SUSTAINABLE PRODUCTION

GUIDE

COLEAD

COCONUT (*COCOS NUCIFERA*)

Funded by the European Union

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WHAT DOES COCONUT NEED?

1.1. INTRODUCTION

The coconut plant (*Cocos nucifera*) is a palm of the family Arecaceae, and the only living species of the genus *Cocos*. It is assumed that coconut had spread over the world in prehistoric times by floating seeds on ocean currents, and originating from Southeast Asia. It is cultivated extensively in tropical areas for its edible fruit, the coconut. The term "coconut" is invariably used to refer to either the whole coconut palm, the seed, or the fruit. Coconut fruit consists of a fibrous one-seeded drupe- a hard stony covering enclosing the seed. In coconut, all drupes have three layers: the exocarp (outer layer), the mesocarp (fleshy middle layer), and the endocarp which is a hard, woody layer that surrounds the seed.

The coconut palm is characterized by slender, ringed trunk that rises to a height of up to 25 metres (80 feet) from a swollen base and is surmounted by a graceful crown of giant featherlike leaves. Mature fruits are usually ovoid or ellipsoid in shape, 300–450 mm (12–18 inches) in length and 150–200 mm (6–8 inches) in diameter with a thick fibrous husk surrounding a single-seeded nut. Coconut palm, which botanically is not a tree as it lacks bark, branches or secondary growth on it, is an economically important palm species cultivated for its oil, coconut juice or coconut milk prepared by squeezing liquid from its grated endosperm to be used in many types of dishes. Other uses of the "palm tree" include production of fiber, fuelwood, utensils or musical instruments from the trunk. Nutraceutical values of tender coconut water, virgin coconut oil as well as that of inflorescence sap are increasing the need for more coconut production (Hebbar et al., 2015; Habber et al., 2020; Rethinam, 2018; Ramesh et al., 2020) to serve a diversity of preventive health and medicine applications. The crop is currently cultivated in more than 94 countries worldwide over an estimated area of at least 11.99 Million hectares (Hebbar, 2022). In 2019, for example, the largest coconut producing countries included Indonesia, Phillipines, India, Sri Lanka, Brazil, Vietnam, Mexico, Papua New Guinea, Tailand and Malaysia. (FAO Stats, 2019). The global coconut market size was valued at 64.95 Billion US Dollars in 2020 and is forecasted to reach 101.9 US Dollars in 2028 (Adroit, 2022)

1.2. CLIMATE

1.2.1. RAINFALL

The optimum rainfall range for coconut is 1300–2300 mm per annum or around 150 mm per month. The lowest threshold is 1000 mm of rainfall per annum (Rao, 1989; Karr, 2011). A short dry spell does no harm provided that the soil forms a buffer and the water table is not too deep (<4m). In contrast, long dry seasons (>3 months) have detrimental effects on flowering and yield. A permanent water table that is shallow enough to be within reach of coconut roots as may be the case in coastal plains may offset inadequate rainfall events while rainfall amounts in excess of 2500 mm per annum as may be the case in the regions 20° south and north of equator could result in prevalences of diseases of flowers and fruits.

1.2.2. TEMPERATURE

As a typical low-altitude crop (<600 m), the optimum temperature for coconut crops is around 27°C, with diurnal variations not exceeding 7°C. The crop grows best between 23°N and 23°S of the equator. Young coconut plants are sensitive to temperature fluctuation although an established coconut palm can tolerate temperatures as low as 1°C provided that the growing tip of the palm is not exposed to prolonged freezing. Coconut also tolerates temperatures as high as 33.9 °C which may occur in hot drier summer months in the tropics.

1.2.3. ALTITUDE

Optimum growth and yield is realized at not more than 600 meters above sea level (m.a.s.l.), although the crop can still grow at altitudes as high as 1000 m.a.s.l. within latitude 23° north and south of Equator. At latitudes more than 23 °, coconut can also do well on the coasts of large land masses such as those of Africa, South America and Australia).

1.2.4. RELATIVE HUMIDITY

An optimum relative humidity (RH) range is 80–90%, but the crop can tolerate a RH as low as 60% without productivity being severely affected. RH above 90% is not good for coconut as this is a conducive condition for *Phytopthora* fungal attacks (Drenth and Guest, 2004).

1.2.5. LIGHT

Coconut requires plenty of sunlight (i.e. ca. 1600 to 2000 hours annually). As a rule of thumb coconut should attain at least 5 to 6 hours of full sunlight exposition everyday for proper growth and production. Thus, most of the tropical and temperate world has sufficient daylight for coconut production.

1.3. WATER

1.3.1. QUANTITY

Coconut crop needs 40–100 l/plant per day depending on soil type, weather, age of plants and method of application. Generally, a young plant requires 5–10 l/plant per day while an adult plant requires 45 l/plant per day (Carr, 2011).

1.3.2. QUALITY

Use clean and fresh, non-saline water for irrigation. Fresh water bodies (rivers, lakes and dams) are preferred and recommended for irrigation water over seawater and brackish water sources. Prolonged use of saline water may decrease the osmotic potential and/or excessive accumulation of ions in the receiving soil and especially around the plants roots. This in turn, may induce ionic toxicity, nutritional imbalance or both (Da Silva et al., 2016) eventually imparing coconut plant's ability to absorb water and nutrients directly affecting growth and development. In coastal areas with persistent water scarcity, use of desalinized sea water (DSW) may be an option although this approach demands high input costs (Martinez-Alvarez et al., 2020). Alternatively, in areas where brackish water is available, its desalization is less costlier than sea water (Shaffer et al., 2012)

1.4. SOIL

The coconut crop can be grown on a wide variety of soils including coastal Arenosols, Acrisols, Ferralsols, Fluvisols, Andosols and Histosols (WRB Classification), provided that they are well aerated and drained.

1.4.1. STRUCTURE AND TEXTURE

Coconut prefers a well-drained, light-textured soil (e.g. loamy sand) over a heavier textured soil (e.g. those rich in clay) (Loganathan et al., 1976). However, the plant tolerates and grows well on many soil structural types provided they are reasonably deep and free-draining hence allowing unrestricted root development and aeration. Coconut palm tolerates a wide range of soil textures ranging from coarse sand, which contains up to 97% sand (0.2–2.0 mm) to relatively heavy clay soils with about 70% clay (Issaka et al., 2012).

1.4.2. SOIL DEPTH

A recommended minimum soil depth for coconut crop is 1.2 m, while best yields are observed on soils deeper than 4m. Most varieties require soils as deep as 1.2–1.5 m or more. In addition, the soils must be free from rocky impediments and hard pans for better root growth and development. Where hard pans are a confirmed problem, use of chisel plough or similar equipment to break the pan prior to crop establishment may be necessary.

1.4.3. SOIL PH

An ideal soil pH range for coconut is 5.5–7.0 although coconut palm can tolerate a wider soil pH ranging from 4.5 to 8.0. In alkaline or acidic environments, the crop may succumb to nutrient imbalances and deficiencies. Therefore, where pH of the soil is below 5.5, it may be necessary to amend the soil using agricultural lime (with calcium carbonate as the main active ingredient although additional chemicals such as calcium oxide and calcium hydroxide may be included). Gypsum ($CaSO_4$) application is recommended if the pH is higher than 6.5 and especially where soil calcium levels are insufficient and thus contribute to crop growth suppression.

1.4.4. ORGANIC MATTER

Adequate levels of soil organic matter are important to ensure a steady supply of nutrients and enhancement of physico-chemical and biological properties of the soil. With the right organic matter content, physical properties such as water holding capacity, water filtration and aeration are improved. Organic matter also helps to improve chemical properties of the soil such as ability to hold onto and supply over time essential plant nutrients such as calcium, potassium and magnesium as well as the ability of the soil to resist abrupt changes in soil pH. Ideally, soils should have between 3 and 6% organic matter content. Where levels are below this range, corrective measures such as incorporation of crop residues, animal manure, compost or green manure may be necessary.

1.4.5. SOIL SALINITY

Coconut palms are moderately tolerant to salinity (Medeiros et al., 2018). Generally increased soil salinity (electrical conductivity exceeding ECe of 11.07 dS m-1) causes severe reductions in leaf expansions and general biomass accumulation especially in young coconut plants (Ferreira-Silva et al., 2010; Medeiros et al., 2018). Cultural practices such as increased irrigation frequency to wash down the soluble salts and addition of organic materials such as crop residues, organic mulch may help reduce the toxic effects of salts on coconut plant growth and development.

1.5. NUTRITION

Coconut requires a continuous supply of potassium, nitrogen, phosphorus, magnesium and calcium and other essential macro and micronutrients for good crop performance. Application rates depend on the soil test results (see section 5.2 for recommended doses of each nutrient).

NITROGEN

In the coconut palm, nitrogen (N) is required for the development of the vegetative parts of the plant namely leaves and shoots. It is a constituent of plant cells as well as chlorophyll, and its deficiency leads to a uniform light-green yellowing of older leaves (uniform chlorosis) with severe deficiency leading to shedding of leaves and inhibited plant growth.

Figure 1 — Uniform chlorosis of older leaves moving from the leaf tip to the leaf base is characteristic of nitrogen deficiency in coconut - Source: Nitrogen deficiency of young coconut palm | Scot Nelson | Flickr

PHOSPHORUS

Phosphorus (P) is required by coconut for its role in cell division, seeds formation and leaves development. It is therefore important in root development in coconut. Deficiency symptoms include purple coloration of leaves, sluggish growth and premature leaf shedding.

Figure 2 — Phosphorus deficiency symptoms. Purple coloration of leaves followed by premature leaf shedding - Source: ICAR-Central Agricultural Research Institute - https://ccari.icar.gov.in/soilgoa/index.php

POTASSIUM

Potassium (K) is required for root development which is crucial for supporting the rather big trunk in often loose soils and palms' increasing ability to absorb more nutrients from the soil. It is also required by the palm tree for its role in formation of sugar, fat, and fibrous material all of which are necessary for the trunk and fruit formation in coconut. Deficiency symptoms usually first appear on older leaves before spreading to younger leaves and may include yellowing of leaf margins characterized by transluscent yellow to orange spots. Severely affected older leaves may show necrotic symptoms and curling of leaf tips.

Potassium has a negative interaction or inhibitory effect on the absorption of magnesium at the root tip in the soil. Excess supply of potassium inhibits magnesium absorption although excessive concentration of magnesium in the soil does not affect K uptake by plant roots. To avoid any potential nutrient imbalances, it is recommended that K application should be guided by results on soil magnesium and calcium levels.

Figure 3 — Necrotic symptoms:Translucent yellow to orange spots on young leaves and yellowing of leaf margins characteristic of potassium deficiency in coconut
Source: Potassium Deficiency in Palms - UF/IFAS Extension Orange County (ufl.edu)

MAGNESIUM

Coconut palm requires magnesium (Mg) for its role in photosynthesis, female flower formation and fruit setting percentage. Deficiency symptoms are characterized by chlorotic bands along the margins with the central portion of the leaves remaining distinctly green. Older leaves become bronzed with dry appearance while severe deficiency may lead to necrosis.

Figure 4 — Broad leaf chlorosis as a characteristic of magnesium deficiency
Source: Horticulture :: Plantation Crops :: Coconut-Physiological Disorders - Minor Nutrients (tnau.ac.in)

CALCIUM

Calcium (Ca) is essential for the growth of meristems and thus important for proper growth and functioning of the root tips as well as leaf growth. It takes part in plant's cell division and elongation. Deficiency of calcium which is common in acidic soils causes young coconut palm leaves to develop intervenal chlorosis characterized by narrow white bands at leaf margins. Severe deficiency develops both rusty appearance in leaf margin and rolling up of terminal leaves. On flowering coconut palms, calcium deficiency may lead to death of flower buds.

Figure 5 — Calcium deficiency symptoms
from left – intervenual chlorosis, rusty appearance and death of flower buds
Source: Horticulture :: Plantation Crops :: Coconut-Physiological Disorders - Minor Nutrients (tnau.ac.in)

Since calcium has a particular tendency of interacting with other cations, especially potassium and magnesium, its nutritional balance when applied to coconut fields is crucial. Calcium fertilization in acidic soils must be balanced because elevated Ca supply can decrease K absorption by antagonism. Appropriate Ca:K ratio to be applied should be informed by soil analytical results on their respective levels in such soils.

SULPHUR

Sulphur (S) is required in the formation of amino acids, proteins, and oils and is also necessary for chlorophyll formation. Sulphur deficiency is characterized by uniform yellowing of the leaves, reduced vegetative growth and improper hardening of kernel. Leaves drop as the stem becomes weak and in older palms, leaf number and size are reduced while nuts may fall prematurely and the kernel (copra) becomes rubbery and of poor quality. Being immobile in plants, sulphur deficiency symptoms show up first in younger leaves.

Figure 6 — Sulfur deficiency symptoms in coconut
https://hort.ifas.ufl.edu/database/nutdef/pic74.shtml

BORON

The roles of Boron (B) in coconut plants are diverse, ranging from supporting multiplication of meristematic tissues to metabolism of protein, synthesis of pectin, maintenance of water relations, and translocation of sugars. It also plays an important role in the fruiting process, growth of pollen tube and in the development of flowers and fruits. Boron deficiency symptoms include leaf wrinkling leading to sharply bent leaf tips (hook leaf). Newly emerging spear leaves fail to open leading to a serrated zigzag appearance of leaves, eventually inflorescence and nuts become necrotic.

Figure 7 — Boron deficiency symptoms in coconut From left leaf wrinkling leading to zigzag appearance, severe distortion of leaves and necrosis of nuts
Source: https://agritech.tnau.ac.in/horticulture/horti_pcrops_coconut_phy_dis_minor.html

ZINC

Zinc (Zn) is an important component of many proteins and enzymes and thus it contributes to a number of important plant functions, such as growth hormone production and internode elongation. It is also responsible for photosynthesis and greenness of leaves. Zinc deficiency can cause rossetting- a condition that produces deformed tender leaves. Leaflets become chlorotic, narrow and reduced in length. In acute deficiency, flowering is delayed and button shedding may occur.

Figure 8 — Zinc deficiency symptoms in coconut: From left reduced leaf size, small nut size and button shedding
Source: Horticulture :: Plantation Crops :: Coconut-Physiological Disorders - Minor Nutrients (tnau.ac.in)

MANGANESE

Manganese (Mn) has a role in the formation of chlorophyll in leaves. Manganese deficiency is very common on alkaline soils and is characterized by chlorotic newest leaflets with longitudinal necrotic streaks. Under severe manganese deficiency, leaflets appear necrotic and withered on all but basal portions of the leaflets. Necrotic leaflet tips eventually fall off and newly emerging leaves consist solely of necrotic petiole stubs. At this stage growth of the coconut palm stops

Figure 9 — Manganese deficiency symptoms - From left: Longitudinal necrotic streaks on chlorotic new leaflets, die off and falling of leaf tips and leaves appearing withered on all but basal portions
Source: Horticulture :: Plantation Crops :: Coconut-Physiological Disorders - Minor Nutrients (tnau.ac.in)

IRON

Iron (Fe) plays a role in chlorophyll formation. The main symptom of iron deficiency is interveinal chlorosis (yellowing between the veins) of new leaves. Severe iron deficiency leads to necrotic and reduced leaf sizes. Iron deficiency is common in palms growing on poorly aerated soils such as under waterlogged conditions or when young palms have been planted too deeply.

Figure 10 — Chlorosis, necrotic leaf tips and reduced leaf sizes due to iron deficiency
Source: Horticulture :: Plantation Crops :: Coconut-Physiological Disorders - Minor Nutrients (tnau.ac.in)

COPPER

Copper (Cu) is required for chlorophyll formation, seed germination, and early seedling growth of many crops including coconut. It is involved in the activation of many enzymes and the catalysis of reactions in several plant-growth processes. Copper deficiency in coconut is manifested by appearance of coppery bluish leaves, rolling of terminal leaves and bleached grey leaves. Plants with severe copper deficiency fail to flower.

Figure 11 — Copper deficiency symptoms- Coppery Bluish Leaf (left) and bleached leaf appearance (right)
Source: Horticulture :: Plantation Crops :: Coconut-Physiological Disorders - Minor Nutrients (tnau.ac.in)

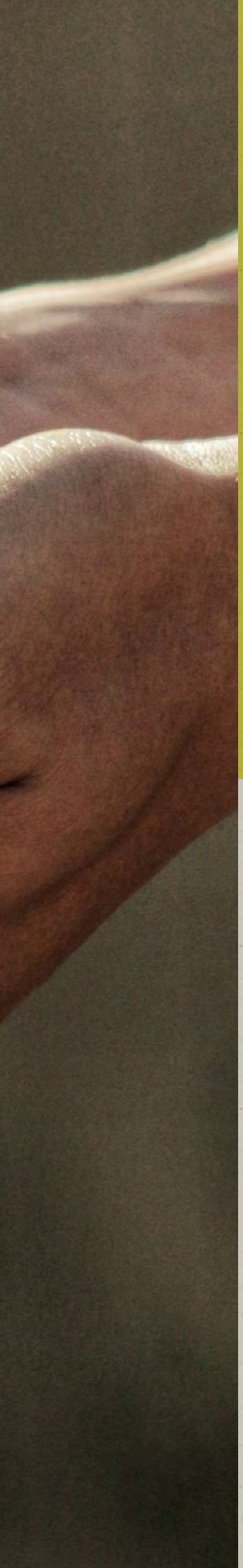
CHLORINE

Chlorine (Cl) performs many biochemical and physiological functions in plants and in coconut it is involved in stomatal opening and closing, stomatal regulation during dry seasons, water balance as well as acting as an osmoticum in maintaining turgor during drought. It also has a role in splitting of water molecule in photosystem II during photosynthesis (Neenu et al., 2020). Chlorine has a strong tendency of interacting with other major nutrients notably potassium, phosphorus and magnesium. Chlorine enhances absorption of K, Mg and P in coconut. Consequently, chlorine application accelerates growth, early flowering, setting of fruits in coconut. Chlorine deficiency in coconut is exhibited by reduced growth rate of palms, reduced number of green fronds, reduced number of nut sets. Other visual symptoms of chlorine deficiency in coconuts include chlorosis, bronzing and necrosis of leafs as well as drying up of leaf tips and edges.

WHAT DO COCONUTS NEED?

KEY POINTS SUMMARY

- **Rainfall**
  1300–2300 mm per annum or around 150 mm per month
- **Relative humidity**
  optimum 80–90%, lower limit 60%, above 90% is undesirable
- **Temperature**
  around 27°C, with diurnal variations not exceeding 7°C.
- **Altitude**
  optimum growth at not more than 600 meters above sealevel although it can still grow at altitudes as high as 1000 m.a.s.l
- **Soil**
  a minimum of 1.2 m deep, well-drained, light textured soil (e.g. loamy sand)
- **pH**
  ideally between 5.5–7.0, although pH conditions between 4.5 and 8 are tolerable
- **Salinity**
  Coconut can tolerate moderate amount of soil salinity
- **Nutritional factors**
  Coconut requires a continuous supply of potassium, nitrogen, phosphorus, magnesium, calcium and other essential macro- and micronutrients. Application rates depend on the soil test results (see section 5.2 for recommended doses of each nutrient).



2

PRE-PLANTING CHOICES

CHOOSE FARMING PRACTICES THAT REDUCE THE IMPACT ON THE ENVIRONMENT

- Varieties adapted to local conditions.
- Maintain species **diversity** in cultivated areas by keeping parcels of land surrounded by **hedges** and by adopting **crop rotation**, **intercropping** and **associated crops**.
- Avoid destroying natural habitats by land clearance and the use of fire to manage weeds, which lead to the loss of nutrients and the disappearance of beneficial fauna and flora.

PRESERVE UNCULTIVATED AREAS

- Conserve the **ponds**, **ditches** and areas close to their natural state located between land parcels to foster the development of **predators** that control crop pests.
- Conserve and maintain **hedges** and other **wind breaks** to serve as safe havens for a whole series of animals, birds and insects.
- Plant **wildflower strips** to foster the presence of **pollinating insects** and the reproduction of other **predator insects and mite species.**
- To know more: browse the COLEAD brochures on the subject.

2.1. CHOOSING A PLOT

Establish a coconut nursery in a well-drained, preferably sandy soil and close to a water source. Locate the nursery in an area with enough sunlight. For field establishment of coconut seedlings there is need to consider farming history of the plot. A plot with a previous history of palm production may have challenges of pests and diseases inherited from a previous host crop, and thus establishment of new palm orchards should be done with this caution.

2.2. PLANTING MATERIAL

Coconut can be propagated either from seeds or through tissue culture techniques, although former is the most common approach. Tissue culture techniques in coconut propagation is still a subject of research & development and both *In vitro* culture of zygotic embryos and micropropagation by somatic embryogenesis have received attention recently although not widely practiced (Ledo et al., 2019).

When coconuts are propaged from seeds, a two stage approach is usually followed: (i) germination of seednuts onto a seedbed and (ii) transfer of seedlings to a nursery prior to field establishment of fully grown seedlings. In the first step, carefully selected seednuts (see section 2.2.1) are distributed next to each other over a flat seedbed, covered with soil up to 2/3 of its length, to allow seednuts to germinate. After germination and when the seedlings reach an average of 0.20 m in height (about four months old), they are transferred to the nursery bed which may be open on-ground seedbeds or into polyethylene bags (See section 2.5). Seedlings remain in the nursery for another six to nine months where they attain 6-8 leaves, 10-12 cm collar girth and 1.0 to 1.2 m in height before they can be ready for field establishment (Ledo et al., 2019).

2.2.1. SELECTION OF MOTHER PALMS

Mother palms are palm trees from which seednuts are selected. Not all palm trees are suitable for provision of seednuts and thus mother palms should be selected for better seednut provision. They should be middle-aged (between 15 and 40 years old), have a straight stout trunk (with even growth and closely spaced leaf scars) and spherical or semi-spherical crown. Other traits of good mother palms include high leaf production (over 30 fully opened leaves) and spathe production of about 12 inflorescences, high yielding rates of at least 100 nuts/palm per annum under irrigated condition (70–80 nuts/palm per annum under rainfed conditions) with husked nuts having at least 600 g and mean copra content of at least 150 g or more per nut.

Figure 12 — Example of healthy straight trunked, high leaf producing and high yielding middle-aged mother palm trees
Source: https//www.coconutboard.in/Mpphotos/Mandyampweekly81/4.jpg

2.2.2. SELECTION OF SEED NUTS

From mother palms high quality seednuts should be selected for better germination and seedling growth results. To guarantee high quality seed nuts, select mature, medium sized, round or oblong-shaped nuts for seeds. Mature seeds are those harvested when at least one nut in the oldest bunch is dry. A dry nut produces a resonant or ringing sound when tapped with a finger.

2.2.3. SEEDNUT CURING AND PRE-PLANTING TREATMENT

Seednuts need an air and sand curing process for at least two months to help dry the outer husk without drying out the coconut water inside the nut because this allows faster and healthy germination of the embryo into healthy seedlings. Seednut curing is a two-stage process comprising of air curing followed by sand curing.

