHER CONTROL METHODS

No information available.

8.2.4.6. *ATHELIA* ROT

SCIENTIFIC NAME

Athelia rolfsii (*Sclerotium rolfsii*, *Corticum rolfsii*).

LIFE CYCLE OF THE FUNGUS

CONSERVATION	It persists in the soil on plant debris, in the form of aggregated mycelium or sclerotia. It is also able to survive on different organic substrates.
SOURCE OF INOCULUM	The main source of inoculum is black microsclerotia in the soil or plant debris of host plants.
INFECTION	Infection begins at soil level, at the base of petioles. Sclerotia, exposed to temperatures above 26-27°C, germinate and emerging hyphae grow and penetrate the stems and other plant structures that come into contact with the soil surface. It can penetrate healthy tissue without injury.
DEVELOPMENT, SPORULATION	Once *Athelia rolfsii* is established in plant tissue, it develops a white mycelium from the site of infection, which eventually forms a fan pattern that continues to progress towards the roots. The pathogen invades the stem and roots and destroys the cortex. If the temperatures are at least 27-35°C, the mycelium compacts, and between 4 and 7 days after infection, it forms sclerotia that quickly turn from white to brown. The fungus infects the corms through wounds made when the suckers detach. Occasionally, *A. rolfsii* has a sexual fruiting stage that develops at the edges of lesions and in places that are shaded from the sun. This stage is not commonly seen in the field and is not thought to be of primary importance in disease transmission.
SPREAD	Sclerotia are slightly heavier than spores, so they are less likely to be carried by the wind. However, they can be dispersed from field to field by contaminated water, animals and ploughs.

OTHER HOST PLANTS

This fungus is very polyphagous and is particularly prevalent in warm tropical and subtropical regions.

It can attack and persist on some 500 plants, cultivated or not, belonging to some one hundred botanical families. Vegetable host plants notably include: tomatoes, peppers, aubergines, various salads, melons, cucumbers, watermelons, beetroot, carrots, cauliflower, celery, garlic, onions, radishes, turnips, sweet potatoes. It also attacks: maize, rice, peanuts, *sorghum*, potatoes.

CROP STAGE(S) AFFECTED

The attack can occur at any stage of vegetation. However, it is especially common in taro plants aged 5 to 6 months. When the latter are attacked very early, particularly as soon as they are planted, the seedlings can immediately die of mould. However, the pathogen prefers to attack adult tissues rather than young and growing tissues. (O.B. Arene *et al.*, 1980).

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
+	++	+++	+++	++	++	++

SYMPTOMS AND DAMAGE

A thick, white mycelium with spherical sclerotia (1mm in diameter), first white then beige to reddish brown, develops at the base of the plant and spreads all around the organic matter of the soil and the roots. This is observable during hot and humid periods and disappears during drought.

LEAVES	The most important symptom is the sudden collapse of an apparently healthy outer petiole. The petiole often shows frayed basal edges *indica*tive of the attacked area, invariably on older organs and tissues. These frayed edges can be accompanied by wet rot, especially in rainy weather. The base of the infected petiole is encrusted with a white thallus of fungal mycelium interspersed with sclerotia at various stages of maturity. Mycelium and sclerotia may radiate a few centimetres from the base of the affected plant and out to the soil surface. (O.B. Arene *et al.*, 1980). Leaf wilting is observed. There are more dead leaves than usual.
CORM	Symptoms are characterised by a caseous rot of the central portion of the flesh, with a thallus of mycelium encrusting the surface of the periderm. Sclerotia typical of the fungus may appear on the thallus in hot, humid weather. A pinkish rot may appear.
WHOLE PLANT	Stunting of the plant

Figure 92 — Mycelium and sclerotia on the taro corm
Yuan-Min Shen, National Taiwan University, Bugwood.org
https://www.forestryimages.org/browse/detail.cfm?imgnum=5426946

IMPACT ON YIELD AND QUALITY

TYPE OF IMPACT	DESCRIPTION
Loss of plants	By decay.
Yield loss per plant	By reduction in the size and number of corms following the weakening of affected plants and by the presence of unsaleable corms.
Reduction in quality	The pathogen can be inadvertently transported on the corm or cormel, from the field to a shed where post-harvest rot will then develop. The quality of the corms or cormels can then decline rapidly.

QUARANTINE ORGANISM

It is not a quarantine organism in the EU.

CONDITIONS CONDUCIVE TO INFESTATION

TYPE	CONDUCIVE CONDITION	IMPACT / EXPLANATION
Soil	Moist, but not excessively so.	Promotes infection.
Soil	Acidic soils, its mycelial growth being optimal between pH 3 and 5; sclerotia germinate between pH 2 and 5. The latter seems to be inhibited above pH 7.	Promotes infection.
Soil	Poor in well-decomposed organic matter.	Fewer active antagonists.
Soil	Nitrogen deficiency.	Fewer active antagonists.
Soil	The more the clay content of the soil decreases, the more the disease increases.	Promotes infection.
Weather conditions	High relative humidity. Heavy rains.	Promotes infection.
Weather conditions	Temperatures above 26-27°C.	Favourable to the germination of sclerotia.
Weather conditions	Warm temperatures (between 26 and 35°C) and relative humidity between 20 and 40%.	Allow sclerotia to survive in soils.

MONITORING

On taros with wilted leaves, the base of the petioles at ground level should be inspected for mycelia and white sclerotia. *Athelia rolfsii* is quite distinct on wilted plants but can be confused with *Marasmiellus stenophyllus* if the plants are dead. The way to distinguish between them is the presence of carpophores for *M. stenophyllus* or sclerotia for *A. rolfsii*. (Carmichael A., *et al.*, 2008).

CONTROL THROUGH GOOD GROWING PRACTICES

The practices mentioned below help to control the disease.

Athelia rolfsii is a major pathogen of several crops, including taro; most of the control measures have been developed on crops other than taro, but they can probably be applied to taro.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
PRIOR CHOICES		
Avoid susceptible prior crops	It is advisable that crop rotations be carried out every 3 years at the most and ensure above all that crops with this parasite in common do not follow one another.* Cereal crops (*Poaceae*) are relatively resistant to the fungus. Maize is a good prior crop. Two years of *Eupatorium* fallow and a yam crop will reduce the pathogenic potential of the inoculum of *A. rolfsii*, (O.B. Arene *et al.*, 1980).	Decline in inoculum in the soil by breaking successive cycles.
Avoid shaded plots	Soil and plants stay moist for longer in shaded areas.	Limits infection.
PREPARATION OF THE PLOT		
Tillage	Proper ploughing of the soil to expose the pathogen to sunlight early in the season, and reduce moisture as much as possible.	Reduction of inoculum in the soil.
Enrich the soil with well-decomposed organic matter	A high rate of organic matter in the soil provides a structure giving good aeration and promotes the development of antagonistic microorganisms.	Control by antagonists is strengthened. Less effect of the disease on plant growth.
Soil liming	Helps raise the pH in overly acidic soils.	Limits infection.
Ensure good soil drainage	Use raised beds to improve drainage of overly wet soils.	Well-drained soil not only limits infection, but also prevents plants from becoming predisposed to the fungus.
PLANTING		
Appropriate planting density	A dense canopy increases soil moisture. Increasing plant spacing can help reduce this moisture.	Reduces infection.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
CROP MAINTENANCE		
No excessive irrigation	A soil that is too wet is conducive to infection.	Avoidance of infection-promoting conditions.
Ensure good nitrogen and calcium-rich fertilisation	Nitrogen application controls the disease and increases yield. Calcium helps raise the pH of the soil.	Less effect of the disease on plant growth. Limits infection.
Uprooting and destruction of visibly diseased plants	Uprooting must be immediately followed by destruction (deep burial, burning or animal feed).	Avoidance of increased inoculum potential. Avoidance of contamination of neighbouring plots.
HARVEST		
Careful harvesting	Corm rotting in storage can be minimised by: — avoiding bruising the corms at harvest; — allowing the remains of petioles to dry completely before removal and storage of the corms to avoid open lesions; — removing harvested corms that are infected with *A. rolfsii*, especially those that show signs of mycelial infestation, before storing them.	Avoidance of contamination of the storage area.
POST-HARVEST		
Storage method	For *X. sagitttfolium*, less rot is observed in cormels placed on raised and uncovered racks. This process generates an unfavourable microclimate of high humidity on the surface of the corms and air circulation accelerates the subsequent hardening of the flesh, which also acts as a barrier to the pathogen. On the other hand, *A. esculenta* is much less exposed to attack by *A. rolfsii* when it is kept in pits or in baskets which are then covered with ashes and pieces of fresh plantain trunks. This process maintains a higher humidity. (O.B. Arene *et al.*, 1980).	Avoidance of favourable conditions.

