SUSTAINABLE PRODUCTION

GUIDE

COLEAD

PINEAPPLE (*ANANAS COMOSUS*)

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INTRODUCTION

Pineapple (*Ananas comosus* (L.) Merr.) is a fruit crop belonging to the Bromeliaceae family. It is grown in most tropical and subtropical countries (Carlier *et al.*, 2012) and is ranked as the third most important tropical fruit in the world (Oculi *et al.*, 2020). The main pineapple-producing countries are Costa Rica (3056.45 Mt), the Philippines (2671.71 Mt), Brazil (2253.90 Mt), Thailand (2153.18 Mt) and India (1891.00 Mt) (FAO, 2022). In terms of representation, Costa Rica contributes 10.62% of total world production, while in second and third place are the Philippines and Brazil with 9.4% and 9.3% respectively (FAO, 2019). The fruit contains vitamins A, B1, B6 and C, as well as other nutrients, such as copper, manganese and fibre (Morton, 1987; Mateljan, 2007; Pérez *et al.*, 2011).

Pineapple is a tropical plant that requires specific conditions in terms of soil, climate and maintenance to thrive.

2

CROP NEEDS

2.1. CLIMATE

2.1.1. TEMPERATURE

Temperature is a determining factor in the pineapple's range. It influences plant growth and the leaf emission rate. The optimum average temperature for pineapple cultivation is 25°C with average daily amplitudes of 12°C (CIRAD, 2002). Values below 20°C or above 36°C are unfavourable for its development and affect the quality of the fruit (CIRAD, 2018). Low temperatures between 0 and 22 days after flower induction result in low flowering rates, fruit malformations and low fruit sugar content (Julius *et al.*, 2017). High temperatures during fruit formation tend to increase sugar content and decrease acidity (CIRAD, 2018).

2.1.2. RAINFALL

This crop is not very water-intensive with a requirement of 12,000 to 1,500 mm evenly spread over the year (i.e. a theoretical average requirement of 3 to 4 mm/day which can be split into one or two inputs per week) (CIRAD, 2002). If the soil is very sandy, it will be necessary to increase the amount and frequency of watering.

2.1.3. RELATIVE HUMIDITY

Pineapples need an average relative humidity of 70% but can tolerate moderate variations. Periods of very low relative humidity (below 50%) can cause fruit to burst and crack during the ripening phase (Souza et Reinhardt, 2007).

2.1.4. INSOLATION

Sunshine affects the plant's vegetative development, yield, quality and fruit colouring (CIRAD, 2018). The plant grows best when annual exposure to the sun varies between 2,500 and 3,000 hours, or 7 to 8 hours of sunshine a day. The minimum requirement is 1,200 to 1,500 hours of sunshine (Souza et Reinhardt, 2007). Radiation and temperature are very important factors affecting pineapple fruit quality (Adabe *et al.*, 2016):

- When they are low, they lead to higher fruit acidity, lower sugar content, poor fruit colouring and slower growth of both the plant and fruit.
- When they are too high, they lead to sunburn and translucency of the fruit, as well as colouring problems. If the fruit is too translucent, it becomes very fragile and, in extreme cases, this is accompanied by fermentation of the flesh, which can even lead to foam exudation.

2.2. WATER

The pineapple's water needs could be met by rainwater, depending on the planting period. However, irrigation is important to keep plants in optimal growing conditions (Ewemoje *et al.,* 2006; Franata *et al.*, 2014); 14). A lack of water slows pineapple development and is particularly damaging during fruit formation. It leads to low fruit weight, with prominent eyes at harvest, as in the case of wilt, a dull appearance of the epidermis, as well as unhealthy crowns; premature wilting of the peduncle and a reduction in the nutrient content and titratable acidity of the fruit.

The water requirements of pineapple crops depend on the stage of growth of the plants and the water conditions of the soil, ranging from 1.3 to 5.0 mm per day. The average water consumption of pineapple plants is: 4.1 to 4.6 mm/day in the vegetative phase, 4.3 mm/day in the flowering phase, 3.8 mm/day in the fruit formation phase and 3.4 mm/day at the harvest stage (de Azevedo *et al.*, 2007). However, too much water also has harmful effects, as roots are very susceptible to asphyxiation (CIRAD, 2018).

2.3. SOIL

An effective soil depth of between 80 and 100 cm is sufficient for pineapple cultivation, as the roots tend to concentrate in the first 15 to 20 cm of soil. This crop has a better tolerance to light, sandy-clay or loose sandy-clay soils that are well aerated and very filtering (limiting asphyxiation) (Agbangba, 2016).

Intermediate-textured soils (15-35% clay and more than 15% sand), with no obstacles to the free drainage of excess water, are best recommended for this crop. Soils with a sandy texture (up to 15% clay and over 70% sand), with no drainage problems in general, are also recommended, but it is almost always necessary to incorporate organic residues and manure to increase their water and nutrient retention capacity. Clay soils (over 35% clay) with good drainage, such as many ferralsols (WRB classification) can also be recommended for pineapple plantations. On the other hand, silty soils (less than 35% clay and 15% sand) should be avoided. High silt content leads to undesirable soil structure characteristics, which affect aeration and drainage and can have a negative influence on plant establishment and development (Souza et Reinhardt, 2007). Pineapple prefers soils with a pH of between 4.5 and 5.5, with slight variations depending on the variety. The presence of organic matter and mineral elements is essential for its nutrition (Souza et Reinhardt, 2007).

2.4. NUTRITION

To ensure its vegetative and reproductive growth, the pineapple plant draws the mineral elements it needs from the soil, some of which are essential (Bartholomew *et al.,* 2003).

2.4.1. NITROGEN

Positively affects growth rate, plant volume and fruit weight with non-negligible effects on yield (PIP, 2015). Plants whose nitrogen requirements are satisfied are recognisable by the bright green to dark green colour of the leaves. Nitrogen (N) deficiency is manifested by yellowing of the foliage, beginning on the oldest leaves, and a reduced plant growth rate (see section 8.2.3) (Omotoso et Akinrinde, 2013; PIP, 2015).

2.4.2. POTASSIUM

It plays a crucial role in the quality of pineapple fruit: sugar content, acidity, colour, flavour, texture (PIP, 2015). Potassium (K) deficiency leads to yellowing of the leaves, which remain short and narrow, and to the appearance of discoloured spots (Adabe *et al.*, 2016). The fruit is lightly coloured, low in acidity and has no fragrance (see section 8.2.3) (Teixeira *et al.*, 2011; PIP, 2015).

2.4.3. PHOSPHORUS

It plays a key role in energy transfers between the plant's organs, in turn having a positive influence on its growth. Phosphorus (P) does not travel very far in the soil, and soil mineral analysis is particularly recommended for controlling inputs of this element. Deficiency of this element is manifested by slowed growth and drying of the leaf tips, starting with the oldest leaves (Bartholomew *et al.*, 2003b; PIP, 2015) (see section 8.2.3).

2.4.4. MAGNESIUM

As a major component of chlorophyll, it also plays a decisive role in fruit quality (sugar content, flavour, resistance and firmness). The appearance of small, roundish, yellowish leaf spots, usually located in the medial part of the leaf blade, evolving to darker shades, is a sign of magnesium (Mg) deficiency (PIP, 2015) (see section 8.2.3).

2.4.5. CALCIUM

It plays a key role in the formation of cell membranes. It contributes to plant development. It has a positive influence on plant development, with the plant displaying a stubby habit, leaves becoming hard and brittle, the terminal bud dying and offshoots proliferating in the event of deficiency (PIP, 2015) (see section 8.2.3).

2.4.6. BORON

The symptoms of boron (B) deficiency: orange and yellow discolouration, turning brown on one side of the leaf; minimal leaf growth to only two-thirds of its normal length and with dry tips; a tendency for the leaf to curl. Similarly, chlorosis of young leaves with reddening of the dead margins at the apex is observed; fruit with multiple crowns; formation of suberised dead tissue between fruiting, and sometimes accompanied by very small spherical fruit (Py *et al.,* 1984; Souza, et Reinhardt, 2007) (see section 8.2.3).

2.4.7. COPPER

Copper (Cu) deficiency results in narrow, light green leaves with wavy margins; leaf tips curled downwards; old leaves with purple-red colouration at the fold; short roots with reduced hairs; stunted plant (Py *et al.,* 1984;Souza, et Reinhardt, 2007) (see section 8.2.3).

2.4.8. IRON

Iron (Fe) is involved in photosynthesis. Its deficiency results in chlorosis of the foliage, with alternating light and darker striations in a "grid" pattern. The fruit is small, globular and takes on a red colour (PIP, 2015) (see section 8.2.3).

2.4.9. MANGANESE

The leaves are damaged, mottled with light green areas, especially towards the veins, surrounding darker green areas. Manganese (Mn) deficiency is rare, but can occur on Ca-rich soils with high pH (Py *et al.,* 1984; Souza, et Reinhardt, 2007) (see section 8.2.3).

2.4.10. ZINC

In young plants, the centre of the leaf rosette is closed, and the young leaves are rigid, cracked and sometimes curved. In older plants, basal leaves show irregular, mottled-looking veins and orange-yellow discolouration on the leaf margins, and the tips are dry (Py *et al.,* 1984; Souza, et Reinhardt, 2007) (see section 8.2.3).

2.4.11. SULPHUR

Sulphur (S) can improve resistance to disease and drought stress, which is particularly important in pineapple cultivation since water management is a critical factor (Py, 1958). Sulphur applications can lower soil pH, which can be beneficial for pineapple cultivation in acid soils (Osseni, 1985). The following symptoms are associated with sulphur deficiency: pale yellow to golden foliage; pink leaf margins, particularly on older leaves; very small fruit (Py *et al.*, 1984) (see section 8.2.3). Sulphur is normally supplied by fertilisers, which are also sources of certain primary macronutrients, such as ammonium sulphate (23 to 24% S), potassium sulphate (17 to 18% S) and simple superphosphate (10 to 12% S). When choosing a fertiliser, it is important to be certain of the amount of S it contains in order to avoid any S deficiency (Souza and Reinhardt, 2007) (see section 8.2.3).

2.4.12. MOLYBDENUM

Molybdenum (Mo) can influence important physiological processes in pineapple, such as sugar synthesis (Ayers, 1960; Georgieva *et al.*, 2006). It has also been associated with the reduction of internal browning in pineapples, a condition that can reduce the quality and marketability of the fruit (Teisson *et al.*, 1979). A deficiency is likely in soils with a pH <4 (Py *et al.*, 1987; Malézieux and Bartholomew, 2003) (see section 8.2.3). The balance of micronutrients, including molybdenum, is important in preventing plant diseases (see section 8.2.3).

CROP NEEDS

To ensure their optimum growth and development, pineapples have a number of essential requirements, including: climatic and nutritional factors such as:

TEMPERATUR

The optimum average temperature for pineapple cultivation is 25°C, with average daily variations of 12°C.

RAINFALL

1,200 to 1,500 mm/year.

RELATIVE HUMIDITY

The optimum relative humidity for pineapple cultivation averages 70%.

WATER

The water requirements of pineapple crops are linked to the growth stage of the plants and the water conditions of the soil, ranging from 1.3 to 5.0 mm per day-1. Water consumption is 4.1 to 4.6 mm/day in the vegetative phase, 4.3 mm/day in the flowering phase, 3.8 mm/day in the fruit formation phase and 3.4 mm/day at the harvest stage.

INSOLATION

The minimum requirement is 1,200 to 1,500 hours of sunlight for the entire cycle.

SOILS

Loose, light, well-aired, permeable soils rich in organic matter with a pH of between 4.5 and 5.5. Flat ground or a slight slope of less than 5%.

NUTRIENTS

- Organic matter content: to be supplemented by the incorporation of crop residues, mulch, compost, manure, etc.
- Essential minerals such as nitrogen, potassium, phosphorus, magnesium, calcium and the trace elements iron, boron, zinc, copper, sulphur, manganese, molybdenum, etc.

3

PLOT PREPARATION

3.1. PLOT SELECTION

3.1.1. PRECEDING CROP

Rotational cropping practices are essential with pineapple in order to optimise the use of resources, particularly soil nutrients (COLEAD, 2020). It is recommended to plant the following types of crops or plants before growing pineapple:

— Legumes (such as cowpeas, lentils and soya). They help to fix nitrogen in the soil, which can enrich the soil for pineapple cultivation. They are of economic interest because they allow the soil to regenerate the nutrients that are essential for crop growth, thereby reducing the cost of purchasing inputs.

— Cover crops (such as mucuna, rattlepods, pigeon pea). They help control weeds and improve soil quality by adding organic matter. During this period, plant debris decomposes, enriching the soil with organic matter and nutrients, which helps to restore soil fertility (Kozak *et al.*, 2021; Żarczyński *et al.*, 2023; Chen *et al.*, 2023).

— Cereals (such as corn and sorghum). They can be used to improve soil structure and increase fertility by returning crop residues to the soil.

— Tubercles or roots (cassava, taro, sweet potato). They help loosen the soil and prepare it for pineapple growing.

However, from a health point of view, the most suitable food crops for pineapple are:

— Sugarcane can be effective in eliminating certain nematode populations such as *Rotylenchulus reniformis* and *Pratylenchus brachyurus*.

— Banana is also an interesting crop to grow in rotation with pineapple, as it is not infested by the same nematode species.

— Ground cover or forage species (such as *Macroptylium atropurpureum Crotalaria usaramoensis, Flemingia congesta, Cajanus indicus, Panicum maximum, Brachiaria decumbens, Digitaria umfolozi, Digitaria decumbens, Eupatorium odoratum, Tagetes patula*) have a nematicidal effect.

On the other hand, nematode host plants to be avoided before pineapple are:

— Groundnut and yam (hosts of *Rotylenchulus reniformis*, minor hosts of *Pratylenchus*).

— Tomato and okra (hosts of *Meloidogyne*, minor hosts of *Pratylenchus*).

— Greater nightshade (host of *Meloidogyne* and *Rotylenchulus reniformis*)

— Cowpea, soybean (hosts of *Rotylenchulus reniformis*)

— Corn, sorghum, rice, cassava and chilli (hosts of *Pratylenchus brachyurus*, minor hosts of *Meloidogyne*).

— Cassava (host of *Rotylenchulus reniformis* and *Pratylenchus brachyurus*).

— Papaya, orange and mango (hosts of *Rotylenchulus reniformis*).

3.1.2. TOPOGRAPHY

Analysing the topography of the soil informs decisions relating to the type of site preparation, drainage layout and planting design. It is of the utmost importance to ensure that internal and surface drainage is properly managed by installing drains to correct waterlogging conditions, while retaining sufficient moisture in the soil to facilitate root development and prevent erosion at the same time (PIP/COLEAD, 2011). Flat ground or ground with a slope of no more than 5% are best suite because, as well as facilitating mechanised cultivation practices, the soil is less susceptible to runoff and therefore erosion (Souza, et Reinhardt, 2007; Hossain, 2016). Opting for ground with a steep slope requires the adoption of conservation practices, such as planting along contour lines (Souza, et Reinhardt, 2007).

3.2. STAGES OF SITE PREPARATION OR DEVELOPMENT

If the field is to be planted with pineapple for the first time, clear the site of existing vegetation as follows:

- Using a subsoiler, go over the ground once to break up compacted layers of soil and bury shrubs, bushes, weeds, etc.
- Using a disc harrow, go over the site 4 times to break up the boulders into fine particles. This operation must be carried out in the direction of the last planting row.
- Leave the debris from plants cut and crushed by the harrow to dry.
- Incorporate the organic matter into the soil using a tractor fitted with a deep plough (PIP/COLEAD, 2011).

If the plot has already been planted with pineapple, the old crop must be completely removed to eliminate any remaining sources of insects and diseases in the pineapple plant residues (PIP/COLEAD, 2011). To achieve this, it is essential that they are decomposed to prevent them from serving as hosts for various types of parasite (nematodes, mealybugs), so that they can help to maintain soil fertility and make some of the mineral elements they contain available to the next crop. Effective decomposition of the residues from the previous crop is only possible by "thoroughly" breaking up this vegetable mass; this is usually done using conventional equipment such as a rotary shredder (Py *et al.*, 1984). A rotary shredder is effective in shredding pineapple leaves and stems (Figure 1).

Figure 1 — Shredding of plants using a rotary shredder
Source: CIRAD, 2018

3.3. SOIL PREPARATION

3.3.1. PLOUGHING

Deep ploughing (generally 40 cm), preceded or not by subsoiling, is essential especially on soils with poor drainage. These operations can be manual or mechanical. Once the plant matter has been cleared, ploughing is carried out using a rotovator (Figure 2a) or a disc plough or a plough with unworn shares (Figure 2b). Ploughing must be carried out while maintaining a regular line to avoid forming crevasses (Daouda *et al.*, 2015).

Figure 2 — Rotovator ploughing (a) and share ploughing (b)
Source: CIRAD, 2018 et Daouda *et al.*, 2015

3.3.2. BURIAL

Residual matter from the previous crop is used to increase the soil's nutrient and organic matter content. The soil should remain bare for only a short time, which also reduces the risk of erosion. It is advisable to leave the organic matter to dry out in the sun for at least 15 days to 3 weeks before incorporating it into the soil (PIP, 2015). After being left to dry for few days, the residue will be buried in the soil (Sossa *et al.*, 2019) for example by using a disc harrow or Rome plough (Figure 3).

Figure 3 — Disc harrow
https://www.hellopro.fr/pulveriseur-a-disques-2010535-fr-1-feuille.html

3.3.3. SUBSOILING

Subsoiling is an agricultural technique for working the soil in depth, allowing it to regain permeability by improving the natural drainage and horizontal capillary circulation of water on ploughed or compacted soils(Figure 4). Subsoiling to a depth of 60-80 cm is recommended (CIRAD, 2002). Cross subsoiling may also be advisable, especially on heavy soil (to be carried out during dry periods), as it improves water infiltration by breaking up the plough sole (CIRAD, 2018).

Figure 4 — Subsoilers
https://www.hellopro.fr/images/produit-2/1/5/5/sous-soleur-repliable-subevo-400-quivogne-6509551.jpg
consulté le 01/08/2025; Guide sous-soleuses 2013, Le bulletin des agriculteurs. http://bit.ly/4mIvoBl

3.3.4. HARROWING

This operation loosens the soil by reducing large clods of earth to finer particles (crumbling). Breaking up these clods of earth reduces the risk of obstacles preventing the roots from developing properly. Depending on the type of soil, this operation is carried out using disc harrows (on heavy or clayey soils) or a chain harrow (on light soils) (Figure 5).

Figure 5 — Harrowing
Source: Daouda *et al.*, 2015

3.3.5. RIDGING

Ridging is a useful way of marking prior to planting. It is essential on heavy or poorly prepared soil (Figure 6) (Sossa *et al.*, 2019). The ridging of the soil on contours allows water to run off properly, limiting erosion and the retention zones that can suffocate roots. It may be supplemented by a more or less dense network of drainage channels to evacuate rainwater. The height of the ridge will depend on the soil and will be greater on soils prone to compaction or asphyxiation. For double row planting, the ridge should be around 70 cm wide at the top, 90 to 100 cm wide at the base and 30 cm high.

Figure 6 — Disc ridgers
Source: CIRAD, 2018

3.3.6. LAYING OF POLYETHYLENE FILM

Polyethylene films (biodegradable or non-biodegradable) help to regulate various environmental parameters crucial to crop growth, such as soil moisture, temperature and structure. Polyethylene film protects the soil from the deteriorating action of rain and improves the development and root activity of plants. The soil can thus be better exploited by the plant, provided that root parasites, which are also favoured, are effectively controlled (Py *et al.*, 1984).

Polyethylene film is not used systematically for pineapple production, except where necessary due to unfavourable soil and climate conditions (very low or high rainfall, heavy soils) and is only used on ridges. Laying polyethylene film offers a number of advantages, including:

- good water management during the first 4 to 5 months by eliminating direct evaporation from the soil;
- maintaining good conditions for the first roots to emerge, provided the soil is initially moist. Offshoot regrowth is faster and more uniform;
- reduced excess water at the foot of the plant, which can cause root asphyxia;
- reduced leaching of fertilisers and plant protection products;
- reduced weed invasion, which is generally very difficult to control in the furrow without polyethylene film;

— the development of the root system and an improvement in foliar emission through an increase in soil temperature and a reduction in soil compaction under the effect of rain;
— improved plot homogeneity, which reduces sorting differences at harvest.

The main disadvantages of this technique are:

— the high cost of polyethylene film (biodegradable or non-biodegradable) for small producers;
— the management and accumulation of non-biodegradable polyethylene residues that are difficult to remove after cultivation;
— as it is difficult to rewet the soil, this technique is not recommended if planting in dry soil;
— reduced effectiveness of spraying when plants are underdeveloped: 35 to 50% of the input is "lost" on the polyethylene or "slides" towards the paths;
— the formation of a microclimate in the soil that is more favourable to parasites (mainly nematodes and symphylans);

The use of biodegradable polyethylene film to standard NF EN 13432 (with a thickness of 3/100 to 5/100 mm) (Figure 7) or mulch, preferably plant mulch (legumes, cover plants), is the most recommended. Due to their impact on the environment, non-biodegradable polyethylene films are not recommended. On the other hand, the use of biodegradable film is limited by its high purchase cost for small pineapple growers.

Figure 7 — Laying polyethylene film (a); Planting offshoots on polyethylene film (b)
Source: PNDFA, 2017; Daouda *et al.*, 2015

3.4. SOIL IMPROVERS

Fertilisation begins as soon as the soil is prepared. A prior soil analysis will ensure that the appropriate soil improvers are used.

3.4.1. BOTTOM DRESSING

Bottom dressing is primarily a corrective and conservative measure for soils exposed to the aggressiveness of the humid tropical climate and should be applied just before ridging, so that it is incorporated into the soil (Sossa *et al.*, 2019). It makes elements that are not very mobile in the soil (phosphorus, calcium, magnesium, trace elements) available to the plant for its entire vegetative cycle (PIP, 2015).

Soil pH is the most important factor for pineapple growers. Excessive acidity leads to increased leaching of: K, Ca, mg and trace elements and to risks of aluminium toxicity (Rahman *et al.,* 2018; Agegnehu *et al.,* 2021).

Moreover, high soil acidity can limit the solubility and mobility of phosphorus in the soil, making it less available to plants (Edwards, 1991; Ron Vaz *et al.*, 1993; Mao *et al.*, 2017). To neutralise the acid residues of the fertilisers used, basal dressing in solid form is applied, for example:

— 3 to 6 g per plant of Phospal (34% P_2O_5 - 11% CaO);

— 10 to 14 g per plant of Dolomite (variable composition of 30 to 36% CaO - 16 to 22% MgO.

3.4.2. ORGANIC SOIL IMPROVERS

Before planting pineapple cultivars and after correcting soil acidity by liming, the soil can be prepared by sowing cover crops. For example, *Mucuna pruriens*, *Vigna unguiculata* (L.) or *Crotalaria* can be used with the aim of covering part of the crop's nitrogen and potassium requirements after shredding and burial and thus reducing additional nitrogen and potassium inputs at the time of planting (Figure 8). Adding organic fertilisers such as compost improves soil condition, increases soil potassium and can improve micronutrient availability (Fournier, 2012).

Figure 8 — Fallow land with *Mucuna pruriens* (a) and *Crotalaria juncea* (b)
Source: Site photo COLEAD, 2023

PLOT PREPARATION

THE IMPLEMENTATION OF ALL OF THESE RECOMMENDATIONS DEPENDS ON THE INITIAL STATE OF THE PLOT, SUCH AS

— Preceding crop: such as cowpea, lentil, soybean, mucuna, rattlepod, pigeon pea, corn, sorghum, cassava, taro and sweet potato;
— Analysis of the topography to decide on the type of site preparation, drainage layout and planting design;

PREPARING THE PLOTS INVOLVES THE FOLLOWING STEPS

— Ploughing (essential): deep ploughing, generally 40 cm, preceded or not by subsoiling.
— Burial (optional): leave the residual matter from the previous crop to dry out in the sun for at least 15 days to 3 weeks before incorporating it into the soil.
— Subsoiling (optional): 60-80 cm deep.
— Harrowing (essential): reduce large clods of earth to finer particles (crumbling).
— Ridging (optional): essential on heavy or poorly prepared ground, applied to the contours.
— Laying of black polyethylene film (biodegradable or non-biodegradable) or mulching with plant mulch (legumes, cover plants) (optional)
— Soil improvers before planting (optional):

- Lime or dolomite to reduce soil acidity
- Organic soil improver: application of composts, manures, green manures.

4

PRE-PLANTING CHOICES

4.1. PLANT MATERIAL

Offshoots are the main reproductive plant material for pineapple cultivation. They are also called suckers or pups. Offshoots with genetic abnormalities, manifested by excessively spiny leaves, deformed or deliberately "off-type" fruit, according to the standards of the variety concerned, and whose presence cannot be explained by nutritional or physiological causes (stress due to drought, intoxication by agrochemicals, etc.), must be removed immediately after harvesting the fruit (Uriza-Ávila *et al.*, 2018).

There are several ways of obtaining plant material for production.

- Plant material (offshoot) from mother plants from old harvested plantations. These offshoots include: crowns, slips and suckers.
- Plant material from a centre specialising in plant reproduction, for the supply of vivoplants or vitroplants.

4.2. VARIETIES

Pineapple (*Ananas comosus*) is the most commercially exploited of the various pineapple species. Pineapple cultivars used worldwide are usually classified into five distinct groups, based on a set of common characters (plant habit, fruit shape, flesh characteristics and leaf morphology) (Table 1) (Py *et al.*, 1984; CIRAD, 2002). Although variety selection depends on a number of aspects (market preferences, price, availability of planting material, etc.), it is essential that the varieties selected have acceptable yield potential, while being adapted to local conditions (prevailing biotic and abiotic stresses). More than twenty pineapple cultivars or varieties are commonly grown worldwide (Table 2). The most common varieties in the various ACP countries are:

4.2.1. SMOOTH CAYENNE

— LEAVES

- The leaves have no spines

— FRUIT

- Large fruit
- Cylindrical fruit shape
- Orange skin when ripe

— FLESH

- Yellowish
- Firm
- Acidic
- Quite fibrous

— IMPORTANCE

- Most widely grown variety (70% of world production)
- Widely used for processing and export

— SUSCEPTIBILITY TO BIOTIC OR ABIOTIC STRESSES

- Very susceptible to wilt disease

Figure 9 — Smooth Cayenne
Source: Ceinfo, 2002 in Queiroga *et al.*, 2023; UN explanatory brochure, 2013

4.2.2. SUGARLOAF

— LEAVES

- The plant's leaves have spines

— FRUIT

- Small fruit (smaller than Smooth Cayenne)
- Pyramidal fruit shape
- Greenish-yellow skin with small, prominent eyes
- Smaller diameter core

— FLESH

- Translucent, non-fibrous
- Whitish colour
- Tastes less acidic than Cayenne
- Very sweet and tender on the palate

— IMPORTANCE

- Variety widely used for table-stock consumption

— SUSCEPTIBILITY TO BIOTIC OR ABIOTIC STRESSES

- Very fragile fruit

Figure 10 — Sugarloaf
Source: Daouda *et al.*, 2015, UN explanatory brochure, 2013

4.2.3. MD2

— LEAVES

- Narrow leaf tips with few teeth

— FRUIT

- Medium-sized fruit (smaller than Smooth Cayenne)
- Fruit with a rather square profile
- Cylindrical fruit shape
- Yellow-orange skin with green incrustations around the eyes.

— FLESH

- Dark yellow colour

— IMPORTANCE

- It is relatively stable in terms of quality

— SUSCEPTIBILITY TO BIOTIC OR ABIOTIC STRESSES

- Susceptible to Phytophthora soft core and root rot diseases

Figure 11 — MD2
Source: Daouda *et al.*, 2015; UN explanatory brochure, 2013

4.2.4. RED SPANISH

— FRUIT

- Fruit smaller than Cayenne
- Globular-shaped fruit
- Reddish-yellow skin when fully ripe,
- Flat, wider eyes
- Core bigger than Cayenne

— FLESH

- Pale yellow colour
- Fibrous
- Peppery taste
- Less sweet than Cayenne

— SUSCEPTIBILITY TO BIOTIC OR ABIOTIC STRESSES

- It is very easy to transport

Figure 12 — Red Spanish
Source: Daouda *et al.*, 2015

4.2.5. QUEEN VICTORIA

— LEAVES

- Leaves can be spiny

— FRUIT

- Small fruit
- Cylindroconical fruit
- Clear yellow skin with prominent eyes that are less wide than those of the Cayenne

— FLESH

- Opaque
- Crunchy
- Less acidic than Cayenne
- Tender, juicy texture

— IMPORTANCE

- Victoria” is the best-known variety among the “Queen” pineapple

— SUSCEPTIBILITY TO BIOTIC OR ABIOTIC STRESSES

- Low susceptibility to wilt

Figure 13 — Queen Victoria
Source: Daouda *et al.*, 2015; UN explanatory brochure, 2013

4.2.6. PEROLERA

— FRUIT

- Cylindrical fruit shape
- Pronounced reddish skin

— FLESH

- Opaque
- Crunchy with alternating yellow to pale yellow radials
- Less acidic taste
- Less sweet than Cayenne

— IMPORTANCE

- Fruit rich in ascorbic acid

— SUSCEPTIBILITY TO BIOTIC OR ABIOTIC STRESSES

- Wilt resistant

Figure 14 — Perolera
Source: Daouda *et al.*, 2015

Table 1 — Characteristics of the main groups of the genus *Ananas comosus*

GROUPS	LEAVES	FRUIT	CROWNS	OFFSHOOTS	DISEASES	TARGET MARKET
CAYENNE	A few spines at the tip, dark green, medium size	1.5 to 2.5 kg, cylindrical, orange, pale yellow flesh, high sugar and acidity content	Single, large	Few slips, few suckers	Susceptible	Exported fresh and processed
SINGAPORE SPANISH	Long, very to slightly spiny, dark green	1 to 1.5 kg, cylindrical, orange-red, bright yellow flesh, low sugar and acidity.	Often multiple	Plentiful	More resistant than Cayenne	Processed
QUEEN	Short, spiny,	0.5 to 1.2 kg, yellow, golden flesh, high sugar content, low acidity, pleasant aroma	Little developed	Plentiful	Less susceptible than Cayenne	Exported fresh
RED SPANISH	Long, spiny	1.2 to 2 kg, cylindrical, white flesh, sweet, slightly acidic	Often multiple	Several slips	Low susceptibility	Exported fresh
PEROLA OR ABACAXI	Long, spiny	0.9 to 1.5 kg, conical, green to pale yellow, very sweet, low acidity, pleasant aroma	Often multiple	Several slips	Low susceptibility to wilt	Local market
PEROLERA OR MORDILONA	Spineless leaf with silver edging	1.5 to 3 kg, cylindrical, yellow to orange, pale flesh, firm, medium sweetness	Often multiple	Several slips	Low susceptibility, Fusarium resistant	Local and export

Source: CIRAD, 2002

Table 2 — Classification of the different cultivars/varieties into the major groups

GROUPS	CULTIVARS
CAYENNE	• Smooth Cayenne • Champaka • Sarawak • Kew • Giant Kew • Nanglae • C10, C13, C30 • Havai or Havaiano • Kayin, • Qianlihua; • Yueyinaoka; • HA10, HA25 • Serrana • N67-10 • Numpung • Pattavia • Bathavia • Lakata • Petburi No. 2 • Baronne de Rothschild • PRI hybrid 53-116 • Singkapropattavia • St Domingue • Hilo • Typhones
SPANISH	• Española Roja • Green Selangor or Selangor Green • Cabezona • Singapore Spanish • Betek • Gandul • Nangka • Ruby • Masmerah • Shenwan (Yellow Mauritius) • Intrachitdang • Intrachitkhao • Hybrid 36 • Pina de Cumana • Pina de Anare • Castilla
QUEEN	• Victoria • Natal Queen • Ripley • MacGregor • Honey Queen • Golden Queen • Queen India • James Queen • Alexandra • Mauritius • Comte de Paris • Jinxiang • Bali • Meitei Keehom • PQM-1 • Moris • Balang • Tailung • Yankee • Phuket • Phulae • Sawi • Tainan • Tradsitong • Petburi • Tadum • CDD • Ninh Binh
PERNAMBUCO	• Sugarloaf • Pernambuco • Abacaxi de Tarauacá • Abacaxi Rondon • Perola • Paulista • Boituva-Amarelo • Yupi • Pan de Azucar • Eleuthera • Venezolana • Pina Valera • Papelon
PEROLERA	• Milagreña • Maipure • Monte Lirio • Bumanguesa • Perolera Mordilona • Piamba de Marquita • Amarillo • Piampa • Tachirense • Rondon • Mariquita

GROUPS	FRUITING PEDUNCLE (LENGTH IN RELATION TO THE FRUIT)	LEAVES	OFFSHOOT FORMATION AT FRUIT HARVEST (SLIPS - SUCKERS)	GENERAL APPEARANCE OF THE PLANT
CAYENNE	Relatively short	• Relatively short • Broad spiny tips • Non-chlorophyll base of leaves: pale green	• Cultivars with and without slips • Some suckers	Relatively voluminous
SPANISH	Longer than Cayenne	• Long and narrow • Usually spiny, but there are clones with no or few spines • Non-chlorophyll base of leaves: reddish green	• Variable number and size of slips • Some suckers	Less voluminous than the Cayenne
QUEEN	Relatively short	• Short and narrow • Very spiny with “hook-shaped” spines • Non-chlorophyll base of leaves: reddish green	• Variable number and size of poorly developed slips • Very large number of suckers in certain cultivars (Natal Queen) (Victoria)	Relatively voluminous
PERNAMBUCO	Longer than Cayenne	• Long and narrow • Very spiny with non-hooked spines • Non-chlorophyll base of leaves: pink-mauve	• Numerous upright slips, well developed in a crown around the fruit • Rare and late suckers	Erect
PEROLERA	Longer than Cayenne	• Long and wide • Non-spiny (Piping type) except for the distalspine • Non-chlorophyll base of leaves: pale green	• Numerous slips of varying size form a crown around the fruit	Less voluminous than the Cayenne

GROUPS	THE MOST APPROPRIATE USES FOR THE FRUIT	BEHAVIOUR IN RESPONSE TO WILT DISEASE AND NEMATODES	FRUIT	
CAYENNE	• Canning • Exported fresh • Local consumption	• Very susceptible	• Average weight: high • Shape: cylindrical • Eyes: large and flat • Skin (when ripe): Yellow orange • Flesh (when ripe): more or less translucent	• Non-fibrous • Flesh (colour): pale yellow • Flavour: sweet and acidic • Core (diameter): medium
SPANISH	• Exported fresh mainly • Local consumption	• Wilt tolerant • Less susceptible to nematodes	• Average weight: lower than Cayenne • Shape: globular • Eyes: broader than Cayenne and flat • Skin (when ripe): reddish yellow • Flesh (when ripe): more or less translucent	• Fibrous • Flesh (colour): whitish "spicy" • Flavour: less sweet than Cayenne • Core (diameter): larger than Cayenne
QUEEN	• Exported fresh • Local consumption	• Less susceptible than • Cayenne to wilt	• Average weight: low • Shape: cylindrical-conical • Eyes: not as broad as Cayenne and prominent • Skin (when ripe): bright yellow • Flesh (when fully ripe): opaque	• Crunchy • Flesh (colour): deep yellow • Flavour: less acidic than Cayenne • Core (diameter): smaller than Cayenne
PERNAMBUCO	• Local consumption	• Less susceptible than Cayenne to wilt	• Average weight: lower than Cayenne • Shape: pyramidal • Eyes: small and partially prominent • Skin (when ripe): greenish yellow • Flesh (when ripe): translucent • Non-fibrous	• Flesh (colour): whitish to yellowish • Flavour: less acidic than Cayenne • Core (diameter): smaller than Cayenne
PEROLERA	• Exported fresh • Local consumption	• Low susceptibility and resistant to Fusarium	• Average weight: similar to Cayenne • Shape: cylindrical • Eyes: broad and flat, often irregular • Skin (when ripe): deep reddish yellow • Flesh (when ripe): opaque	• Crunchy • Flesh (colour): alternating radial yellow to pale yellow • Flavour: less acidic and less sweet than Cayenne; richer in ascorbic acid • Core (diameter): similar to Cayenne

4.3. INTERCROPPING AND OTHER ASSOCIATIONS

The use of legumes in association with cash crops results in higher productivity, low disease impact, plant stability and weed suppression compared to monoculture (Garcia De La Cruz et García- López, 2021). However, intercropping and other associations are rarely used.

FAVOURABLE CROPS

Recommended associations of pineapple and cover crops are *Vigna unguiculata*, *Mucuna pruriens, Crotalaria juncea, Glycine max (L.) Merr., Arachis hypogaea*, *Vigna subterranea* (Garcia De La Cruz et García- López, 2021; Sessou *et al.*, 2022). Intercropping of pineapple with *Carica papaya L.* (papaya solo) is also reported. This prevents sunburn, which affects fruit quality (Sessou *et al.*, 2022).

HARMFUL CROPS

Crops such as *Zea mays* (corn), *Solanum lycopersicum L.* (tomato) and *Capsicum* (chilli pepper) that favour nematode populations are harmful to pineapple and should therefore be avoided (COLEAD, 2020). Moreover, the cultivation of *Manihot esculenta* (cassava) is also harmful in association with pineapple because it is demanding in nutrients, particularly potassium, which affects the quality of pineapple fruit (sugar content, acidity, colour, flavour, texture).

4.4. CROP ROTATION

Crop rotation systems help improve soil structure, favour biodiversity, and increase organic matter and nutrient content in the top layer of the soil (Tullio *et al.*, 2016). They also allow nematode control (García de la Cruz *et al.*, 2006; Paull *et al.*, 2016; COLEAD, 2020); weed suppression (Nurbel *et al.*, 2021; Garcia De La Cruz et García-López, 2021); and improved water retention during dry periods following burial of the plant cover (PIP, 2015). Some recommended crops are *Mucuna pruriens or Mucuna deeringiana; Vigna unguiculata; Arachis hypogaea; Crotalaria juncea; Crotalaria spectabilis; Stylozanthes guanensis etc.*

PRE-PLANTING CHOICES

PLANT MATERIAL

- Offshoots: crown; slips; suckers from old harvested plantations; and vivoplants or vitroplants.
- Selection criterion: offshoots complying with the standards for the variety concerned, and free of disease and nutritional or physiological deficiencies.

THE MOST COMMON VARIETIES IN THE VARIOUS ACP COUNTRIES ARE

- Smooth Cayenne
- Sugarloaf
- MD2
- Red Spanish
- Queen Victoria
- Etc.

INTERCROPPING AND OTHER ASSOCIATIONS

- Favourable crops: *Vigna unguiculata*, *Mucuna pruriens*, *Crotalaria juncea*,
- Harmful crops: corn, tomatoes, chillies and cassava.

CROP ROTATION

- *Mucuna pruriens*,
- *Mucuna deeringiana*,
- *Vigna unguiculata*,
- *Arachis hypogaea*,
- *Stylozanthes guanensis*,
- *Crotalaria juncea*,
- *Crotalaria spectabilis*.

5

OFFSHOOT PRODUCTION

Pineapple offshoots are generally produced by vegetative propagation. Offshoots are often also called suckers or pups. Different types of pineapple offshoot are produced for this purpose, the name by which they are known depending on their position on the mother plant. Each of them has its own characteristics (growth time, the number of offshoots produced, etc.) which condition the choice of their multiplication or propagation (Cunha *et al.*, 2021; Shamim *et al.*, 2016) (Table 3).

Table 3 — Characteristics of the different types of pineapple offshoot

DIFFERENT TYPES OF OFFSHOOT	EXPLANATIONS	CHARACTERISTICS
CROWN	It develops from the apex of the fruit (the upper part of the fruit).	• Only one crown is produced per plant • The crowns become dormant when the fruit ripens • Less commonly used as planting material because the fruit is sold with the crowns • The fruit tends to ripen evenly • The average growing cycle (from planting to fruit harvest) is 22 to 24 months.

Figure 15 — View of the crown on the fruit

DIFFERENT TYPES OF OFFSHOOT	EXPLANATIONS	CHARACTERISTICS
SLIPS	They develop at the base of the fruit from an axillary bud on the peduncle.	• Large number of offshoots produced (15 to 25 offshoots per plant) • Uneven fruit ripening • The crop cycle (from planting to fruit harvest) averages 20 months.

Figure 16 — Slip formation

DIFFERENT TYPES OF OFFSHOOT	EXPLANATIONS	CHARACTERISTICS
HAPAS	They develop from the axillary bud, in the transition zone between the stem and the peduncle (Py *et al.* 1984). Hapas are similar to slips but develop well below the base of the fruit and do not have the characteristic curve at the base of the leaves.	• Low number of offshoots produced • Their base is arrow-shaped, like the slips.

Figure 17 — View of a hapa in the transition zone between the stem and the peduncle

DIFFERENT TYPES OF OFFSHOOT	EXPLANATIONS	CHARACTERISTICS
AERIAL SUCKERS	They grow several cm up the stem.	• Low number of offshoots produced • Can only be obtained on certain varieties such as Smooth Cayenne.

Figure 18 — Onset of aerial suckers
https://www.tropicalpermaculture.com/pineapple-growing.html

DIFFERENT TYPES OF OFFSHOOT	EXPLANATIONS	CHARACTERISTICS
GROUND SUCKERS	They originate on the underground part of the stem or on the collar of the plant (Cunha and Reinhardt, 2004). The ground sucker has a typical duckbill appearance (Py *et al.* 1984).	• Low number of offshoots produced • Offshoots are difficult to plant because of their large size; • Uneven fruit ripening • The average growing cycle (from planting to fruit harvest) is 15 to 18 months.

Figure 19 — View of ground suckers

5.1. PRODUCTION OF OFFSHOOTS FROM A PLOT OF HARVESTED PINEAPPLE

This method involves maintaining the pineapple plants after harvesting the fruit for 8 to 12 months. To do this:

— after harvest, prune the leaves of pineapple mother plants to reduce the surface area consumed by nutrients by these mother plants, which accelerates the emission of offshoots (Queiroga, 2023);
— regularly weed the plot to aerate the mother plants and reduce the humidity in the plot;
— if necessary, treat with a mixture of insecticide and fungicide authorised in ACP countries and compatible with your destination market (https://eservices.colead.link/fr/listes-produits-protection-plantes-homologues-pays-acp; https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/start/screen/active-substances) (Table 4).
— apply a monthly input of urea and potassium chloride (KCl), based on the results of leaf or soil analysis (Vásquez-Jiménez and Bartholomew, 2018; Queiroga, 2023).
— harvest the offshoots at the desired size every month.

Advantages/difficulties: This method makes it possible to use all types of conventional planting material, including crowns, slips, hapas and suckers. Only the slips and the suckers are used more for reproduction, as they are easily available in large quantities to growers.

5.2. PRODUCTION OF OFFSHOOTS FROM TISSUE CULTURE OR VITROPLANTS

The stages in the production of tissue culture offshoots (Figure 20) are:

— once the buds have been removed from the mother plant, the first step is disinfestation to eliminate any micro-organisms present and minimise the risk of fungal and bacterial contamination. Under totally aseptic conditions in a laminar flow chamber, these buds must be further reduced by removing excess tissue before being introduced into the culture medium;
— the process of swelling pineapple buds is relatively slow and several transfers to fresh culture media of the same composition are necessary before the multiplication stage begins. 45 days after placing the buds in the culture medium, it is time to add growth regulators. The presence of a cytokinin is essential for the initiation of the cell division process and its balance with an auxin, generally in a ratio of around 3:1, favours the elongation and subsequent rooting of seedlings;
— when the first shoots or aggregates of shoots appear, they need to be subdivided and transferred to a new medium (transplanting), and so on for periods of 45 to 60 days, with multiplication rates depending on each variety. The first offshoots may appear after around 90 days of cultivation, when multiplication cycles need

to be started by inducing latent buds present at the base of small shoots, thus generating new individuals. Many varieties elongate in the same medium, but others need to be transferred to a specific medium in a larger container to elongate their shoots;

- rooting of pineapple plants in vitro can most often be achieved in the absence of growth regulators or with the addition of low concentrations of auxin, such as naphthalene acetic acid (NAA), or the combination of auxin with cytokinin;
- the final stage in the production of seedlings by micropropagation is acclimatisation. This phase involves transferring the seedlings from the in vitro condition to a greenhouse. This passage is fairly critical and, in some cases, represents the main limiting factor in the micropropagation process. The seedlings should be carefully removed from the flasks, their roots thoroughly washed under running water to remove any residue of the culture medium, and transferred to small polystyrene trays or tubes, or another suitable container. As far as substrates are concerned, preference should be given to those with low density, good moisture retention and good aeration, including mineral supplementation (Reinhardt *et al.*, 2018).

Figure 20 — Key stages of pineapple micropropagation
Source: Reinhardt *et al.*, 2018

5.3. PRODUCTION OF OFFSHOOTS FROM THE USE OF GROWTH REGULATORS

The natural emergence of pineapple plant buds is enhanced and stimulated by the use of a growth regulator approved in ACP countries and your destination market (https://eservices.colead.link/fr/listes-produits-protection-plantes-homologues-pays-acp; https://www.fao.org/pesticide-registration-toolkit/information-sources/maximum-residue-limits/en/) (Table 5). This is a good reproduction method when planting material is scarce or unavailable. The process begins once the plant has been forced and takes 5 days.

