SUSTAINABLE PRODUCTION

GUIDE

COLEAD

GINGER (ZINGIBER OFFICINALE)

Funded by the European Union

CONTRIBUTIONS TO THIS PUBLICATION

Coordination/Editors: Pieterjan De Bauw[1], Alice Jacques[1], Edouard Lehmann[1]
Authors: Louise Abayomi[2],
Layout and graphic design: Mazy Graphic Design srl

AFFILIATIONS:

1 Committee Linking Entrepreneurship – Agriculture – Development (COLEAD)
2 Natural Resources Institute, University of Greenwich

HOW TO CITE

L. Abayomi, P. De Bauw, A. Jacques, E. Lehmann. 2025, Sustainable Ginger Production Guide, COLEAD, Fit For Market Plus, Brussels, Belgium, 164p

Permanent link to cite or share this item: https://resources.colead.link/en/e-bibliotheque/sustainable-production-guide-of-ginger-zingiber-officinale

Funded by the European Union

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1

INTRODUCTION

It is important to adopt 'Good Practices' to promote the long-term sustainability of ginger production. By employing sustainable techniques, biodiversity is enhanced, natural resources are conserved, and negative impacts on the environment minimized. Understanding what ginger needs, this guide discusses the agronomy of ginger, providing an overview of important ginger varieties, their characteristics, crop maintenance, and handling requirements, which influences quality and yield. The guide also emphasises on the importance of soil health, water conservation, and integrated pest management, with guidelines and examples on proper implementation. Such techniques include fertiliser management, crop rotation, companion planting and good postharvest management.

In order to secure the economic sustainability of ginger production with a focus on environmental responsibility, it is crucial to align with market trends, value chains, and certification schemes. By gaining insight into consumer preferences and accessing high-end markets, farmers have increasing prospects to receive recognition for their dedication to sustainability. This supports ginger producers to meet the rising demand for ginger produced responsibly while promptly adapting to consumer preferences.

1.1. SOME HISTORICAL AND GEOGRAPHICAL INFORMATION ON THE CROP

The use of ginger is reported to date back at least 5000 years. Its exact origins are unclear but it is proposed as most likely originating from Asia (Prasath et al., 2023). Most production occurs in the tropics and subtropics.

Ginger (Zingiber officinale Roscoe) is an herbaceous perennial monocotyledonous plant from the family Zingiberaceae. Ginger's generic name, Zingiber, is derived from the Greek zingiberis.

From a botanical perspective, ginger is classified as follows:

- Kingdom: Plantae (plants)
- Clade: Tracheophytes (vascular plants)
- Clade: Angiosperms (flowering plants)
- Clade: Monocots (monocotyledons)
- Order: Zingiberales
- Family: Zingiberaceae (ginger family)
- Genus: Zingiber
- Species: Zingiber officinale

1.2. GLOBAL/REGIONAL IMPORTANCE OF GINGER

Ginger is of significant economic importance as a cash crop for many countries and it is the most widely used and globally traded of all spices. Ginger contains several bioactive compounds, and it is used for flavouring, traditional medicine and homeopathy. The main commercial forms are fresh roots, dried roots, and oleoresins.

India and Nigeria account for 60% of global ginger production[1]. **India**, the largest producer, is known as the "spice bowl" of the world. India has a long history of ginger cultivation and is known for its high-quality varieties. **Nigeria** is the largest ginger producer in Africa and has been increasing its production in recent years. It supplies ginger to both domestic and international markets. Other ginger producing countries with significant outputs are **China**, which has vast areas suitable for ginger cultivation. **Nepal** has been increasing its ginger production in recent years and has become one of the top ginger-producing countries in the world. Ginger cultivation is widespread in **Indonesia**, particularly in the regions Java and Sumatra. It is a significant ginger exporter as well. **Thailand** has a favourable climate for ginger cultivation and is a significant producer and exporter of ginger. **Peru** is one of the main ginger producers in South America. It has suitable growing conditions, and its ginger is exported to various countries. **Brazil** also has a significant ginger production, primarily in the states of Minas Gerais and São Paulo, and it exports ginger to several countries. **Vietnam** is known for its ginger production, and it exports ginger to various parts of the world. It has favourable climate conditions for ginger cultivation. The largest exporter of ginger globally however is **China**. Due to the optimal climate and advanced organic farming practices, South American countries have specialized in the cultivation of organic ginger, with organic ginger from **Peru** being highly popular in the EU.

1.3. MAIN GINGER VARIETIES OF IMPORTANCE, PRINCIPAL CHARACTERISTICS, AND THEIR DISTRIBUTION

Ginger varieties are characterized by colour, aroma, morphology, and chemical composition. There are 25 commercial varieties of ginger globally, with little genetic variation. Ginger is characterized as spicy, 'hot' or pungent in taste and aroma. According to Le and co-workers (2014), environmental factors such as soil type, season, climate, cultivation practice, location, maturity, and postharvest processes contribute to differences in these characteristics. Further information on popular ginger varieties is presented in the following sections.

1.4. GINGER MORPHOLOGY

Ginger is a perennial plant and has an underground rhizome. It can grow up to 1 meter tall. The leaves are long and thin and grow in a pattern where each leaf is

1 https://www.fao.org/faostat/en/#data/QCL.

positioned alternately. The plant produces clusters of white and pink flower buds that turn into yellow flowers as they mature. These flowers are arranged in an elongated cone-shaped spike and are covered with green bracts. The plant also produces leafy shoots, called pseudostems, which are formed by the leafy sheaths and carry 8 to 12 leaves in a distichous arrangement. The flowering structure, or inflorescence, grows directly from the rhizome (Fig. 1).

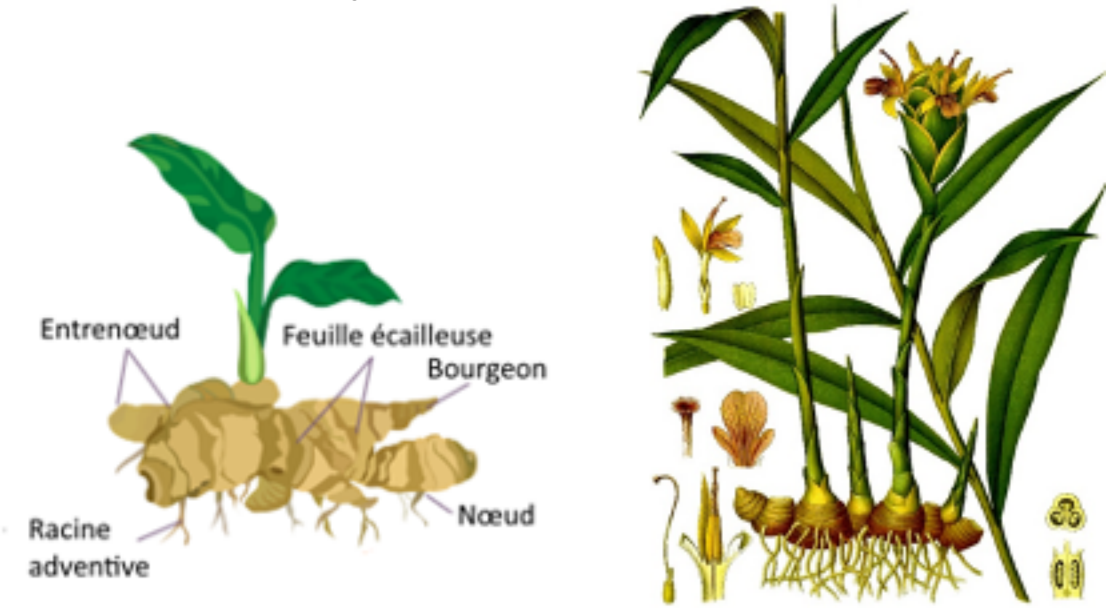


Figure 1: Ginger morphology
(Image credit: Far left - Kozlova Elena; Above - Köhler et al., 1887)

These pseudostems are not true stems but are composed of tightly packed leaf sheaths that enclose the actual stem. The pseudostems can reach heights of 60 to 120 cm or more.

Figure 2.: Cross section of fresh ginger
(Image credit: Far left - Sanjay Ach; Above - cured ginger hand, Britania)

Ginger plants develop fibrous roots that extend from the rhizome into the surrounding soil. These roots help anchor the plant and facilitate nutrient uptake. The young shoots (pseudostems) are edible components. The leaves are alternately arranged along the stem and have prominent veins. They can grow up to 15 - 30 cm in length. Ginger plants develop clusters of flowers called inflorescences, which grow from the lower part of the pseudostem. These inflorescences are composed of closely packed bracts, which are modified leaves that encircle the individual flowers. The bracts often exhibit shades of green or yellow and may display streaks of pink or white. Ginger flowers themselves are small and tubular, commonly appearing in a light-yellow hue as they emerge from the bracts within the inflorescence (Fig. 3).

Figure 3. Ginger plant with flowers (Image credit: Plantvillage)

2

WHAT DOES GINGER NEED?

In this section, we provide a general overview of the essential conditions necessary for the successful cultivation of ginger. These conditions would not only ensure high yields but also contribute to the improvement of farmers' livelihoods and income. Critically these conditions emphasize the importance of employing environmentally sustainable agroecological practices throughout the production process.

2.1. CLIMATE

2.1.1. CLIMATICAL ZONES

Ginger flourishes in areas with ample rainfall and high humidity, commonly seen in tropical and subtropical settings. It favours well-drained soils that are slightly acidic and enriched with humus. Nevertheless, by giving it appropriate care, ginger can also be grown successfully in cooler subtropical and temperate regions. The quality, growth rate, and yield heavily depends on the prevailing climatic conditions.

2.1.2. TEMPERATURE

Ginger cultivation favours temperature of 19 - 28°C. Ginger is sensitive to frost and cannot tolerate temperatures below 10°C.

2.1.3. RELATIVE HUMIDITY

Ginger cultivation favours a humidity of 70 - 90%. Outdoor and indoor temperature and humidity meters are readily available and widely used in monitoring these two variables. They come in both digital and analogue formats.

a.

Figure 4: Low cost temperature & humidity measurement (a),
(Image credits: a. Ibaste Multifunctional Humidity Monitor Temperature Meter

2.2. LIGHT AND SHADING

Performance of ginger is better in partial shade. They need about 4 to 6 hours of indirect sunlight daily. One should avoid exposing ginger plants to direct sunlight, as it can scorch the leaves. Ginger prefers 30% shade. High tunnel structures, such as those constructed with plastic, provide sufficient shade, whilst growing ginger on field conditions require intercropping with appropriate cover crops for shading ginger (Table 7).

2.3. ALTITUDE

The ginger crop can grow at altitudes between 300 - 1500 meters above sea level. Elevations above 500m yield increased productivity, with up to 900m being optimal.

2.4. WATER

2.4.1. RAINFALL

The optimum rainfall for ginger production is ca.1500mm per annum. In general, ginger plants benefit from receiving between 1270 and 1900mm of rainfall per cropping cycle.

2.4.2. IRRIGATION

Supplementary irrigation may be required for export targeted ginger and/or during dry spells for local rainfed production. Several irrigation systems are available, and more information on this is provided in the water management section below.

Fgure 5: Example of a drip irrigation system for ginger production
(Image credits: Far left, NAGZARI. Far right, Khetibiz.com , Milind Kumar)

2.5. SOIL

2.5.1. STRUCTURE

A soil that is well-draining and loose is best for ginger.

2.5.2. TEXTURE

For the optimal development and size of rhizome shape, it is recommended to cultivate ginger in clay loam and sandy soils, although it is adaptable to different soil types.

2.5.3. DEPTH

Material (cut seed rhizomes) are planted at a depth of 3-5 cm, but the fibrous roots may grow to 30cm deep, depending on variety.

2.5.4. PH

Soil pH ranging from 5.7 - 6.5 is optimal, whilst a pH of between 5.5 - 8.5 will still give respectable yields. There are several easy to use and affordable commercial soil pH testing kits available (Fig. 6).