*Although crop rotation is a traditional and preferred method for disease control, it is not very effective in controlling *A. rolfsii* due to its wide host range and the survivability of sclerotia in the soil.

BIOLOGICAL CONTROL

A lack of organic amendments or poorly decomposed organic matter, or even a nitrogen deficiency in the soil, decreases the activity of antagonistic microorganisms, such as *Bacillus subtilis* and *Trichoderma*, and therefore promotes the development of the fungus.

CONTROL USING PLANT PROTECTION PRODUCTS

There is no recommendation for the use of fungicides against this disease on taros.

OTHER CONTROL METHODS

Solarise the soil - cover the soil with plastic and allow the sun to heat the trapped air. (Carmichael A., *et al.*, 2008).

8.2.5. BACTERIAL DISEASES

8.2.5.1. BACTERIAL SOFT ROT

SCIENTIFIC NAME

Pectobacterium carotovorum (syn.: *Erwinia carotovora*) and *Dickeya chrysanthemi* (syn. *E. chrysanthemi*) on taro and macabo are pantropical diseases.

LIFE CYCLE OF THE BACTERIA

CONSERVATION	The pathogen lives in plant debris and roots as well as in soils surrounding the roots of host plants.
SOURCE OF INOCULUM	Bacteria present in the water.
INFECTION	The pathogen enters the host tissues through wounds mainly at the base of the petiole on the corm or cormel.
DEVELOPMENT	After entering, the bacterium multiplies at an exponential rate in the intercellular spaces.
SPREAD	The bacteria is spread through infected planting material, irrigation water, tools, animal pastures, workers' shoes etc. It is also found in the intestines of insects nesting in decaying plants and can spread through crops this way.

DESCRIPTION/IDENTIFICATION

OTHER HOST PLANTS

Both bacteria attack several hosts in different regions of the world.

DESCRIPTION OF THE PATHOGEN

D. chrysanthemi is a gram-negative, facultatively anaerobic, motile, non-spore-forming, rod-shaped bacterium, usually unicellular, 0.5 – 0.7 x 1 – 2.5 µm, with multiple peritrichous flagella. (Sweetpotato DiagNotes, 2022).

Pectobacterium carotovorum is also rod-shaped and gram-negative.

CROP STAGE(S) AFFECTED

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
+	++	+++	+++	+++	++	++

SYMPTOMS AND DAMAGE

This is a soft rot of corms in the field and in storage. (Carmichael A. *et al.*, 2008)

WHOLE PLANT	When soft rot disease strikes, the infected part of the plant softens and rots rapidly until the entire plant wilts.
CORM	In the field, the infection causes a soft, smelly and creamy-white corm rot. A similar rot occurs in corms harvested and stored at a high temperature and humidity. (Carmichael A. *et al.*, 2008)

IMPACT ON YIELD AND QUALITY

TYPE OF IMPACT	DESCRIPTION
Loss of plants	The plant can eventually die, especially if the attack is early.
Yield loss per plant	Loss of corms showing rot and therefore not marketable.
Losses and decline in quality in storage	Soft rots can be very destructive, especially for corms stored in high humidity in plastic bags.

QUARANTINE ORGANISM

It is not a quarantine organism in the EU.

CONDITIONS CONDUCIVE TO INFESTATION

TYPE	CONDUCIVE CONDITION	IMPACT / EXPLANATION
Temperature	The optimal development of the disease occurs at 30°C, but the bacterium survives in a wide temperature range below 27°C. (Sweetpotato DiagNotes, 2022).	Greater rotting.
Humidity	To develop, the disease needs high humidity.	
Storage conditions	High humidity levels, either in earth pits or in plastic bags.*	Greater rotting.

*Otherwise, this type of storage would prolong shelf life by preventing infection by other plant pathogens such as *Phytophthora colocasiae* and *Pythium splendens*. A reduction in the incidence of these types of rot is possible if the corms are pre-treated with bleach (1% sodium hypochlorite). (Carmichael A. *et al.*, 2008)

MONITORING

The sudden collapse of the leaves of mature plants is often a sign of bacterial rot. At this point, the corms are usually so decomposed that the plants can topple over in the wind. In storage, in pits dug in the earth or in plastic bags, the bacterium can be detected by the presence of soft rot with a strong unpleasant smell. (Carmichael A. *et al.*, 2008)

CONTROL THROUGH GOOD GROWING PRACTICES

The practices mentioned below help to control the disease.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
PRIOR CHOICES		
Choice of cuttings	Do not take cuttings from infested corms.	Prevents the bacteria from being introduced into a healthy site.

BIOLOGICAL CONTROL

No information available.

CONTROL USING PLANT PROTECTION PRODUCTS

There is no recommendation for the use of bactericides against this disease on taros.

OTHER CONTROL METHODS

No information available.

8.2.6. VIRAL DISEASES

8.2.6.1. *ALOMAE/BOBONE* VIRAL COMPLEX

SCIENTIFIC NAME

This is a viral complex called (ABVC *Alomae Bobone* Viral Complex) and is restricted to the Solomon Islands and Papua New Guinea.

The only virus clearly associated with ABVC is the "*Colocasia bobone disease-associated virus*" (CBDaV). The only other viruses systematically present in symptomatic plants are badnaviruses: "*taro bacilliform virus*" (TaBV) and/or "*taro bacilliform CH virus*" (TaBCHV).

The presence of CBDaV alone leads to a mild form of the disease, called "*Bobone*".

When TaBV and/or TaBCHV combine with CBDaV, it causes the disease called "*Alomae*". However other viruses could be at play in *alomae* disease.

Alone, TaBV and TaBCHV do not affect plant growth. A slight chlorosis may sometimes appear on the leaves.

LIFE CYCLE OF THE VIRUSES

SOURCE OF INOCULUM	Vector insects.
INFECTION	When bitten by sucking/biting insects.
DEVELOPMENT	The whole plant can be invaded once these viruses are transmitted by the vector.
SPREAD	Via vector insects (mainly leafhoppers such as *Tarophagus proserpina*), but also scale insects such as *Planococus citri* for badnaviruses) or via cuttings.

DESCRIPTION/IDENTIFICATION

OTHER HOST PLANTS

Their host range appears to be limited to *araceae* only.

CROP STAGE(S) AFFECTED

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
+	++	+++	+++	++	0	0

SYMPTOMS AND DAMAGE

Symptoms can be very variable depending on the situation and the varieties of taro.

— Symptoms of *alomae*

Symptoms differ depending on the size of the plants and their reaction to *alomae*.

LEAVES	The leaves wrinkle and growths form on the surface. The leaf and the veins become thick. Young leaves are wrinkled and do not unfurl normally. The petiole is short and has irregular growths on its surface. Necroses eventually appear.
WHOLE PLANT	Sometimes the whole plant stunts and dies.

Figure 93 — First signs of *alomae* on the mother plant and suckers (Malaita, Solomon Islands). Note the shrivelled leaves, tightly coiled and yellow https://apps.lucidcentral.org/pppw_v12/text/web_mini/entities/taro_alomae__bobone_001.htm Photo 1

Figure 94 — Stunting of mother plant and suckers probably caused by *alomae* (Madang, Papua New Guinea). In this case, the plant remains green
https://apps.lucidcentral.org/pppw_v12/text/web_mini/entities/taro_alomae__bobone_001.htm Photo 2

Figure 95 — Mother plant and suckers with *alomae*, starting to die (Madang, Papua New Guinea)
https://apps.lucidcentral.org/pppw_v12/text/web_mini/entities/taro_alomae__bobone_001.htm Photo 3

Figure 96 — Plant destroyed by *alomae*: one living shoot and many dead leaves remain (Madang, Papua New Guinea)
https://apps.lucidcentral.org/pppw_v12/text/web_mini/entities/taro_alomae__bobone_001.htm Photo 4

— Symptoms of *bobone*

Bobone symptoms are similar, but the leaves are more stunted and the leaf blade is curled and twisted. *Bobone* does not usually cause the complete death of the plant. Plants usually recover after three to five leaves have been affected. Symptoms sometimes return after recovery.