For air curing, heap carefully selected seednuts in layers of up to eight nuts, one on top of another, under a shade and in the open air. Tall and hybrid coconut varieties should be air-cured for about 1 month while dwarf varieties should be air-cured for around 2 months. For best results, air curing should be immediately followed by sand curing. **For sand curing**, arrange seednuts under a shade in five layers with the stalk end pointing up on a sandy surface (the sand surface layer should be 8 cm or more). Cover the nuts with more sand to prevent drying. Sand curing should be done for 2 months for tall and hybrid coconut varieties and up to 1 month for dwarf varieties. Avoid rain from hitting the nuts during this process (Shareefa et al., 2018).

Figure 13 — Coconut seed air curing (left) and sand curing (right) under shade and on open air
Source: https://agritech.tnau.ac.in/horticulture/horti_pcrops_coconut_plantingmaterial.html

2.2.4. PRE-PLANTING TREATMENT (DECONTAMINATION)

Coconuts do not always require pre-planting treatments except when the selected seednuts had a history of fungal and insect pest attack. To decontaminate the seednuts, treat by dipping them into a 0.01 or 0.02 M potassium nitrate and sodium carbonate solution prior to sowing on a nursery bed. Alternatively, seed nuts can be dipped into copper oxychloride to decontaminate them from fungal diseases.

Figure 14 — Dipping of coconut seed into copper oxychloride solution (using protective measures) as a way of decontamination
Source: Horticulture :: Plantation Crops :: Coconut-Planting Material (tnau.ac.in)

2.2.5. VARIETIES

Two main categories of coconut varieties exist, the tall and the dwarf varieties. In addition, intervarietal crosses (i.e. hybrids) which normally have better combinations of attributes like high yield, resistance to diseases and high copra quality do exist. Tall varieties have longer economic life than their dwarf counterparts. Distinct varieties of dwarf coconut naturally occurred in Malasia, Philippines, Fiji Islands, Vietnam, Ceylon and India as opposed to a much wider tropical world distribution of the tall varieties (Swaminathan and Nambiar, 1961; Perera et al., 2014). Despite their distinction, both species require similar cultural conditions for healthy and productive growth. However, the comparatively poor vigour, susceptibility to diseases and poor copra quality of the dwarf palms, render them less preferable for plantation scale cultivation as compared to the tall and hybrid varieties.

TALL VARIETIES ALSO KNOWN AS "TYPICAL (NAR)"

The trees grow to about 18 m or more, over a lifespan of 80–90 years. They are generally more resistant to insect pests and diseases, as well as to abiotic stresses such as low moisture stress and low temperatures, compared to dwarf varieties (Bila et al., 2016). The trees grow well at a wide range of altitude, sometimes as high as 915 m above sea level. Tall varieties have larger fronds thus fewer trees can be planted per unit area compared to dwarf varieties. Examples of tall varieties of coconut include West Coast Tall (WCT); East Coast Tall; Lakshadweep Ordinary (LCT); Philippines Ordinary (Kerachandra); Andaman Ordinary Tall (ADOT); Aliyar Nagar; Tiptur Tall; Kera Sagara (Seychelles) and Malayan Straight Settlement Apricot Tall (SSAT).

DWARF VARIETIES KNOWN AS "NANA (GRIFF)"

Dwarf, or short varieties generally have a small stature, growing to about 6–7 m tall over an average lifespan of 40–50 years. They take 3–4 years to flowering and reach steady and regular bearing after 8–9 years. They are comparatively more susceptible to abiotic stresses like low moisture stress and pest attack than their tall counterparts. Examples of dwarf varieties include Chowghat Orange Dwarf (COD), Gangabondam Green Dwarf (GBGD), Malayan Yellow Dwarf (MYD) and Chowghat Green Dwarf (CGD).

HYBRID VARIETIES

These are intervarietal crosses between the tall and dwarf varieties. They can either be from a tall variety as the female parent and a dwarf as the male parent (tall × dwarf) or a dwarf as the female parent and a tall variety as the male parent (dwarf × tall) (Chan and Elevitch, 2006).

Examples of hybrid varieties include Kerasankara (WCT × COD); Chandrasankara (COD × WCT); Chandralaksha (LCT × COD); Keraganga (WCT × GBGD); Lakshaganga (LCT × GBGD); Anandaganga (ADOT × GBGD); Kerasree (WCT × MYD); and Kerasoubhagya (WCT × SSAT).

West coast tall coconut tree
https://www.coconutboard.in/

East coast coconut tree
https://www.coconutboard.in/

Chowghat Green Dwarf

Chowghat Orange Dwarf

Kera sankara hybrid tree
source: amazon.in

Keraganga coconut hybridtree
source: Amazon.in

Figure 15 — Examples of various coconut varieties (dwarf, tall and hybrid)

2.3. GROWING PERIOD

Tall varieties start flowering at around 5 years after planting and the fruits become ripen 11 to 12 months after fruit setting. This means first harvest is expected at around 6 years after planting. Furthermore, tall varieties take 8–10 years since planting to attain a steady nut-bearing stage and can live for up to 90 years. Short varieties grow to reach a nut-bearing age at about 3–4 years after planting and take up to 10 years to come to a steady nut bearing stage. Short varieties have a relatively shorter life span living for up to 50 years. After reaching the nut bearing age, coconut palms bloom all year round, except when they are stressed by cold or too hot weather and lack water.

2.4. PLANTING METHOD

2.4.1. PROPAGATION BY SEED

Plant a healthy, cured and decontaminated seed on its side or slightly tilted in a shallow hole, with soil covering at least two-thirds of the seed. Place the seednuts with its narrower side pointing down tilted at an angle of 45° to position embryo on top. Irrigate the planted seeds regularly to prevent them from drying. Ensure that the nursery beds are not kept too wet as this may lead to termite infestation and seed rotting. Well-managed coconut seeds take about 3 months to germinate but some may take up to 6 months.

Follow the key steps below to establish a coconut seed nursery.

— **Land preparation**

  Clear the land, plough it and harrow the soil to ensure a fine tilth of the entire plot.

— **Seed bed preparation**

  Seed beds should be 10–20 cm high by 200 cm wide. Separate beds by a walkway of about 60 cm width.

— **Seed sowing**

  Place the seed nuts at a spacing of 15 cm between nuts (within row) and 15–20 cm between rows in a seedbed (Figure 16). Lay seed nuts in trenches of 10–15 cm depth. Firmly set them either horizontally on their side or slightly tilted with the embryo end at the top. Cover the seeds with topsoil such that about two-thirds of the seed nut is buried and one-third of the upper surface is visible. Nuts can also be sown individually in soil-filled Polyethylene Grow Bags as shown in Figure 16.

Figure 16 — seed sowing on a nursery bed
Source: https://lespalmistes.ci/pepiniere-de-palmier-a-huile

2.5. SEEDLING NURSERY MANAGEMENT

When seedlings are ordered from elsewhere or from a commercial venture, it is important to observe phytosanitary precautions. It is important to demand a phytosanitary certificate of any shipment to ensure that received coconut seedlings are free of pests and diseases of international concern. In a locally established nursery, ensure regular spraying of permissible pesticides to prevent insect and diseases attacks and keeping the nursery generally clean. On the nursery, the seedlings should continue to be cared for through regular watering and pest control measures until they reach around 8 to 10 months, a stage at which seedlings would have attained 3 to 4 fully open leaves and ready for field transplanting.

2.6. IRRIGATION

Where rainfall amounts received are below the required range, supplemental irrigation can help achieve expected yield levels. As a coconut tree needs at least ca. 50 liters of water per day, generally, supplement with irrigation at an average rate of 600–800 l/plant in every 4–7 days if the annual mean rainfall is below 1000 mm or during severe dry conditions (Karr, 2011; Surendran, et al., 2019). Irrigate the nursery regularly to keep the nuts moist but not wet. Too much moisture may encourage termite infestation and seed rotting, but prolonged dryness may kill seeds before germination. Apply a disease and insect pestfree mulch to conserve moisture and discourage weeds. Both drip and basin/fallow irrigation can be used in coconut production (see section 5.1 for details on how to irrigate).

2.7. ASSOCIATIONS

Coconut can also be grown in association with other types of crops, especially in small scale as opposed to commercial, large scale (plantation) type of farming. Where associations are considered- especially under small-scale coconut farming, the following decision tree can help guide the decision making process.

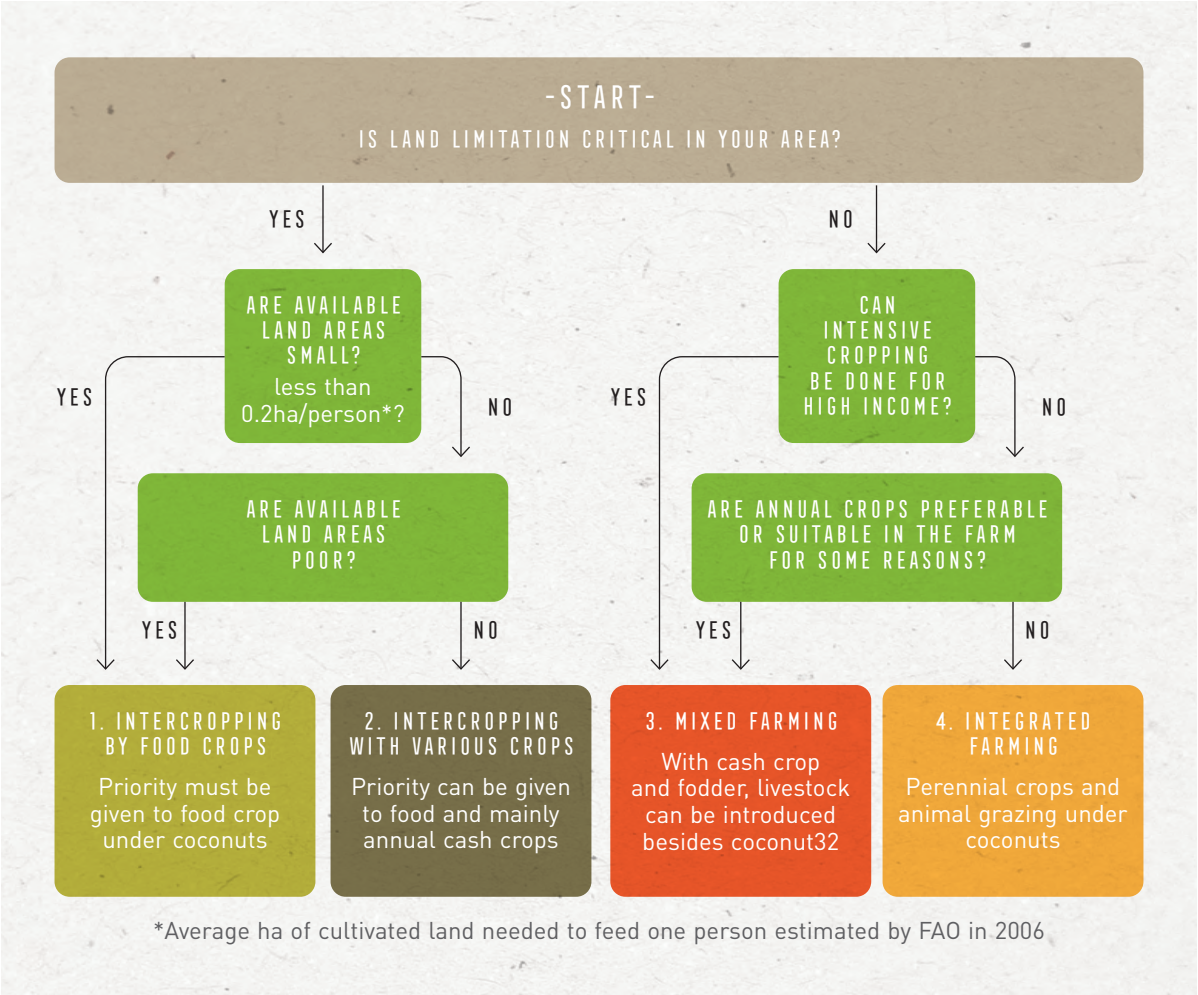


Figure 17 — What type of cropping/ farming is recommended in your coconut farm?
https://openjicareport.jica.go.jp/pdf/12283446_02.pdf

2.7.1. INTERCROPPING AND/OR MIXED CROPPING

Coconut can be intercropped with a wide range of annual crops and mixed cropped with other perennial crops. The naturally wide spacing between coconut trees offer opportunities for raising other crops in the interspaces as additional source of income to the farmer. Intercropping systems can be applied all across the board from smallholdings to medium and large scale plantations. In all such scenarios, intercrops can be any of the following:

- Legumes: cowpea, groundnuts, chick pea
- Cereals: maize, paddy, sorghum
- Other nut trees: cocoa; areca nuts
- Horticultural tree crops: oranges, mangoes, banana, jackfruit
- Vegetables: pepper and other leafy vegetables

Preferred crops to associate with coconuts may be selected based on the climatic requirement of the crop, available irrigation facilities, soil type and stage of growth of the coconut. Intercropping with annual crops is usually suitable during early growth years of the coconut while mixed cropping with other perennials is recommended at later growth stages of the coconut, as shown in Table 1 below.

Table 1 — Recommended inter- and mixed cropping crops for coconut

COCONUT GROWTH STAGE	RECOMMENDED INTERCROPS
Below 7 years of age	Practice intercropping using annual crops such as legumes (Groundnut, cowpea, groundnuts, and chick pea), cereals (maize, paddy, sorghum) or other crops (turmeric, sweet Potato, ginger and pineapple).
7 to 20 years of age	Practice mixed cropping with biennial crops such as banana
Above 20 years of age	Introduce mixed cropping with other shade tolerant crops such as cocoa, pepper and jackfruits

2.7.2. MIXED FARMING

Integrating livestock farming with coconut in the same farm is possible, especially when the palms have attained enough height that leaves cannot be reached/destroyed by the livestock. Several mixed cropping models can be adopted with coconut, some of which may include coconut-fruit-legume model or mixed fruit coconut model (Figure 18) or even the coconut agroforestry model. In the coconut agroforesty model considerations on the nutritional and other tree crop requirements (light, rooting space etc.) must be made to ensure that they complement one another for existence in the farm. (See Figure 19 for more details)

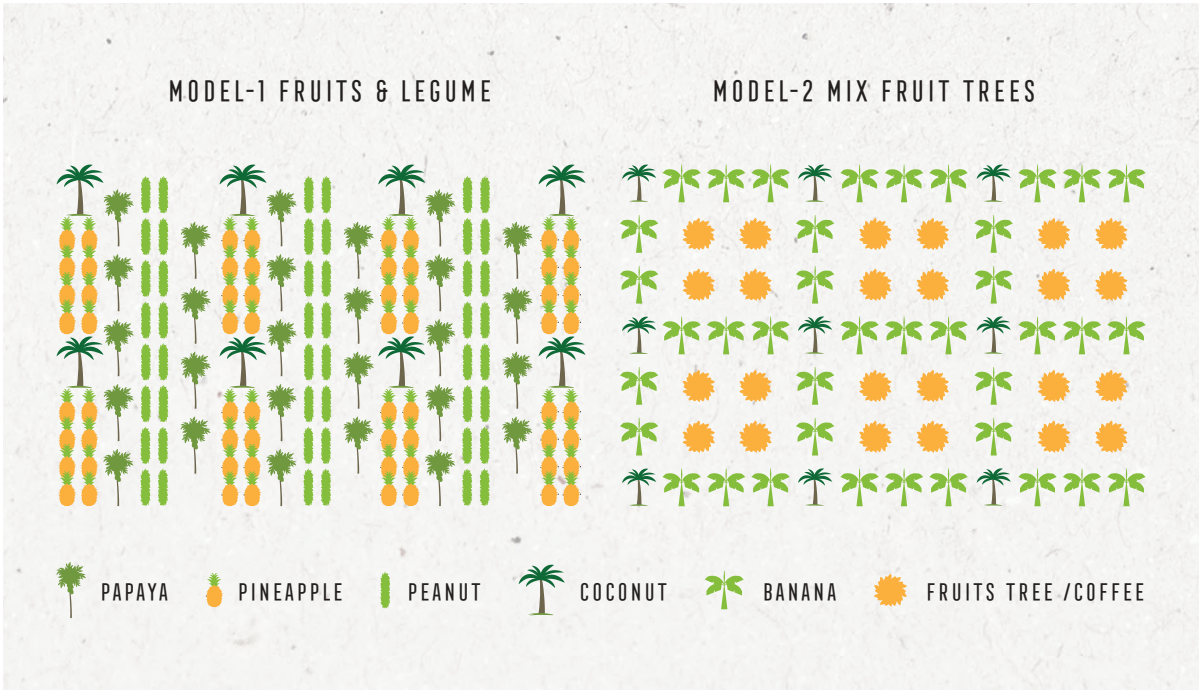


Figure 18 — Examples of Mixed cropping models involving coconut trees
Source: https://openjicareport.jica.go.jp/pdf/12283446_02.pdf

Figure 19 — Example of an agroforestry system that includes coconut trees, with nuances on light needs
Source: World Agroforestry Center - http://www.worldagroforestry.org/

In any case, intercropping or mixed cropping with coconut, suitability/compatibility of intercrops or mixed crops with coconut needs to be observed so as to avoid competition with coconut for soil moisture during stress period, incidence of sunlight, infestation of pests and occurrence of diseases. The crops selected for mixed-cropping should preferably be shade-tolerant since at later stages of coconut growth sunlight may be prevented from efficiently penetrating the coconut canopy to reach the below canopy crops.

PRE-PLANTING CHOICES

KEY POINTS SUMMARY

Bad choices before planting coconut would always result in losses. It is therefore important to carefully consider the choices relating to:

- **Location of the plot:**
  In a well-drained, preferably sandy soil and close to a water source, with sufficient light intensity
- **Planting material:**
  Use mature, healthy, cured and decontaminated coconut seeds
- **Varieties to plant:**
  Plant either tall, dwarf or hybrid coconut varieties depending on needs and preferences
- **Seed treatments:**
  Coconuts do not always require pre-planting treatments except when the selected seednuts had a history of fungal and insect pest attack. To decontaminate the seednuts, dip them into a 0.01 or 0.02 M potassium nitrate and sodium carbonate or copper oxychloride solution prior to sowing on a nursery bed
- **Irrigation methods:**
  Both drip and basin irrigation methods are acceptable. Perform regular irrigation of the coconut seed nursery or final field plot to supplement otherwise insufficient rainfall
- **Associations:**
  Depending on the desired production system, intercrops can be of any type (e.g. legumes, cereals or other trees such as coffee and tea). Mixed cropping models involve coconut with legumes and fruits or coconut in agroforestry mixtures with other tree plants.

Note that the impacts of any wrong selection may sometimes be exhibited several years after planting leading to massive losses.

3

PREPARING THE PLOT

3.1. LANDSCAPING

3.1.1. DRAINAGE

On fields that remain waterlogged through a greater part of the year, establish drains by digging deep canals (90 cm wide × 90–120 cm deep) to drain the water out of the field.

Cut drains between alternate rows of palms and, in extreme cases of permanent waterlogging, cut drains next to every row.

3.1.2. WINDBREAKS

Windbreaks protect the coconut crop from wind damage, reduce soil erosion, prevent soil from extreme dryness and provide economic benefits such as using material from the "live fence" for livestock fodder (Brandle et al., 2004). Plant hedge grass and trees (live fence) along the windward borders of the coconut farm. Either: (i) plant a single row of trees intertwined with hedge grass as a windbreak for a small farm; or (ii) plant hedge grass, a row of medium sized trees and a row of large sized trees along the windward border of a large sized coconut plantation.

3.1.3. FIREBREAKS

Establish and maintain a 4–5 m wide road or passway just along the perimeter of the farm to act as a firebreak.

3.2. WEED MANAGEMENT

At the plot preparation stage mechanical ploughing of the entire field would suffice to remove actively growing weeds prior to coconut palms transplanting. Any tillage system (ploughing, digging, raking or forming mounds) that effectively controls actively growing weeds may be applied. Weeds can also be controlled by chemical methods - applications of herbicides can be made according to manufacturer's usage recommendations.

3.3. SOIL PREPARATION

Coconut plant's growth can be impeded by physical soil constraints such as subsoil hard pans. When this is the case, use a chisel plough to break up any subsoil hard pans in a compacted soil selected for coconut field establishment. An ordinary plough can be used on a non-compacted soil. Ploughing should be done at the beginning of the rainy season when the soil is moist but not wet. Dig planting holes (1 × 1 × 1 m) according to the layout plan (see sections 2.5 and 4.3). Separate the topsoil from the bottom soil by heaping the different types on opposite sides of the hole.

3.4. SOIL AMENDMENTS PRIOR TO PLANTING

3.4.1. MANURE

Mix the topsoil from the planting hole with farmyard manure or compost at a ratio of 1:1 or as may be dictated by local soil conditions and availability of manure in the area. Fill the planting hole with this mixture to about 50% of its volume. Adding manure or compost helps to add organic matter into the planting hole, which in addition helps to supply important nutrients such as nitrogen, phosphorus, potassium, and calcium upon decomposition. These organic resources will help improve other physical and chemical properties of the soils around the plant to be established. Under alkaline conditions, decomposition of organic resources produces acidity that may help reduce the pH to more ideal ranges.

3.4.2. DOLOMITE/GYPSUM

Apply dolomite (or agricultural lime) to acidic soils (pH < 6.5) that are deficient in calcium, at a rate of 1 kg per planting hole. Apply gypsum ($CaSO_4$) when the pH is higher that 6.5 and the soil is calcium deficient (Osayande et al., 2020).

In soils with both high calcite (calcium carbonate) content and high pH (pH > 7.5), apply regularly all nutrients that are usually less available in high pH, calcite-rich soils, such as phosphorus, iron and zinc as a means of ensuring sufficient nutrient supply to coconut plants. This is because calcium carbonate provides a good pH buffering capacity such that all added acidifying chemicals may be consumed without noticeable changes in soil pH.

3.5. TRANSFORMATION OF AN EXISTING PLOT

Remove old unproductive plants in stages by dividing a farm of 1 ha into 4 or 6 subplots over a period of 4–6 years. Prepare planting holes as explained in section 4.

Attend one subplot each year so that in each year of the transformation process, at least one subplot has nut-bearing palms.

PREPARING THE PLOT

KEY POINTS SUMMARY

- **Landscaping**

  If land is water-logged, establish drains by digging deep canals (90 cm wide × 90–120 cm deep) to drain the water out of the field. Establish windbreaks to protect the coconut crop from wind damage, reduce soil erosion, and prevent soil from extreme dryness.

- **Weed management**

  Perform thorough ploughing of entire field to discourage weeds. Also apply permitted herbicides to control weed growth.

- **Soil preparation**

  Ploughing should be done at the beginning of the rainy season when the soil is moist but not wet.

- **Soil amendments prior to planting**

  Add manure by mixing it with the topsoil from the planting hole with farmyard manure or compost at a ratio of 10–15 kg soil to 10 kg manure.

  Adjust low soil pH by adding dolomite (or lime). Apply gypsum when the pH is near neutral (6.5 to 7.5) but calcium deficient

- **Transformation of an existing plot**

  Remove old unproductive plants in stages by dividing a farm of 1 ha into 4 or 6 subplots over a period of 4–6 years and attend one subplot each year so that in each year of the transformation process, at least one subplot has nut-bearing palms

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PLANTING COCONUT

4.1. TIMING

Transplant coconut seedlings at the onset of the main rainy season or 1 month before the onset of rains if supplemental irrigation is available. Select 1-year-old seedlings (with at least six leaves and a collar level girth of about 10 cm) for transplanting.