Figure 6: Common, low-cost pH soil testing kit (Image credit: Lusterleaf)

2.5.5. SALINITY

For optimal ginger cultivation, it is preferable to keep the electrical conductivity (EC) of the soil, which indicates its salinity level, below 2 deciSiemens per meter (dS/m). Ginger productivity is negatively affected by saline, and especially sodic conditions.

2.6. NUTRITION

Ginger production benefits from the practices of integrated soil fertility management (ISFM) including integrated nutrient management (INM). Ginger is a crop that depletes nutrients rapidly and requires timely application of multiple nutrients. Generally, ginger plants thrive when provided with a well-balanced fertilizer schedule that caters to their nutrient requirements at various growth stages. Some symptoms of nutrient deficiency are described below (Fig. 8 & Table 1). Kindly note that proper diagnosis of nutrient deficiencies should be done by soil- and tissue analyses, of which results should be used to derive correct, site-specific nutrient recommendations.

The ginger plant requires the following essential elements for optimum growth and production:

- Nitrogen
- Phosphorus
- Potassium
- Calcium
- Magnesium
- Sulphur
- Boron
- Copper
- Iron
- Manganese
- Zinc
- Carbon
- Oxygen
- Hydrogen
- Molybdenum
- Chlorine
- Sodium

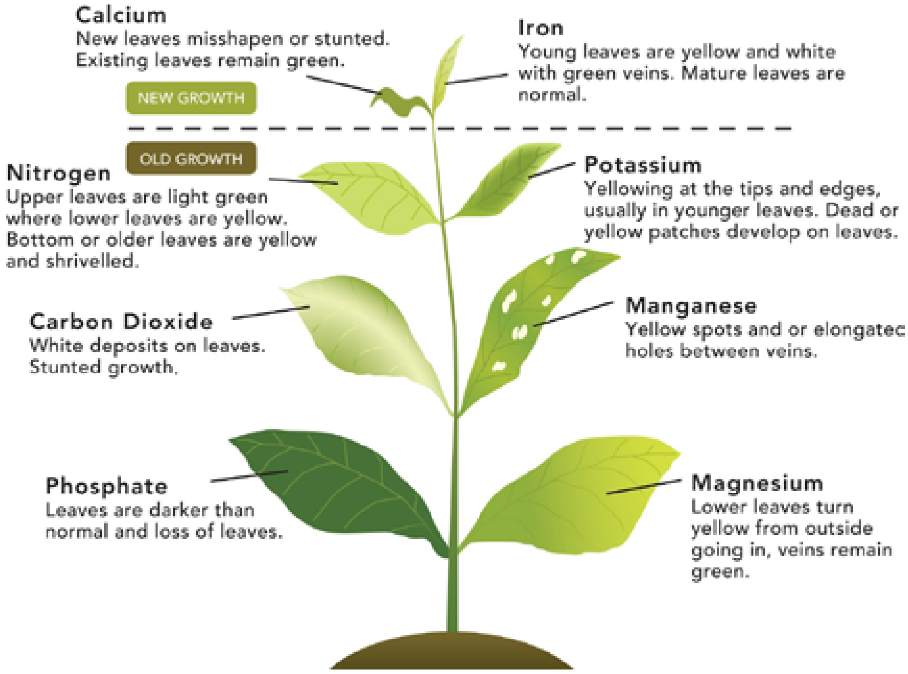


Figure 7: A simplified nutrient deficiency guide for plant diagnosis

2.6.1. IDENTIFICATION OF NUTRIENT DEFICIENCIES AND CORRECTIVE MEASURES FOR GINGER

Table 1. Symptoms of nutrient deficiencies on ginger plants, with some examples of general recommendations

Nitrogen (N) - Older leaves turn pale yellow or white — apply ammonium sulphate or urea following recommended rates
Phosphorus (P) - Older leaves turn purplish or dark green — use superphosphate or bone meal according to recommended rates
Potassium (K) - Older leaves develop brown or yellow edges — apply potassium sulphate or potassium nitrate following recommended rates
Magnesium (Mg) - Interveinal chlorosis in older leaves — apply magnesium sulphate (e.g. Epsom salt) following recommended rates
Iron (Fe) - Young leaves show interveinal chlorosis — use iron chelate fertilizers (e.g., iron sulphate) as foliar sprays or soil amendments
Zinc (Zn) - New leaves display interveinal chlorosis — apply zinc sulphate or zinc chelate fertilizers following recommended rates
Manganese (Mn) - Interveinal chlorosis in young leaves — apply manganese sulphate or chelate fertilizers
Calcium (Ca) - Growing tips and young leaves show necrosis — incorporate gypsum or agricultural lime into the soil
Sulphur (S) - New leaves turn pale yellow — apply elemental sulphur or sulphate-based fertilizers
Copper (Cu) - Young leaves exhibit chlorosis — apply copper sulphate or chelate fertilizers
Boron (B) - Growing points show abnormal growth — apply borax or boron-containing fertilizers
Molybdenum (Mo) - Leaves exhibit interveinal chlorosis — apply molybdenum-containing fertilizers.
Nickel (Ni) - Leaves show interveinal chlorosis — apply nickel sulphate or chelate fertilizers.
Silicon (Si) - Leaves become weak and damaged — apply silicon-based fertilizers or foliar sprays.
Chlorine (Cl) - Leaves may wilt and develop necrosis — ensure proper irrigation and nutrient balance.

*Note: Sodium deficiency is rare in ginger, and excessive sodium can be harmful. Address sodium toxicity by improving drainage and using sodium-free fertilizers.

Reportedly, potassium stands out as a significant limiting factor for ginger production. It is crucial to determine the appropriate type and amount of fertilizer based on soil testing. There are several test kits for assessing soil fertility on the field (Fig. 8), but chemical analyses in certified laboratories provide more detailed information. The frequency of fertilizer applications in ginger cultivation may vary depending on factors such as soil fertility, past fertilizer usage, crop health, and local conditions.

Figure 8: Example of a portable commercial soil NPK testing kit
(Image credits: Far left, environmental concepts; Middle and far right, Soil Savvy™)

Figure9: Symptoms of potassium (left) and nitrogen (right) deficiencies in ginger
(Image credit: Aries Agro Ltd)

CHECKLIST OF GENERAL REQUIREMENTS

- Ginger thrives in tropical and subtropical climates and necessitates substantial rainfall for optimal growth.
- Subtropical areas characterized by warm temperatures and high humidity are most suitable for ginger cultivation.
- Regions at higher altitudes with cold climates or prolonged frost periods are generally unsuitable for ginger.
- To determine fertilizer applications and soil corrections, soil testing should serve as the foundation, with timing of plant requirements being crucial.
- Maintaining a balanced pH level and providing sufficient soil organic matter are important.
- Commercial testing tools and laboratories are available to monitor key variables, such as soil moisture and acidity.
- Lastly, to achieve favourable ginger production, ensuring an adequate supply of nitrogen, phosphorus, potassium, calcium, magnesium, iron, zinc, manganese, copper, and boron is essential.

3

PRE-PLANTING CHOICES FOR GINGER

Pre-planting considerations for ginger should include sustainable practices that have a positive environmental, social, and economic impact.

3.1. LABOUR REQUIREMENTS

It is important to ensure that sufficient attention and proper labour arrangements are given to tasks such as planting, controlling weeds, managing pests and diseases, carrying out harvesting, and conducting postharvest operations. Often these are moments of high labour requirements, which needs planning in advance.

3.2. CHOOSING A PLOT

3.2.1. PLOT HISTORY

Prior to planting ginger, it is essential to choose fields that are uncontaminated by substances such as industrial effluents, hospital waste, toxic heavy metals, and pesticides. Additionally, it is advisable to avoid using land that is infested with persistent weeds, or soil-borne diseases.

3.2.2. TRANSPLANTING OF GINGER SEEDLINGS

High-quality seedlings, free from diseases, can be transplanted approximately 30 to 40 days after the initial planting of the rhizome buds, or once the ginger seedlings reach a height of 10 - 15 cm and have developed multiple sets of leaves.

In preparation for transplanting (to larger pots, or to the field), ensure the site has been cleared from any weeds or debris. It is also important to have a readily available water source that is free from microbial or heavy metal contamination for irrigation, fertigation, and pesticide application.

Checking the soil for heavy metal content and the potential presence of pathogens causing diseases such as rhizome rot, yellowing, wilt (*Pythium, Fusarium, Ralstonia*) is suggested when selecting a plot. A number of commercial qualitative and semi-quantitative portable test kits for assessing soil or water heavy metal presence are available (Fig. 10), and the presence of pathogens in soil and rhizome samples can be ordered from several laboratories.

Figure 11: Examples of commercial heavy metal test kit for soil or water (Image credit: Far left two, Watersafe; Far right, Osumex)

3.2.3. CROP BACKGROUND

Continuous ginger cropping should therefore be avoided. If a cultivation site has a history of contamination or pathogen presence, soil testing should be undertaken at an accredited laboratory or one utilizing Good Laboratory Practices, to assess whether there are any unacceptable soil contaminants, their levels, and to determine mitigating measures that need to be employed.

3.2.4. EXPOSURE TO SUNLIGHT

When searching for suitable new or unused land for ginger cultivation, it is crucial to have knowledge of the site's history to prevent the occurrence of persistent weeds, pests and diseases and to enhance productivity. Additionally, it is important to identify and address any potential environmental risks associated with establishing new planting areas. Opt for a sunny location for ginger production where the soil can be effectively sterilized by receiving prolonged periods of direct sunlight, ideally 4-6 weeks before planting seed rhizomes.

3.2.5. TOPOGRAPHY

Mapping a ginger field before planting is important to optimize resource allocation, manage pests and diseases, streamline operations, and enable effective monitoring and evaluation. Planting in flood prone areas as well as strongly sloping areas should be avoided.

3.3. PLANTING MATERIAL

There are three ways of propagating ginger (i.e. via seeds, seed rhizomes, or single bud propagation). Through the ginger seeds, we can perform rhizome division and tissue culture. Commercially grown cultivars of ginger are generally infertile, so seed production is rare (Fig. 11). Consequently, the majority of ginger plants are reproduced asexually using pieces of seed rhizomes or "sets" (Fig. 11), from which sprouting 'buds' emerge. The absence of viable seeds presents a challenge in breeding programs, as it hinders the production of hybrid offspring breeding for disease resistance and adaptability to different environments (Prasath et al., 2023). Partly therefore, only a relatively limited amount of diverse ginger varieties are existing globally.

Do verify nursery certification and permits when sourcing seedlings (or rhizome sets/ seeds). Avoid obtaining planting material from disease-affected areas. Local extension authorities may be able to provide guidance on quality planting material.

Figure 11: Ginger seeds (left) and Rhizome (right) (Image credits with permission: Rajender Kumar Nitin Kumar; Abayomi, 2023)

Tissue culture from seeds or rhizomes is a modern propagation technique used to multiply ginger planting material efficiently and disease-free, although rarely conducted. It involves sterilizing the seeds/rhizomes and cultivating their tissue in a controlled laboratory environment using nutrient-rich growth media. The process begins with the extraction of explants, typically embryos or meristematic tissues, which are then placed in sterile culture containers. These tissues are exposed to hormones like auxins and cytokinins to stimulate cell division and differentiation, leading to the formation of plantlets. This method allows for rapid multiplication of genetically uniform and disease-free ginger plants, ensuring high-quality planting material. Tissue culture is especially beneficial in meeting large-scale production demands and combating challenges like limited availability of healthy seed rhizomes and susceptibility to pathogens in traditional propagation methods.

3.3.1. STIMULATING SPROUTING, CUTTING, AND PRE-TREATMENT OF SEED RHIZOMES FOR PEST/DISEASE PREVENTION

Ginger rhizomes naturally go through a period of dormancy, during which they stay inactive or experience delayed sprouting. It is important to select planting material which are healthy, free from signs of pest and disease, mature, firm, and not dried or shrivelled. Air dry the rhizomes before planting to help prevent excessive moisture and rot. This improves survival rates of seedlings. For traditional production, seed rhizomes should have 2 - 3 growing buds into 5cm sets weighing around 30 - 60g and not smaller than an inch (2.5cm). They should not be too young to prevent disease and encourage strong plants.