Figure 97 — Typical symptoms of *bobone* with shrivelled and twisted green leaves (Madang, Papua New Guinea). The plant will recover from these symptoms by producing leaves that look healthy, but the plant will remain infected with virus.
https://apps.lucidcentral.org/pppw_v12/text/web_mini/entities/taro_alomae__bobone_001.htm Photo 8

Figure 98 — Galls on the leaf petiole of a plant that is probably in the early stages of *alomae* (Madang, Papua New Guinea). The early stages of *alomae* and *bobone* are similar and unless you know the variety, it is impossible to know which disease is present https://apps.lucidcentral.org/pppw_v12/text/web_mini/entities/taro_alomae__bobone_001.htm Photo 9

— **TaBV symptoms**

Figure 99 — On this leaf, the feathery mosaic is very evident.
Figure 17 in https://www2.pestnet.org/wp-content/uploads/2021/02/Taro-virus-story.pdf

IMPACT ON YIELD AND QUALITY

In the Pacific, the *alomae* viral disease causes serious damage. However, in many cases only isolated plants in taro fields appear to be affected by either disease, and in the case of *bobone*, infected plants may recover from symptoms.

TYPE OF IMPACT	DESCRIPTION
Loss of plants	In the case of *alomae*, the plants are stunted and then disappear.
Yield loss per plant	Severe cases of *alomae* can result in total crop loss, while *bobone* can cause up to a 25% yield loss. (Anonymous, 2022).

QUARANTINE ORGANISM

It is not a quarantine organism in the EU.

The CBDaV virus is apparently eliminated from taro plants if meristem culture is used. The restricted occurrence of this virus - confined to Papua New Guinea and the Solomon Islands - means that strict quarantine measures must be followed when transferring genetic material internationally. Guidelines suggest that all transfers should be in the form of sterile, pathogen-free seedlings growing in tissue culture medium. (Carmichael A., *et al.*, 2008).

Although TaBV viruses are widespread, care should be taken when transporting taro (and other aroids) internationally, as sequence variability has been observed. Strict quarantine measures must be applied. Guidelines suggest that all transfers be made as sterile, pathogen-free seedlings growing in tissue culture medium. (Carmichael A., *et al.*, 2008).

CONDITIONS CONDUCIVE TO INFESTATION

The main condition favourable to infestation is the presence of vector insects and the proximity of plants already affected.

MONITORING

Preliminary identification is based on the examination of leaves for typical symptoms. However, since symptoms vary by variety, an accurate diagnosis requires additional testing. It is very difficult to differentiate between the early symptoms of *alomae* and *bobone*. If the plants die, they had *alomae*. If plants recover, there are two possibilities (Carmichael A., *et al.*, 2008):

i. infection by CBDaV alone (as *alomae* is thought to be caused by a virus complex);

ii. infection by CBDaV, causing *bobone* in *alomae*-resistant taro.

Diagnostic tests have been developed at the Queensland University of Technology in Australia, which use molecular methods (polymerase chain reaction). They have proven to be both sensitive and robust. (Carmichael A., *et al.*, 2008).

CONTROL THROUGH GOOD GROWING PRACTICES

The practices mentioned below help to control the disease.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
PRIOR CHOICES		
Choice of plot	Isolated and protected plots (clearing).	
Choice of cuttings	Use of cuttings from healthy mother plants.	Prevents the virus from being introduced into a healthy site.
Choice of resistant or tolerant varieties	Some tolerant cultivars, obtained by recurrent breeding, have been released in the Solomon Islands since 1992.	Limits infection.
CROP MAINTENANCE		
Uprooting of affected plants	Elimination of diseased plants by burning or burying. Care should be taken to ensure that all insects on infected plants are killed before the plants are removed for destruction, or that the plants are carefully uprooted to prevent the spread of insects.	Avoidance of sources of infestation.

BIOLOGICAL CONTROL

No information available.

CONTROL USING PLANT PROTECTION PRODUCTS

This involves the control of vector insects such as leafhoppers and scale insects.

OTHER CONTROL METHODS

No information available.

8.2.6.2. TARO MOSAIC VIRUS

SCIENTIFIC NAME

Dasheen Mosaic Virus (*DsMV*) on taro and macabo.

This pantropical virus is present in all taro growing regions.

LIFE CYCLE OF THE VIRUS

CONSERVATION	In infected plants
SOURCE OF INOCULUM	Aphids
INFECTION	Transmission between individuals is ensured in a non-persistent mode by various species of widely distributed aphids, including *Myzus persicae*, *Aphis gossypii* and *Aphis craccivora*.
DEVELOPMENT	The whole plant can be invaded once the virus is transmitted by the vector.
SPREAD	Via aphids. The virus can also be spread by mechanical means, by tools (secateurs and shears) that have not been disinfected. Transmission between successive generations is largely by infected planting material (corms, cuttings, offshoots).

DESCRIPTION/IDENTIFICATION

OTHER HOST PLANTS

The typical host range consists of plant species of the family *Araceae*.

DESCRIPTION OF THE PATHOGEN

This is a flexuous rod-shaped virus.

CROP STAGE(S) AFFECTED

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
+	+	++	++	+	0	0

SYMPTOMS AND DAMAGE

The plants generally eventually overcome these attacks and resume a normal appearance, but a few cases of severe and unrecovered attacks have been reported.

Sometimes the symptoms are highly developed, but they can disappear completely during cultivation when the plants have very strong growth.

LEAVES	A wide variety of mosaic types: small, irregular, sparse, with spots varying from green to yellow, passing through grey and white, feather-shaped on either side of the main veins. Leaves can sometimes be deformed.
WHOLE PLANT	Stunting in severe cases.

Figure 100 — Symptom of the taro/*dasheen mosaic virus*; notice the pale green feather-like pattern between the leaf veins. These patterns often appear along the main veins https://apps.lucidcentral.org/pppw_v12/text/web_mini/entities/taro_alomae__bobone_001.htm Photo 12

Figure 101 — Severe *Dasheen mosaic virus* in French Polynesia. Leaves are severely deformed and symptoms of *DsMV* appear on most of them, unlike the symptoms seen in other Pacific island countries. The other difference with "normal" *DsMV* is that the plants do not recover from the symptoms. It is most often observed on the Mana Ura variety
https://www2.pestnet.org/wp-content/uploads/2021/02/Taro-virus-story.pdf

IMPACT ON YIELD AND QUALITY

TYPE OF IMPACT	DESCRIPTION
Yield loss per plant	Decline by stunting of the plants but yields are generally little affected.
Reduction in quality	This concerns the leaves that are marketed.

QUARANTINE ORGANISM

It is not a quarantine organism in the EU.

Although *DsMV* is widespread, caution should still be exercised when transporting taro (or other aroids) internationally, especially since there appear to be severe forms of the disease. Strict quarantine measures must be followed. Guidelines suggest that all transfers should be in the form of sterile, pathogen-free seedlings growing in tissue culture medium. (Carmichael A., *et al.*, 2008).

CONDITIONS CONDUCIVE TO INFESTATION

The manifestation of the disease as well as its spread depend on the conditions that promote the proliferation of aphids.

MONITORING

Preliminary identification is based on the examination of leaves for typical symptoms. However, since symptoms can vary depending on the variety and environmental conditions, an accurate diagnosis requires additional testing. Diagnostic tests have been developed at the Queensland University of Technology, which use molecular methods (polymerase chain reaction). They have proven to be both sensitive and robust. (Carmichael A., *et al.*, 2008).

CONTROL THROUGH GOOD GROWING PRACTICES

There are no effective control measures against *DsMV*. The virus is transmitted easily by aphids and is then conserved in plants due to vegetative propagation techniques.