4.2. DENSITY

Planting density depends on the layout system (spacing) used (see section 4.3 for layout options; Fernando and Bandaranayake, 2010). If a square system is followed, plant density will be about 173 palms per hectare. The triangular, single hedge and double hedge layouts will result into slightly more trees per hectare (about 198, 220 and 280 palms per hectare), respectively. These indicative spacings are subject to variations based on the coconut varieties under consideration. Wider spacings and thus lower densities, such as those attainable by the square layout, are more suitable and recommended for tall varieties due to their naturally larger fronts and canopies while other layouts, which lead to higher densities per hectare, are more suitable for dwarf and hybrid coconut varieties.

4.3. PLANTATION LAYOUT

— Adopt contour terracing or bunding layouts to mark the lines and planting hole positions when the field is on sloping and undulating terrain.

— Planting can follow the triangular, square, single hedge or double hedge systems as shown in Fig. 20.

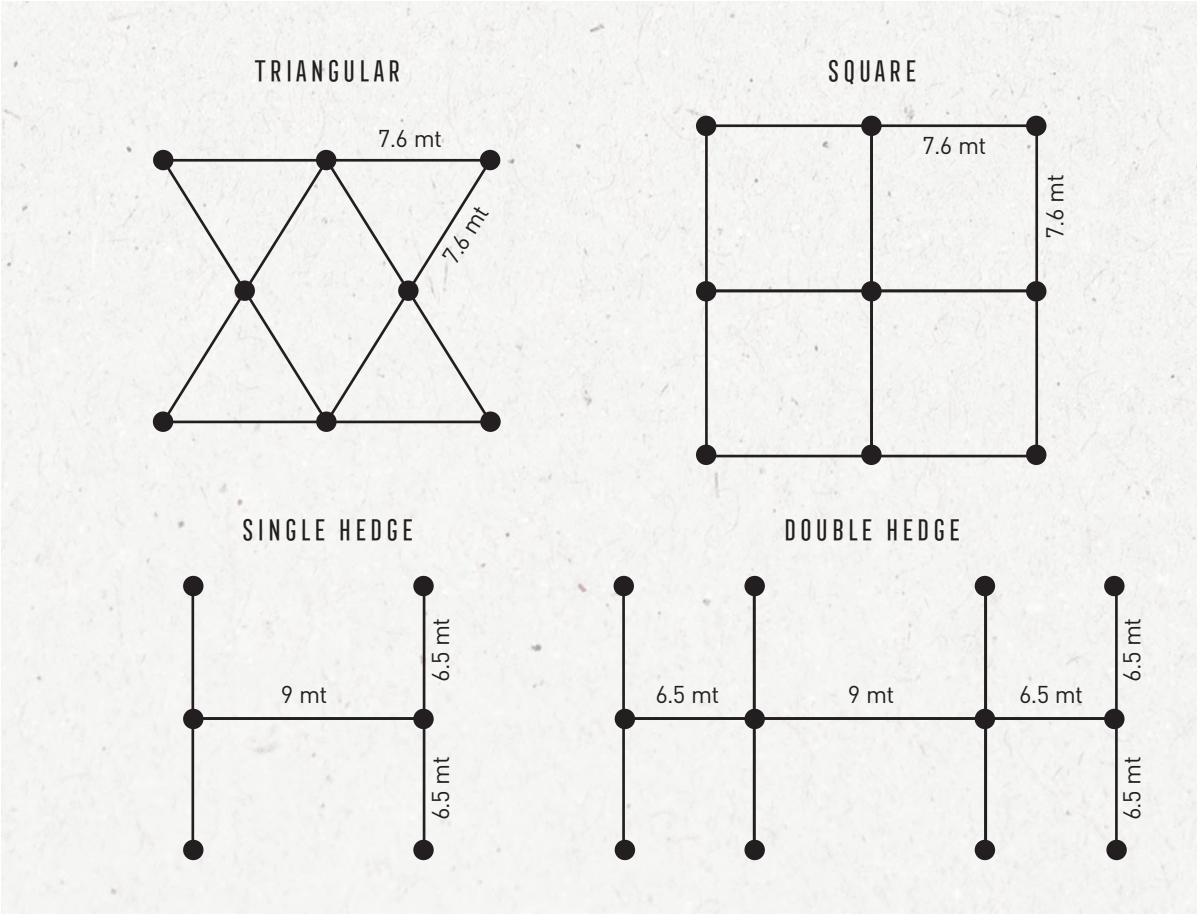


Figure 20 — Sketch of coconut plantation layouts

4.4. METHOD

- Fill the planting hole (1 × 1 × 1 m) with a mixture of topsoil and manure to about half the size of the hole, then place the seedling at the centre of the half-filled hole. Where manure and/or organic fertilizers are unavailable, inorganic fertilizers (especially phosphorous fertilizers) can be mixed and placed slightly below the planting depth in the planting hole (see section 5.2 for application rates of inorganic fertilizers). Use the bottom soil heaped on one side of the hole to fill the remainder of the planting hole until the entire nut is covered by soil.
- Press the soil firmly down around the seedling to prevent it from being blown out by wind.

PLANTING COCONUT

KEY POINTS SUMMARY

- **Timing**: Transplant coconut seedlings at the onset of the main rainy season or 1 month before the onset of rains if supplemental irrigation is available
- **Density**: If a square system is followed, plant density will be about 173 palms per hectare. The triangular, single hedge and double hedge layouts will result in about 198, 220 and 280 palms per hectare, respectively.
- **Plantation layout:** Planting can follow the triangular, square, single hedge or double hedge systems as shown in Fig. 20.
- **Planting Method:** Fill the planting hole with a mixture of topsoil and manure to about half the size of the hole, then place the seedling at the centre of the half-filled hole. Fill the remainder of the hole with bottom soil and firm the soil around the plant by pressing it down

IMPROVE WATER RETENTION OF SOIL

1. Increase the **organic matter content** and maintain the **lumpy texture** of the soil.
2. Reduce loss through evaporation by **covering** the soil with **mulch**.
3. **Hoe** the soil surface to break up the crust that contributes to water evaporation.

MANAGE LAND PARCELS TO REDUCE THE WATER REQUIREMENTS

1. Install **wind breaks** to reduce evaporation and produce a bedding.
2. On flat ground, arrange the surface to foster the **infiltration** of water.
3. On sloping ground, arrange the slope to **slow run-off**.

REDUCE WASTAGE OF IRRIGATION WATER

1. Roughly estimate the **soil humidity** (the soil water content).
2. **Adapt input** strictly to the needs of the plant, on the basis of its state of growth and the crop densityand apply water close to the root system.
3. Adapt the surface areas to be irrigated to the water resource available and use the most **efficient technique** to avoid over-exploiting this resource (sustainable water management). Strategically capture and store rainfall water during high intensity precipitation events

PLANTING COCONUT

DIVERSIFY AND PROTECT WATER RESOURCES

1. To avoid water loss, carefully **maintain equipment** and irrigation systems (clean filters, channels and drippers, replace worn or defective items).
2. Diversify and exploit **different water sources** (including rain water and water used to wash fruit and vegetables); making sure that water contaminated with microbes (faecal contamination) or hazardous products is not used. Never use used domestic waste water: it contains bacteria that are dangerous to man.
3. **Protect** wells from all pollution (organic or chemical) and ensure that watering places and wet areas (ponds, pools and creeks) are kept **clean**.

To know more: browse the COLEAD brochures on the subject

5

MANAGEMENT OF COCONUT

5.1. WATER MANAGEMENT

DRAINAGE

Coconut does not tolerate waterlogged conditions. While it needs enough water for its growth, it does not tolerate flooded conditions because it retards growth and root activities. Under prolonged exposure to flooded or saturated conditions, coconut shows symptom of stunted growth and yellowish leaves. Drainage systems that may include deep water drainage canals (90 cm wide × 90–120 cm) or controlled drainage structures should be constructed or installed to remove excess water and potential salt accumulation from the field. Controlled drainage provides better control of the amount of water that is removed, avoiding overdraining the fields as this may be the case in open ditch canals.

Figure 21 — Example of a structure installed on a main canal to control movement of water from the field
Source:https://content.ces.ncsu.edu/controlled-drainage

IRRIGATION AND SOIL MOISTURE CONSERVATION

Akin to the challenges of climate change, most coconut fields may face shortage of water and hence there is a need to irrigate. Water is a limiting resource in most plantation settings and thus must be used wisely to attain maximum water use efficiency (WUE) and avoid wastage of this precious resource. Water use efficiency (WUE) represents a given level of biomass or grain yield per unit of water used by the

crop. Maximum WUE is attained when a small amount of water is used to produce more biomass and harvestable parts of the plant, coconut in this case. Water added through irrigation must be properly managed to ensure better water use efficiencies. Research shows that it is possible to increase Water Use Efficiency (WUE) by 25 to 40% through soil management practices that involve tillage and that WUE can be increased by up to 25% by modification of the plant nutrient management practices (Hatfield et al., 2001). Generally, all soil management practices that increase the soil water holding capacity, improve the ability of roots to extract more water from the soil profile. Also decreasing leaching losses could positively influence the WUE. For instance, drip irrigation (both surface and sub-surface) can attain a high degree of WUE. This technique drops just enough water within the root zone, avoiding unnecessary water waste through percolation outside the root zone. Water that is applied in the area can be most efficiently consumed. However, its expansion and in-field maintainance is usually costlier especially in large scale plantation agriculture such as that of coconut. Although other methods such as sprinkler or open ditch irrigation techniques are rather less costly, they expose the water to evaporation which leads to increased water losses (between 10 and 30%) of the supplied water, hence significantly reducing the WUE.

- Irrigate during in-season dry spells and dry months of the year to improve palm growth, fruit setting, size and copra content.
- **For drip-irrigation**, open four pits of 30 × 30 × 30 cm on opposite sides of a palm trunk, place drippers in each pit and allow them to drip water 30 cm below the surface. Cover the drip irrigation pits with coir pith to prevent excessive evaporation. Allow 45–65 l/palm per day (Figure 22).

Figure 22 — Drip irrigation

— *For basin irrigation*, create basins of about 1.8 m radius around each palm and interconnect the basins using main and subcanals (Fig. 23), using the canals to allow water to reach every palm tree.

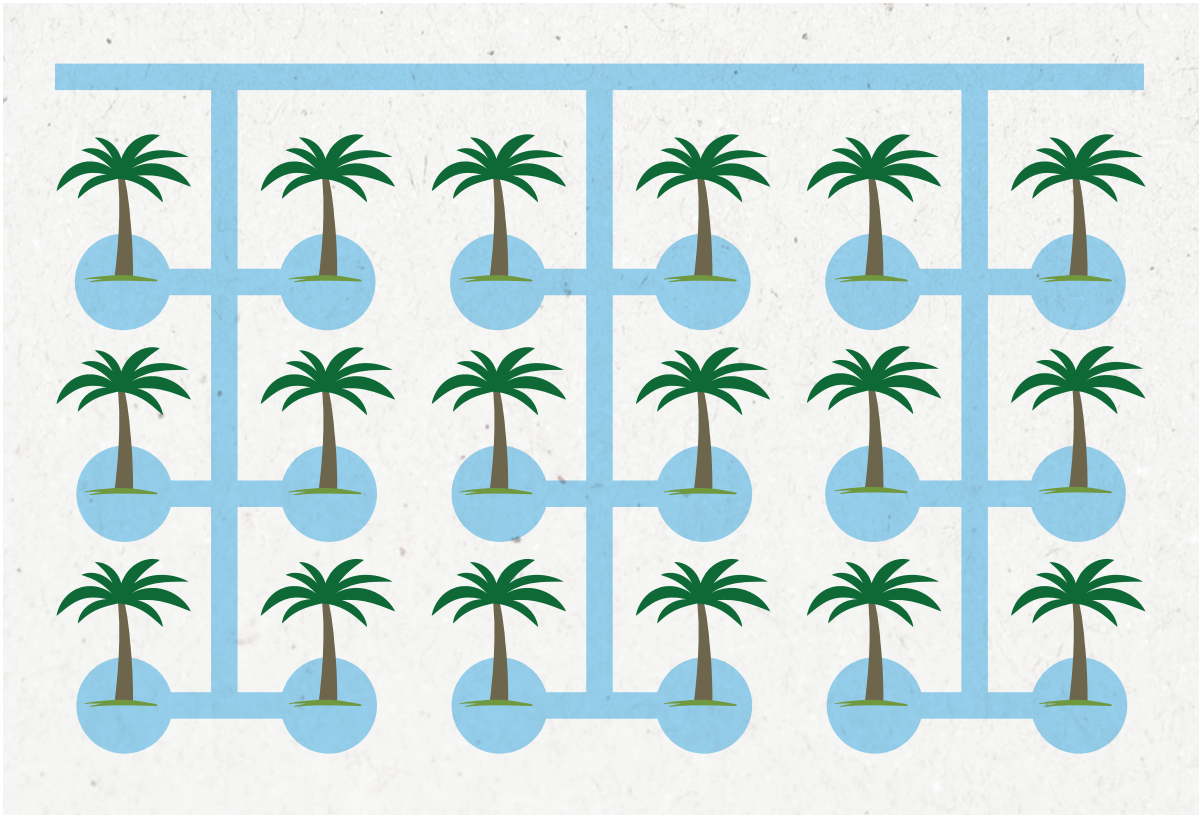


Figure 23 — Basin irrigation of a coconut plantation

5.2. FERTILIZERS

Sustainable coconut production incorporates the idea that natural resources should be used to generate increased output and incomes, without depleting the natural resources. Part of the solution is the correct application of integrated Soil Fertility Management (ISFM). It refers to "a set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions in aim of maximizing the agronomic use efficiency of the applied nutrients and improving crop productivity". ISFM seeks that all inputs are managed following sound agronomic practices' (Vanlauwe et al., 2010). The conjunctive use of organic and inorganic sources improves soil health and helps in maximising production as it involves utilisation of local sources and, hence, turned to be rational, realistic and economically viable way of supply of nutrients.

The ISFM targets different sources of fertilizers including inorganic inputs, organic resource management, such as crop residues, manure, compost and other types of organic wastes, next to rotation or intercropping with legumes and use of plant growth promoting micro-organisms.

Appy fertlizers using the 4R strategy by targetting the right source, right rate and right timing of nutrient inputs, at the right placement.

An example for coconut is presented by applying a multi-nutrient inorganic fertilizer N+P+K+Cl+S+B (14% N-5% P_2O_5-20% K_2O, with 15.5% Cl, 4.5% S and 0.02% B) and organic fertilizer sources at different ratios based on the weight of the tree (IF+OF at 1+0; 1+2; 2+4; 4+2 and 4+4) (Magat et al. 2009).

Potassium is required in large quantity compared to nitrogen and phosphorus (Fig. 24). When applying fertiliser, for example, in the first year the recommendation is for 135g of potassium, 50g of nitrogen and 40g of phosphorus. Therefore, the amounts of fertiliser to be added can be calculated from these recommendations. Note that the amounts to replenish depend on the initial natural nutrient status of the soil.

Table 2 — Overview of general practices of 4R strategy

RIGHT SOURCE	RIGHT RATE	RIGHT TIME	RIGHT PLACEMENT
• Measured or estimated nutrient content. • Known mode of action For example use Ammonium based formulation, Potassium or organic manure of cattle, goat, chicken	Field specific, the rate is set considering the unique factors in each field. E.g. Apply N, P, K, Cl, S and Mg using annual soil test Or Follow provisional guidelines based on soil and crop to meet sufficiency level	• Move application timing closer to period of highest demand E.g. Apply P at planting	Side banding Broadcasting and incorporation in the soil Fertigation for nutrients such as N, and K
	Rate optimized for subfield variation	• Multiple applications to synchronies timing with crop demand and growing conditions. Apply fertilizers every six months in the split application ½ at the start of the rainy season and ½ six months before the end of the rainy season	

Source: https://fertilizercanada.ca/wp-content/uploads/2019/06/4R-Guidance-Tables.pdf

IMPROVE SOIL FERTILITY

— Apply **rational inputs** of **organic manures** and **minerals** considering dynamic crop needs and seasonal balances to offset losses arising from harvesting.

— Opt for **associations** that are beneficial to cultivated plant nutrition (development of bacteria and fungi on roots, certain bacteria fixing nitrogen from the air in the soil).

— Adopt **sustainable agricultural practices** that protect the soil and foster microbial life. Consider the practices of integrated soil fertility management (ISFM).

PROTECT SOIL FERTILITY

— **Avoid salinisation** of the soil due to irrigation with salt water and the excessive use of certain forms of fertiliser such as potassium chloride (KCl).

— **Avoid soil loss through erosion**. Retain trees in cultivated land parcels to exploit deep mineral resources.

— **Avoid soil compaction** through trampling or the passage of machinery that destroys the structure and prevents air and water circulating.

OPTIMIZE SOIL FERTILITY

— Before applying the appropriate inputs, **estimate the need for nutrients** in the soil by observing plants indicative of low fertility and through laboratory plant and soil **analysis**.

— **Avoid** all **shortages** and **over-applications** of mineral and organic inputs since this favours the development of crop pests (white flies, leaf diseases).

— **Combine mineral inputs with organic inputs** (combine forms of nutrient inputs to avoid excess and leaching) consider the 4R principles on nutrient stewardship to optimize nutrient use efficiencies.

To know more: browse the COLEAD manuals on "**soil management**" and "**organic production**".

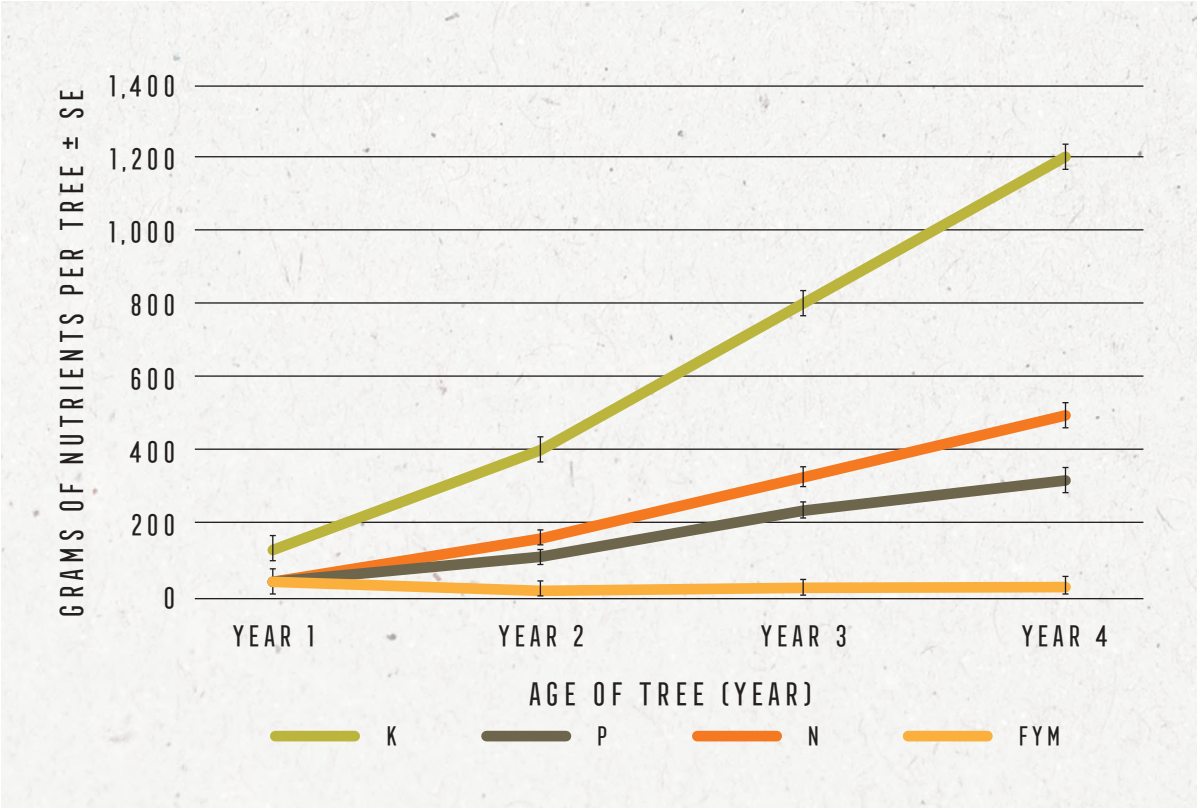


Figure 24 — Changing of nutrients needs of coconut plants during the first years (gram/tree/age of coconut plant) - Note that farmyard manure is expressed in kg/tree

5.2.1. SOIL ANALYSIS

Sample soils for analysis to diagnose the type and quantity of available plant nutrients. Use soil analysis results to determine the requirements of important nutrients such as potassium, calcium, magnesium, phosphorus and nitrogen for optimum palm growth.

Organic fertilisers:

- Apply organic manure (farmyard manure, compost) at a rate based on annual soil test per palm per year, during or just after the onset of rains.
- Where basin irrigation is used, apply manure in the basin dug around the palm tree and cover it with soil.
- Application of manure by broadcast method must be followed by ploughing to incorporate the manure into the soil as this minimizes nutrient losses due to volatilization.

Inorganic fertilisers:

- Quantities of major nutrients (nitrogen, phosphorous, potassium) to be applied to the palm field should be based on soil analysis results.
- Follow provisional guidelines based on soil and crop information to meet sufficiency level.
- Apply fertilizer by either broadcast and incorporation, placement, fertigation, or using circular trench method.

5.3. GROUND COVER

5.3.1. COVER PLANTS

A wide range of annual and perennial crops can be planted to provide ground cover of the coconut field.

Use ground cover species with high biomass like cowpea, (*Vigna unguiculata*), sun-hemp (*Crotalaria juncea*), dhaincha (*Sesbania aculeata*), wild sun-hemp (*Crotalaria striata*) and mucuna (*Mucuna pruriens*).

Alternatively, use the interspace in the field to plant traditional annual food crops such as corn, upland rice, mung bean, cassava and vegetable crops such as ginger, pepper and eggplant.

THE COVER CROPS WILL HAVE MULTIPLE FUNCTIONS, INCLUDING

- Protect the soil (avoid erosion in the rainy season and conserve moisture in the dry season)
- Limit the development of weeds
- Improve soil structure through root development and biomass (organic matter)
- Provide a greater quantity of nitrogen (legume cover crops) to the orchard trees (subject to the presence of nodules, otherwise nitrogen will be taken away)
- Increase the biological life of the soil
- Favour biological control by conservation

Source: translated from «Fiche n°2: les plantes de couverture sous verger»:
https://bsvguyane.wordpress.com/cultivons-autrement-exemples-locaux-de-techniques-agro-ecologiques/

5.3.2. MULCHING

Apply disease-free mulch over the irrigation basins for each plant. Mulching material can be coconut husks, dry leaves or coir pith. Alternatively, bury the coconut husks or coir pith in the irrigation basins around the palm tree or in the interspaces to prevent loss of irrigation water through evaporation from the soil.

5.4. WEED MANAGEMENT

5.4.1. CULTURAL CONTROL OF WEEDS

— Apply mulching (see section 5.3) to suppress weeds around the palm basins.
— Use cover crops to discourage weeds in the interspace (see section 5.3).

5.4.2. CHEMICAL CONTROL OF WEEDS

Use permitted herbicides such as diuron, glyphosate, or paraquat according to manufacturer recommendations and by using personal protective equipment (Senarathne and Perera, 2009) to control weeds.