- On the first day, application is made with ethephon at 1.4 kg dissolved in 3,750 litres of water per hectare;
- on the second day, the same dosage is applied;
- on the fifth day or 72 hours after the second application of ethephon, apply 2.2 kg of chloroflurenol in 2,300 litres of water per hectare. Chloroflurenol is applied when (2 kg) and after pruning the offshoots;
- after 4.5 to 5 months, the planting material can be harvested.

5.4. OFFSHOOT PRODUCTION USING THE TRUNK SECTION

The technique of breaking up the stem after harvesting the fruit gives very good results. This technique enables the characteristics of the parent plant to be fully preserved. It consists of:

- digging up the fresh stumps (stems) and cutting off all the leaves at the base to obtain a cylindrical stem (Figure 21a and 21b);
- cutting the stems lengthways to obtain several fragments of around 3 to 4 cm (Figure 21c);
- disinfecting the fragments obtained by soaking them completely in an approved fungicide solution (Table 6);
- making a 15 cm high ridge with black earth or humus, and digging parallel furrows 5 cm apart, inside which the fragments are planted;
- placing the fragments end to end and flat in the furrows, at intervals of 15 cm;
- making sure that the cut side is facing the ground, which will facilitate root development (Figure 21d);
- covering with a thin layer of soil (1 cm) and mulching lightly;
- watering once every 3 days. After three weeks, each fragment will have budded on the upper side and 2 months later, your young seedlings will be 4 to 5 cm high (Figure 21e);
- setting up a nursery consisting of one or more ridges 15 to 20 cm high, with shade;
- dividing the stem fragments into as many pieces as there are buds;
- then making holes 5 cm deep, by hand or with a planter, at spacings of 15 cm x 15 cm (44 plants per m^2) or 25 cm x 10 cm (40 plants per m^2);
- treating the buds with a fungicide solution before placing them in the pots;
- packing lightly around the crown, then watering thoroughly every day;
- the offshoots will be ready to be transplanted to the field after 11 months in the nursery. Unlike the conventional method, this method has the advantage of producing homogeneous offshoots in large quantities (Figure 21f) (Reinhardt *et al.*, 2018).

ADVANTAGES/DIFFICULTIES

The seedlings produced by this technique are of superior sanitary quality, but their size, weight and vigour are generally inferior to those of suckers and slips. As a result, their initial development after planting in the field is slower and their overall performance is closer to that of crowns.

Figure 21 — Production of pineapple seedlings from stem fragments
Source: Reinhardt *et al.*, 2018

5.5. OFFSHOOT PRODUCTION BY FLORAL ABLATION/CASTRATION

The procedure for this technique is as follows:

— 5 to 6 months after planting, carry out a flower induction treatment (hormone treatment) on developed plants, using calcium carbide at a rate of 500 g in 150 l of water; then pour in 50 ml/plant overnight, then repeat the treatment twice at 3-day intervals;

— 1 to 2 months after hormone treatment, remove the inflorescence after it has emerged. Just after removing the flowers, prune the leaves;

— 3 to 4 months after removing the inflorescence, offshoots develop; collect those of acceptable size for 8 to 12 months;

— continue to maintain the plot regularly for as long as the offshoots are producing (Reinhardt *et al.*, 2018).

ADVANTAGES/DIFFICULTIES

few publications have focused on this method.

5.6. OFFSHOOT PRODUCTION FROM CROWNS

Fruit crowns are another source of planting material. These are good planting materials, but they need to be sorted and graded to avoid sending material with defects to the field for planting. When they reach maturity, they become dormant. Two methods of propagating this type of material have been developed:

METHOD 1

- Ripe pineapple fruit is selected to separate the crown from the fruit.
- A cut section of pineapple fruit is soaked in charcoal ash and left to dry for several days. If the crown leaf is not dried, the rotting process occurs.
- The detached crown is immersed in water to form roots (Figure 22a and 22b).
- Once the crown forms 7 to 9 roots under the leaves, it is planted in humus soil where it continues to vegetate and begins to grow, forming new leaves (Figure 22c) (Shakarovna et Hamdamovich, 2022).

Figure 22 — Offshoot reproduction from the pineapple crown
Source: Shakarovna et Hamdamovich, 2022

METHOD 2

- Divide the base of the crown into 4 parts and cut off any excess leaves (Figure 23a);
- Treat the fragments at the base of the crown with potassium permanganate;
- Plant the fragments in the soil and water (Figure 23b);
- After a while, a new plant will grow from each planted piece (Figure 23c) (Shakarovna *et* Hamdamovich, 2022).

Figure 23 — Offshoot reproduction from crown fragments
Source: Shakarovna *et* Hamdamovich, 2022

METHOD 3

The PIF (Plants from Stem Fragments) technique was developed by Kwa in Cameroon in 2003 and is based on the principle of breaking the apical dormancy of the crown by destroying the apical meristem (Figure 24). The procedure consists of:

- trimming the crown by removing the rest of the fruit from the base of each crown using knives;
- removing all the leaves from the crown by hand, one by one, from the base to the top;
- making two or three criss-cross incisions in the centre of the tip of the explant or making an incision longitudinally in two (2) on the trimmed explant, passing through the apex;
- planting in sawdust to a depth of 2 to 5 cm;
- drying the explants for 2 hours under shade after disinfection with approved fungicide (Bodjona *et al.*, 2020).

Figure 24 — Offshoot reproduction phase using the PIF method
Source: Bodjona *et al.*, 2020

METHOD 4

This technique has been used for many years and many modifications of the original technique have been tested. Each leaf on the pineapple crown covers a bud on the stem at its base. The first step is to:

- remove and discard the base of the crown and any dry leaves. Each green leaf on the crown can then be carefully removed with a small piece of the stem just below the bud;
- the upper part of the crown with the associated leaves is too soft to allow single buds to be removed, so the whole top is simply divided vertically into four pieces;
- the cuttings are then soaked in a sodium hypochlorite solution followed by a fungicide bath to protect against rotting, and then planted in beds containing moistened sand, a mixture of black soil and peat, or agarose (agar medium).
- one month after transfer to the culture medium, the buds develop into seedlings. No fertiliser needs to be applied at this stage;
- after two to three months' growth, the seedlings are transferred to propagation trays (leaf pots) or beds in a greenhouse. The growing medium used at this stage consists of 45% black peat, 40% white peat, 15% clay and 4 kg osmocote (osmocote can be replaced by other fertilising compounds);
- The propagation trays are shaded (40%) and irrigated with small sprinklers just to keep the soil moist;
- after a further three months of growth under light shade, i.e. when they are five to six months old, they are ready to be transplanted to the field. A crown can produce up to sixty seedlings, depending on the variety of pineapple.

5.7. OFFSHOOT PRODUCTION USING A TEMPORARY IMMERSION BIOREACTOR

The micropropagation system in temporary immersion bioreactors was first adapted by; Escalona *et al.* (1998) for the large-scale production of pineapple seedlings. It allows the use of large containers, increasing efficiency with reduced costs and excellent survival rates during acclimatisation compared with micropropagation in stationary culture.

— Bud establishment takes place using the conventional micropropagation system, in small containers (Figure 25a), and the initial bud aggregates are then transferred to the bioreactors to start the multiplication phase (Figure 25b).

— This technique alternates temporary immersion of the buds in A liquid medium with periods of absence of culture medium at regular intervals.

— Each unit of the system consists of two vials, one containing a large volume of medium depending on the size of the vials and the other with the explants for multiplication.

— The bottles are connected to each other by means of a hose through which the culture medium goes from one bottle to the other by activating an air compressor.

— The interval between immersions of the explants is variable and must be adapted to the conditions of each species or cultivar.

ADVANTAGES/DIFFICULTIES

The automation of the system reduces the labour required for explant transfers between culture media and increases multiplication rates, as it avoids material losses through hyperhydration and asphyxiation, and therefore leads to reductions in the cost of seedling production (Reinhardt *et al.*, 2018).

Figure 25 — Small plastic pots or containers (a) and bioreactor (b)

5.8. OFFSHOOT PRODUCTION BY ETIOLATION

The method of pineapple micropropagation based on the in vitro elongation of nodal segments was demonstrated by Kiss *et al.* (1995).

— in vitro plants are used as explants. Shoot etiolation is induced by placing these explants in a medium containing NAA (10 µM = 1.86 mg/L) and incubating them in the dark at 28ºC for 30 to 40 days (Figure 26a and 26b);

— the etiolated shoots, developed in the dark (Figure 26C), are harvested and placed horizontally in a medium supplemented with kinetin (25 µM = 5.38 mg/L) or BA (20 µM = 4.50 mg/L), incubated at 26 ºC and a photoperiod of 16 h, and after 4 to 6 weeks, the shoots have regenerated along the nodes (Figure 26d);

— regenerated seedlings are rooted on MS medium without growth regulator (Figure 26e) and transferred to the greenhouse (Reinhardt *et al.*, 2018).

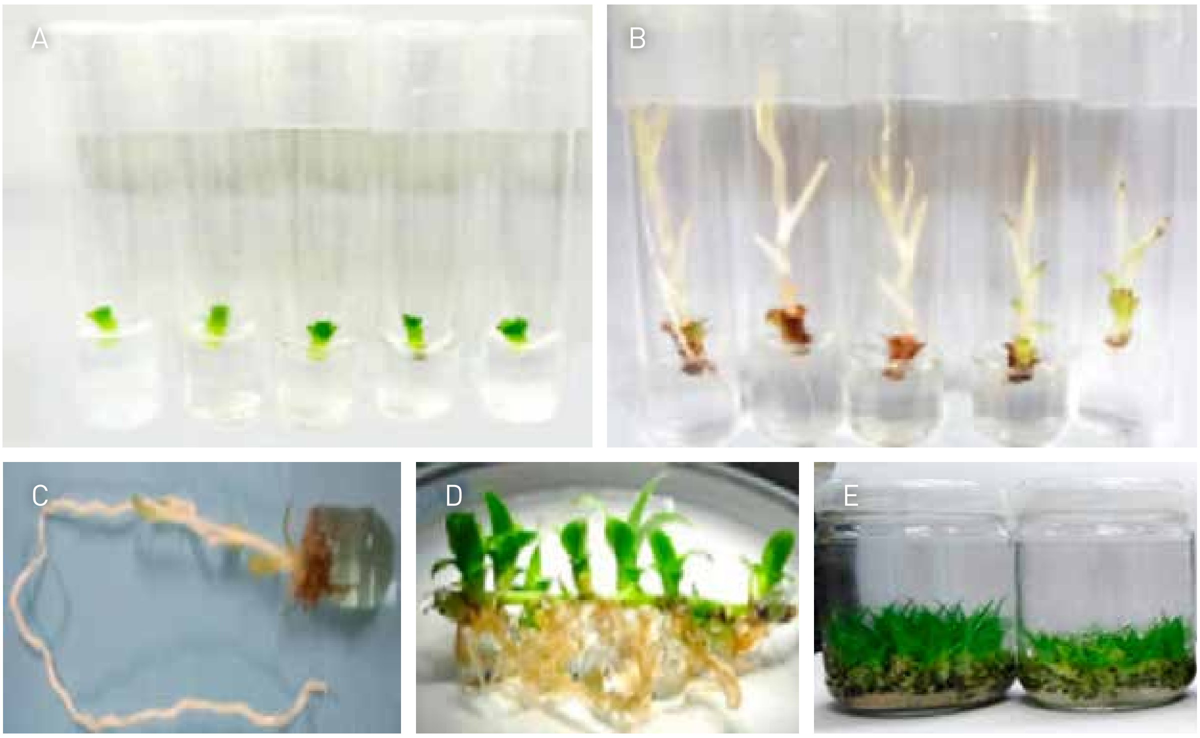

Figure 26 — Main stages in pineapple micropropagation by nodal segment etiolation:
(a) Plants inoculated for incubation in the absence of light; (b) Plants etiolated after incubation in the dark;
(c) Etiolated nodal segment ready for subculture after removal of the stem apex;
(d) Shoots obtained from nodal segments; (e) Plant multiplication phase
Source: Reinhardt *et al.*, 2018

5.9. OFFSHOOT NUTRITION

All offshoots produced by the different methods require appropriate fertilisation to keep the plants well nourished until the planting material is of good quality and can produce a fast-growing crop with quality fruit at the same time. Whatever the system chosen to produce planting material, the fertilisation programme is the same in all cases.

5.10. HARVESTING OFFSHOOTS

Offshoot production usually takes 6 to 11 months depending on weather conditions and mineral nutrition. The number of "sessions" needed to harvest them should be frequent, every 2 to 3 weeks, to ensure that the offshoots are as uniform as possible and do not overgrow, which would hinder the subsequent development of younger offshoots. The optimum average weight is between 400 and 500 grammes. However, it is possible to use smaller offshoots (preferably not less than 300g) if you want to speed up the emergence of the next offshoots and if the conditions for planting are favourable; or larger offshoots, but not more than 600g, if you want to achieve short crop cycles. It is best to place them on the mother plant for a few days, with their base pointing skywards, to allow the section to heal quickly. This makes it possible to control *Ceratocystis paradoxa,* responsible for black rot of the offshoot stem, and mealybugs exposed to the sun after light trimming of the plants. This operation may precede or follow the sorting, trimming and bundling of the offshoots. Six months after harvesting the fruit, the slips and suckers with an average weight of between 400 and 500 g are harvested every 3 weeks.

5.11. OFFSHOOT STORAGE

Before planting pineapple offshoots, they must first be processed or stored to rid them of certain insects and diseases. Offshoot processing operations include:

GRADING

this operation involves sorting the offshoots to be planted and classifying them into several homogeneous groups according to their weight, size and thickness (Figure 27). These offshoots will be planted in homogeneous groups in the field. This prevents the larger offshoots from developing and suffocating the smaller ones, making subsequent treatments easier and ensuring that the fruit is the same size.

Figure 27 — Grading pineapple offshoots

TRIMMING

consists of removing the small leaves from the base and dead or dried leaves for the suckers and slips 24 to 48 hours before planting, to expose the young roots and facilitate their penetration into the soil (Figure 28).

Figure 28 — Trimming pineapple offshoots

this is an important operation and involves soaking the base of the offshoots to be planted either in a solution of fungicide and insecticide, respecting the manufacturer's doses and wearing protective gloves. The bases are soaked in a mixture of fungicide and insecticide, diluted in 200 litres of water for 20,000 offshoots, taking care not to keep this solution for more than 24 hours. After this time, the solution loses its effectiveness (Production Guide Benin, 2023). After soaking, the offshoots are laid upright for 12 hours to ensure good distribution of the product (Figure 29).

Figure 29 — Offshoot soaking or treatment operations

OFFSHOOT EXPOSURE

this operation involves turning the offshoots over (leaves against the ground) to expose the roots to the sun (Figure 30). This kills insects, prevents rotting and facilitates healing. This only applies to ratoons (taken from the crown, but close to the roots of the stump). The offshoots can be stored for more than a month (the offshoots enter a slower stage of life), if necessary in a damp period in the open air, with the base facing upwards. In dry weather, in the shade, with the base on the ground. Prolonged storage is always to be avoided: the offshoots lose their vigour, take longer to recover and are more heterogeneous. In wet or cool, dry periods, the offshoots can be stored on the mother plants, with their base facing the sun. In hot, dry weather, it is preferable to place them vertically in light shade after exposing their base to the sun for a few days.

Figure 30 — The offshoots are turned upside down to expose the roots to the sun
https://www.yumpu.com/es/document/read/62396788/manual-de-pina

OFFSHOOT PRODUCTION

PINEAPPLE OFFSHOOTS ARE CLASSIFIED INTO FIVE TYPES ACCORDING TO THE PART OF THE PLANT IN WHICH THEY ARE PRODUCED

- crown (develops from the apex of the fruit);
- slip (develops from the fruit peduncle);
- hapa (develops from the axillary bud, in the transition zone between the stem and the peduncle);
- Ground sucker (develops from the area where the peduncle enters the stem or the peduncle);
- aerial sucker (develops from the stem).

EACH TYPE OF PLANT HAS ITS OWN CHARACTERISTICS AND ADVANTAGES, WHICH MUST BE TAKEN INTO ACCOUNT WHEN CHOOSING AND PROPAGATING PLANTS. THE MOST COMMON MULTIPLICATION METHODS ARE

- a method of propagating offshoots from a plot of harvested pineapple or from the stem plant;
- a method of propagating offshoots from tissue culture or vitroplants;
- a method of propagating offshoots using growth regulators;
- a method of propagating offshoots by using the section of the trunk;
- a method of propagating offshoots by floral ablation/castration;
- a method of propagating offshoots from crowns;
- a method of propagating offshoots using a temporary immersion bioreactor;
- a method of propagating offshoots by etiolation.

6

PLANTING

6.1. PLANTING PERIOD

One of the major characteristics of pineapple growing is that it can be planned. Depending on the soil and climate conditions, it is possible to organise a steady production throughout the year (Table 4).

Table 4 — Planting period according to water availability (rain-fed or irrigated) and growing season (rainy/dry)

WATER AVAILABILITY	PERIOD	PLANTING PERIOD
WITHOUT IRRIGATION	Rainy season	Start of season
	Dry season	End of season
WITH IRRIGATION	_	All year round

Source: Souza, *et* Reinhardt, 2007

Offshoots planted in periods of heavy rain are often prone to heart and root rot (Belew *et al.*, 2022).

PLANTING PERIODS FOR DIFFERENT TYPES OF OFFSHOOTS

The planting period for all available planting materials can be extended to the whole year when mulching, irrigation and shade netting are available (Uriza-Ávila *et al.*, 2018).

- **Crowns:** the planting period can extend throughout the year.
- **Slips:** they can be planted all year round if irrigated. They are most often used to prevent premature flowering, as they are less sensitive than the suckers.
- **Suckers:** indications are similar to those of the previous type, but taking into account their more vigorous growth rate and greater susceptibility to premature flowering.

6.2. OFFSHOOT PREPARATION

6.2.1. OFFSHOOT QUALITY

Checks are necessary to ensure that the offshoots are free of parasites, diseases and undesirable weed seeds before planting (Figure 31). Frequent phytosanitary and nutritional sampling should therefore be carried out, from the time the offshoots germinate on the mother plants until shortly before harvest, in order to determine the treatment to be applied to keep them free of these pests and to consider them as healthy material (Uriza-Ávila *et al.*, 2018).

Figure 31 — Plant infested by a colony of mealybugs (a); Healthy pineapple plant (b)
https://www.google.com/search?q=plant%20pineapple&tbm=isch&hl=fr&tbs=rimg:CX69njsuA9_1pY-dl9AlYqOSq7sgIMCgIIABAAOgQIABABwAIA2AIA4AIA&sa=X&ved=0CB4QuIIBahcKEwjAs4fT8sL_AhUAAAAAHQAAAAAQBw&biw=1349&bih=610#imgrc=6t7f_iNpmu6NpM&imgdii=23G6twdO1JizEM

6.2.2. GRADING

Grading consists of classifying the offshoots into homogeneous groups according to their size, weight and thickness. Offshoots from the same source and of uniform size are planted on the same plot to ensure uniformity of plants at the time of flower induction (Figure 32). This uniformity ensures consistent fruit size development and even fruit ripening (Py *et al.*, 1984; Paull *et al.*, 2016). This also prevents the larger offshoots from suffocating the smaller ones as they grow, making subsequent treatments easier and ensuring uniform growth and harvesting. Lighter offshoots lengthen the cycle. On the other hand, larger plants increase the risk of natural (uncontrolled) flowering at certain times of the year. As they are more physiologically mature, large offshoots have a tendency to fruit early, and this is particularly the case when the weight of the offshoot exceeds 600 g (Paull *et al.*, 2016).

During sorting, the weight (in grammes) is checked using a load cell and four weight classes are often established: 500 to 600 g; 400 to 500 g; 300 to 400 g and 200 to 300 g.

Figure 32 — Selection of good quality offshoots
Source: https://www.chfusa.com/pineapples_process.htm

6.2.3. TRIMMING

Trimming involves removing small, dead or dried leaves from the base of the offshoot to expose the eyes from which new roots develop. These leaves should be removed so that the roots of the offshoots underneath have no difficulty in coming into direct contact with the soil and can therefore become active and develop as quickly as possible (Figure 33). When the dry basal leaves are very abundant and are not removed before the offshoots are planted, they form a barrier, where the roots are trapped inside, so that they cannot come into contact with the soil immediately and completely, nor develop and fulfil their function of feeding the plant. This operation speeds up root development once the offshoot has been planted. The base of the offshoots must be slightly dried before planting to avoid rot caused by fungi of the genus *Ceratocystis* during the rainy season (Uriza-Ávila *et al.*, 2018; COLEAD, 2020).

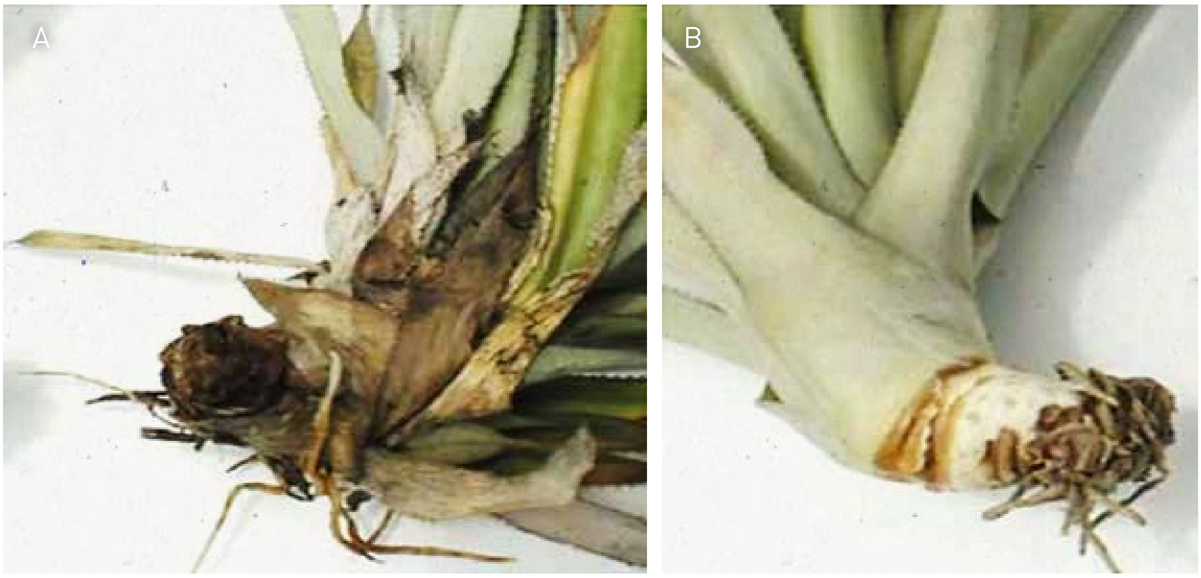

Figure 33 — Untrimmed plant (a); Trimmed plant (b)
Source: CIRAD, 2018

6.2.4. OFFSHOOT TREATMENT

Offshoot treatment involves disinfecting the plant material in a fungicide + insecticide solution to prevent attacks by various insects (especially mealybugs) and Phytophtora diseases. After trimming, bundles are formed according to size. These bundles of offshoots are then soaked in an insecticide-fungicide spray (chosen according to the regulations in force in each country) (Figure 34). Finally, the treated offshoots are laid upright for 12 hours to allow a good distribution of the product (Adabe *et al.*, 2016). If soaking is not carried out, it is important to spray the plants separately with an insecticide and fungicide solution after planting, and in the days that follow, to destroy any parasites (mealy bugs, ants) still present on the plants.

Figure 34 — Bundling and drying of offshoots (a),
Soaking of offshoots in fungicide-insecticide solution (b)
Source: Daouda *et al.*, 2015

6.2.4.1. BIOLOGICAL TREATMENT OF OFFSHOOTS

Organic pineapple growers soak the offshoots in aqueous extracts of neem seeds and papaya leaves to prevent the onset of disease. These extracts are also used against phytophthora rot (Sessou *et al.*, 2022). The effective use of aqueous extracts of neem seeds and papaya leaves to treat pineapple offshoots promotes their growth and health before planting.

PREPARATION OF THE AQUEOUS EXTRACTS

— For dried neem seeds: start by crushing the neem seeds, then macerate this powder in water for around 24 hours. Then filter the mixture to obtain an aqueous extract ready for use.
— For fresh papaya leaves: crush the papaya leaves and macerate in water for around 24 hours. Then filter the mixture to obtain the aqueous extract.

METHOD OF APPLICATION ON PINEAPPLE OFFSHOOTS

— Soak the pineapple offshoots in the prepared aqueous extracts.

6.3. PLANTING DENSITY

Planting density has a direct impact on average fruit weight and is determined in line with production objectives, varieties, climate, water availability and the grower's level of technical expertise (Py *et al.*, 1984). Plants should be planted in staggered rows to ensure better root distribution in the soil, more efficient absorption of solar energy and less competition from weeds, particularly at medium and high densities. The rows must be laid out and sown equidistantly in order to facilitate tillage and applications, especially when these are mechanised (Uriza-Ávila *et al.*, 2018). Densities can be in the range of 50,000 - 70,000 plants/ha (PIP/COLEAD, 2015). In countries, where the Smooth Cayenne variety or its hybrids are grown, densities can reach 86,000 plants/ha (Hepton, 2003).

6.3.1. SINGLE ROW PLANTING

The single row system on a ridge or bed is generally used in the case of a traditional crop and usually in association with other food crops produced in the area (Adabe *et al.*, 2016). The spacing between plants in a row should not be less than 20 cm for small-fruited cultivars and 25 cm for large-fruited cultivars (Figure 35) (Paull *et* Duarte, 2011; Paull *et al.,* 2016). Table 5 shows single row planting densities for the Smooth Cayenne and Sugarloaf varieties.

Table 5 — Some planting densities used in single rows

VARIETIES	SPACING (cm)	DENSITY (PLANTS/ha)	REFERENCES
SMOOTH CAYENNE	100 cm x 100 cm	10,000 plants/ha	(Adabe *et al.*, 2016)
SUGARLOAF	90 cm x 25 cm	45,000 plants/ha	(COLEAD, 2020)

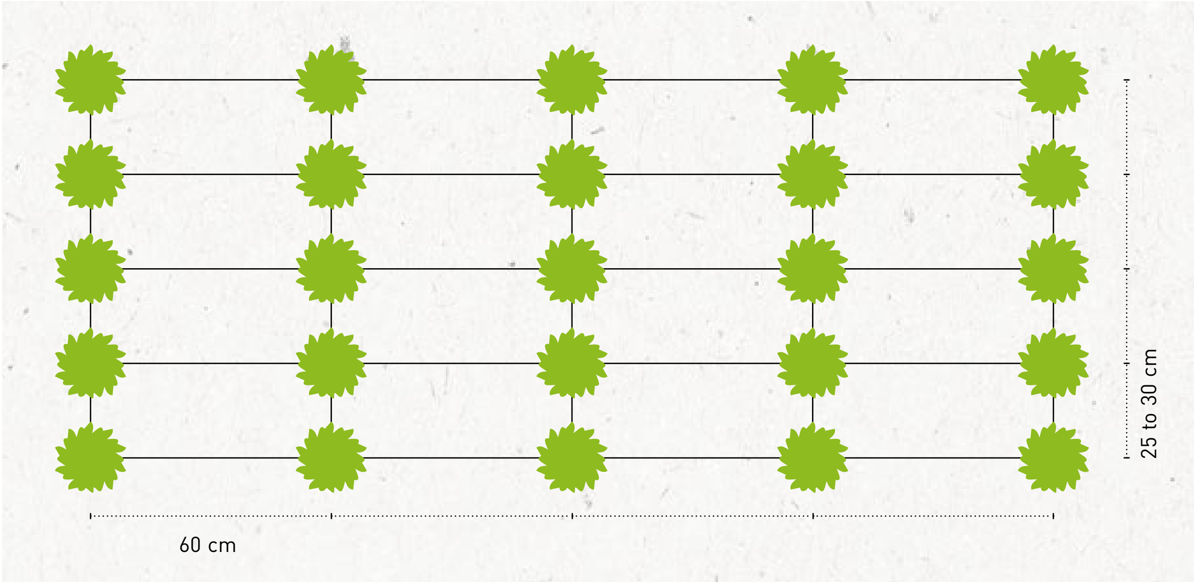

Figure 35 — Single-row planting

6.3.2. PLANTING IN DOUBLE OR PAIRED ROWS

Paired row planting makes weeding easier and, for high densities, ensures identical space for each plant, resulting in more uniform fruit at harvest (Py *et al.*, 1984). The plants are arranged in staggered rows with variable spacing (Figure 36). In most commercial plantations, a two-row system has been widely adopted. The spacing between two ridges is approximately 90 to 120 cm (Paull *et* Duarte, 2011; Paull *et al.*, 2016).

Table 6 — Some commonly used densities for double or paired rows

	SPACING (cm)	DENSITY (PLANTS/ha)
SMOOTH CAYENNE	90 x 40 x 25 Between two ridges: 90 cm Between the rows on the ridge: 40 cm On the row between two plants: 25 cm	61,500
	90 x 30 x 25 Between two ridges: 90 cm Between the rows on the ridge: 30 cm On the row between two plants: 25 cm	66,800
	90 x 40 x 28 Between two ridges: 90 cm Between the rows on the ridge: 40 cm On the row between two plants: 28 cm	55,000
	90 x 40 x 40 Between two ridges: 90 cm Between the rows on the ridge: 40 cm On the row between two plants: 40 cm	45,000
SUGARLOAF	90 x 40 x 33 Between two ridges: 90 cm Between the rows on the ridge: 40 cm On the row between two plants: 33 cm	45,000

Source: Adabe *et al.*, 2016; COLEAD, 2020

Figure 36 — Double or paired row system
https://www.google.fr/imgres?imgurl=https%3A%2F%2Fwww.asiafarming.com%2Fwp-content%2Fuploads%2F2016%2F09%2FPineapple-Plantation

6.3.3. MULTIPLE ROW PLANTING

If the bed is wide and the soil well drained, it is possible to plant 3 or even 4 rows per bed (Figure 37). Three-row planting is used mainly when polyethylene film is deployed; its presence simplifies weeding, which three-row planting tends to make more difficult (Py *et al.*, 1984). The higher the density, the greater the competition between plants and the greater the heterogeneity of plant growth on the plots (Py *et al.*, 1984); (PIP, 2015).

Figure 37 — Three-row system
https://www.freshplaza.com/remote/https/agfstorage.blob.core.windows.net/misc/FP_es/2021/12/21/front11.jpg?preset=ContentFullSmall

6.4. PLANTING OFFSHOOTS

This is an essential operation to ensure that the plants get off to a good start and develop evenly. It must allow good contact between the soil and the offshoot, avoiding the formation of a smooth wall which would disturb root emission and encourage the accumulation of water and the risk of rotting (PIP/COLEAD, 2015; CIRAD, 2018; COLEAD, 2020).

It is therefore advisable:

- before planting the offshoots, to stake them out to ensure that the plants are evenly spaced when they are planted at the chosen density. On permeable ground with a gentle slope, to stake the lines perpendicular to the steepest slope. On heavy, steeply sloping ground, to stake out along the contour lines;
- to respect the planting distance, using a chalk line marked every 25 or 30 cm depending on the distance between plants;
- to plant at a depth of no more than 8 to 10 cm (depending on the size of the offshoot) to avoid rotting and "silting up the heart" of the plants;
- to plant the offshoot upright, in slightly damp soil, without rotating it, which could damage the terminal part and cause stunted growth or even rotting or death of the plant;
- to prevent the soil from entering the heart of the plant, which could lead to rotting and stunted growth;
- to fill in the hole, then pack the soil lightly to ensure good contact between the stem and the soil. A well-planted offshoot should not be uprooted when the leaf is pulled (Figure 38a).

Lastly, a replacement may be made if some plants do not start at the same time as others. A slightly larger plant should be replanted so that it is not handicapped by stunted growth. For example, if you have planted 300g plants, they should be replaced with 400g plants. After 2 months, replacement will be pointless as the new plants will never catch up.

For offshoots with excessively long leaves that only hinder their transport and handling, one approach is to cut off the excess foliage using a very sharp knife/machete, without however compromising the active leaf zone or the apical meristem (bud) (Figure 38b). This is done after careful selection and sorting by size/weight (Uriza-Ávila *et al.*, 2018). Trying to match offshoots of varying weights/sizes by pruning them in exactly the same way is counterproductive at the end of the cycle, as it leads to a large disparity in fruit size at harvest time (Uriza-Ávila *et al.*, 2018).

Figure 38 — Planting pineapple offshoots (a), Planting offshoots with foliage cut (b)
https://www.chfusa.com/pineapples_process.htm
https://wikifarmer.com/fr/plantation-de-lananas-densite-des-plants-dananas

MISTAKES TO AVOID WHEN PLANTING OFFSHOOTS

- The following mistakes should be avoided when planting offshoots:
- Do not push the offshoots in too far;
- Avoid planting during rainfall;
- Avoid planting in strong sunlight;
- Avoid planting in strong winds;
- Never rotate the offshoots when planting;
- Observe planting distances;
- Respect the planting system and planting densities.

PLANTING

PLANTING PERIOD

- Without irrigation: at the end of the dry season and the start of the rainy season
- Irrigation: all year round.

OFFSHOOT PREPARATION

- Quality: free of parasites, diseases and undesirable weed seeds before planting
- Grading: classify into homogeneous groups according to size, weight and thickness.
- Trimming: remove small, dead or dried leaves from the base of the offshoot.
- Offshoot treatment: drying, bundling, soaking in an insecticide-fungicide solution.

PLANTING DENSITY

Depends on production objectives, varieties, climate and the grower's level of technical expertise.

- Planting should be done in staggered rows
- Planting system: single rows, paired rows or multiple rows.

PLANTING OFFSHOOTS

- Staking: ensures that the plants are evenly spaced when they are planted at the chosen density.
- 8 to 10 cm deep in the soil (depending on the size of the offshoot) to prevent rotting and "silting up" of the heart of the plants.

7

WATER MANAGEMENT

The water requirements of pineapple cultivation depend on the plant growth stage and soil water conditions, rising from 1.3 to 5.0 mm per day (de Azevedo *et al.*, 2007). Pineapple plants require more water during the vegetative phase (de Azevedo *et al.*, 2007); (Sossa *et al.*, 2020).

A lack of water in any phenological stage of pineapple plants leads to a reduction in fruit production and quality (de Azevedo *et al.*, 2007). The first symptoms of water deficit develop slowly, with the first visible signs being wilting of the lower leaves followed by a change in leaf colour from dark green to pale green, then yellow and finally red. At a more advanced stage, the margins of the leaves curl downwards and the leaves lose their turgidity (Py *et al.,* 1984; Carr, 2012)..

Pineapple requires a minimum total monthly rainfall of 80-100 mm. Supplementary irrigation becomes essential when annual rainfall is less than 500 mm; or when the monthly rainfall is less than 15 mm for three consecutive months. Also, irrigation is essential when monthly rainfall is less than 25 mm for four consecutive months or 40 mm for five consecutive months (Almeida *et al.,* 2002; Carr, 2012). In addition, potential evapotranspiration from pineapple can reach 4.6 mm/day (Carr, 2012) and the water retention capacity of soil rarely exceeds 100 mm, which means that, in the absence of rain, water reserves will be exhausted in three or four weeks (Paull *et al.*, 2016).

It should also be noted that poorly managed irrigation can have harmful consequences (excess water, leaching of mineral elements and pesticides, soil structure, discontinuity of water supply) and affect quantitative and qualitative growth and yield (Py *et al.*, 1984).

7.1. IRRIGATION

7.1.1. SPRINKLER IRRIGATION

Sprinkler irrigation using self-propelled boom sprayers and mobile cannon systems has lower capital costs and is commonly used where the need for irrigation is intermittent (Carr, 2012; Paull *et al.,* 2016).

Maintaining sufficient moisture at the base of the plants (0 to 5 cm) is more difficult in the absence of polyethylene and requires frequent (once a week) and abundant irrigation (3 to 4 mm /day) (Py *et al.*, 1984).

Polyethylene reduces the amount of water required by at least 50% to maintain sufficient humidity in the area covered by the roots. On bare soil, the frequency of application should be weekly. Irrigation at the fruiting stage is very cost-effective, but can be very dangerous (in terms of fruit quality) if it is poorly managed. If the soil reserves have been well maintained, it is preferable to stop irrigating 8 to 15 days before harvesting to improve the "firmness" of the fruit. It can then be resumed on the same basis to ensure the growth of shoots, if necessary (Py *et al.*, 1984) (Table 7 (Figure 39).

Table 7 — Sprinkler flow rate based on soil characteristics and slope of the ground (Py *et al.*, 1984)

SOIL	LOW TO NO SLOPE	SLOPES GREATER THAN 5%
CLAYEY	5 to 6 mm /h	3 to 4 mm /h
SAND AND SILT	8 to 12 mm /h	6 to 8 mm /h
SANDY	15 to 18 mm /h	10 to 12 mm /h
VERY SANDY	20 to 30 mm /h	15 to 20 mm /h

Figure 39 — Sprinkler irrigation for pineapple crops
https://web.facebook.com/200451883729478/posts/1054052608369397/

7.1.2. DRIP IRRIGATION

Using the drip irrigation method for pineapple crops allows water to be used as efficiently as possible and helps to reduce weed problems, as the wetted surface of the soil is reduced (Figure 40). Drip irrigation also allows fertilisers and nematicides to be applied to the root system after planting, with increased efficiency and safety, leading to higher yields (Paull *et al.*, 2016); (Santos *et al.*, 2022). The drip technique is well suited when:

- the water deficit is significant,
- water availability is limited,
- the cost of water is high,
- labour costs are high,
- the plantation is highly technical.

It requires significant investment: at a rate of one pipe per row of plants, around 8,000 m are needed to supply 55 to 60,000 plants per hectare (Py *et al.*, 1984).

Provided it is used frequently enough, this technique is effective in maintaining water reserves close to the root system. The ridges must be the right height to avoid the disadvantages of excess water (Py *et al.*, 1984).

Figure 40 — Drip irrigation systems
https://cameroon-food.over-blog.com/2015/12/saison-seche-saison-d-irrigation.html
https:// photos/pcb.127956142120443/127954105453980/?type=3&theater

N.B.

- Sprinkler irrigation is not recommended after the start of flowering and petal opening, as it encourages fruit diseases (Paull *et al.*, 2016); Carr, 2012). The irrigation efficiency of sprinkler systems is lower than that of drip systems due to evaporation losses and the tendency to favour leaf diseases (Midmore *et al.*, 2012).
- A combination of the two can be used. For example, during the early stages of plant development, use sprinkler irrigation shortly after planting, as it helps plants to establish themselves well in the soil and allows harmonious root development. However, overhead irrigation is not ideal for watering plants during flower induction and the fruiting stage, as it can increase the incidence of fruit diseases. Drip irrigation, on the other hand, can be used after the roots have developed. It is crucial to supplement irrigation with organic or plastic mulching with biodegradable black polyethylene film, particularly in areas where water sources are limited (Nadia Umi *et al.*, 2020).

Irrigation gives a shiny appearance to pineapple fruit (Py *et al.*, 1984). Fruit harvested during rainy periods will not keep as well (Py *et al.*, 1984).

7.2. WATER EFFICIENCY AND PRODUCTIVITY

Pineapples have a crassulacean acid metabolism (CAM) that facilitates carbon dioxide uptake at night, when evaporative demand and temperature gradients between leaves and air are lower (Bartholomew *et al.*, 1994; Paull *et al.*, 2016). It has a transpiration rate ranging from 0.3 to 0.5 mm per square centimetre of leaf per hour (de Azevedo *et al.*, 2007).. The stomata of CAM plants remain closed for most of the day, so there is little water loss from the leaf canopy and little evapotranspiration. Evapotranspiration from a pineapple crop decreases as the leaf canopy expands and shades the soil (Paull *et al.*, 2016).

Like all constituent CAM plants, pineapple is a drought-tolerant xerophyte, whose leaf anatomy includes a water-storing parenchyma and a complex of epidermal and hypodermal layers that make it resistant to desiccation (Paull *et al.*, 2016). This greatly improves its water-use efficiency in dry conditions (Carr, 2012).

Well-watered pineapples have a water use efficiency (CO_2 fixed per unit of water lost) up to three times higher than C4 plants (*e.g.* Sugar cane), and at least six times higher than C3 plants such as rice (Carr, 2012).

The water efficiency of pineapple is very high: it takes 50 to 60 g of water to develop one gramme of dry matter compared with 200 g for mesophytic plants (Py *et al.*, 1984).

7.3. SOME WATER-SAVING TECHNIQUES

Tillage: ridging improves water stocks and root length during the vegetative and flowering stages unlike flat tillage (Sossa *et al.*, 2020).

The use of polyethylene film (biodegradable): limits soil water losses through evaporation, when the rate of coverage by the plant is still low, particularly during the first few months (de Azevedo *et al.*, 2007). Provided it is laid on initially damp soil, it maintains good conditions for the first roots to emerge. Offshoot recovery is faster and more uniform. The polyethylene film reduces the surface moisture gradient. It also reduces daily variations in humidity, temperature and radiation losses. Moreover, it protects soil structure and limits the leaching of mineral elements and pesticides. The root environment is more constant in the short and medium term. The roots have a larger diameter and are richer in absorbent hairs (Py *et al.*, 1984) (Figure 41).

Figure 41 — Soil mulching with biodegradable polyethylene film

Soil mulching with harvest residues: The soil can also be mulched with harvest residues to limit water loss and help maintain soil moisture during pineapple production (Figure 42a). The burial of 10 t/ha of residues results in an increase in soil water stocks followed by superficial mulching of residues at all phenological stages (Sossa *et al.*, 2020). This technique will therefore involve firstly removing and eliminating diseased plants (nematode, wilt) and using a rotovator on the pineapple plot after harvesting the offshoots. The residues are then left to dry on the surface of the soil for at least 3 months (another crop such as corn could be grown during this period). The plot can then be ploughed and the pineapple planted.

Similarly a cover crop can also be planted on the plot after the pineapple harvest and the green biomass then incorporated into the soil during ploughing before the pineapple is planted (Figure 42b).

Figure 42 — Soil mulching with pineapple harvest residues (a), Cover crop installation, also commonly known as "green manure" (b)

MULCHING OF RIDGES WITH TREATED CROP RESIDUES OR APPLICATION OF ORGANIC FERTILISER

Another water-saving technique may be to install ridges perpendicular to the direction of the slope (the size of the ridges will depend on the steepness of the slope) and mulch these ridges with treated crop residues (at least 20 t/ha) or apply an organic fertiliser (compost, poultry droppings or manure) before any pineapple planting operation (Figure 43).

Figure 43 — Ridges mulched with harvest residues

N.B.

- Always treat harvest residues that are to be returned to the soil (sorting, removing diseased plants, shredding and drying in the sun).
- Always position the ridges perpendicular to the direction of the slope on eroded land
- Always use a high-quality plastic film and make sure it is correctly positioned.
- Agronomic techniques (ground clearing, soil management and preparation, soil cover, irrigation, parasite control, etc.) therefore have a major influence on water efficiency by making it possible to preserve the best root activity through the most appropriate management of soil water (Py *et al.*, 1984).

WATER MANAGEMENT

IRRIGATION REQUIRES THE USE OF MULCH

- Sprinkler irrigation: not recommended after flowering and petal opening, as it encourages fruit diseases.
- Drip irrigation is more economical in terms of water management

WATER EFFICIENCY AND PRODUCTIVITY

- pineapple has a crassulacean acid metabolism (CAM) that allows it to considerably improve its water use efficiency in dry conditions.

WATER-SAVING TECHNIQUES

- tilling the soil (ridging); mulching the soil with polyethylene film, crop residues, green manure, etc.


N°: 09
PLANTING: 28-12-17
Nbrs Plants: 12 500
Variété: P.S

8

SOIL AND FERTILISATION MANAGEMENT

8.1. INTEGRATED SOIL FERTILITY MANAGEMENT

Increasing pressure on soil and water resources and the depletion of soil nutrients have called for a reassessment of the evolution of strategies and approaches to soil fertility management and plant nutrition (Srivastava *et al.*, 2021). In keeping with sustainable development principles, integrated soil fertility management has therefore emerged as a set of soil fertility management practices that includes a variety of elements combined with knowledge on how to adapt practices to local conditions, in order to optimise the use of the nutrients applied and increase crop yields. The components of integrated soil fertility management (ISFM) are diverse. The components most developed in pineapple production are shown in Table 8. The implementation of integrated soil fertility management (ISFM) varies considerably from one farmer to another (Figure 44 and 45). The adoption of a soil management system must take into account the level of soil fertility following a soil analysis, and the availability of water (particularly if the plantation is irrigated or not). In organic farming, for example, soil fertility deserves particular attention because of the limited use of chemical fertilisers.