The practices mentioned below nevertheless help to control the disease.

ACTION	REASON AND/OR DESCRIPTION	EFFECT
PRIOR CHOICES		
Choice of plot	Isolated and protected plots (clearing).	
Choice of cuttings	Use of cuttings from meristem cultures. The virus would be eliminated on taro plants by meristem culture, but reinfection is rapid in the field.	Prevents the virus from being introduced into a healthy site.

BIOLOGICAL CONTROL

No information available.

CONTROL USING PLANT PROTECTION PRODUCTS

This involves the control of aphids, the vector insects.

OTHER CONTROL METHODS

No information available.

8.2.7. MOLLUSCS

8.2.7.1. SNAILS

SCIENTIFIC NAME

Notably the pantropical *Lissachatina fulica* (formerly *Achatina fulica*), which attacks taros and macabo. Its native habitat is southern Africa. Today, it is present in almost all tropical and humid regions of the globe.

LIFE CYCLE OF THE PEST

The giant African land snail is a large and highly visible pest, hiding during the day and feeding at night.

Figure 102 — *Lissachatina fulica* cycle
https://www.phytojournal.com/archives/2021/vol10issue5/PartD/10-5-93-883.pdf

DESCRIPTION/IDENTIFICATION

OTHER HOST PLANTS

Many plants are attacked. *Brassicaceae* are the preferred plants.

DESCRIPTION OF THE SNAIL

The eggs are spherical to ellipsoidal in shape (4.5-5.5 mm in diameter) and are yellow to cream in colour. The snail is easily identified by its large size and long, narrow, conical shell, which is light brown with alternating bands of brown and cream on the upper whorls of larger specimens, the colour becoming lighter towards the tip of the shell.

CROP STAGE(S) AFFECTED

CUTTINGS	EMERGENCE / INSTALLATION	LEAF DEVELOPMENT	CORM GROWTH	SENESCENCE OF AERIAL APPARATUS	HARVEST	POST-HARVEST
0	+	++	++	+	0	0

SYMPTOMS AND DAMAGE

LEAVES The leaves are devoured, with only the main veins remaining.

Figure 103 — Damage to the taro leaf
https://www.pestnet.org/wp-content/uploads/2021/03/P6250147.jpg

IMPACT ON YIELD AND QUALITY

Taro and other edible aroids do not appear to be the giant African land snail's favourite plants in Pacific island countries. The damage is linked to the population level. When the population level is high, soon after the snail is introduced, the plants can be severely defoliated. When populations decline and other plants are available for food, the taro is rarely eaten. (Carmichael A., *et al.*, 2008).

TYPE OF IMPACT	DESCRIPTION
Yield loss per plant	The impact on yields of corms or cormels is rarely significant except in the event of very severe defoliation. For leaf yields, the impact is obviously very significant.

QUARANTINE ORGANISM

It is not a quarantine organism in the EU.

However, it poses a major quarantine threat to hot, humid countries not yet infested. It is also a carrier of the rat lungworm, *Angiostrongylus cantonensis*. Inspection and treatment of goods that may harbour the snail is an important way to prevent further spread. Snails are easily transported from country to country on plant parts, vehicles and other machinery, and in packaging of all kinds. (Carmichael A., *et al.*, 2008).

CONDITIONS CONDUCIVE TO INFESTATION

The snail is very sensitive to humidity. The decrease in the humidity level in its environment leads to its burial in the ground within a short period of time.

MONITORING

Monitoring is preferably done at night or in overcast and drizzly weather. The snail can also be detected by its slime trail.

CONTROL THROUGH GOOD GROWING PRACTICES

Physical barriers: The giant African land snail rarely moves on bare ground. A 1.5 m strip of bare soil around the crops therefore offers some protection. (Carmichael A., *et al.*, 2008).

BIOLOGICAL CONTROL

THROUGH CONSERVATION OF THE AUXILIARIES PRESENT

There are several natural enemies (*e.g.* predatory snails) but the introduction of exotic species should generally be avoided for controlling the giant African land snail because they are generally not specific.

CONTROL USING PLANT PROTECTION PRODUCTS

Metaldehyde can be used as a poison in the form of granules. Caution should be exercised when using this chemical to ensure that other animals are not at risk of poisoning themselves. (Carmichael A., *et al.*, 2008).

OTHER CONTROL METHODS

Collecting individuals and destroying them in salt water, or by crushing or burying them is effective if done frequently. (Carmichael A., *et al.*, 2008).

8.3. KEY TAKEAWAYS

8.3.1. MAIN PESTS AND DISEASES BY CROP STAGE

The main pests and diseases to be considered by crop development stage are listed below.

Remember that monitoring and control measures should only be planned if the pest or disease is known to be problematic in the growing area.

CUTTINGS

Cuttings should be free of the following main pests and diseases in order to avoid losses during crop development.

Particular care should be given to the choice of mother plants and the preparation of the cuttings, including any treatments.

- *Aphis gossypii* and other aphids
- *Patchiella reaumuri*
- Whiteflies
- *Tarophagus proserpina*
- Nematodes
- *Phytophthora colocasiae*
- *Pythium* spp.
- *Athelia rolfsii*
- *Pectobacterium carotovorum* and *Dickeya chrysanthemi* bacteria
- The viruses responsible for *Alomae*/*Bobone* and Taro mosaic

EMERGENCE AND INSTALLATION

If the cuttings are free of the pests and diseases mentioned above, the plants can be installed without too much constraint but pests and diseases can come from already infected soil or from surrounding crops and natural vegetation

The young plants should be especially monitored during this phase in order to detect the appearance of the following pests and diseases:

- *Aphis gossypii* and other aphids
- *Patchiella reaumuri*
- Whiteflies
- *Phytophthora colocasiae*
- *Pythium* spp.
- *Athelia rolfsii*
- *Pectobacterium carotovorum* and *Dickeya chrysanthemi* bacteria
- *Ophiomyia* spp.
- Defoliating caterpillars
- Leaf diseases (*Cladosporiosis* and *Phyllosticta*)
- Snails

LEAF DEVELOPMENT

You should continue to monitor the pests and diseases mentioned for the installation phase. You will also need to monitor the appearance of the following possible viruses:

- *Alomae/bobone*
- Taro Mosaic virus

GROWTH OF THE CORMS

During this phase, the aforementioned pests and diseases can continue to cause damage. In addition to these, you will also need to monitor the appearance of any symptoms due to the pests and diseases mentioned below.

— Nematodes
— Scarab beetles
— Taro root rot (*Marasmiellus* sp.)

SENESCENCE OF THE AERIAL APPARATUS

The pests and diseases mentioned above can continue to develop during this phase but no control is now possible to prevent damage. They have to be controlled inthe earlier stages.

HARVEST AND POST-HARVEST OF CORMS

The presence or absence of pests or diseases on the corms at harvest and post-harvest will depend on the effectiveness of their control during cultivation. Good sorting helps to avoid diseases that could develop during storage and/or be rejected by buyers. Thefollowingpests and diseases should notably be considered in relation to sorting and possible post-harvest treatments

— Presence of root aphids
— Symptoms of scarab beetle damage
— Symptoms of nematode damage
— Symptoms of fungal diseases such as *Phytophthora*, *Pythium*, *Marasmiellus* and *Athelia*
— Bacterial soft rot

8.3.2. SUMMARY OF THE MAIN ENVIRONMENTAL CONDITIONS FAVOURABLE TO CROP ENEMIES

The main environmental conditions favourable to the development of pests and diseases are summarised in the tables below. They are categorised in two main categories: weather conditions and soil.

This summary makes it possible to identify the favourable conditions that are common to several pests and diseases. Those that are common to the greatest number of pests and diseases will obviously be those that must be avoided as a priority.

The table of weather conditions shows which pests and diseases are most abundant during periods without rain (or light rain) and which are favoured by rain.

The table also shows the effect of temperature on the abundance of pests and diseases. Some are more adapted to relatively cool temperatures (conditions found especially at altitude in the tropics), such as *cladosporiosis* and *Phyllosticta* disease. Others are more adapted to higher temperatures, such as *Pythium*, *Athelia* and bacterial diseases.