Figure 12: shrivelled and sprouting planting material (Source: adapted from agro4africa.com)

Seed rhizomes are soaked in clean water for 10 - 12 hr to stimulate sprouting. Seeds may be soaked in a copper-based fungicide, insecticide and/or nematicide solution according to manufacturer guidelines and respecting local registrations of products. Rhizomes are then drained, shade-dried (direct sunlight negatively affects rhizomes), and cured (Fig. 13) for a few days prior to planting.

Figure 13: Rhizome drying and curing after soaking
(source: COLEAD; Raffie and Mullins, Virginia State University)

3.3.2. SINGLE BUD PROPAGATION (SBT)

Ginger seedlings can also be raised in a nursery using a single bud technology. The source and quality of the media should be confirmed before purchase. To reduce costs, locally available composting materials and technology can be used to prepare the grow mix. The source and quality of the media should be confirmed beforehand, in case of purchasing.

After the ginger buds have sprouted and the shoots have grown to an appropriate length, the sprouted rhizome sections or individual buds can be treated to encourage further growth. This can be done through rhizome cutting, where the sprouted rhizome sections are divided into smaller pieces, thus maximising the amount of viable planting material. The seed rhizomes used for SBT should be washed with clean water. Single bud rhizomes can be treated with (bio)pesticides and or biofertilizers (i.e. microbial inoculants / bio-stimulants) if available. Synthetic fungicides, if used, should be registered for use to control that particular pathogen. Prepare the fungicide solution as per recommended dosage. After treatment, shade-dry in a ventilated area. Single buds can be planted in trays filled with growing media (Fig. 14).

At around 20 days following nursery propagation, consider applying micronutrient foliar treatments to the seedlings, using a locally available product.

Figure 14: Cut ginger rhizome planting material demonstrating preparation and planting for single bud propagation (Image credit: Above: Propagating ginger seed rhizomes, showing size, depth and spacing (Image credit: NurseyLady.com)

Figure 15: Growing plantlets propagated using single bud technology for ginger multiplication (Image credit: left, ICAR-Indian Institute of Spices Research Kozhikode; right, Pro Tray)

Once in trays, it is important to store the seed rhizomes in a sanitised and well-ventilated environment. Seedling trays should be placed under the shade, preferably in a greenhouse, ensuring they are kept elevated, away from walls. Ideal conditions to encourage sprouting and achieve consistent growth of seedlings, involve controlling temperature, humidity, and applying appropriate pre-planting treatments. After sufficient growth, seedlings can later be moved to larger containers or planted directly in the field (Fig. 16).

When transferring the seedlings from the nursery to the planting area, it is advisable to do so in the morning or evening to avoid heat and/or water stress. The vehicle used for transportation, if being used, should be clean and hygienic, containing only uncontaminated planting material.

FFigure 16: Ginger rhizomes and single buds ready for planting out in field or larger units

To transplant, ensure proper land preparation using mechanised or manual labor to loosen the soil and enhance aeration. Then, using a trowel, dig a hole equal to the depth and twice the width of the root ball of the ginger plant being transplanted. Position the ginger plant in the hole. The top of the root ball should be at the level of the soil surface (Fig. 17). Avoid planting the seed too deep as rhizomes need exposure to air. Also ensure the buds on the rhizomes are facing upright. It is recommended to space them approximately 20 - 30 cm apart. Once the seed is in place, carefully backfill the hole, so the rhizomes are well covered. Transplanted seeds will need watering immediately. This helps settle the soil around the plant roots and mitigates against transplant shock.

Figure 17: Planting ginger (Image credit: Practical Self-Reliance)

3.4. NURSERY MANAGEMENT

3.4.1. NURSERY LOCATION

When propagating own planting material, a nursery site considering drainage and plot history should be carefully chosen. Select a sunny location where the soil can receive extended periods of direct sunlight, preferably 4 - 6 weeks at a time, to aid soil sanitation.

3.4.2. PHYTOSANITARY MEASURES

Consider the historical presence of pests and diseases on the premises, as well as neighbouring crop production areas that involves plants known to be susceptible to ginger pests and diseases. During the preparation of seedlings in a nursery, it is crucial to maintain a sanitised environment and clean equipment, keeping the facility closed to prevent the entry of pests (such as worms and leaf feeders) and the spread of pathogen spores through wind or rain splash. Regularly monitoring the seedlings for uniformity, pests, and diseases. Removing and incinerating any abnormal seedlings promptly is important. It is also important to inspect for ash-grey coloured, water-soaked lesions, which indicate the presence of leaf spot disease. Some significant host plants to scope for in the target area are:

- Banana plants, particularly those infected with pests or diseases, can attract nematodes, which are tiny soil-borne pests capable of damaging ginger roots.
- Turmeric crops can also act as hosts for some of the same pests and diseases. If nearby turmeric plants are infected, they have the potential to harbour and spread pests and diseases to ginger crops.
- Citrus trees are known to attract several pests - for example, aphids and whiteflies. If ginger crops are in close proximity to citrus trees, these pests may migrate and infest the ginger plants.
- Leguminous crops, such as beans and peas, can also serve as hosts for pests such as aphids, which can transmit viral diseases to ginger.
- Other plants in the Zingiberaceae family, which include turmeric, galangal, and cardamom, have the potential to harbour similar pests and diseases.

Certain weed species have been observed to serve as hosts for pests and diseases. Examples include the purple nutsedge species (Cyperus rotundus, difformis and esculentus). Other important weed species include Ageratum conyzoides, known to harbour ginger rhizome rot caused by Fusarium spp., whilst Eclipta prostrata and Field Bindweed (Convolvulus arvensis) can serve as a host for root-knot nematodes. More on weed identification can be found in Table 6.

3.4.3. BASIC NURSERY EQUIPMENT

- Seed sprouting trays or containers are necessary for holding the ginger rhizomes as they sprout. Trays or containers are generally made of plastic, wood, or other composite materials. Trays should have adequate drainage holes to prevent water from accumulating.
- Substrate or grow mix, such as vermiculite, perlite, coir, or a mixture of soil and organic matter, is required to create an ideal environment for sprouting. The substrate should promote good drainage while retaining moisture without becoming waterlogged.
- Fungicide or organic plant protection products may be needed to treat the ginger rhizomes or protect them from fungal infections during the sprouting phase. Follow the instructions provided with the specific fungicide for proper dilution and application.
- A long bench to elevate trays
- A watering can, irrigation equipment, or sprinklers are necessary to keep the sprouting trays or containers adequately moist. This helps maintain the required humidity and moisture levels for successful sprouting.
- Cutting tools, such as a clean sharp knife or secateurs, are used to divide the rhizomes into smaller sections, ensuring that each section contains a well-developed bud.
- Planting tools, such as a garden spade, hand trowel, or dibber, are required for planting the sprouted rhizome sections or individual buds in the field.
- Irrigation equipment, including drip lines, emitters, connectors, sprinklers, and hoses, is essential for delivering water to the ginger plants.
- Storage containers will be needed to store the ginger rhizomes before and after treatment. Ensure that the containers have proper ventilation and can protect the rhizomes from pests and excess moisture.
- Protective gear, such as gloves and masks, should be worn when handling chemicals, including PPPs, to ensure personal safety.
- Measurement tools, such as a measuring tape or ruler, can be useful for maintaining accurate spacing between ginger plants during planting.

Figure 19 Example of a stainless steel soil sampler to assess soil quality of target fields, 7(Penn Ltd)

- Shade house with 60% shade.
- Soil pH meter
- Soil sampler
- Hand-held soil moisture meter
- Temperature/humidity meter

Where employing irrigation, for small farms of 0.5 - 10Ha, consider also a drip or sprinkler kit, or rain pipe with a solar-powered system with connecting pipes and rain storage tanks, portable diesel or petrol motor pump during pre-planting planning. Employing irrigation to supplement rain-fed ginger production will promote ginger yields and extend the harvest and marketing season.

3.5. GINGER VARIETIES

Ginger variety names are given based on the location or regions in which they are grown. There are around 25 varieties of ginger all over the world, characterised by size of rhizomes, flavour, aroma, pungency, colour and fibre content. Diverse varieties tend to bear local or regional names, depending on the producing country. Some popular commercial varieties grown in the top ginger producing countries are provided below (Table 2). It should be noted that ginger producing countries continue to introduce additional varieties from other countries, and so it is advisable to consult local agricultural extension services or national seed councils when selecting planting material.

Table 2. Local ginger varieties in key ginger producing countries

COUNTRY	GINGER VARIETY/LOCAL NAME
INDIA	Nadia (also known as Maharashtra ginger), Maran (also known as Coimbatore ginger), Rio De Janeiro, Rio Grande, Suruchi, Himachal White, Suprabha ginger
CHINA	Guangxi Yellow Ginger, Laiwu Ginger, Anqiu Ginger, Shandong Ginger, White ginger, Jiangyou ginger, Hainan ginger, Yunnan ginger
NIGERIA	Yasu biri (black ginger) and Tafin giwa (yellow ginger) Other local names for these: Igbo-Ora ginger, Kaduna ginger, Jos ginger, Enugu ginger, Gombe ginger, Awka-Etiti Ginger, Kano Ginger, Atose, Benue, Nsukka ginger
INDONESIA	Banten ginger, Java ginger, Bali ginger, Sumatra ginger, Lombok ginger, Aceh ginger
NEPAL	Sankhuwasabha ginger, Rasuwa ginger, Lamjung ginger, Dhading ginger, Sindhupalchok ginger, Sundar, Khasi Pauwa, Goljamuna, Gorkha, Bhairung ginger
THAILAND	Sriracha ginger, Chiang Mai ginger, Ayutthaya ginger, Lopburi ginger, Suphanburi ginger, Khaoma Ginger, Nonthaburi Ginger, Ratchaburi Ginger, Surat Thani ginger
BRAZIL	Hawaiian Yellow, Brazilian Yellow, Amarelinho, Brazilian Red ginger

Other edible ginger types found across countries are Jamaica, Canton, Beni Shoga, Burrito, Greater Galangal, Lesser Galangal, Light Galangal, Gari, Torch, Shell, Butterfly, Japanese, Mango, Red, including Globba (not exhaustive).

3.5.1. CLASSIFICATIONS

Ginger is generally classified as low, medium, and high pungency. Large and small varieties are distinguished mainly based on the thickness of the rhizome and the level of pungency.

Figure 19: Two contrasting commercial Chinese ginger root varieties (Image credit: Anna Frodesiak)

Tolerance and/or resistance to pests, abiotic factors

Genetic engineering is currently the sole available technology to enhance ginger's resistance to pathogens, but its progress in this field is limited (Jiang et al., 2018). The overall performance of a ginger variety can be influenced by multiple factors, including local climate, cultivation practices, and management strategies.

Certain ginger varieties, distinguished in specific countries, are recognized for their superior tolerance to locally present pests and diseases compared to other varieties.

Target markets

As previously highlighted, ginger varieties may be produced for local consumption, or be targeted for regional or international export markets, for example the EU. Local varieties are often selected based on available planting material, local market demand and utilization. The market for organic ginger into the EU has been growing steadily, alongside businesses acquiring both social and environmental related certifications. Fair Trade International has developed a specific standard for spices for small-scale producer organisations who are responsible for the bulk of ginger crop production globally.

Globally, Guangdong ginger and Yunnan ginger from China are widely traded varieties. Indian ginger varieties, such as Coimbatore Large ginger and Himachal ginger, are traded in international markets. Nepali ginger varieties, including Himchuli ginger and Palung ginger, are also popular, likewise, Indonesian ginger varieties Jember and Pontianak ginger. Ginger varieties from Nigeria, such as Kaduna ginger and Gombe ginger, are also traded in international markets. Peru exports Yellow ginger and Kedah ginger; Brazilian ginger varieties, Amarelo ginger and Rio de Janeiro ginger are also traded, whilst Vietnam exports Yellow ginger and Hanoi ginger.

Baby ginger is white and pink (where it is immature without a brown epidermis), and has a particular market. Baby ginger is unique in that it has the full ginger flavour and spiciness but almost no fibres. It is therefore popular for pickling and other preserved food industries, internationally.