Table 8 — Various components and practices of integrated soil fertility management under pineapple crops

COMPONENTS	DIFFERENT INTEGRATED SOIL FERTILITY MANAGEMENT PRACTICES
CULTIVARS/ VARIETIES	Cultivation of cultivars/varieties with the ability to maintain quality production under variable soil pH conditions
TILLAGE	Mechanical ploughing
	Manual ploughing
	Ridging
SOIL MULCHING	Use of soil cover plants (legumes)
	Use of polyethylene films
	Use of harvest residues
CHEMICAL FERTILISERS	Adoption of the '4Rs' principle governing the efficient use of mineral fertilisers
	Application of mineral fertilisers in microdoses
ORGANIC INPUTS	Incorporation of different types of animal waste (poultry litter, cow dung, etc.)
	Incorporation of residues from the previous crop into the soil
	Recycling of pineapple harvest residues by incorporating them into the soil
	Recycling of waste from pineapple processing units by incorporating it into the soil
	Application of various composts
	Cultivation of green manures (preferably legumes)
BIO-FERTILISERS	Application of biostimulants to improve plant growth
	Inoculation with mycorrhizal fungi
	Inoculation with micro-organisms
	Inoculation with fixing bacteria
CROPPING SYSTEM	Association of pineapple crops with legumes
	Rotation of pineapple crops with legumes
	Fallow land

Source: Moshiri *et al.*, 2019; Srivastava and Ngullie; 2009

Figure 44 — Different integrated soil fertility management practices

Figure 45 — Different integrated soil fertility management practices

8.2. NUTRITIONAL DIAGNOSIS OF PLANTS

Pineapple is a very nutrient-demanding crop, which means that mineral and/or organic fertilisers are needed to meet the plant's needs during its growth cycle to achieve high productivity and fruit quality. The main essential nutrients considered limiting for pineapple cultivation are N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B and Mo (Maia *et al.*, 2020). Several methods are used to identify nutrients that are deficient in the crop. These include soil analysis, leaf analysis, identification of nutrient deficiency symptoms (Vásquez-Jiménez et Bartholomew, 2018). Nutritional requirements vary according to pineapple cultivar and generally follow the following order of absorption: K > N > Ca > Mg > S > P (Maia *et al.*, 2020). With regard to micronutrients, the decreasing order of accumulation is as follows: manganese (Mn) > iron (Fe) > zinc (Zn) > boron (B) > copper (Cu) (Borges, 2021).

8.2.1. SOIL ANALYSIS

Soil analysis is an essential part of any crop fertilisation programme, as it makes it possible to determine the macronutrient (nitrogen, phosphorus and potassium) and micronutrient (exchangeable aluminium, calcium, magnesium, etc.) levels, as well as the soil pH. The results of such an analysis can be used to calculate the quantities of fertiliser or nutrients to be applied to the soil in time for fertilisation operations, and in particular to correct soil acidity. To this end, the soil samples must represent uniform plots, i.e. plots with the same topographical position, the same colour, the same texture, the same previous crop or vegetation and the same fertilisation. Soil samples must be taken in accordance with laboratory recommendations. It is therefore advisable to take samples by walking in a zigzag pattern. The equipment used for soil sampling consists of an auger, a straight shovel or hoe, a plastic bucket and a plastic bag. It is therefore advisable to take single samples, trying to cover the entire plot to a depth of more than 20 cm, as this is the area where most of the crop's feeder roots are found. The number at which the sampling error is greatly reduced is 20 single samples. These samples should be collected in a plastic bucket and, at the end of collection, homogenised to create a single composite sample of at least 1 kilogram. Each composite sample must then be dried, stored in a plastic bag, correctly labelled and sent to a laboratory (Queiroga, 2023). By way of example, Table 9 provides information on the optimum level and critical threshold of soil nutrients required for pineapple cultivation.

Table 9 — Optimal and critical soil nutrient levels for pineapple cultivation

NUTRIENTS	OPTIMUM LEVEL IN THE SOIL	CRITICAL LEVEL IN THE SOIL	METHODS USED
	mg/kg		
TOTAL N	120	50	Kjeldahl method (Bremner 1965).
TOTAL P	20	5	White and Black method
TOTAL K	150	60	Helmke and Sparks method (1996)
TOTAL Ca	100	⩾ 25	Helmke and Sparks method (1996)
TOTAL Mg	50	⩾ 10	Helmke and Sparks method (1996)
TOTAL Fe	27 - 78	⩾ 3.0	Helmke and Sparks method (1996)
TOTAL Zn	4	⩾ 3.0	Helmke and Sparks method (1996)

Source: Yallanagouda, 2015; Vásquez-Jiménez *et* Bartholomew, 2018

8.2.2. LEAF ANALYSIS

It should be emphasised that leaf analysis does not mean that soil analysis should be excluded, as these analytical methods are complementary tools.

In pineapple cultivation, the leaf used to assess the nutritional status of the plant is the "D" leaf, which is the youngest among the adults and physiologically active (Siebeneichler *et al.*, 2002; Souza *et* Reinhardt, 2007) (Figure 46a). This leaf should not be taken within a week of fertiliser application. For the purpose of analysis, either the central third of the non-chlorophyllous (white) part of the basal area or the whole leaf can be used (Souza *et* Reinhardt, 2007; Vásquez-Jiménez *et* Bartholomew, 2018) (Figure 46b-c). The results of leaf analysis are generally interpreted by comparing actual data with previously established critical values or sufficiency intervals (Arrobas *et al.*, 2014) in each region or country. Table 10 shows the reference values for D leaves in each region according to the varieties grown.

Figure 46 — Identification of the D leaf on a pineapple plant
Source: Saavedra *et al.*, 2022

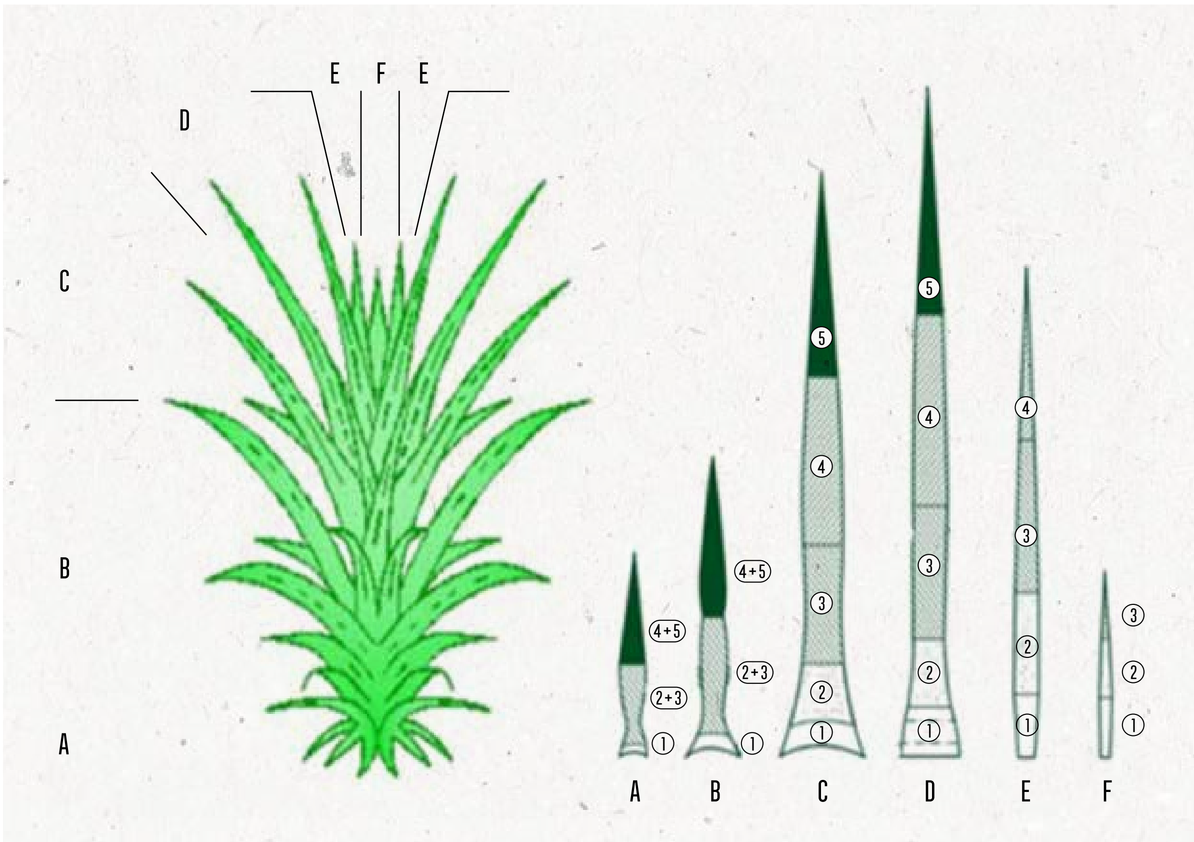

Figure 47 — Categories of pineapple leaves with their different sections
Source: Vásquez-Jiménez et Bartholomew, 2018

Table 10 — Adequate concentrations of nutrients in the pineapple "D" leaf

NUTRIENTS	OPTIMUM STANDARDS		
	MEXICO	AUSTRALIA	COSTA RICA
	(MD-2)	(SMOOTH CAYENNE)	(MD-2)
MACRO-NUTRIENTS	g/kg OF DRY MATTER		
N	0/14 - 0.18	-	0.15 - 0.18
P	0.012 - 0.02	0.014 - 0.035	0.02
K	0.30 - 0.45	0.43 - 0.64	0.27 - 0.30
Ca	0.04 - 0.06	0.022 - 0.04	0.025 - 0.03
Mg	0.025 - 0.05	0.041 - 0.057	0.025 - 0.03
S	-	-	0.013 - 0.015
MICRO-NUTRIENTS	mg/kg		
Fe	200 - 300	80 - 150	100 - 200
Mn	130 - 170	150 - 400	75 - 100
Zn	20 - 30	15 - 70	30 - 35
Cu	8 - 15	10 - 50	10 - 15
G	15 - 30	-	35 - 40
REFERENCES	(Rebolledo, 2002)	(Sanewski, 2022)	(Sanewski, 2022)

8.2.3. SYMPTOMS OF NUTRITIONAL DEFICIENCY IN PLANTS

Deficiencies in essential nutrients such as nitrogen, phosphorus, potassium, calcium and magnesium can occur in pineapple plantations if the uptake of nutrients by the crop and losses through leaching are not compensated for. Conversely, deficiencies in sulphur, iron, zinc, boron, copper, manganese, molybdenum and chlorine are more common in certain regions. Given the presence of sulphur in the various fertilisers used in pineapple cultivation, it is highly unlikely that pineapples will suffer from deficiencies in this nutrient. Furthermore, when pineapple plants receive adequate doses of nutrients, particularly nitrogen, molybdenum deficiency is not observed. Visible symptoms on plant leaves can provide an indication of severe nutrient deficiency. Pineapple, like many other crops, shows clear symptoms of nutrient deficiencies on the leaves (Fairhurst, 2015) (Table 11).

Table 11 — Description of some symptoms of nutrient deficiency in pineapple plants

NUTRIENTS	SYMPTOMS OF DEFICIENCY
NITROGEN (N)	— The plants have greenish-yellow or yellow foliage; — The lower leaves are lighter than the upper ones; — Moderate leaf fall; — Poor stem formation; — The plant is stunted; — The fruit is small with a small crown.

Figure 48 — Symptoms of nitrogen deficiency
Sources: Ramos *et al.*, 2006 and Yallanagouda, 2015

PHOSPHORUS (P)	— The edges of the leaves turn yellow from the tips; — The leaves are a dark bluish-green colour; — The tips of the leaves are brownish-red in colour with brown transverse striations; — The fruit is small and reddish in colour.

Figure 49 — Symptoms of phosphorus deficiency
Source: Yallanagouda, 2015

NUTRIENTS	SYMPTOMS OF DEFICIENCY
POTASSIUM (K)	— Small yellow spots appear on the leaves; — The lower leaves are mottled; — Progressive yellowing from the leaf margins towards the centre; — The peduncles are small in diameter. — The fruit is small, low in acidity and has no aroma.

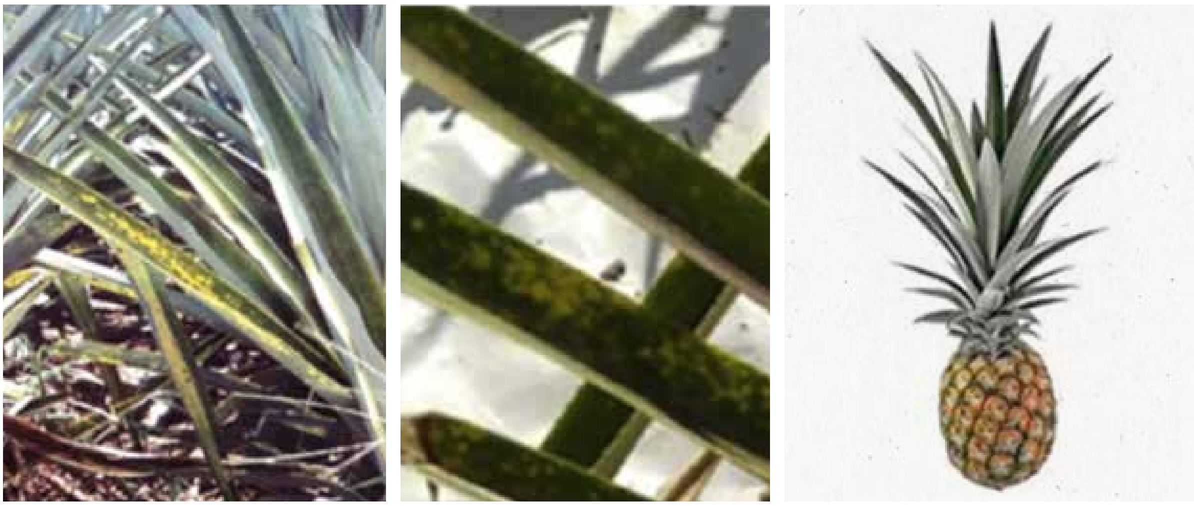

Figure 50 — Symptoms of potassium deficiency
Sources: Vásquez-Jiménez *et* Bartholomew, 2018

CALCIUM (Ca)	— The leaves are very small, short, narrow and brittle; — The tips of the young leaves die off; — The tips of the leaves are hook-shaped. — Fruit malformation and a high number of crowns

Figure 51 — Symptoms of calcium deficiency
Source: https://polysulphate.com/global-en/deficiency-symptoms-gallery/
Photo par Alveiro Salamanque

NUTRIENTS	SYMPTOMS OF DEFICIENCY
MAGNESIUM (Mg)	— Old leaves have a bright yellow blade; — The lower leaves are yellow between the veins (the veins remain green); — The edges of the leaves curl upwards or downwards or the leaves wrinkle.

Figure 52 — Symptoms of magnesium deficiency
Source: Yallanagouda, 2015

SUL PHUR (S)	— The leaves are pale yellow or yellowish green; — Older leaves have pinkish-red borders; — The upper leaves are light green; — The veins of the leaves are lighter than the surrounding areas; — The fruit is very small.

Figure 53 — Symptoms of sulphur deficiency
Sources: Souza *et* Reinhardt, 2007

NUTRIENTS	SYMPTOMS OF DEFICIENCY
IRON (Fe)	— Chlorosis develops on young leaves; — The new upper leaves turn yellow between the green veins; — The old leaves are dry; — The fruit is red with a chlorotic crown.

Figure 54 — Symptoms of iron deficiency
Sources: Souza *et* Reinhardt, 2007 and Yallanagouda, 2015

MANGANESE (Mn)	— Damaged leaves are mottled with light green or darker areas. — The tip of the shoot remains alive; — The new upper leaves have dead spots on the surface; — The leaf may look netted because the small veins remain green. — Sulphur and manganese deficiencies in pineapples are fairly rare.
ZINC (Zn)	— Young leaves are rigid, cracked and sometimes curved; — The surfaces of older leaves show yellowish-brown spots the size of pinheads, which group together to form blotches;

Figure 55 — Symptoms of zinc deficiency
Sources: Vásquez-Jiménez *et* Bartholomew, 2018

NUTRIENTS	SYMPTOMS OF DEFICIENCY
COPPER (Cu)	— The tips of the leaves curve downwards; — Old leaves are purple-red at the folds.

Figure 56 — Symptoms of copper deficiency
Sources: Souza *et* Reinhardt, 2007

BORON (B)	— The fruit grows multiple crowns; — Formation of suberised dead tissue between fruiting bodies; — Chlorosis of young leaves with reddening of dead edges at the apex; — The stems and petioles are brittle.

Figure 57 — Symptoms of boron deficiency
Sources: Vásquez-Jiménez *et* Bartholomew, 2018
and Cunha *et al.*, 2021

8.3. FERTILISATION PROGRAMME

Because of the variations in nutritional requirements between cultivars (Table 12), fertilisation programmes for pineapple must be based on the results of chemical analyses of the soil and/or the plant (leaf analyses) (Maia *et al.*, 2020; Borges, 2021). In addition to the nutritional requirements of pineapple and the level of nutrient availability in the soil, it is important to take into account other factors such as the local availability of fertiliser, the level of technology adopted on the farm, the destination of the production and the economic return (cost/benefit ratio of fertilisation) to formulate an appropriate fertilisation programme from one region or country to another (Py *et al.*, 1984; Maia *et al.*, 2020).

Table 12 — An example of the total quantity of elements to be supplied per pineapple production cycle (g/plant)

NUTRIENTS	VARIETIES				
	MD-2	MD-2	MD-2	PEROLA	SMOOTH CAYENNE
N	8.00 - 10.67	8.00 - 18.00	5 - 6	6.00 -10.00	4.00
P_2O_5	2.00 - 4.00	3.00 - 6.00	1 - 2	1.00 - 4.00	1.00 - 2.00
K_2O	8.00 - 13.33	8.00 - 18.00	12.5 - 15	4.00 - 15.00	8.00 - 10.00
S	0.67 - 1.33	-	-	-	-
CaO	0.80 - 2.00	-	-	-	-
MgO	1.33 - 2.00	2.00 - 4.00	2 - 3	-	2.00 - 3.00
G	0.07	-	-	-	-
Zn	0.07	-	-	-	-
Fe	0.11	-	-	-	-
COUNTRY/ REGION	Costa-Rica	Mexico	Côte d'Ivoire	Brazil	Europe
REFERENCES	(Tessenderlo, 2020)	(Uriza-Ávila *et al.*, 2018b)	(Koné, 2015)	(Souza *et* Reinhardt, 2007)	(PIP, 2011)

Table 13 — Fertiliser recommendations for non-irrigated pineapple, based on soil analysis results

NUTRIENT LEVELS IN THE SOIL	FERTILISER RECOMMENDED AT PLANTING	FERTILISER RECOMMENDED AT PLANTING AFTER PLANTING		
		1ST AND 2ND MONTHS	5TH AND 6TH MONTHS	8TH AND 10TH MONTHS
N (kg ha)				
MINERAL OR ORGANIC N	-	75	110	125
P_2O_5 (kg/ha)				
P IN SOIL (MEHLICH)/ (mg/dm^3)				
0 - 5	90	-	-	-
6 - 10	70	-	-	-
11 - 15	40	-	-	-
K_2O (kg/ha)				
K IN SOIL (cmol/dm^3)				
0 - 0.07	-	110	165	190
0.08 - 0.15	-	75	110	125
0.16 - 0.23	-	60	80	95
0.24 - 0.31	-	40	55	60

Source: Souza, 2000

Table 14 — Fertiliser recommendations for irrigated pineapple in semi-arid regions, based on soil analysis results

NUTRIENT LEVELS IN THE SOIL	FERTILISER RECOMMENDED AT PLANTING AFTER PLANTING			
	1ST AND 2ND MONTHS	4TH AND 5TH MONTHS	6TH AND 7TH MONTHS	8TH AND 9TH MONTHS
N (kg ha)				
MINERAL OR ORGANIC N	60	80	90	90
P_2O_5 (kg ha)				
P IN SOIL (MEHLICH)/ (mg/dm^3)				
0 - 5	120	-	-	-
6 - 10	80	-	-	-
11 - 15	40	-	-	-
K_2O (kg/ha)				
K IN SOIL (cmol/dm^3)				
0 - 0.07	90	12	135	135
0.08 - 0.15	75	100	110	115
0.16 - 0.23	60	80	90	90
0.24 - 0.31	45	60	65	70

Source: Souza *et al.*, 2001

Table 15 — Fertiliser recommendations for pineapple under rainfed conditions based on soil analysis results

NUTRIENT LEVELS IN THE SOIL	FERTILISER RECOMMENDED AT PLANTING AFTER PLANTING				
	TWO APPLICATIONS		THREE APPLICATIONS		
	N (kg ha)				
MINERAL OR ORGANIC N	85	125	60	70	80
	P_2O_5 (kg ha)				
P IN SOIL (MEHLICH)/ (mg/dm^3)					
0 - 5	50	-	50	-	-
6 - 10	40	-	40	-	-
11 - 15	30	-	30	-	-
	K_2O (kg/ha)				
K IN SOIL (cmol/dm^3)					
0 - 0.07	105	155	75	85	100
0.08 - 0.15	85	125	60	70	80
0.16 - 0.23	60	95	45	50	60
0.24 - 0.31	40	65	30	35	40

Source: Matos *et al.*, 2011

Table 16 — Recommendations for pineapple fertilisation based on expected yield and taking into account soil P and K content

NUTRIENT LEVELS IN THE SOIL	EXPECTED YIELD (t/ha)		
	< 30	30 - 40	> 40
	N (kg/ha)		
MINERAL OR ORGANIC N	80	100	120
	P_2O_5 (kg/ha)		
P IN SOIL (MEHLICH)/(mg/dm^3)			
0 - 10	40	60	80
11 - 20	20	40	60
21 - 30	10	20	40
	K_2O (kg/ha)		
EXCHANGEABLE K (mg/dm^3)			
0 - 40	200	260	320
41 - 70	140	200	260
71 - 106	100	140	200

Source: Rodrigues and Veloso, 2010

Table 17 — Recommended doses of trace elements or micronutrients for pineapple

MICRONUTRIENTS	RECOMMENDED DOSE (kg/ha)	SOURCES OF FERTILISER
ZINC (Zn)	1 - 6	Zinc sulphate $7H_2O$ (20% Zn)
COPPER (Cu)	1 - 10	Copper sulphate $5H_2O$ (13% Cu)
		Copper oxychloride (35% - 50% Cu*)
BORON (B)	0.3 - 2	Borax 10 H_2O (11% of B)
IRON (Fe)	1 - 10	Ferrous sulphate 7 H_2O (20% Fe)
MANGANESE (Mn)	1 - 2.5	Manganese sulphate 4 H_2O (25% Mn)

Source: Souza, 2009

TO OPTIMISE THE EFFICIENCY OF LOCAL FERTILISER USE, GROWERS NEED TO TAKE INTO ACCOUNT

— soil analyses (mineral content);

— and the 4R principle governing nutrient management. This concept emphasises the need to apply fertilisers or manures from the right source, at the right dose, at the right time and in the right place (Fairhurst, 2015).

8.3.1. DIFFERENT TYPES OF FERTILISER

IN TERMS OF SOURCE, FERTILISERS CAN BE CLASSIFIED AS FOLLOWS

— **Mineral fertilisers**: products of a mineral or synthetic nature, obtained by a physical, chemical or physico-chemical process, which supply plants with one or more nutrients (Table 18). They are subdivided into:

- Simple mineral fertiliser: product consisting mainly of a chemical compound containing one or more plant nutrients.
- Mixed mineral fertiliser: product resulting from the physical mixing of two or more mineral fertilisers.
- Complex mineral fertiliser: product made up of two or more chemical compounds, resulting from the chemical reaction of their components, containing two or more nutrients, such as NPK formulas.

— **Organic fertilisers**: natural products of plant or animal origin, containing one or more plant nutrients. It is also a fundamentally organic product, obtained by a natural or controlled physical, chemical or biochemical process, from raw materials of industrial, urban or rural, plant or animal origin (Table 19).

— **Biofertilisers:** products containing an active principle or organic agent, free from agrotoxic substances, capable of acting directly or indirectly on all or part of the cultivated plants, increasing their productivity, regardless of the hormonal or stimulating value.

IN TERMS OF THEIR PHYSICAL FORM OR NATURE, FERTILISERS CAN BE CLASSIFIED AS FOLLOWS

— Powder: simple or mixed fertilisers ground into powder form.

— Granules: fertiliser in granular form.

— Liquid: fertiliser in liquid form.

In all cases, the law requires the producer to guarantee the content of the nutrient(s) contained in the product, i.e. to indicate the quantity as a percentage by weight of each chemical element, its corresponding oxide or any other component of the product, including, where applicable, the total content, the soluble content or both contents of each component, as well as the specification of the physical nature. However, there is a tolerance, i.e. permissible differences between the analytical result observed and the guarantees recorded or declared by the manufacturer.

When choosing fertilisers, it is important to consider the cost in relation to their nutrient concentration (cost per unit of N, P_2O_5, K_2O). In general, more concentrated fertilisers provide the nutrient at a lower price.

The most common nitrogen alternatives are urea (45% N) and ammonium sulphate (20% N). Other sources of nitrogen, such as potassium nitrate (13% N) and ammonium nitrate (33% N), can be used in pineapple cultivation, provided they are economically viable.

Water-soluble phosphate fertilisers such as triple superphosphate (42% P_2O_5,), monoammonium phosphate-MAP (48% P_2O_5,), diammonium phosphate-DAP (45% P_2O_5,) and simple superphosphate (18% P_2O_5,) have been the most widely used P sources in pineapple production. Magnesium thermophosphates (17% P_2O_5,) have also been used as a source of P in pineapple cultivation and are also a source of Mg (9%).

Potassium (K) can be supplied by potassium chloride (58% K_2O), potassium sulphate (50% K_2O), double potassium and magnesium sulphate (20% K_2O) and potassium nitrate (44% K_2O), the last three being more expensive and less commonly available.

As far as micronutrients are concerned, particular attention should be paid to Fe, Zn, Cu and B. They are available in solid or liquid form. Copper sulphate is applied to the soil, close to the plants, bearing in mind that spraying directly onto the leaves can cause severe burns. As far as iron sulphate is concerned, it is advisable to protect it from oxidation, and citric acid can be used in the solution. In general, the presence of urea in solutions promotes the absorption of micronutrients.

Table 18 — Mineral fertilisers used in pineapple cultivation

MINERAL NITROGEN FERTILISERS	NUTRIENT COMPOSITION				
	TOTAL N		CaO	MgO	S
	%				
Ammonium nitrate	37		-	-	-
Sodium nitrate	14		-	-	-
Ammonium sulphate	20		-	-	24
Urea	45		-	-	-
MINERAL PHOSPHORUS FERTILISERS	P_2O_5	TOTAL N	CaO	MgO	S
	%				
Simple superphosphate	19 - 21	-	25 - 28	-	12 - 14
Triple superphosphate	42 - 48	-	17 - 23	-	-
Thermophosphate	19	-	30	18	-
Monoammonium phosphate (MAP)	48 - 60	11	-	-	-
Diammonium phosphate (DAP)	44 - 52	18	-	-	-
MINERAL POTASSIUM FERTILISERS	K_2O		CaO	MgO	S
	%				
Potassium chloride	58 - 62		0 - 3	0 - 3	0 - 3
Potassium sulphate	48 - 52		0 - 2.5	0 - 2	15 - 19
Potassium nitrate	44		-	-	-
Potassium and magnesium sulphate	20 - 22		-	18 - 19	20 - 22

Table 19 — Carbon, nitrogen, phosphorus and potassium content and C/N ratio of some organic fertilisers used in agriculture

ORGANIC FERTILISER OR GREEN MANURE	C	N	P_2O_5	K_2O	C:N
	g/kg				
Water hyacinth	202.0 ± 50.0	1.3 ± 0.3	0.3 ± 0.0	1.5 ± 0.3	161.6
Peanut forage	220.0 ± 10.0	25.5 ± 2.5	7.6 ± 0.3	9.6 ± 1.0	8.6
Bokashi	271.0 ± 3.5	12.5 ± 1.5	6.0 ± 1.0	2.5 ± 0.5	21.7
Poultry litter	337.5 ± 57.5	33.5 ± 1.5	38.5 ± 0.4	8.8 ± 4.5	10.1
Compost from household waste	186.2 ± 65.1	12.1 ± 4.4	5.9 ± 0.8	6.3 ± 2.6	15.4
Organic compost	269.0 ± 87.0	15.1 ± 5.3	13.5 ± 6.2	13.7 ± 7.9	17.9
Compost of forage peanut (*Arachis pintoi*) + brachiaria (*Urochloa sp*) + crotalaria (*Crotalaria juncea*) + millet (*Pennisetum glaucum*).	224.5 ± 25.5	18.7 ± 0.7	8.0 ± 0.9	27.1 ± 2.1	12.0
Crotalaria juncea	180.7 ± 28.8	32.5 ± 6.7	10.3 ± 4.2	32.0 ± 5.0	5.6
Fresh cattle manure	145.3 ± 34.9	8.6 ± 2.5	7.5 ± 1.1	12.3 ± 5.2	16.9
Chicken manure	174.7 ± 29.5	25.1 ± 11.0	19.4 ± 6.5	14.1 ± 5.3	7.0
Pig manure	75.5 ± 15.5	8.8 ± 1.8	5.8 ± 1.2	11.1 ± 5.1	8.6
Sewage sludge	242.3 ± 54.1	24.1 ± 6.5	27.7 ± 7.6	7.3 ± 5.2	10.1
Millet residues	75.5 ± 15.5	3.8 ± 0.8	1.7 ± 0.3	4.5 ± 0.9	20.1
Mucuna	140.0 ± 21.6	12.7 ± 2.1	5.3 ± 1.2	30.7 ± 3.9	11.1
Sunflower press cake	380.0 ± 76.3	38.4 ± 6.1	12.4 ± 0.4	25.0 ± 13.6	9.9
Castor oil seed cake	410.8 ± 146.2	52.0 ± 10.4	25.6 ± 6.2	11.7 ± 2.9	7.9
Jatropha seed cake	298.5 ± 13.5	39.5 ± 3.5	20.0 ± 1.0	15.0 ± 2.9	7.6
Vermicompost	257.0 ± 87.0	11.0 ± 4.0	13.5 ± 0.5	15.7 ± 1.3	23.4

Sources: Sobral *et al.*,2007; Kiehl; 2010; Freire *et al.*, 2013

Table 20 — Maximum authorised limits for heavy metals/contaminants in organic fertilisers

HEAVY METALS/CONTAMINANTS		MAXIMUM AUTHORISED VALUE
Arsenic (mg/kg)		20
Cadmium (mg/kg)		3
Lead (mg/kg)		150
Hexavalent chromium (mg/kg)		2
Mercury (mg/kg)		1
Nickel (mg/kg-1)		70
Selenium (mg/kg)		80
Thermotolerant coliforms (most likely number per gramme of dry matter)		1000
Viable helminth eggs (number in four grammes of total dry matter)		1
Salmonella sp		Absent in 10 g of dry matter
Inert materials	Glass, plastics, metals > 2 mm	0.5% of dry mass
	Stones > 5 mm	5.0% of dry mass

Sources: Brazil, 2006

8.3.2. FERTILISER APPLICATION RATE

The doses of fertiliser to be applied to the plants are calculated according to their needs and the types of fertiliser. By way of example, tables 21, 22 and 23 show some of the fertilisation plans used depending on the type of fertiliser available and the region.

Table 21 — Example of a simple manure fertilisation plan (granular solid) used in Cameroon in a pineapple plantation (Smooth Cayenne variety)

WEEK	N (g/plant)	UREA (g/plant)	P_2O_5 (g/plant)	PHOSPHATE (g/plant)	K_2O (g/plant)	POTASSIUM SULPHATE (g/plant)	MgO (g/plant)	DOLOMITE (g/plant)
Before planting	-	-	1 - 2	3 - 6	-	-	2 - 3	10 - 14
4	0.5	1.09	-	-	1.1	2.2	-	-
10	0.5	1.09	-	-	1.1	2.2	-	-
15	0.5	1.09	-	-	1.1	2.2	-	-
20	0.5	1.09	-	-	1.1	2.2	-	-
24	0.5	1.09	-	-	1.1	2.2	-	-
27	0.5	1.09	-	-	1.1	2.2	-	-
30	0.5	1.09	-	-	1.1	2.2	-	-
32	0.5	1.09	-	-	1.1	2.2	-	-
Total quantity (g/plant)	4	8.72	1 - 2	3 - 6	8.8	17.6	2 - 3	10 - 14

Table 22 — Example of a complete manure fertilisation plan (solid granular) used in Cameroon in a pineapple plantation (Smooth Cayenne variety)

TYPE OF FERTILISER	WEEK AFTER PLANTING	APPLICATION DOSE (g/plant)	N (g/ plant)	P_2O_5 (g/ plant)	K_2O (g/ plant)	MgO (g/ plant)
Type of formulation 11-5-27-5	4 - 5	7.25	0.8	0.36	1.96	0.39
	9 - 11	7.25	0.8	0.36	1.96	0.60
	15 - 17	7.25	0.8	0.36	1.96	0.60
	20 - 22	7.25	0.8	0.36	1.96	0.60
	26 - 27	7.25	0.8	0.36	1.96	0.60
Total quantity (g/plant)		36.25	4	1.8	9.8	1.8

Table 23 — Example of a fertigation plan used in Brazil in a pineapple plantation (Perola variety, with a density of 40,000 plants/ha) under an irrigation system in a semi-arid region, based on the results of soil analyses (as cited by Souza *et al.*, 2001)

MONTHS AFTER PLANTING	N (kg/ha)	P_2O_5 (kg/ha)			K_2O (kg/ha)			
		Mg P/dm³ OF WATER			Mg K/dm³ OF WATER			
		< 5	6-10	11-15	<30	31-60	61-90	91-120
1-2	60	120	80	40	90	75	60	45
4-5	80	-	-	-	120	100	80	60
6-7	90	-	-	-	135	110	90	75
8-9	9	-	-	-	135	115	90	60
Total quantity (kg/ha)	239	120	80	40	480	400	320	240

N.B.

For a higher density of around 50,000 plants/ha, for example for the Smooth Cayenne variety, the doses will increase by 25%.

8.3.3. FERTILISER APPLICATION METHODS

The producer's choice of application methods depends on the manpower required and the financial means at their disposal (Fairhurst, 2015). To this end:

- Solid granular fertilisers can be applied close to the plants or at the base of the oldest leaves (Figure 58a). It is important that, after surface spreading, the soil is reworked to cover the fertiliser that has been applied. It can be applied by hand or using simple tools such as drinks or bottle caps. Regardless of the method of application used, fertilisers must not fall on the youngest upper leaves or in the centre of the plant, as they can cause damage.
- Liquid fertilisers are applied by foliar spraying.
- In an irrigated production system, solid and liquid fertilisers are applied by fertigation (in the irrigation water). Mineral fertilisers other than phosphorus are usually applied by irrigation or high-frequency localised irrigation.
- Organic fertilisers are generally applied in holes or furrows, and can also be used after the crop has been planted, in the form of mulch next to the plants (Figure 58b and c).
- Fertilisers such as phosphate and organic matter can be applied in bands just alongside the planting row to allow early root interception (Souza *et* Reinhardt, 2007).
- Potassium fertilisers should be split into 3, 4 or 5 applications.
- Soluble and liquid fertilisers are applied to the leaves as foliar sprays. The architecture of the plant and the morphological and anatomical characteristics of its leaves favour leaf uptake of nutrients (Souza *et* Reinhardt, 2007). Foliar applications are made using spray booms attached to backpacks or tractor-mounted tanks. In general, the concentration of fertiliser in the solution should not exceed 10%. Mature pineapple leaves tolerate high concentrations of fertiliser well, but excessive soil applications can injure or kill roots through desiccation. Spraying fertiliser can damage plants if the concentration and volume are high (Souza *et* Reinhardt, 2007).

Figure 58 — Fertiliser application methods:
application of mineral fertiliser to the basal part of the plant (a);
application of organic fertiliser to the planting lines (b and c)
Source: Djido *et al.*, 2019

8.3.4. TIMING OF FERTILISATION

In principle, it is recommended to apply fertilisers to pineapple throughout the vegetative phase of the plant cycle (from planting to induction of flowering) (Spironello *et al.*, 2004). At the time of planting, organic fertilisers (such as manures, composts) or phosphate fertilisers are generally applied in a single operation, in the planting hole or furrow or in the first top dressing. Post-planting fertilisation can also be adopted for water-soluble phosphate fertilisers (such as superphosphates), provided it is more convenient for the grower.

Nitrogen and potassium fertilisers, on the other hand, must be spread on the surface during vegetative growth. Surface fertilisation should begin after the plants have taken root (30 to 90 days after planting) and continue until the month before artificial flowering. Normally, between the 6^{th} and 9^{th} month after planting, the rate of nutrient uptake by the pineapple increases significantly. It is therefore essential that during the period between the 5^{th} month after planting and the artificial onset of flowering, the plant is supplied with sufficient nutrients to build up reserves that will be important during the fruit development and growth phase. In principle, the fertilisation schedule should take into account whether the fertiliser will be applied in solid or liquid form and whether the crop will be grown with or without irrigation, which will determine whether the fertiliser will be spread more or less evenly. In non-irrigated plantations, the prevailing recommendation in most growing regions is to split solid N and K fertilisation into three or four doses, in the period between planting (usually 30 to 60 days after) and the 30 days preceding the flower induction treatment. In these conditions, it is essential to factor in the region's rainfall pattern, so that fertilisation coincides with periods of good soil moisture. In irrigated plantations, fertiliser in solid form can be distributed at more frequent intervals over a longer period - between four and five times - at pre-established times throughout the vegetative phase of the cycle (for example, every two months from planting). When the alternative of liquid fertiliser application is used, the fertiliser is generally distributed on a much more regular basis. In this case, foliar fertilisation by spraying or fertigation is generally carried out at monthly, fortnightly or even weekly intervals, between planting and the start of flowering. Nitrogen and potassium are always predominant in these fertilisations, but other nutrients (such as magnesium and trace elements) can also be added if recommended. Foliar sprays should be applied during the coolest part of the day (early morning or late afternoon) to prevent the leaves from burning. It is normal, especially in large plantations, for foliar spraying to be carried out at night. It is also important to avoid excessive run-off and accumulation of solutions in the leaf axils, and to pay particular attention to the concentration of the solutions used (the total concentration of fertilisers in the solution must not exceed 10% - 100 g per litre of water), to avoid damaging the plants. Another aspect to be observed when applying several products together is the degree of compatibility between the components of the mixture, to avoid compromising the effectiveness of some of them, or even of the operation as a whole.

SOIL AND FERTILISATION MANAGEMENT

PINEAPPLE CULTIVATION IS VERY DEMANDING IN TERMS OF NUTRIENTS AND MUST BE PROPERLY MANAGED TO ENSURE SUSTAINABLE SOIL FERTILITY AND GOOD QUALITY YIELDS. GOOD FERTILISATION PRACTICES MUST FACTOR IN

- integrated soil fertility management;
- soil analysis;
- leaf analysis;
- the 4R principles (R for "right"), i.e. applying the right nutrient source, at the right dose, at the right time and in the right place or location.

9

WEED MANAGEMENT

Herbicide use is common practice to control weeds that can compete with pineapple plants for nutrients, water and sunlight and compromise their productive capacity and fruit quality particularly in the first four months of growth (Daouda *et al.*, 2015b; Maia *et al.*, 2020b). However, excessive use of herbicides can have negative effects on the environment and human health. Weed management also destroys potential reservoirs and breeding grounds for certain pests in particular mealybugs, symphylans and nematodes. Weed interference throughout the production cycle reduces pineapple yield by 69.50%. The critical period for preventing weed interference is 14 to 259 days after planting (Oliveira *et al.*, 2021). Weeds can be controlled chemically, biologically or mechanically.

9.1. CHEMICAL CONTROLS

In the case of chemical control, weeds are essentially controlled by the use of herbicides (Figure 59). This application is generally made both before planting and up to 5 and 6 months after planting, the period when soil cover by pineapple is sufficient to slow down weed growth (Py *et al.*, 1984; PIP/COLEAD, 2009). The choice of herbicide depends on the level of restriction and legislation in each country (PIP/COLEAD, 2009). The treatment consists of an initial application of a pre-emergence herbicide to the soil, just after planting, to prevent the emergence of weed seeds that are still present and likely to stifle the growth of pineapple plants once they have developed. Herbicides are applied between the rows and in the paths between two double rows or in the furrows between the rows. A repeat application of herbicide can be made the 16th week after planting. Any other weeding must be done manually (PIP/COLLEAD, 2009; Daouda *et al.*, 2015).

Beyond the first 6 months of the plant's cycle, pineapple development is often sufficient for no additional herbicide application to be required before harvest (PIP/COLEAD, 2011).

N.B.

It is important:

— before using plant protection products, to check that they are approved in your country and authorised in the countries to which your produce is exported;

— when handling and using products, to follow all instructions and recommendations. Responsible product use implies using appropriate personal protective equipment (PPE), protecting the environment and consumer health, and complying with maximum residue limits (MRLs) and pre-harvest intervals (PHIs). When using pesticides, it is essential to follow the instructions on the label, reading the useful information on the type of product (use), safety advice for the user (wearing PPE, storage), instructions for use (dose, PHI, protection of biodiversity and the environment), as well as the date of manufacture and use-by date.

— For the Africa-Caribbean-Pacific horticultural sector, the COLEAD Crop Protection Database allows you to search by crop and active substance to obtain information on Good Agricultural Practices (GAPs) that ensure compliance with current European Union (EU) and Codex Alimentarius Maximum Residue Limits (MRLs).

Figure 59 — Application of herbicide
Source: CIRAD, 2018

9.2. BIOLOGICAL AND CULTURAL CONTROL

Mulching is a means of covering the soil with materials that form a shield or blanket to limit the germination of weeds or slow down their development and/or to disrupt the biological cycles of pests (Figure 60). Synthetic manufactured mulches (biodegradable polyethylene film 35 to 40 microns thick) are applied just before planting, after soil preparation and suitable irrigation. Mulching can be done in different ways:

— Mulching the ridges and inter-ridges with mulching film. A biodegradable mulching film is used on the ridge and the inter-ridges can be mulched, either with bagasse, fragmented wood, or a reuseable canvas (CIRAD, 2018).

— Cassava peel mulch, *Gliricidia sepium* leaves, *Leucaena Leucocephala* leaves, oil palm bunch waste or wood chips can also be used in weed control (Ewere *et al.*, 2017).

— As can dry straw from corn, legumes, grasses, as well as plant residues and pineapple leaves, which should be evenly distributed over the surface of the soil, particularly along the rows.

OTHER CULTIVATION TECHNIQUES CAN BE USED TO CONTROL WEEDS

— The practice of false seeding consists of preparing the soil, which encourages the seeds to germinate, and then, when the young shoots are between 5 and 8 cm high, they are destroyed by ploughing again. However, this calls for in-depth knowledge of weeds and of how long the seeds remain dormant and, above all, how they reproduce. However, plants that multiply by cuttings will multiply using this technique. For vegetatively propagated plants, it is useful to carry out solarisation, which involves covering the soil with a black tarpaulin. The heat of the sun will destroy the weeds (CIRAD, 2018).

— Respecting seeding densities: not leaving space for weeds (Nurbel *et al.*, 2021).

— The use of cover crops that successfully suppress weeds through a variety of mechanisms, including modifying the seed environment, altering the availability of light, soil temperature and moisture, and through allelopathy (Creamer *et al.,* 1996; Weston *et* Duke, 2003; Reberg-Horton *et al.,* 2012; Soti *et* Racelis, 2020). Pineapple can be associated with the recommended cover crops (*Vigna unguiculata*, *Mucuna pruriens, Crotalaria juncea*). Cover crops are sown at the same time as pineapple between two ridges (Garcia De La Cruz *et* García- López, 2021).

Figure 60 — Mulching of ridges with biodegradable film (a), mulching of ridges with bagasse (b), installation between double rows of pineapples of cowpea (*Vigna unguiculata*) (c), mulching with fragmented wood from pruning of green spaces (d)
Source: CIRAD, 2018; Garcia De La Cruz *et* García- López, 2021

9.3. MECHANICAL CONTROL

Weed control is essential during the first five to six months between planting and flower differentiation. Weeding is carried out in different ways, either manually using hoes or mechanically using agricultural machinery such as electric mowers (Figure 61). It should be carried out at least once every two months for the first 6 months. Once the pineapple plants are larger, weeds will be shaded out and less weeding will be required (Tullio *et al.*, 2016).

Figure 61 — Weeding with electric mower
Source: Tullio *et al.*, 2016

WEED MANAGEMENT

CONTROLLING WEEDS LIMITS THEIR COMPETITION WITH PINEAPPLE PLANTS FOR NUTRIENTS, WATER AND LIGHT - FACTORS THAT CAN COMPROMISE FRUIT YIELD AND QUALITY. CONTROL METHODS INCLUDE

CHEMICAL

— use of pre-emergence herbicides, as approved in the relevant country, on the soil after planting and this in the interrows and in the aisles separating two double rows; and at the 16^{th} week after planting.

BIOLOGICAL AND CULTURAL

— mulching of ridges with polyethylene film and inter-ridges with bagasse, fragmented wood, or reusable canvas; use of grass straws and cover plants; or combinations of pineapple and cover plants (*Vigna unguiculata*, *Mucuna pruriens, Crotalaria juncea).*

MECHANICAL

— at least once every two months for the first 6 months (either manually with hoes or mechanically using farm machinery).

BIOLOGICAL CONTROL AND CROP CONTROL

— as well as manual weeding are the easiest and safest ways to control weeds around pineapple plants. As the pineapple plants get bigger, weeds are shaded out and less weeding will be needed.

10

FLOWER INDUCTION

The natural flowering of pineapples is a highly complex process, with a number of disadvantages. The flowering process of pineapple plants is intrinsically linked to their life cycle. This cycle takes 12 to 30 months until the first inflorescence is produced, depending on environmental conditions and crop management. Several factors influence the crop cycle, such as climatic conditions, mineral nutrition, the type and weight of planting material and the planting period.

The susceptibility of pineapple plants to natural or artificial flowering is linked to the age or size of the plant. Natural flowering is induced by environmental factors, while artificial flowering is achieved through the use of chemicals, usually plant growth regulators. In both cases, hormones synthesised by the plant, such as indoleacetic acid (IAA) and ethylene, are involved, the latter being the real inducing factor. Ethylene is synthesised by the sequential action of the enzymes ACC synthase and ACC oxidase.