5.4.3. MECHANICAL CONTROL OF WEEDS

— Remove weeds mechanically around the irrigation basin, e.g. using a hand hoe, digging and tillage in case of perennial weeds to remove the underground parts of weeds,
— Trim grasses in other parts of the farm using a slasher.

5.5. PRUNING

— Using a pruning saw, cut away any fronds that have turned brown, have died or look unhealthy.
— Cut at the base of the frond's stem, only 1–2 cm away from the palm's trunk.
— Dip the pruning saw in a detergent to sterilize it each time after removing a diseased frond.
— Some of the climbing techniques for maintenance and pruning include:

- **Walking Technique:** you can either put the balls of your feet or the soles of your feet in front of you on the trunk and then wrap your arms around the tree. Then climb the tree with your right arm up, right leg up then left arm up, left leg up and continue to the top. Always set up and use safety equipment.
- **Hopping technique,** this technique is easier, you need thick rope to hold you, around the legs. To do it, first mount the tree with your arms around and the soles of your feet in front then reach higher with your arms then "jump" up and repeat. Always set up and use safety equipment.

5.6. FRUIT SETTING

Coconut is a monoecious species with male and female flowers on the same inflorescence. Flowering occurs continuously and, with the help of insects and wind, the male flowers pollinate the female flowers. Once female flowers are pollinated, they become coconuts after a period of 10 months. Chemical floral induction is a not common practice in coconut (Inpeuy et al., 2011).

Fruit setting happens naturally and continuously in coconut when temperatures are favorable (27–30°C) and moisture is sufficient. Apply 150–450 ppm of gibberellic acid to increase fruit set (Carlos et al., 1976) in coconut palms.

6

PEST MANAGEMENT

6.1. IPM PACKAGE FOR COCONUT

An integrated pest management (IPM) package for coconut is composed of cultural, mechanical, biological and chemical control methods. The latter is used when other methods have failed to reduce populations to non-economic levels. Attention should be given to controlling the pests and diseases by enhancing environments for the natural enemies, including diversification of the coconut ecosystem (Kalidas, 2012).

6.2. CULTURAL CONTROL

- **Selection of matured nuts for seed** – Start with healthy seeds to ensure vigorous plants.
- **Host plant resistance** – Use resistant varieties like East Africa Tall and Malayan Green Dwarf (Quaicoe et al., 2009).

COMPANY/ SEED SOURCE	CULTIVAR	RESISTANCE OR TOLERANCE		
		COCONUT MITE	BUD ROT	LETHAL YELLOWING
INDIA	Chowgart Dwarf	+		
SOUTH EAST ASIA	Malayan Yellow Dwarf		+	+ but susceptible to the LY of Tanzania and Ghana
	Ball Tall			
	Malayan Yellow Dwarf x Palu Tall hybrids			
WEST AFRICA	Malaysian Tall	+		
	PB 121 (West African Tall x Malayan Yellow Dwarf			
SOUTH EAST ASIA	Malayan Yellow Dwarf			+ but susceptible to the LY of Tanzania and Ghana
	Malayan Yellow Dwarf Malayan Yellow Dwarf x Panama Tall			+

- **Spacing** – Choose wide spacing when intercropping with tree crops for controlling fungal and viral diseases (Proud, 2005).
- **Weeding** – Maintain the coconut field free from weeds at all times.
- *Field sanitation* – To reduce pest infestation remove and dispose of (by burying) affected plant parts such as leaves.
- **Intercrop coconut** with crops like cocoa, banana, pineapple, cassava, mucuna and *Gliricidia*.
- **Reasoned fertilisation** – Apply organic manure and micronutrients like boron to reduce the severity of pests and diseases. Apply mycorrhiza and plant growth promoting rhizobacteria like *Trichoderma* and *Pseudomonas fluorescens.*
- **Mulching** – Keep the soil covered with live mulches all year around to control weeds and conserve soil moisture.

6.3. MECHANICAL CONTROL

Trap insects like red palm weevil and rhinoceros beetle using pheromone traps if available. Use a sweep net and sticky cards to control small flying insects such as leaf and plant hoppers, the vectors of coconut lethal yellowing disease (Satyagopal et al., 2014).

6.4. BIOLOGICAL CONTROL

Release and conserve predators and parasitoids of detrimental insects on coconut. Apply formulations of entomopathogens (see section 7).

6.5. CHEMICAL CONTROL

Apply natural pesticides such as cloves, azadirachtin, garlic, pyrethrum and when necessary, use new generation synthetic pesticides. Alternate the active ingredients so as to avoid development of pests resistance to pesticides. Spray selective insecticides only when needed by alternating and avoid broad spectrum insecticides. When using plant protection products, ensure compliance with local, national regulations, and ensure compliance of pesticide residues with the market of destination.

COLEAD CROP PROTECTION DATABASE PROVIDES INFORMATION ON GOOD AGRICULTURAL PRACTICES

It was put online in 2018 and is in open access. To date, it is the only database of its kind to provide information specifically dedicated to supporting the horticultural sector in ACP countries. The GAP data are obtained from a combination of sources, including COLEAD field PPP trials, PPP manufacturer data and scientific literature. The crop protection database brings together the MRLs set by the EU and 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, can be accessed on our website:
https://resources.colead.link/en/vue-substance-active-culture.

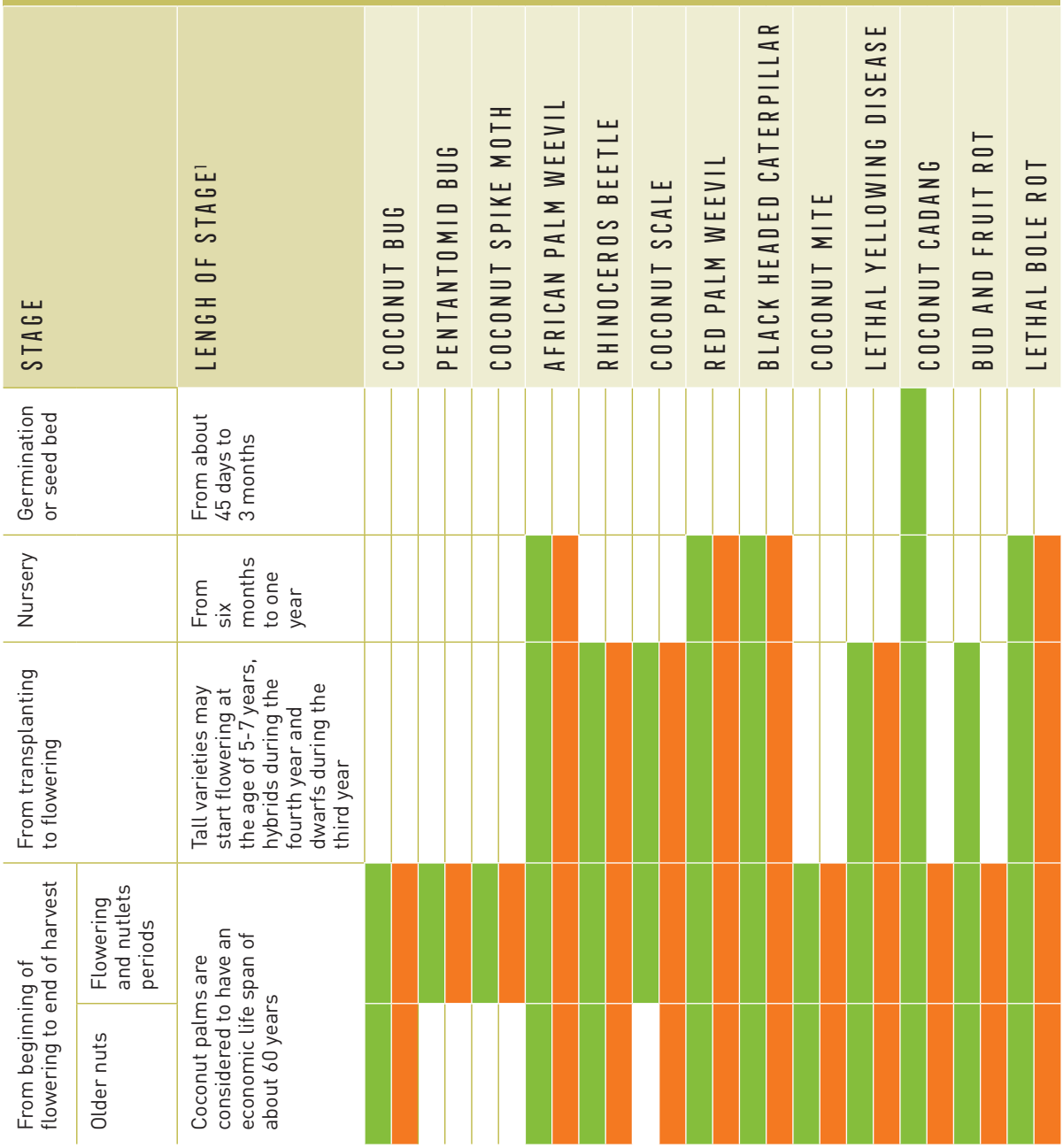
7

KEY PESTS AND DISEASES

SUMMARY OF KEY PESTS AND DISEASES AFFECTING COCONUT

APPEARANCE OF PESTS AND DISEASES IN TERMS OF THE PHENOLOGICAL STAGES OF THE PLANT

The presence of pest, disease or pathogenic agent is not always harmful to the crop. The following table shows the stages of cultivation during which crop enemies are potentially present and the stages during which their presence can do the most harm. It is especially during the latter stages that they must be monitored and controlled if necessary.



1. Length of stage will vary with (Tall, dwarf or hybrid), mode of production and enviornmental conditions

Periods during which pest or pathogenic agent is potentially present

Periods during which the apperance of a large numberss of pest or pathogenic agent can cause the greatest loss.

7.1. COCONUT BUG (*PSEUDOTHERAPTUS* SPP.)

DESCRIPTION/IDENTIFICATION

Adult *P. wayi* is reddish brown in colour but lighter on the under surface. The adults range in size from 12 to 14 mm long. They have a raised shiny black spot on the lateral side mid thorax. Their heads are extended horizontally with reddish eyes. The first three antenna segments are red, and the furthest segment is brown with a pale tip. Male antennae are cylindrical, slightly longer than the combined length of body and head. Female antennae are slightly shorter than combined length of body and head. Nymphs are red brown to green-brown in colour and have long antennae. Each nymph possesses reddish pink eyes and ocelli (except the second instars where eyes and ocelli are obscured). Their antennae are flattened laterally as opposed to those of adults which are cylindrical (Way, 1953; Brown, 1955; Egonyu et al., 2013).

Figure 25 — Adult
P. wayi - https://www.inaturalist.org/taxa/604846-Pseudotheraptus-wayi/browse_photos

PEST LIFE CYCLE AND BIOLOGY

P. wayi eggs are creamy in colour, oval-shaped, and smooth with size around 2mm long. They are laid singly on the plant at a rate of 2 to 3 per day, for a total lifetime fecundity of 74 – 100 eggs per female. Toward hatching the colour of the eggs changes to reddish brown and that takes about 6-8 days. Nymphs look like adults but lack wings. They are red brown to green brown in colour and have long antenna. There are five nymphal stages, and total development time of premature stages is 31 – 41 depending on temperature. Pre-oviposition period is 9 – 13 days (Way, 1953; Mitchell, 2000; Egonyu, 2014; CABI, 2022a).

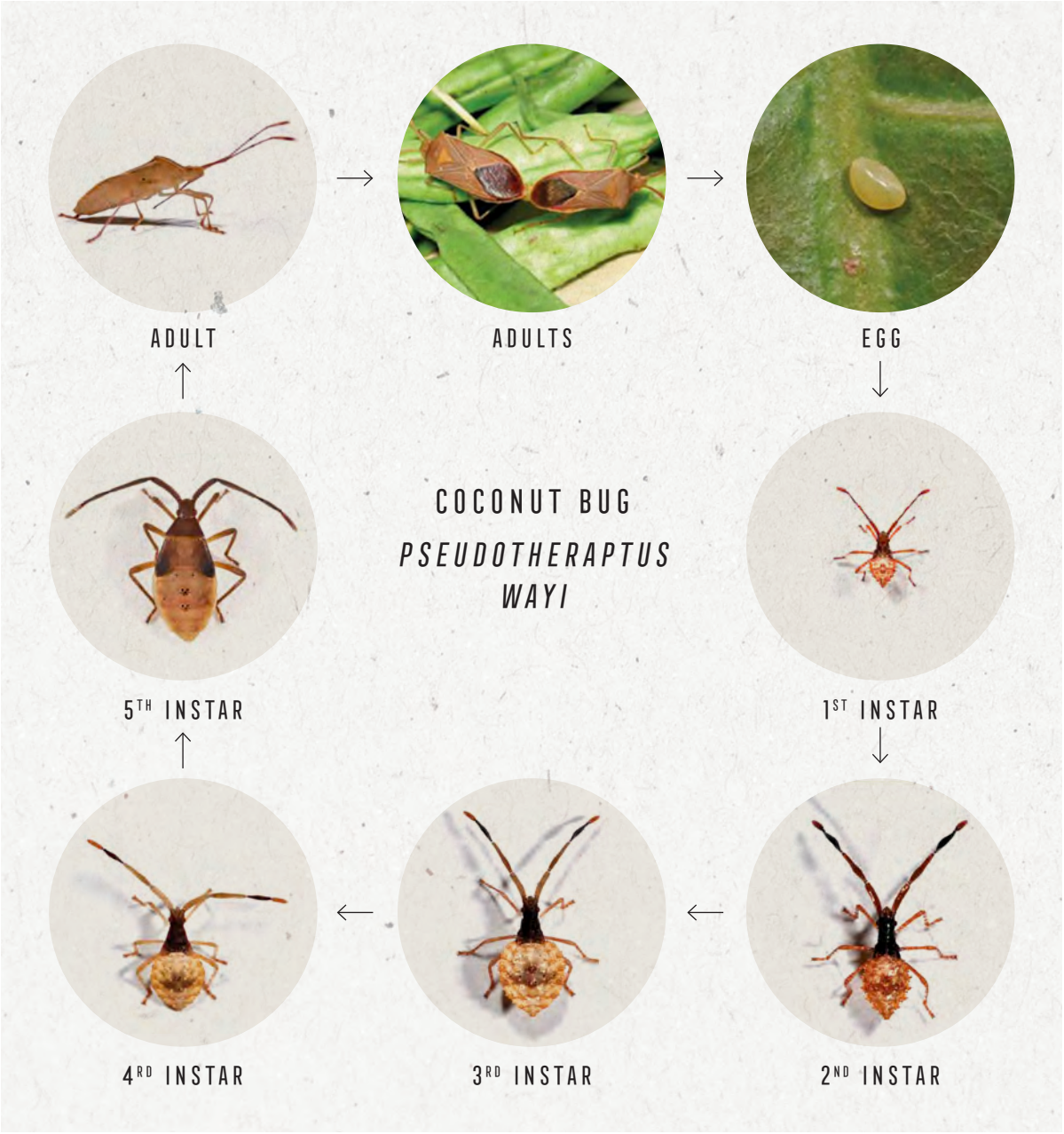


Figure 26 — Life stages of *P. wayi*
Source: https://doi.org/10.1673/031.013.9101

AFFECTED STAGES OF THE CROP

Young stems, leaves, inflorescences and fruits (CABI, 2022)

SYMPTOMS AND DAMAGES

Symptoms of damage due to attacks by sap sucking nymphs and adults include wilting and necrosis of young stems, leaves, inflorescences and fruits. These attacks cause premature fruit drop (Way, 1953; CABI, 2022a)

Figure 27 — Necrotic lesion leading to cracks on nut, dry out of inflorencenss caused by *P. wayi*
Source: https://infonet-biovision.org/PlantHealth/Crops/Coconut

IMPACT ON YIELD AND QUALITY

Infestation of coconut by *P. wayi* can result in more than 75% shoot damage, 98% flower drop at early flowering stage and 80% coconut yield loss. Their feeding also causes shrivelling of kernels, lowering their market value. (Way, 1953; Nyambo, 2009).

QUARANTINE ORGANISM

Yes (EPPO, 2022a).

FAVOURABLE CONDITIONS

Tropical and sub-tropical climate, with laboratory biological studies conducted successfully at 24°C and relative humidity of 80% (Egunyu et al., 2014). High infectivity of a similar species *P. devastans* was recorded at 22 – 25°C and relative humity of 75 – 75% (Fukunang et al., 2004; (CABI, 2022a).

SURVEILLANCE/MONITORING

Monitoring techniques for *P. wayi* are mostly experimental. For example, bright yellow masonite obstruction traps covered with a polybuthene sticky coating, palced at 20 m apart, can be used. Another method is the use of battery powered (A4 sized) sticky traps suspended between the rows of trees.

Use of trap crops like sunflowers and crotalaria capensis as monitoring technique is still rudimentary (Schoeman et al., 2010).

CULTURAL CONTROL

Maintain a healthy crop by pruning, mulching, weeding, intercropping and maintaining fire breaks (Peng, 2015).

BIOCONTROL

Introduce and conserve the predatory weaver ant *Oecophylla longinoda* in coconut fields (Way and Khoo, 1992). Collect nests of weaver from the wild to boost populations. Cut nests from a tree using a shear or secateur. Apply ash or dusts to your hands to avoid ants' bites. Place nests of ants of same colonies in plastic or paper bags and label them before transporting. When in coconut farm, hang and open the bags to let ants climb the trees freely. Do not mix nests from different colonies to avoid ants' fighting during transport and release. Try as much as possible to include nest with a queen (normally this nest has more ant trails and aggressive workers).

Protect weaver ants from the competing ants such as big headed ant *Pheidole megacephala,P. punctulate* and crazy ants *Anoplolepsis custodiens* by:

i. Connecting the canopies of neighboring palms/trees with wires or ropes so that the weaver ants can easily walk among trees searching for food thus avoiding enemy ants active on the ground. Maintain ground vegetation for enemy ants to forage (otherwise they will be forced to go up the trees and displace weaver ants).
ii. Providing ants with other sources of food during dry periods.
iii. Intercropping coconuts with plants favoured by weaver ants such as citrus, soursop, guava, and mango.
iv. Keeping bushes and trees that are hosts for weaver ants in the surrounding of coconut fields.
v. Reducing application of insecticides. (Nene et al., 2016; 2017 *).*

PARASITOIDS

Parasitoids wasps are highly diverse and specialized insects belonging to the order Hymenoptera found in the natural and human modified environment. They need the presence of hosts, particularly other insects, to feed, survive and reproduce. They lay eggs and their larvae hatch and feed on living host insects until they complete their life cycle and the host is eventually killed. They attack the various stages of the host insect: eggs, larvae, pupae and adults. In doing so, they are used as a biological control agent against insect pests in agroecosystems.

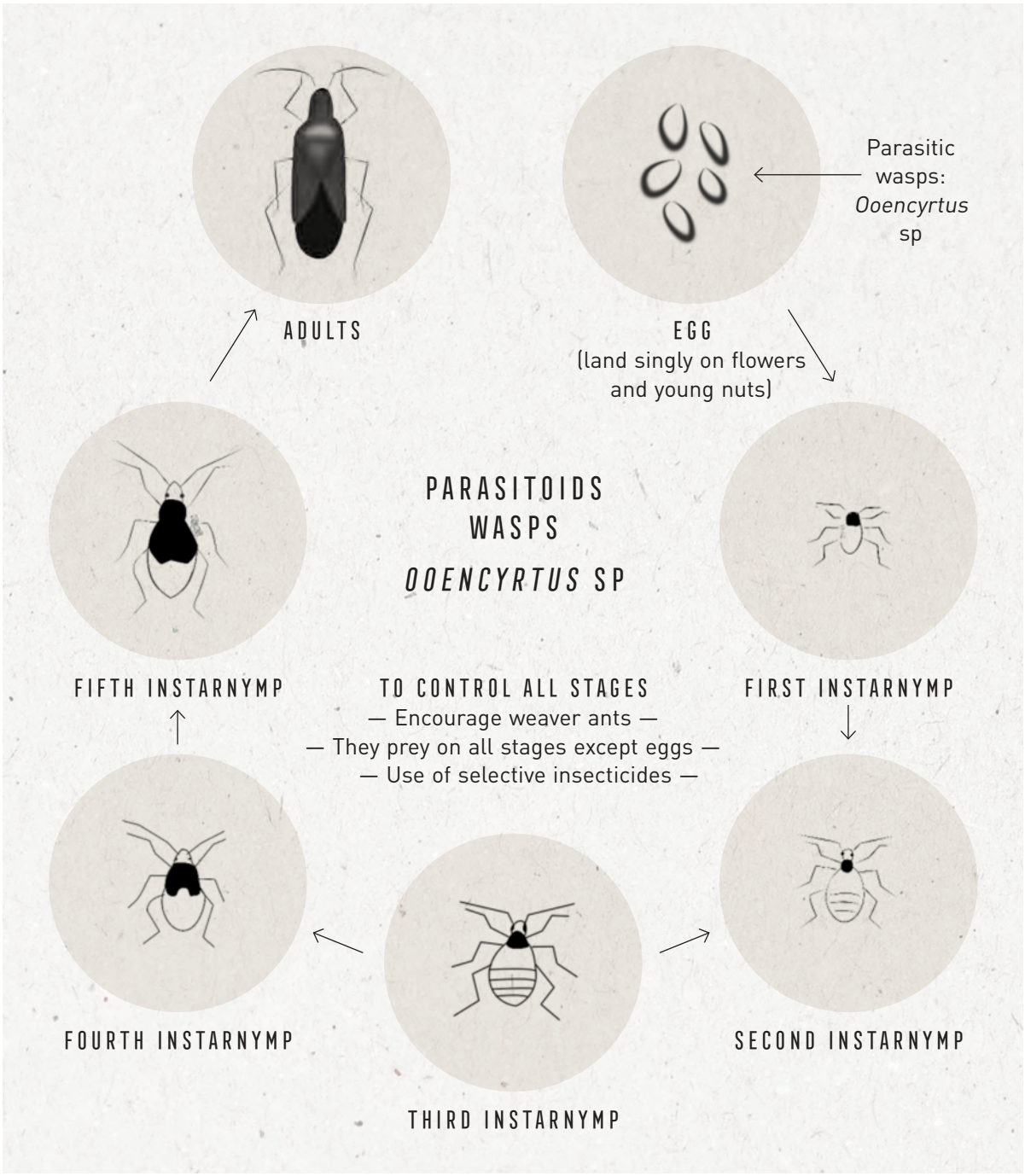


Figure 28 — Positioning of control methods in terms of development cycle of the pest

Figure 29 — African weaver ant - Jean Francois Vayssieres

Figure 30 — African weaver ants attacking *P. wayi* - Jean Francois Vayssieres

CONTROL WITH PLANT PROTECTION PRODUCTS

Apply selective and registered pesticide products approved by the country regulatory authority like Lambda-cyhalothrin (Schoeman et al., 2010; Abdulla et al., 2016).

OTHER CONTROL METHODS

No other distinct methods are available.

7.2. PENTATOMID BUG (COCONUT SPATHE BUG) - *AXIAGASTUS CAMPBELLI*

DESCRIPTION/IDENTIFICATION

Adult *A. campbelli* is dark brown bugs with yellow marks, about 15 mm long. The nymphs are white at first then orange with black markings (Tsasia and Jackson, 2021).