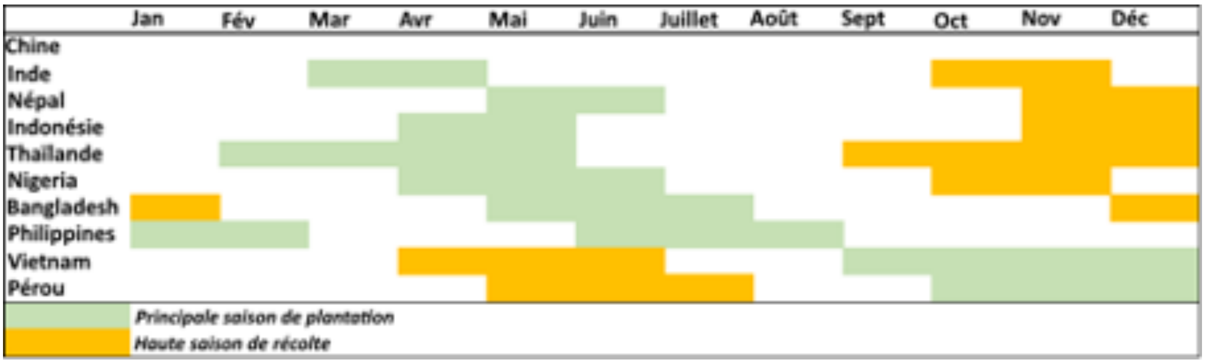
3.6. GROWING PERIOD

The ideal planting period for a given region, mainly depends on prevailing rainfall patterns and altitude.

3.6.1. REGIONAL DIFFERENCES

Unless irrigated, in which case planting can start earlier, ginger is mostly planted after the rainy season commences. An overview of major planting and harvesting periods for key ginger producing countries are given in the table 3 below, though local variations may exist.

Table 3. Main planting and harvesting periods for key ginger production/export countries



In China for example, the planting and harvesting periods for ginger vary depending on the region due to climatic differences.

Planting Period

— Southern China (e.g., Guangdong, Guangxi, and Fujian provinces): February to April

— Central and Eastern China (e.g., Jiangsu, Zhejiang, and Hunan provinces): March to May

— Northern China (e.g., Shandong and Hebei provinces): April to May

—

Harvesting Period

— Southern China: October to December

— Central and Eastern China: November to January

— Northern China: November to January

The exact timing can vary based on local climatic conditions, the specific variety of ginger planted, and agricultural practices. Generally, ginger takes about 8 to 10 months to mature from planting to harvest. In some regions with milder climates, ginger can be grown almost year-round.

3.7. ROTATION & ASSOCIATION

3.7.1. OPTIONS FOR HEALTHY GINGER CROP MANAGEMENT

Concerning beneficial ginger associations and rotations, there is a diverse range of possible suggestions aimed at enhancing soil health and addressing the occurrence of significant pests and diseases, and optimising yields (Table 4). Depending on the locations, care should be taken to the particular growing periods of these crops, to be compatible with ginger.

Table 4. Examples of potentially beneficial intercropping and crop rotation options for ginger production

INTERCROPPING	ROTATION
— Turmeric - both ginger and turmeric are from the same family and have similar soil and climatic requirements, making them compatible companions. However, watch out for associated pests and disease vectors	— Legumes (e.g., peas, beans, lentils) - legumes have nitrogen-fixing capabilities, which enriches the soil with nitrogen, benefiting ginger and other subsequent crops.
— Garlic - garlic helps repel pests that may attack ginger, such as aphids and mites.	— Leafy greens (e.g., spinach, lettuce, kale) -these crops have shallow root systems and are quick-growing, providing ground cover while not competing heavily with ginger for resources.
— Onion - onion acts as a natural deterrent against certain pests and helps enhance the growth of ginger.	— Mustard greens - mustard greens are known to suppress nematode populations, which can be beneficial for ginger health.
— Lemongrass - lemongrass repels insects and can help deter pests that commonly affect ginger.	— Radishes - radishes break up compacted soil, improve drainage, and help control soil-borne pests and diseases.
— Chilli peppers - chilli peppers can help deter pests, including nematodes, which are harmful to ginger.	— Sweet potatoes - unlike ginger, sweet potatoes are planted as groundcover and can help suppress weed growth while adding organic matter to the soil when harvested.
— Mustard greens - mustard greens act as a natural biofumigant, suppressing soil-borne pests and diseases in ginger.	— Cabbage - cabbage can help repel certain pests that impact ginger, such as aphids and cabbage worms.
— Coriander - coriander attracts several beneficial insects and helps improve soil quality.	— Cucumbers - cucumbers have deep root systems that break up soil, increase soil nutrient availability, and add organic matter when their vines break down.
— Cabbage - cabbage acts as a trap crop, attracting several pests away from ginger and protecting it from damage.	— Tomatoes - tomato plants release compounds in their roots that protect against nematodes and improve soil structure.
— Beans - beans are nitrogen-fixing plants that enrich the soil with nitrogen, benefiting the growth of ginger.	— Carrots - growing carrots in rotation with ginger can help improve soil structure and break up compacted soil.
— Peas - similar to beans, peas also fix nitrogen in the soil and help improve soil fertility.	— Onions - onions deter some pests and diseases that can affect ginger, such as thrips and root-knot nematodes.
— Carrots - carrots have a shallow root system that does not compete much with ginger, allowing them to be intercropped together.	— Beets - beets are a good rotational crop as they help break up soil and add organic matter when harvested.

— Spinach - spinach grows quickly and can be harvested before it competes for resources with ginger.	
— Lettuce - lettuce can be harvested early, allowing ginger plants to have more space and light as they grow.	— Broccoli - broccoli can help deter pests such as aphids, whiteflies, and cabbage worms, which can also impact ginger.
— Celery - celery acts as a natural pest repellent and can deter insects that may harm ginger. Celery has a shallow root system and can be grown as a companion crop to ginger, providing ground cover and shading out weeds.	
— Basil - basil repels several pests and attracts some beneficial insects, promoting a healthier growth environment for ginger.	— Spinach - spinach is an excellent cover crop that helps suppress weeds and adds organic matter to the soil when tilled in.
— Mint - mint has similar growth requirements as ginger and helps repel some insects and pests.	
— Sunflowers - sunflowers act as a natural attractant for pollinators, which also benefit ginger plants, though production does not depend directly on pollination. Sunflowers can also act as a trap crop for certain pests, drawing them away from ginger	
— Marigolds - marigolds repel nematodes and other soil-borne pests harmful to ginger.	
— Tomatoes - tomatoes deter pests and can provide shade for ginger plants during hot summer months.	
— Okra - okra can provide shade for ginger and has a deep root system that does not compete much with the root system of ginger	

The specifics of rotations and intercropping (see Fig. 20), and their duration depend on the region. Adopting these production strategies forms an integral part of a proper Integrated Pest Management (IPM) as well as an Integrated Soil Fertility Management (ISFM) strategy, which support sustainable ginger production management and the surrounding ecosystems.

Figure 20: Ginger cropping techniques with (above) and without (bottom) intercropping (Image credit: iowa ag-literacy wordpress)

CHECKLIST FOR GINGER PRE-PLANTING CHOICES

- Ensure sufficient labour will be available at key times during production, crop maintenance and harvesting
- Ensure proper nursery management
- Select suitable varieties compatible with agroecological conditions and tolerant against major pest and diseases, aligned with target market demands
- Check for plot history, topographyand and plan intercropping and crop rotation
- Consider local and regional differences in growing seasons
- Test the soil or growing media for possible contamination and nutrient requirements

4

PREPARING THE PLOT

4.1. LANDSCAPING

To enhance a ginger farm's landscape, consider incorporating windbreaks, hedging, fencing, firebreaks, and well-defined paths. These elements improve cultivation, protect crops, ensure safety, and create an organized and visually appealing environment.

Clear the field of all undesired vegetation. Provide proper drainage to avoid water stagnation in flood prone areas. If there are any chances of contaminated water infiltrating ginger fields, prepare the land to prevent entry.

4.2. WEED MANAGEMENT

There are numerous weed types associated with ginger production. Common ones are purple nutsedge (*Cyperus rotundus*) and goosegrass, also known as *Eleusine indica* (Fig. 22). Mowing maintains a clear space around ginger plants, reducing competition for nutrients, water, and sunlight while preventing weed seeds to spread.

Figures 21: Goosegrass and purple nutsedge, as examples of typical weeds affecting ginger production (Image credits: Left, Wikipedia; Right, Acta Plantarum)

4.2.1. MOWING, MULCHING, MECHANICAL AND CHEMICAL WEED CONTROL

Mulching with organic materials such as straw, hay, wood chips, or dried leaves offers several benefits. Aim for a recommended mulch thickness of 5 - 10cm. Calculate the volume of mulch needed by multiplying the total area of ginger beds by the desired thickness. Additional mulch should be added initially to account for potential settling. If purchasing mulch commercially, suppliers often provide coverage recommendations based on the product and desired thickness.

The use of mechanical technologies for weeding involves using spades, forks, hoes, or manually assisted non-motorized or motorized equipment (Figs. 22 and 23). The choice of technology depends on the scale of production, market requirements, available labour, available technologies, and levels of weed infestation.

Figure 22: Mechanical weeding using motorized finger weeder (Image credits: Left, Cioni and Maines, 2010; Right, AgriFutures, Australia)

Figure 23: Power weeders suitable for ginger (Image credit: Kumari, 2022)

Weeding is critical to minimize competition for resources, but also to minimize pest and disease hosts in ginger fields. Hand/manual weeding selectively removes weeds without harming ginger plants. Herbicides can be used to control pre- and post-emergent weeds, following recommended rates and precautions.

4.3. SOIL PREPARATION

- It is recommended to plough the soils to a depth of at least 30cm and allow to be exposed to the elements. Create drainage channels in heavy soils to channel excess water.
- The land should be refined just before planting, incorporating any necessary organic matter or corrections at this stage. For mature manure, this should be done one month prior to planting, while fresh manure may require 2 - 4 months to obtain suitable planting conditions.
- To reduce soil erosion, avoid excessive tillage. When working with land that has a slope greater than 20 degrees, it is best to avoid mechanical land preparation.
- Contour-based land preparation should be employed on steeper hills when ploughing on slopes to prevent soil erosion.
- Prior to allowing tractors and other machinery onto the land for preparation, ensure that they are clean and free from soil particles and dirt originating from other fields.
- When harrowing, prepare the field to a fine tilt by ploughing 2 - 3 times after receiving early rains.

4.3.1. SANITATION

Soil solarization is a beneficial technique for sanitation in farming. It is best carried out before planting and during extended periods of dry, sunny weather. This method is especially useful in fields with a history of rhizome rot disease. To begin the solarization process, remove all existing plant materials, debris, and weeds from the planting area. Prepare the soil by loosening it with a tiller or garden fork, enhancing soil aeration and heat penetration.

Figure 24: Example of soil solarization for the control of nematodes and bacterial wilt (Image credits: Far left, Hagan et al., 2021; Far right, Horita et al., 2023)

For solarizing raised beds or ridges, saturate the soil with water to a depth of around 30cm using irrigation or rainfall. If available and affordable, seal the area with a clear polythene sheet and expose it to sunlight for 4 - 6 weeks. It is recommended to use UV-stabilized plastic mulch, approximately 1 - 2mm thick, for greater durability. Secure the edges of the plastic sheeting in the soil using rocks, boards, or mounds to trap heat and create a greenhouse-like environment. To effectively control pests and diseases, the temperature within the sheets during solarization should reach 40 - 45°C.

Soil solarization enhances mineralisation of organic matter, and so increases nutrient availability in the soil, benefiting crop growth. After solarization, remove the plastic sheets to prevent recontamination. Allow the soil to cool naturally before planting and consider amending it with organic matter or compost if necessary. For further information on soil amendments, refer to the next section.

It is important to note that solarization may not completely eliminate all soilborne pests and diseases, particularly those with resistant or deep life stages. Therefore, it is advisable to integrate solarization with other good agricultural practices, such as crop rotation, using disease-resistant cultivars, and maintaining sanitation measures.