Basically, the onset of pineapple flowering depends on the plant's physiological state and nutritional reserves, the length of the day and the temperature. Depending on environmental conditions, natural flowering also varies from year to year, depending on the season and the growing region.

In different production areas, natural flowering rates vary widely, but rates of 5% to 10% over a growing season are very common. In other words, under natural flowering conditions, this means that only 5% to 10% of plants will actually produce fruit. These rates are highly specific to the context; for example, in Mexico, depending on climatic conditions, these rates can be as low as 20%, while in Australia, in certain years, they vary from 50% to 70%. Trials carried out by the Territorial Agricultural Development Agency of Pole 7 and funded by ENABEL in 2021 in various organic pineapple-producing municipalities in Benin showed that natural floral induction of Sugarloaf and Smooth Cayenne pineapple (*Ananas comosus*) reached a maximum of just 3% and 3.33% respectively. Similarly, in the trial conducted by Lebeau *et al.* (2009) in Togo, natural flowering reached only 11% after 10 weeks, while all the treated plots (flower induction) exceeded 80%.

While this may be acceptable for growers supplying small volumes to local markets, or in some cases for processing (on large plantations), it is unsuitable for crops intended for export.

Treatments for flower induction in pineapple have been known for a long time, as this crop lends itself well to this practice (see section 3 - History of use). Flower induction treatment has technological, economic and social advantages such as: (a) rational use of land; (b) uniformity of fruiting and concentration of harvest, with reduced costs; (c) regular and constant supply of fruit for industry and the fresh fruit market, and during more favourable commercial periods, without affecting fruit quality; (d) ensuring that production can match the large volumes needed to complete export shipments according to times agreed in advance with buyers; synchronisation of production allowing supplies to be obtained from multiple small growers; e) easier control of pests and diseases, as flowering can be induced during periods when the inoculum potential is lowest; f) control of fruit weight and size, according to the demands of the consumer market; g) increased income from the crop, due to the greater number of fruits harvested per area; h) better distribution of labour and easier administration of the property; i) possibility of exploiting a second or offshoot harvest (extracted and adapted from Cunha, 2005).

10.1. THE BEST PERIOD FOR FLOWER INDUCTION

The FIT can be carried out all year round, which means that the production cycle can be planned. Floral induction of pineapple plants must take several factors into account to ensure optimum flowering and fruiting. Here are a few criteria to consider when determining the right time for flower induction:

- **Plant Age and Size**: Pineapple plants must reach a specific age and size before undergoing flower induction. In general, they need to have enough leaves and a certain height to ensure uniform flowering and good fruit production.
- **Climatic Conditions**: Flower induction should be timed to suit local climatic conditions. Moderate temperatures, neither too hot nor too cold, are ideal for flower induction. Stable climatic conditions encourage plants to respond better to treatment.
- **Plant Nutrition**: Plants must be in good nutritional condition before flower induction. An adequate supply of essential nutrients, including nitrogen, phosphorus and potassium, is crucial for successful flowering.
- **Day length**: Day length plays an important role in flower induction. Shorter days or changes in light duration can influence the response of plants to floral induction.
- **Harvest Planning**: It is essential to plan flower induction in line with the desired harvesting period. Flower induction must be synchronised to guarantee fruit production during periods of high demand or favourable market conditions.
- **Health Status of Plants**: Plants must be in good health, free from disease and pests, to respond effectively to flower induction. Stressed or diseased plants may have a reduced response to induction.

The FIT is triggered in particular by the size of the plant, which is assessed by the mass of the D leaf. The FIT is carried out between six months (large offshoots) and one year (small offshoots) after planting, when the fourth of the largest leaves (D leaf) weighs between 50 and 70g. It is important to wait until the plant has developed sufficiently, but a plant that is too large will produce a small fruit. Careful planning and close observation of plants and local conditions are essential for successful flower induction and optimum fruit production.

Several floral induction treatment (FIT) techniques presented in the following sections can be used in pineapple production. However, as the pineapple plant's susceptibility to flowering is linked to several factors described above, the dosage and number of applications will have to be adapted to local agro-climatic conditions. The sections below outline the recommendations based on scientific literature, field trials and growers' practices. Slight adjustments may be made to the dosage and number of applications to suit specific local agro-climatic conditions.

10.2. FLOWER INDUCTION IN CONVENTIONAL CULTIVATION

10.2.1. ACETYLENE TREATMENT USING CALCIUM CARBIDE

Calcium carbide, also known as calcium acetylide, is a chemical compound with the chemical formula CaC_2. This compound is mainly produced by an industrial process known as the electric arc furnace method, where lime (calcium oxide) and carbon are heated to high temperatures. The reaction between the two materials leads to the formation of calcium carbide. The purity of calcium carbide can vary depending on the production process and the impurities present in the raw materials used. It is important to note that calcium carbide is a highly reactive compound and must be handled with care (Oladipupo *et al.*, 2022). It has several notable physical properties. It is a crystalline solid in the form of grey-black or brown-black lumps or granules. The compound has a melting point of around 2,000°C, making it suitable for high-temperature applications (Jiang *et al.*, 2022). Calcium carbide is insoluble in water but reacts vigorously with moisture to produce acetylene gas, which is its main application. This reactivity with water also leads to degradation of the compound over time when exposed to wet conditions. It is important to store calcium carbide in a dry, hermetically sealed container to keep it stable (Gasik, 2013).

In the agricultural sector, it is used in the production of calcium cyanamide, a compound used as a nitrogen fertiliser, which helps to improve crop yields and soil fertility (Kashif *et al.*, 2012). Calcium carbide is also used as a source of ethylene gas, a plant hormone that promotes flowering. This controlled release of ethylene from calcium carbide is an economical alternative to expensive synthetic ethylene or natural gas (Okeke *et al.*, 2022). Calcium carbide is also used in orchards to stimulate the initiation and development of flower buds in various fruit trees, thereby promoting synchronised flowering and improving fruit production (Lestari *et al.*, 2020). The cost of calcium carbide can vary depending on factors such as purity, quantity and supplier. As a general rule, unit costs are lower for larger quantities. However, it is essential to consider that calcium carbide is regulated in some regions due to its reactivity and potential hazards, so availability and accessibility may vary depending on local regulations and safety requirements (Shaeda, 2018).

Acetylene is obtained through the reaction of water with calcium carbide. In a 200-litre plastic drum 3/4 full of water, add 500 g of calcium carbide in small pieces (Figure 62). The water used should be as cold as possible to facilitate the dissolution of the ethylene. Always leave a volume of air in the container. The barrel is immediately corked and shaken vigorously for 10 minutes to ensure complete gas release and good dissolution. The resulting spray is immediately poured into the heart of each plant in a volume sufficient to drown it, i.e. at least 50 ml. This can be done using a plastic cup, or a modified backpack sprayer, from which all the metal parts in the tank and the pressure wand have been removed. The mixture flows by gravity through a pipe attached to one end of the tank. At this level, two treatments must be carried out 3 or 4 nights apart. This is the most common technique. Up to 6,000 litres of water and 800 g to 4,000 g of ethylene are necessary to spray one hectare. The treatment can be carried out at night or early in the morning. Usually, the treatment consists of two applications. The second application is made 2 to 3 days after the first, and a third application is made only if samples taken after the initial treatment indicate that it is necessary.

Figure 62 — Acetylene treatment using calcium carbide

10.2.2. APPLICATION OF GASEOUS ETHYLENE IN MECHANISED PRODUCTION

However, this method requires the use of specific machines. These are generally the same equipment and spray booms commonly used for the application of liquid fertilisers/plant protection products, but modified to allow the carbon to mix with the water discharged at a pressure of 20 psi and the ethylene gas at 35 psi. The pressure must first be reduced from 1,200 psi to 35 psi to prevent freezing. The activated carbon, dissolved in the water, is then pumped to the spray bar at 20 psi. This makes it easier for the carbon to absorb the gas, which is then released uniformly and gradually onto the plants.

10.2.3. ETHEPHON TREATMENT

In several ACP countries, the practice of flower induction treatment with ethephon is the most common because it is a simple technique involving a single, generalised application during the day using backpack sprayers. The effectiveness of the treatment is increased when urea (2.5 to 5% urea) is added to the spray mixture. Generalised application by spraying requires a volume of 2 to 3,000 l/ha of spray containing 200 to 800 mg/L ethephon (Good Practice Guides for Pineapple in Benin, 2023).

To reduce the amount of ethephon applied, calcium carbonate can be added. Carbon, oxygen and calcium are combined to form a chemical compound, calcium carbonate, with the formula CaCO3. It is a typical material found in rocks around the world (mostly in the form of limestone), and is the main component of marine animal shells, snails, coal balls, pearls and eggshells (Omari *et al.*, 2016). Adding calcium carbonate effectively reduces the dose of ethephon required while providing additional benefits to encourage plant growth and fruit production (Shenghui *et al.*, 2020). More specifically, adding 0.04% calcium carbonate reduces the dosage of ethephon from 800 mg/L to 50 mg/L while inducing flowering.

However, flower induction treatment with ethephon is a practice that should be avoided, as it is very risky for the grower: any error in dosage or failure to comply with one of the recommendations for use will result in the presence of residues in concentrations that exceed the Maximum Residue Limit (MRL).

If the grower wishes to use ethephon as a flower induction treatment, it is important to find out about the recommendations for use adapted to the variety grown and the recommendations made by the product manufacturer, and/or to seek advice from a supervisory agent (http://www.colead.org).

To avoid ethephon residues, it is preferable to use calcium carbide or activated carbon enriched with ethylene (applied to the heart of the plant). Ethylene gas can also be used, but it requires special spraying equipment, which can be expensive for small producers.

10.2.4. AVIGLYCIN TREATMENT

Aviglycin is a natural, non-toxic compound that can be used to induce flowering in pineapple and other plants by regulating plant hormones and promoting flowering in response to environmental cues (Bello-Amez *et al.*, 2022).

10.2.5. TREATMENT WITH ETHYLENE-ENRICHED ACTIVE CARBON FOR NON-MECHANISED OPERATIONS

Treatment with activated carbon enriched with ethylene is carried out using 800 g (or approximately 650 l) of ethylene and 3 kg of activated carbon for 6,000 litres of fresh water per hectare, using a backpack sprayer or a dosing device (in the case of small producers). The treatment (250 mg/plant) is repeated at 3-day intervals.

This treatment consists of depositing ethylene-enriched activated carbon directly in the rosette to facilitate the diffusion of ethylene into the plant. The activated carbon enrichment process requires only standard equipment that is readily available on the market: a vacuum pump, an ethylene cylinder with pressure reducer, a suitable leakproof container, a pressure gauge and a few pipes, valves, fittings and filters. Standard workshop equipment is required to assemble the enrichment system.

For best results, the treatment should be carried out at dawn. Two application methods can be used:

— Application of dry activated carbon: the enriched activated carbon is applied directly to the heart of the plant, ideally using a suitable device. In this case, it is preferable to use granular activated carbon (*e.g.* Filtrasorb 400 from Chemviron Carbon). In the study by Lebeau *et al.* (2009), a powder dosing device generally used to reload artillery cartridges (Hornady, Lock-n-load type) was used. After minor modifications, alternating movements of the crank handle enable a set dose of activated carbon to be applied. Calibration of the dose should be carried out using scales to weigh the quantity of activated carbon released by the device. This technique is particularly advantageous when water is not readily available and is also less physically demanding than wet application. Current knowledge shows that a dose of 250 mg per plant (activated carbon enriched to 5%), possibly repeated 3 days after the first treatment, ensures a very satisfactory flowering rate and therefore a successful treatment in most circumstances. The dose can be adapted to local conditions depending on the meteorological, phenological or climatic varietal characteristics (Lebeau, *et al.*, 2009) (Figure 63b).

- Wet application of activated carbon: enriched activated carbon is mixed with water directly before application and applied using a backpack sprayer. The activated carbon used in this case is preferably of the "powder" type (*e.g.* Pulsorb GW from Chemviron Carbon). Application is adapted by calibrating the sprayer, where the application time per plant is determined as a function of the flow rate of the sprayer and the recommended dose per plant. Before application, the operator is trained to respect the application time per plant. Efficacy trials have shown that, in most situations, a dose of 250 mg of powdered activated carbon (enriched to 2.5%) per plant ensures successful treatment. In a typical situation, 62.5 grammes of powder are mixed with 15 litres of water in the spray tank, allowing induction treatment of about 250 plants, i.e. 60 ml per plant (Lebeau, F., *et al.* 2009). The actual amount of activated carbon applied per hectare will depend on plant density and climatic conditions, which can vary. For example, at a density of 100 plants per 30 m^2, around 8.5 kg of enriched activated carbon would be needed to treat 1 hectare at the maximum recommended dose of 250 mg per plant according to Lebeau *et al.* (2009). It should be noted that, under the agro-climatic conditions of Benin, high flower induction rates (94-96%) were obtained with just 100 g per plant (Figure 63c).

With these two application techniques, a trained operator can manually treat around 1,000 plants per hour. The wet process is slightly faster but requires access to water, which can be a challenge in some remote tropical areas. Another advantage of the wet process is that it can be applied mechanically using a boom sprayer.

Finally, whatever the treatment technique used, for it to be effective, it is necessary to:

- Carry out the treatment at night, very early in the morning or at the end of the day (preferably in calm weather);
- Repeat the treatment twice at intervals of three or four days;
- If it rains within three hours of a treatment, the treatment is considered to be null and void.

Figure 63 — Application of activated carbon using the dosing unit:
dosing unit in its initial state (a); dry application (b); wet application (c)
Source: COLEAD, 2007

10.2.6. ETHREL TREATMENT

Ethrel is a plant growth regulator used to induce flowering in pineapple plants. It contains ethephon, which releases ethylene, a natural plant hormone. Ethylene stimulates the pineapple flowering process, resulting in synchronised flowering and more predictable harvests. The use of ethrel at a rate of 1,200 ppm on eleven-month-old 'MD2' pineapple plants was the most effective treatment for achieving a high percentage of floral initiation and red bud development (Valesser, 2018).

10.2.7. ZEOTHENE TREATMENT

Zeothene is a commercial plant growth regulator containing a high concentration of ethylene. It is used as an agent for induced flowering in pineapple cultivation. By releasing ethylene, zeothene promotes flowering and increases fruit production in pineapple plants. During a field experiment carried out in Ecuador in 2009, researchers studied the induction of flowering in the hybrid pineapple cultivar MD-2 using zeothene. Zeothene, consisting of zeolite beads containing ethylene gas, was placed in the central cup of each plant to induce flowering. The efficacy of zeothene was compared with that of other agents, including ethephon and ethylene gas. Different application methods were used, such as placing the agents in the central cup or spraying the entire plant. It was found that applications to the central cup were more effective than treatments to the whole plant (Van de Poel *et al.*, 2009).

10.2.8. ETHREL, UREA AND CALCIUM CARBONATE MIXTURE

The mixture of ethrel, urea and calcium carbonate $CaCO_3$ is used as an induced flowering agent in pineapple plants. Ethrel, a synthetic plant growth regulator, stimulates the production of ethylene, a hormone that triggers flowering. Urea, a nitrogen-rich compound, provides nutrients that are essential for plant growth. $CaCO_3$ is probably included to adjust soil pH levels, as pineapples prefer slightly acidic conditions. This combination aims to promote and synchronise the flowering of pineapple plants, thereby improving fruit production.

10.2.9. NAPHTHALENEACETIC ACID TREATMENT

Naphthaleneacetic acid (NAA) is a synthetic growth regulator used to induce flowering in pineapple plants. It belongs to the auxin hormone group and is applied to stimulate the formation and development of flower buds, resulting in increased flower production. NAA is commonly used in commercial pineapple cultivation to synchronise and accelerate flowering for a more uniform and predictable fruit harvest. The method of application and the concentration of NAA may vary depending on factors such as the variety of pineapple and local growing conditions. Treatment of pineapple plantations with naphthaleneacetic acid at the 40-leaf stage showed the highest percentage of flowering (85.27%) and the shortest duration of flowering (36.43 days) according to Kumari *et al.* (2020).

10.2.10. TREATMENT WITH PACLOBUTRAZOL

Paclobutrazol is a plant growth regulator used to induce flowering in pineapple plants. It works by suppressing the synthesis of gibberellins, a class of plant hormones that promote vegetative growth. By inhibiting the production of gibberellins, paclobutrazol redirects the plant's energy towards reproductive processes, such as the initiation and development of flower buds.

10.3. FLOWER INDUCTION IN ORGANIC FARMING

Research by CIRAD (2013) and Soler *et al.* (2006) report on four techniques commonly used for flower induction in pineapple: ethylene gas injected into water with activated carbon; calcium carbide with water (releasing acetylene); ethephon and cold water. Calcium carbide and ethephon are not approved for organic production. Cold water (5°C) can be used in organic production, but results are inconsistent and unreliable (except for plants under nutritional or mechanical stress). Cold treatment is possible, but difficult to apply in ACP countries because of the high temperature of the mains water and the lack of refrigeration equipment. However, it is felt here that the costs, energy demands and logistical challenges of using chilled water in tropical areas make this option unviable.

Smoke was also historically used but only works for indoor production and does not correspond to agronomic practices in tropical regions where pineapples are grown outdoors. In addition, smoke production has a negative impact on air quality, releases CO_2 and contributes to deforestation.

As a result, ethylene remains the only available and viable option for flower induction in organic pineapples intended for export, particularly to the European Union.

There will no longer be any chemical products authorised to carry out the FIT from the entry into force on 01/01/2025 of Regulation (EU) 2018/848 on organic production and labelling of organic products (on this date ethephon and calcium carbide will be banned in organic farming). The only conceivable technical solution could be ethylene on activated carbon, but there is no certainty that this technique will be authorised in 2025 under the new organic regulations.

Table 24 — Summary of the different flower induction agents and their method of application

AGENT	DOSAGE	APPLICATION METHOD	MONTHS AFTER PLANTING	RESULTS	REFERENCES
AVIGLYCINE (AVG)	(150 mg/L, 250 mg/L and 350 mg/L) of AVG 40 ml/plant	Directly from the heart of the plant	8 months	Significant effect in delaying the appearance of inflorescences	Bello-Amez *et al.*, 2022
CALCIUM CARBIDE (CaC_2)	10 g CaC_2/L H_2O and 15 g CaC_2 /L H_2O 50 ml/plant	Directly from the heart of the plant	10-13 months	Accelerates growth for uniform flowering	Fassinou Hotegni *et al.*, 2015
CALCIUM CARBIDE WITH ACTIVATED CARBON	50 ml/plant	Spraying	10 months	Does not improve growth or quality	Raposo *et al.*, 2019
	50 ml/plant	Directly from the heart of the plant	11 months	Sufficient to force the development of reproduction	Maruthasalam *et al.*, 2009

AGENT	DOSAGE	APPLICATION METHOD	MONTHS AFTER PLANTING	RESULTS	REFERENCES
ETHEPHON	40 ml	Directly from the heart of the plant	12 months	Less flowering	Shenghui *et al.*, 2020
	200 mg/L and 800 mg/L 60 ml/plant	Directly from the heart of the plant	12 months	800 mg/L ethephon successfully induced flowering	
ETHEPHON WITH ACTIVATED CARBON	50 ml/plant	Directly from the heart of the plant	11 months	Sufficient to force the development of reproduction	Maruthasalam *et al.*, 2009
ETHEPHON WITH CALCIUM CARBONATE	(50 mg/L, 100 mg/L and 200 mg/L) with 0.04% calcium carbonate 60mL/plant	Directly from the heart of the plant	12 months	Lengthening of the peduncle and an increase in the number of offshoots (slips). The number of fruit and their weight also increased.	Shenghui *et al.*, 2020
ETHREL	2,500 L/Ha 33.33 ml/plant	Spraying	9-11 months	Increased flower initiation and red bud development	Valleser, 2018
ETHYLENE DISSOLVED IN WATER WITH ACTIVATED CARBON	(0.389 g C_2H_4/L; 0.292 g C_2H_4/L and 0.195 g C_2H_4/L) with 2.86 g/L activated carbon	Directly from the heart of the plant	8-9 months	Highly effective flower induction	Van de Poel *et al.*, 2009

AGENT	DOSAGE	APPLICATION METHOD	MONTHS AFTER PLANTING	RESULTS	REFERENCES
MIXTURE OF ETHEL, UREA AND CACO3	50 ml/plant	Spraying	12 months	Highly effective flower induction	Espinosa *et al.*, 2016
NAPHTHALENE ACETIC ACID (NAA)	10 ppm 20 ppm	Spraying	11 months	Significant flowering	Kumari *et al.*, 2020
PACLOBUTRAZOL (PBZ)	2 ml Paclobutrazol/ L H_2O	Spraying	10 months	Longer flowering period	Lestari *et al.*, 2019
ZEOTHENE	13.5 mg/bead 3-4 beads/ plant	Directly from the heart of the plant	8-9 months	Highly effective flower induction	Van de Poel *et al.*, 2009

Source: Sanchez and Jamero, 2024

FLOWER INDUCTION

FLOWER INDUCTION TREATMENT (FIT) IS CARRIED OUT BETWEEN 6 MONTHS (LARGE OFFSHOOTS) AND 12 MONTHS (SMALL OFFSHOOTS) AFTER PLANTING, WHEN THE D LEAF WEIGHS BETWEEN 50 AND 70 G BY

- Treating with acetylene from calcium carbide: at least 50 ml/plant of acetylene spray. Two treatments must be carried out 3 or 4 nights apart.
- Treating with ethephon (with or without calcium carbonate)
- Treating with aviglycine
- Treating with activated carbon enriched with ethylene
  - Via a wet application: one volume of 60 ml/plant of Pulsorb GW from Chemviron Carbon; if necessary repeat at two-day intervals.
  - Via a dry application: one dose of 250 mg/plant of Chemviron Carbon's Filtrasorb 400 enriched to 5%; repeat at three-day intervals if necessary.
- Treating with ethel
- Treating with zeothene
- Applying a mixture of ethel, urea and calcium carbonate
- Treating with naphthalene acetic acid
- Treating with paclobutrazol

In organic production, only ethylene is suitable for flower induction in pineapple (gaseous or diffused by activated carbon).

11

PEST AND DISEASE MANAGEMENT

11.1. INTEGRATED PEST MANAGEMENT

Integrated pest management is an environmentally-friendly approach to crop management. Its main objective is to solve problems caused by harmful organisms while limiting undesirable effects on the environment and human health.

Integrated pest management involves the use of a variety of biological, chemical and physical methods and cultivation techniques specific to each crop. This approach promotes healthy crops and keeps the use of pesticides to a minimum. Cutting down on the use of pesticides reduces the risks to human health and the environment.

Integrated pest management, as a sustainable agricultural practice, aims to:

- Manage damage caused by harmful organisms as economically as possible;
- Limit undesirable effects on people, property and the environment;
- Avoid negative consequences for farmers;
- Foster biodiversity and conservation;
- Protect the human right to food.

11.1.1. BENEFITS OF INTEGRATED PEST MANAGEMENT

Integrated pest management offers a host of benefits for both humans and the environment:

- Reducing negative impacts on biodiversity, preserving soil and water resources; for example, the judicious use of alternative control methods prevents the disappearance of beneficial insects resulting from the inappropriate use of chemical pesticides.
- Reduced health risks for farm workers: less use of pesticides means less exposure and fewer health problems.
- Reduced risk of pesticide resistance developing and of pests reappearing.

11.1.2. STAGES OF INTEGRATED PEST MANAGEMENT

Integrated pest management programmes are broken down into a number of implementation stages: pest identification, definition of an action threshold, monitoring, prevention and control.

11.1.2.1. IDENTIFYING PESTS

Correct identification of the harmful organism is a key stage in decision-making and the use of targeted measures. This stage is essential to assess whether the organism is likely to become a problem and to select the appropriate management strategies.

Poor identification or lack of information about the target pest generally leads to the selection of inappropriate measures and failure of pest control. Sampling the pest, disease or weed ensures correct identification. If necessary, call on the expertise of an extension agent.

The pest is not always visible, in which case the symptoms need to be investigated.

11.1.2.2. DEFINING AN ACTION THRESHOLD

Defining an action threshold is one of the most important aspects of integrated pest management. The intervention threshold or action threshold is the threshold above which measures must be taken to control the harmful organism. The action threshold indicates the density of harmful organisms (for example, the number of harmful organisms per unit area) above which direct action is justified to prevent or mitigate the damage caused by this harmful organism.

To define an action threshold in an integrated pest management strategy, the following questions need to be asked:

IS THERE AN ECONOMIC THREAT AND WHAT IS THE COST OF PEST CONTROL?

Pest control measures will only be taken if the action threshold is exceeded. The cost of pest control must be less than or equal to the estimated losses caused by the pest if nothing is done.

WHAT ARE THE HEALTH AND SAFETY RISKS?

The intervention threshold will have to be lowered when a harmful organism poses a threat to human health or safety.

IS THERE A RISK OF VISUAL DAMAGE?

Any alteration in the appearance of a product can be a cause for concern. Damaged products are difficult to sell.

The definition of action thresholds must be based on regular crop monitoring, which brings us to the third stage of integrated pest management.

11.1.2.3. MONITORING

Monitoring and keeping records of pest populations is important in informing decisions on the need for action. This avoids using control methods when not absolutely necessary. Pest monitoring and management must be adapted to each situation.

Action thresholds can be determined, for example, on the basis of:

— Average number of pests caught per trap each week
— The percentage of damaged or infested leaves/plants found during the inspection
— The number of parasites dislodged per sample (*e.g.* for each plant struck as part of the inspection).

11.1.2.4. PREVENTION

Prevention is a key stage in integrated pest management. It offers the best line of defence against pests. The aim of prevention is to stop pest populations from reaching economically damaging levels.

Integrated pest management aims to prevent pest problems. This method of pest control is often cheaper and gives better long-term results. While prevention may not eliminate pests, it can reduce their numbers and make them easier to control.

Preventive actions include:

- Choosing a suitable site for the crop
- Selecting the most appropriate variety
- Planting and crop rotation strategies
- The use of preventive biopesticides
- Mechanical, physical and cultural methods of crop protection
- Water management
- Optimising plant nutrition
- Protecting natural habitats close to farmland

These actions can be highly effective and present little risk to the environment or to people.

11.1.2.5. CONTROL

Pest control is necessary when action thresholds are exceeded and when preventive measures no longer work.

Combining different methods produces better results in terms of duration and effectiveness.

The methods used in integrated pest management include:

- Trapping (*e.g.* pheromone traps)
- Heat or cryogenic treatments
- Physical removal (manual, mechanical, etc.)
- Biological control
- Applying pesticides

It is important to assess the effects of pest control measures and the strategies implemented.

These assessments can be carried out by keeping:

- A regularly updated register of all pest control methods used (monitoring, prevention, control), including all pesticide applications (organic and non-organic).
- A summary of past experience so as not to repeat the same mistakes and avoid future problems

COLEAD'S CROP PROTECTION DATABASE PROVIDES INFORMATION ON GOOD AGRICULTURAL PRACTICE

It was put online in 2018 and is accessible to all its members and beneficiaries. To date, it is the only database of its kind to provide information specifically dedicated to supporting the horticultural sector in ACP countries. The Good Agricultural Practice (GAP) data are obtained from a combination of sources, including COLEAD field PPP trials, PPP manufacturer data and scientific literature. The database brings together the MRLs set by the EU and the Codex Alimentarius for key horticultural crops in ACP countries. It also brings together good agricultural practices (dose, interval between treatments, pre-harvest interval, etc.) that ensure compliance with these MRLs. Additional information such as the pesticide type, 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) are also available. The COLEAD database is available on our website: https://resources.colead.link/en/vue-substance-active-culture.

12

MAIN PINEAPPLE PESTS AND DISEASES

12.1. MAIN PESTS

12.1.1. NEMATODES

SUMMARY

Nematodes are tiny larvae that colonise and feed on the tips of the main roots, affecting the development of the plant and the quality of the fruit. The most widespread and economically important species are root-knot nematodes (*M. javanica* and *M. incognita*), which infest root tips and cause nodules or galls to form. Lesion nematodes (*P. brachyurus*), feed in cortical parenchyma causing lesions and, depending on the level of infection, can destroy body cells. Reniform nematodes (*R. reniformis*), attack lateral roots and feeder roots, but other roots elongate normally. The effect of these nematodes alters the root system, affects the growth and development of the plant and has a major impact on production.

PESTS (SPECIES RESPONSIBLE)

— *Meloïdogyne javanica* (Treub) (major pest)
— *Meloidogyne incognita* (Kofoid and White) (major pest)
— *Pratylenchus brachyurus* (Godfrey) (major pest)
— *Rotylenchulus reniformis* (Linford and Oliveira) (major pest)
— *Helicotylenchus dihystera* (Cobb) (minor pest)

Figure 64 — Nematodes: (a) *Meloidogyne javanica*, (b) *Meloidogyne incognita*, (c) *Pratylenchus brachyurus*

DESCRIPTION/IDENTIFICATION

PEST(S)

Nematodes are round exoskeleton worms with non-segmented bodies covered by a thick, rigid, elastic and impermeable cuticle. Their average size varies from 0.4 to 0.8 mm in length. They are characterised by a hollow, protruding stylet that enables them to pierce and penetrate root walls and move through plant tissue.

SYMPTOMS

WHOLE PLANT	— The plant is stunted; — Formation of areas or batches of heterogeneous plants (with low vegetative growth); — Weight reduction for the whole plant.
LEAVES	— Wilting of the leaves; — Generally narrow and erect; — Presence of pinkish-yellow to red stains or discolouration; — Drying out of leaf tips (in the most severe cases); — Reduction in the surface area of the D leaf.
ROOTS	— Formation of nodules (galls) visible to the naked eye; — Reduction of the active root system (when the plant is uprooted); — Discolouration or yellowing of the roots; — Reduction or disappearance of the root hair; — Presence of lateral lesions visible under the microscope; — Formation of small necroses.
FRUIT	— Reduced flower and fruit formation — The fruit remains small, with whitish, acidic flesh; — Reduced fruit weight.

Figure 65 — Formation of galls or nodules (roots infested by *Meloidogyne*)

DAMAGE

- Loss of plant vigour;
- Affected roots are generally less resistant to other diseases;
- Parasitised plants are often stunted;
- Reduction in first-harvest yield;
- Low offshoot production.

IMPACT ON YIELD

Nematodes can cause a yield loss of around 30 to 40% in the first harvest.

MAIN PARTS AFFECTED

- Roots

VEGETATIVE STAGES AFFECTED

- Planting
- Vegetative growth
- Flowering
- Fruiting

QUARANTINE PEST

Nematode species such as *Meloïdogyne javanica (Treub)* and *Meldidogyne incognita (Kofoid and White)*, are widespread and reported in almost all pineapple-producing countries. *Meldidogyne incognita (Kofoid and White)* is the most widespread and probably the most serious plant-parasitic nematode in tropical and subtropical regions worldwide. It is present as a pest on a very wide range of crops.

In contrast, the nematode species *Pratylenchus brachyurus* (Godfrey) is only reported in the Hawaiian Islands, West Indies, Australia, South Africa and Côte-d'Ivoire.

The species *Rotylenchulus reniformis* (Linford and Oliveira) is mainly reported in Hawaii and the West Indies.

FAVOURABLE CONDITIONS

GROWING CONDITIONS

— Monoculture;

— The presence of weeds.

TEMPERATURES

— High temperatures and humid conditions are favourable to the development of nematodes;

— The dry season is favourable for symptoms to appear.

SOIL MOISTURE

— The presence of a film of water is essential for the larvae or adults to move in the soil or on the attacked organs, using undulatory movements.

SOILS

— Well-aerated, sandy-textured soils encourage movement and encounters between males and females, leading to reproduction and rapid population growth.

— Acid soils with a pH ranging from 4.5 to 5.5 and very acid soils (< 4) favour an increase in nematode populations such as *R. reniformis* and *Pratylenchus* populations respectively.

— Low soil organic matter content.

— High temperatures at ground level (> 27° C).

LIFE CYCLE OF THE PEST

Generally speaking, the development cycle of nematodes is typically divided into 6 stages: the egg stage, four juvenile stages and an adult stage.

Nematodes have a life cycle divided into two phases:

- an exophytic phase in the soil: from egg-laying to the penetration of juveniles into the root.
- an endophytic phase of development of the feeding site at root level: this enables the nematode to establish itself, develop and reproduce.

MELOÏDOGYNE JAVANICA (TREUB) AND MELDIDOGYNE INCOGNITA (KOFOID AND WHITE)

EGGS	— Complete cycle (formation): between 3 and 4 weeks at 25°-30°C; — Hatching: 8 to 10 days after laying in the soil.
LARVAE	— Divided into four named juvenile/larval stages (larvae L1, L2, L3 and L4); — The growth of the larvae at the end of each larval stage induces moulting; — The L1 larva develops inside the egg; — The L3 larva is the infectious form; — The juvenile/larval stages (L2, L3 and L4) lead to the formation of the immature adult; — The L4 larva measures between 0.35 and 0.40 mm in length.
ADULTS	The life cycle of these species (between inoculation of the root and the hatching of the first eggs) averages 63 days at a temperature of 15.7°C, 25 days at a temperature of 25°C and 17 days at a temperature of 27°C. MALES — Mobile — Wiry shape — Length: 1 to 3 µm — Rounded head — Short, powerful stylet with very pronounced basal swellings. FEMALES — Sedentary and attached to the root system — Piriform shape — Length: 0.8 mm — Whitish colour — Size: 0.5 mm diameter — Lays eggs in clusters of 40 to 60 in a mucilaginous mass

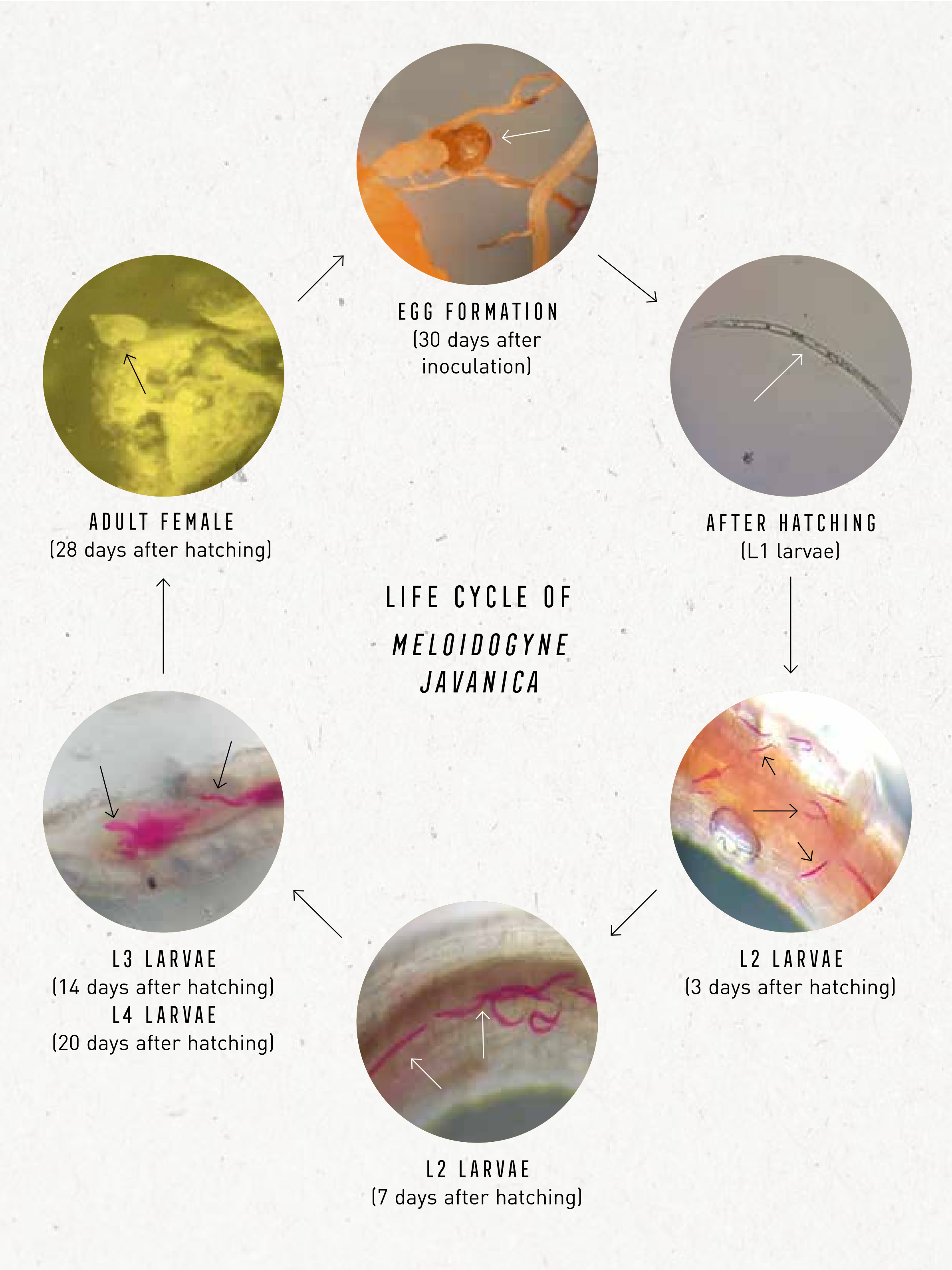

Figure 66 — Life cycle of *Meloidogyne javanica* in the roots.
The arrows indicate the life stages of the nematode in the root. The roots were stained with acid fuchsin
Source: Asadi-Sardari *et al.*, 2022

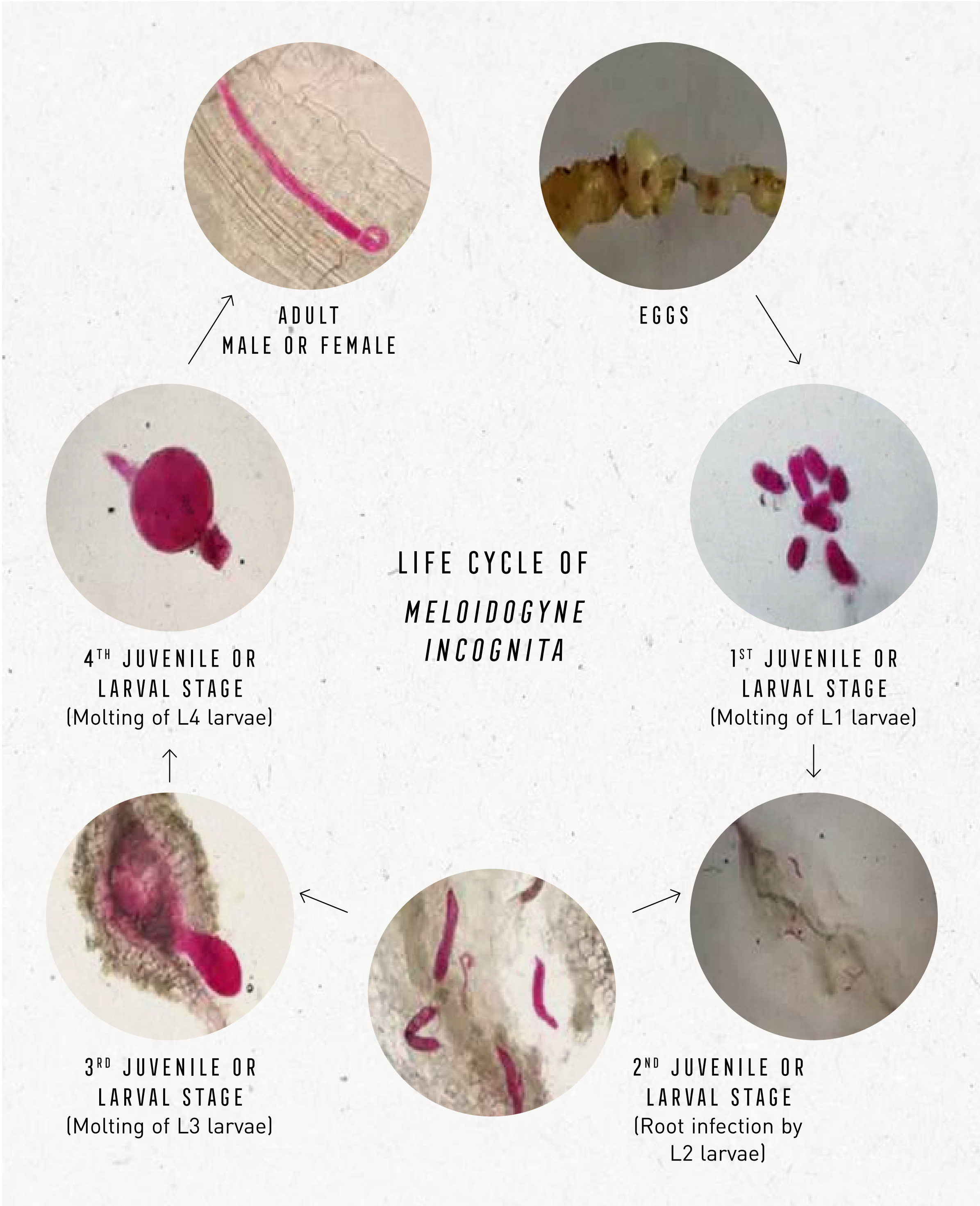

Figure 67 — Life cycle of *Meloidogyne incognita*
Source: Sikandar *et al.*, 2020

PRATYLENCHUS BRACHYURUS (GODFREY)

The *Pratylenchus brachyurus* species is able to penetrate the root, mainly in the vicinity of the elongation zone, at any stage of its development and lay eggs very quickly after their penetration.

EGGS	— Laying: Approximately 33 days; — Hatching: 17 days after laying in the soil.
LARVAE	— The L3 larva is the infectious form; — The juvenile/larval stages (L1, L2, L3 and L4) last 16 days.
ADULTS	— The adult stage lasts 15 days; — The female is a typically vermiform migratory endoparasite, 0.4 to 0.8 mm long, with a short, strong stylet; — Males are very rare; — A highly polyphagous species, which allows it to survive easily between two pineapple crop cycles in the presence of the crop's residual roots; — Their survival could reach 96 weeks in the presence of living root fragments, while in their absence survival would be reduced to around 30 weeks.

ROTYLENCHULUS RENIFORMIS (LINFORD AND OLIVEIRA)

EGGS	— The eggs are released in a gelatinous mass that usually contains more than 100 eggs; — Egg-laying begins 9 days after penetration by the juvenile female. They hatch after 8 days, for a total cycle of around 25 days.
LARVAE	— The L2 larva is less than half a millimetre long; — The L3 larva enters the pineapple root where, after a final moult, it transforms into a sedentary, semi-endoparasitic female.
ADULTS	— As the gonads develop, the female takes on a typical swollen shape; — The non-parasitic male lives freely in the soil; — Reproduction is essentially sexual.

HELICOTYLENCHUS DIHYSTERA (COBB)

The species belonging to this genus are ectoparasitic or semi-endoparasitic, attacking only the superficial layers of cells; as a result, their economic importance is much less than that of the preceding species. However, in the event of heavy outbreaks, their impact is probably not negligible.

MONITORING

- Nematode control should begin as early as possible in the site preparation phase.
- A regular and careful inspection must be carried out on the farm, based on an observation and monitoring form, to identify plants showing progressive yellowing of the leaves, loss of vigour, delayed growth (stunting) or possible death.
- If any of these symptoms are present, laboratory analysis of the soil and roots will provide an overview of the level of nematode infestation and detect any damage (lesions, galls) caused by the nematodes.
- The first inspection should be carried out before the first booster treatment to assess the effectiveness of the planting treatment. A second inspection should be carried out around 2 months later, at around 5 months, to decide whether a second treatment is required. As a guide, the treatment thresholds for *Pratylenchus* are 5,000 individuals/100 grammes of roots in heavy, high pH soils and 10,000 individuals/100 grammes of roots in other cases.
- A FIT inspection allows the effectiveness of the treatment to be assessed afterwards. It is possible to use the same molecules as those offered in liquid form for treatment at planting.

CROP CONTROL

PRE-PLANTING STAGE

- Rotate to lower the initial nematode population or delay infestation of pineapple roots for a few months. These may be food, fruit or fodder crops. Some examples of crops to include in rotations are:
  - Fodder plants: *Mucuna pruriens,* Crotalaria *juncea, Cajanus indicus, Triticum aestivum, Glycine javanica, Panicum maximum, Brachiaria decumbens, Digitaria decumbens, etc.*).
  - Food crops: sugar cane and bananas
- Set aside fallow land cultivated with plant improvers that are not parasitised by nematodes. The choice of plant must take into account the nematode species to be controlled, its ease of cultivation (speed of emergence, soil covering capacity) and the possibility of controlling it later so that it does not compete with the pineapple crop. Potentially useful plant species include:
  - *Mucuna pruriens* (against *Rotylenchulus, Pratylenchus and Meloidogyne*)
  - *Macroptylium atropurpureum (Siratro)* (against *Rotylenchulus*)
  - *Crotalaria usaramoensis, Flemingia congesta* (against *Pratylenchus and Meloidogyne*)
  - *Cajanus indicus* (against *Meloidogyne*)
  - *Panicum maximum* (against *Rotylenchulus, Pratylenchus and Meloidogyne*)
  - *Brachiaria decumbens* (against *Rotylenchulus*)
  - *Digitaria umfolozi* (against *Pratylenchus*)

- *Digitaria decumbens* (against *Meloidogyne*)
- *Eupatorium odoratum* (against *Pratylenchus*)
- *Tagetes patula* (against *Rotylenchulus*)

— Use the “STRong” rotation system to manage root-knot nematodes. The system was developed by African Farmers' Organic Research and Training (AfFOResT), an NGO in Zimbabwe. This involves planting a susceptible crop in rotation, followed by a tolerant crop and then a resistant crop, before returning to the susceptible crop.