Figure 31 — *Axiagastus campbelli* - pestnet.org

PEST LIFE CYCLE AND BIOLOGY

Females lay white, barrel-shaped eggs in clusters on flowers, at the base of the fronds and sometimes on leaflets. Eggs hatch in 6-8 days, and the nymphs, moult four times before they become adults. They give out a strong unpleasant smell when held or disturbed. Egg to adult duration is about 45 days (Tsasia and Jackson, 2021).

AFFECTED STAGES OF THE CROP

Young fruits.

SYMPTOMS AND DAMAGES

Adults and nymphs insert long piercing mouthparts into young coconuts to suck sap. This feeding that is presumed to cause young nuts to fall, and those that remain become long and thin, without 'meat' and 'milk'. However, damage done by the bug is uncertain (Tsasia, H., Jackson, G. 2021).

IMPACT ON YIELD AND QUALITY

A minor pest (Hill, 2008). There is some loss of young nuts when populations are high and during outbreaks.

QUARANTINE ORGANISM

Yes (EPPO, 2022b).

FAVOURABLE CONDITIONS

Recorded from tropical of Papua New Guinea, Singapore and Solomon Islands (Tsasia and Jackson, 2021). Mean annual temperature of these locations rage from 20 – 31°C, and relative humidity of 70 – 90%.

SURVEILLANCE/MONITORING

Visual inspection of newly opened flowers, where the pest occurs in large numbers (Tsasia and Jackson, 2021). Inspection should be done weekly during flower initiation. Shake coconut branches to disurb the bugs. Once the bugs are disturbed they produce a special smell that can be indicator for their presence

CULTURAL CONTROL

No other distinct methods are available.

BIOCONTROL

Introduce and conserve the predatory weaver ant *Oecophylla smaragdina* in coconut fields (Way and Khoo, 1992; CABI 2022b). Collect nests of weaver ants from the wild to boost populations as explained in 7.1. Do not mix nests from different colonies to avoid ants' fighting and try as much as possible to include nest with a queen (normally this nest has more ant trails and aggressive workers).

Protect weaver ants from the competing ants such as big headed ant *Pheidole megacephala,P. punctulate* and crazy ants *Anoplolepsis custodiens* by:

i. Connecting the canopies of neighboring palms/trees with wires or ropes so that the weaver ants can easily walk among trees searching for food thus avoiding enemy ants active on the ground. Maintain ground vegetation for enemy ants to forage (otherwise they will be forced to go up the trees and displace weaver ants).
ii. Providing ants with other sources of food during dry periods.
iii. Intercropping coconuts with plants favoured by weaver ants such as citrus, soursop, guava, and mango.
iv. Keeping bushes and trees that are hosts for weaver ants in the surrounding of coconut fields.
v. Reducing application of insecticides

(Nene et al., 2016; 2017*).*

Introduce egg, nymph and adult parasitoids like the wasps, Trissolcus basalis and Trichopoda pennipes (Bartlett *et al.*, 1978; Waterhouse 1998)

CONTROL WITH PLANT PROTECTION PRODUCTS

The use of insecticides is not recommended because populations are normally very low and outbreaks are rare.

7.3. COCONUT SPIKE MOTH - *TIRATHABA RUFIVENA*

DESCRIPTION/IDENTIFICATION

The caterpillars are brownish grey with dark brown heads, up to 30 mm when fully grown. They have brown narrow forewings and broad light-yellow hindwings. Pupation occurs in a cocoon formed by debris (Lever, 1969; Jackson, 2021).

Figure 32 — *Tirathaba rufivena* - Pest and Diseases Image Library, Bugwood.org

PEST LIFE CYCLE AND BIOLOGY

A female moth lay up to 250 eggs either singly or in small groups at the base of the flower spike and leaf. Eggs hatch in about six days and go through five stages over the next month. Early stages feed on the male flowers; later stages bore into the female flowers causing them to drop either to the ground. Pupation occurs in a cocoon formed debris. Adults emerge after one to two weeks and live for up to ten days (Lever, 1969; Jackson, 2021).

Figure 33 — Life stages of the coconut spike moth (Salmah Yaakop, Centre for Insect Systematics)

AFFECTED STAGES OF THE CROP

Male and female flowers. Male flowers are preferred but female flowers are also attacked; one caterpillar usually destroys only one female flower (Lever, 1969; Jackson, 2021; CABI, 2022c).

SYMPTOMS AND DAMAGES

Webbing of inflorescence, signs of external feeding on growing point an inflorescence (CABI, 2022c). Caterpillars bore into the nuts that causes droppings which looks like gum or oozing out of the bored hole coming out of the nut. The infested nut when cut into longitudinal section the kernel shows brown stains at the site of boring.

Figure 34 — Nut halves showing brown staining at the site of boring and on the kernel
Source: coconutpests.org

IMPACT ON YIELD AND QUALITY

Tirathaba rufivena has very little, if any, effect on coconut production, despite its conspicuous damage to both male and female coconut flowers (Lever, 1969; Waterhouse and Norris, 1987). However, the pest can cause 100% damage of female flowers of young hybrid palm varieties e.g. Malayan Dwarf x West African Tall. Other reports indicate a loss of more than 20% of the nuts on a spike (Jackson, 2022).

QUARANTINE ORGANISM

Yes (EPPO, 2022c).

FAVOURABLE CONDITIONS

Warm topics

SURVEILLANCE/MONITORING

Use light traps placed in the field with a height of 150 cm from the ground e.g. Approximately two traps per hectare (Baadu et al., 2018).

Inspect plants for presence caterpillars amongst frass, silken threads, and decaying debris, at the base of the leaves. Cocoons containing the caterpillars occur among coconut leaves (Jackson, 2021).

CULTURAL CONTROL

No known cultural methods of controlling the pest.

BIOCONTROL

Introduce parasitoids like *Trichospilus pupivora*, *Apanteles tirathabae*, *Argyrophylax basifulva* and *Telenomus tirathabae*, *Venturia palmaris* (Lever, 1969; Jackson, 2021).

CONTROL WITH PLANT PROTECTION PRODUCTS

No other distinct methods are available.

OTHER CONTROL METHOD

No other distinct methods are available.

7.4. THE AFRICAN PALM WEEVIL - *RHYNCHOPHORUS PHOENICIS*

DESCRIPTION/IDENTIFICATION

Adults reddish brown in colour, with two reddish bands on the thorax. Adults are 40-55 mm long with a long snout. Grubs are whitish-yellow, legless, and oval in shape with a reddish-brown head. Fully-grown grubs are 50 to 60 mm long. The pupal stage is passed within a cocoon of vegetal debris made by the grub at the end of its development (Lever, 1969; CABI, 2022d; www.infonet-biovision.org).

Figure 35 — *Rhynchophorus phoenicis*
Pest and Diseases Image Library, Bugwood.org

PEST LIFE CYCLE AND BIOLOGY

The adults lay eggs in wounds in the stems of dying or damaged parts of palms. After hatching, the weevil larvae excavate tunnels in the trunk, feed on the shoot and young leaves. Sometimes the grubs feed on the terminal bud and kill the palm. The larvae of this palm weevil are edible. The insect completes its development in about 3 months (Lever, 1969; Gries et al., 1994; CABI, 2022d).

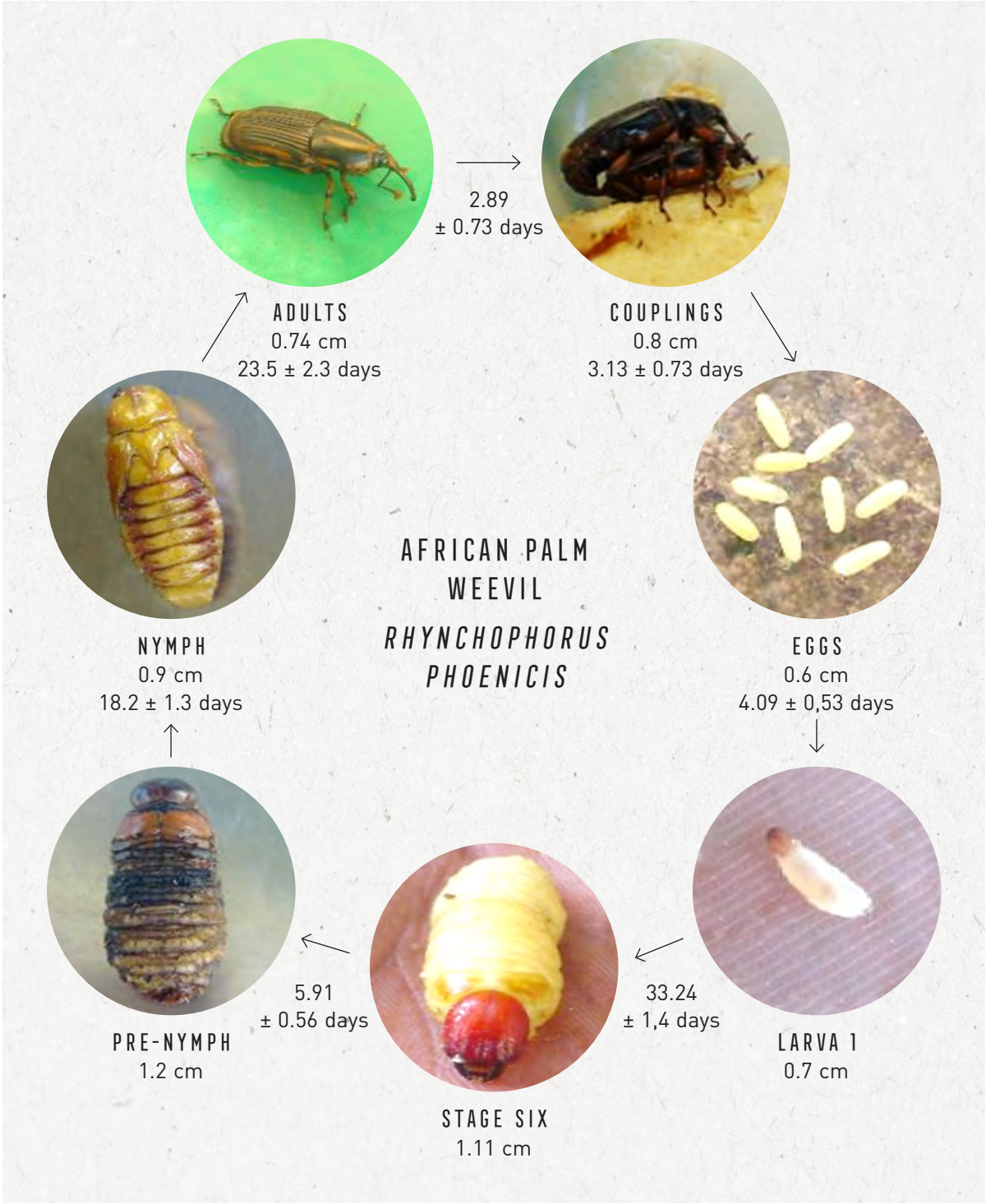


Figure 36 — Life cycle of laboratory reared *Rhyncophorus phoenicis (Gnanda, 2018)*

AFFECTED STAGES OF THE CROP

Young palms

SYMPTOMS AND DAMAGES

Yellowing of foliage, necrosis on flowers, mining of the trunks and leaf stems. Affected plant, emit an unpleasant and characteristic odour (Lever, 1969; CABI, 2022d).

IMPACT ON YIELD AND QUALITY

A serious pest of palms. Damage on spikes lead to few fruit set and if not managed 50% nut falling before they get matured may occur. The damage to nuts is not so serious and under less attack the losses is about < 10%. High infestation especially on Dwarf varieties due to its constricted flowers and compact crown leads to high losses (CABI, 2022d).

QUARANTINE ORGANISM

Yes (EPPO, 2022d).

FAVOURABLE CONDITIONS

Wet tropics (Lever, 1969; Baguma et al., 2019; CABI, 2022d).

SURVEILLANCE/MONITORING

Use plant volatiles to monitor both sexes of weevil, or to increase the effectiveness of pheromone traps that attract and capture male weevils. They include ethyl acetate, ethyl propionate, isobutyl propionate, ethyl butyrate, and ethyl isobutyrate (Gries et al., 1994).

CULTURAL CONTROL

Avoid wounds during plantation management. Adults are attracted to the odour of feeding sites and to injured palms, in which they lay their eggs.

Remove all heavily attacked, wounded palms, including those showing growth disorders.

Trap weevils using split palm trunks to divert weevils away from cultivated palms. Adults are attracted to the chemicals emitted from damaged wood. Burn trap- heaps frequently and replace them with fresh trap wood.

(Lever, 1969; www.infonet-biovision.org).

BIOCONTROL

No other distinct methods are available.

CONTROL WITH PLANT PROTECTION PRODUCTS

No distinct methods are available.

OTHER CONTROL METHODS

No other distinct methods are available.

7.5. RHINOCEROS BEETLE (*ORYCTES RHINOCEROS*)

DESCRIPTION/IDENTIFICATION

- *Oryctes rhinoceros* adults are dark-brown to black in colour and shiny, stout-looking, 35–50 mm long and 20–23 mm wide, with a prominent horn on the head. Males have a rounded, shiny terminal abdominal segment while females have a hairy tail (Figs 37 and 38; CABI, 2021e). The undersides of males and females have reddish-brown hairs, but the female has a fuzzy grouping of these hairs at the tip of the abdomen.
- Females lay yellowish-white eggs, usually within rotting plant matter. The eggs hatch in 11–13 days and emerging larvae are yellowish-white and may grow up to 60–100 mm long before moulting into pre-pupal and pupal stages.
- Adult *O. rhinoceros* is similar to a larger species of scarabeid, *Oryctes gnu*, but the latter has three tubercles on the thoracic ridge against only two in the former.
- *O. rhinoceros* adult beetles eat coconut leaves and burrow into the crown, stunting plant development (Giblin-Davis, 2001) and can pave the way to secondary infections from bacteria or fungi (Hinckley, 1973). Visual signs that help detect and locate the beetles include holes bored at the base of leaves and V-shaped feeding damage. This ultimately lowers the yield of nuts by up to 10%.

Figure 37 — Adult female (left) and male (right) of *Oryctes rhinoceros*
Photograph by Mike Dornberg, https://entnemdept.ufl.edu/creatures/orn/palms/Oryctes_rhinoceros.htm

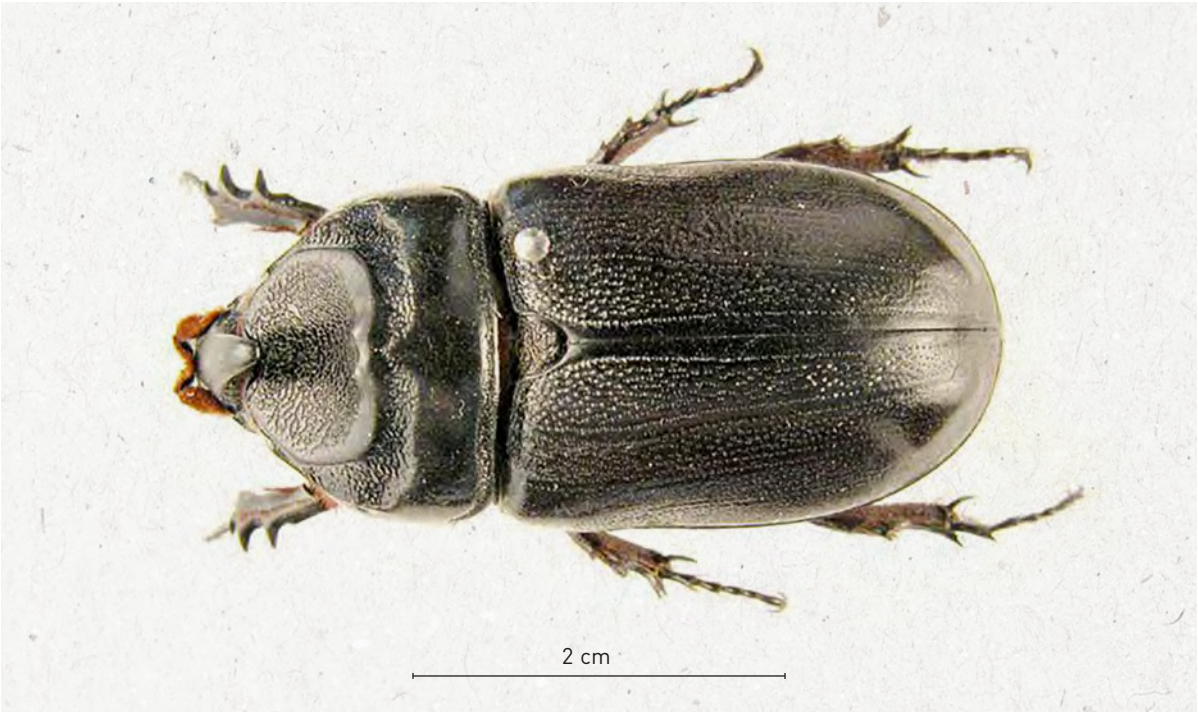


Figure 38 — Rhinoceros beetle
Pest and Diseases Image Library, www.ipmimages.org

AFFECTED STAGES OF THE CROP

The beetle attacks young coconut leaves at all growth stages. Young palms are severely damaged.

SYMPTOMS AND DAMAGES

The adult beetle bores into the crown of coconut palms, and cuts across young fronds and flowers. The attacks produce fronds which have wedge-shaped gaps or the characteristic V-shaped cuts to fronds. Other symptoms include die back/ dead heart of the growing point and holes at the base of fronds (CABI, 2022e).

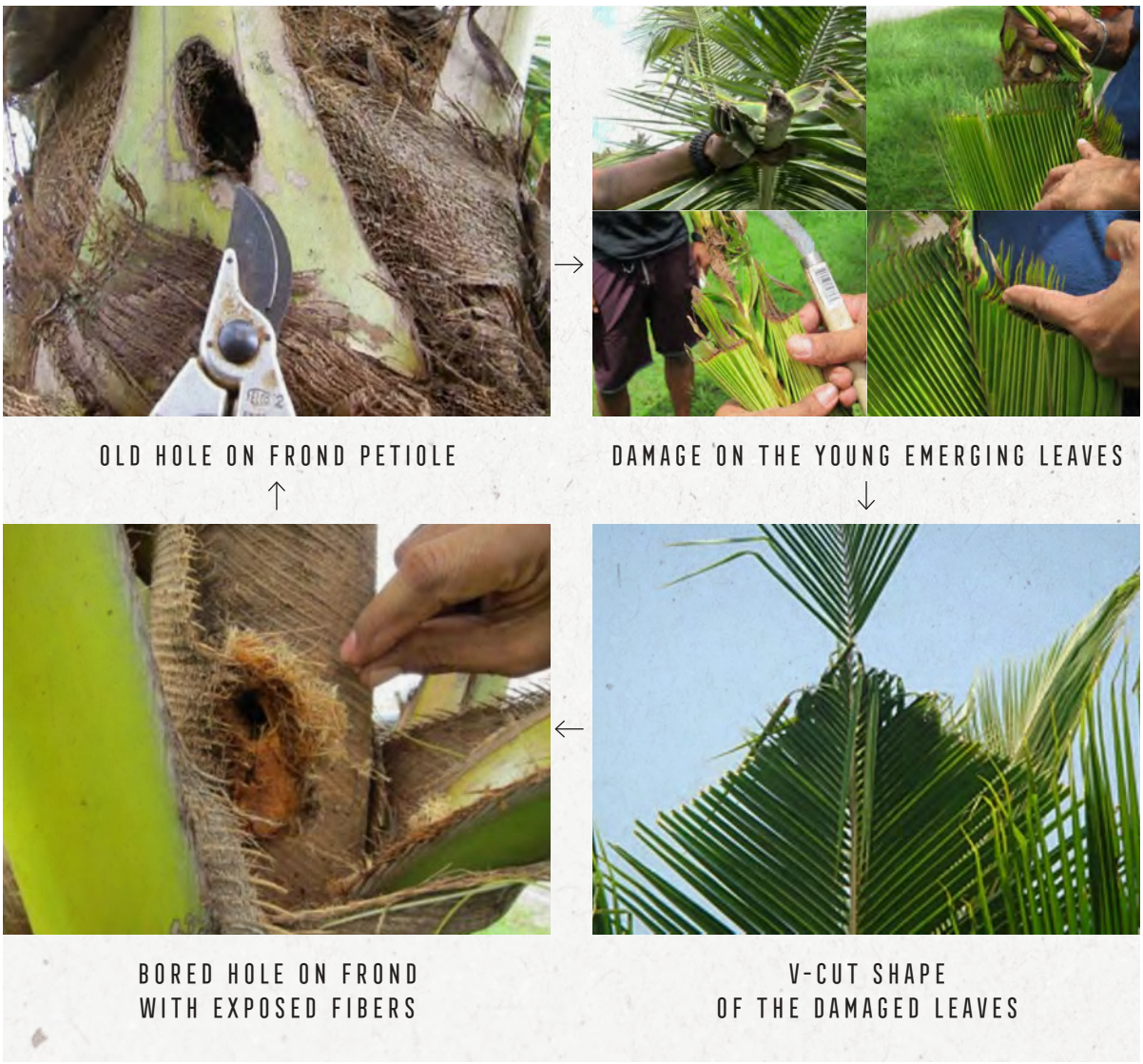


Figure 39 — Progressive damage symptoms of Rhinoceros beetle on Coconut tree
Source: Modified from https://slideplayer.com/slide/14486369/

IMPACT ON YIELD AND QUALITY

Loss of leaf area, dead flowers, early nut fall, stunting, snapping of fronds, and lower yields. Young palms may be killed. Losses of up to 10% in nut yield have been reported.

QUARANTINE ORGANISM

Yes (EPPO, 2021e)

FAVOURABLE CONDITIONS

Adult *O. rhinoceros* beetles spend most of their lifetime burrowing in decaying organic matter while larvae live entirely in decaying matter. For larval development optimal temperatures are 27–29°C and RH 85–95%. In equatorial regions, the beetles can be active and reproductive throughout the year.

- Eggs are laid below the surface of moist organic materials, such as sawdust, manure, compost and garbage heaps, or above ground in tunnels in the axils of coconut fronds. Hatching happens 8–12 days later (CABI, 2021e) into C-shaped white larvae (Fig. 40).
- The larvae have three instar stages that last for a period of 80–200 day, depending on the quality of the diet, after which they pupate. Growth and development are delayed in drier conditions. There are two pupal stages lasting about 25–40 days.
- Pupae emerge into adults which remain underneath the rotting organic materials for 2–3 weeks before chewing their way out.
- The adult beetles are nocturnal, flying to the tops of coconut palms where they use their mandibles, horns and strong forelegs to tunnel into the crowns. The adult beetles feed by boring into the growing point or meristem of coconut palms during all growth stages and this is the primary cause of crop damage. *O.rhinoceros* females live for about 9 months and lay around 50 eggs, while males live for about 5 months.