4.4. SOIL AMENDMENTS PRIOR PLANTING

It is important to assess the soil status before planting. Parameters to assess include salinity, acidity, structure, moisture, organic matter content, and nutrient availability. During organic soil conditioning, it is also important to ensure that manure from human waste should not be applied to the ginger field.

4.4.1. LIMESTONE, MANURES, AND FERTILIZATION

— To improve drainage and prevent waterlogging in heavy or clayey soil, add coarse sand or perlite. Adding 2 to 4 Mt/ha of coarse sand or perlite may be recommended. In some cases, applying a pre-emergent herbicide may be necessary.

— To enhance soil structure and fertility, incorporation of ca. 10 - 20 t/ha of matured or aged manure mixed to a depth of 5 - 10cm may be recommended. Consider inclusion of organic soil amendments, for example, bone meal, eggshells, fish emulsion, seaweed extracts, or rock powders to improve soil fertility. These can provide a broader range of nutrients to ginger plants.

— For fields with a history of rhizome rot disease and nematode infestation, application of neem cake at a rate of 2 t/ha during planting may be recommended.

— Before planting ginger rhizomes, application of a balanced fertilizer such as NPK (nitrogen, phosphorus, and potassium) at a rate of approximately 28 - 57 g per seed or ca. 9 Kg/ha may be recommended. It may for example be recommended to use a balanced fertilizer ratio of 10-10-10 or 14-14-14. Adjust fertilizer levels when applying organic manure/compost/green manure.

— For soil pH adjustment, apply limestone or wood ash based on the results of the soil analysis. Typically, around 2 - 4 t/ha are considered necessary to adjust the pH by 0.5 units. Monitor the soil pH periodically.

Table 5. Examples of soil amendments that can be used to adjust soil pH

RAISING SOIL PH	LOWERING SOIL PH
Limestone Different forms are useful for different types of soil and levels of moisture. For optimal results, apply lime 2-3 months before planting. Example rates: for more sandy soil 11 Kg/m^2, loamy soil 31 Kg/m^2, and around 45 Kg/m^2 if the soil is rich with clay.	Compost, manure, peat and acidic mulch Effective but slow acting. Depending on the type of material, an initial rise in soil pH may be observed.
Potassium carbonate This is more water-soluble and can be used with the irrigation system. Follow manufacturer instructions.	Aluminium sulphate fast acting
Wood ash Tree ashes will substantially increase soil's pH over time. It works best when mixed with sandy soil. Wood ash will improve soil and plant growth, and is much more beneficial in this aspect, as opposed to Lime. Wood ash can damage seedlings and may contain higher levels of heavy metals, so don't add it directly onto young plants (MSU).	Sulphur or thiosulphates fast acting
Baking soda (i.e. sodium bicarbonate) The measurement is 1 tablespoon to 3.8 litres of water. The changes in pH can appear as fast as in 24 hours. Be carefull not to apply too much sodium.	**Vinegar** (1-2 weeks) Can be added directly to the soil, or into the irrigation system.
Oyster, shell Lime, eggshells Oyster shell lime is organic and made of oyster shells. It can be used to treat calcium deficiency, whilst at the same time, increasing soil pH. **It is easily incorporated into the soil and is safe for people and animals.** Eggshells are also rich in calcium, and an eco-friendly solution.	**Iron Sulphate** Good for clay soils. .

CHECKLIST TO REMEMBER FOR PREPARING OF THE PLOT

- Ensure effective plot drainage and mitigate external factors
- Consider landscaping, slopes, contours, and field layout to prevent soil erosion and disturbances during crop establishment, growth, and development
- Clear all weeds using mechanical of chemical control
- If possible, solarize the field to reduce pathogen populations
- Adjust soil properties with soil amendments based on observations, experience, and testing

5

PLANTING GINGER

Once quality planting material has reached the appropriate growth stage (Fig. 25), transplanting may take place under cover in high tunnels, or in the open field. To plant, place ginger rhizomes directly onto pre-prepared beds, spacing them 20 - 25 cm apart with the rhizomes with the bud facing upwards. Make holes for transplanting the rhizome seeds. Gently press the rhizomes into the soil to secure and support them..

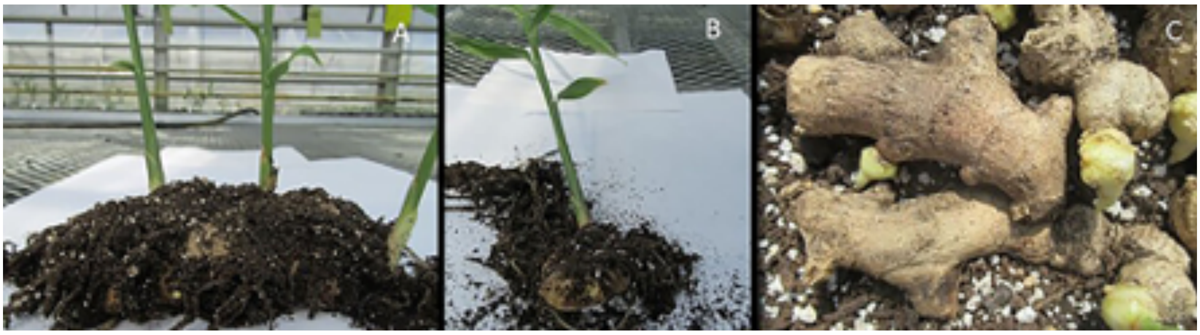


Figure 25: a. Multi-shoot ginger seedling; b. Single-shoot ginger seedling; c. Rhizome seed piece (Image credit: **Marsh *et al.*, 2023**)

Figure 26: Tray of rhizome seeds (Image credit: Shyka, P.)

Figure 27: Manual planting of ginger rhizomes in the field on raised beds (top)
(Image credit: Farmers Trend, Kenya, 2023) , and on plain ground (bottom)

Figure 28: Manual planting of ginger in the field
(Image credit: https://cms.ctahr.hawaii.edu/gingerwilt/Ginger)

5.1. LAND PREPARATION METHOD

There are two common methods for preparing the soil for ginger cultivation, the flat bed and the ridging methods, using manual or power-driven mechanical means. It is crucial to prepare the soil, and ensure it is free from pests, weeds, well-drained and nourished.

5.1.1. FLAT BED METHOD

Figure 29: Mechanical land preparation of ginger for flat bed cultivation (Image credit: asiafarming.com))

Figure 30: Mechanical land preparation for ginger production on flat beds (Image credit: Panama Trading Corporation, 2017)

Figure 31: Manual land preparation for ginger production on a slope (Image credit: Slopes of Narogiovoce Farm, Conway School))

5.1.2. RIDGING/RAISED BED METHOD

Create ridges or raised beds by mounding the soil. The land should be ploughed beforehand, forming beds of about 15 cm high, 1-meter wide with at least 50 cm spacing between beds. Leave pathways between the beds for easy access. Raised beds or ridge and furrow systems benefit ginger growth, promoting sunlight exposure, soil drainage, aeration, irrigation, weed control, and easy plant access for maintenance and harvesting.

Figure 32: Preparation for rhizome planting on raised beds (image: COLEAD)

Figure 33: Raised bed preparation for ginger cultivation (Image credit: Agro4africa.com)

5.2. DENSITY

Planting density typically ranges between 30,000 to 40,000 rhizomes per hectare, with each rhizome weighing around 25 - 30g, so approximately 800 - 900 kg of planting material is required for one hectare of ginger propagation.

When using Single Bud Technology (SBT), required planting material quantity may differ. The average weight of a single bud or sprouted section used for planting out can be around 5 - 10g. Therefore, approximately 400 to 500 kg/ha of planting material is required in this case (see previous sections on SBT).

5.3. PLANTING TOOLS AND METHODS

5.3.1. TOOLS

The following materials are required for planting ginger at small-scale (0.5 ha of land):

- Spade or shovel for soil preparation, digging trenches, and creating planting holes.
- Rake: Used for levelling the soil and removing debris.
- Garden fork for loosening compacted soil.
- Measuring tape or ruler to ensure proper spacing between ginger plants.
- Watering can or hose for irrigation during the planting process and subsequent care.
- Big drums, each half-full with clean water
- clean planting pieces (rhizome seeds), 3 - 5 cm long with all soil removed.
- clean polypropylene or mesh bags
- Water-proof, protective gloves and personal protective equipment, and sturdy sticks to mix fungicide

5.3.2. MECHANICAL PLANTING

Where animal-drawn ploughs are used to assist planting, manual coverage of rhizomes is still needed. When using tractors, placed pieces of rhizome should be covered with a reverse disc. Press seed rhizomes gently into the soil on the ridges, then thoroughly water the beds to settle the soil around the rhizomes, ensuring the moisture reaches the rhizome depth (5 - 10cm). Check the soil moisture using a soil moisture meter or by manual inspection. If dry, water the beds. During hot and dry periods, ginger plants may require watering every 2-3 days.

5.3.3. PLANTATION LAYOUT AND SPACING

In traditional rainfed cultivation, seed rhizomes are spaced around 25 - 30cm among plants and 60 - 75cm among beds (in case not sown on plain). Within 3 - 6 weeks after planting the shoot can be seen above ground, provided that the soil is moist. For planting out from single buds, use 30cm plant to plant in a row and using a spacing of 45 - 75cm between rows for providing proper drainage and aeration. .

Figure 34: Raised beds for ginger production covered with mulch- 15cm height x 1m wide, with 50cm maintained between beds (Source: FarmIndia)

5.3.4. ORIENTATION

The orientation and planting density will ultimately depend on the slope of land and soil type. During planting, always orient rhizomes with the buds facing upwards to ensure emerging shoots will grow towards the soil surface.

Figure 35: Ginger growing on raised beds/ridges with drainage channels between them (Image credit: FarmIn)

Figure 36: Harvesting ginger in a greenhouse for transplanting (Image credit: Freedom Farm, Polly Shyka)

Figure 37: Visualisation of sprouting pre-germinated ginger (source COLEAD))

CHECKLIST TO REMEMBER FOR THE PLANTING

— Ensure all planting equipment and tools are sanitized, including transport equipment needed for moving planting material
— Prepare the land according to the cultivation method (i.e. flat beds or raised mounds), and prevent water logging where needed
— Ensure availability of seed rhizomes that are of the correct maturity, and that the climate is conducive for planting
— Carefully handle planting materials to avoid contamination with diseases, and pre-treat rhizomes where required
— Plant using the prescribed density, on flat or raised beds, using correct spacing

6

CROP MAINTENANCE POST TRANSPLANTING

After planting, during ginger crop growth and development, attention needs to be paid to soil moisture, ground cover, nutrient management, weed emergence, and pest and disease control, to ensure the well-being of the plants and optimise yields.

6.1. WATER MANAGEMENT

Ginger, being a crop with high water requirements, needs a consistent water supply throughout its growth period. Concerning the role of water for fertiliser uptake, adequate watering procedures are essential, as underwatering can cause drought stress and nutrient deficits, while overwatering can cause nutrients to be lost. Supplementary irrigation may be required for rain-fed ginger production, while drainage may be needed in wet, waterlogged conditions.

Farm enterprises or projects utilizing community ponds around ginger cultivation areas can harvest and store rainwater for irrigation (e.g. in underground reservoirs or plastic tanks (Fig. 40), as well as establish check-dams in watershed areas near ginger farms to replenish groundwater levels. Such reservoirs can facilitate the timely use of drip irrigation and can help reduce the cost of water necessary to nourish the crop.

6.1.1. IRRIGATION: QUANTITY, PERIOD, WATER QUALITY, AND METHODS

Water requirements for ginger plants vary based on climate, soil type, and growth stage. To determine watering needs, check the soil's moisture level (manually or make use of a soil moisture meter). If the top layers are dry , it is time to water the plants. If the soil is damp, it is recommended to delay a few days before watering again. Waterlogging makes the plants more susceptible to infection and should be avoided.

Key watering periods are during planting, seedling stages, rhizome initiation (around 90 days after planting), and rhizome development (90 – 120 days after planting). When plants start to enter the senescence phase (after maturity), watering can be halted. Generally, ginger plants require around 2.5 - 5cm of water per week. During its crop cycle, ginger typically needs 1300 - 1500mm of water, depending on soil and weather conditions. Sandy soils require more frequent watering, while clay soils retain moisture better and need less frequent watering. Plan ahead to ensure there is sufficient water over the course of the production cycle.