PLANTING STAGE

— Use healthy, disease-free offshoots.

— Avoid planting in wet weather.

— Plant in an unshaded area.

— Do not grow crops such as tomatoes in association with pineapple plants.

— Use trap crops such as tagetes (Tagandes spp.) and Indian mustard in association with pineapple crops (these trap crops are crops planted to attract a pest and which are then destroyed along with the pest). Combining pineapple crops with tagetes or Indian mustard helps to minimise the damage caused by root-knot nematodes.

Use non-host plants such as:

— *Mucuna pruriens, Crotalaria juncea, Triticum aestivum*, *Sinapis alba*, *Tag*andes *erecta*, *Glycine javanica*, *Digitaria umfolozi.* These plants eliminate nematodes. Their residues have a "biofumigant" effect when they decompose (Soler *et al.*, 2021).

— *Brassica juncea* var. Integrifolia or *Brassica juncea* var. Juncea. These plants can be used as intercrops in infested fields. As soon as the species flower, they are mulched and incorporated into the soil. As the incorporated plant parts decompose in moist soil, the nematicidal compounds in this decomposition process kill the nematodes.

VEGETATIVE STAGE

— Remove infected plants to reduce the incidence at the next planting.

— Remove weeds periodically.

— Remove and destroy plants or parts of plants infected by disease or damaged by insects.

REPRODUCTIVE STAGE (FLOWERING AND FRUITING)

— Remove weeds from around the plants.

— Remove and destroy plant debris and infested plants.

POST-HARVEST STAGE

- Uproot whole plants from the field after harvesting and destroy crop debris.
- Maintain a weed-free fallow period of at least 6 months to achieve a significant decline in the nematode population.

BIO-CONTROL

VEGETATIVE STAGE

Use nematode biocontrol agents such as:

- Beetles of the *Staphylinida*e family,
- Predatory fungi, including ovicidal fungi that kill eggs.
- Fungi with adhesive spores; endomycorhyzae (living in symbiosis with roots).
- *Trichoderma spp.*: mainly recognised for their direct biological control action against a wide range of pathogens, both telluric and on the aerial parts of plants.
- *Purpureocillium Lilacinum.*
- *Stratiolaelaps scimitus* (for preventive control: apply 250 individuals per m^2 once and for curative control; reapply the preventive dose or increase it up to 4 times).
- Effective options include the fungus *Paecilomyces lilacinus*, which parasitises the eggs and larvae of nematodes, reducing their population. In addition, the entomopathogenic nematode *Steinernema carpocapsae* is used to infect and kill harmful nematodes.

BIOPESTICIDES

Subject to approval in the countries of use and compliance with the standards in force in ACP countries, the use of biopesticides such as abamectin, azadirachtin or garlic extract can be effective against nematodes.

Finally, products based on chitosan, a biopolymer derived from crustacean chitin, strengthen plants' natural defences and reduce the impact of nematodes by modifying their behaviour and reproduction.

CHEMICAL CONTROL

Subject to approval in the countries of use and compliance with current standards (maximum residue levels MRLs) in ACP countries, there are several chemical products active against nematodes (nematicides) that can be used against nematodes, such as fosthiazate or fluopyram.

N.B.

- These products can be toxic. Contact your plant protection product supplier to find the appropriate commercial product and to find out the conditions of use (method and dose of application) best suited to your specific situation, in compliance with the legislation of your country.
- Please note that these product recommendations are for guidance only and that regulations may change. To find out more about the list of locally approved products, please contact your national authorities.
- When using PPPs, always take account of local approval and maximum residue limits for target markets. In view of changing regulations and phytosanitary standards governing the use of plant protection products, including changes to European Union (EU) and Codex Alimentarius maximum residue limits (MRLs), COLEAD has created a crop protection database, accessible here. The database provides up-to-date information on Good Agricultural Practice (GAP), notably extracted from COLEAD's crop protection product (PPP) field trials, data from PPP manufacturers and scientific literature. Additional updated information on Maximum Residue Limits (MRLs) in various target markets can be accessed via the FAO Pesticide Registration Toolkit.

OTHER CONTROL METHODS

PRE-PLANTING STAGE

New strategies or methods for controlling pineapple nematodes have been tested:

- The use of ozonated water (Veronico *et al.*, 2017),
- The use of silicon (Roldi *et al.*, 2017),
- The use of steam and solarisation (Kokalis-Burelle *et al.*, 2016).

Other more empirical approaches include the use of animal manure:

- Cow urine: Dilute one litre of cow's urine in ten litres of water and wet the entire plant at a rate of 80-120 litres/acre at regular intervals.
- Cow dung + Cow urine: 12.5 kg of fresh cow dung and 12.5 litres of cow urine are collected in an earthen pot and mixed with 12.5 litres of water. The pot is covered and the mixture left to ferment for a week. From time to time, it is stirred with a stick. After a week's fermentation, the mixture is filtered and 100g of lime is added. The concentration is diluted with water at a ratio of 1:10 and sprayed onto the crop at a rate of 80-100 l/acre.

Note that the use of homemade mixtures risks leaving residues that are a bit of an unknown quantity, and that further research is needed to determine their effectiveness and optimum application doses.

12.1.2. SYMPHYLIDS

SUMMARY

Symphylids are small myriapods that devour the root tips (including the absorbent hairs), resulting in poor absorption of nutrients by the pineapple plant, followed by dieback of the root system and slower growth, with a consequent depressive effect on pineapple yield. The main species are *Scutigerella sakimurai, Hansentella unguiculata and Hanseniella ivorensis*.

PESTS (SPECIES RESPONSIBLE)

- *Hanseniella ivorensis* (major pest)
- *Scutigerella sakimur*ai (major pest)
- Hanseniella unguiculata (major pest).

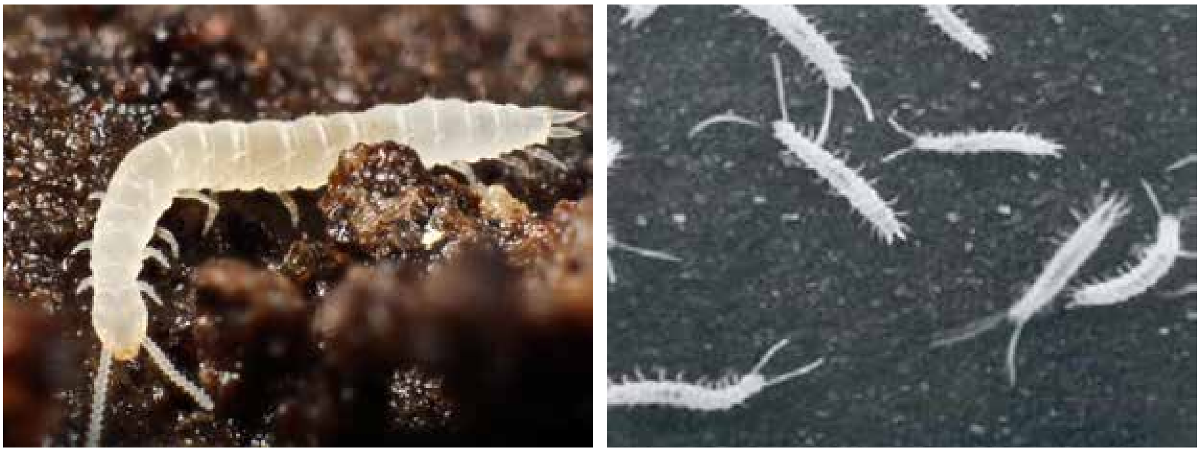

Figure 68 — *Hanseniella ivorensis*

DESCRIPTION/IDENTIFICATION

PESTS

Adult symphylids are tiny myriapods measuring 6 to 10 mm long and a few mm wide. They are white in colour, their head has 2 long antennae and their body, made up of 15 to 22 segments, is covered in bristles and extended by two large cerci. They have 10 to 12 pairs of legs (the larva of *Scutigerella sakimura*. has 6 but that of *H. ivorensis/ unguiculata* has 7). They are blind, lucifugic and hygrophilic but are unable to detect the presence of moisture at a distance and dig galleries in the soil, they move rapidly in cracks or galleries created by variations in soil moisture, plant roots or subterranean animals (Queiroga *et al.*, 2023).

SYMPTOMS

WHOLE PLANT	— Formation of homogeneous groups of plants with poor vegetative growth or very different development from one plant to another in the field. — The plants are stunted and poorly rooted.
ROOTS	— Reduction in root mass or root dieback; — Formation of "witches' brooms"; — Very short roots form around the base of the stem (the apex of the main root is gnawed into a crater); — Lateral lesions on very tender roots;
FRUIT	— Reduced by poor plant development

DAMAGE

- Poor root system development.
- Plant lodging.
- Slower plant growth.
- The fruit does not ripen, which inevitably has a depressing effect on yield.
- Favours the entry of pathogens (viruses).

IMPACT ON YIELD

Losses in fruit yield due to symphylids are estimated at 40-50%.

MAIN PARTS AFFECTED

- Root.
- Fruit.

VEGETATIVE STAGES AFFECTED

- Vegetative growth.
- Fruiting.

QUARANTINE PEST

- The species *Hanseniella ivorensis* is widespread in Africa.
- Species of *Scutigerella sakimurai* and *Hanseniella unguiculata* are widespread in America.

FAVOURABLE CONDITIONS

SOILS

- Well aerated soils with a relatively high clay content.
- Soils with a silty-clay, silty-sandy and gravelly texture.
- Soils with a stony, coarse-grained structure.
- Soils rich in organic matter.
- Loosening the soil makes it easier for them to get through.
- Stony, coarse-grained soil structures offer favourable conditions.

SOIL HUMIDITY AND TEMPERATURE

- Low humidity
- Temperature of 28°C.
- Very dry or very rainy seasons are not conducive to symphylid outbreaks.

LIFE CYCLE OF THE PEST

EGGS	— Among symphylans, there is no direct mating; the male deposits spermatophores in cavities in the soil, which the female recovers and stores in a seminal pouch close to the mouth, using the contents to fertilise her own eggs. Between each moult, a mass of 10 to 11 eggs is laid and the female takes very good care of them. — The eggs hatch after around ten days.
JUVENILES OR LARVAE	— *Scutigerella sakimura* larvae have six (6) pairs of legs but those of *H. ivorensis* or *unguiculata* have 7.
ADULTES	— Length: 6 to 10 mm (depending on species) — Colour: white — The head is made up of two (2) long antennae — The body is made up of segments, covered in bristles and extended by two large cerci. — They have 12 pairs of legs — The complete cycle of *H. ivorensis*, under optimal conditions (with a temperature of 28° C) is 47- 48 days. Adults can live for several years.

MONITORING

- Attacks by the pest are particularly dangerous at two periods in the plant's cycle: in the two months following the planting of shoots, at the time of the first wave of root emission, and 2 to 3 months later at the time of the second wave. Generally speaking, attacks during the latter wave usually have fewer consequences than during the former.
- If infestation is suspected:
  - Sample the soil in containers;
  - Disperse the soil sample on black plastic to look for small white "worms" (2-6 mm) that quickly burrow into the soil to escape the light when disturbed.
  - Shake pineapple root systems on black plastic;
  - Examine the roots for witches' brooms.

CROP CONTROL

PRE-PLANTING STAGE

- Till the soil to increase the mortality rate of the symphylid population.
- Use rotation and fallowing.
- Thoroughly prepare the soil between cycles to ensure a minimum infestation of symphylans at planting time.

PLANTING STAGE

- Use healthy, pathogen-free waste.

VEGETATIVE STAGE

- Eliminate plants infected by symphylans to reduce the impact on other plants.
- Remove weeds periodically.

REPRODUCTIVE STAGE (FLOWERING AND FRUITING)

- Remove weeds from around the plants.
- Remove and destroy plant debris and infested plants.

POST-HARVEST STAGE

- Uproot whole plants from the field after harvesting and destroy crop debris.
- Maintain a weed-free fallow period of at least 6 months to achieve a significant decline in the nematode population.
- Rotate with non-host plants such as cereals.
- The pineapple plants must be completely destroyed during the fallow period (PIP/COLEACP, 2007).

BIO-CONTROL

VEGETATIVE STAGE

Use nematode biocontrol agents such as:

— Centipedes: *Lamyctemus coeculus Broleman*
— Beetle larvae.
— *Stratiolaelaps scimitus*, for preventive control: apply 250 individuals per square metre in one go. For curative control: reapply the prevention dose or increase it up to 4 times.

CONTROL USING BIOPESTICIDES

PRE-PLANTING STAGE/PLANTING STAGE/VEGETATIVE STAGE/REPRODUCTIVE STAGE/ OFFSHOOT PRODUCTION STAGE

Use plant extracts such as:

— Neem seed extract (Azadirachtin): spray the soil with an Azadirachtin-based product before planting, during the vegetative growth phase and during offshoot production.
— Garlic extract: spray the soil with a solution of garlic extract. Garlic (Allium sativum) has repellent and insecticidal properties thanks to its sulphur compounds, such as allicin, which can be applied to repel and kill symphylids.
— Wood ash: spray the soil with a wood ash solution from planting to flowering.
— Extracts of Quassia amara: Extracts of this tropical plant contain quassinoids, natural compounds which act as insecticides by disrupting the nervous system of symphylids.
— Clove essential oil: Rich in eugenol, this essential oil is used as a contact insecticide, rapidly killing symphylids on direct contact.
— Diatomaceous earth: Although often classified as a mechanical biopesticide, diatomaceous earth is a natural abrasive powder that damages the exoskeleton of symphylids, causing them to dehydrate and die.
— Pyrethrins can be used as a biological product against symphylids in pineapple crops. Pyrethrins are natural insecticides extracted from the flowers of certain chrysanthemum species (Chrysanthemum cinerariifolium and Chrysanthemum coccineum). They act quickly on the insects' nervous system, paralysing and killing them.

CHEMICAL CONTROL

Subject to their registration in the countries of use and compliance with the standards in force (maximum residue levels MRLs) in ACP countries, there are several active substances against symphylids that can be used, such as pyrethrins, deltamethrin or lambda-cyhalothrin.

N.B.

— These products can be toxic. Contact your plant protection product supplier to find the appropriate commercial product and to find out the conditions of use (method and dose of application) best suited to your specific situation, in compliance with the legislation of your country.

— Please note that these products are for guidance only and that regulations may change. To find out more about the list of approved products, please consult the following links.

When using PPPs, always take account of local approval and maximum residue limits for target markets. In view of changing regulations and phytosanitary standards governing the use of plant protection products, including changes to European Union (EU) and Codex Alimentarius maximum residue limits (MRLs), COLEAD has created a crop protection database, accessible here. The database provides up-to-date information on Good Agricultural Practice (GAP), notably extracted from COLEAD's crop protection product (PPP) field trials, data from PPP manufacturers and scientific literature. Additional updated information on Maximum Residue Limits (MRLs) in various target markets can be accessed via the FAO Pesticide Registration Toolkit.

12.1.3. MEALYBUGS

SUMMARY

The mealybug also known as the pineapple mealybug or mealy louse (*Dysmicoccus brevipes*) is a pest that causes serious damage to pineapple cultivation worldwide, as it is associated with a disease known as "pineapple wilt" or "Wilt disease". Mealybugs are generally found in leaf axils, at the base of offshoots, on aerial roots and at the base of fruit. They suck the sap from the plant, hindering fruit growth and causing chlorotic areas to appear.

The known vectors of the disease are:

- *Dysmicoccus brevipes*, *Dysmicoccus*
- *neobrevipes* and *Pseudococcus longispinus*.

PESTS (SPECIES RESPONSIBLE)

- *Dysmicoccus brevipes* (Cockerell) (major pest)
- *Dysmicoccus neobrevipes* (major pest)
- *Pseudococcus longispinus* (minor pest)

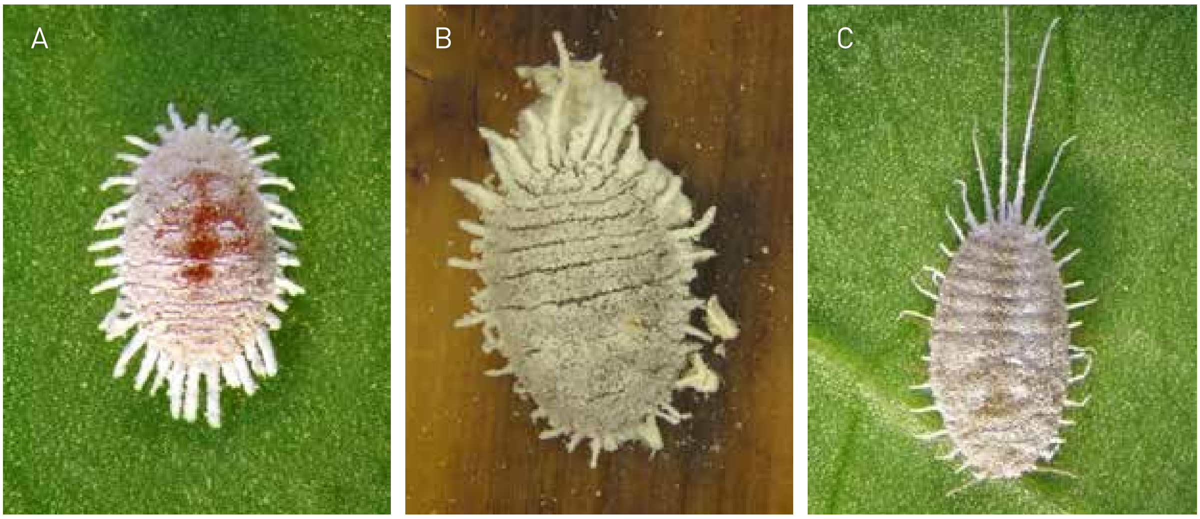

Figure 69 — The different species of mealybug. *Dysmicoccus brevipes* (a); *Dysmicoccus neobrevipes* (b) and *Pseudococcus longispinus* (c)
Source: https://nrcb.icar.gov.in/album

DESCRIPTION/IDENTIFICATION

PEST(S)

Dysmicoccus (family: hemiptera; order: pseudococcidae) are biting, sucking insects that measure around 3 mm long and 2 mm wide in the adult stage. There are two different species of pineapple mealybug: pink and grey.

In pink pineapple mealybugs (*Dysmicoccus brevipes*), the adults are only female and have a half-spherical body shape. They are pink or pink-orange in colour. In contrast, in grey pineapple mealybugs (*Dysmicoccus neobrevipes*), the adult female, 3 to 4 mm long, has an elongated oval shape with a greyish colour (Figure 70). Pink pineapple mealybugs (*Dysmicoccus brevipes*) are found mainly on the roots, in the axils of old leaves and at the base of the plant, then reproduce by parthenogenesis (which means that no male fertilises the eggs), whereas grey pineapple mealybugs (*Dysmicoccus neobrevipes*) are more commonly found at the base of fruits and shoots, and reproduce sexually.

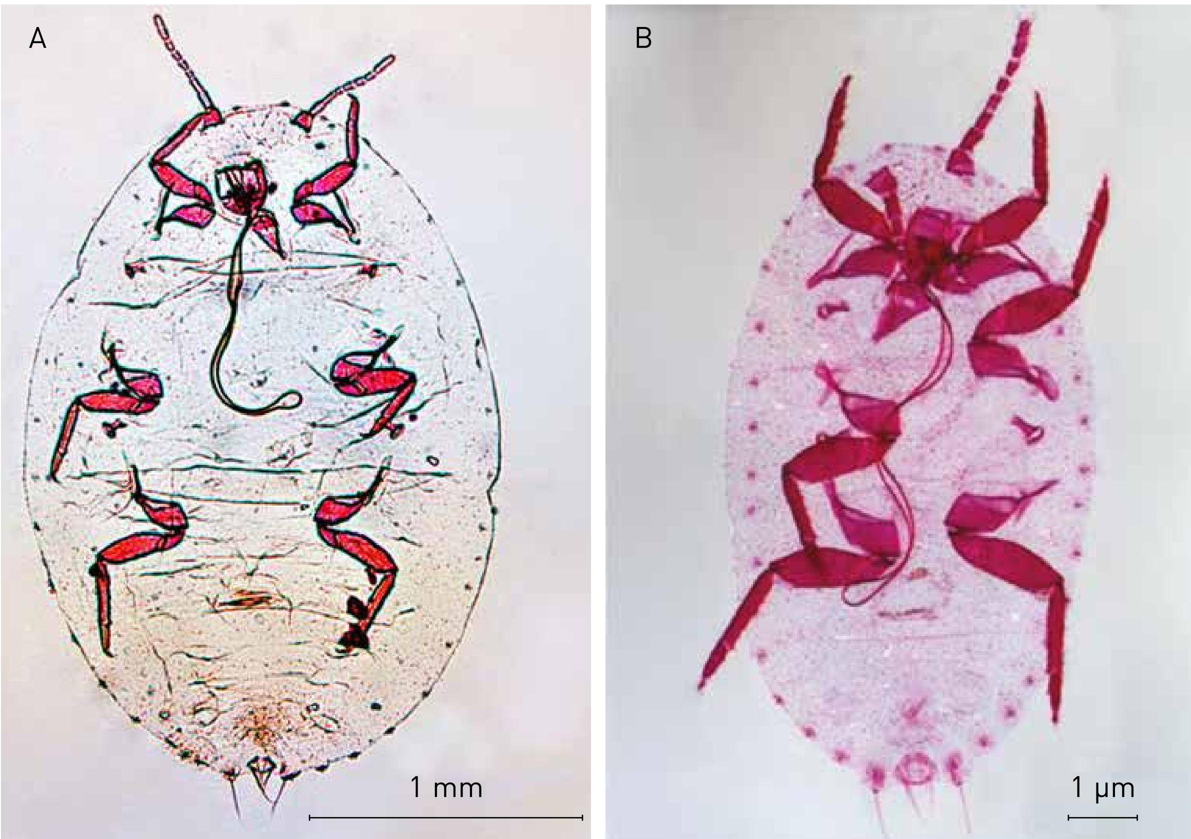

Figure 70 — Biological and morphological differences between pink pineapple mealybugs (*Dysmicoccus brevipes*) (a) and grey pineapple mealybugs (*Dysmicoccus neobrevipes*) (b)
https://entnemdept.ufl.edu/creatures/fruit/mealybugs/pineapple_mealybug.htm

SYMPTOMS

LEAVES	— White colonies of mealybugs in the leaf axils; — Discolouration (reddening, followed by yellowing) of leaves; — The edges of the leaves curl downwards, then the leaves curve towards the ground and eventually dry out.
RACINES	— White colonies of mealybugs on the roots.
FRUITS	— White colonies of mealybugs at the base of the fruit; — The fruit is atrophied.

Figure 71 — Colonies of *Dysmicoccus* at the base of the fruit

DAMAGE

- Root growth of plants stopped;
- Reduction and necrosis of root systems;
- Sudden, rapid and irreversible wilting of plants;
- Loss of plant rigidity.

IMPACT ON YIELD

Dysmicoccus induces a loss of pineapple yield ranging from 30 to 35%.

MAIN PARTS AFFECTED

- Leaves
- Roots
- Fruit

VEGETATIVE STAGES AFFECTED

- Vegetative growth
- Fruiting

QUARANTINE PEST

- *Dysmicoccus* spp. is a quarantine organism in Europe. Its incidence is more marked in tropical and subtropical areas.

FAVOURABLE CONDITIONS

TEMPERATURES

- Temperatures between 8 and 35°C are conducive to the development of *Dysmicoccus* spp.

LIFE CYCLE OF THE PEST

EGGS	— The eggs are pink in colour. — The length of the development time and other physical characteristics of this stage have not yet been studied.
LARVAE OR NYMPHS	— Pineapple mealybugs have three nymphal stages. The first stage is called the caterpillar and is the insect's primary dispersal stage. It feeds during the first and part of the second instar and is then mainly transported by the wind to a new location. Nymphs are smaller versions of the adults, with white, flattened bodies covered in a waxy coating with long wax filaments. — The total time it takes for the transformation from nymph to adult is between 26 and 55 days, with an average of 34 days. The first stage lasts from 10 to 26 days, the second from 6 to 22 days and the third from 7 to 24 days, depending on the outside temperature (Mau and Kessing 2007).
ADULTS	— Development to the adult stage takes 24 days in both males and females. The lifespan of an adult female varies between 48 and 72 days, and that of a male between 1 and 3 days. The adult is not very mobile and generally lives attached to the plant because the development of the body exceeds the development of the legs. It is transferred from one plant to another mainly by ants. These are very fond of mealybug honeydew and they maintain and move mealybug colonies. Females do not lay eggs, but give birth to live larvae. — The adult stage lives between 31 and 80 days, averaging 65 days. It has a pre-larviposition period, before giving birth to young, which lasts around 27 days. The adult then gives birth periodically, every 25 days or so, with an average of around 250 young, but this number can rise to as many as 1,000. Once she has finished giving birth, she will live for around five more days before dying (Mau and Kessing, 2007).

Figure 72 — Gelechioid nymph of the pineapple mealybug (*Dysmicoccus brevipes*)
Sources: Malumphy, 2015

Figure 73 — The adult female pineapple mealybug (*Dysmicoccus brevipes*)
Sources: Malumphy, 2015

MONITORING

- Regular monitoring, particularly at the vegetation and fruiting stages (6 weeks, 14 weeks, 6 months, 8 months and 10 months) by pulling up and checking the base of the last leaf. Control measures are chosen according to changes in the pest's population density. The intervention threshold is targeted according to local conditions on the farm. Monitoring is also carried out using ant baits. Action is taken as soon as the first mealybug is trapped.
- Ten points on 50 plants in plantations of less than five hectares; 20 points on 50 plants in plantations of more than five hectares. If you find five plants (plantations of up to 5 ha) or ten plants (plantations of more than 5 ha) showing symptoms during vegetative development (from the second month after planting until the flower induction treatment), carry out a treatment.

CROP CONTROL

PRE-PLANTING STAGE

- Deep ploughing to destroy weeds in the field.
- Collection and destruction of residues from the previous harvest.

PLANTING STAGE

- Use healthy shoots; trim and disinfect shoots before planting.
- Use healthy shoots free of mealybugs
- Disinfect the offshoots before planting.
- Avoid planting in wet weather.
- Plant in an unshaded area.

VEGETATIVE STAGE

- Eliminate plants infected with Dysmicoccus (during the first 3 months) to reduce their impact on other plants.
- Remove invasive plants periodically.
- Remove weeds from around the plants.
- Collect and destroy plant debris and infested plants.

POST-HARVEST STAGE

- Maintain a weed-free fallow period of at least 6 months to obtain a significant decline in the mealybug population.

BIO-CONTROL

VEGETATIVE STAGE

Use bio-control agents for mealybugs such as:

- Parasitoids of the Encyrtidae family, *Anagyrus ananatis*, *Euryrhopalus propinquus* and *Hambeltonia pseudococcina*.
- Predators from the Coccinellidae family, *Nephus bilucenarius* and *Scymnus uncinatus*.
- The predatory mite *Anystis baccarum*: it is recommended to release 250 individuals per 1,000 plants for prevention and 1,000 individuals or more, for the same number of plants, when the crop attack threshold is high.
- ***Stratiolaelaps scimitus***: For preventive control, it is recommended to release 250 individuals per square metre once, and for curative control to release at the same preventive rate, or to increase the rate up to 4 times.
- Strains of *Metarhizium anisopliae* have been successfully tested on pineapple mealybugs (*Dysmicoccus brevipes*) (Cockerell) under controlled conditions (Liang, 2008).

N.B.

In many countries, bio-control is effective when ants (*Pheidole, Iridomyrmex* and *Solenopsis*) are controlled.

CONTROL USING BIOPESTICIDES

VEGETATIVE STAGE

Use essential oils or plant extracts such as:

- Neem oil: spray neem oil on infested plants.
- Oil of *Gaultheria fragrantissima*: the essential oil of *Gaultheria fragrantissima*, is a bioinsecticide for the control of pineapple mealybugs (N'Guessan *et al.*, 2024).

Neem cake: application of neem cake to the soil 100 days after planting and then 180 days after planting (N'Guessan *et al.*, 2024).

CHEMICAL CONTROL

Subject to their registration in the countries of use and compliance with the standards in force (maximum residue levels MRLs) in ACP countries, there are several active substances against mealybugs that can be used, such as diazinon, pyrethrins, deltamethrin or lambda-cyhalothrin.

N.B.

- These products can be toxic. Contact your plant protection product supplier to find the appropriate commercial product and to find out the conditions of use (method and dose of application) best suited to your specific situation, in compliance with the legislation of your country.
- Please note that these products are for guidance only and that regulations may change. To find out more about the list of approved products, please consult the following links.
- When using PPPs, always take account of local approval and maximum residue limits for target markets. In view of changing regulations and phytosanitary standards governing the use of plant protection products, including changes to European Union (EU) and Codex Alimentarius maximum residue limits (MRLs), COLEAD has created a crop protection database (e-GAP), accessible here. The database provides up-to-date information on Good Agricultural Practice (GAP), notably extracted from COLEAD's crop protection product (PPP) field trials, data from PPP manufacturers and scientific literature. Additional updated information on Maximum Residue Limits (MRLs) in various target markets can be accessed via the FAO Pesticide Registration Toolkit.

Pineapple plantations are treated by spraying:

PLANTING STAGE

- When seedlings come from a plantation infested with mealybugs, they should be treated by immersing them for 3 to 5 minutes in an insecticide-acaricide mixture using one of the products listed above. Add a spreader sticker to the mixture so that it is evenly distributed and sticks to the surface of the plant. After soaking, the seedlings should be placed in paper or perforated plastic boxes so that the excess mixture returns to the solution. The plants are then spread out to dry.

VEGETATIVE STAGE

- If at least one plant showing symptoms of wilting or a colony of mealybugs is detected in a plantation of up to five hectares, or at least two plants showing symptoms of wilting or colony(ies) of mealybugs in plantations of more than five hectares, localised chemical control (in the clumps and adjacent plants) should be carried out, applying one of the insecticides listed above. Continue monitoring and repeat the treatment if necessary. Insecticides against pineapple mealybugs are applied at monthly intervals.

- In the event of heavy infestations, 2 successive treatments should be carried out 1 month apart.
- Given the location of the mealybugs, a large volume of liquid per hectare is necessary to ensure good contact between them and the solution. The spray should fill part of the rosette and then seep down to the base of the plant. It is preferable to use different insecticides alternately to avoid the development of resistance.

OFFSHOOT PRODUCTION STAGE

Treatments must be repeated after the fruit has been harvested on plots producing offshoots.

OTHER CONTROL METHOD

VEGETATIVE STAGE

Use natural homemade mixtures:

Chillies: take 1 cup of dried chillies or 2 cups of fresh chillies, reduce to a fine paste, put in a bucket with 1 litre of water and rub with your hands. Cover your hands with a plastic bag or wear rubber gloves, leave to soak for at least 1 hour; squeeze and filter, top up with 1 litre of water and add 1 teaspoon of hand soap.

Note that the use of homemade mixtures risks leaving residues that are a bit of an unknown quantity, and further research is needed to determine their effectiveness and optimum application doses.

12.1.4. SCALE INSECTS

SUMMARY

Scale insects generally develop on the plant's foliage and fruit. Their presence in large numbers reduces the photosynthetic activity of the leaves, slowing growth and encouraging the formation of cracks between the eyes of the fruit. In extreme cases, the harvest can be wiped out.

PESTS (SPECIES RESPONSIBLE)

- *Diaspis bromeliae* (Kerner) (major pest);
- *Diaspis* boisduvalii (Signoret) (major pest);
- *Melanapsis bromeliae* (Hemiptera) (minor pest)
- *Rhizoecus americanus* (minor pest)

Figure 74 — Scale insects: (a) *Diaspis bromeliae;* (b) *Diaspis boisduvalii*
Source: https://edis.ifas.ufl.edu/publication/IN838

DESCRIPTION/IDENTIFICATION

PEST(S)

The species *Diaspis bromeliae* is a biting-sucking insect that feeds on elaborated sap. It is visible to the naked eye and measures just a few millimetres. Roughly triangular, it is yellow in colour with a soft body; the legs and antennae are not visible and the mouthparts have long, hair-like stylets.

Female *Diaspis boisduvalii* are white to light yellow, approximately 1.2 to 2.25 mm in diameter, circular or oval in shape and covered with a centrally-located flat, transparent white circular or oval shed skin. When the covering of scales is removed, a single horn-shaped projection can be seen on each side of the body, near the head and thorax. Males are oval to elongated and around 1 mm long, with a white cover and marginal skin.

SYMPTOMS

WHOLE PLANT	— Drying out of the plant; — White colonies of *Diaspis* spp. at the base of the plant.
LEAVES	— Presence of yellowish, greyish spots on leaves (due to injection of toxin-laden saliva by *Diaspis bromeliae* and *Diaspis boisduvalii*).
FRUITS	— Formation of cracks between the eyes of fruit (*Diaspis bromeliae* and *Diaspis boisduvalii*); — Malformation or poor presentation of the crown on the fruit (due to a proliferation of *Pseudococcus longispinus* in the heart of the leaf rosette when the inflorescence appears and then on the crown of the fruit).

Figure 75 — Chlorosis caused by the boisduval scale *Diaspis boisduvalii*
https://edis.ifas.ufl.edu/publication/IN838

DAMAGE

- Slower growth.
- Death of the plant.
- Depreciation in the commercial value of the fruit.

IMPACT ON YIELD

The harvest can be wiped out.

MAIN PARTS AFFECTED

- Leaves
- Fruit

VEGETATIVE STAGES AFFECTED

- Vegetative growth
- Fruiting

QUARANTINE PEST

- The species *Diaspis bromeliae* (Kerner) is found mainly in both tropical and temperate countries,
- The species *Diaspis boiduvali* (Signoret) is very widespread, its presence has been reported in Latin America, as well as in West Africa but also in Hawaii, Sri Lanka and Taiwan.
- *Pseudococcus longispinus* (Targiani) is widespread in South Africa and Hawaii.

FAVOURABLE CONDITIONS

- Shading favours the outbreak of *Diaspis bromeliae* and *Diaspis boiduvali* species.
- Zinc deficiency in plants encourages them to multiply.
- Wind encourages the spread of mealybugs.

LIFE CYCLE OF THE PEST

DIASPIS BROMELIAE (KERNER) AND DIASPIS BOISDUVALII (SIGNORET)

EGGS	— The oval, translucent eggs are protected by a light beige circular shield. — They are laid under the cover of the insect's scales. — They hatch after around 7 days.
LARVAE	— The three larval stages, plus a pupal stage, are completed in around 60 days in summer. — The larval stages develop under an elongated follicle made of whitish wax. — Newly hatched immature Diaspis spp. larvae are tiny, yellowish and very active. — The larvae lose their legs during the first moult and then remain on this site.
ADULTS	— The female is an insect protected by a light beige circular shield. The adult male is a winged insect. — The male takes the form of small orange winged insects that mate and die after a short life.

MONITORING

- Plants, especially shady shoots where growth is dense, should be visually inspected regularly, especially during dry spells.
- In the event of a zinc deficiency in plants, extra vigilance is required as this seems to encourage multiplication.

CROP CONTROL

PLANTING STAGE

- Trimming and solarisation (healing in the sun on upside-down mother plants for 24 to 48 hours).
- Space out the offshoots so that their leaves do not touch. This can help prevent mealybugs moving from infested plants to clean neighbouring plants.

VEGETATIVE STAGE

- Remove infested plants from the plantation to prevent mealybugs spreading.

BIO-CONTROL

VEGETATIVE STAGE

Release scale insect bio-control agents such as:

- Predators such as ladybirds: *Rhizobius sp.*, *Orcus sp.*, *Telsimis nitida* and *Lindorus lophantae*.
- Parasites such as those belonging to the genus *Aphytis,* Hymenoptera such as *Ablerus elegantulus* and *Encarsia spp*. (Aphelinidae); *Tetrastichus sp*.; *Coccidencyrtus ochraceipes* Gahan and *C. chraceipes*.

CONTROL USING BIOPESTICIDES

VEGETATIVE STAGE

Use essential oils or plant extracts such as:

- Neem oil (azadirachtin): apply neem oil at the first sign of pests. In the event of high pest populations, apply at seven-day intervals. Spray until run-off. Complete coverage of all plant tissues is necessary to combat the insects.
- Thyme oil: thyme oil comes from the leaves of the thyme plant, which contains an active ingredient called thymol. This is a biopesticide that acts as a repellent and controls insects. The application methods are: (Foliar application: you can spray or mist the product onto the leaves of plants using standard spray equipment; soaking: you can soak the plants in the product mixture. The product can be applied to the soil by spraying the mixture onto the ground or by injecting it into the field's irrigation system.

CHEMICAL CONTROL

PLANTING STAGE

- Use insecticides and acaricides such as diazinon, deltamethrin or lambda-cyhalothrin.
- Control of scale insects must be carried out at the immature stage of the scale to ensure the effectiveness of the control, as scale insects are armoured scale and the waxy covering may still be present even after it has been effectively killed.

Always check the product label for the correct application and dosage.

Subject to their approval in the countries of use and compliance with the standards in force (maximum residue levels MRLs) in ACP countries, there are various products active against scale insects that can be used.

N.B.

- These products can be toxic. Contact your plant protection product supplier to find the appropriate commercial product and to find out the conditions of use (method and dose of application) best suited to your specific situation, in compliance with the legislation of your country.
- Please note that these products are for guidance only and that regulations may change. To find out more about the list of approved products, please consult the following links.
- When using PPPs, always take account of local approval and maximum residue limits for target markets. In view of changing regulations and phytosanitary standards governing the use of plant protection products, including changes to European Union (EU) and Codex Alimentarius maximum residue limits (MRLs), COLEAD has created a crop protection database (e-GAP), accessible here. The database provides up-to-date information on Good Agricultural Practice (GAP), notably extracted from COLEAD's crop protection product (PPP) field trials, data from PPP manufacturers and scientific literature. Additional updated information on Maximum Residue Limits (MRLs) in various target markets can be accessed via the FAO Pesticide Registration Toolkit.

OTHER CONTROL METHODS

VEGETATIVE STAGE

Use products based on natural substances from mineral sources such as:

- Paraffin, which covers harmful insects and mites with a layer of product. The paraffin asphyxiates the pests, which die quickly.
- Kaolin, a clay material. It forms a physical barrier over crops, preventing insects from feeding on them.

Use homemade mixtures:

- Chillies: take 1 cup of dried chillies or 2 cups of fresh chillies, reduce to a fine paste, put in a bucket with 1 litre of water and rub with your hands, protecting your hands with a plastic bag or wearing rubber gloves, leave to soak for at least 1 hour; squeeze and filter, top up with 1 litre of water and add 1 teaspoon of hand soap.

Note that the use of homemade mixtures risks leaving residues that are a bit of an unknown quantity, and further research is needed to determine their effectiveness and optimum application doses.

12.1.5. FRUIT BORERS

SUMMARY

The fruit borer " *Strymon megarus"* formerly known as *Thecla basalides*, is considered one of the main pests of pineapple cultivation in several pineapple-producing countries. It is a pest that digs cavities of varying depths, causing deformation of the fruit. The caterpillars live at the base of leaves and on young fruit. The plant reacts to caterpillar activity by forming brown gum exudates. It is attracted by the pineapple inflorescence. Without control measures, it can cause losses of up to 80%. It has a small number of hosts; in addition to pineapples, it can be found on native bromeliad varieties.

PESTS (SPECIES RESPONSIBLE)

- *Strymon megarus/Thecla basilides* (Geyer) (major pest)
- *Batachedra sp.* (minor pest)
- *Pyroderces sp.* (minor pest)
- *Decadarchis sp.* (minor pest)

Figure 76 — The fruit borer *Strymon megarus* (formerly known as *Thecla basalides*)
Photo: Oirse, 2013

DESCRIPTION/IDENTIFICATION

PEST(S)

Strymon megarus/ Thecla basilides is a lepidoptera in the Lycenidae family. It is a small butterfly, around 28 mm long, with wings that are dark grey on the upper surface and light grey on the underside. The red caterpillar measures around 1.5 mm.

SYMPTOMS

FRUIT

- Formation of amber-coloured gum exudation, which hardens on contact with the atmosphere and takes on a darker colour.
- Observation of cavities of varying depths.
- Deformation of the fruit.

Figure 77 — Damage caused by *Strymon megarus* on fruit

DAMAGE

- Fruit unfit for sale.

IMPACT ON YIELD

Damage to yield can be estimated at between 30% and 80%.

MAIN PARTS AFFECTED

- Fruit
- Crowns
- Flowers

VEGETATIVE STAGES AFFECTED

- Flowering
- Fruiting

QUARANTINE PEST

- The distribution of the pineapple fruit borer or caterpillar is limited in Latin America particularly in Mexico and Argentina (Pires De Matos, 2019) and Trinidad in the Caribbean Islands, it is unknown on other continents.
- Given the limited geographical distribution of the pests, it is forbidden to introduce uncontrolled bromeliads to other continents.

FAVOURABLE CONDITIONS

- Poorly maintained plantations
- Production losses caused by the fruit borer (*Strymon megarus*) depend on the harvest season.

LIFE CYCLE OF THE PEST

The complete cycle of *Strymon megarus* (formerly known as *Thecla basalides*) is 23 to 32 days.

EGGS	— The eggs are circular — They often measure just over 0.5 mm. — Whitish in colour, finely reticulated and slightly flattened. — They are often deposited at the base of a floral bract by the female before the first flower blossoms. — They hatch 5 days after laying.
LARVA	— In the first larval stage, the larva measures 1.5 mm and has a yellowish or pale yellow body with a slightly darker head and thoracic region. It is finely pubescent with four rows of long abdominal hairs and four rows of shorter hairs. It penetrates the fleshy base of the main bract of a fruit eye, devours the floral parts and then burrows into the flesh of the developing fruit. — In the second larval stage, the larva reappears on the surface of the fruit 13 to 16 days later and measures almost 20 mm long by 6 mm wide with a bright pink colour. The head is concealed by the prothorax, the body is compressed dorsoventrally and the terminal abdominal segments are flattened in a wedge-shape.
NYMPH	— The larva pupates in a cocoon attached to the underlying slip leaves. 7 to 11 days later, the adult form (the insect) emerges. — At this stage, the larva is around 13 mm long, pink in colour with dark spots and has a characteristic dorsal hump.
ADULT	— Female: the female of the *Strymon megarus* (formerly called *Thecla basalides*) is a butterfly with a wingspan of 28 to 35 mm. Slate-grey dorsally with a darker border and a fringe of whitish scales. Ventrally, the wings are silvery grey with a number of orange spots. — Its hindwings have two orange spots near a pair of wiry appendages bordered in white and two pairs of tapering appendages. — Male: the male of *Strymon megarus* (formerly known as *Thecla basalides*) is a butterfly smaller than the female, with a large black spot in the centre of the hindwings.

Figure 78 — Development cycle of *Strymon megarus*

MONITORING

- In plantations of five hectares or less, ten points per hectare should be sampled, walking in a zigzag pattern, assessing 20 inflorescences in a row at each point, giving a total of 200 plants per hectare. In plantations larger than five hectares, 20 points should be sampled, assessing 20 inflorescences in a row at each point, for a total of 400 plants per plantation. Assessments should begin each week as soon as the inflorescence appears, around the sixth week after flower induction, and end around the twelfth week after the last flowers of the inflorescence have closed. During these assessments, if at least one adult or two inflorescences with at least one egg are detected, it is essential to use one of the control methods.
- Periodic checks of the inflorescences is very useful, allowing the first application to be started only when the adult appears and/or the first borer eggs are laid, thus reducing insecticide application and labour costs, while being consistent with environmental conservation concerns.
- Offshoots and developing fruit should be examined for the presence of eggs as inflorescences appear. The eggs are easily visible. Particular vigilance is required at times of year when the pest is most active.

CROP CONTROL

PLANTING STAGE

- Select less susceptible pineapple cultivars (*e.g.* the 'Perola' variety).

REPRODUCTIVE STAGE (FLOWERING)

- Remove and destroy inflorescences attacked by the pest.

BIO-CONTROL

VEGETATIVE STAGE

Release bio-control agents such as:

- Caterpillar predators such as: *Heptasmicra spp*, *Polistes rubiginosus* and *Metadontia curvidentata*.
- Parasitoids such as *Trichogramma pretiosum* can help control Lepidoptera butterfly populations. Depending on the species, parasitic wasps can infest pests at different stages of their lives (eggs, larvae or adults).

Use bio-insecticides such as:

- Insecticides based on *Bacillus thurigiensis*: apply in the eighth week after flower induction and then every eight days, for a total of four applications.

CONTROL USING BIOPESTICIDES

VEGETATIVE STAGE

Use essential oils such as:

- Neem oil (azadirachtin): apply neem oil at the first sign of pests. In the event of high pest populations, apply at seven-day intervals. Spray until run-off. Complete coverage of all plant tissues is necessary to combat insects.

Thyme oil: thyme oil comes from the leaves of the thyme plant, which contains an active ingredient called thymol. It is a biopesticide that acts as a repellent and helps to control insects. You can either apply the product directly to your crops, or mix it with water first. The application methods are: (i) foliar application; (ii) dipping and (iii) soil application.

CHEMICAL CONTROL

Malathion, deltamethrin and lambda-cyhalothrin can be used against fruit borers, provided they are registered in the countries of use and comply with current standards (maximum residue levels MRLs) in ACP countries. Always check the product label for the correct application and dosage.

N.B.