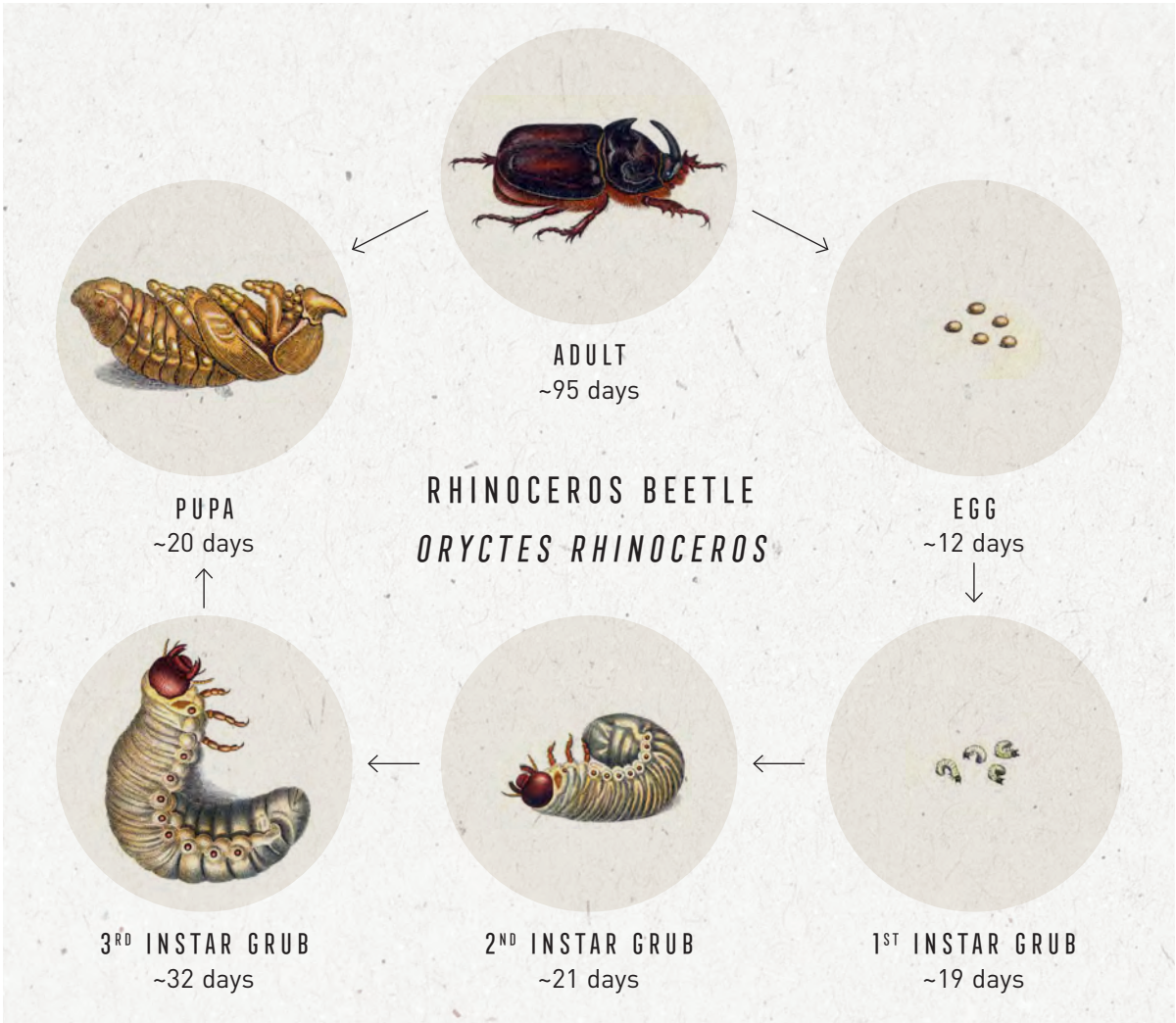


Figure 40 — Rhinoceros beetle (*Oryctes rhinoceros*) life cycle
www.slideshare.net/duhmanisha19/pest-of-plantation-crops

SURVEILLANCE/MONITORING

- Use traps with the attractant ethyl 4-methyl octanoate to monitor incidence and populations of *O. rhinoceros* in the field. Use one trap per 2 ha and inspect the traps weekly (Waterhouse and Norris, 1987).
- Monitor populations of larval, pupal and adult rhinoceros beetle by breaking open breeding sites such as underneath rotting organic residues and rotting trunks, as well as active feeding sites on the trunk and frond petioles.

CULTURAL CONTROL

- Physically destroy fallen palm trees by splitting, allowing them to dry and burning the remains.
- Inspect breeding sites such as manure and organic matter heaps and remove adult beetles and their grubs.
- Catch adult beetles from their breeding sites by covering the rotting organic matter heaps with gill nets.
- Use hooked wires to catch adult beetles from their active feeding sites such as in the crowns of palms.
- Plant leguminous cover crops such as lablab around remaining stumps of old coconut to discourage the beetles from selecting them as breeding sites.

BIOCONTROL

- Release the entomopathogenic fungus *Metarhizium anisopliae* var. *major* into *O. rhinoceros* breeding sites to infect the larvae and adults.
- Introduce nudivirus to breeding and feeding sites by first dipping adult beetles into a suspension of ground, previously infected larvae, allow them to crawl about for 24 h through sterilised sawdust mixed with the above suspension and then release them to further infect the grubs in breeding sites and adults in feeding sites (CABI, 2021e).

CONTROL WITH PLANT PROTECTION PRODUCTS

- Target plant protection products mainly toward adult beetles.
- Apply naphthalene balls at a rate of three balls (each weighing 3 g) per palm, placed at each of the three topmost sheaths, after every 45 days to act as an insect repellent. The moth balls can provide up to 95% control of the pest (Singh, 1987).
- Apply lambda cyhalothrin to reduce the number of holes on spears and fronds.

OTHER CONTROL METHODS

No other distinct methods are available.

7.6. RED PALM WEEVIL (*RHYNCHOPHORUS FERRUGINEUS* OLIVIER)

DESCRIPTION/IDENTIFICATION

- The red palm weevil (*Rhynchophorus ferrugineus*) is also known as the Asian palm weevil or the sago palm weevil.
- The larvae can grow up to 35mm long, yellowish-white, segmented and legless, and have a chitinous head capsule, brown to dark-brown in colour (Fig. 41).
- The pupae have an average size of 80 × 35 mm, are initially creamy in colour then turn brown (Fig. 42). They are reticulated and greatly furrowed with a shiny surface. The male is characterised by the presence of a series of black hairs (setae) on the dorsal and frontal parts of the snout. The female does not exhibit hairs, and has a comparatively narrower, more curved and longer rostrum than the male.
- Adult weevils are large, rusty red in colour (35 × 10 mm) with a characteristic long and curved rostrum which comprises about one-third of the total length (Fig. 43). The weevil has dark spots on the underside of the thorax. In males, the anterior dorsal half of the rostrum has short brownish setae. By contrast, the female rostrum lacks any hair. The adult weevils have well-developed wings and are capable to undertake long flights (Dembilio and Jacques, 2015).

Figure 41 — Red palm weevil (*Rhynchophorus ferrugineus*) grub
Mike Lewis, www.ipmimages.org

Figure 42 — Red palm weevil (*Rhynchophorus ferrugineus*) stages
Christina Hoddle, www.ipmimages.org

Figure 43 — Adult red palm weevil (*Rhynchophorus ferrugineus*)
John Kabashima, www.ipmimages.org

QUARANTINE ORGANISM

Yes (EPPO, 2022f).

AFFECTED STAGES OF THE CROP

Flowering stage, fruiting stage and vegetative growing stage (CABI, 2022f).

SYMPTOMS AND DAMAGES

Dieback, gummosis, rotting, tunnelling in stem and base of the crown, withered crown, frass, oozing of brown juice.

IMPACT ON YIELD AND QUALITY

Losses of up to 34% in coconut have been reported Ganapathy et al. (1992)

FAVOURABLE CONDITIONS

- This pest is now present on all continents of the world, except Antarctica. Temperature is the main abiotic factor influencing the biology and population dynamics of *R. ferrugineus*.
- Generally, the most suitable temperature for development of *R. ferrugineus* is in the range 26–30°C, under which the number of cyclic weevil emergences increases (Salama et al., 2002; Ge et al., 2015). Mean monthly temperature below 10.3°C is lethal to neonate larvae and below 4.5°C for older immature stages. Less than one generation per year could be expected in areas with MAT below 15°C and more than two generations per year can occur in areas with MAT above 19°C (Dembilio and Jacas, 2011).

PEST LIFE CYCLE

- Females lay creamy-white eggs in holes excavated using their snouts, in the trunks or leaf stalks of palms. About 2–5 days later the eggs swell and the larvae hatch out.
- The grubs feed on the soft plant tissue on the inside of the palm trunk. Larval development may last for 24–128 days. Symptoms of larval feeding include holes in the bark from which plant tissue may stick out. Grub feeding areas vary with palm age.
- When ready to pupate, the larva spins a fibrous cocoon under the bark of the palm. Pupation begins 3 days later and lasts for 12–20 days before the adult emerges (Fig. 44; Dembilio and Jaques, 2015; Al-Dosary et al., 2016).

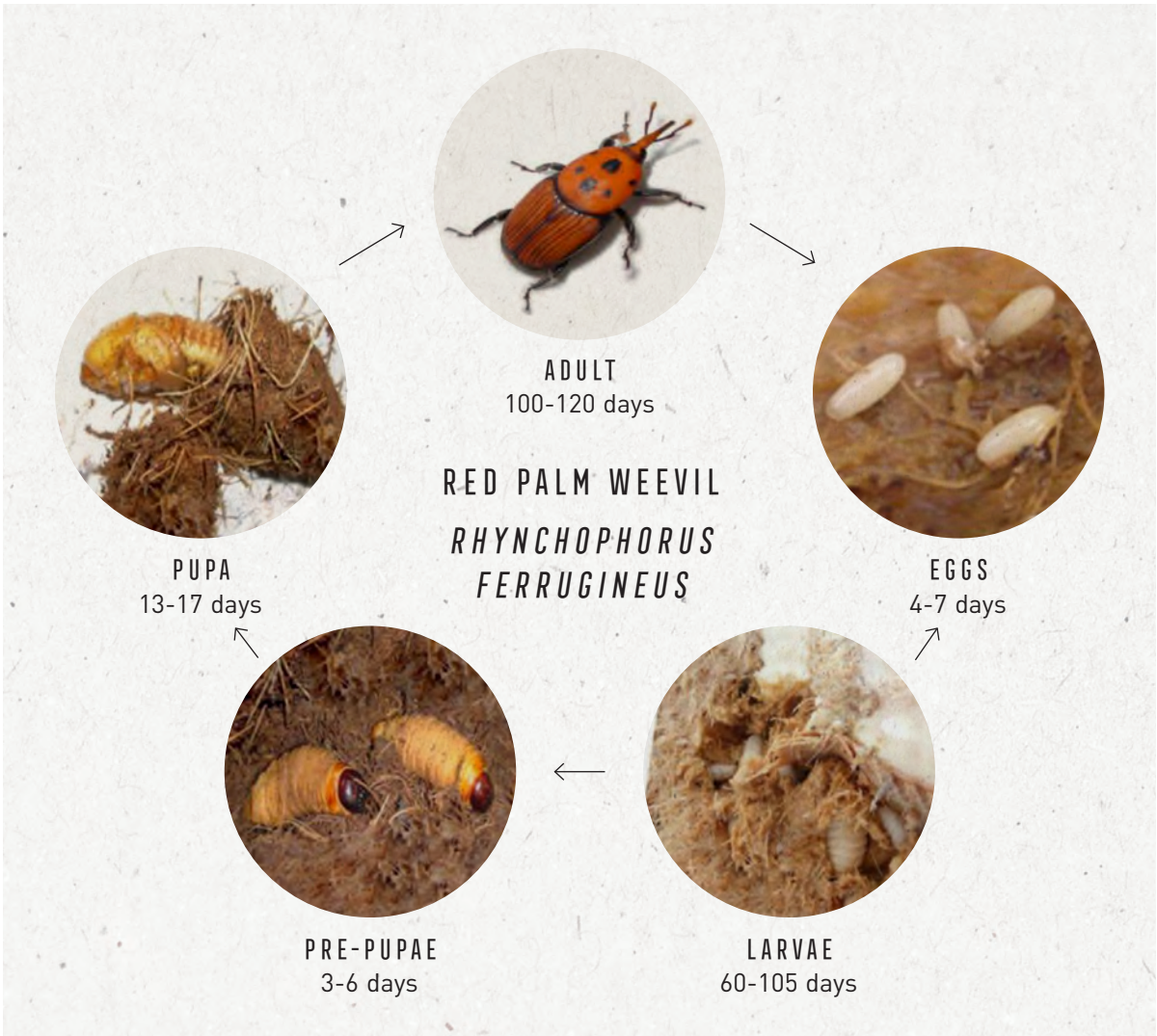


Figure 44 — Red palm weevil (*Rhynchophorus ferrugineus*) life cycle (Ali et al., 2018)

SURVEILLANCE/MONITORING

- **Visual inspection** – Inspect non-infested areas quarterly and infested areas bimonthly.
- **Trapping** – Use pheromones and host volatile baited traps to monitor populations of red palm weevil. Ferrugineol is the main aggregation pheromone of *R. ferrugineus*. The standard four window bucket trap (Soomro et al., 2022) is widely used in trapping this pest. These bucket traps (2 l volume) are wrapped with gunny cloth having four holes of diameter 4.5 cm. Tie the pheromone lure to the inner surface of the bucket trap lid. Hang the trap on the coconut palms at 0.6 m height and set under shade to ensure maximum lure longevity. Service the traps (renewal of food bait and water) at least biweekly and maintain a trap density of 1–2 traps/ha in infested areas. Enhance capture by incorporating ethyl acetate and food baits like palm tissue, date and sugarcane (e.g. 200 g dates in 1 l water). Other commercially available traps like Picusan Trap TM can be used (Azmi et al., 2014).

Figure 45 — Four windows bucket trap (Soomro et al., 2022)

CULTURAL CONTROL

- Inspect the farm and eliminate the weevil from all hidden breeding sites.
- Remove and shred all wilting or damaged palms to prevent the further spread of the pest. Remove stems of infested palms and destroy the various stages of the pest, burying them to reduce breeding grounds. Avoid burning as palms do not burn easily when green and the pest may penetrate deeper into the trunk to escape the fire.
- Cut the fronds where the leaflets begin to emerge, to reduce the entry of weevils into the stem during and after harvest (Jaques et al., 2017). Dig the soil deeply around the coconut trunk to make a trench for the grubs to fall in to. Where possible, hand-pick the grubs and kill them.

BIOCONTROL

- Apply commercial formulations of *Beauveria bassiana*. Inspect every 24 h for 30 days of treatment (Hajjar et al., 2015).
- Apply *Metarhizium anisopliae* at and observe the mortality rates after 7 days (Abdel-Raheem et al., 2019); or *M. anisopliae* and check the mortality rate for 12 days (Yasin et al., 2019).
- Use entomopathogenic nematode *Steinernema carpocapsae* in a chitosan formulation with an application spray to the stipe crown.
- Encourage the presence of predators like the red assassin bug (*Platymeris laevicollis*) and earwigs (*Chelisoches moio*) in palm fields.

CONTROL WITH PLANT PROTECTION PRODUCTS

Currently stem injection of infested palms using pressure injectors is practised in some countries. In attacked palms, observe for the boreholes and seal them except the topmost one. Pour the insecticide through the topmost hole using a funnel, then plug this hole also. If needed, repeat this process after 1 week. Apply new generation insecticides such as:

- lambda-cyhalothrin
- emamectin benzoate

OTHER CONTROL METHODS

- **Mass trapping** – Spot application of pheromone in combination with insecticides can provide an 'attract and kill' technique. Place 12 traps per hectare.
- **IPM** – Implement an IPM program comprised of locating and eliminating hidden breeding sites; maintaining crop and field sanitation; pest surveillance based on periodic field surveys for detecting infestations; pheromone traps; checking palms to detect infestations; preventive and curative chemical treatments; eradicating severely infested palms; and implementing quarantine measures (Abbas, 2010).

7.7. COCONUT SCALE (*ASPIDIOTUS DESTRUCTOR* SIGNORET, 1869)

DESCRIPTION/IDENTIFICATION

- The freshly laid eggs of *Aspidiotus destructor* are smooth, elongate and whitish, becoming pale yellow over time.
- Newly hatched nymphs (crawlers) are light-green to yellowish-brown, translucent and somewhat oblong, with an average length and width of 0.23 mm and 0.11 mm, respectively. Male nymphs become reddish-brown and more elliptical in shape. Female nymphs remain pale yellow, circular and somewhat transparent (Fig. 46).
- The adult female is circular in shape, approximately 2 mm in diameter. The orange-yellow body is visible beneath a milky white, semi-transparent, thin scale (1.5–2.0 mm) that covers her body. The scale cover is oval to circular and fairly flat. The female body can be greenish-yellow depending on the food plant (Taylor, 1935).
- Adult males are minute, two-winged, yellowish/brown-orange insects, with antennae, eyes, three pairs of legs and a prominent long appendage projecting from the tip of the abdomen (Metcalf, 1962).
- Colonies resemble miniature fried eggs "sunny-side up" (Tabibullah and Gabriel, 1975; Salahuddin et al., 2015).

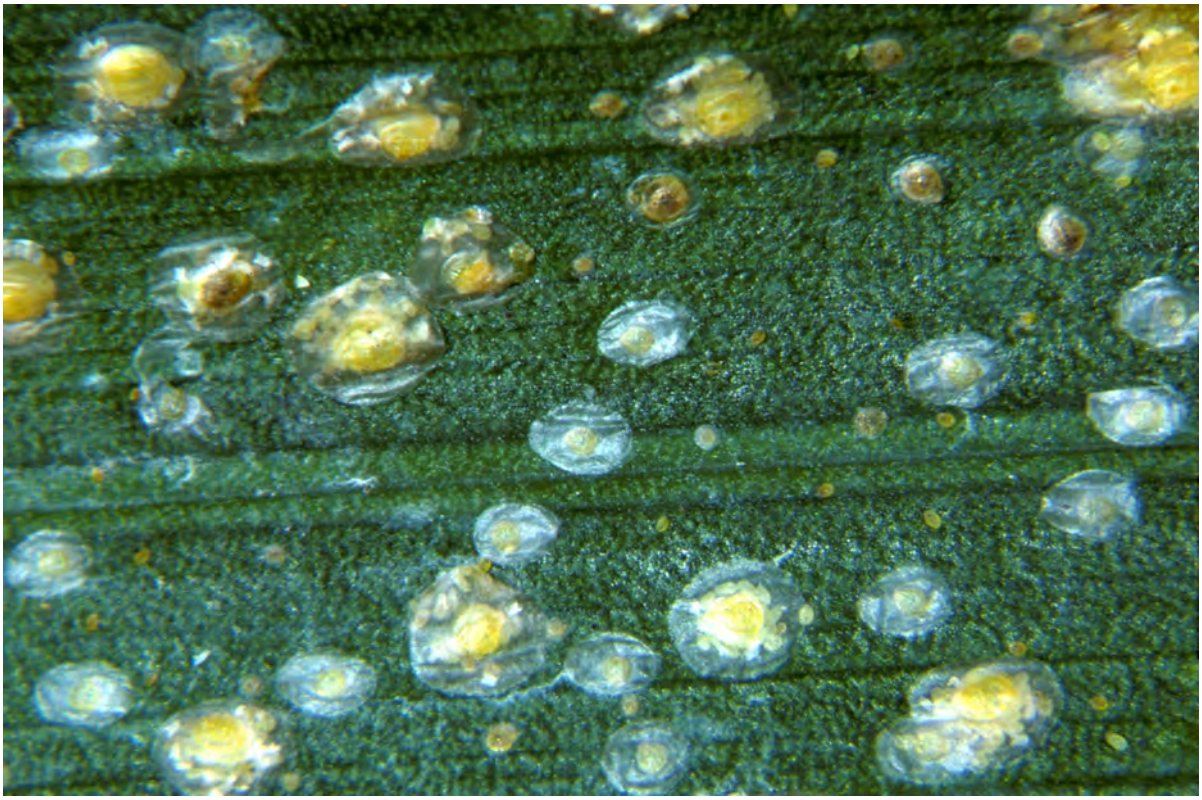


Figure 46 — Coconut scale (*Aspidiotus destructor*)
United States National Collection of Scale Insects Photographs, www.ipmimages.org

QUARANTINE ORGANISM

Yes (EPPO, 2022g).

AFFECTED STAGES OF THE CROP

All plant stages are attacked by scales. Mature scales are found on older leaves.

SYMPTOMS AND DAMAGES

Yellowing of the leaves due to removal of sap by the sucking mouth parts and the toxic effects of the saliva of the scales.

IMPACT ON YIELD AND QUALITY

A very destructive pest of coconut, causing up to 25% loss in yield (CABI, 2022g).

FAVOURABLE CONDITIONS

The species occurs year-round in tropical areas. The coconut scale is a global species distributed throughout tropical and subtropical regions.

PEST LIFE CYCLE

- The eggs are laid under the scale around the body of the female. They are very small and white when laid, and turn yellow.
- After hatching, the young nymphs push their way out from beneath the adult scale. Females have two nymphal stages, while males have two feeding nymphal stages, followed by non-feeding pre-pupal and pupal stages (four immature stages altogether). The first-instar females are about 1 mm long, yellowish-brown, oval and translucent. Second instar females become immobile and secrete a translucent wax scale cover. The second instar males are smaller than the females. They group together, secrete a filamentous waxy material and become immobile. The male pre-pupal and pupal stages are spent under the scale produced by the second instar stage (Fig. 47).
- The pale yellow exuviae are more or less central on the scale cover of the adult female. The adult male scale cover is redder than the female's, smaller and more oval (Williams and Watson, 1988). The male has one pair of wings and is motile. Fertilisation is not essential as unfertilised females can reproduce parthenogenetically. A generational cycle is between 32 days (male) and 35 days (female) (Salahuddin et al., 2015).