8.3.2.1. WEATHER CONDITIONS

Table 17 — Weather characteristics favourable to pests and diseases

	HIGH TEMPERATURES	LOW TEMPERATURES	HIGH RELATIVE HUMIDITY	LOW RELATIVE HUMIDITY	HEAVY RAINS	ABSENCE OF RAIN
Aphids	+			+		+
Root aphids						+
Whiteflies	+			+		+
Leafhoppers						+
Root-knot nematodes	+				+	
Phytophthora	+*		+		+	
Cladosporiosis		+	+			
Phyllosticta		+	+		+	
Pythium	+					
Athelia	+		+		+	
Soft rot	+		+			
Snails			+			

*but relatively cool at night

8.3.2.2. SOIL

The characteristics of the soil have an impact mainly on telluric organisms attacking the crowns, roots and corms.

Table 18 — Soil characteristics favourable to the development of pests and diseases

	PERSISTENT HIGH MOISTURE LEVEL	SANDY	POOR IN ORGANIC MATTER	POOR IN CLAY	POOR IN NITROGEN	HYDROMORPHY	MOIST, BUT NOT EXCESSIVELY SO	LOW PH (ACIDIC)
Scarab beetles	+							
Root-knot nematodes	+	+	+	+				
Pythium	+					+		
Athelia			+	+	+		+	+

8.3.3. MAIN GOOD GROWING PRACTICES THAT HELP TO CONTROL PESTS AND DISEASES

Tables summarising the growing practices that help to control pests and diseases are summarised below. They are categorised in 5 main categories:

1. Prior choices
2. Preparation of the plot
3. Planting (sowing)
4. Crop maintenance
5. Harvest and post-harvest

This summary makes it possible to identify the practices that are useful for controlling several pests and diseases. Those that are common to the greatest number of pests and diseases will obviously be those that must be put in place as a priority, all the while considering as a priority the main pests and diseases known to be problematic in the growing area. You will also need to ensure that the practices put in place do not risk favouring pests and diseases hitherto considered to be minor in the production area.

The type of effect expected from the different practices is also summarised in these tables.

8.3.3.1. PRIOR CHOICES

Table 19 — Growing practices for pest and disease control to be considered when making prior choices

Growing practice		Resistant/tolerant varieties	Avoid proximity to a plot with a host plant	Use completely isolated land*	Rotation with non-host crop	Prior use of cover plants (green manure)	Avoid proximity to an area favourable to the reproduction of the pest or disease	Avoid heavy, clay soils	Avoid waterlogged or poorly drained soil	Avoid contaminated water sources	Crop combinations	Land flooded before cultivation	No presence of host trees	Plot not too shaded	Grow in an area with an unfavourable climate for the pest or disease
Type of effect	Avoidance	√	√	√			√	√	√	√	√		√	√	√
	Breaking of the cycle of the pest or disease				√	√						√			
	Improved plant defence	√						√	√						
Aphids			+												
Root aphids					+										
Whiteflies			+												
Leafhoppers			+		+										
Scarab beetles					+	+	+								
Root-knot nematodes					+	+				+		+	+		
Phytophthora		+		+							+				+
Pythium		+	+		+	+		+	+	+					
Athelia					+									+	
Alomae/bobone		+		+											
Mosaic				+											

* Isolated, away from other taro fields, surrounded by tall vegetation (forest clearing etc.)

8.3.3.2. PREPARATION OF THE PLOT

Table 20 — Growing practices for pest and disease control to be considered when preparing the plot

PRATIQUE CULTURALE		INTENSIVE TILLAGE (DEEP TILLAGE)	RAISED BEDS / DRAINAGE	WELL-DECOMPOSED ORGANIC MATTER	SOIL LIMING	CLEANING OF AGRICULTURAL EQUIPMENT	FLOWER STRIPS	HEDGES	WINDBREAKS (BARRIERS)
TYPE OF EFFECT	AVOIDANCE		√	√	√	√			√
	BREAKING OF THE CYCLE OF THE PEST OR DISEASE	√							
	IMPROVED PLANT DEFENCE			√					
	STRENGTHENED AUXILIARY ACTION			√			√	√	
Aphids							+	+	
Root aphids							+	+	
Whiteflies							+	+	+
Leafhoppers							+	+	
Defoliating caterpillars							+	+	
Root-knot nematodes				+		+		+	
Phytophthora									
Pythium		+	+	+	+				
Athelia		+	+	+	+				

8.3.3.3. PLANTING

Table 21 — Growing practices for pest and disease control to be considered when planting

GROWING PRACTICE		CUTTINGS TAKEN FROM HEALTHY PLANTS	TREATMENT OF CUTTINGS WITH HOT WATER	PROPER PREPARATION OF THE CUTTINGS *	CUTTINGS FROM MERISTEM	PLANTING AT LOW DENSITY	MULCHING
TYPE OF EFFECT	AVOIDANCE	√			√		
	CONDITIONS LESS FAVOURABLE TO THE PEST OR DISEASE					√	√
	BREAKING OF THE CYCLE OF THE PEST OR DISEASE		√	√			
Root aphids		+	+	+			
Leafhoppers		+		+			
Root-knot nematodes		+		+			
Phytophthora		+		+		+	+
Pythium		+		+			
Taro root rot (*Marasmiellus* sp.)		+					
Athelia						+	
Soft rot		+					
Alomae/bobone		+					
Mosaic					+		

*elimination of parts with defects, removal of the base of the petiole, washing to remove soil

NOTE ON THE IMPORTANCE OF THE QUALITY OF CUTTINGS (ADAPTED FROM JANICE Y. *ET AL.*, 2002)

— **Use clean stem cuttings**

Disease in cuttings is a problem that begins a few months before the taro harvest. Rots are not easy to find and often form under the skin of the corm or cormel, with no signs of disease on its surface.

A field that has had low levels of disease for at least a month or two before harvest is generally healthy and ideal for collecting healthy cuttings. The farmer should take the time to carefully check each cutting for any signs of rot. Sometimes hidden rot is exposed when the cutting is taken, and these rots need to be cut away. Cutting the skin of the corm of the cutting also exposes these hidden rots, and the rotten parts can still be cut away. Rotten cuttings can be further trimmed or discarded if seriously diseased

— **The attention paid to cuttings is extremely important**

Stem cuttings should be planted the day after they are harvested, or two days later at most. They should be kept in the shade in a dry place. Each day that the cutting is not planted, it uses more food and water to stay alive and therefore depletes its reserves. After a week, the cutting will be seriously weakened and will take longer to produce a vigorous plant and may not be able to root for several weeks. Some farmers place unused cuttings in water to store them until the field is ready. This allows the cutting to start growing, so it's best to choose a location that gets some sun. Cuttings that already have roots should be transplanted carefully to avoid root damage.

Cuttings should not be packed in airtight boxes or bags. Containers of the "laundry basket" type generally allow the cuttings to be kept for one or two days. Place the cuttings in the basket with all the corm sections at one end.

8.3.3.4. CROP MAINTENANCE

Table 22 — Growing practices for pest and disease control to be considered during crop maintenance

	GROWING PRACTICE	BALANCED NITROGEN FERTILISER	IRRIGATION BY SPRINKLERS	NO EXCESSIVE IRRIGATION	MULCHING	REGULAR WEEDING OF THE LAND AND THE PERIMETER	REMOVAL OF HEAVILY INFESTED ORGANS OR ENTIRE PLANTS
TYPE OF EFFECT	AVOIDANCE	√	√			√	
TYPE OF EFFECT	BREAKING OF THE CYCLE OF THE PEST OR DISEASE		√				√
TYPE OF EFFECT	IMPROVED PLANT DEFENCE				√		
TYPE OF EFFECT	CONDITIONS LESS FAVOURABLE TO THE PEST OR DISEASE	√		√	√		
Aphids			+				+
Root aphids							
Whiteflies			+				
Leafhoppers							
Scarab beetles						+	
Defoliating caterpillars							
Root-knot nematodes							
Phytophthora					+		+
Cladosporiosis							+
Phyllosticta							+
Pythium				+			
Corm and root rot							+
Athelia		+		+			+
Alomae/bobone							+
Snails						+	