- These products can be toxic. Contact your plant protection product supplier to find the appropriate commercial product and to find out the conditions of use (method and dose of application) best suited to your specific situation, in compliance with the legislation of your country.
- Please note that these products are for guidance only and that regulations may change. To find out more about the list of approved products, please consult the following links.
- When using PPPs, always take account of local approval and maximum residue limits for target markets. In view of changing regulations and phytosanitary standards governing the use of plant protection products, including changes to European Union (EU) and Codex Alimentarius maximum residue limits (MRLs), COLEAD has created a crop protection database (e-GAP), accessible here. The database provides up-to-date information on Good Agricultural Practice (GAP), notably extracted from COLEAD's crop protection product (PPP) field trials, data from PPP manufacturers and scientific literature. Additional updated information on Maximum Residue Limits (MRLs) in various target markets can be accessed via the FAO Pesticide Registration Toolkit.

OTHER CONTROL METHODS

VEGETATIVE STAGE

- Use the ethological method: this consists of setting red traps in the seventh week after flower induction and removing them in the eleventh week after induction.
- Cover the inflorescences with waxed paper bags 45 to 55 days after flower induction to prevent eggs being laid on the inflorescences (Queiroga *et al.*, 2023).

12.1.6. MITES

SUMMARY

The pineapple mites, *Dolichotetranychus floridanus* (Banks, 1900) and *Steneotarsonemus pineapple* (Tryon), are also known as the flat mite. They can be found in almost every pineapple-growing region of the world. They feed on the trichome cells at the base of young leaves, as well as on the bracts and sepals of developing fruit.

PESTS (SPECIES RESPONSIBLE)

- *Steneotarsonemus ananas* (Tryon) (major pest)
- *Dolichotetranychus floridanus* (Banks) (major pest)

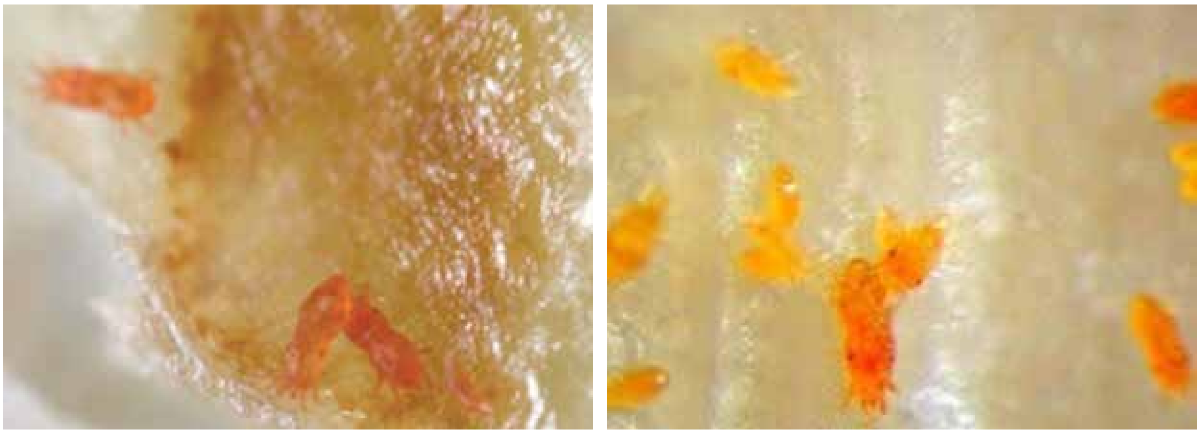

Figure 79 — *Dolichotetranychus floridanus*
Source: Malumphy, 2015

DESCRIPTION/IDENTIFICATION

PEST(S)

Dolichotetranychus floridanus (Acari: Tenuipalpidae) is a mite visible to the naked eye thanks to its intense orange colour.

SYMPTOMS

LEAVES	
	— Presence of necrotic lesions on leaf tissue; — Appearance of scattered small wrinkled formations in the centre of the upper surface of the leaf blade.

Figure 80 — Formation of necrotic zones at the base of the pineapple leaf
Sources: Sanches. 2023)

DAMAGE

The most significant damage resulting from attack by this mite is observed in the soft tissues of the propagation material.

IMPACT ON YIELD

Fruit for export loses its commercial value

MAIN PARTS AFFECTED

— Young leaf bases
— Flower (inflorescence)
— Fruit

VEGETATIVE STAGES AFFECTED

— Growth
— Flowering
— Fruiting

QUARANTINE PEST

- The *Steneotarsonemus ananast* mite is widespread throughout the world. The mite *Dolichotetranychus floridanus* is most commonly found in countries such as Central America, the Philippine Islands, Brazil, Hawaii, Cuba, Taiwan, India, South Africa and Australia.

FAVOURABLE CONDITIONS

- Warm temperatures;
- Very high relative humidity;
- Low light levels are ideal for the development of mites.
- Period of water deficit;
- *Dolichotetranychus floridanus* can cause problems, particularly on young plants, during dry periods.

LIFE CYCLE OF THE PEST

STENEOTARSONEMUS ANANAS (TRYON)

The cycle can be completed in 7 to 14 days.

EGGS	— Oval, opaque white and large compared to the adult; they are laid singly.
LARVA	— Oval and white, — Has three pairs of legs in the same position as the first three pairs of adult legs.
NYMPH OR PUPA	— Mature larvae enter a quiescent pupal or nymphal stage, which is bright white and an elongated oval shape.
ADULT	— Adult female: elongated oval (150-240 µm wide), light amber to creamy brown; the fourth pair of legs is very fine and ends in long bristles. — Adult male: the fourth pair of legs of the smallest male is robust and resembles claws.

DOLICHOTETRANYCHUS FLORIDANUS (BANKS)

The cycle can be complete in less than 10 days.

EGGS	— Oval and light orange; large in relation to the size of the mite.
LARVA	— Amber, with distinct red eyes and six legs.
NYMPH OR PUPA	— Yellow-orange, with eight legs.
ADULT	— Adult female: elongated, orange-red oval, measuring 450 by 170 µm. — Adult male: slightly smaller than the female, i.e. 300 by 140 µm, with a more pointed abdomen.

MONITORING

— In plantations of five hectares or less, ten points per hectare should be sampled, walking in a zigzag pattern, assessing 20 inflorescences in a row at each point, giving a total of 200 plants per hectare. In plantations larger than five hectares, 20 points should be sampled, assessing 20 inflorescences in a row at each point, for a total of 400 plants per plantation. Assessments should begin each week as soon as the inflorescence appears, around the sixth week after flower induction, and end around the twelfth week after the last flowers of the inflorescence have closed. During these assessments, if at least one adult or two inflorescences with at least one egg are detected, it is essential to use one of the control methods.

CROP CONTROL

PRE-PLANTING STAGE

— Destroy crop residues completely, as they are excellent sources of infestation and contribute to the proliferation of pests.

CONTROL USING BIOPESTICIDES

VEGETATIVE STAGE

Use plant extracts such as:

— Neem seed extract (Azadirachtin): spray infested areas with azadirachtin-based biopesticides.

— Garlic: active against mites, thrips and possibly certain fungal diseases. To do this, scrape 4 garlic bulbs into a small quantity of vegetable oil, leave to soak overnight, make up to 2 litres with water, filter and add 2 teaspoons of hand soap.

CHEMICAL CONTROL

VEGETATIVE STAGE

- The chemicals used to control pineapple mealybug, either as a plant treatment or as a spray during the growing season, can also be used to control pineapple mites.

There are a number of active chemicals (pesticides) that can be used, subject to approval in the countries of use and compliance with the standards in force (maximum residue levels MRLs) in ACP countries.

N.B.

- These products can be toxic. Contact your plant protection product supplier to find the appropriate commercial product and to find out the conditions of use (method and dose of application) best suited to your specific situation, in compliance with the legislation of your country.
- Please note that these products are for guidance only and that regulations may change. To find out more about the list of approved products, please consult the following links.
- When using PPPs, always take account of local approval and maximum residue limits for target markets. In view of changing regulations and phytosanitary standards governing the use of plant protection products, including changes to European Union (EU) and Codex Alimentarius maximum residue limits (MRLs), COLEAD has created a crop protection database (e-GAP), accessible here. The database provides up-to-date information on Good Agricultural Practice (GAP), notably extracted from COLEAD's crop protection product (PPP) field trials, data from PPP manufacturers and scientific literature. Additional updated information on Maximum Residue Limits (MRLs) in various target markets can be accessed via the FAO Pesticide Registration Toolkit.

12.2. MAIN FUNGAL DISEASES

12.2.1. ROOT ROT AND GREEN FRUIT ROT

SUMMARY

Root rot and green fruit rot are caused by the same fungal pathogens, *Phytophthora cinnamomi* and *Pythium arrhenomanes* Drechsler

PATHOGENS RESPONSIBLE

— *Phytophthora cinnamomi* (major agent)

— *Pythium arrhenomanes* Drechsler (major agent)

Figure 81 — Sporangium/mycelium of *Phytophthora* sp. (fine white down)
Source: Espinosa Rodríguez *et al.*, 2015

DESCRIPTION/IDENTIFICATION

PATHOGENIC AGENTS

Phytophthora cinnamomi and *Pythium arrhenomanes* are fungi living in the soil in the form of sporangia (mycelium) and then zoospores (chlamydospores: resistant forms) that produce an infection and cause "root rot" and "heart rot" of pineapple plants respectively. Sporangia form in water, and are more abundant if the water contains mineral salts. The zoospores are released after a shock: thermal shock by cooling to 15-18°C or osmotic shock by replacing the mineral solution with distilled water.

SYMPTOMS

LEAVES	— Change in colour of all the leaves from dark green, to a yellow more or less tinged with pink or red (Chand *et al.*, 2021); — Loss of leaf turgidity (Pires De Matos, 2019; Chand *et al.*, 2021); — Rolling of the edges of the blade towards the outer surface; — Curvature of leaf tips towards the ground; — Drying out of the oldest leaves; — The tips and margins of the leaves eventually become necrotic.
ROOTS	— Root rot.
FRUIT	— Development of a distinct brown, water-soaked margin (Chand *et al.*, 2021); — Fruit development stops; — Red colouration of the fruit; — Reduction in fruit size.

Figure 82 — Signs of root rot: (a) Uninoculated roots; (b) Inoculated roots
Source: Espinosa Rodríguez *et al.*, 2015

Figure 83 — Green fruit rot caused by *Phytophthora* spp.
Source: Green and Scot, 2015

DAMAGE

- Destruction of the root system;
- Progressive and irreversible drying out of the entire plant.
- The plants are easily pulled out of the ground (Pires De Matos, 2019; Chand *et al.*, 2021);

IMPACT ON YIELD

Yield losses due to *Phytophthora cinnamomi* or *Pythium arrhenomanes* Drechsler can reach up to 80% at harvest (Sapak *et al.*, 2021).

MAIN PARTS OF THE CROP AFFECTED

- Root
- Fruit

AFFECTED CROP STAGES

- Vegetative growth
- Fruiting

QUARANTINE PEST

- *Phytophthora cinnamomi* and *Pythium arrhenomanes* are more widespread worldwide.

FAVOURABLE CONDITIONS

FAVOURABLE ENVIRONMENT

- Presence of host plants (tomato, bean, etc.);
- Water-saturated soils;
- Soils with poor drainage;
- Heavy soils;
- Very wet soils with a relatively high pH;
- Liming the soil;
- Covering the ground with black polyethylene;
- High altitude areas (*P. cinnamomi*);
- Soil pH (from 5.3).

PERIODS

- Rainy season;
- Low temperatures between 19 to 25°C favour the development of *P. cinnamomi*;
- Temperatures between 28°C and 38°C favour the growth of *Pythium arrhenomanes.*

LIFE CYCLE

INOCULUM SOURCES

Inoculum sources are infested plant material.

INFECTION

The fungi produce sporangia which release spores (zoospores) capable of travelling through water and soil for several hours to the roots or projected by rain onto fruit close to the ground, thus causing infection. One zoospore is enough to infect a plant and the fruit (Chand *et al.*, 2021).

DEVELOPMENT OR SPORULATION

After infestation, infected plants are covered in sporangia, which give the appearance of a fine white down. The sporangia break off to directly infect other plants or release other zoospores (Identification sheet-COLEAD, 2021).

SPREAD

Spread via soil, open water and air (foliage, stolons, branches and fruit tips) (Identification sheet-COLEAD, 2021).

MONITORING

— Pineapple plantations should be inspected as a whole, in particular poorly drained fields or in areas with high rainfall, to identify symptoms of attacks by *Phytophthora* spp. Early detection of symptoms due to *Phytophthora* spp. allows decisions to be taken in good time, in order to reduce the level of infestation in plantations (Identification sheet-COLEAD, 2021).

— Under the most favourable conditions for *Phytophthora* spp. pathogens, the first symptoms do not appear until two weeks after infection. The first visible symptom (beginning of leaf discolouration) occurs on average 4 weeks after infection; the plant then dries out and dies. In the stem, the normally white and opaque tissues are replaced by a spongy, cheese-like mass (Identification sheet-COLEAD, 2021).

CROP CONTROL

PRE-PLANTING STAGE

— Choose well-drained sandy soil with a low pH.

PLANTING STAGE

- Use healthy, certified plants;
- Avoid planting offshoots deep so that the soil does not penetrate the heart of the plant;
- Use Anderson's (1951) spore trapping technique, which detects the presence of *Phytophthora* in the soil or in rotten plant organs.

VEGETATIVE STAGE

- Regularly maintain plantations by removing and destroying infected plants.

POST-HARVEST STAGE

- Avoid injury to the fruit during harvesting and transport.

BIO-CONTROL

VEGETATIVE STAGE

Apply bio-control agents such as:

- The bacterium *Pseudomonas putida*, which inhibits the development of *P. cinnamomi* by parasitism, antibiosis and competition (Yang *et al.*, 2001).
- *Trichoderma*: this is a potential bio-control agent
- *Muscodor albus*, an endophytic fungus isolated from wild pineapple *Ananas ananasoïdes* was shown in vitro to be an effective antagonist of *Phytophthora spp*. (Banguela-Castillo *et al.*, 2015).

CONTROL USING BIOPESTICIDES

VEGETATIVE STAGE

- Garlic: grate 4 garlic bulbs into a small quantity of vegetable oil, leave to soak overnight, make up to 2 litres with water, filter and add 2 teaspoons of hand soap.

Apply biofungicides such as:

- Sodium bicarbonate: sodium bicarbonate can be an effective way of controlling fungal growth - it is registered by the US Environmental Protection Agency as a biopesticide. Sodium bicarbonate increases the alkalinity of the leaf surface, which is not conducive to the growth of fungi. We recommend dissolving one or two tablespoons of bicarbonate of soda in 4.5 litres of water and spraying the plants once a week.

CHEMICAL CONTROL

VEGETATIVE STAGE

Subject to approval in the countries of use and compliance with the standards in force (maximum residue levels MRLs) locally and for the target market, several active substances can be used, such as fosetyl, phosphonic acid, potassium phosphonate, metalaxyl, propamocarb and ascorbic acid.

N.B.

- These products can be toxic. Contact your plant protection product supplier to find the appropriate commercial product and to find out the conditions of use (method and dose of application) best suited to your specific situation, in compliance with the legislation of your country.
- Please note that these products are for guidance only and that regulations may change. To find out more about the list of approved products, please consult the following links.
- When using PPPs, always take account of local approval and maximum residue limits for target markets. In view of changing regulations and phytosanitary standards governing the use of plant protection products, including changes to European Union (EU) and Codex Alimentarius maximum residue limits (MRLs), COLEAD has created a crop protection database (e-GAP), accessible here. The database provides up-to-date information on Good Agricultural Practice (GAP), notably extracted from COLEAD's crop protection product (PPP) field trials, data from PPP manufacturers and scientific literature. Additional updated information on Maximum Residue Limits (MRLs) in various target markets can be accessed via the FAO Pesticide Registration Toolkit.

https://resources.colead.link/en/vue-substance-active-culture

OTHER CONTROL METHODS

PRE-PLANTING STAGE

- Soil solarisation controls the rate of spread of *P. cinnamomi*.

12.2.2. HEART ROT OR TOP ROT

SUMMARY

Pineapple plant heart rot is caused by the pathogen *Phytophthora nicotianae* van Brenda de Haan var. parasitica.

PATHOGENS RESPONSIBLE

— *Phytophthora nicotianae* van Brenda de Haan var. parasitica (Dastur) (major agent)

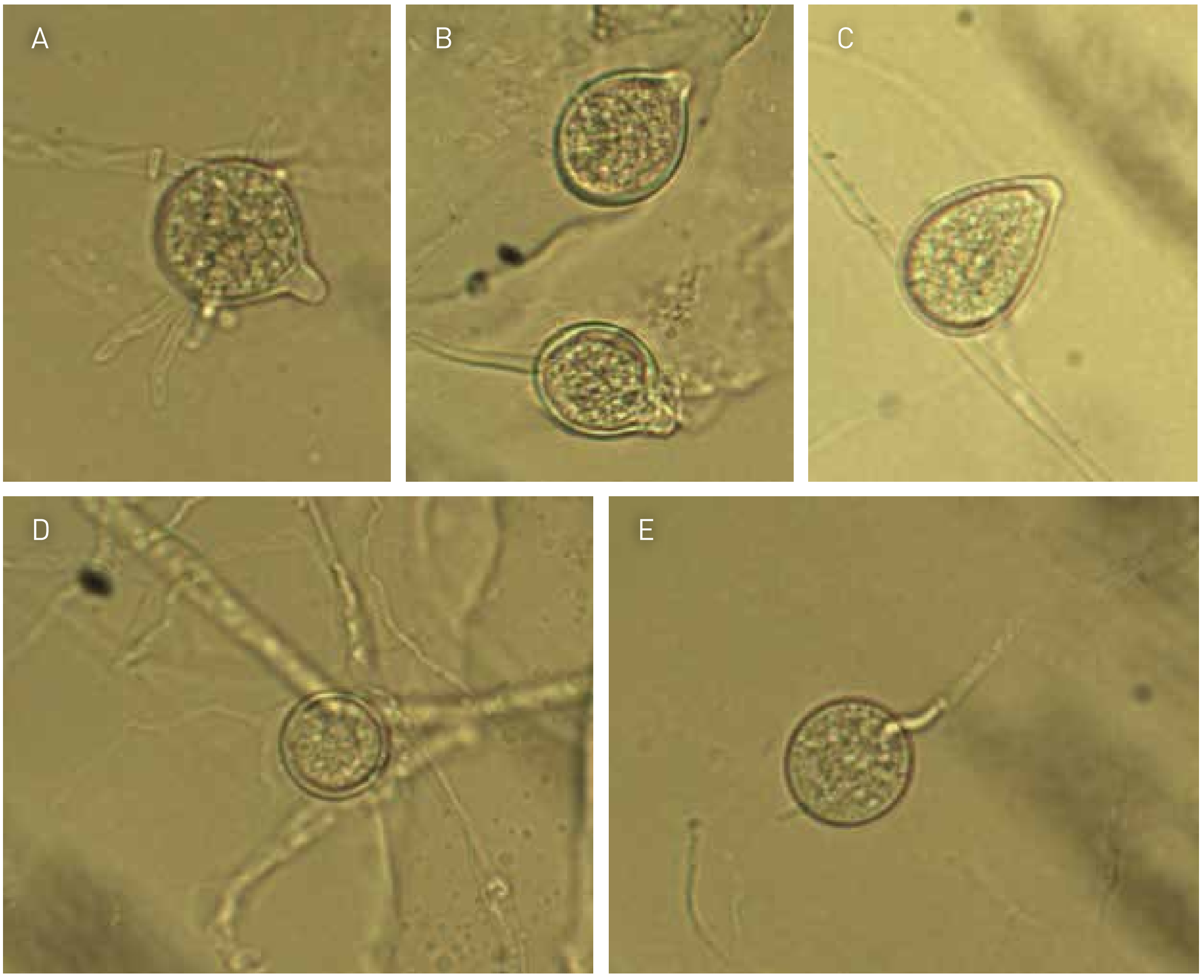

Figure 84 — Asexual structures of *Phytophthora nicotianae*.
(a) spherical sporangium; (b) *slimoniform sporangium*; (c) ovoid sporangium;
(d) intercalated chlamydospore and (e) terminal chlamydospore
Source: Espinosa Rodríguez *et al.*, 2015

PATHOGENIC AGENTS

Phytophthora nicotianae var. *parasitica* is a fungus living in the soil in the form of sporangia (mycelium) and then zoospores (chlamydospores) that produces an infection and causes "heart rot" of pineapple plants. Sporangia form in water.

SYMPTOMS

LEAVES	
LEAVES	— Discolouration of the youngest leaves (from green to yellowish-green to brown); — All the young leaves are easily detached from the rest of the plant with a light tug; — Rot of the non-chlorophyllous basal part of young leaves; — The rotten base of young leaves gives off a nauseating odour; — Wilting of the youngest leaves (Chand *et al.*, 2021).

Figure 85 — Overview of symptoms of plant heart rot caused by *Phytophthora* spp.
Source: Green and Scot, 2015

DAMAGE

- The plants can be pulled out of the ground easily (Pires De Matos, 2019; Chand *et al.*, 2021);

IMPACT ON YIELD

Average yield losses due to *Phytophthora nicotianae* van Brenda de Haan var. parasitica (Dastur) amount to approximately 26.85% (Martin and Rahmat, 2017).

MAIN PARTS OF THE CROP AFFECTED

- Leaf

AFFECTED CROP STAGES

- Vegetative growth

QUARANTINE PEST

- *Phytophthora nicotianae* var. *parasitica* is present in regions far from the equator: Hawaii, South Africa, Australia and Taiwan, but also in warmer areas with tropical and sub-equatorial climates. Heart rot at this stage is more common in Côte d'Ivoire than in other producing countries.

FAVOURABLE CONDITIONS

FAVOURABLE ENVIRONMENT

- Water-saturated soils;
- Soils with poor drainage;
- Heavy soils;
- Very wet soils with a relatively high pH;
- Soil liming;
- Covering the ground with black polyethylene;
- Low-lying areas or the subtropical zones mentioned above and in hot regions;
- Soil pH (from 5.3) (Pires De Matos, 2019).

PERIODS

- Rainy season (Pires De Matos, 2019);
- Low temperatures between 25 and 36°C favour the development of *P. nicotianae var. parasitica* (Rohrbach and Johnson, 2003)

LIFE CYCLE

INOCULUM SOURCES

Inoculum sources are infested plant material.

INFECTION

Fungi produce sporangia which release spores (zoospores) capable of travelling via water and soil for several hours to the roots or projected by rain onto fruit near the ground so infection occurs. One zoospore is enough to infect a plant and the fruit (Chand *et al.*, 2021).

DEVELOPMENT OR SPORULATION

After infestation, infected plants are covered in sporangia, which give the appearance of a fine white down. The sporangia break off to directly infect other plants or release other zoospores (Identification sheet-COLEAD, 2021).

SPREAD

Spread is by soil, open water and aerial means (foliage, stolons, branches, and fruit tips) (Chand *et al.*, 2021; Identification sheet-COLEAD, 2021).

MONITORING

— Pineapple plantations should be inspected as a whole, in particular poorly drained fields or in areas with high rainfall, to identify symptoms of attacks by *Phytophthora* spp. Early detection of symptoms due to *Phytophthora* spp. allows timely decision-making to reduce the level of infestation in plantations (Chand *et al.*, 2021; Identification sheet-COLEAD, 2021).

— Under the most favourable conditions for *Phytophthora* spp. pathogens, the first symptoms do not appear until two weeks after infection. The first visible symptom (beginning of leaf discolouration) occurs on average 4 weeks after infection; the plant then dries out and dies. In the stem, the normally white and opaque tissues are replaced by a spongy, cheese-like mass (Identification sheet-COLEAD, 2021).

CROP CONTROL

PRE-PLANTING STAGE

- Choose well-drained sandy soil with a low pH.

PLANTING STAGE

- Use healthy, certified plants;
- Avoid planting shoots deep so that the soil does not penetrate the heart of the plant;
- Use Anderson's (1951) spore trapping technique, which detects the presence of *Phytophthora* in the soil or in rotten plant organs.

VEGETATIVE STAGE

- Regularly maintain plantations by removing and destroying infected plants.

POST-HARVEST STAGE

- Avoid injury to the fruit during harvesting and transport.

BIO-CONTROL

VEGETATIVE STAGE

Apply bio-control agents such as:

- The bacterium *Pseudomonas putida* which inhibits the development of *P. cinnamomi* by parasitism, antibiosis and competition (Yang *et al.*, 2001).
- *Trichoderma*: it has a potential use as a biocontrol agent.

CHEMICAL CONTROL

Chemical treatments are used at 3 stages:

PLANTING STAGE

- Spray a fungicidal suspension onto or inside the pineapple core as soon as possible (no more than two days after planting).
- The treatments make it possible to decontaminate the offshoots after planting. It is mandatory as soon as conditions are favourable to *Phytophtora*, i.e. very often (high soil pH, rainy season, known history of *Phytophtora*attack, storage of offshoots).

VEGETATIVE STAGE

- Treatment can be applied in response to a one-off outbreak of the disease. It should be carried out as soon as symptoms appear on a few plants. A late reaction makes it all the more difficult to control the disease and can result in it spreading and destroying all or part of the plot.
- The treatment is identical to the planting treatment, but is targeted around the affected plants.
- Stake out the areas where the plants have been removed. These areas should be treated with a fungicide, which should be extended to the ten plants located on either side of the affected area, which are very likely to be already contaminated.
- In the event of a significant history of *Phytophtora* attack or significant risk factors (high pH, clay soils in the rainy season), total treatment of the plot should be considered.

FLOWER INDUCTION STAGE

- The reaction of carbide with water produces a solution with a pH of 12. This situation is very favourable to the development of *Phytophtora*. At this high pH, fungicides are ineffective. It is necessary to wait 8 days before carrying out a treatment in the same conditions as after planting. Given the large volume of plants at this stage, application must be made with a large volume of water.

Subject to approval in the countries of use and compliance with current standards (maximum residue levels MRLs) in ACP countries, several active substances can be used, such as fosetyl, phosphonic acid, potassium phosphonate, metalaxyl, propamocarb and ascorbic acid.

N.B.

- These products can be toxic. Contact your plant protection product supplier to find the appropriate commercial product and to find out the conditions of use (method and dose of application) best suited to your specific situation, in compliance with the legislation of your country.
- Please note that these products are for guidance only and that regulations may change. To find out more about the list of approved products, please consult the following links.
- When using PPPs, always take account of local approval and maximum residue limits for target markets. In view of changing regulations and phytosanitary standards governing the use of plant protection products, including changes to European Union (EU) and Codex Alimentarius maximum residue limits (MRLs), COLEAD has created a crop protection database (e-GAP), accessible here. The database provides up-to-date information on Good Agricultural Practice (GAP), notably extracted from COLEAD's crop protection product (PPP) field trials, data from PPP manufacturers and scientific literature. Additional updated information on Maximum Residue Limits (MRLs) in various target markets can be accessed via the FAO Pesticide Registration Toolkit.

OTHER CONTROL METHODS

VEGETATIVE STAGE

Apply biofungicides such as:

- Garlic: grate 4 garlics bulbs into a small quantity of vegetable oil, leave to soak overnight, top up to 2 litres with water, filter and add 2 teaspoons of hand soap.
- Sodium bicarbonate: Sodium bicarbonate can be an effective way of controlling fungal growth - it is registered by the US Environmental Protection Agency as a biopesticide. Sodium bicarbonate increases the alkalinity of the leaf surface, which is not conducive to the growth of fungi. We recommend dissolving one or two tablespoons of bicarbonate of soda in 4.5 litres of water and spraying the plants once a week.

12.2.3. BUTT ROT OR BASE ROT
BLACK ROT OR WATER BLISTER
WHITE LEAF SPOT

SUMMARY

Butt rot, white leaf spots and black rot are caused by the same fungal pathogens, *Thielaviopsis paradoxa* (de Seynes) Hohn (anamorphic condition) and *Ceratocystis paradoxa* (Dade) C. Moreau. The pathogen *Thielaviopsis paradoxa* (de Seynes) Hohn is an ascomycete fungus and has two stages of reproduction, namely asexual and sexual, which represent the formation of anamorph and teleomorph states respectively. The teleomorphic state of *Thielaviopsis paradoxa* is known as *Ceratocystis paradoxa* (Dade) C. Moreau which is considered a less virulent pathogen and only attacks the host plant under stress conditions such as overwintering.

PATHOGENS RESPONSIBLE

— *Thielaviopsis paradoxa* (de Seynes) Hohn/ *Chalara paradoxa* (De Seynes) Sacc. (major agent)

— *Ceratocystis paradoxa* (Dade) C. Moreau (major agent)

DESCRIPTION/IDENTIFICATION

PATHOGENS

Thielaviopsis paradoxa (de Seynes) Hohn is an ascomycete fungus and has two stages of reproduction: asexual and sexual, which represent the formation of anamorph and teleomorph states of fungi respectively. The teleomorphic state of *T. paradoxa* is known as *Ceratocystis paradoxa* (Dade) C. Moreau (Beer *et al.*, 2014).

SYMPTOMS (BUTT/BASE ROT)

STEM	— Observation of soft basal rot; — Blackening and disintegration of parenchyma; — Release of an acetic odour.
OFFSHOOTS	— Poor recovery of offshoots; — Leaf wilting and yellowing; — Rot at the base of offshoots before or just after planting; — Grey to black staining of infected tissue (Nurnadirah *et al.*, 2018 ; Chand *et al.*, 2021).

SYMPTOMS (BLACK ROT/WATER BLISTER)

FRUIT

- Soft, watery rot of the fruit flesh which liquefies at an ambient temperature of 25°C;
- Side rot of the fruit caused by bruising during harvesting;
- Release of a sweet odour;
- Black spores appear on the central axis (heart);
- Skin oozes at the slightest touch of the fruit. ;
- Stem rot caused by infection of the peduncles after harvest, which develop in the shape of a cone with the heart and base of the fruit as its axis;
- Circular, water-soaked spots present on broken peduncle after harvest (Sapak *et al.*, 2021).

Figure 86 — Black rot/water blister with *Thielaviopsis paradoxa* and *Thielaviopsis ethacethica*

SYMPTOMS (WHITE LEAF SPOT)

LEAVES

- White leaf spot begins as a small brown lesion, generally caused by wounds caused by the wind rubbing against the leaves.
- Presence of white patches bordered by a dark line on the longest leaves;
- Severe leaf dry-up after planting the offshoots.
- The affected area dries out and takes on a greyish colour. As the disease develops, the central part of the lesion dries out and takes on a white colour, surrounded by dark brown edges.

Figure 87 — White leaf spot

DAMAGE

- Very significant economic impact (if control of black rot/water blister is not respected).

IMPACT ON YIELD

Yield losses due to pathogens can reach 20% to 80% of exportable fruit (Sapak *et al.*, 2021). For example, yield losses of around 10% due to the incidence of black rot/water blister have been reported in India (Jackson, 2009).

Black rot is one of the main phytosanitary problems in pineapple cultivation and is responsible for major losses, particularly in fruit intended for industry (Matos, 2003).

White spot of pineapple, caused by the fungus *Chalara paradoxa* (= *Thielaviopsis paradoxa*), is considered a disease of little importance to the crop, as it does not cause losses in fruit production or quality.

MAIN PARTS AFFECTED

- Offshoot
- Leaf
- Peduncle
- Fruit

VEGETATIVE STAGES AFFECTED

- Planting
- Fruiting
- Harvest

QUARANTINE PEST

- Black rot/water blister is a widespread disease in all the world's producing countries, particularly in Africa, Asia, Europe, Oceania and Central, North and South America (Jackson, 2009). It is therefore particularly dangerous when fresh fruit is exported over long distances.
- Butt rot/Base rot due to *Ceratocystis paradoxa* is particularly observed in Hawaii, South Africa and Australia because of the high proportion of crowns used as planting material. Then in Côte d'Ivoire and Martinique because of the poor conditions in which the suckers are stored before being planted.

FAVOURABLE CONDITIONS

FAVOURABLE ENVIRONMENT

- A soil pH ranging from 3 to 8 during cultivation favours the normal growth of *Ceratocystis paradoxa*;
- A temperature between 25° and 28°C favours the development of *Ceratocystis paradoxa*.

PERIODS

- Hot, humid periods increase infection rates and are highly conducive to the growth of pathogenic fungi (Nurnadirah *et al.*, 2018 ; Chand *et al.*, 2021).

LIFE CYCLE

Sources of inoculum: the fungi *Thielaviopsis paradoxa* and *Ceratocystis paradoxa* invade the pineapple plant via wounds, microscopic cracks, a natural opening on the flesh region or insect bites (Sapak *et al.*, 2021). They also penetrate through wounds caused by the separation of shoots or fruit from mother plants, as well as any type of wound caused by pests of any kind.

INFECTION

Infection occurs through the cut stem and through wounds on the surface of the fruit caused during harvesting. Infected fruit initially show dark yellow soft rot in the flesh, which turns black as the disease develops.

DEVELOPMENT OR SPORULATION

Thielaviopsis paradoxa produces infectious spores called conidia which can be broken down into macrospores and microspores. Macrospores are responsible for the blackening of infected tissue in the final stage of the disease's development. The *Ceratocystis paradoxa* produces two kinds of conidia: some hyaline and cylindrical, quite small (microspores), others distinctly larger, brown and ovoid (macrospores) which give the blackish appearance of rots at the end of evolution.

SPREAD

The two types of spore produced respectively by the pathogens remain viable in the soil and plant debris and are always present in any pineapple field. These pathogens can be spread by wind, water, soil, insects or rodents.

MONITORING

- In plantations of five hectares or less, ten points per hectare should be sampled, walking in a zigzag pattern, assessing 20 inflorescences in a row at each point, giving a total of 200 plants per hectare. In plantations larger than five hectares, 20 points should be sampled, assessing 20 inflorescences in a row at each point, for a total of 400 plants per plantation. Assessments should begin each week as soon as the inflorescence appears, around the sixth week after flower induction, and end around the twelfth week after the last flowers of the inflorescence have closed. During these assessments, if at least one adult or two inflorescences with at least one egg are detected, it is essential to use one of the control methods.
- Look for pineapple sets (crowns, stems, suckers) that are not establishing properly, are wilting or dying. Look for foot rot - black soft, with a cavity at the base of the stem. On the fruit, look for black, soft, watery rot under a fragile skin. Look for long, white or cream-coloured leaf rot extending to the tip of the leaf.

CROP CONTROL

To control rot at the base of the offshoots and white leaf spot:

PLANTING STAGE

- Planting material (offshoots) must be handled with care when separating the fruit or plant to avoid serious injury.
- Planting tools and equipment must be properly disinfected to avoid contaminants coming from infected soils or areas.
- The tip of the planting tools should be exposed to the sun.
- Freshly removed offshoots can be stored on the mother plants during the dry season.

To control black rot/water blister, it is advisable to:

POST-HARVEST STAGE

- Minimise mechanical damage or injury during harvesting by handling the fruit with care, as fungal infections can occur even through the smallest wounds.
- Do not sell sunburnt or damaged fruit, as it is likely to have cracks in the skin.
- Maintain strict hygiene at packing centres, by collecting and burying rejected fruit.
- Remove fruit damaged by sunburn before marketing (Joy and Sindhu, 2012).
- Disinfect harvesting tools correctly to prevent infection of broken peduncles.
- Dry the cut ends of the peduncles in the sun to reduce the incidence of black rot on the fruit.
- Soak the cut ends of the peduncles in water heated to 54°C for 3 minutes.
- Do not leave pieces of fruit attached to the crowns when removing them from the plants, as this could lead to rapid infection at the base of the crown.
- Store the planting material on top of the rows of plants or on the ground in single layers, with the bottoms exposed to the sun.
- Eliminate infected plants and fruit, close to where the fruit is stored.
- Harvest the fruit, keeping a section of the peduncle about 2 cm long, and handle it appropriately, both during and after harvesting, avoiding damaging the surface.

BIO-CONTROL

PLANTING STAGE

- Use bacteria such as *Pseudomonas sp., Bacillus sp., Chromobacterium sp.* and *Serratia sp.* These bacteria have strong antagonistic activity against *Thielaviopsis. paradoxa*. (Nurnadirah *et al.*, 2018).
- Use *Pichia guilliermondii* yeast and *Trichoderma asperellum* fungus (Wijesinghe *et al.*, 2010; Wijesinghe *et al.*, 2011).

CHEMICAL CONTROL

VEGETATIVE STAGE

- For chemical control of the pathogens of butt rot/base rot, black rot/water blister and white leaf spot, we recommend the use of fungicides approved in accordance with the phytosanitary regulations and standards governing the use of plant protection products in each country.

Subject to approval in the countries of use and compliance with current standards (maximum residue levels MRLs) for the target market, several active substances can be used to combat butt rot/base rot and black rot/water blister, such as fosetyl or ascorbic acid.

N.B.

- These products can be toxic. Contact your plant protection product supplier to find the appropriate commercial product and to find out the conditions of use (method and dose of application) best suited to your specific situation, in compliance with the legislation of your country.
- Please note that these products are for guidance only and that regulations may change. To find out more about the list of approved products, please consult the following links.
- When using PPPs, always take account of local approval and maximum residue limits for target markets. In view of changing regulations and phytosanitary standards governing the use of plant protection products, including changes to European Union (EU) and Codex Alimentarius maximum residue limits (MRLs), COLEAD has created a crop protection database (e-GAP), accessible here. The database provides up-to-date information on Good Agricultural Practice (GAP), notably extracted from COLEAD's crop protection product (PPP) field trials, data from PPP manufacturers and scientific literature. Additional updated information on Maximum Residue Limits (MRLs) in various target markets can be accessed via the FAO Pesticide Registration Toolkit.

OTHER CONTROL METHODS

VEGETATIVE STAGE

- Garlic: grate 4 garlic bulbs into a small quantity of vegetable oil, leave to soak overnight, make up to 2 litres with water, filter and add 2 teaspoons of hand soap.

12.2.4. FUSARIUM

SUMMARY

Pineapple fusariosis is always associated with several species of fungi of the genus *Fusarium* spp. The pathogen often infects the tissues of pineapple plant parts such as the fruit, offshoots, stems and crowns) causing exudation or discharge of a gum-like substance.

PATHOGENS RESPONSIBLE

- *Fusarium guttiforme* (major agent)
- *Fusarium concentricum,*
- *Fusarium fujikuroi,*
- *Fusarium incarnatum,*
- *Fusarium oxysporum,*
- *Fusarium polyphialidicum,*
- *Fusarium proliferatum,*
- *Fusarium temperatum*
- *Fusarium verticillioides*

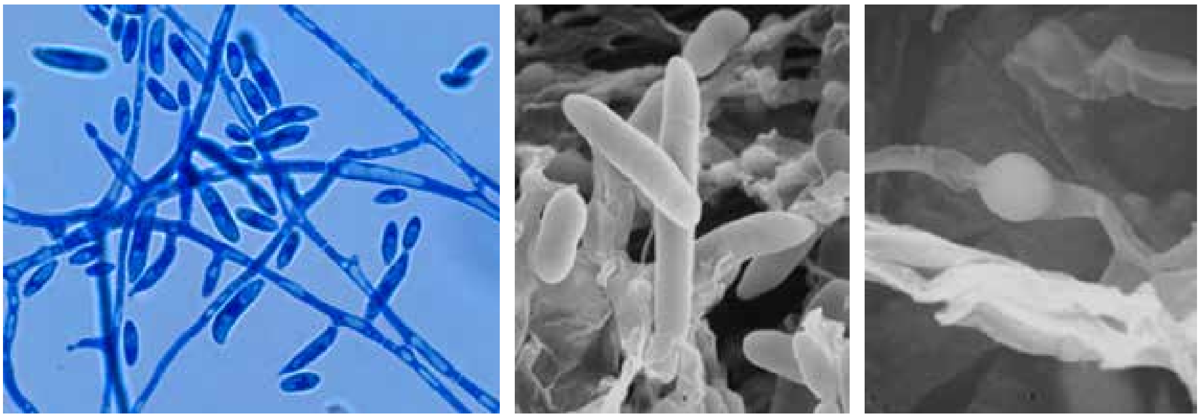

Figure 88 — Microscopic view of *Fusarium oxysporium*
Source: Identification sheet-COLEAD, 2021

DESCRIPTION/IDENTIFICATION

PATHOGENS

The *Fusarium* are vascular, imperfect fungi. They have the appearance of a flattened cone and are characterised by:

- a fairly loose, greyish-white aerial mycelium that can take on other pigmentation (violet, mauve),
- an abundant asexual spore produced by sporodochia or sclerotia;
- micro-conidia of variable size, 20 µm long, which are ellipsoidal, single- or two-celled, spindle-shaped to kidney-shaped, composed of 3 to 5 cells;
- spores grouped together in the form of false dry heads at the end of elongated micro-conidiophores;
- chlamydospores: round spores with one or two cells in the middle of the hyphae (Identification sheet-COLEAD, 2021).

SYMPTOMS

LEAVES	— Leaf curvature; — The leaves are centred and upright; — Gummy accumulation at the base of affected leaves (if the plant is uprooted); — Leaf rot; — Leaf chlorosis;
STEM	— Necrosis from the bottom to the top of the stem; — Release of a characteristic rancid oil odour; — Stem curvature; — The stem shrinks.
FRUIT	— The surface of the eyes is more coloured than that of eyes of neighbouring fruit; — Exudation of hyaline gum; — Development of large translucent beige to brown patches; — Lesion and brown discolouration of the fruit; — Rotting of the fruit skin; — Natural cracks on fruit (Ibrahim *et al.*, 2016).
OFFSHOOTS	— Small brown necroses appear near their point of insertion on the peduncle; — Formation of gummy droplets.

Figure 89 — Symptoms of leaf rot

Figure 90 — *F. oxysporum* damage on the stem of a pineapple plant (necrosis of the lower stem)

Figure 91 — Symptoms of *F. oxysporum* on fruit

Figure 92 — Symptoms of *F. oxysporum* on pineapple offshoots

DAMAGE

- Decline in productivity;
- Death of the offshoot.

IMPACT ON YIELD

Fusarium disease can cause fruit yield losses of up to 80% (Pires De Matos, 2019). For example, in Brazil, pineapple fruit yield losses due to *Fusarium guttiforme* have been estimated at around 30-40% (Carnielli-Queiroz *et al.*, 2019).

MAIN PARTS AFFECTED

- Fruit
- Stem
- Leaf
- Offshoot

VEGETATIVE STAGES AFFECTED

- Vegetative growth
- Fruiting

QUARANTINE PEST

- The *Fusarium* are widely distributed in the world under various species.

FAVOURABLE CONDITIONS

In general, the ideal conditions for the disease to develop are high relative humidity and rainfall during the flowering phase. The temperature must be between 15ºC and 25ºC (Goes, 2005; Matos *et al.*, 2000; Pires De Matos, 2019 ; Queiroga *et al.*, 2024).

FAVOURABLE ENVIRONMENT

- Shading;
- Agar medium;
- Acidic pH environment (2 to 3);
- The presence of root-knot nematodes.

LIFE CYCLE

INOCULUM SOURCES

The sources of inoculum are infested planting material and insects.

INFECTION

Infections start from the inflorescence to fruit formation and occur mainly via wounds caused by insects, in particular the pineapple fruit caterpillar (*Thecla basilides*) and via infected planting material (Chand *et al.,* 2021). On contact with the host, the chlamydospores germinate and the young filaments penetrate the roots. The mycelium branches out and colonises all the neighbouring cells. Mycelial hyphae spread within cells by colonising the cortex and xylem vessels in the stem via micro-conidia that are easily carried by the sap to all parts of the plant.

DEVELOPMENT OR SPORULATION

Fruiting bodies called sporodochia form on the leaf surface and produce macro-conidia, which in turn contaminate other plants when carried by wind or insects (Identification sheet-COLEAD, 2021).

SPREAD

Fungi penetrate the plant through wounds, resulting from cracks and fissures in the plant's normal growth process or caused by the action of biotic or abiotic agents. Pathogen dispersal is by wind, water and insects such as *Aphis mellifera*, *Bitoma sp.*, *Bombus sp. Lagria villosa*, *Libindus dichrovus, Pollistes sp.* and *Trigona spinipes* (bee) (Goes, 2005; Matos, 2003; Sapak *et al.*, 2021).

MONITORING

— The plantation should be inspected as a whole, as its symptoms due to *Fusarium* can easily be confused with those of root rot caused by *Phytopthora.*

CROP CONTROL

PRE-PLANTING STAGE

- Destruction of crop residues to prevent the emergence of structures that are resistant to pathogens, such as chlamydospores, which can remain in the soil for a long time.

PLANTING STAGE

- The use of disease-free planting material;
- The use of resistant pineapple cultivars, such as "BRS Imperial" (Viana *et al.*, 2020).

VEGETATIVE STAGE

- Eradication or removal of infected plants during crop development.

BIO-CONTROL

PRE-PLANTING STAGE/VEGETATIVE STAGE

- The use of bio-control agents such as *Trichoderma spp.* during the soil preparation phase or in the first few months of planting reduces the incidence of *Fusarium* in the crop.

REPRODUCTIVE STAGE (FRUITING)

- Using bacteria such as *Bacillus subtilis* GA1, *Pseudomonas fluorescens* F19 and *Pseudomonas fluorescens* CI reduces post-harvest losses of pineapple fruit due to fungal contaminants

CHEMICAL CONTROL

REPRODUCTIVE STAGE

- The use of chemical fungicides remains the main method of controlling the disease on many pineapple farms. But the sporadic nature of the disease makes chemical control impractical and uneconomical.
- Products should be applied at flower induction and three weeks after flower induction to reduce disease.