Growers should assess the source and quality of irrigation water for pH and electrical conductivity (EC). Ideally, irrigation water should have a pH of 6.5 - 7.5 and an EC lower than 1 dS/m. Adjust the pH if the water source is highly alkaline or acidic.

There are various methods of irrigating ginger plants, depending on available resources and the scale of cultivation:

Sprinkler irrigation - suitable for larger-scale ginger cultivation, this method provides overhead irrigation by delivering water in a spray. Care should be taken to avoid excessive wetting of foliage to prevent fungal diseases.

Drip irrigation - a more efficient method that delivers water directly to the root zone of plants. It conserves water, minimizes weed growth, and allows precise water application. Drip irrigation is particularly useful for ginger cultivation as it reduces evaporation and aids in preventing rhizome rot and bacterial wilt.

Furrow irrigation - commonly used in traditional farming systems, this method involves digging shallow trenches between ginger rows and directing water to flow through the furrows. It may not be as efficient as sprinkler or drip irrigation and consumes much larger water quantities.

Hand watering - suitable for small-scale ginger cultivation or areas without irrigation systems. Water can be applied using a watering can or hose, ensuring even distribution around the plants and reaching the root zone.

While rainfed ginger production is widespread, irrigated systems can increase productivity, especially in drought prone areas. Alternative technologies such as solar-powered or gravity-based drip irrigation systems can also be employed.

Figure 38. Drip irrigation in ginger field
(Image credit: https://atouchofbusiness.com/startup-ideas/ginger-farm/)

Figure 39: Water filling and storage on-farm in plastic tank (Image credit: Wikimedia commons)

Figure 40: Ginger field with drip irrigation (Image credit: TNAU Agritech Portal)

6.1.2. DRAINAGE

Sandy loam or loamy soil types facilitate water percolation and prevent pooling around ginger roots. Planting on a slope or contouring the land diverts excess water away from plants, improving drainage. Poorly draining soil benefits from raised beds or mounds to elevate the root zone and enhance water drainage. Adding organic matter improves soil structure and porosity, aiding water movement and drainage of excess water. Monitor soil moisture levels to prevent rhizome rot from excessive water. Consider installing drainage infrastructure in high rainfall areas. Avoid thick mulch layers that hinder drainage. Heavy machinery and foot traffic compact soil, leading to poor drainage. Use raised beds and pathways to minimize soil compaction.

CHECKLIST TO REMEMBER FOR WATER MANAGEMENT

1. **Soil Moisture Monitoring:**

   Regularly check soil moisture levels to ensure they remain optimal for ginger growth. Overwatering or underwatering can lead to poor yields and disease.

2. **Irrigation Scheduling:**

   Develop an irrigation schedule based on the growth stages of ginger. Young plants need less water, while mature plants, especially during rhizome development, require consistent and adequate watering. The use of drip irrigation systems is most efficient.

3. **Drainage Management:**

   Ensure proper drainage to prevent waterlogging, which can lead to root rot and other diseases. Raised beds or mounds can improve drainage in heavy soils.

4. **Water Quality:**

   Use clean water free from contaminants and pathogens. High salinity or polluted water can harm ginger plants and affect yield quality.

5. **Mulching:**

   Apply organic mulch to retain soil moisture, regulate soil temperature, and reduce evaporation. Mulching also helps in suppressing weed growth and improving soil structure.

6.2. GROUND COVER

Regular mulching reduces weeds, fosters faster growth, and shields seedlings from the elements. It buffers rapid changes in soil temperature by acting as an insulating layer. This promotes the growth of ginger roots by keeping the soil warmer during colder months and cooler during hotter months.

6.2.1. MULCHING

Mulching is important for ginger cultivation as it helps control surface run-off, preventing soil erosion and nutrient leaching. Mulching is particularly crucial on sloping or uneven terrain where soil erosion is a particular concern.

The optimum time to mulch is at 4 - 6 weeks after planting. There are many potential bio-mulches, depending on the local environment, for example, sugarcane trash, banana or mango leaves (or similar) can be used, including, grasses, straw, plant remains, and wood chips. The mulch is placed around the growing plant as mulch. Mulches are laid typically with a thickness of 8 to 10cm.

Figure 41: Mulching the seedbeds for ginger (above), and Ginger growing in mulch (bottom) (Image credit: Pinterest)

6.2.2. HILLING

In ginger production, hilling reduces rhizome exposure to sunlight, promotes tiller and rhizome development, and optimises fertiliser delivery. After four to six weeks, the sprouting ginger stem should have a swollen, bright pink base. At that point, mound the plant with about 10cm of soil and fertiliser. Every 2 - 4 weeks, repeat the hilling and fertilising again. Hill the soil in the plant row periodically to encourage vertical rhizome growth and combat horizontal growth. Seed spacing affects how often hills are formed. Better weed control is achieved by hilling at the emergence or early development stages (Agronegocios La Grama S.A.C.; Burke, 2012).

Mulching and hilling are also both important for temperature regulation, weed, and pest and disease management strategies. The efficiency of various mulch mixes varies. Care should be taken as mulches may promote germination and soft rot, thus their procurement needs to be carefully managed.

CHECKLIST TO REMEMBER FOR GENERAL MANAGEMENT STRATEGIES DURING PRODUCTION

- Adopt mulching practices to conserve water, and minimize weed emergence
- Till and hill periodically, alongside side-dressing at the plant roots
- Beware of frost damage, remove and cut back old and diseased flowers
- Learn to identify key pests and disease symptoms
- Periodically monitor for pests and diseases
- Organic or natural pesticides can be a last resort after other control methods have failed

6.3. SOIL FERTILITY AND NUTRIENT MANAGEMENT

To enhance soil health and optimise input use efficiency it is recommended to develop and implement a strategy of integrated soil fertility management (ISFM). Integrated Soil Fertility Management (ISFM) involves the combined use of adapted/improved varieties, chemical fertilizers, organic amendments, and improved agronomic practices to enhance soil fertility and crop productivity sustainably. This approach maximizes the efficiency of nutrient use, improves soil health, and promotes long-term agricultural sustainability by integrating organic and inorganic inputs tailored to specific soil and crop needs. A part of ISFM includes the development of a nutrient management plan to ensure all required nutrients are timely provided to the plant.

Nutrient management plans should be based on soil and plant analyses, and recommendations should consider the 4 R's of nutrient stewardship. The 4Rs of nutrient stewardship refer to the Right Source, Right Rate, Right Time, and Right Place. These principles guide sustainable and efficient nutrient management in agriculture. Choosing the right fertilizer source, applying the right amount, at the right time, and in the right location helps optimize nutrient use, minimize environmental impact, and improve crop productivity.

Three essential macronutrients are needed by ginger plants in order to grow vegetatively. It needs nitrogen, phosphorus for root growth and blooming, and potassium for overall plant health and disease resistance. Ginger plants also need a variety of other secondary macronutrients like calcium, magnesiun, sulfur, and micronutrients which include molybdenum, iron, manganese, zinc, copper, and boron.

Commercial macro- and micronutrient fertilisers are commonly used to provide plants with these elements. Organic sources, such as compost or seaweed extracts could be an alternative. When applying organic fertilizers be careful however to ensure they are free from microbial and chemical contaminants.

The proper timing and quantity of fertiliser application are crucial. Slow-release fertiliser can be incorporated into the soil before planting the ginger rhizomes. Throughout the growing season, a balanced fertiliser every 4 - 6 weeks may be recommended to be applied as the plants expand.

In many ginger producing countries, fertilization is often neglected. For improved growth and development of the ginger rhizome, it may be advisable to amend higher rates of calcium. It is also recommended to conduct a soil test to determine the nutrient levels and pH of the soil before applying any fertilizers. Ideally a local agronomist is consulted to derive a site-specific nutrient plan with the locally available inputs. In cases where a soil or plant test is not available, some general schemes for fertilizer application are followed, however, this is not advisable.

Le moment d'application et la quantité d'engrais revêtent une importance cruciale. Un engrais à libération lente peut être incorporé dans le sol avant de planter les rhizomes de gingembre. Tout au long de la saison de production, l'application d'un engrais équilibré toutes les 4 à 6 semaines peut être recommandée à mesure que les plants grandissent.

De nombreux pays producteurs de gingembre négligent la fertilisation. Pour une croissance et un développement améliorés des rhizomes de gingembre, il est conseillé d'appliquer un amendement plus riche en calcium. Il est également recommandé de réaliser un test du sol avant d'appliquer des engrais afin de déterminer les teneurs en nutriments et le pH du sol. L'idéal est de consulter un agronome local pour établir un plan de gestion des nutriments spécifique au site avec les intrants disponibles localement. Si un test du sol ou des plantes n'est pas disponible, vous pouvez suivre des programmes de fertilisation généraux, mais ce n'est pas conseillé.

Figure 42: Applying organic matter to boost yields, before planting (Image credit: Rob Abbas)

Example fertilizer scheme for Inorganic fertilization

Kindly note that fertilizer application should always be guided by site specific soil analyses, the below are only examples and should not be interpret as a blind recommendation.

Pre-planting - the recommended NPK (nitrogen, phosphorus, and potassium) application rates for pre-planting ginger vary depending on the soil conditions and nutrient content. It is important to do a soil test prior to planting ginger to determine the specific nutrient requirements for the soil. Soil testing will help fine-tune the application rates. Additionally, consider incorporating organic matter or compost into the soil before planting to improve overall soil fertility. Apply a balanced fertilizer such as NPK (nitrogen, phosphorus, and potassium) before planting the ginger rhizomes. The exact fertilizer ratio will depend on the specific formulation available, but a common recommendation is 10-10-10 or 14-14-14, applying nitrogen at 50 - 80 Kg/ha, phosphorus at 40 - 60 Kg/ha, and potassium 60-80 Kg/ha of growing area. Mix the fertilizer into the soil, at the place where ginger will be planted, before planting the ginger rhizomes. When organic manure/compost/ green manure are applied, the rates might be reduced.

At planting – place small amounts of fertiliser in the planting hole and mix with the soil. Fertiliser can also be broadcasted onto the soil and rotavated into the soil before the crop is planted. Apply NPK fertiliser high in phosphorus, for example 12:24:12, to encourage root growth.

Two to three weeks - after shoots emerge, usually 1 month after planting, apply NPK fertiliser high in nitrogen, for example 20:10:10 or Calcium Nitrate, to encourage vegetative growth.

Side-dressing - after the ginger plants have emerged and started growing, side-dress the plants with a nitrogen-rich fertilizer. This can be done approximately 4 - 6 weeks after planting. Apply a fertilizer with a higher nitrogen content, such as ammonium sulphate (21-0-0), urea (46-0-0), or a similar nitrogen-based fertilizer. Side-dress the plants by applying the fertilizer evenly along the rows, avoiding direct contact with the rhizomes.

Mid-season fertilization - around 2 - 3 months after planting, provide another round of fertilizer to support continued growth. Use a balanced fertilizer or one with a slightly higher potassium content (e.g. 10-10-20) to promote rhizome development and tillering. Nitrogen-based fertilization is also recommended during this growth period to promote tillering. Potassium-based fertilization - is recommended during rhizome development (4 - 6 months after planting).

Example fertilizer scheme for Organic fertilization

The fertilizer regime for organic production of ginger will differ from conventional fertilizer applications. In organic farming, organic sources of nutrients are applied to meet the plant's nutritional requirements. Organic fertilizers release nutrients more slowly compared to synthetic fertilizers. They rely on microbial activity in the soil to break down organic matter and make nutrients available to plants over time. It is essential to focus on building soil health through organic matter additions, crop rotation, and other organic farming practices to ensure the long-term fertility and sustainability of the soil. In organic cultivation, the use of organic fertilizers is adopted.

- The recommended amount of well-decomposed manure to use on a hectare of ginger is 10 to 20 Mt/ha, depending on factors, which include soil fertility and nutrient requirements.
- Spread the manure evenly across the field and incorporate it into the soil before planting or during land preparation.