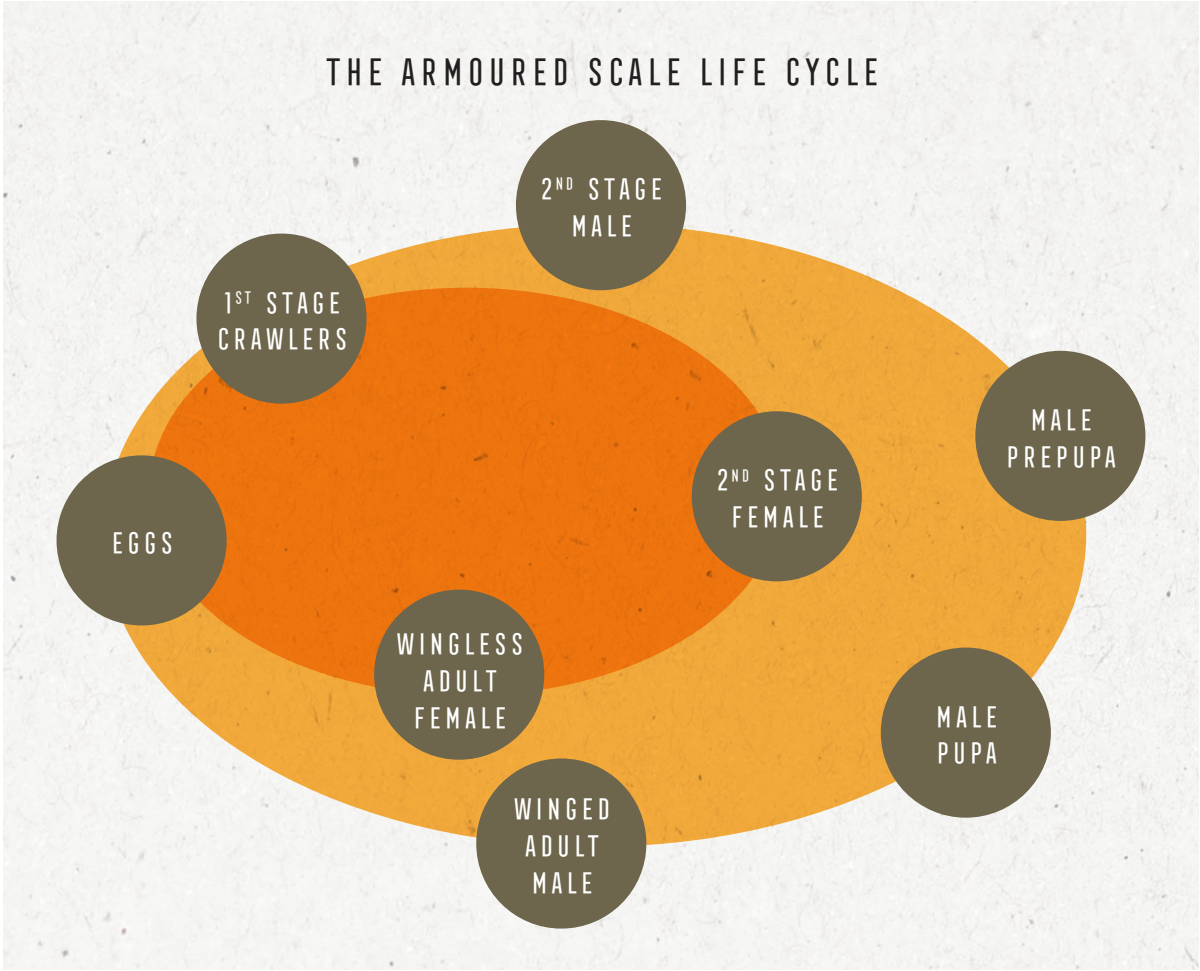


Figure 47 — Coconut scale (*Aspidiotus destructor*) life cycle
apps.lucidcentral.org/ppp/text/web_full/entities/coconut_scale_104.htm

SURVEILLANCE/MONITORING

- Detection of scale colonies, rather than counting scales in the plantations, is simpler and more easily adopted by growers. Counting individual *A. destructor* is difficult since the pest develops large, dense colonies which occur under the leaves (Salahuddin et al., 2015).
- Direct inspections can be made of the leaf undersides, aided by a ×8 hand lens and a powerful torch if required, or using a dissection microscope in the laboratory. Look for yellow or brown patches on leaves, with scale insects on the underside. Identify pale buff, translucent, fairly flat, circular scales about 1.5–2.0 mm in diameter (Watson, 2002).
- Advanced detection techniques include IT-based monitoring systems, e.g. a support vector machine to detect pests from images. A wireless sensor network can check infestation by the pest at an early stage, and notify the farmer to take necessary action (Azfar et al., 2015). Threshold or computer vision techniques can be used for pest detection (Gondal and Khan, 2015). Molecular marker-based detection techniques can also be carried out using the 16S–rRNA gene from coconut scale bacterial endosymbionts (Timple et al., 2017).

CULTURAL CONTROL

During the early stages of an outbreak of *A. destructor* on coconut, cutting and burning the affected fronds may be effective. Carry out pruning, train fruit trees and dispose of infested leaves, branches and twigs. Avoid excessive use of plant fertilisers (CABI, 2022g).

BIOCONTROL

Biocontrol is effective through the use of predators rather than parasitoids. Introduce predatory insects of the scale (Simmonds, 1960; Kinawy, 1991; Spenneman et al., 2019) such as:

- *Cryptognatha nodiceps*
- *Chilocorus politus* and *C. nigritis*
- *Rhyzobius pulchellus*
- *Pseudoscymnus anomalus*
- *Telsimia nitida*
- *Lindorus lophanthae*

CONTROL WITH PLANT PROTECTION PRODUCTS

- Sprays are only effective on the crawler stage of scales. Contact action insecticides, including horticultural oils, become progressively less effective once the scale insects develop their waxy cover. Furthermore, insecticides may be useful on young palms, but not those that are mature because the crowns are too high to reach.
- For management of *A. destructor*, parasitoids may be conserved by using oils and insect growth regulators (IGR) while systemic insecticides may also be used in the case of severe infestations.
- The first spray must be applied before parasitosis emergence. Recommended products include pyriproxyfen.

OTHER CONTROL METHODS

- **White oil** – Mix 3 tablespoons (one-third cup) cooking oil in 4 l water, add half a teaspoon detergent soap, shake well and use.
- **Soap** – Add 5 tablespoons of pure soap (not detergent) in 4 l water, or 2 tablespoons of dish washing liquid in 4 l water and apply (Jackson, 2021).

7.8. BLACK-HEADED CATERPILLAR (*OPISINA ARENOSELLA* WALKER)

DESCRIPTION/IDENTIFICATION

- The adult *Opisina arenosella* is a greyish-white (ash grey) moth measuring 10–15 mm long and 20–25 mm in wingspan across outstretched wings. The male is smaller in size, characterised by a slender abdomen ending in a short brush of scales, while in females the abdomen is stouter and pointed toward the tip. The adult female moth of this caterpillar is medium sized and is larger than the male moth. The female has long antennae and three faint spots on the forewings. The male has fringed hairs on the hind wings in the apical and anal margin.
- The caterpillar measures 15 mm in length and is light-green with red/brown stripes and a black head.
- Eggs are creamy-white (Nasser and Abdurahiman, 2001; Seni, 2019; CABI, 2022h).

QUARANTINE ORGANISM

Yes (EPPO, 2022h).

AFFECTED STAGES OF THE CROP

All coconut growth stages are attacked.

SYMPTOMS AND DAMAGES

Dried up patches on leaflets of lower leaves, galleries of silk and frass on the underside of the leaves, scorched appearance of patioles.

IMPACT ON YIELD AND QUALITY

Causes severe damage to palms.

FAVOURABLE CONDITIONS

Outbreaks of the pest usually occur under congenial conditions. The population of *O. arenosella* reaches serious proportions in hot months. The abundance of the pest is directly correlated with RH and nearly inversely proportional to the temperature and sunshine (Sathiamma et al., 1973, in Nasser and Abdurahiman, 2001).

PEST LIFE CYCLE

- Females of *O. arenosella* lay their eggs in small groups on the under surface of coconut leaflets. The larvae usually have five instars and feed on the under surface of coconut leaves, at first gregariously, then singly, consuming the lower epidermis and mesophyll but leaving the upper epidermis intact.
- The larvae construct a gallery of silk and frass, into which they retreat if disturbed.
- Pupation takes place within the larval gallery. Adults are frequently found during the day resting on the under surface of the leaves of palms damaged by the larvae (Fig. 48).
- The moth flies at night, but little is known of its dispersal abilities. The total life cycle is completed in about 2 months (Nasser and Abdurahiman, 2001).

Figure 48 — Black-headed caterpillar (*Opisina arenosella*) life stages
www.goodhands.lk/damages-by-coconut-caterpillar-opisina-arenosella/

SURVEILLANCE/MONITORING

- Use cross-vane traps baited with synthetic pheromone (Z,Z,Z)-3,6,9-tricosatriene. Suspend the traps in the middle of the palm canopy at a density of 40–120 traps/ha (Muniyappa et al., 2018).

— Visually examine plants by sampling 20 leaflets taken at random from the lower fronds of randomly chosen palms. Sample between 5 to 25 plants/ha (Perera, 1988).

CULTURAL CONTROL

— Cut and destroy lower fronds during the early stages of pest infestation.

— Physically remove the infestation from the palm, e.g. using light traps.

BIOCONTROL

— Carry out inundative/augmentive releases of larval parasitoids, *Trichogramma minutum*, *Goniozus nephantidis* (Muesebeck) and *Bracon hebetor*, as well as early pupal instar parasitoid *Brachymeria nosatoi*.For example, release *G. nephantidis* at the rate of ten parasitoid/palm and *B. hector* at the rate of 20 parasitoid/palm at fortnightly intervals; four to six releases are effective for management of black-headed caterpillar (Rao et al., 2018)

— Alternatively, release 3000 parasitoids/ha under the coconut trees when the pest is in the second or third instar larval stage.

CONTROL WITH PLANT PROTECTION PRODUCTS

— **Frond injection** – Inject insecticides such as acetamiprid, emamectin benzoate or spinosad. Select a middle frond and inject the insecticide in the upper surface of its base. Drill a hole of 0.3 cm diameter at an angle of 45° to a depth of 1.5 cm for inserting the syringe (Sharma et al., 2020).

— **Trunk injection** – First harvest all the mature nuts then drill a downward slanting hole and inject emamectin benzoate into the stem at about 1.5 m above the ground level. Plug the hole with clay mixed with copper oxychloride.

— **Root feeding technique** – Apply bio pesticide azadirachtin. Select dark-brown coloured roots for root administration of pesticide. For plants of 4.5 m height, make a slant cut in the root and keep the root in a polythene bag containing pesticide mixed with water. Allow the root to absorb the chemical for 24–48 h (Seni, 2019). Alternatively, apply azadirachtin in aqueous solution at the base of the trunk. Spray the under surface of the fronds with insecticides like malathion.

OTHER CONTROL METHODS

No other distinct methods are available.

7.9. ERIOPHYID MITES (*ACARI*: TENUIPALPIDAE AND ERIOPHYIDAE; *ACERIA GUERRERONIS*)

DESCRIPTION/IDENTIFICATION

— Adult eriophyid mites are tiny and cannot be seen with the naked eye but with the aid of a ×10 hand lens. They are found mostly under the leaf-like structures called the "perianth".

— Colonies of mites appear as vague silvery patches underneath the coconut leaf. Symptoms of mite infestation include triangular patches with a pale yellowish colour that turn brownish after few days; uneven growth of the infested nut; longitudinal splits on the outer surface of the husk, sometimes accompanied with brownish gummy exudates oozing out from the infested surface; bronzed leaves and later necrosis (Fig. 49; Peña and Sabelis, 2012).

Figure 49 — Damage from coconut mites
Florida Division of Plant Industry, www.ipmimages.org

QUARANTINE ORGANISM

Yes (EPPO, 2021i)

AFFECTED STAGES OF THE CROP

Fruiting stage.

SYMPTOMS AND DAMAGES

Gummosis, premature fruit drop, reduced fruit size, nercosis, stunting of the coconut.

IMPACT ON YIELD AND QUALITY

The coconut mite is considered the most important pest of coconuts in the Americas, Africa and most recently in South-East Asia. Coconut mites may cause up to 60% losses in yield. Average copra losses range from 20 to 30% (CABI, 2022i).

FAVOURABLE CONDITIONS

High temperatures (27–33˚C) and humid conditions (75–80%) favour mite proliferations (Nair, 2002).

PEST LIFE CYCLE

- Eriophyid mites have four stages of development. The female mite lays 30–50 eggs that are ovoid, translucent and reddish in colour. Before hatching they turn pearly white and last for 3 days.
- Nymphs develop at the fourth day and last for 2 days. They look like an adult with pale colours and start feeding instantly after emergence.
- Adults are pale in colour and their bodies are long and slender like a worm with two pairs of legs (Fig. 50). The life cycle is completed within 7–10 days (Ansaloni and Perring, 2004).

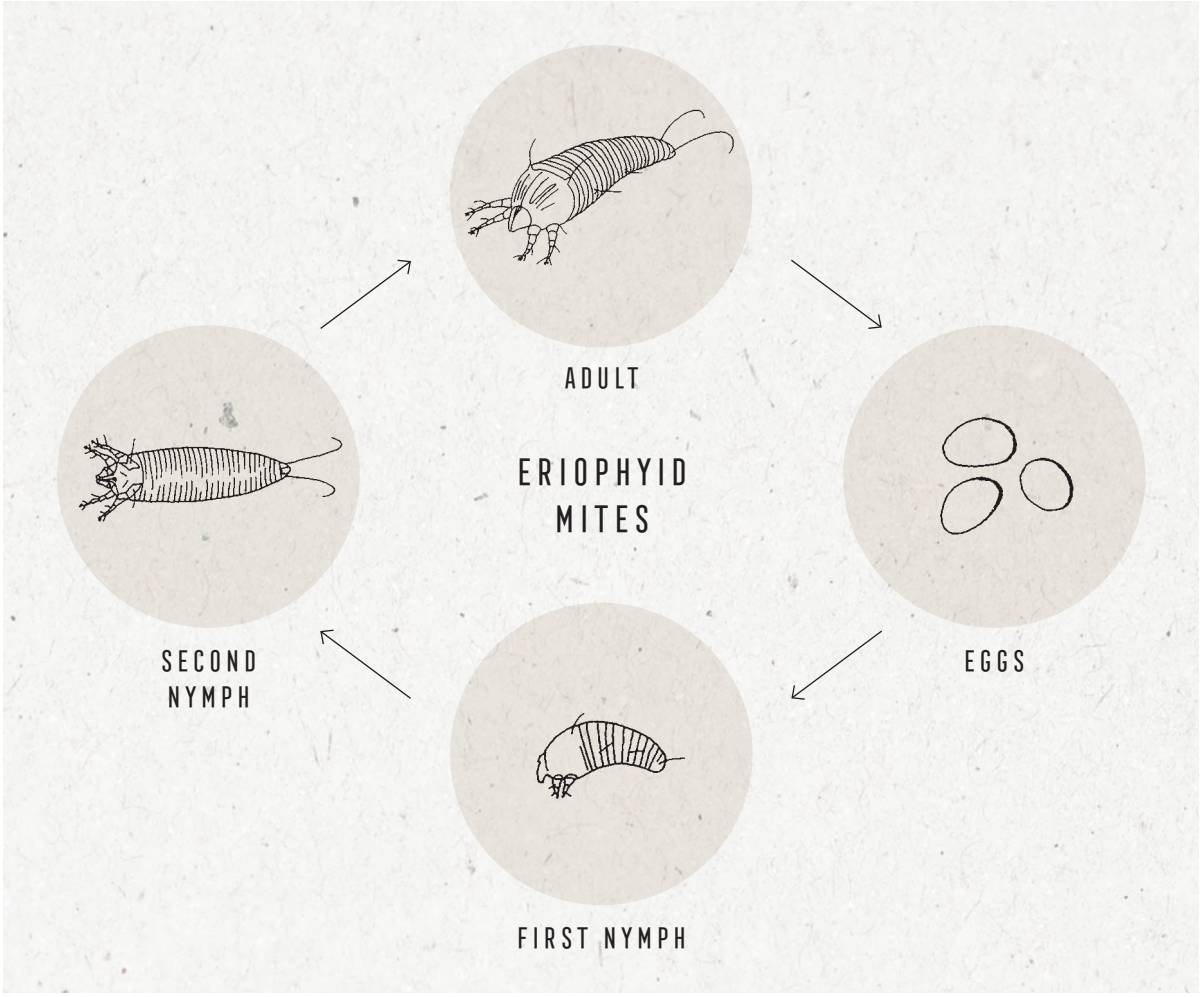


Figure 50 — Life cycle of eriophyid mite
Illustration by J.R Baker

SURVEILLANCE/MONITORING

- Carefully observe fallen nuts for the presence of damage symptoms caused by mites (Fig. 51).
- Take a sample of nuts aged more than 6 months old from different trees for verification. Wash the nut perianth with detergent to remove and immobilise the mites.
- Observe the presence of mites in water suspension using a hand lens. The mites' maximum activity is between 6:00–9:00 am (CABI, 2021i).

Figure 51 — Damage to coconuts from palm mites
Tim Broschat, www.ipmimages.org

CULTURAL CONTROL

- Plant resistant varieties such as Polynesian Tall (PYT), Malayan Red Dwarf (MRD), Rennel Tall (RLT), Cameroon Red Dwarf (CRD) and Equatorial Green Dwarf (EGD) (Seguni, 2000).
- Plant *Casuarina* windbreaks along the coconut field borders to block the spread of the mites by wind.
- Carry out field sanitation by collecting all immature fallen nuts and destroying them by deep burying. Clean the palm crown and bases regularly.
- Properly irrigate the coconut field, especially during the dry season, with 70 l/day per tree.
- Mulch the coconut bases/field with live mulch (cover crops/*Mucuna pruriens*) or with coconut husks to conserve moisture.
- Apply a recommended fertiliser dose of NP and 3.5 kg of K per tree per year. Add 50 kg of farmyard manure or compost manure per tree per year (Faleiro et al., 2016).
- Intercrop coconut with *Sesbania bispinosa* or *Crotalaria juncea*; sow 30 g per tree of either species around the trunk base.

BIOCONTROL

- Use pathogenic fungi that are commercially available.
- Carry out three sprays per year with chalk-based formulation of *Hirsutella thompsonii*.
- Spray nuts and flowers during evening hours with liquid biopesticides of *Verticillium lecanii* (green verticil). Under heavy mite infestations, repeat the treatment after 15 days.

CONTROL WITH PLANT PROTECTION PRODUCTS

- Mix 200 ml palm oil with 5 g sulphur to form an emulsion; spray the emulsion on coconut bunches and flowers. The application should be caried out during Jan–Feb, Apr–May and Oct–Nov.
- Spray a neem formulation, for example a suspension garlic mixed in neem oil and water. Use the suspension to spray the fronds during flowering and nut formation.
- Apply a neem oil and garlic emulsion at intervals of 45 days. Grate the soap and dissolve it in luke-warm water.
- Feed the roots with azadirachtin.

OTHER CONTROL METHODS

No other distinct methods are available

Visit and inspect plants for a wilt of the spear leaf, which bends over slightly. Examine the bases of the petioles of the young leaves to look for large patches of yellow to brown rot. At this stage, the rot has probably completely destroyed the bud. Once the bud is destroyed the outer leaves remain green for some months after the death of the spear and inner leaves.

7.10. TERMITE-ODONTOTERMES OBESUS

DESCRIPTIONS AND IDENTIFICATION

Termites are found in the hills or moulds especially in the field. Adult termites are cream coloured with their bodies resembling ants with black heads sometimes with wings. Workers are relatively small.

LIFE CYCLE

Mating takes place between winged adult male and female termite. They enter into the tree through crack or wound and sometimes chewing their way in. In the tree the they establish a colony and the female lays eggs which hatch to workers and soldiers that feeds and take care of the king and queen.The queen lays more eggs and the colony grows.Colonies may last for more than 20 years.

Figure 52 — Termite adults with and without wings
Source: https://apps.lucidcentral.org/pppw_v10/text/web_full/entities/coconut_termite_116.htm

AFFECTED STAGE OF THE CROP

Coconut can be infested with termites at its seedling stage in the nursery but serious attack may happens soon after transplanting in the field.

SYMPTOMS AND DAMAGE

They construct a tunnel toward the coconut tree and start feeding on the coconut young seedlings transplated in the fields. The major symptoms of termites damage is wilting of seedling especially if attacked at the seedling stages. For matured palms the base of the truncks are plastered with runways maddy of soil and fibers. Farmers sometimes may recognize if the fields are having termites by looking at the presence of the hills or their tunnels down the soils during land preparations.

Figure 53 — Termite damage on coconut trunk

FAVOURABLE CONDITIONS

The termite problem is more serious under drought conditions.

IMPACT ON YIELD

The termite damages the trunk by making holes. These holes weaken the trunck that may cause palm snapping off. Under high infestation the yield is reduced and sometimes the coconut tree may be killed without fruits.

Figure 54 — Destruction of internal tissues of palm trunck and death of the palm
Source: https://apps.lucidcentral.org/pppw_v10/text/web_full/entities/coconut_termite_116.htm

CULTURAL CONTROL

Remove and burn infested coconut palms as soon as the net-like groove are seen on the bark

Digg the termite moulds /colony and remove the queen

BIOLOGICAL CONTROL

Use of sticks of *Euphorbia* sp. during transplanting to protect the young palms from termite attack.

In the nurseries the Euphorbia plants can be planted around the seedbeds (Seguni, TARI-Mikocheni personal communication).

CHEMICAL CONTROL

Spray Copper Sulphate, Cashew Nut Shell oil, Neem Oil to preserve plaited coconut leaves from the termite attack. Apply calcium at the base of the trunk. Swabbing with neem oil once on the base and up to 2 m height of the trunk for effective control.

7.11. LETHAL YELLOWING DISEASE (*CANDIDATUS PHYTOPLASMAPALMAE*)

DESCRIPTION/IDENTIFICATION

Diagnosis of lethal yellowing disease is based on a series of progressive symptoms in mature coconut trees

- **Drop of coconut before maturity** – Fallen nuts have a brown to black, water-soaked appearance at the fruit base.
- **Necrosis and death of the inflorescence** – The emerging male flowers may be partially or totally black in colour and soon die. The tree cannot set fruits.
- **Foliar discolouration** – This is cultivar specific; the leaves turn golden yellow for tall cultivars and reddish- to greyish-brown for dwarf cultivars. Yellowing begins with the older (lowermost) leaves and progresses upward to involve the entire crown. Affected leaves often hang down forming a skirt around the trunk for several days before falling. Yellowed leaves turn brown, desiccate and die (Figs 55 and 56).
- **Death of the spear (youngest leaf)** – This leaf hangs down from the crown, marking the total death of the coconut palm, which by now looks like a telephone pole (Fig. 57).

From the onset of symptoms of this disease, affected coconut trees normally die within 3–5 months. The insect vectors for phytoplasma diseases are leafhoppers (*Haplaxicus crudus*) and plant hoppers (*Myndus crudus*) (Frison and Putter, 1993). Lethal yellowing is a fatal disease that can cause 100% losses in coconut plantations.

Figure 55 — Lethal yellowing disease in a coconut palm
www.palmtreedr.com/blog/lethal-yellowing/

Figure 56 — Lethal yellowing disease symptoms in coconut
Monica Elliott, www.ipmimages.org

Figure 57 — Lethal yellowing disease symptoms in coconut: following loss of leaves and death of the spear (youngest leaf), the palm resembles a telephone pole
Monica Elliott, www.ipmimages.org

QUARANTINE ORGANISM

Yes (EPPO, 2022j).

AFFECTED STAGES OF THE CROP

Flowering stage, fruiting stage, vegetative growing stage (CABI, 2022j).

SYMPTOMS AND DAMAGES

Premature drop of coconuts of both ripe and underdeveloped fruits, inflorescence with blackened tips, yellowing of leaves, premature death of older leaves, death of the vegetative bud, falling of the tree. Finally, the entire top of the palm leaving the tall trunk of the palm tree, resembling a telephone pole (CABI, 2022j: Gurr et al., 2016).

IMPACT ON YIELD AND QUALITY

Severe losses have been reported amounting to millions of coconut trees. Losses of up to 38% of plam trees have been reported (Gurr et al., 2016).

FAVOURABLE CONDITIONS

Lethal yellowing disease will thrive at temperatures of 26–36°C and low to medium RH (50–70%).

DISEASE LIFE CYCLE

The disease can only survive in plant or vector tissues and is transmitted by plant phloem-feeding insects (plant hoppers).