Captan, fosetyl-aluminium and ascorbic acid may be used, subject to approval in the countries of use and compliance with current standards (maximum residue levels MRLs) in ACP countries.

N.B.

- These products can be toxic. Contact your plant protection product supplier to find the appropriate commercial product and to find out the conditions of use (method and dose of application) best suited to your specific situation, in compliance with the legislation of your country.
- Please note that these products are for guidance only and that regulations may change. To find out more about the list of approved products, please consult the following links.

When using PPPs, always take account of local approval and maximum residue limits for target markets. In view of changing regulations and phytosanitary standards governing the use of plant protection products, including changes to European Union (EU) and Codex Alimentarius maximum residue limits (MRLs), COLEAD has created a crop protection database (e-GAP), accessible here. The database provides up-to-date information on Good Agricultural Practice (GAP), notably extracted from COLEAD's crop protection product (PPP) field trials, data from PPP manufacturers and scientific literature. Additional updated information on Maximum Residue Limits (MRLs) in various target markets can be accessed via the FAO Pesticide Registration Toolkit.

OTHER CONTROL METHODS

VEGETATIVE STAGE

- Use essential oils such as:
- Thyme oil (*Thymus vulgaris*) to control fusariosis (Vilaplana *et al.*, 2018; Valencia-Chamorro *et al.*, 2021).
- Garlic extract: grate 4 garlic bulbs into a small quantity of vegetable oil, leave to soak overnight, make up to 2 litres with water, filter and add 2 teaspoons of hand soap.

12.2.5. FRUITLET CORE ROT, EYE ROT OR BLACK SPOT

SUMMARY

Fruitlet core rot, eye rot or black spot is caused by *Penicillium funiculosum*. Infected fruit becomes unfit for consumption.

PATHOGENS RESPONSIBLE

— *Penicillium funiculosum* (major agent)
— *Fusarium* spp. (major agent)

DESCRIPTION/IDENTIFICATION

SYMPTOMS

FRUIT	
	— Presence of brown to black spots on the eye tissue of the fruit (Barral *et al.*, 2020); — The surface of affected eyes tends to become depressed, turning yellow-orange more quickly than neighbouring healthy eyes and showing signs of senescence when the fruit is harvested; — The number of eyes affected per fruit is high; — Change in colour of ovarian tissue in cross-section; — Very fine transverse cracks on the sepals; — Inflorescences are shiny at the end of flowering; — Browning of the centre of fruit, starting below the floral cavity and sometimes extending to the core (Chand *et al.*, 2021).

Figure 93 — Fruit black spot symptoms caused by *Fusarium spp.*
Source: Cano Reinoso *et al.*, 2021

DAMAGE

- Economic impact for processing plants;
- Commercial impact.

Impact on yield: Fruit yield losses due to the incidence of fruitlet core rot in pineapple fields have been estimated at around 58% in French Guiana (Rouffiange, 1993).

MAIN PARTS AFFECTED

- Fruit

VEGETATIVE STAGES AFFECTED

- Flowering
- Fruiting

QUARANTINE PEST

The pathogens responsible for fruitlet core rot are present in all pineapple-producing countries.

FAVOURABLE CONDITIONS

PERIODS

- Cool weather with temperatures ranging from 16 to 21°C for 6 weeks after the fruiting induction treatment favours the incidence of fruitlet core rot caused by *Penicillium funiculosum*.
- Warm weather favours infection by *Fusarium* spp.

LIFE CYCLE

INOCULUM SOURCES

The Steneotarsonemus pineapple mite is the vector of pathogens responsible for fruitlet core rot.

INFECTION

Open flowers are the main sites of infection; however, pathogens can also enter host tissues through wounds on the fruit surface. *Penicillium funiculosum* infects developing fruit at some stage between initiation and an open flower. Infection is favoured by cool temperatures (16-20°C) for five weeks after flower initiation, during which time the fungus accumulates in the hairs of leaves damaged by mites. Similar cool temperatures are required for infection around 10 to 15 weeks after flower induction. However the *Fusarium moniliforme* enters the fruit through open flowers or wound sites.

DEVELOPMENT OR SPORULATION

The course of the disease depends on the period of penetration of the pathogens. Early penetration (just after flowering) is the most effective. The greatest increase in black spots was obtained by artificial infestations (without wounding) of spores of *P. funiculosum* and *Fusarium* spp. between 1 and 7 weeks after the flower induction treatment.

CROP CONTROL

For crop control of *P. funiculosum* and *Fusarium* spp, it is recommended to:

PLANTING STAGE

- Avoid cultivars in the Queen and Perolera groups, which are more sensitive.

REPRODUCTIVE STAGE (FRUITING)

- Use a net to protect pineapple fruit from insects.

BIO-CONTROL

REPRODUCTIVE STAGE (FRUITING)

- Using bacteria such as *Bacillus subtilis* GA1, *Pseudomonas fluorescens* F19 and *Pseudomonas fluorescens* CI reduces post-harvest losses of pineapple fruit due to fungal pathogens.

CONTROL USING BIOPESTICIDES

VEGETATIVE STAGE

Use essential oils such as:

- Eucalyptus oil, as well as *Acalypha wilkensiana* and *Syzygium aromaticum* extraction oils for disease control (Adewuyi-Samuel *et al.*, 2019).

CHEMICAL CONTROL

REPRODUCTIVE STAGE

- Using chemical fungicides remains the main method of controlling the disease on many pineapple farms. But the sporadic nature of the disease makes chemical control impractical and uneconomical. However, it is recommended to use fungicides that include one of the registered substances or active ingredients.
- Apply directly to the opening in the terminal leaves created by the emergence of the inflorescence.

Fosetyl, captan and ascorbic acid may be used, subject to their approval in the countries of use and compliance with current standards (maximum residue levels MRLs) in ACP countries.

N.B.

- These products can be toxic. Contact your plant protection product supplier to find the appropriate commercial product and to find out the conditions of use (method and dose of application) best suited to your specific situation, in compliance with the legislation of your country.
- Please note that these products are for guidance only and that regulations may change. To find out more about the list of approved products, please consult the following links.
- When using PPPs, always take account of local approval and maximum residue limits for target markets. In view of changing regulations and phytosanitary standards governing the use of plant protection products, including changes to European Union (EU) and Codex Alimentarius maximum residue limits (MRLs), COLEAD has created a crop protection database (e-GAP), accessible here. The database provides up-to-date information on Good Agricultural Practice (GAP), notably extracted from COLEAD's crop protection product (PPP) field trials, data from PPP manufacturers and scientific literature. Additional updated information on Maximum Residue Limits (MRLs) in various target markets can be accessed via the FAO Pesticide Registration Toolkit.

12.2.6. FRUIT ROT BY YEAST

SUMMARY

Yeast disease in pineapples is caused by several species of yeast such as *Saccharomyces* spp., *Hanseniaspora valbyensis* and *Candida* spp. It is commonly found in ripe fruit and the pathogen spreads easily in overripe or damaged fruit. The yeast penetrates through wounds in the fruit and the flesh becomes increasingly soft and yellow, losing its uniformity due to the gas bubbles produced by fermentation.

PATHOGENS RESPONSIBLE

- *Saccharomyce spp.* (major agent)
- *Hanseniaspora valbyensis* (minor agent)
- *Candida spp.* (minor agent)

DESCRIPTION/IDENTIFICATION

PATHOGENS

The *Saccharomyces* are microscopic fungi composed of single oval cells that reproduce by budding and are capable of transforming the sugar in pineapple fruit into alcohol and carbon dioxide (Chand *et al.*, 2021).

SYMPTOMS

FRUIT	
	— Foaming exudations of a viscous liquid through cracks or wounds in the pineapple skin; — Gradual brown or olive-green discolouration of the fruit skin; — Releases an odour of alcoholic fermentation; — The flesh of the fruit becomes spongy; — Bright yellow discolouration of the rotting flesh inside the fruit; — Development of large gas cavity (Chand *et al.*, 2021; Sapak *et al.*, 2021).

Figure 94 — Fermentation by yeasts (*Saccharomyces spp.*)

MAIN PARTS AFFECTED

— Fruit

VEGETATIVE STAGES AFFECTED

— Fruiting
— Harvest (pre or post)

QUARANTINE PEST

— Fruit rot by yeast or "Yeasty rot" is a disease that is widespread throughout the world.

FAVOURABLE CONDITIONS

PERIODS

— Fruit rot by yeast occurs mainly during spring in overripe or damaged fruit (Sapak *et al.*, 2021).

CROP CONTROL

HARVEST STAGE

- Limiting damage or injury to fruit skin caused by insect pests can reduce the incidence of disease on farms.
- Protect ripening fruit in frost-prone areas by covering young developing fruit with paper bags.
- Any fruit with cracks situated between young fruit should be picked at the earliest stages of fruit maturity to minimise losses (Chand *et al.*, 2021; Sapak *et al.*, 2021).

BIO-CONTROL

REPRODUCTIVE STAGE (FRUITING)

- Using bacteria such as *Bacillus subtilis* GA1, *Pseudomonas fluorescens* F19 and *Pseudomonas fluorescens* CI reduces post-harvest losses of pineapple fruit due to fungal contaminants

CHEMICAL CONTROL

REPRODUCTIVE STAGE

- Use fungicides that include one of the substances or active ingredients approved under the phytosanitary regulations and standards governing the use of plant protection products in each country.
- Apply directly to the opening in the terminal leaves created by the emergence of the inflorescence.

Fosetyl, captan or ascorbic acid may be used, subject to their approval in the countries of use and compliance with the standards in force (maximum residue levels MRLs) in the ACP countries and the target market.

N.B.

- These products can be toxic. Contact your plant protection product supplier to find the appropriate commercial product and to find out the conditions of use (method and dose of application) best suited to your specific situation, in compliance with the legislation of your country.
- Please note that these products are for guidance only and that regulations may change. To find out more about the list of approved products, please consult the following links.
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OTHER CONTROL METHODS

VEGETATIVE STAGE

- Garlic: grate 4 garlic bulbs into a small quantity of vegetable oil, leave to soak overnight, make up to 2 litres with water, filter and add 2 teaspoons of hand soap.

12.3. MAIN BACTERIAL DISEASES

12.3.1. PINK DISEASE

SUMMARY

Pink disease is a disease caused by the bacterial agents *Tatumella morbirosei* (formerly known as *Pantoea citrea*) and *Tatumella ptyseos*. It is a very common disease in Australia, Hawaii, Mexico, the Philippines, South Africa and Taiwan. The pineapple pulp turns pink in colour.

PATHOGENS RESPONSIBLE

- *Tatumella morbirosei* (formerly *Pantoea citrea*) (major agent)
- *Tatumella ptyseos* (major agent)

DESCRIPTION/IDENTIFICATION

SYMPTOMS

FRUIT	— Pink colouration of raw flesh (after slicing) (Chand *et al.*, 2021); — Pink to brown or reddish colouration when fruit, pulp or juice is cooked (Cha *et al.*, 1997; Marín-Cevada *et al.*, 2010); — Pronounced browning of raw slices of flesh during sterilisation of canned fruit (Chand *et al.*, 2021); — Release of an aromatic odour of ripe melon (Chand *et al.*, 2021); — Low Brix (soluble sugar content) (Chand *et al.*, 2021).

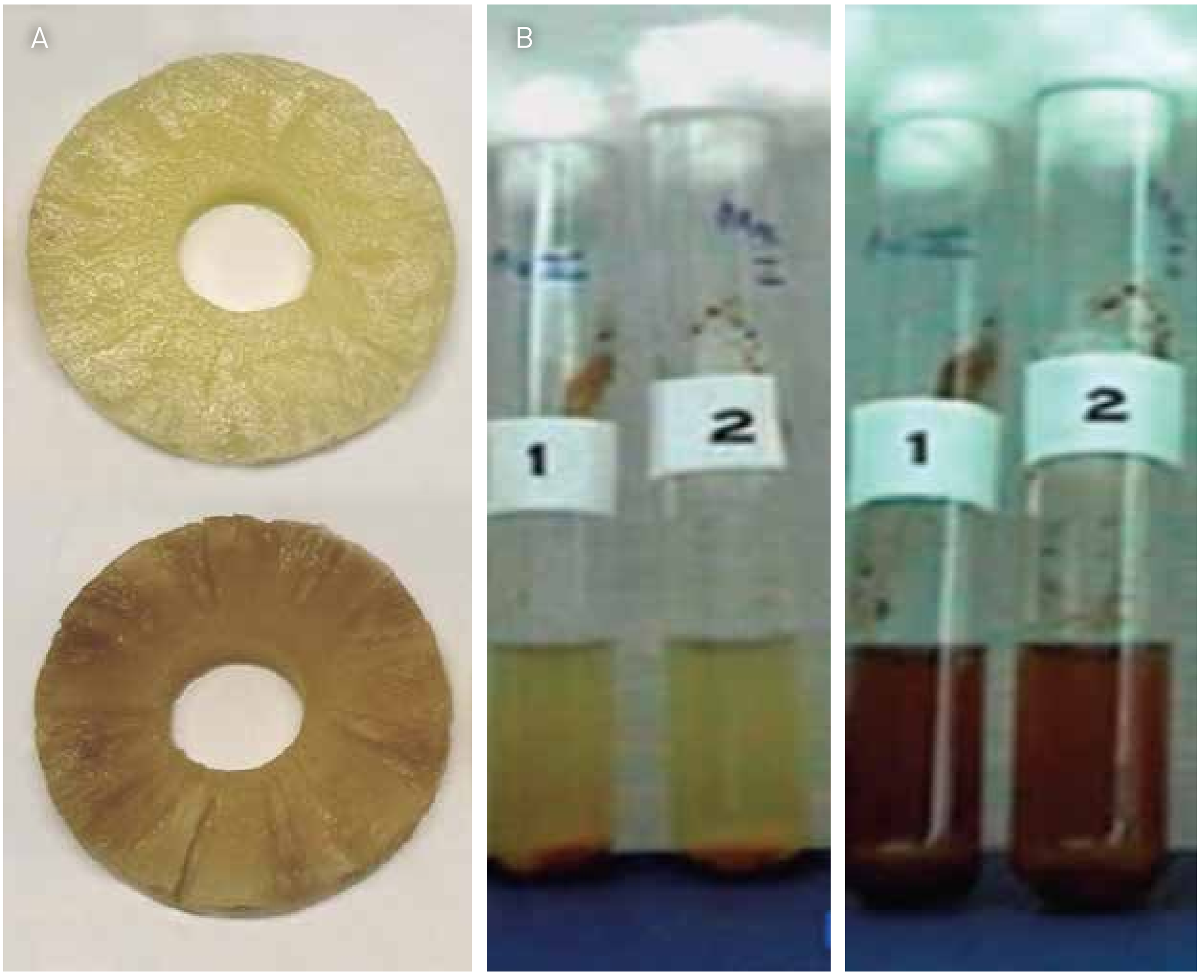

Figure 95 — Diagnostic test for pink disease by heating a slice (a) and pineapple juice infected with 1. *Pantoea citrea*; 2. *Tatumelle ptyseos* (b)
Source: Marín -Cevada *et al.*, 2010; Marín-Cevada *et* Fuentes-Ramírez, 2016

DAMAGE

— Economic impact for canning manufacturers.
— Quality of processed pineapple declines

IMPACT ON YIELD

Between 50 and 90% of fruit is affected by pink pineapple disease in winter.

MAIN PARTS OF THE CROP AFFECTED

— Fruit

AFFECTED CROP STAGES

— Fruiting

FAVOURABLE CONDITIONS

PERIODS

- The first rains come after a long dry season;
- Cool and wet seasons;
- Spring (September - October)

LIFE CYCLE

INOCULUM SOURCES

Insects and mites

INFECTION

The bacterium infects the fruit through the open flower during cool periods.

DEVELOPMENT OR SPORULATION

This disease only occurs sporadically when the fruit develops in cool, damp conditions.

SPREAD

Pathogenic bacteria are spread by insects and mites.

CROP CONTROL

PLANTING STAGE

- Use resistant varieties such as Smooth Cayenne.

CHEMICAL CONTROL

REPRODUCTIVE STAGE

- Use bactericides that include one of the substances or active ingredients approved under the phytosanitary regulations and standards governing the use of plant protection products in each country.
- Apply directly to the opening in the terminal leaves created by the emergence of the inflorescence.

N.B.

- Plant protection products (PPPs) can be toxic. Contact your plant protection product supplier to find the appropriate commercial product and to find out about the conditions of use (method and dose of application) best suited to your specific situation, in compliance with the legislation of your country.
- Please note that these products are for guidance only and that regulations may change. To find out more about the list of approved products, please consult the following links.
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12.3.2. BACTERIAL FRUIT HEART ROT AND FRUIT COLLAPSE

SUMMARY

Bacterial fruit heart rot and fruit collapse are diseases caused by the bacteria *Erwinia chrysanthemi* and *Dickeya zeae* syn. Affected pineapple plants develop watery leaf lesions resembling blisters and soft rot of ripe fruit.

PATHOGENS RESPONSIBLE

- *Dickeya zeae* syn. (major agent)
- *Erwinia chrysanthemi* (major agent)

DESCRIPTION/IDENTIFICATION

Pathogenic agents: The pathogen *Erwinia chrysanthemi* is a virulent bacterium from the Enterobacteriaceae family. The pathogen *Erwinia chrysanthemi* belongs to the latter group and is considered the most commercially important soft rot pathogen (Yogendra Singh and Purohit, 2017; Nor *et al.*, 2019).

Two strains of *Erwinia chrysanthemi* from pineapple host plants have been identified as strains of *Dickeya* zeae and strains of *Dickeya* dadantii (Ramachandran *et al.*, 2015).

LEAVES

- Presence of aqueous (liquid-soaked) lesions on the white basal sections of the leaves, which may extend (as the plant grows) into the green part of the leaf (Pires De Matos, 2019; Sapak *et al.*, 2021);
- Leaf discolouration from olive-green to brown (Chand *et al.*, 2021; Sidik *et* Sapak, 2021);
- Yellowing of leaves and drying out of their apices (Queiroga *et al.*, 2023);
- Swelling of the leaves due to a foul-smelling gas formed when the leaf tissue is fermented by bacteria;
- Heart or central stem tissue rot.

Figure 96 — Symptoms of bacterial heart rot. (a) and (b) Aqueous lesions (soaked in liquid) on the white basal sections of the leaf, progressing towards the green part of the leaf;
(c) Swelling of leaves due to the formation of a malodorous gas;
(d) Leaf discolouration from olive-green to brown
Source: Young *et al.*, 2022

SYMPTOMS (FRUIT COLLAPSE)

FRUIT

- Olive-green colouration of the fruit skin as it approaches ripeness (Pires De Matos, 2019; Chand *et al.*, 2021; Sapak *et al.*, 2021);
- Flow of abundant, frothy exudate (white liquid) from the cracks between the eyes of the fruit (Chand *et al.*, 2021);
- Release of gas bubbles due to fermentation caused by bacteria (Pires De Matos, 2019; Sapak *et al.*, 2021);
- Presence of rotten cavities in slices of infested fruit (Sapak *et al.*, 2021);
- Strong acidic odour.

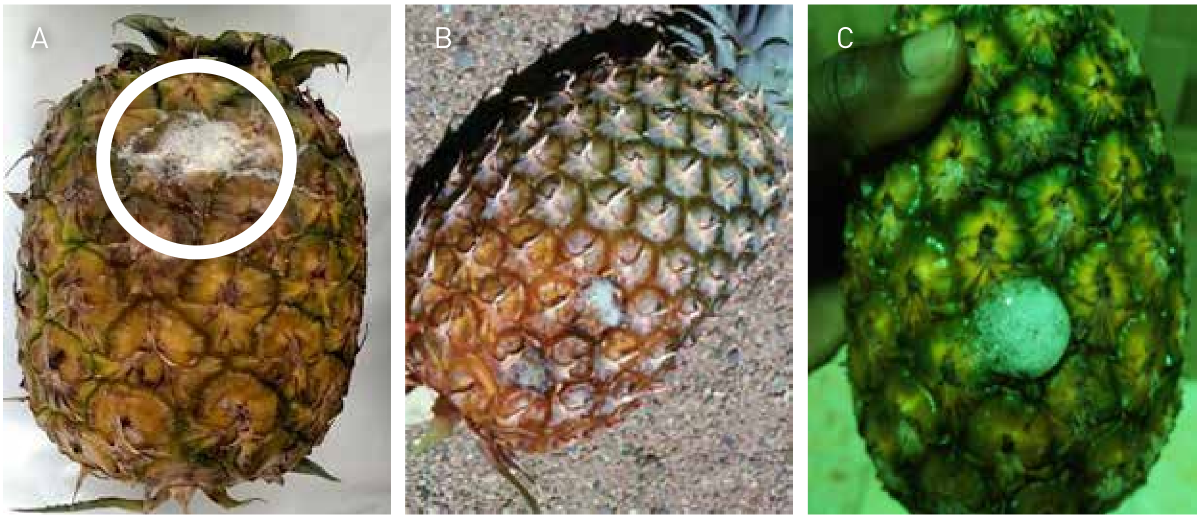

Figure 97 — Symptoms of pineapple fruit collapse disease after harvest.
(a) Abundant, frothy exudate (white liquid) from the cracks between the eyes of the fruit;
(b) Olive-green colouration of the fruit skin; (c) Release of gas bubbles
Source: Cano Reinoso *et al.*, 2021

DAMAGE

- Destruction of the entire plant once infected;
- Pathogens spread to other healthy plants.

IMPACT ON YIELD

Fruit yield losses due to bacterial heart rot alone were of the order of 30% in Malaysia (Lim, 1985). Recently, the incidence of both diseases in plantations has caused yield losses of up to 40% in Malaysia (Fisheries and Forestry, 2012).

MAIN PARTS OF THE CROP AFFECTED

- Leaf
- Stem
- Fruit

AFFECTED CROP STAGES

— Vegetative growth
— Fruiting

QUARANTINE PEST

— Bacterial heart rot and pineapple fruit collapse disease are recorded in pineapple plantations in Brazil, Costa Rica, Hawaii, Malaysia and the Philippines.
— *Erwinia chrysanthemi* and *Dickeya zeae* syn are widespread species in both tropical and subtropical regions.

FAVOURABLE CONDITIONS

— Environmental factors such as high humidity, warm temperatures (25 to 30°C) and rain considerably enhance the development of bacteria (Sapak *et al.*, 2021).

LIFE CYCLE

Sources of inoculum: Debris from infested plants, contaminated soil and irrigation water are sources of inoculum for two bacteria (Pires De Matos, 2019). Infested juice, on the other hand, is a secondary source of infection for the plant itself and nearby plants (Sapak *et al.*, 2021). Planting material is less of a major source of the bacteria since bacteria do not survive long on leaf surfaces (Pires De Matos, 2019).

INFECTION

After entering the plant, the bacteria multiply, moving into the vascular system and stomata and causing damage to several parts of the plant. Fruit infection occurs through flowers when ants or other insects transfer infected liquid or sap from infected plants to healthy plants. Infected fruit are generally asymptomatic until 2 to 3 weeks before ripening.

DEVELOPMENT OR SPORULATION

Once the bacterium enters the ovary, it remains latent for up to 2-3 weeks before maturing. At this stage, sugar levels increase while polyphenol oxidase levels decrease (Pires De Matos, 2019). Bacterial heart rot, on the other hand, takes 1 to 2 weeks to develop after the first symptoms appear under optimum conditions.

SPREAD

Ants, the acid beetle, the pineapple tarsonemid mite and flies are the main vectors for disseminating the bacterium. Environmental factors such as wind as well as wind-blown rain also contribute to the transmission of the disease (Pires De Matos, 2019). It is highly mobile in water. It is therefore easily transmitted by water, soil, dew, insects or workers. It develops more frequently in crops with poor drainage systems, or during rainy periods and those when plant growth is most active (Queiroga *et al.*, 2023).

MONITORING

- Inspect pineapple crops regularly for symptoms of bacterial core rot or fruit collapse.
- Insects must be properly controlled to prevent their spread (Queiroga *et al.*, 2023).

CROP CONTROL

PRE-PLANTING STAGE

- Use certified disease-free offshoots to start new crops.

PLANTING STAGE

- Use resistant varieties rather than relatively susceptible and sensitive varieties;
- Keep farm equipment and waste spreading equipment clean;
- Avoid sharing machinery and equipment with other growers.

VEGETATIVE STAGE

- Remove and destroy infected plants in the plantation immediately, if any plants show symptoms of pineapple wilt or heart rot.
- Avoid water stress. Plants are more susceptible to rot when they are subjected to water stress in hot, dry conditions followed by heavy rain.
- Improve drainage in plantations where water collects after rain.

BIO-CONTROL

VEGETATIVE STAGE

- Use bio-control agents such as *Trichoderma asperellum* (Ishak *et al.*, 2021).
- Use *Bacillus cereus* which has a good potential for inhibiting the growth of bacterial pathogens.

CHEMICAL CONTROL

VEGETATIVE STAGE

- Use bactericides that include one of the substances or active ingredients approved under the phytosanitary regulations and standards governing the use of plant protection products in each country.
- Foliar application of bactericides suppresses pathogens and reduces the severity of both diseases on pineapple plants (Sidek and Sapak, 2021).
- Insecticides and acaricides are also used to combat the main vectors of the bacteria (ants and mites).
- According to Queiroga *et al.* (2023), there is no all-round effective chemical control, which is why its management is mainly preventive.

N.B.

- Plant protection products (PPPs) can be toxic. Contact your plant protection product supplier to find the appropriate commercial product and to find out about the conditions of use (method and dose of application) best suited to your specific situation, in compliance with the legislation of your country.
- Please note that these products are for guidance only and that regulations may change. To find out more about the list of approved products, please consult the following links.
- When using PPPs, always take account of local approval and maximum residue limits for target markets. In view of changing regulations and phytosanitary standards governing the use of plant protection products, including changes to European Union (EU) and Codex Alimentarius maximum residue limits (MRLs), COLEAD has created a crop protection database (e-GAP), accessible here. The database provides up-to-date information on Good Agricultural Practice (GAP), notably extracted from COLEAD's crop protection product (PPP) field trials, data from PPP manufacturers and scientific literature. Additional updated information on Maximum Residue Limits (MRLs) in various target markets can be accessed via the FAO Pesticide Registration Toolkit.

OTHER CONTROL METHODS

VEGETATIVE STAGE

- Care should be taken when handling plants, because if they are injured, bacteria can penetrate more easily. In this case, the use of copper helps to protect and heal wounds.
- Products based on copper sulphate, quaternary ammonium and iodine can be used.

12.3.3. PINEAPPLE MARBLING DISEASE

SUMMARY

Marbling is a minor disease that occurs sporadically. The disease is only serious in countries where pineapple fruit ripens in tropical conditions. Infected fruit show no external symptoms, but inside the flesh is reddish-brown and grainy.

PATHOGENS RESPONSIBLE

- *Erwinia pineapple*
- *Pontea ananatis*
- *Acetobacter spp.*

DESCRIPTION/IDENTIFICATION

PATHOGENS

Erwinia is a very common bacterium in our environment and is not a disease that produces problematic toxins.

SYMPTOMS

FRUIT	
	— Yellow to red or very dark brown discolouration of the fruit flesh after cutting; — Infected tissues develop a granular texture with a woody consistency; — The fruits are low in acidity and sugar (Chand *et al.*, 2021).

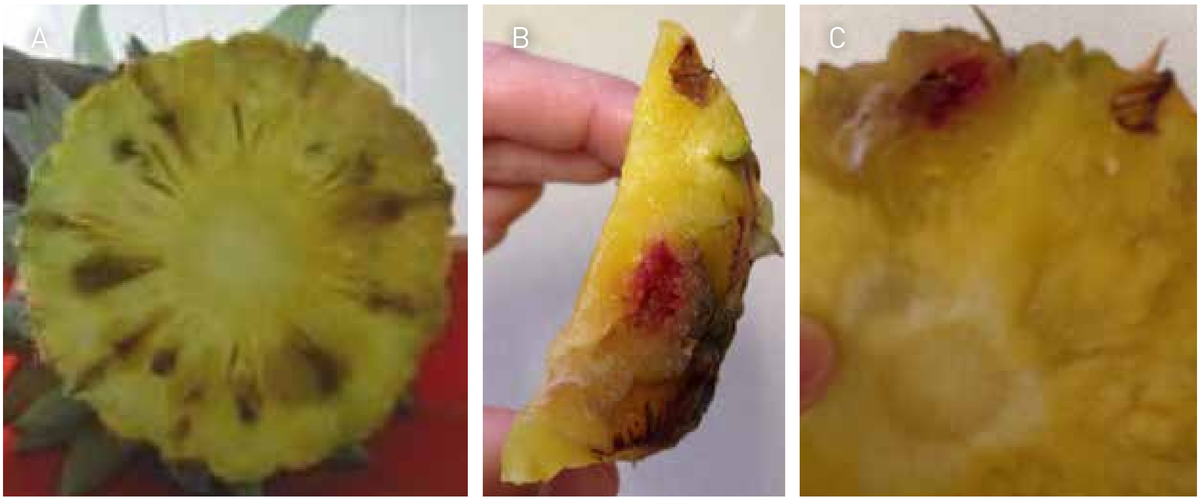

Figure 98 — Overview of the symptoms of marbling disease in pineapple flesh.
(a) Yellow to very dark brown discolouration of the flesh;
(b) and (c) Development of red spot caused by *Erwinia herbicola* on pineapple flesh
Source: Joy and Sindhu, 2012; https://ask2.extension.org/kb/faq.php?id=259383

MAIN PARTS OF THE CROP AFFECTED

- Fruit

AFFECTED CROP STAGES

- Flowering
- Fruiting

FAVOURABLE CONDITIONS

- Hot and humid seasons.

LIFE CYCLE

INFECTION

The bacteria penetrate through the open flower and the natural growth cracks on the surface of the fruit.

CROP CONTROL

PLANTING STAGE

- The use of the Smooth Cayenne pineapple variety, which appears to be moderately resistant to the disease.

BIO-CONTROL

VEGETATIVE STAGE

- Use *Bacillus gordonae:* it reduces the incidence of pathogens in combination with insecticides.

CHEMICAL CONTROL

REPRODUCTIVE STAGE

- Use bactericides (thymol) approved in accordance with the phytosanitary regulations and standards governing the use of plant protection products in each country.

N.B.

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12.4. MAIN VIRAL DISEASES

12.4.1. YELLOW SPOT

SUMMARY

Yellow spot on the leaves is caused by a virus from various weeds transmitted to cultivated plants by small flying insects (called thrips); it particularly affects the fruit.

PATHOGENS RESPONSIBLE

- *Thrips tabaci* (Linderman)
- *Frankliniella schultzei* (Trybom)
- *Frankliniella occidentalis* (Pergete)
- *Frankliniella fusca* (Hinds),

Figure 99 — *Frankliniella occidentalis*
Source: https://infonet-biovision.org/PlantHealth/Pests/Thrips

DESCRIPTION/IDENTIFICATION

PATHOGENS

Thrips are small insects measuring 1 to 1.5 mm. They reproduce entirely parthenogenetically; males are very rare. The female lays around 30 to 80 whitish eggs in small cuts she has made in the plant tissue using her ovipositor. The full thrips cycle can be completed in 12 days in warm climates and there are generally three to five generations per year.

SYMPTOMS

LEAF	— Small, round, yellowish spots (2 to 5 mm) on the upper surface of the plant's leaves; — Formation of yellow coloured spots which turn brown and soon become necrotic (Chand *et al.*, 2021). — The leaves curl up, turn brown and fall off.
FRUIT	— Progressive necrosis of the upper part of the fruit; — Complete drying of the crown; — Fruit curvature; — Absence or non-formation of a crown on the fruit; — Development of a black, dry cavity on the side of the fruit due to the death of one or more eyes (Chand *et al.*, 2021).

Figure 100 — Symptoms of yellow spot: Yellow discolouration of the leaves with brown spots
Source: Joy and Sindhu, 2012

Figure 101 — Symptoms of yellow spot: Development of a black, dry cavity on the side of the fruit due to the death of one or more eyes
Source: Joy and Sindhu, 2012

DAMAGE

- The plant dies;
- The fruit dies from top to bottom.

IMPACT ON YIELD

Significant harvest losses.

MAIN PARTS OF THE CROP AFFECTED

- Leaf
- Fruit
- Crown

AFFECTED CROP STAGES

- Growth
- Fruiting

QUARANTINE PEST

- It is most commonly found in Hawaii, the Philippines, Australia and South Africa, where the vast majority of pineapples are grown from the crown. *Thrips tabaci* is thought to be of Mediterranean origin, but is now found all over the world.

LIFE CYCLE

The life cycle takes around two to three weeks in warm conditions.

INOCULUM SOURCES

Infected pineapple plants.

INFECTION

In parasitic thrips species, the eggs are inserted into the plant tissue; they hatch after 5 to 10 days, and the larva goes through four successive stages lasting a total of 15 to 30 days. The larva acquires the virus by feeding on infested plants (it survives successive moults) and the resulting adult is capable of transmitting the disease. Infections occur through open flowers, causing large black cavities to develop on the fruit. On plants, infection occurs early in growth and the crowns of developing fruit are sometimes infected (Chand *et al.*, 2021).

EGGS

are very small, with a single egg measuring 0.25 mm long and 0.1 mm wide. They are white when freshly laid and turn pale yellow as they mature. The eggs are generally laid individually inside the plant tissue and are therefore not visible. Some thrips (for example *Haplothrips* spp) lay eggs singly or in clusters attached to the plant surface.

LARVAE

The first and second instar larvae are very small (0.5 to 1.2 mm), elongated, slender and vary in colour from pale yellow to orange or red depending on the species. They have piercing-sucking mouthparts. They look like a miniature version of adults but have no wings.

PRE-NYMPH AND PUPAE

These two or three stages are intermediate between the nymph and the adult. They have short wing buds but no functional wings. During these stages, thrips are inactive and do not feed, so they do not cause any damage to the plant. Pupation may occur on a plant or in the soil below, depending on the species.

ADULT

Thrips are small (usually 1 to 1.5 mm), slender and usually winged. The wings are long, narrow and edged with long hairs, and when at rest are tied along the body on the back. Their colour varies according to the species. Most species are black, brown or yellow.

MONITORING

- Monitor the crop regularly. Early detection of thrips is important in determining an appropriate control strategy. Thrips can be easily detected by shaking the leaves on a piece of white paper.

CROP CONTROL

VEGETATIVE STAGE

- Keep the plantation free of weeds;
- Avoid destroying old patches of weeds near young crown plantations or fields with developing fruit.

CHEMICAL CONTROL

VEGETATIVE STAGE

- Use insecticides approved in accordance with the phytosanitary regulations and standards governing the use of plant protection products in each country to control the vectors of the yellow spot virus.

N.B.

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from PPP manufacturers and scientific literature. Additional updated information on Maximum Residue Limits (MRLs) in various target markets can be accessed via the FAO Pesticide Registration Toolkit.

CONTROL USING BIOPESTICIDES

VEGETATIVE STAGE

- Garlic: grate 4 garlic bulbs into a small quantity of vegetable oil, leave to soak overnight, make up to 2 litres with water, filter and add 2 teaspoons of hand soap.
- Papaya leaves: we recommend stirring 1 kg of leaves into 1 litre of water, pressing them into a cloth and adding 4 litres of soap solution (100g of soap/25 litres of water).

12.4.2. WILT DISEASE

SUMMARY

Mealybug wilt disease is caused by *Ampelovirus* viruses transmitted by the insect pests *Dysmioccus brevipes* and *Dysmioccus neobrevipes* when they feed on young leaves.

PATHOGENS RESPONSIBLE

— *Ampelovirus spp.* (major agent)

DESCRIPTION/IDENTIFICATION

PATHOGENS

There are two species of virus in the genus *Ampelovirus*, which have been classified as subgroup I (named PMWaV-1) and subgroup II (named PMWaV-2) (Dey *et al.*, 2018). PMWaV-2 has a more complex RNA genome than PMWaV-1 and both viruses are the most commonly reported main strains responsible for wilt disease (Alvarez *et al.*, 2015).

SYMPTOMS

LEAVES	— Red discolouration of the leaves halfway up the plant; — Downward leaf-curl to the margin and leaf tip dies (Chand *et al.*, 2021); — Yellow discolouration of the inner leaves (Sapak *et al.*, 2021); — Browning of leaf tips (Dey *et al.*, 2018).
FRUIT	— The fruit is smaller (Chand *et al.*, 2021); — Malformed fruit (Sapak *et al.*, 2021).

Figure 102 — Visual example of the symptoms of Wilt disease in pineapples:
(a) Red discolouration of leaves; (b) Downward curling of leaves and yellow discolouration of inner leaves
Source: Field shot, 2021

DAMAGE

- The plant does not produce fruit or dies (Sapak *et al.*, 2021).

IMPACT ON YIELD

The impact of the disease on yield is around 35% of the yield of plants affected by wilt disease (Sether and Hu, 2002).

MAIN PARTS OF THE CROP AFFECTED

- Leaf
- Fruit

AFFECTED CROP STAGES

- Growth
- Fruiting

QUARANTINE PEST

- Wilt disease is present in pineapple crops throughout the world (Nyarko and Asare-Bediako, 2019; Massé *et al.*, 2021).

FAVOURABLE CONDITIONS

PERIODS

- Winter
- Wet season

LIFE CYCLE

SPREAD

The main dispersers of the pathogen are ants (*Pheidole megacephala*), which play a very important role in the dispersal of mealybugs in pineapple fields. The wind is a secondary agent (Pires De Matos, 2019; Chand *et al.*, 2021; Sapak *et al.*, 2021).

CROP CONTROL

PLANTING STAGE

- Use planting material from wilt-free areas or fields with low levels of wilt;
- The planting material must be immersed in hot water (50°C) for 30 min (Pires De Matos, 2019);
- Removal and destruction of infected plants showing wilting symptoms (Pires De Matos, 2019);
- Removal of old pineapple stumps;
- Destroying wilt-infected plants and pineapples after the first offshoot harvest and initiating fallow periods have all proved effective for the integrated management of MWP (Sapak *et al.*, 2021).

BIO-CONTROL

VEGETATIVE STAGE

- Use potential natural enemies such as *Lobodiplosis pseudococci* Felt (Diptera: Cecidomyiidae), *Nephus bilucernarius* Mulsant (Coleoptera: Coccinellidae), and *Anagyrus ananatis* Gahan (Hymenoptera: Encyridae) (Sapak *et al.*, 2021).

CHEMICAL CONTROL

PLANTING STAGE/VEGETATIVE STAGE

- When seedlings come from a plantation infested with mealybugs, they should be treated by immersion for 3 to 5 minutes in an insecticide-acaricide mixture using one of the effective products. Add a spreader sticker to the mixture so that it is evenly distributed and sticks to the surface of the plant. After soaking, the seedlings should be placed in paper or perforated plastic boxes so that the excess mixture returns to the solution. The plants are then spread out to dry.
- If at least one plant showing symptoms of wilting or a colony of mealybugs is detected in a plantation of up to five hectares, or at least two plants showing symptoms of wilting or colony(ies) of mealybugs in plantations of more than five hectares, localised chemical control (in clumps and adjacent plants) should be carried out, applying one of the insecticides listed. Continue monitoring and repeat treatment if necessary.

Use insecticides and acaricides approved in accordance with the phytosanitary regulations and standards governing the use of plant protection products in each country. Diazinon, deltamethrin and lambda-cyhalothrin may be used, subject to their approval in the countries of use and compliance with current standards (maximum residue levels MRLs) in ACP countries.

N.B.

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- Please note that these products are for guidance only and that regulations may change. To find out more about the list of approved products, please consult the following links.

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CONTROL USING BIOPESTICIDES

PLANTING STAGE

- Soak the offshoots in white oil or horticultural oil to rid the planting material of mealybugs.

OTHER CONTROL METHODS

VEGETATIVE STAGE

- Use ant traps to allow predators and parasitoids to control mealybugs naturally.
- Use baits such as Amdro® and other insect regulators to eliminate ant populations (Dey *et al.*, 2018).

12.5. KEY POINTS TO REMEMBER

The main pests and diseases affecting pineapple crops are shown in the table below:

Table 25 — Main species of pests or diseases and their stages in pineapple cultivation

PEST OR DISEASE SPECIES	PLANTING	ROOT SYSTEM EMISSION (1- 6 MAP)	VEGETATIVE GROWTH	FLOWERING	FRUITING	HARVEST	PRODUCTION OF OFFSHOOTS
Meloïdogyne javanica (root-knot nematodes)	0	+++	+++	+	+	+	+
Meloidogyne incognita (root-knot nematodes)	0	+++	+++	+	+	+	+
Pratylenchus brachyurus (lesion nematodes)	0	+++	+++	+	+	+	+
Rotylenchulus reniformis (reniform nematodes)	0	+++	+++	+	+	+	+
Hanseniella ivorensis (sucking insect)	0	+++	++	0	0	0	0
Scutigerella sakimurai (sucking insect)	0	+++	++	0	0	0	0
Hanseniella unguiculata (sucking insect)	0	+++	++	0	0	0	0
Dysmicoccus brevipes (biting-sucking insect)	+++	+++	+++	0	0	0	0
Dysmicoccus neobrevipes (biting-sucking insect)	0	0	0	0	+++	+++	+++
Diaspis bromeliae (biting-sucking insect)	0	0	+++	0	+++	0	0
Diaspis boisduvalii (biting-sucking insect)	0	0	+++	0	+++	0	0
Strymon megarus/ Thecla basilides (fruit borer)	0	0	0	++	+++	0	0
Steneotarsonemus pineapple (pineapple mites)	0	0	+++	+++	+++	0	0
Dolichotetranychus floridanus (pineapple mites)	0	0	+++	+++	+++	0	0
Phytophthora cinnamomi (Root rot fungus and Green fruit rot fungus)	0	0	+++	0	+++	0	0

PEST OR DISEASE SPECIES	PLANTING	ROOT SYSTEM EMISSION (1- 6 MAP)	VEGETATIVE GROWTH	FLOWERING	FRUITING	HARVEST	PRODUCTION OF OFFSHOOTS
Pythium arrhenomanes (Root rot fungus and Green fruit rot)	0	0	+++	0	+++	0	0
Phytophthora nicotianae (Heart rot or Top rot fungus)	0	0	+++	0	0	0	0
Thielaviopsis paradoxa (Butt rot or Base rot fungus, Black rot or Water blister fungus and White leaf spot fungus)	0	0	++	0	+++	+++	+++
Ceratocystis paradoxa (Butt rot or Base rot fungus, Black rot or Water blister fungus and White leaf spot fungus)	0	0	++	0	+++	+++	+++
Fusarium guttiforme (fusariosis)	0	0	+++	0	+++	+++	+++
Penicillium funiculosum (Fruit core rot, Eye rot or Black spot fungus)	0	0	0	0	+++	+++	0
Saccharomyce spp. (Fruit rot by yeast fungus)	0	0	0	0	0	+++	0
Tatumella morbirosei (Pink disease)	0	0	0	0	0	+++	0
Tatumella ptyseos (Pink disease)	0	0	0	0	0	+++	0
Dickeya zeae (Bacterial fruit heart rot and Fruit collapse)	0	0	++	0	0	+++	0
Erwinia chrysanthemi (Bacterial fruit heart rot and Fruit collapse)	0	0	++	0	0	+++	0
Erwinia pineapple (Pineapple marbling disease).	0	0	0	0	0	+++	0
Pontea ananatis (Pineapple marbling disease)	0	0	0	0	0	+++	0
Thrips tabaci (Yellow spot disease)	0	0	0	0	0	+++	0
Frankliniella schultzei (Yellow spot disease)	0	0	+++	0	0	+++	0
Frankliniella occidentalis (Yellow spot disease)	0	0	+++	0	0	+++	0
Ampelovirus spp. (Wilt disease)	0	+++	+++	0	0	0	0

13

PINEAPPLE HARVEST

13.1. PRE-HARVEST FRUIT CARE

Several operations are carried out before harvesting. These include protection against "sunburn", control of fruit-destroying insects and degreening with ethephon.

13.1.1. PROTECTING FRUIT AGAINST SUNBURN

"Sunburn" is caused by excessive localised heating due to the sun's rays. The phenomenon occurs mainly during periods of strong sunshine. A fruit that has "shed" or supported by a peduncle that is too long or by plants with a deficient leaf system is more exposed to "sunburn" (PIP/COLEAD, 2009; COLEAD, 2020). These phenomena lead to defects in pineapple fruit such as:

— discolouration of the fruit skin (straw yellow) (Figure 103a);
— burn marks on their skin (Figure 103b);
— increased translucency of the pulp.

Figure 103 — Fruit skin discolouration (a) and burn mark (b)
http://ephytia.inra.fr/fr/C/26556/Tropifruit-Coup-de-soleil

To avoid this, the fruit should be protected for 4 to 6 weeks before harvesting, when sunshine is intense. There are several techniques that can be used for this purpose (PIP/COLEAD, 2009; CIRAD, 2018; COLEAD, 2020):

- tie the leaves into a bundle above the fruit (Figure 104 and 105);
- lightly mulch the top of the fruit, but do not over-shade, as excessive shading increases the acidity of the fruit;
- fit shade cloths;
- install a protective net;
- place string along each row to draw the leaves back towards the inside of the row.

Figure 104 — Protecting fruit from sunburn:
Leaves bound to protect the fruit (a and b), straw deposited on the fruit (c and d)
https://www.shutterstock.com/fr/search/sun-protecting-pineapple?image_type=photo&page=4
https://www.shutterstock.com/fr/search/sun-protecting-pineapple?image_type=photo&page=2

Figure 105 — Protect fruit from sunburn using shade cloths (e and f), bonnets (g) and nets (h)
Source: Paull *et al.*, 2016 and CIRAD, 2018
https://www.shutterstock.com/fr/search/sun-protecting-pineapple?image_type=photo

13.1.2. CONTROL OF INSECT PESTS OF FRUIT

Some pests such as the beetle *Augosoma centaurus* (Figure 106); the stinking variegated grasshopper (*Zonocerus variegatus*), the main pineapple grasshopper pest, and crickets can damage pineapple fruit.