- For pre-planting, incorporate organic matter such as compost or aged manure into the soil at a depth of 5 - 10 cm across the entire growing area. When using raised beds, organic matter can be concentrated on the beds only.
- Side-dress the plants with organic amendments approximately 4 - 6 weeks after planting, applying at a rate of 0.5-1 Kg/m^2 of growing area.
- Provide mid-season organic fertilization around 2 - 3 months after planting, following manufacturer's instructions or organic farming guidelines.
- Poultry-based manure and seaweed or fish emulsion can also be used for good results.
- Composts or organic fertilisers used should be materials that are well decomposed or actively decompose, be free of pathogens, and contain a relatively high concentrations of nutrients.

6.3.1. GOOD FERTILIZER APPLICATION PRACTICES

The concept of nutrient management known as the **4Rs** (right time, place, source, rate) serves as a valuable framework for enhancing nutrient utilization efficiency and lessening environmental impacts.

When applied to the cultivation of ginger, the "**right time**" aspect pertains to the timing of nutrient application. It becomes crucial to align nutrient delivery with the distinct growth stages of ginger plants, ensuring nutrients are administered when they are most needed. Typically, ginger demands greater nutrient inputs during its initial growth phases and when rhizome formation commences.

The "**right place**" dimension involves directing nutrients to the specific part of the plant where they are most essential. In the context of ginger, nutrients should be administered in proximity to the root zone to facilitate optimal uptake and reduce loss to the environment. Techniques such as banding or localized application can be employed to achieve this goal effectively.

Selecting the "**right source**" means choosing suitable nutrient sources. Ginger requires a balanced blend of vital nutrients - nitrogen, phosphorus, potassium, and micronutrients. Organic sources such as compost, well-decomposed manure, and biofertilizers can complement synthetic fertilizers to provide additional nutrients, improve soil structure, increase the soil cation exchange capacity, and hence increase the agronomic use efficiency of mineral fertilizers.

The "**right rate**" emphasizes applying nutrients at the appropriate dosage. It is imperative to avoid both over-application and under-application, as either can result in nutrient imbalances and reduced yields. To determine the ginger crop's nutrient needs, soil testing is recommended, and fertilizers should be applied accordingly. Where possible, leaf tissue analyses of ginger can also guide the nutrient management plan.

By adhering to the 4Rs of nutrient management, ginger cultivators can ensure that their crop receives the correct nutrients, in the proper quantities, at the right timing and location. This fosters robust plant growth, increased yields, and mitigates the risk of nutrient loss and environmental contamination.

Practicing principles of the 4Rs, integrated soil fertility management (ISFM) and concepts related to agronomic efficiency and fertilizer use efficiency are gaining significant attention within sustainable production systems. These ISFM practices and integrated nutrient management (INM) approaches are strongly advised throughout the entire ginger cultivation process, from pre-planting to harvest. Some pertinent nutrient management practices applicable to ginger are highlighted:

Split applications - divide fertilizer applications into multiple doses throughout the growing season to provide a steady nutrient supply to ginger plants.

Banding or localised application – concentrate fertilizers close to ginger roots.

Timing of applications - apply fertilizers when ginger plants are actively growing and avoid applying during dormancy or stressful weather conditions.

Micronutrient supplements - consider using organic or synthetic micronutrient fertilizers if nutrient deficiencies or imbalances are observed.

Crop rotation and cover crops - incorporate crop rotation and cover crops to improve soil health, fertility, and reduce nutrient depletion, pests, and disease buildup. Cover crops can also enhance nitrogen fixation, organic matter content, and weed suppression.

Build on soil organic matter – by incorporating organic material

CHECKLIST TO REMEMBER FOR SOIL AND NUTRIENT MANAGEMENT

- Soil and plant analyses are crucial to determine deficiencies and develop a tailored nutrient management plans
- Learn to identify nutrient deficiency symptoms
- Mulching and hilling are important for soil correction and timely fertilizer applications.
- A nutrient management plan should fit within an overarching strategy of integrated soil fertility management, and it should consider the 4Rs (i.e. right source, right rate, right place, right moment)

6.4. WEED MANAGEMENT STRATEGIES

One of the biggest threats to ginger crop yields is weeds, which may cause production losses of more than 80% if left unchecked (Walsh et al., 2022). Weeds harbour pests and diseases. Weeds must be controlled to prevent competition for soil nutrients, moisture, and sunlight, especially within a distance of 30 - 60 cm away from the ginger plants. A number of Good Practices are available as tools to manage weeds (i.e. mechanical or manual, cultural, chemical weed management).

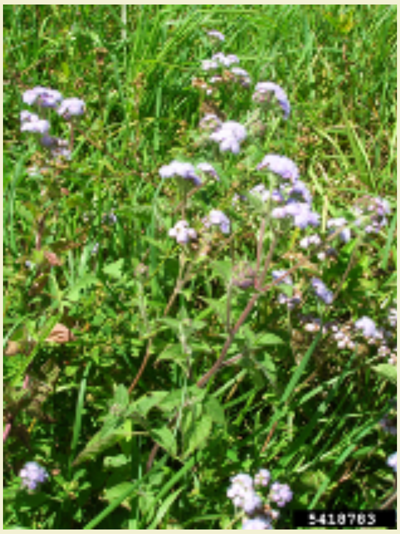
Two weeding activities are generally undertaken during the growth cycle (i.e. after tilling and planting) - the first just prior to the second mulching, then repeated 45 - 60 days later. Care should be taken during the weeding process not to expose or damage the seed rhizomes. Common weeds associated with the ginger crop, that increase the occurrence of pests and diseases are presented below (Table 6).

Tableau 6 : Exemples de mauvaises herbes courantes associées négativement au gingembre (source : Weed Science Society of America)

WEED TYPE	IDENTIFICATION	COMMENTS
Grass Weeds		Weeds belonging to the grass family (Poaceae) can host various pests and diseases. **Crabgrass**
		**Signalgrass**
		**Barnyard grass.** These weeds can harbour insects such as grasshoppers and cutworms, which can also attack ginger plants.

WEED TYPE	IDENTIFICATION	COMMENTS
Broadleaf Weeds	  	Weeds with broad leaves can also harbour pests and diseases. Examples include: **Pigweed** **Lambs quarters** **Purslane.** These weeds can provide shelter and a food source for insects that might later move to ginger plants.
Sedges	 	Sedge weeds **Yellow nutsedge** Purple nutsedge These weeds can be problematic as well. They can host root-knot nematodes, which are known to attack ginger roots and can cause significant damage.

WEED TYPE	IDENTIFICATION	COMMENTS
Morning Glory	  	Morning glory species can serve as hosts for various pests and diseases, including nematodes and whiteflies. These pests can later transfer to ginger plants.

WEED TYPE	IDENTIFICATION	COMMENTS
Bindweed		Bindweed, also known as wild morning glory, can be a host for insects and diseases that affect ginger. Aphids and other pests can inhabit bindweed and then move to ginger crops.
Ageratum		This flowering weed can harbour aphids and whiteflies, which are common pests that can infest ginger plants.

WEED TYPE	IDENTIFICATION	COMMENTS
Wild Amaranth	  	Wild amaranth species can host aphids, which are sap-sucking insects that can transmit viruses to ginger plants.
Cyperus spp. (Nutgrass):		Similar to sedges, nutgrass can host nematodes that can damage ginger roots.

6.4.2. CHEMICAL HERBICIDES

When managing weeds in ginger production, it's possible to utilize herbicides. However, it's essential to choose herbicides explicitly approved and adhere to the provided instructions and safety guidelines. Herbicides can be applied either before weed seeds germinate (pre-emergence) or after weed emergence (post-emergence). It's crucial to prevent herbicide contact with ginger plants to avoid damage. Effective and safe chemical weed control relies on proper timing, application techniques, and herbicide selection. Therefore, it is crucial to consult a local weed specialist for advice on how to control specific weed species, and how to select and use appropriate products.

6.4.3. MECHANICAL, MANUAL, AND OTHER CULTURAL WEED CONTROL STRATEGIES

Manual weeding and hand-roguing - involves physically removing weeds by hand or tools is labour-intensive but precise, targeting weeds without harming the ginger crop.

Hand hoeing and herbicidal spot treatment - hand tools, for example, hoes or cultivators can be used for targeted weed removal between ginger rows. Herbicidal spot treatment selectively applies herbicides to specific weed-infested areas, taking care to avoid contact with ginger plants.

Crop rotation - rotating ginger with competitive crops reduces weed populations and breaks the weed life cycle, benefiting soil health and fertility.

Cover crops - planting legumes or grasses between ginger rows competes with weeds for resources, inhibiting weed seed germination, enhancing soil quality, and providing habitat for beneficial insects.

Mechanical cultivation - using machinery to disturb the soil surface and uproot weeds, is primarily suitable for larger-scale ginger production but requires care to protect shallow ginger roots.

Crop residue management - Proper disposal of crop residue, such as ginger tops and leaves, can help minimize the potential for weed seed banks. Removing and disposing of crop residues properly can prevent weed seeds from being reintroduced into the field during subsequent cultivation.

Flame weeding and biological control - specialized equipment can be used for controlled flame weeding to burn off weed seedlings. Biological control involves introducing natural enemies, such as insects or pathogens, to suppress weeds while monitoring for unintended ecological consequences.

Adequate spacing between ginger plants is important for improved air circulation, sunlight penetration, and effective weed control. Proper spacing reduces weed competition and facilitates targeted weed removal through manual weeding or herbicide application.

The use of weed barrier fabric also known as landscape fabric, can be implemented around ginger plants. This fabric acts as a protective layer, obstructing sunlight and hindering weed seed germination, thereby preventing weed growth. It is particularly beneficial when applied to ginger production beds or raised beds.

Practicing good hygiene and sanitation measures is essential in preventing weed spread. Thoroughly cleaning equipment, machinery, and vehicles used in ginger production prevents accidental introduction or dispersal of weed seeds. Removing weeds before they produce seeds and ensuring weed-free areas during harvesting and storage are crucial to prevent weed contamination.

Encouraging knowledge sharing and research collaboration among farmers, researchers, and extension services promotes the exchange of information and the development of innovative agroecological practices tailored to ginger cultivation.

Figure 43: Well weeded ginger field (Source: National Agricultural Advisory Centre, Uganda)

CHECKLIST TO REMEMBER FOR WEED MANAGEMENT

- Learn to identify weeds
- The choice of weed control tools and practices relies on factors such as production scale, available resources and technologies, weed species, severity, and environmental factors.
- Regular monitoring, early intervention, and a combination of strategies are crucial for achieving weed-free conditions and maximizing ginger yield and quality.
- Regular monitoring of both the ginger plants and the surrounding weed populations will help identify possible problems early and take appropriate measures to avoid their spread.
- It is important to control all weeds, and at least two weeding sessions should be planned throughout the cropping cycle.

6.5. PRUNING

Trim aerial stems at a height of 30 cm to promote bushier growth, remove broken or dead leaves, and trim densely populated plants to improve ventilation. In areas where there is a chance of frost, cut plants back to the ground. weeds should always be removed. When plants are around two months old, cutting off a portion of the roots encourages the growth of new shoots, increasing the number of stems for subsequent planting.

6.6. PEST AND DISEASE SURVEILLANCE AND MANAGEMENT

There are a significant number of crop-pest-disease associations for ginger, depending on the country, growing region and agroecological zone. Major diseases include **Ginger Rhizome Rot** (Fusarium spp., Pythium spp.), a major concern for ginger crops worldwide. Fungal pathogens, such as ***Fusarium* and *Pythium*** species, can infect the ginger rhizomes, leading to rotting, discoloration, and decay. **Pythium Soft Rot** (Pythium spp.) can affect the rhizomes of ginger plants, causing decay, sliminess, and foul odour. **Ginger Rust** (Puccinia spp.) is a fungal disease that affects the foliage of ginger plants. It leads to the appearance of reddish-brown pustules on the leaves, which can result in defoliation and reduced photosynthetic capacity.

Bacterial Soft Rot (Erwinia spp.) can affect ginger rhizomes during storage or after harvest. It causes softening, foul odour, and a slimy appearance in the affected rhizomes.