8.3.3.5. HARVEST AND POST-HARVEST

Table 23 — Growing practices for pest and disease control to be considered during and after harvest

GROWING PRACTICE		AVOID HARVESTING TOO LATE	DESTRUCTION OF CROP RESIDUES	BAGGING OF CORMS AFTER HARVEST*	AVOID INJURY TO CORMS AT HARVEST	SORTING CORMS BEFORE STORAGE	SUITABLE STORAGE CONDITIONS	DISCING OF SOIL AFTER CLEANING THE GROUND	DEEP PLOUGHING AFTER LAST HARVESTS
TYPE OF EFFECT	AVOIDANCE	√		√	√	√	√		
	BREAKING OF THE CYCLE OF THE PEST OR DISEASE		√					√	√
Root aphids									+
Whiteflies									
Leafhoppers									
Defoliating caterpillars									
Root-knot nematodes								+	
Phytophthora		+	+	+			+		
Cladosporiosis									
Phyllosticta									
Pythium						+	+		
Corm and root rot		+	+						
Athelia					+	+	+		

* Place the corms, with the "crowns" and suckers attached, in plastic bags. The high humidity allows the corms to develop, which prevents most fungal and oomycete rots from developing in the same way as in earth pits. However, rots due to bacteria can be a problem, affecting around 10% of corms.

NOTE ON THE STORAGE OF TARO/DASHEEN CORMS (GRAHAME JACKSON, 2021).

The storage period can be extended by doing the following:

— Harvest the corms leaving the "crowns" and suckers attached, but remove the leaves, cutting the leaf stalks to around 10 cm.Enlevez les grosses mottes de terre, mais ne lavez pas les cormes.

— Remove large earth clods, but do not wash the corms.

— Place the corms in an earth pit lined with banana leaves, for example. The pit should be located in a shady, well-drained area.

— Cover with additional banana leaves.

This is a traditional practice in Sikaiana, in the Solomon Islands. The corms will stay in good condition and taste acceptable for up to 4 weeks. The corms remain active and the leaves continue to grow. Leaving the "crowns" and suckers in place presumably reduces injury and the risk of infection. There are variations to this technique depending on whether growers want to market taro locally or overseas:

This method, and the method of packing in plastic bags, can be improved if the corms are washed and soaked in 1% sodium hypochlorite (bleach) for 2 minutes. The downside to this method is that the surface colour of the corms becomes lighter than normal, which might bother some consumers. Lower concentrations of bleach or shorter treatments may be effective.

8.3.4. PPP APPLICATION STRATEGIES

The application of PPPs on taros is carried out essentially during two main periods:

1. When planting on the cuttings and in the planting holes or just after planting at the foot of the plants.
2. After harvest before storage, for fungal diseases only.

Table 24 — Main applications of PPPs on cuttings, on planting, at the foot of plants and post-harvest for taros (for macabo these applications will apply only to scarab beetle and *Pythium* control)

PLACE OR TIME OF APPLICATION	METHOD OF APPLICATION	TARGETED PESTS AND DISEASES	EXAMPLE OF ACTIVE SUBSTANCE	OTHER PESTS AND DISEASES PROBABLY IMPACTED
Cuttings	Soaking	Leafhoppers	Malathion	Aphids, whiteflies
	Soaking	*Pythium*	Fosetyl-Al Metalaxyl-M	*Phytophthora*
Planting hole	Watering	Scarab beetles	*Metarhizium*	
Foot of plant	Watering (after planting)	Leafhoppers	/	
	Spraying	*Pythium*	Fosetyl-Al Metalaxyl-M	*Phytophthora*
	Watering (3 months after planting)	Scarab beetles	/	
Post-harvest	Soaking (for 2 minutes)*	*Phytophthora* *Pythium*	1% bleach solution (sodium hypochlorite)	

*Then dry the corms thoroughly before packing in polyethylene bags.

Foliar applications for insect control during cultivation including aphids, whiteflies, leafhoppers and caterpillars.

Taro (*Phytophthora*) leaf blight disease can be controlled by foliar applications of fungicides, but these are tedious and often expensive given the number of applications to carry out over the crop cycle. The recommended intervention threshold is 5 to 10% of plants attacked. For other foliar fungal diseases, *Cladosporiosis* and *Phyllosticta*, treatment is not usually necessary.

Sprayed PPPs must be applied in such a way as to best reach their target. Many pests and diseases are found on the underside of leaves and/or in the cones of leaves that have not yet unfurled. Applications can be made using a power sprayer or manually-maintained pressure backpack sprayer, but the power sprayer will best reach the target. The other advantage of a power sprayer compared to a hydraulic backpack sprayer is the speed at which the product is applied over large areas. This feature is important in areas of high rainfall.

However because the taro leaves are waxy, the addition of a wetting agent to the mixture is essential to ensure the good distribution of the product on the taro leaves.

The use of nematicides is only recommended for plant material multiplication plots.

Metaldehyde granules can be used to control snails.

8.3.5. MAIN BIOCONTROL PRODUCTS

Table 25 — Main biocontrol products identified in Appendix 3

BIOCONTROL AGENT	APHIDS	LEAFHOPPERS	SCARAB BEETLES	*HIPPOTION CELERIO*	*SPODOPTERA LITURA*	*PHYTOPHTHORA*
Azadirachtin	x	x		x	x	x
Bacillus thuringiensis				x	x	
Metarhizium anisopliae			x			
SNPV					x	
Ocinum sanctum (extract)						x
Trichoderma asperellum						x
Trichoderma viride						x

Several other biocontrol products could be used against insects such as aphids (cf. 8.2.2.1), and whiteflies (cf. 8.2.2.3), but little is known about their effectiveness on taros and macabo.

9

HARVEST

The taro harvest takes place, depending on the variety and climatic conditions, between 5 and 12 months after planting in rainfed/exposed cultivation and between 12 to 15 months in flooded cultivation (taro/dasheen).

As maturity approaches, the canopy loses height with progressive yellowing of the foliage, less marked in flooded systems than in rainfed cultivation [ref 6]. In Bangladesh, the harvest begins when 80% of the leaves have turned yellow. [ref 41].

Yield levels at harvest are highly variable depending on the climate, the region and the crop system. According to FAO statistics (see Appendix 1), the average yield (2018-2020) is 6.9 t/ha worldwide. These figures cover very contrasting situations between the CAR (3.2 t/ha on average), where mainly macabo is grown at low density in agroforestry systems, and Egypt (35.8 t/ha), where taro dasheen is produced with irrigation.

In Japan, where mainly eddoe taro is grown, the average yield is 12.8 t/ha. For dasheen taro in the same region, the yield in irrigated conditions is generally more than double (70-80 t/ha) than in rainfed/exposed cultivation (35 t/ha), as in Hawaii (see chapter 3.5). For the macabo, the average yield in Costa Rica is 10-12 t/ha of marketable cormels [ref 13].

9.1. MANUAL HARVESTING

In flooded cultivation, the roots remain alive and must be cut with a machete to pull out the corms, even when mechanised systems are used.

In exposed cultivation, the root system regresses at the end of the cycle, which facilitates the harvesting of corms that have reached maturity. Harvesting is traditionally done by pulling the petioles by hand or lifting the corms with a spade. These keep fairly well if the plant remains in place, allowing the harvest to be staggered on the same plot according to needs.

For macabo, the crop cycle varies from 9 to 12 months depending on the variety. The full harvest can be spread out until the 16th month after planting, especially for the purple varieties, by detaching only the cormels of sufficient size and leaving the others to continue to grow. [ref 13].

9.2. HARVEST MECHANISATION

Harvesting can be mechanised in non-flooded systems and tools have been developed in several countries to mechanise the process, partially or completely, by adapting tools initially designed for potatoes or root vegetables. Due to a lack of sufficiently large markets, few manufacturers have embarked on the development of specific tools for taro. [ref 41]

The tools most easily adaptable without major modification for harvesting dasheen taro are the carrot harvester type, consisting of an adjustable blade of 1.2-1.5 m which cuts the corms at a depth of 20 cm. These are then pulled out from the ground by the workers, who remove the rootlets and cut the petioles 30 cm above the corm and put them in boxes. This type of tool has been tested with some success by CIRAD in New Caledonia and causes few injuries to the corms provided that they have been planted shallow. [ref 1].