— *Augosoma centaurus* digs cavities in fruit and inflorescences and gnaws at the base of leaves, which becomes spongy;

— *Zonocerus variegatus* gnaws off the tips of the crown leaves, making the fruit unfit for export.

That is why it is imperative to clean the plots, surroundings and set traps to control these insect pests (PIP, 2009; Adabe *et al.*, 2016).

Figure 106 — Insect attack on pineapple fruit
Source: https://fr.haenselblatt.com/dealing-with-pineapple-problems

13.2. DEGREENING TREATMENT WITH ETHEPHON

This treatment consists of applying ethrel in order to group together the fruit harvest and homogenise the colouration without damaging the quality of the fruit (Figure 107). The aim is to remove the chlorophyll from the fruit's skin. The green colouring fades and is replaced by yellow/orange pigments in the fruit skin. Ethephon does not act on all the phenomena of ripening, but essentially on the colouration of the epidermis (CIRAD, 2020; COLEAD, 2020b). This treatment is not compulsory, but is carried out solely according to market requirements, in line with consumer expectations.

For optimum effectiveness, and to comply with European regulations on Maximum Residue Limits (MRLs), the treatment must incorporate the following factors:

— the stage of development/maturity of the fruit (generally estimated in degrees Brix). The ideal Brix is >12, generally around 130-135 days after the FIT in the dry season or 135-145 days in the rainy season);
— the size of the fruit (the volume of treatment will be reduced for small fruit);
— climatic conditions;
— the application method;
— the interval between application and harvest.

Degreening treatments are carried out 7 to 10 days before harvesting at the latest. As a localised application, a dose of 1.5 kg/ha of active ingredient, in 800 litres of water, at a rate of 15 ml per fruit (55,000 fruits treated) is applied 10 days before harvest.

N.B.

— Even light rainfall in the first few hours, i.e. within 8 hours of application, can wash away the product applied and greatly reduce or cancel its effectiveness. A second application is then necessary, but the risk of exceeding the maximum ethephon residue limit is increased if the 10-day ARfD is not respected.
— Rain 24 hours later has no impact on its effectiveness and considerably reduces residues, which are mainly present on the skin;
— The ethephon residue limit may be reached or exceeded in very dry conditions or on small fruit;
— Washing and brushing the fruit before packing reduces residues by almost 60%;
— Applying the product too early in relation to the stage of physiological ripeness of the fruit is also counter-productive, as it disconnects the relationship between colour and ripeness, an important criterion in the consumer's decision to buy.

Figure 107 — Ethephon treatment
Source: Daouda *et al.*, 2015

13.3. HARVEST PERIOD

The fruit is harvested at the "mid-maturity" stage, which corresponds to the yellowing of the lower quarter of the fruit. This ripeness is reached around 160 days after FIT, and between 145 and 174 days for extreme cases (Adabe *et al.*, 2016) (Figure 108).

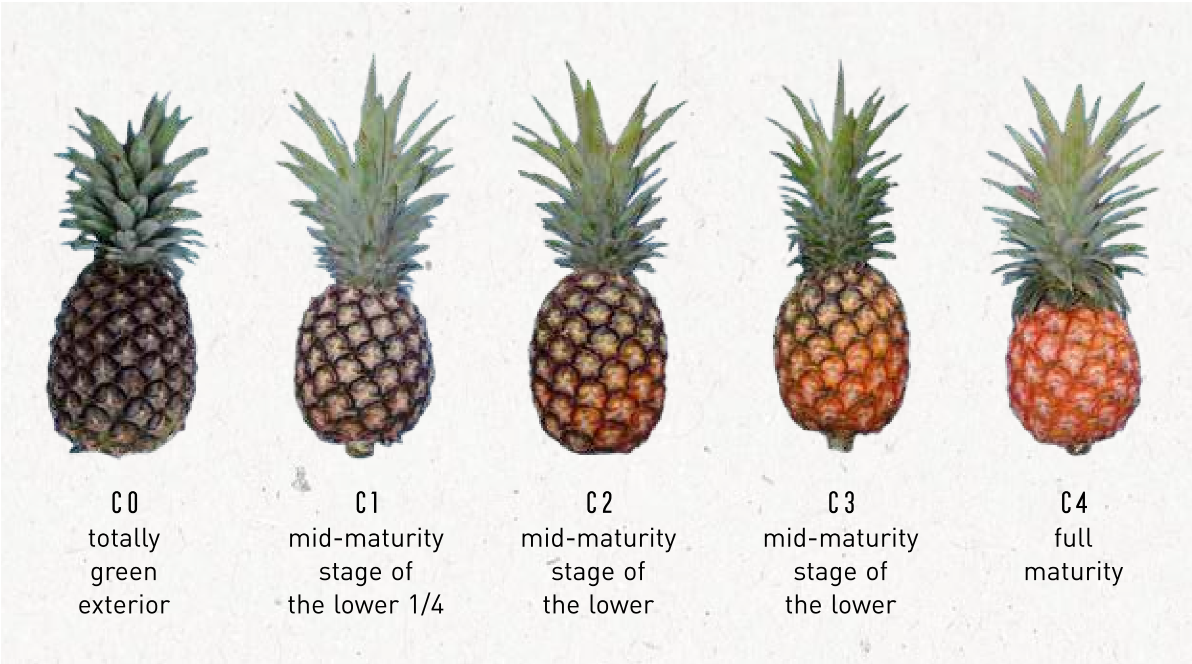

Figure 108 — Pineapple ripening stages
Source: UNECE explanatory brochure for the pineapple standard; Adabe *et al.*, 2016b

13.4. HARVESTING

Harvesting is usually done by hand. It is done by passing between the rows and cutting the fruiting peduncle using a sharp tool (Figure 109a and b). It can be done either once (on plots of uniform external colouration) or in two cuts, preferably spaced one or two days apart. It is advisable to take the following steps:

— cut off the peduncle with secateurs or a machete 10-15 cm from the base of the fruit;

— if necessary, cut off the crown to facilitate packaging and recover the plant material (this practice must be approved in advance by the customer);

— arrange the fruit in a staggered, horizontal position in a clean crate, avoiding overcrowding.

At the end of the rows, the fruit is placed in crates and transported quickly from the field to the packing station by vehicle or tricycle. The fruit is harvested and transported to the packing stations with the utmost care and in the shortest possible time. An antifungal treatment is often applied to the site where the peduncle has been cut to prevent possible mould growth (UNCTAD, 2016).

The harvesting process can also be mechanised. A specially adapted vehicle passes through the plots, the pickers follow a defined row, pick the fruit and place it on the towed conveyor, which transports the fruit to the edge of the plot (Figure 109c and d). They are then sent to packing stations or processing plants (Figure 109e and f) (UNCTAD, 2016).

Figure 109 — Pineapple harvesting techniques: hand harvesting (a and b); conveyor belt harvesting (c and d), mechanised harvesting (e and f)
https://www.shutterstock.com/fr/image-photo/farmer-harvesting-pineapple-farm-fruits-field-1668685699
https://www.chfusa.com/pineapples_process.htm

13.5. COMMERCIAL QUALITY

13.5.1. MINIMUM QUALITY CHARACTERISTICS

The minimum quality characteristics that pineapples must have after preparation and packing are defined by the CODEX Alimentarius standard for pineapples and UNECE standard FFV- 49, 2017.

PINEAPPLES MUST BE

— WHOLE, WITH OR WITHOUT THE CROWN

They must not show signs of any damage, injuries or cracks that could compromise the product (Figure 110a and b). The crown, if present, can be reduced or trimmed (Figure 110c and d).

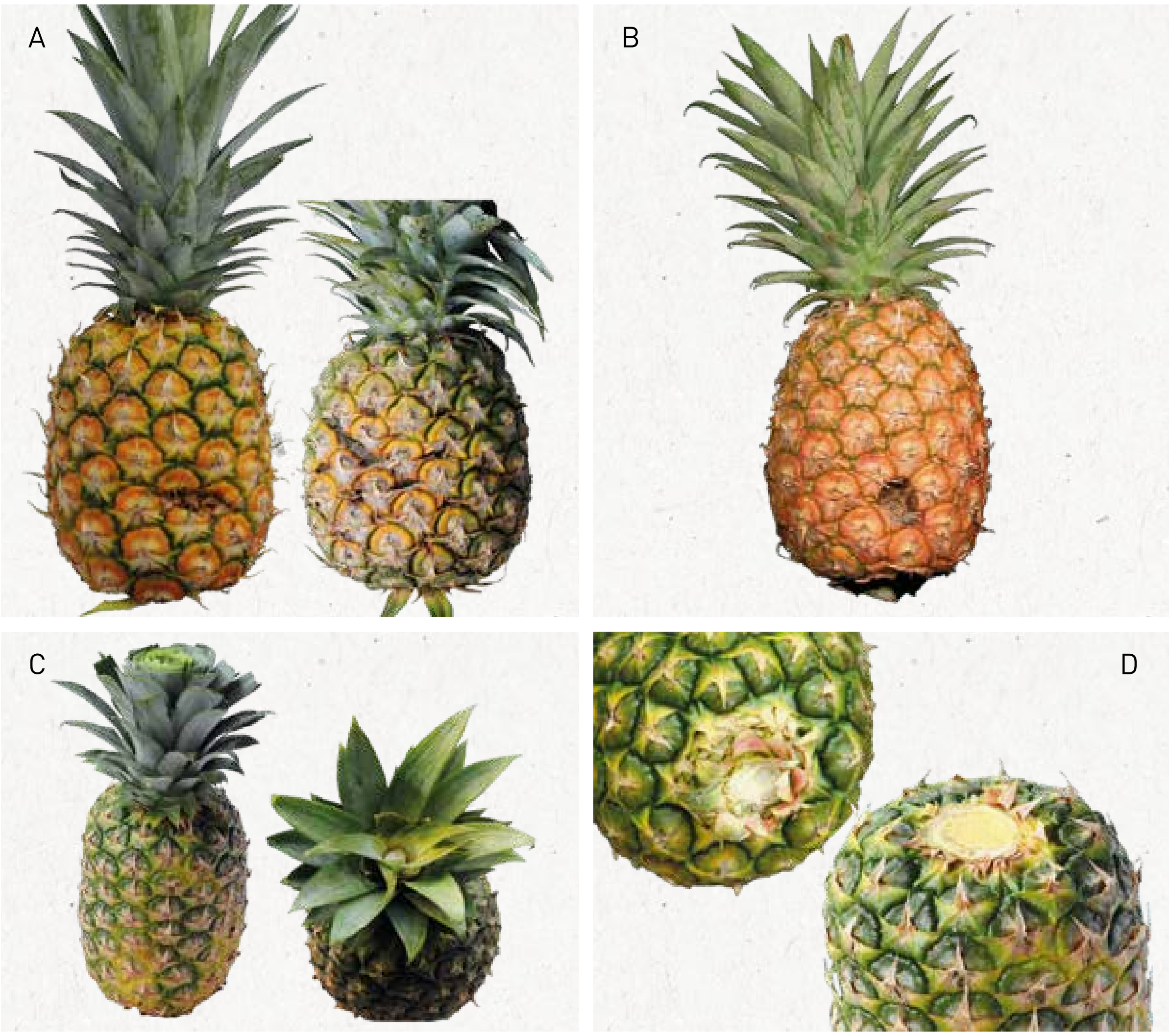

Figure 110 — Pineapple with cracks altering the flesh (a),
pineapple with damage revealing the interior (b),
Crown "trimmed": the overabundant part is carefully cut (left) or removed by twisting (right),
Crown "removed": carefully twisted (left) or cut (right)
Source: Good practice guide for the pineapple sector in Benin

— PRODUCTS AFFECTED BY ROTTING OR DETERIORATION RENDERING THEM UNFIT FOR CONSUMPTION ARE REJECTED

Pineapples with signs of mould, deep bruising, sunburn, waterlogging or cold injury are rejected (Figure 111).

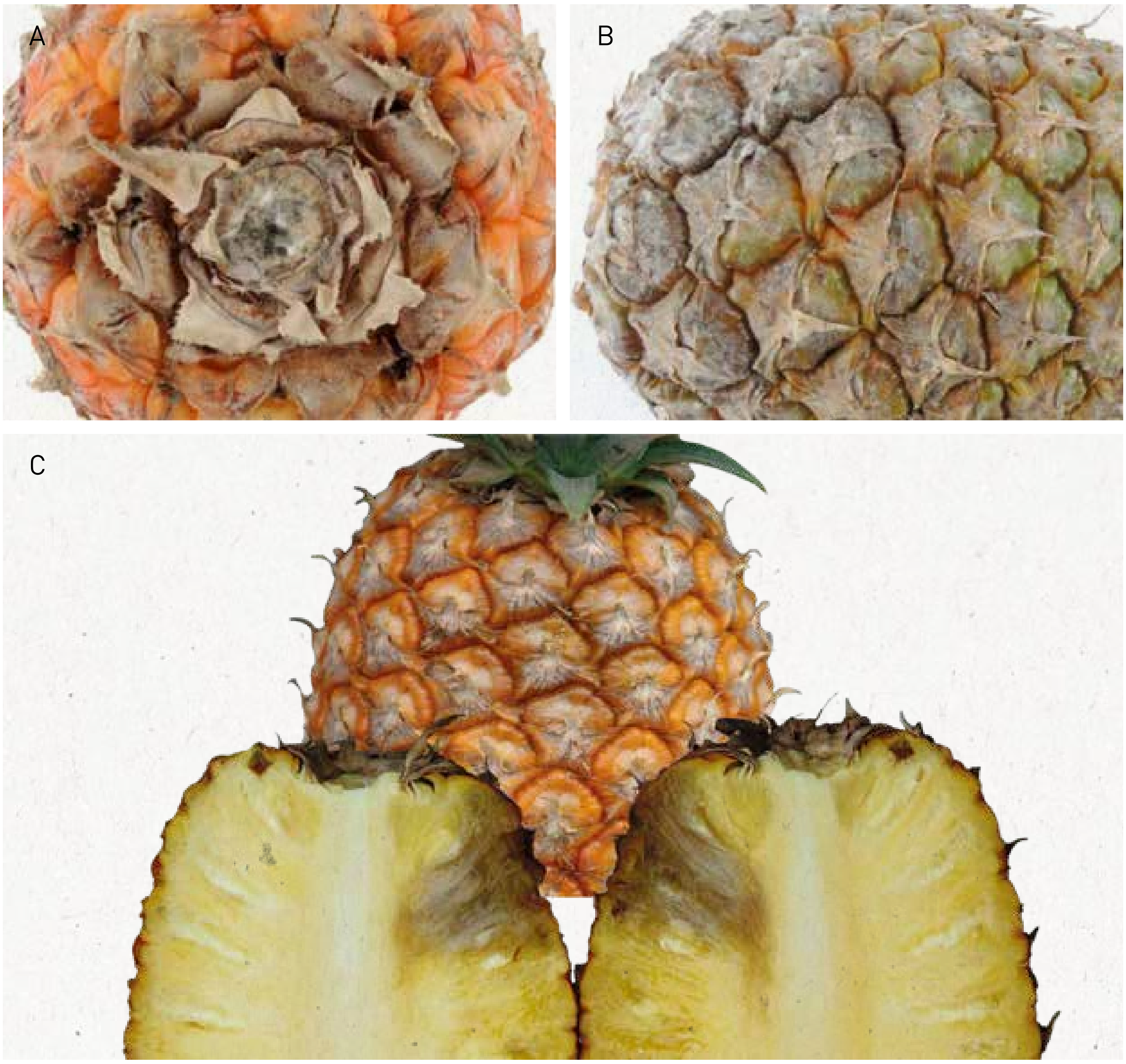

Figure 111 — Mould on peduncle (a); Mould on epidermis (b); Pineapple with a bruise
Source: CIRAD, 2020; Good practice guide for the pineapple sector in Benin

— CLEAN, PRACTICALLY FREE OF VISIBLE FOREIGN MATTER IN PARTICULAR

soil, dust and chemical residues (Figure 112).

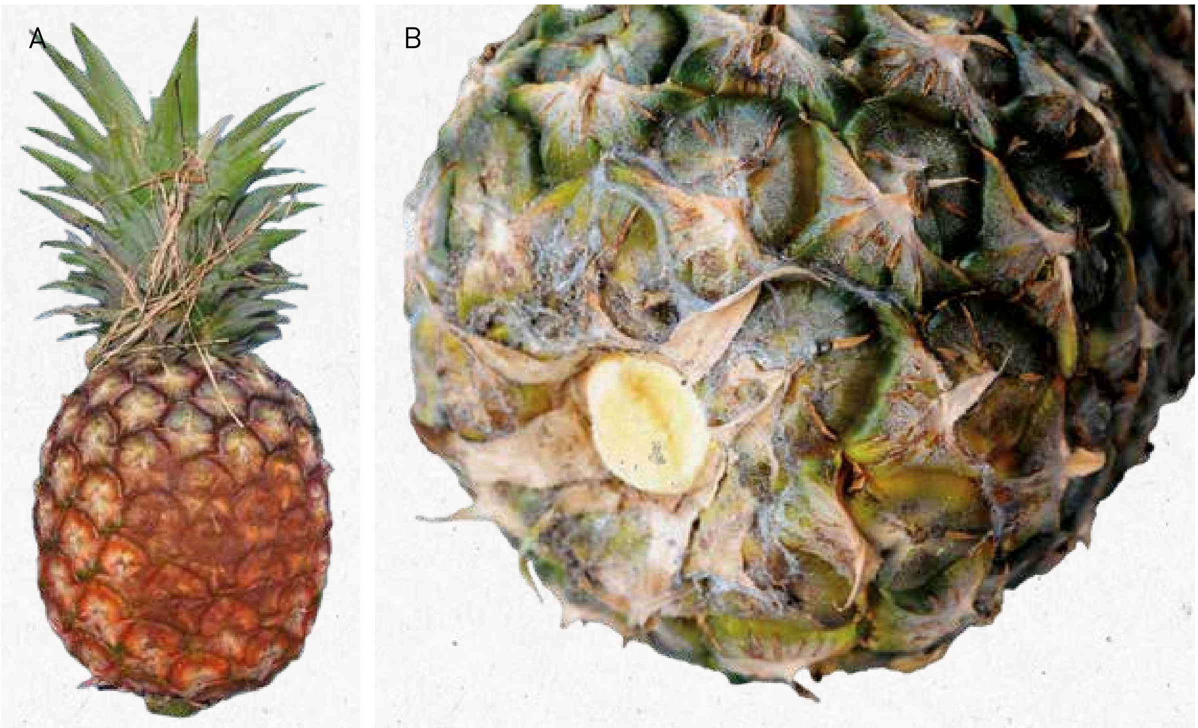

Figure 112 — Excessive soil on pineapple (a); pest residue (b)
Source: Good practice guide for the pineapple sector in Benin

— PRACTICALLY FREE OF PARASITES (SUCH AS MEALYBUGS) THAT AFFECT THE OVERALL APPEARANCE OF THE PRODUCT

Pests can affect the commercial presentation and acceptance of pineapples. The acceptable limit would be occasionally finding an insect, mite or other pest in the packaging or sample; any presence of colonies leads to rejection of the product (Figure 113).

Figure 113 — Colonies of scale insects
Source: Good practice guide for the pineapple sector in Benin

— FREE FROM PARASITES THAT AFFECT THE FLESH

Parasites that alter the flesh make the product unfit for consumption and lead to its rejection. Attacks by parasites which alter the epidermis alone are taken into account in the tolerances allowed for epidermal defects in each category (Figure 114).

Figure 114 — Damage caused by insects
Source: CIRAD, 2018c, 2020

— A FRESH APPEARANCE, INCLUDING THE CROWN

Where the crown is present, it should be fresh and not discoloured, free from any dry or dead leaves. A slight lack of freshness is permitted at stages following export or dispatch. The pineapples should be firm and turgid, with no signs of wilting or dehydration (Figure 115).

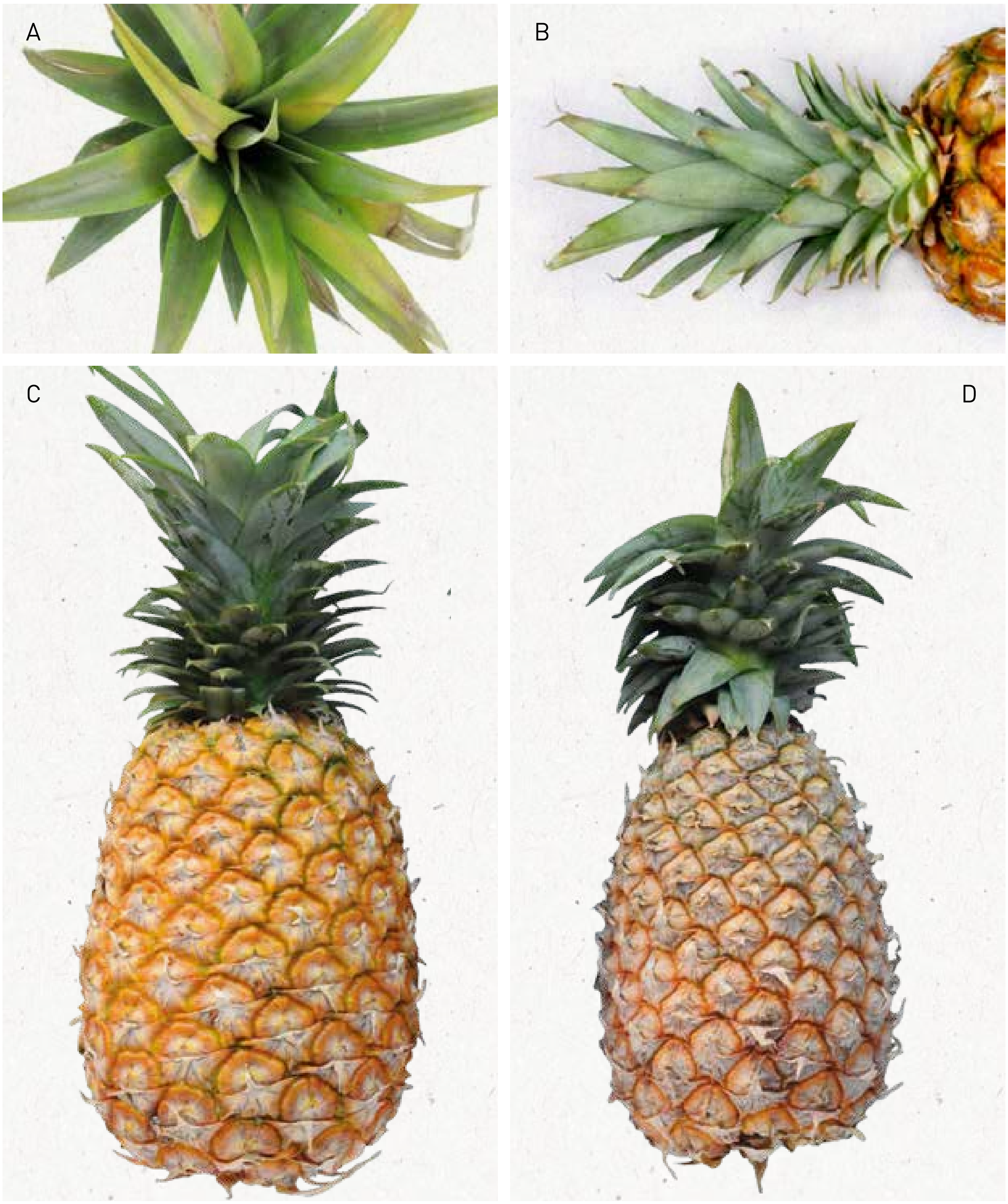

Figure 115 — Crown yellowing (a); Crown drying (b); Normal fruit (c); Dehydrated fruit (d)
Source: CIRAD, 2020

— FREE FROM ABNORMAL EXTERNAL HUMIDITY, WITH THE EXCEPTION OF CONDENSATION THAT APPEARS WHEN REMOVED FROM THE COLD ROOM

— FREE OF ANY FOREIGN ODOURS AND/OR FLAVOURS

Applies to pineapples that have been stored or transported in poor conditions and have therefore absorbed abnormal odours and/or flavours, particularly due to the proximity of other products that give off volatile odours.

— FREE FROM DAMAGE CAUSED BY LOW AND/OR HIGH TEMPERATURES (FIGURE 116)

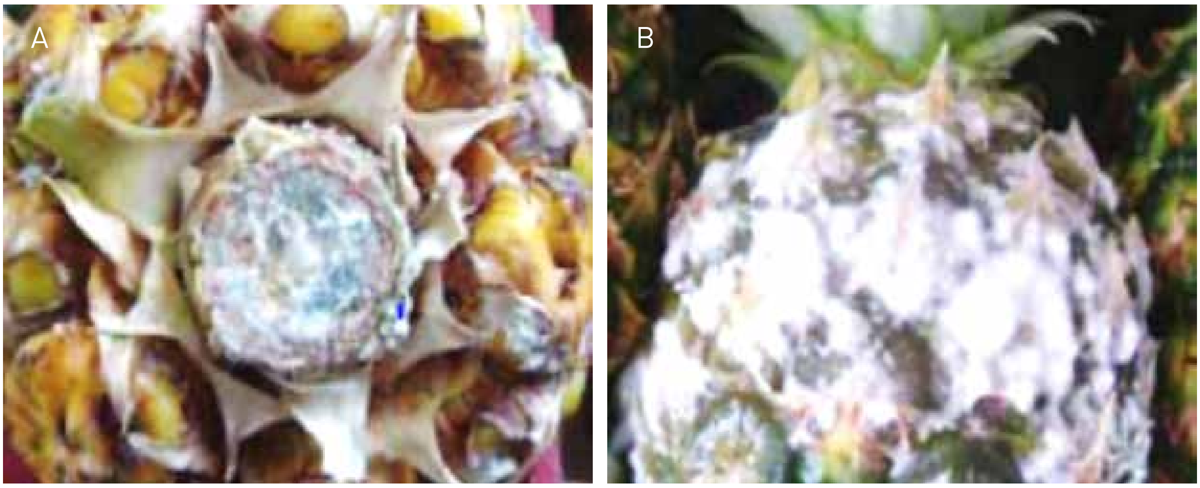

Figure 116 — Mould after transport on peduncle (Penicillium) (a);
Mould after transport on pineapple (Penicillium) (b)
Source: CIRAD, 2018c

Figure 117 — Internal browning on pineapple
Source: CIRAD, 2020

Where there is a peduncle, it should be no longer than 2.5 cm from the surrounding base, and the cut should be transverse, straight and clean. However, a longer stem is accepted during transport (Figure 118).

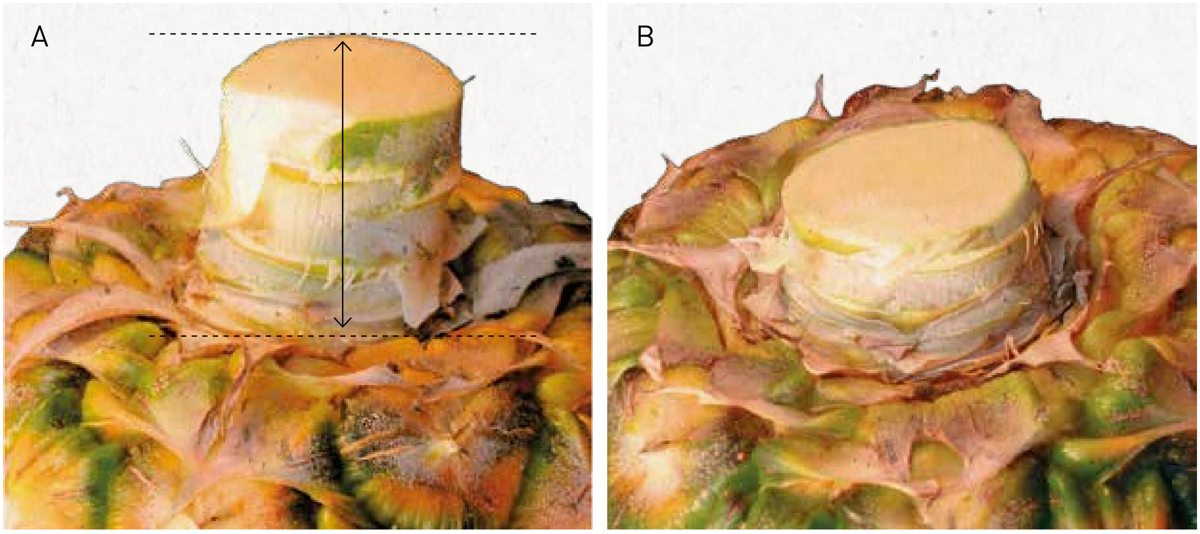

Figure 118 — Pineapple with peduncle exceeding 2.5 cm (a)
and pineapple complying with the required 2.5 cm fruit base length measurement (b)
Source: Good practice guide for the pineapple sector in Benin

PINEAPPLE FRUIT MUST

- be sufficiently developed and physiologically ripe, i.e. free from signs of immaturity (opaque, tasteless, excessively porous flesh) or over-ripeness (excessively translucent or fermented flesh);
- have a sugar content of between 12 and 14° Brix and can be stored for up to 14 days at room temperature in an airy room (16°C).

THE DEVELOPMENT AND CONDITION OF THE PINEAPPLE FRUIT MUST BE SUCH AS TO ALLOW THEM

- to withstand transport and handling;
- to arrive in satisfactory conditions at the final destination.

13.5.2. PRODUCT RIPENESS CRITERIA

Pineapple fruit must be sufficiently developed and ripe, depending on the specific characteristics of the variety and the production region. They must meet the following criteria:

- Total soluble solids content in the fruit pulp must be at least 12°Brix (twelve degrees Brix).
- Acidity: pH not exceeding 3.6
- Odour: pineapple fragrance, this fragrance becomes very intense from the 150th day after FIT.
- Overripe fruit whose edibility is affected is rejected
- The outer part of the fruit may be green, provided the minimum ripeness requirements are met.

To determine the Brix level, a representative sample of the juice is taken from the whole fruit.

13.5.3. PRODUCT CLASSIFICATION

CLASSIFICATION BASED ON EPIDERMAL COLOURATION

The fruit must reach a level of ripeness that ensures satisfactory flavour and optimum keeping qualities. There is a very good correlation between the natural external colour of the fruit and its actual ripeness (Figure 119). This gives the following classification:

- C0: completely green fruit;
- C1: yellow-orange colour reaching a third of the surface of the fruit;
- C2: yellow-orange colour up to half the surface of the fruit;
- C3: yellow-orange colour up to two-thirds of the surface of the fruit;
- C4: fruit completely yellow-orange.

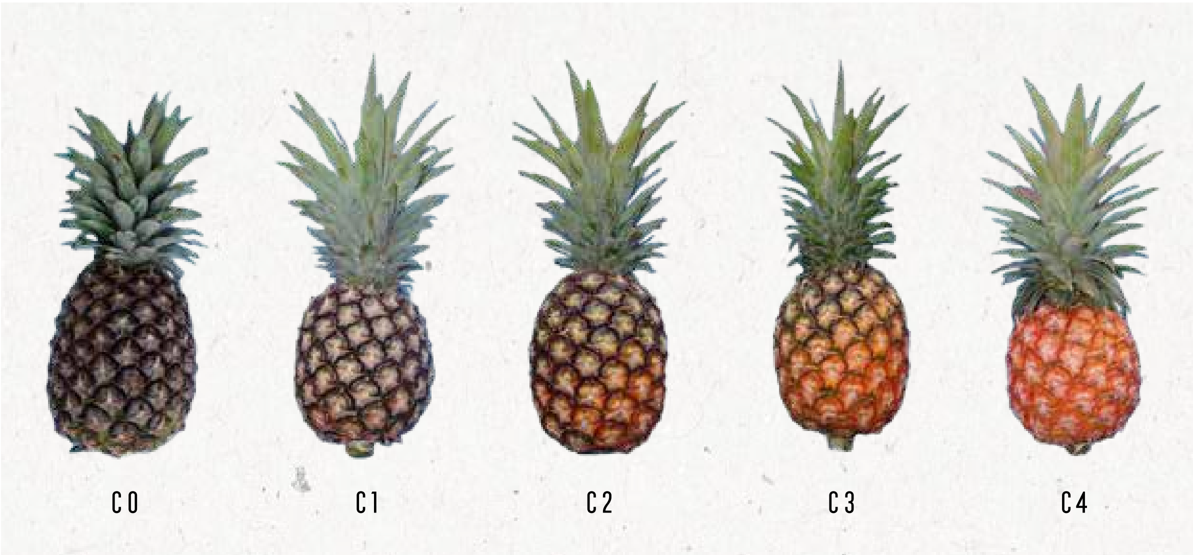

Figure 119 — Example of C0 to C4 classification according to colour (epidermal colour index)
Source: Good practice guide for the pineapple sector in Benin

THERE ARE THREE LEVELS OF RIPENESS

- M1: 130 days after FIT, slightly edible fruit, 10 to 12° Brix
- M2: 145 days after FIT, normal consumption fruit, 12 to 14° Brix
- M3: 150 days after FIT, fruit close to over-ripeness, 15 to 16° Brix. This last category is not suitable for export.

CLASSIFICATION OF PINEAPPLES BY CATEGORY

Pineapples are classified into three categories, as follows:

"EXTRA" CATEGORY

Pineapples in this category must be of superior quality and have the characteristics of the variety and/or commercial type.

- The pineapples must be free from defects with the exception of very slight superficial defects provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package.
- The crown, if present, should be single, simple and straight, with no offshoots, and should measure between 50 and 150% of the length of the fruit. It must be fresh and not discoloured, with perfectly healthy flesh (Figure 120).

Figure 120 — An example of a pineapple in the "extra" category
Source: Good practice guide for the pineapple sector in Benin

CATEGORY I

The pineapples must be of good quality and have the characteristics of the variety and/or commercial type. However, slight defects may be observed, provided that these do not affect the general appearance of the product, its quality, keeping quality or presentation in the packaging:

- slight defect in shape;
- slight discolouration;
- slight skin defects (scratches, scars, scrapes, bruises) not exceeding 4% of the total surface area of the fruit.

However, the crown, if present, should be simple and straight or slightly inclined, without any offshoots, and should measure between 50 and 150% of the length of the fruit. It may show defects such as slight damage and discolouration as well as a slight curvature with a maximum inclination not exceeding 30° from the longitudinal axis of the fruit (Figure 121).

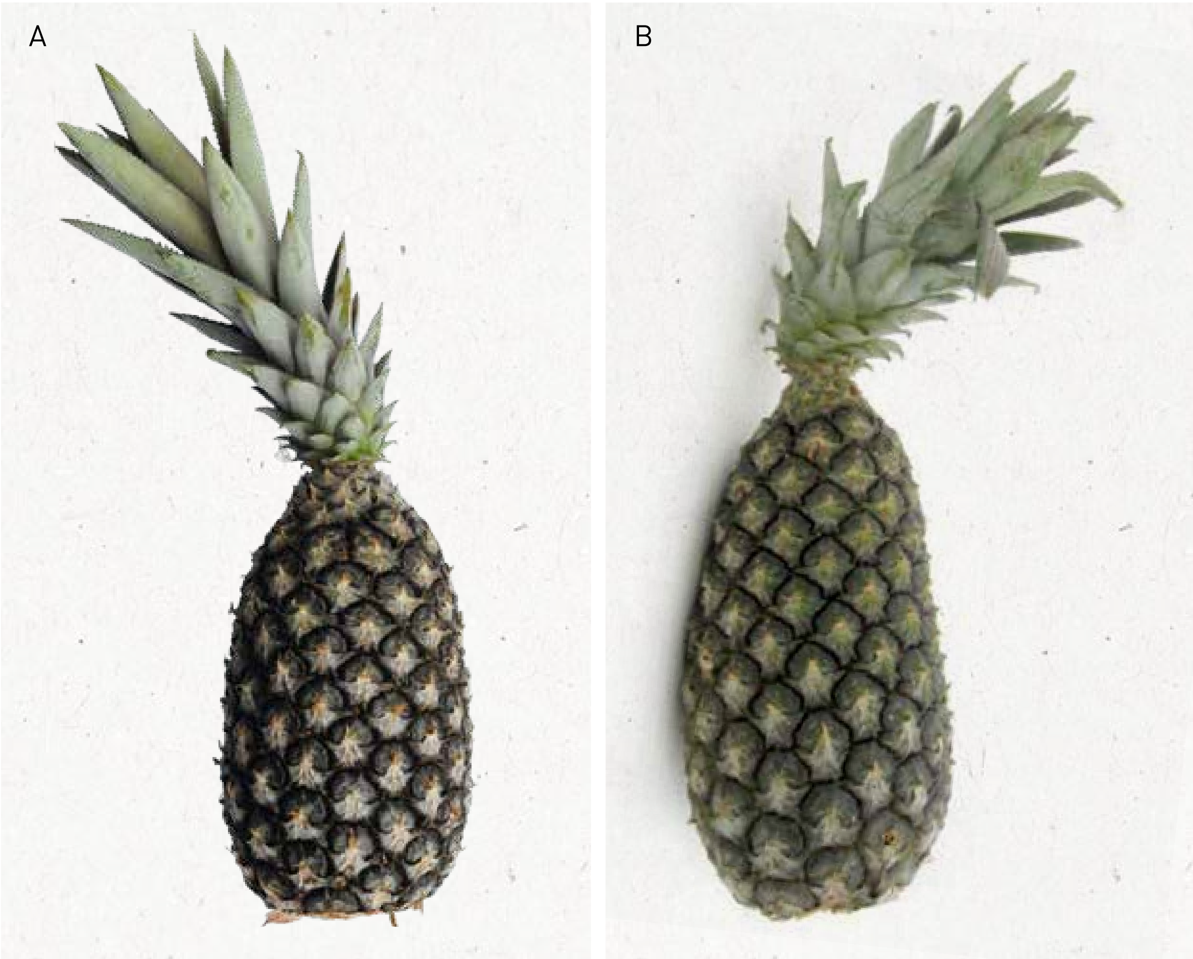

Figure 121 — Pineapple with crown defects
"inclination of 30° from the longitudinal axis of the fruit - Permitted limit" (a);
Pineapple with very inclined crown exceeding the permitted limit (b)
Source: Good practice guide for the pineapple sector in Benin

CATEGORY II

This category includes pineapples that meet the minimum requirements and are mostly reserved for consumption on the local and regional markets. Provided they retain their essential characteristics as regards the quality, the keeping quality and presentation, the following defects may be allowed:

- defects in shape; including a double crown;
- colour defects, including sun spots;
- skin defects (scratches, scars, scrapes, bruises, lesions), not exceeding 10% of the total surface area of the fruit.

The crown, if present, should be single or double, straight or slightly inclined, with no offshoots (Figure 122).

Figure 122 — Pineapple with a double crown
Source: CIRAD, 2020

13.6. YIELDS

Yields depend on the variety used, the planting system, sowing densities and compliance with technical procedures. Plant density affects average fruit weight and yield per unit area of pineapple. Higher planting densities favour higher productivity, lower densities generally allow the production of a higher percentage of large fruit (Souza *et* Reinhardt, 2007). Yield/ha increases with density but average fruit weight decreases with increasing densities (Py *et al.*, 1984).

Adherence to good production practices has proved effective in obtaining quality fruit, with a high yield i.e. a gross yield that can exceed 70 t/ha (CIRAD, 2018). Pineapple is a very demanding crop and skipping a single stage of the crop protocol entails substantial risks in terms of quality and yield (CIRAD, 2018).

PINEAPPLE HARVEST

PRE-HARVEST OPERATIONS

- Protection against sunburn: use of techniques (leaves tied in a bundle above the fruit; fruit lightly mulched; shade cloths, protective caps and netting laid down; etc.) 4 to 6 weeks before harvesting, when there is a lot of sunshine.
- Controlling insect pests: cleaning plots and surrounding areas and laying traps.
- Degreening treatment with ethephon: carried out 7 to 10 days at the latest before harvesting, while respecting the conditions (stage of development/ripeness of the fruit; size of the fruit; weather conditions; method of application and interval between application and harvest).

HARVEST

- carried out as soon as the lower quarter of the fruit turns yellow (around 160 days after FIT, and between 145 and 174 days for extreme cases).
- requires care and precision, with the use of equipment adapted to the weather conditions and handling procedures.

POTENTIAL YIELD: DEPENDS ON THE VARIETY USED, SOWING DENSITIES AND COMPLIANCE WITH CROP PROTOCOLS AND GOOD PRODUCTION PRACTICES

PRECISE REQUIREMENTS IN TERMS OF STANDARDS AND REGULATIONS

- Minimum quality characteristics
- Product ripeness criteria
- Product classification (based on skin colour; type of category)

INCORRECT OR INAPPROPRIATE PINEAPPLE MANAGEMENT AND PRE-HARVEST TREATMENTS, AS WELL AS THE WAY THE PINEAPPLES ARE HARVESTED AND HANDLED, HAVE A MAJOR INFLUENCE ON FRUIT QUALITY

- Harvest damage affects the quality and shelf life of harvested fruit, resulting in massive losses due to rejection by traders and consumers. The reputation of the exporting country is also affected, not to mention the losses suffered by producers.

14

PINEAPPLE POST-HARVEST

14.1. PACKING

Packing is carried out on the same day as cutting, in a clean, well-ventilated room protected from the elements. The fruit must respect the quality characteristics of the fruit. Packing involves operations such as:

14.1.1. TRIMMING

This involves removing the bracts from the base of the fruit, and removing pests and dust by light brushing (compressed air can also be used).

14.1.2. SORTING

Fruit with defects or anomalies should be eliminated: knocks, injuries, sunburn, multiple or damaged crowns (or crowns that are twisted, too long, too short, withered, yellow), torn peduncles, over-ripe fruits and those with visible black spots (green discolouration of the eye). The fruit must be physiologically ripe, i.e. free from signs of immaturity (opaque, tasteless, excessively porous flesh) or over-ripeness (excessively translucent or fermented flesh).

14.1.3. BRUSHING, WASHING AND WRINGING/DRAINING

The sorted fruit is then lightly brushed to remove dust and any pests (mealybugs and others). The fruit is washed in batches to avoid the risk of mixing and to prevent cross-contamination. Washing is done by hand using borehole or pump water, and involves immersing the fruit in clean water to minimise any ethephon residue that may remain on the fruit skin. The fruit is then dried for 15 to 30 minutes before being graded (Figure 123).

Figure 123 — Packing operations of pineapple fruit
http://taxis.brousse.free.fr/ananas_culture.htm
https://www.chfusa.com/pineapples_process.htm

14.2. TRANSPORT AND MARKET

14.2.1. SEA TRANSPORT

Sea transport is the most economical way of handling large quantities of fresh produce for international trade. They go from the harvest to the packing stations, where they are generally washed and packed by size. The fruit is placed in crates weighing between 10 and 20 kg and then palletised. The pallets, properly maintained in refrigeration chambers, are loaded into polythermal ships or refrigerated containers and kept at 7.5 - 8° C before export. Each container has a capacity of around 1,500 20 kg boxes and/or 3,000 10 kg boxes. They also have a thermograph for monitoring and recording temperature during the journey as well as the respective filters for monitoring ethylene (CNUCED, 2016).

14.2.2. AIR TRANSPORT

The goods are grouped together and then sent to the airport, loaded onto aircraft pallets and flown to the destination markets (Figure 124). The appropriate storage temperature is 7.5ºC and 85 to 95% relative humidity (CNUCED, 2016).

Figure 124 — Weight checked again, palletising, pre-cooling of boxes
https://www.chfusa.com/pineapples_process.htm
http://taxis.brousse.free.fr/ananas_culture.htm

14.2.3. LOCAL MARKET AND SUB-REGION

The local market is characterised by a short marketing circuit, linking local producers directly to local consumers or processing companies. This can be done through local collectors, local wholesalers and local retailers who serve as intermediaries between producers and consumers. Pineapples intended for the local market or the sub-region have no specific requirements other than fruit size. For the local and regional market, three sizes have been identified: Big, medium and fist-sized. The local market accepts all sizes. However, on the regional market, demand is higher for the medium and large sizes.

Fruit earmarked for local and regional markets is packed in crates or cardboard boxes and transported in appropriate lorries.

14.2.4. INTERNATIONAL MARKET

Pineapples must comply with the precise requirements in terms of standards and regulations presented (see section 12). Customers draw up specifications specifying fruit quality, size, variety, sugar content and certificates, with traceability established.

Figure 125 — Pulp temperature measurement and recording on the box
https://www.chfusa.com/pineapples_process.htm

PINEAPPLE POST-HARVEST

PACKING

- Trimming: the bracts at the base of the fruit, parasites and dust are removed.
- Sorting: any fruit showing signs of defects or anomalies is removed.
- Brushing, washing and drying/draining: the fruit is dried/drained, leaving it to dry for 15 to 30 minutes before being graded.

PRECISE REQUIREMENTS IN TERMS OF STANDARDS AND REGULATIONS

- Grading
- Tolerances
- Presentation
- Marking
- Storage and transport

POST-HARVEST HANDLING ACTIVITIES SHOULD AIM TO FURTHER REDUCE PHYSICAL DAMAGE TO THE FRUIT. PRESCRIBED TREATMENTS MUST PREVENT DETERIORATION IN FRUIT QUALITY IN ORDER TO MEET MARKET QUALITY REQUIREMENTS

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