SURVEILLANCE/MONITORING

- Conduct weekly surveillance of the field after 3 months of field establishment and identify the emerging symptoms. Lethal yellowing diseases cannot be monitored properly; the symptoms cannot be solely used for identification. Use of molecular techniques (e.g. loop-mediated isothermal amplification, LAMP) for early detection of the infected but symptomless plants is very important (Bila et al., 2016).
- Remove infected plants and burn them away from the field and replace with new plants. When available, plant resistant or tolerant varieties like Mozambique Tall. Ensure a good fertilisation regime (see section 6 for cultural management practices).
- Adhere to strict farm to farm quarantine rules and reduce human movement within the farm.

CULTURAL CONTROL

Use legumes (e.g. *Mucuna pruriens*) rather than grasses as intercrop ground cover, as they are less likely to harbour the disease vectors. Plant natural barriers around the coconut farm like *Lignum vitae* trees that will block the disease vectors.

BIOCONTROL

N/A

CONTROL WITH PLANT PROTECTION PRODUCTS

Phytoplasma diseases cannot be treated with pesticide.

OTHER CONTROL METHODS

Strict quarantine. Restriction of movement of palms and non-palm hosts such as grasses, enforced by casual observation at borders (Gurr et al., 2016).

7.12. COCONUT *CADANG-CADANG* VIROID

DESCRIPTION/IDENTIFICATION

Symptoms are categorised into three stages:

- **Early stage** – An abnormal fruit shape is seen; the nuts become rounded with reduced copra content. Newly developing nuts show equatorial surface scarification. These symptoms appear after 2–4 years of infection.
- **About 2 years later** – Fine, translucent, bright yellow, water-soaked leaf spots appear on the leaflets, giving a bronze/yellow colour to the lower two-thirds of the crown. The inflorescence is stunted with tip necrosis.
- **Late stage** – The leaves show abnormal colours and form, and begin to decline in size and number. Dwarfing of the whole plant and death of the palm finally occur.

Figure 58 — Damage symptoms of coconut *cadang-cadang* disease - John Randles, ipmimages.org

QUARANTINE ORGANISM

Yes (EPPO, 2022k).

AFFECTED STAGES OF THE CROP

Flowering stage, fruiting stage, vegetative growing stage (CABI, 2022k).

IMPACT ON YIELD AND QUALITY

The virus cause epinasty, rugosity, chlorosis and necrosis on leaves, internode shortening of stems leading to stunted plants, bark cracking, deformation and color alterations of fruits and storage organs, and delays in foliation, flowering and ripening. Infection leads to cessation of coconut production, followed by decline and death of diseased palms (King et al., 2012). About 40 million palms are estimated to have died from cadang-cadang in the Philippines with a loss of about US$100 per infected palm due to lost production and delay in replacement (Rodriguez, et al., 2017).

FAVOURABLE CONDITIONS

Tropical climate, with more than 600 mm precipitation per month (CABI, 2022k).

DISEASE LIFE CYCLE

- Coconut *cadang-cadang* is caused by viroids, the smallest known pathogens and found only in plants. Unlike viruses, they do not have a protein coat, and consist solely of a small circular, single-stranded infectious RNA molecule that can replicate in the host cell and be transmitted independently of any other microorganism.
- The viroid route has not been established well but they have been detected in pollen, husks and the embryos of the nuts. The disease is said to be transmitted by seed at a low rate of about 1 in 300. The viroid vector is not well established. Mechanical spread may occur by use of human machetes and other tools from palm to palm, when used without proper sanitation (CABI, 2022k).

SURVEILLANCE/MONITORING

- Morphological diagnosis of the disease at its early stage is very difficult because symptom development is slow and unreliable. Viroid isolation is essential to confirm diagnosis.
- Monitor the early symptoms on nuts. The occurrence of rounded and prematurely falling nuts are indicators of the disease (CABI, 2022k).

CULTURAL CONTROL

Remove diseased plants and replant new coconut palms using clean planting materials and preferably certified seeds to avoid the further spread of the disease (Krishnakumar and Chowdappa, 2016).

BIOCONTROL

N/A

CONTROL WITH PLANT PROTECTION PRODUCTS

N/A

OTHER CONTROL METHODS

Enforce strict quarantine regulations concerning safe movement of coconut germplasm from infected areas. Field quarantine is the only method considered to be effective in controlling the spread of the disease (Krishnakumar and Chowdappa, 2016).

7.13. BUD AND FRUIT ROT (*PHYTOPHTORA PALMIVORA*)

DESCRIPTION/IDENTIFICATION

Bud and fruit rot (also known as "heart rot") is a fungal disease. Coloured coconut varieties are more susceptible to bud and fruit rot, while green dwarfs and tall varieties show high levels of tolerance to the disease. It is well adapted to the tropics and young palms are more susceptible than older ones (Fig. 59).

Figure 59 — Coconut bud and fruit rot symptoms (Kohler et al., 1997)

SYMPTOMS AND DAMAGES

Symptoms of bud rot include the following:

Chlorosis and collapse of the youngest leaves, rot of the bud and withering of the spear leaf, yellowing of leaves, rotting of basal tissue, discoloured tissues beneath the bud (turn pink to purple with dark brown borders), pale spear that breaks at the base, light-brown to yellow, oily sunken lesion on older leaves, dieback of stem, premature nut fall (CABI, 2022l).

AFFECTED STAGES OF THE CROP

Symptoms of fruit rot include brown to black necrosis with yellow borders developing on the surface of the tender tissues of young nuts. Internally, the nuts become mottled. Once infected, young nuts fail to mature and they fall down.

QUARANTINE ORGANISM

Regulated diseases A1 (EPPO, 2022l)

IMPACT ON YIELD AND QUALITY

The pathogen can cause losses of up 15% (Drenth and Guest, 2013).

FAVOURABLE CONDITIONS

Bud and fruit rot disease is most active during the wet season when temperatures are low (25.27–33.20°C) and RH is very high (75–95%). Rain splash and air currents disperse the fungal spores. The spores may survive in soil and coconut debris.

DISEASE LIFE CYCLE

- The first visible symptom is the formation of small, water-soaked lesions in the tender tissues of the leaflets at the base of the spear leaf, where fungi spores start their infections.
- Lesions extend to developing leaflets in the heart tissue of diseased palms. When these lesions dry out, the middle lamella falls out leaving a shot-hole appearance on the middle of the leaflet. With high temperature and humidity, sporation of fungi increases leading to more infection with culmination to secondary infection.
- Sequential infections cause more and larger lesions, affecting an increasing number of leaflets near the heart of the coconut palm. In advanced stages of the disease, the emerged outer part of the spear leaf looks completely dry and rotten. A foul smell emitted by the rotting tissue meristem indicates that it has been destroyed and no more young leaves will develop (Torres et al., 2016).
- Young coconut trees are most vulnerable to the disease.

SURVEILLANCE/MONITORING

Visit and inspect plants for a wilt of the spear leaf, which bends over slightly. Examine the bases of the petioles of the young leaves to look for large patches of yellow to brown rot. At this stage, the rot has probably completely destroyed the bud. Once the bud is destroyed the outer leaves remain green for some months after the death of the spear and inner leaves.

CULTURAL CONTROL

- Remove and destroy rotten parts of the palm in the initial stages of bud rot, to reduce the spread of the disease.
- Provide adequate drainage to avoid too much moisture in the nursery and field that might favour the development of the fungus.
- Trees that have died due to bud rot should be removed and burnt to avoid further spread of the disease.
- Adopt proper spacing of 8.5–9.5 m in the plantation to avoid overcrowding.

BIOCONTROL

- Apply biocontrol agents as talcum powder formulations, such as *Pseudomonas fluorescens* or *Trichoderma viride* in the crown region of coconut seedlings. Adapt the rate according to manufacturer recommendations for coconut seedlings aged 6 months, 1 year, 2 years, 3 years, 4 years and 5 years (and above), respectively.
- Spray a 10–15-day-old culture filtrate of *Pseudomonas fluorescens* on the crown region and on nuts of coconut.
- Spray with a fresh leaf extract from henna (*Lawsonia inermis* Linn).

CONTROL WITH PLANT PROTECTION PRODUCTS

- Remove all the affected tissue of the crown region and apply cupric hydroxide at every 6 months through a canopy spray or by drenching with the solution direct to the axils of leaves and fruits.
- Apply Bordeaux paste and protect it from rain until normal shoots emerge.
- Spray copper oxychloride on the crowns of the palms as a prophylactic measure before the onset of rainfall.
- Partially dehusk healthy seed nuts and treat with fungicides as a measure to reduce disease transmission.

OTHER CONTROL METHODS

No other distinct methods are available.

7.14. LETHAL BOLE ROT - *MARASMIELLUS COCOPHILUS*

DESCRIPTION/IDENTIFICATION

On older palms, leaves wilt, and remain as a 'skirt' around the trunk, the spear leaf dies and a foul-smelling soft rot develops. A dry, reddish-brown rot with a yellow margin is typically present at the base of the bole. Cavities within these areas of rot are lined with mycelium in young palms (CABI, 2022m).

PEST LIFE CYCLE AND BIOLOGY

Mycelial cultures from infected bole tissues and from sporophores are highly pathogenic to seedlings, and slowly invaded older tissue. M. cocophilus reaches the inner bole tissues only through the roots, and wounding of roots of their aerenchymatous protuberances is important in infection. Seedlings may also become infected through roots damaged during transplanting from nurseries to the field. Movement of seedlings from affected areas is one certain method of dispersal (Bock, 1970).

AFFECTED STAGES OF THE CROP

Seedlings and palms up to 8 years old (Bock, 1970).

SYMPTOMS AND DAMAGES

Premature death of the oldest two or three leaves, white fungal threads and toadstools at the base of the petioles, on top of the seednut, brown rots and cracking occurs in the leaf bases of younger leaves. A dry, reddish-brown rot with a yellow margin is typically present at the base of the bole. Toadstools commonly occur on exposed roots, leaf bases of seedlings and on the soil surface around holes where diseased palms were present 2-years' before (CABI, 2022m).

Figure 60 — Lethal bole rot. Grahame Jackson - EcoPort, www.ecoport.org

IMPACT ON YIELD AND QUALITY

Losses of up to 90% of seedlings were reported in East Africa during out breaks in late 1960s (Bock, 1970).

QUARANTINE ORGANISM

Yes (EPPO, 2022m).

FAVOURABLE CONDITIONS

Tropical climate

SURVEILLANCE/MONITORING

No known methods of surveillance for the disease.

CULTURAL CONTROL

- Select healthy seedlings for transplanting.
- Uproot and burn affected palms immediately after detection of the disease
- Prune and treat damaged roots
- Sterilise the soil periodically.
- Remove weeds in the nursery
- Avoid close packing of seedlings in nurseries. Provide at least 1 m between seedlings.

BIOCONTROL

Not known.

CONTROL WITH PLANT PROTECTION PRODUCTS

Dipping seedlings in fungicides: seednuts should be taken directly from the palm, partially dehusked by trimming at the top and three sides and dipped in an appropriate fungicide.

OTHER CONTROL METHODS

No other distinct methods are available.

7.15. SUMMARY TABLE OF ACTIVE INGREDIENT / BIOLOGICAL AGENT AGAINST COCONUT PEST AND DISEASES

ACTIVE INGREDIENT OR BIOLOGICAL AGENT	MODE OF ACTION (IRAC AND FRAC CLASSIFICATION)*	AFRICAN PALM WEEVIL	BLACK HEADED CATERPILA	COCONUT BUG	COCONUT MITE	COCONUT SCALE	COCONUT SPIKE MOTH	PENTANTOMID BUG	RED PALM WEEVIL	RHINOCEROS BEETLE	TERMITE	LETHAL YELLOWING DISEASES	BUD AND FRUIT ROT	LETHAL BOLE ROT
ACETAMIPRID	4A, néonicotinoïdes		×											
APANTELES TIRATHABAE	Parasitoids						×			×				
ARGYROPHYLAX BASIFULVA	Parasitoids						×			×				
AZADIRACHTIN	UNE		×		×						×			
BEAUVERIA BASSIANA	UNF								×					
BRACHYMERIA NOSATOI	Parasitoids		×											
BRACON HEBETOR	Parasitoids		×											
CEROMASIA SPHENOPBORI	Parasitoids	×												
CHELISOCHES MOIO	Predator								×					
CHILOCORUS POLITUS	Predator					×								
CHILOCORUS NIGRITIS	Predator					×								
COPPER SULPHATE	M01				×								×	
COPPER HYDROXIDE	M01		×		×								×	
COPPER OXYCHLORIDE	M01		×										×	
CRYPTOGNATHA NODICEPS	Predator					×								

ACTIVE INGREDIENT OR BIOLOGICAL AGENT	MODE OF ACTION (IRAC AND FRAC CLASSIFICATION)*	AFRICAN PALM WEEVIL	BLACK HEADED CATERPILLA	COCONUT BUG	COCONUT MITE	COCONUT SCALE	COCONUT SPIKE MOTH	PENTANTOMID BUG	RED PALM WEEVIL	RHINOCEROS BEETLE	TERMITE	LETHAL YELLOWING DISEASES	BUD AND FRUIT ROT	LETHAL BOLE ROT
EMAMECTIN BENZOATE	6: Avermectines & milbemycines		×											
GARLIC	UNE				×									
HENNA	UNE				×								×	
GONIOZUS NEPHANTIDIS	Parasitoids		×											
HIRSUTELLA THOMPSONII	UNF				×									
LAMBDA-CYHALOTHRIN	3A: Pyrethroids	×		×										
LINDORUS LOPHANTHAE	Predator					×								
MALATHION	1B: Organophosphorés		×											
METARHIZIUM ANISOPLIAE	UNF	×							×					
NEEM	UNE	×			×						×			
NEEM OIL	UNE	×			×						×			
NUDIVIRUS	Virus									×				
OECOPHYLLA LONGINODA	Predator			×				×						
PALM OIL	UNE				×									
PLATYMERIS LAEVICOLLIS	Predator								×					
PSEUDOMONAS FLUORESCENS	Antagonist				×								×	
PSEUDOSCYMNUS ANOMALUS	Predator					×								

ACTIVE INGREDIENT OR BIOLOGICAL AGENT	MODE OF ACTION (IRAC AND FRAC CLASSIFICATION)*	AFRICAN PALM WEEVIL	BLACK HEADED CATERPILA	COCONUT BUG	COCONUT MITE	COCONUT SCALE	COCONUT SPIKE MOTH	PENTANTOMID BUG	RED PALM WEEVIL	RHINOCEROS BEETLE	TERMITE	LETHAL YELLOWING DISEASES	BUD AND FRUIT ROT	LETHAL BOLE ROT
PYRIPROXYFEN	7C					×								
QUICK LIME	/				×								×	
RHYZOBIUS PULCHELLUS	Predator					×								
SOAP	UNM				×									
SPINOSAD	5: Spinosynes		×											
STEINERNEMA CARPOCAPSA	Parasitoids								×					
SULPHUR	M02				×									
TELENOMUS TIRATHABAE	Parasitoids						×			×				
TELSIMIA NITIDA	Predator	×												
TRICHODERMA VIRIDE	BM02				×								×	
TRICHOGRAMMA MINUTUM	Parasitoids		×											
TRICHOPODA PENNIPES	Parasitoids							×						
TRICHOSPILUS PUPIVORA	Parasitoids						×	×		×				
TRISSOLCUS BASALIS	Parasitoids							×						
VENTURIA PALMARIS	Parasitoids						×			×				
VERTICILLIUM LECANII	UNF				×									

*Mode of action classification **FRAC** for fungicides can be found here, and **IRAC** for insecticides can be found here.

8

HARVESTING COCONUT

8.1. COMMERCIAL QUALITY

Coconut yields are variable according to variety, ecological conditions, and management and may range from 250 kg/ha to 5000 kg/ha of dry copra per year.

Extract following coconuts from the marketable batch: (i) damaged (cracked during harvest, attacked by insect pests or with signs of disease); and (ii) abnormal (too small or too big, irregularly shaped) nuts. Prepare both coconut for water extraction and coconut for copra and milk, as described in section 8.3.

8.2. WHEN TO HARVEST

FOR COCONUT WATER

- Harvest coconut around 7 months after flowering. At this stage, the nuts will have attained full size, have a maximum water content and jelly-like meat but will still be immature.
- At 7 months after flowering, the immature nuts are still green, yellow or gold depending on the variety. The short stem above each individual coconut will have just started to dry (NARI, 2004).

FOR COPRA AND MILK

- Harvest the coconut at around 12 months after flowering. At this stage the nuts are fully mature, have maximum copra and oil content and firm coconut meat.
- At 12 months after flowering, mature nuts are brownish in colour and the stem on top of the coconut is also brown (NARI, 2004; Terdwongworakul et al., 2010).

8.3. GOOD PRACTICES

HARVESTING FROM SHORT (STILL GROWING) TREES

Harvest while standing on the ground by cutting the stem just above the shoulder of the fruit (nut) using a sharp machete or knife.

Fruits from short coconut trees may be harvested using a machete or knife by cutting the stem just above the shoulder of the fruit. The fruits may also be twisted or snapped off the tree by hands.

Figure 61 — Coconut harvesting from short variety trees
Source: farmingsystems.wordpress.com

HARVESTING FROM TALL TREES

Cut the stem of an individual nut using a sharp harvesting blade attached to a long pole; or sever the stem holding the entire bunch (if the majority of the nuts in the bunch are ready for harvesting). Alternatively, use skilled climbers with tree climbing devices to reach the nuts and sever them (Punchihewa, and Arancon, 1999).

Coconut harvesting can be done using several methods such as climbing, powertiller operated ladder and harvesting robot. Climbing is the most common method used by coconut growers. It is done with the help of a rope ring round the feet or ankles of the climber or by using a ladder. On reaching the top, the climber taps the nut in the lowermost bunch with his harvesting knife to test its maturity. Once satisfied with maturity, he cuts the bunch at the base of the stalk and the bunch drops to the ground. If the ground is very hard or tender nuts are harvested, the bunches are lowered by using a rope.

http://www.agritech.tnau.ac.in/expert_system/coconut/coconut/coconut_harvest_postharvest.html

A new technology of harvesting using a robot called Amaran has been developed by scientists in India. The user manually assembles the robot ring-shaped body around the base of coconut tree and wirelessly controls the robot from the ground, utilizing either a joystick unit or a smartphone application to move it up and down and to rotate it around the tree trunk. Once the robot has reached the coconuts, its arm is extended and positioned at the base of the bunch of ripe coconuts. Utilizing a circular saw blade on the end of the arm, cuts through that base allowing coconuts to fall to the ground (Megalingam et al., 2020).

Amaran at work in a coconut tree **Amrita Vishwa Vidyapeetham University**

Figure 62 — Coconut harvesting from tall variety trees
Source: stockarch.com

CLEANING AND DEHUSKING

Coconut marketed for its water can be sold without dehusking to retain sugar content and overall quality of the water, although this adds export weight and volume. Clean the non-dehusked coconuts using a damp cloth or using cotton gloves to remove stains, dirt and dust.

Always dehusk coconut intended for copra and milk. Dehusk after one or several days of drying at ambient temperature, using a sharp pointed metal stake mounted on a platform.

SORTING OF DEHUSKED COCONUTS

Separate coconuts based on size (small, medium and large), shape (uniformity) and presence or absence of blemishes before marketing non-dehusked nuts. The skin colour of non-dehusked coconuts is a characteristic of the variety (green, yellow or gold). Dehusked coconuts should be free of cracks and have deeply sunken eyes.

PACKING

Various containers are used for coconut packing depending on market destination. Domestically marketed coconuts may be packed in large synthetic or mesh sacks. In large-scale operations, fruits are packed in large wooden bins. Coconut for export are usually dehusked and packed in strong well ventilated fibreboard cartons and dividers may be used to separate individual fruits (Gosh, 2015).

9

POST-HARVEST

PROCESSING OF COCONUT

Once harvested, coconut delivers products such as coconut water and copra that can be processed into coconut milk and coconut oil using different methods.

Coconut water is a refreshing natural drink, low in calories and fat but rich in minerals, vitamins and beneficial phytohormones. External contaminants, enzymatic and non enzymatic browning are critical factors that causes spoilage of coconut water. To avoid this, different preservation methods have been applied including conventional heating, filtration, and ultraviolet treatment with the use of chemical additives. There are new technologies also reported on preservation of coconut water including but not limited to ultrasonic, ohmic heating, microwave processing, cold plasma processing and high pressure carbondioxide (Mohan et al., 2022).

Coconut milk has a growing market potential following its increasing applications in food and beverage industries. It is extracted from mature coconut meat which is rich in protein and fat. Basically coconut milk is oil in water emulsion, stabilized by some proteins existing in the aqueous phase (Divya et al., 2022). Coconut milk is obtained from the edible portion when coconut is subjected to removal of the shell followed by paring and draining of water. The coconut meat can then be collected manually and grated using a rotary wedge cutter machine, mixed with or without water and pressed to extract coconut milk. Coconut milk is naturally stabilized by proteins and phospholipids but additional stabilizer can be added to work in conjugation with coconut proteins (Patil et al., 2018). The milk can further be centrifuged and processed to products like milk concentrate, coconut cream and coconut powder (Manikantan et al., 2018).

Virgin coconut oil is a useful substance in human daily life as it contains high percentage of lauric acid which has many health benefits. The oil is believed to have medicinal values including antifungal, antioxidants, antibacterial, antiviral, hepaprotective, low glycaemic index and immune system enhancement. The traditional methods used for oil extraction are cold and hot extraction which is challenged with low yield oil and hot extraction, which reduces antioxidant properties of the oil. To reduce these effects, several modern processing methods have been introduced including low pressure extraction, chilling, freezing and thawing method, fermentation, centrifugation, enzymatic extraction and supercritical carbondioxide (Ng et al., 2021).

9.1. FIELD

PRECAUTIONS FOR FIELD HANDLING

If dehusking (see section 8.3) is done in the field, separate all nuts with signs of cracking and insect damage from good, high-quality nuts, prior to transporting.

POSTHARVEST STORAGE OF COCONUT

Harvested coconuts should be stored under ideal temperature and relative humidity to extent its market life. The ideal storage temperature ranges from 0-1^{0}C at which coconut stores up to 2 months. Moderately cool temperature of 12-16^{0}C allows coconut storage of up to 3 weeks. Alternatively coconut can be held in a shaded location at ambient temperature for up to 2 weeks without significant quality loss. The ideal storage relative humidity (RH) is between 80-85%. Low RH at storage leads to coconut weight loss and transpiration while high RH above 90% makes harvested coconuts susceptible to surface mold (Ghosh, 2015). Waxing helps to extent the market life of water coconuts by preventing loss of coconut water and sugar content, for both dehusked and non-dehusked water coconuts. Waxing significantly reduces weight loss of coconut water and is also effective in reducing stress cracking of dehusked coconuts during transportation. Wax the coconuts by rapidly dipping them into a tank of melted paraffin (NARI, 2004).

Longer storage under ambient temperature (25^{0}C) without processing, physical and physical-chemical properties of coconut pulp and water results into postharvest deterioration. The deterioration includes among others, increased acidity, fermentation odors, pulp softening and discoloration as well as fungal problems (Carlos et al., 2019).

9.2. TRANSPORT

Transport non-dehusked coconuts from the field, either loose in the back of a lorry/pickup vehicle or after packing them in sacks/bags. Dehusked coconuts should be packed in containers that reduce the risk of stress cracks before loading into lorries or other forms of transporting vehicles.

10

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