In other situations, machines designed for potato harvesting have been adapted for taro harvesting. The range of possible tools ranges from the simple lifter (Figure 104) which leaves the corms on the surface of the ground for harvester-loaders, self-propelled or towed. These lift the corms, carry them on a conveyor belt and tip them into boxes (palloxes) that can hold 3 to 400 kg of corms. Steering trailers are also used (Figure 105).

Adaptations must take into account the size of the corms, depending on whether they are large corm taro (dasheen) or cormels attached to mother corms (eddoe and macabo).

The most advanced manufacturers of this type of equipment are found in Japan and China, with small-scale production mainly aimed at their domestic market [42].

HARVEST

TAKEWAYS FOR HARVESTING

- The average yield for all types of taro combined is 6.9 t/ha worldwide.
- The situations are very contrasting depending on the crop systems and the countries. In CAR, where macabo is mainly grown in agroforestry systems, it is 3.2 t/ha, while in Egypt, which produces taro dasheen with irrigation, it reaches 35.8 t/ha.
- In Japan, the average yield (mainly eddoe) is 12.8 t/ha. In Hawaii, for dasheen taro, the yield of taro/dasheen in irrigated conditions is more than double (70-80 t/ha) than in rainfed/exposed conditions (35 t/ha), as in Hawaii (see chapter 3.5). In Costa Rica, the average macabo yield is 10-12 t/ha of marketable cormels.
- Taros are harvested, depending on the variety and climatic conditions, between 5 and 12 months after planting in rainfed/exposed cultivation and between 12 and 15 months in flooded systems.
- For macabo, the crop cycle varies from 9 to 12 months depending on the variety.
- In flooded cultivation, the roots remain alive and must be cut with a machete to pull out the corms, even when mechanised systems are used.
- In exposed cultivation, the root system regresses at the end of the cycle, which facilitates the harvesting of corms that have reached maturity.Harvesting is done by pulling the petioles by hand or lifting the corms with a spade.
- The partial or full mechanisation of the harvest is possible in a non-flooded system by adapting tools originally designed for potatoes or root vegetables.
- Adaptations must take into account the size of the corms, depending on whether they are large corm taro (dasheen) or cormels attached to mother corms (eddoe and macabo).
- The most advanced manufacturers for this type of equipment are found in Japan and China, with small-scale production mainly aimed at their domestic market.

Figure 104 — Mechanised harvesting of eddoe taro with a lifter that leaves the cormels on the surface, from Hebei Province, China
Photo: https://fr.123 #ID 187058142

Figure 105 — Mechanical harvesting of taro/eddoe with tractor-towed loader, Hebei province, China
Photo: https://en.123 #ID161354372

10

POST-HARVEST

10.1. WASHING AND CLEANING

The stage following the actual harvest consists of corm cleaning operations. These are stripped of their roots and rootlets by hand or with a knife and the secondary corms separated from the main corms (Figure 106).

For dasheen, a few centimetres of the main petiole are usually left above the crown (2 to 30 cm depending on the market) in order to limit desiccation and make the product more attractive. (Figures 107 & 108) These operations can be done either in the field or at the farm. The corms are then cleaned with water with a pressurised jet to remove the earth, sorted by size and then left in the open air in the crate to dry again.

When large volumes have to be processed, these operations can be partly mechanised with tuber or root vegetable washers and conveyor belt sorters operated by people who complete the sorting by hand. The rootlets that remain on the corms or cormels can be removed using a rotating brush, taking care not to abrade the skin too much.

To increase the life of the product, especially after vigorous cleaning, which may have damaged the cuticle of the corms, corms can be cured in order to heal wounds and prevent the risk of rot. Curing consists in storing the corms, as quickly as possible after cleaning, for 5-7 days in a confined atmosphere at 34-36°C and 90-95% humidity with good ventilation. After this treatment, the corms are stored between 10 and 15°C in a humid atmosphere (80-90% RH) [ref 44].

Figure 106 — Cleaning of the dasheen corms after harvest. Preparation for export, Samoa
photo: https://www.aciar.gov.au/media-search/blogs/fresh-hope-samoan-taro-exports-australia

10.2. POST-HARVEST CHEMICAL TREATMENT

Some producers are required to carry out post-harvest treatments in order to block the development of mould and rot. One of the treatments used for regional exports in the Pacific zone is soaking the corms in a 1% sodium hypochlorite solution before storing them in polyethylene bags.

Chemical fungicides are sometimes used for export to prevent fungal attacks during storage, such as soaking in a solution of a fungicide (metalaxyl-M) for 5 minutes [ref 23].

Note: Before any treatment with a plant protection product, it must be ensured that its use is authorised for taro corms in the exporting country, in compliance with the manufacturer's recommendations for use, and that the residues comply with the MRL in force in the end consumption country.

10.3. SIZING AND QUALITY STANDARDS

For international exports, there are no universal quality standards and each exporter or importer can decide which categories they intend to use. It is often specified that the corms must be fresh (not dried out), clean (without earth), without buds, without rot or mould. The products are most often differentiated by the colour of the flesh (cream, yellow, red, purple etc.).

For dasheens, the weight of traded corms usually ranges between 0.9 and 4.5 kg (2-10 lb). On the US market, the usual sizes vary from 1.2 to 3 kg (3-6 lbs) and from 0.5 to 4 kg on European markets [ref 23].

For eddoes, the weight of the corms marketed for export ranges from 40 to 120 g, and for macabo from 150 to 450 g and 100 to 300 mm in length.

10.4. PACKAGING

The type of packaging used for taro and macabo corms varies according to the market, depending on whether the market is local, national or for export.

For short supply chains, the packaging is often quite basic: net, jute, polyethylene plastic or canvas bags, boxes or baskets. (Figures 109-111)

For *long distance* export, "banana" type crates are mainly used, from 6 to 20 kg depending on the destination (Figures 110-112-113-114). Taro/dasheen corms are sometimes wrapped in transparent plastic film to prevent drying out (Figure 110).

10.5. STORAGE AND TRANSPORT

International transport is by refrigerated container. Storage at the production site and on arrival before retail sale must take place under the same temperature and humidity conditions.

Recommendations and practices for long-term storage for taros are quite variable depending on the source. The following standards (Table 26) are those commonly followed in international trade.

Table 26 — Most commonly recommended storage conditions for taros

TYPE OF TARO	TEMPERATURE	RELATIVE AIR HUMIDITY	STORAGE PERIOD (IN DAYS)
Dasheen and eddoe	11-13°C	85-90%	150
Macabo	7-10°C	80%	120-150

Source [ref 44]

Dasheen is shipped from Fiji to New Zealand in wooden crates in 5°C refrigerated containers [ref 1]. In these conditions, they can be stored for at least 6 weeks but once the corms are returned to room temperature, their storage life will be no more than a few days.

In importing countries, retail sale takes place at room temperature and without misting. The storage life of corms is a minimum of one to two weeks.

Figure 107 — Dasheen taro corms with short petiole remnant, Guyana
Photo: P. Vernier

Figure 108 — Dasheen corms with long petiole remnant, Vanuatu
Photo: V. Lebot

Figure 109 — Dasheen corms – exported film-wrapped, Rungis
Photo: P. Vernier

Figure 110 — Dasheen corms – exported loose in box, Rungis
Photo: R. Vernier

Figure 111 — Macabo corms in net, Vanuatu
Photo: V. Lebot

Figure 112 — Macabo corms – exported in box, Rungis
Photo: R. Vernier

Figure 113 — Export type box, Rungis
Photo: P. Vernier

Figure 114 — Eddoe tar corms – exported in box, Rungis
Photo: P. Vernier

POST-HARVEST

TAKEAWAYS FOR POST-HARVEST OPERATIONS

- After harvest, the corms and cormels are stripped of their roots and rootlets and cleaned with a jet of water.
- For dasheen, a few centimetres of the main petiole are usually left above the crown (2 to 30 cm) in order to limit desiccation and make the product more attractive.
- For large volumes, these operations can be mechanised with tuber or root vegetable washers and conveyor belt sorters.
- The rootlets that remain on the corms are removed with rotating brushes, taking care not to abrade the skin.
- To increase the shelf life of corms, they can be cured. Curing consists in storing the corms, after cleaning, for 5-7 days at 34-36°C and 90-95% with good ventilation. The corms are then stored between 10 and 15°C in a humid atmosphere (80-90% RH).
- Post-harvest treatment: To control the risk of mould or rot during storage, treatments can be carried out by soaking the corms (1) in a 1% sodium hypochlorite solution before storage in a polyethylene bag, or (2) in a fungicide solution (metalaxyl- M) for 5 minutes.
- Sizing and quality standards: for export there are no universal quality standards and each exporter or importer chooses their quality criteria. The products must be clean, not dried out, without buds and the type of taro, (dasheen, eddoe, macabo) is differentiated mainly by the colour of the flesh.
- For dasheens, the corm weight varies from 1.2 to 3 kg (3-6 lbs) in the US market, and from 0.5 to 4 kg in European markets.
- For eddoe, the export weight ranges from 40 to 120 g and for the macabo, from 150 to 450 g and 100 to 300 mm in length.
- Packaging: For *long distance* export, 6 to 20 kg "banana" type crates are mainly used.
- International transport is by refrigerated container. Storage at the departure and arrival locations before retail sale must take place under the same temperature and humidity conditions:
    - *Colocasia* (dasheen and eddoe): 13°C with 85-90% RH; duration: 150 days.
    - Macabo: 7-10°C with 80%; duration: 120 to 150 days.
- The products are sold at room temperature, without misting.
- The shelf life of corms is in the order of one to two weeks once removed from refrigerated storage.

11

APPENDICES

APPENDIX 1 — MAIN TARO PRODUCING COUNTRIES

THREE-YEAR AVERAGES (2018-2020)

COUNTRY	PRODUCTION (TONNES)	AREA (HECTARES)	YIELD (T/HA)
World	12,385,452	1,806,721	6.9
Nigeria	3,215,426	816,098	3.9
China	1,887,228	97,287	19.4
Cameroon,	1,808,724	230,551	7.8
Ethiopia	1,789,743	70,313	25.5
Ghana	1,410,181	215,652	6.5
Papua New Guinea	280,442	35,257	8.0
Madagascar	228,202	38,050	6.0
Burundi	192,976	8,351	23.1
Rwanda	175,943	29,290	6.0
Japan	139,536	11,073	12.6
CAR (Central African Republic)	133,637	41,318	3.2
Laos	126,468	10,929	11.6
Egypt	120,688	3,370	35.8
Guinea	111,750	28,859	3.9
Philippines	106,774	14,931	7.2
Thailand	99,749	10,015	10.0
Ivory Coast	87,439	70,296	1.2
Gabon	86,767	14,328	6.1
Democratic Republic of Congo	69,291	17,981	3.9
Fiji	51,558	3,129	16.5

Source: FAOSTAT 2022 (“taro” entry, English version)

APPENDIX 2 — CHEMICAL COMPOSITION OF TARO LEAVES AND CORMS/CORMELS

	COLOCASIA ESCULENTA (TARO/DASHEEN)		*XANTHOSOMA SAGITTIFOLIUM* (MACABO)
BASED ON FRESH PRODUCT	LEAVES	CORMS	CORMELS
H_2O content %	85.4	69.1	67.1
energy (kcal/100g)	27	114	124
protein %	4.2	1.12	1.55
starch %	0.07	24.5	27.6
sugar %	0.92	1.01	0.42
fibre %	5.03	1.46	0.99
fat %	0.61	0.10	0.11
ash %	1.58	0.87	1.04
total oxalate (mg/100g)	426	65	–
Of which calcium oxalate	400	43	–
MINERAL ELEMENTS (MG/100G)			
Calcium (Ca)	182	32	8.5
Phosphorus (P)	61	70	53
Magnesium (Mg)	90	115	27
Sodium (Na)	7.9	1.8	6.6
Potassium (K)	487	448	530
Sulphur (S)	24	8.5	7.9
Iron (Fe)	0.62	0.48	0.4
Copper (Cu)	0.15	0.20	0.19
Zinc (Zn)	0.66	3.6	0.52
Manganese (Mn)	4.5	0.34	0.17
Aluminium (Al)	1.81	0.39	0.53
Boron (B)	0.36	0.09	0.09
VITAMINS (MG/100G)			
vitamin A	–	0.007	0.005
Thiamine (B1)	–	0.032	0.024
Riboflavin (B2)	–	0.025	0.032
nicotinic acid (B3)	–	0.760	0.80
Ascorbic acid (C)	–	15	13.6

Source: Lebot 2020 [ref 1] according to Bradbury and Holloway (1988) [ref 45]

APPENDIX 3 — LIST OF ACTIVE SUBSTANCES RECOMMENDED ON TAROS AND MACABO AGAINST THE MAIN PESTS AND DISEASES

COLEAD stresses the importance of respecting the instructions *indica*ted on the label of PPPs. In addition, before applying any product, it is advisable to consult the latest regulatory changes in the EU databases on pesticides and the Codex Alimentarius and ensure compliance of applied Good Agricultural Practices (GAP) to the demands of the target market (MRLs and buyer specifications). Information on GAP to meet EU and Codex Alimentarius MRLs is available in the COLEAD crop protection database here.

LIST OF ACTIVE SUBSTANCES RECOMMENDED ON TAROS AND MACABO AGAINST INSECTS, NEMATODES AND SNAILS

ACTIVE SUBSTANCE	COTTON APHIDS	ROOT APHIDS	WHITEFLIES	LEAFHOPPERS	*PAPUANA* SPP.	*HIPPOTION CELERIO*	*SPODOPTERA LITURA*	NEMATODES	SNAILS
abamectin				×12					
azadirachtin	×4			×12		×, ×2	×, ×1		
Bacillus thuringiensis						×, ×1, ×2, ×4	×, ×1, ×11		
chlorantraniliprole							×5		
cypermethrin	×, ×3	×	×	×	×8, ×13	×	×		
dazomet								×1	
deltamethrin	×, ×3	×	×	×		×	×		
emamectin benzoate							×5		
esfenvalerate						×	×		
flupyradifurone	×7		×7	×7					
lambda-cyhalothrin	×3			×12					
malathion				×1, ×11, ×12			×4, ×11		
metaldehyde									×1
Metarhizium anisopliae					×1				
methoxyfenozide							×5		
pyrethrins						×2			
spinosad						×1, ×2, ×4	×1, ×4, ×5		
spirotetramate	×6	×10	×6	×6					
Spodoptera Nuclear Polyhydrosis Virus							×4		
sulfoxaflor	×9			×9					

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×3 https://www.cabidigitallibrary.org/doi/full/10.1079/cabicompendium.6204#sec-38

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×5 https://www.cabi.org/isc/datasheet/44520#topreventionAndControl

×6 https://www.cropscience.bayer.ca/-/media/Bayer-CropScience/Country-Canada-Internet/Products/Movento/28953_approved_F_14July20213.ashx?la=fr-CA&hash=9E06D8E51BA146E70D7ADDD37D3C8AABD0D8C8BD

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×10 http://westernipm.org/index.cfm/searchable-data-sources/docPull/?ID=SPI_3

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LIST OF ACTIVE SUBSTANCES RECOMMENDED ON TAROS AND MACABO AGAINST FUNGI

ACTIVE SUBSTANCE	*PHYTOPHTHORA*	*PYTHIUM*
azadirachtin	×4	
captan		×
copper	×, ×3, ×4	
fosetyl		×, ×5
sodium hypochlorite	×1	×1
metalaxyl	×, ×3, ×4, ×5, ×6	×5
metalaxyl-m	×, ×6	×
Ocinum sanctum (extract)	×4	
potassium phosphonates	×4	
Trichoderma asperellum	×4	
Trichoderma viride	×4	

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×3 http://docplayer.fr/157716150-Fletrissure-des-feuilles-de-taro.html

×4 http://www.sac.org.bd/archives/publications/Promotion%20of%20Underutilized%20Taro.pdf

×5 https://ipmdata.ipmcenters.org/documents/cropprofiles/AStaro.pdf

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