Ginger Yellow Mosaic Virus (GYMV) is a viral disease that can cause yellowing, mosaic patterns, and stunted growth in ginger plants. It can significantly reduce yields in affected crops.

White Grubs (Holotrichia spp. and Leucopholis spp.) are a significant underground pest that feed on the roots of ginger plants, leading to reduced nutrient uptake, wilting, and plant decline. Some of these pests and disease vectors are discussed in following sections.

Root-Knot Nematodes (Meloidogyne spp.) can attack ginger plants' roots, leading to the formation of knots or galls, stunted growth, and reduced plant vigour.

The ginger **Shoot Borer** (Conogethes punctiferalis) is a significant insect pest that affects ginger crops in various regions. The larvae bore into the ginger shoots, leading to wilting, drying, and reduced yields.

Rhizome Fly (Mylabris pustulata) can infest ginger rhizomes, causing damage and reducing the quality and market value of the harvested crop.

Scale Insects (Aspidiella spp., Pinnaspis spp.) are common pests that can infest ginger plants, particularly on the lower surface of leaves and the rhizomes. They can cause yellowing, wilting, and reduced plant vigour.

To ensure the healthy growth of ginger plants, it is important to regularly inspect them for any signs of pests and diseases. This can be done by checking the leaves, stems, and roots for unusual symptoms which include discoloration, wilting, or deformities. It is also beneficial to become familiar with common ginger pests such as aphids, mealybugs, mites, and root-knot nematodes. It is important to correctly identify the pest before taking any control measures. In addition, familiarize yourself with common ginger diseases like rhizome rot, bacterial wilt, and ginger yellows. Recognizing symptoms such as rotting rhizomes, yellowing leaves, or wilting can help in early detection.

Consider planting pest-repellent plants such as marigolds, garlic, or basil alongside ginger plants to naturally deter pests and reduce their populations. Using organic or natural pesticides should be a last resort after other control methods have failed. Always follow instructions carefully and apply pesticides only when necessary.

To control pests, encourage the presence of beneficial insects, for example, ladybugs, lacewings, and predatory mites in your field. If unsure about specific pests or diseases affecting ginger in your area, it is recommended to consult with local agricultural extension services or experts who can offer guidance. Lastly, maintaining a healthy growing environment and implementing good cultural practices will greatly reduce the risks associated with ginger pests and diseases. More detail on specific pests and disease management in the next section.

COLEAD's Crop Protection Database provides up to date information on Good Agricultural Practices (GAP) specifically dedicated to supporting the horticultural sector in ACP countries. The data provided is obtained from a combination of sources, including COLEAD field trials of plant protection products (PPP), data from PPP manufacturers 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 provides good agricultural practices (dose, interval between treatments, preharvest 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 crop protection database is accessible **here**.

Additional up-to-date information about Maximum Residue Levels (MRLs) in diverse target markets can be accessed via the pesticide registration toolkit of FAO.

7

PEST MANAGEMENT

7.1. INTEGRATED PEST MANAGEMENT (IPM) STRATEGY

Integrated Pest Management (IPM) is a holistic approach that aims to minimize pesticide use and prioritize the long-term health and sustainability of your ginger crop in a systematic way. The IPM strategy for ginger should begin with ensuring a healthy and vigorous ginger plant by:

- Implementing cultural practices that promote healthy plant growth and reduce pest pressure, such as maintaining proper plant spacing, proper nutrient management, optimizing irrigation and drainage, and implementing proper rotation (and association) cycles.
- Selecting appropriate ginger varieties suited to the climate and tolerant to the major diseases and pests (if such varieties are available)
- Ensuring that planting materials come from reputable sources, preferably certified to be pest and disease free.
- Employing pollinator-friendly practices by providing flowering plants, nesting sites, and minimizing pesticide use during periods of pollinator activity.
- Encourage the presence of beneficial insects and organisms that can naturally control pests. These can include predators, parasitoids, and pathogens. Create habitats for beneficial insects by maintaining hedgerows, providing flowering plants, and avoiding broad-spectrum pesticide use that may harm them.
- Avoiding planting on recently grubbed up ginger plots due to the risk of disease transmission.
- Selecting plots with soils that are deep and well-draining, high in organic matter.
- Ensuring the organic content of the soils are high, through the use of manures, composts and mulches.
- Controlling weeds to prevent competition for soil nutrients and moisture especially within a distance of 30-60cm from the ginger plants.
- Adequate soil preparation before planting.
- Regular scouting for pests, natural enemies and disease symptoms is also essential to understand the current state of the cropping ecosystems and the trends that can inform the forecasting of pest and disease problems
- Setting thresholds at which action needs to be taken. This threshold will vary depending on the specific pest, crop stage and economic considerations.
- Using pesticides if pest populations exceed the action threshold, choosing pesticides that are specific to the target pest and have minimal impact on beneficial insects. Always follow all label instructions and use personal protective equipment to ensure effective and safe pesticide use.
- Chemical interventions should only be used if all preparatory work, crop husbandry practices and natural regulatory processes such as natural enemies are not preventing the pests/diseases.

- When fumigating, store containers with an approved fumigant prior to storage by suitably licensed or trained personnel.
- Record keeping: Maintain detailed records of pest populations, pesticide applications, and crop performance. This information will help you track trends, evaluate the effectiveness of your IPM program, and make informed decisions in subsequent seasons.

Integrated Pest Management (IPM) practices have evolved to reduce the harmful effects of chemical pesticides. Farmers are encouraged to make decisions based on field observations and experience, moving away from solely relying on the economic threshold level (ETL). Ecological engineering uses cultural techniques and habitat manipulation to manage pests. It promotes biodiversity by attracting parasitoids and natural enemies through nectar-producing flowers, enhancing biological control. Selecting appropriate flowering plants for pest management depends on availability, agro-climatic conditions, and soil types..

7.2. BASIC, NON-EXHAUSTIVE LIST OF TOOLS FOR IMPLEMENTING IPM:

- Field notepad and pen - note down observations, sample information, and the severity of the illness
- Tools for Data Recording - keep accurate records, using notebooks, data sheets, or digital devices
- Using knives or sterilised scalpels, collect representative samples
- Use a hand lens or magnifying glass for better assessment of ginger rhizomes and plants for pests and diseases
- Use plastic bags or containers to transport and store obtained samples hygienically and well-ventilated
- Use a portable scale to obtain quantitative data related to its ginger safety and quality, aiding strategic decision-making
- Soil sampler – to obtain soil samples for quality and safety analyses
- Equipment for weather monitoring – Monitor temperature, humidity, and rainfall to evaluate optimum planting times, and estimate the danger of diseases.
- Laboratory resources – portable, rapid test kit for heavy metals, soil pH, soil minerals, and other equipment
- Tools for measuring soil moisture - Use moisture metres or probes to gauge soil moisture levels.
- Utilise drones or satellite photos to detect crop health issues and disease outbreaks using remote sensing technologies.
- Digital platforms and mobile applications

7.3. KEY PESTS AND DISEASES

Ginger pests and diseases can have a significant negative impact on resources and yields. Undertaking surveillance and monitoring is an essential component of pest and disease management. By regularly assessing the presence and severity of infestations and taking timely action to control them, significant damage to ginger plants can be minimized. The tools used for surveillance and monitoring exercises varies depending on the climatic conditions and organism of interest.

A general guide on the main management practices associated with key ginger pests and diseases are provided in the following sections.

7.3.1. RHIZOME SCALE (ASPIDIELLA HARTII (COCKERELL)

Description/identification

Rhizome scale, is also known as ubi scale, yam rhizome scale, and yam scale. Female scales are circular and measure approximately 1mm in diameter. They appear as pale brown to grey encrustations on the seed rhizomes. Male scales, on the other hand, are orange in colour and have transparent wings, as well as distinct head, thorax, and abdomen. If the seed rhizomes are heavily infested, they become shrivelled. Initially, white scales can be found scattered on the seed rhizomes, but later they gather near the growing buds (Satyagopal et al., 2014).

Figure 44: *Aspidiella hartii* spp.; damage on ginger plants; and affected seed rhizomes (Image credit: CABI)

Quarantine organism

Rhizome scale is currently not listed as a quarantine organism. For recent updates on quarantine status, refer to the EPPO global database. (https://gd.eppo.int/)

Favourable conditions

Scale insects, including rhizome scale, prefer warm climates (24 - 32°C) for increased activity and reproduction. They thrive in humid environments and benefit from moisture for their survival and reproduction. High humidity levels facilitate scale multiplication by promoting the growth of fungi and molds they feed on. Insufficient airflow around ginger plants contributes to scale development, as stagnant air creates a favourable microclimate for infestations. Adequate ventilation reduces humidity, keeping plants dry and less suitable for scale infestation. Overcrowding and poor spacing of ginger plants promote the spread of scale insects by impeding air circulation. Weak and stressed plants are more susceptible to scale infestations, caused by factors such as poor nutrition and inadequate watering. Maintaining optimal growing conditions, including proper fertilization and irrigation, helps enhance plant vigour and reduces susceptibility to infestations. Regular pest monitoring and control practices are essential to prevent the development and spread of rhizome scale. Timely interventions are crucial as scale populations can increase and become challenging to manage if left unchecked.

Pest life cycle

Rhizome scale insects undergo egg laying, hatching of mobile nymphs, scale formation, feeding and growth, mating, and egg production, with an incubation period of 2-5 days and a larval period of 13-18 days, ultimately pupating into rotten seed rhizomes.

Surveillance / monitoring

For monitoring, look for odd patches of yellowed plants in the field, sudden yellowing of leaves and yellowing that remains for long periods. Examine seed rhizomes for brown colour scales (about 1mm) by hand lens. Monitor leaves for damage caused by scale infestation after harvest and during storage of ginger (CABI, 2016).

Conduct visual inspections by carefully examining all parts of your ginger plants for signs of rhizome scale infestation, including scales, scale coverings, honeydew, and sooty mould. Check both upper and lower leaf surfaces and the plant base. Utilize a magnifying lens to get a closer look at the scale insects, particularly for identifying smaller stages such as crawlers or newly settled scales.

Place yellow sticky traps near your ginger plants to capture adult scales and regularly monitor them for population assessment. Additionally, use a beat sheet or shaking method to dislodge scales onto a white cloth for easier detection.

Keep records of your observations to track infestation severity and evaluate control measures, while also monitoring neighbouring plants for potential spread. Early detection is key, so conduct regular surveillance during the growing season.

Cultural control

At the vegetative stage, manage rhizome scale by uprooting and destroying damaged plants. Cultural control measures for preventing and managing rhizome scale infestations on ginger include:

Proper plant spacing - maintain sufficient distance between ginger plants to discourage scale insect spread.

Weed management - control weeds and eliminate nearby plants that may harbour scales.

Plant health maintenance - optimize growing conditions for ginger, including watering, fertilization, and light exposure, to promote plant health and resilience.

Pruning and sanitation - regularly inspect ginger plants, remove infested or damaged parts, and dispose of them properly.

Soil improvement - maintain well-drained soil to discourage scale insects that thrive in excessively wet conditions.

Crop rotation - rotate crops to disrupt the scale insect life cycle and reduce the risk of recurring infestations.

Clean tools and equipment - ensure gardening tools and equipment are clean and free from scale insects before working with ginger plants.

Avoid overfertilization - provide adequate nutrition to ginger plants without excessive nitrogen fertilization, which can attract scale insects. Follow recommended fertilization guidelines.

Bioprotection

At the rhizome development stage, one can utilize natural biocontrol agents such as ladybird beetles, spiders, and various parasitic wasps for scale insect control. Consider the release Trichogramma chilonis or application of biopesticides such as neem, garlic extracts, hot pepper extracts, spinosad, and Bacillus thuringiensis (Bt) products.

Other bioprotection methods:

- Plant flowers to attract ladybugs and lacewings that prey on scales.
- Introduce species specific to scale control.
- Release parasitic wasps or mites that feed on scale insects.
- Apply fungi that infect and kill scale insects.
- Apply nematodes targeting scales to the soil.
- Use insecticides containing bacteria or fungi for scale control.
- Create a habitat that supports scale insect predators by planting diverse vegetation and reducing broad-spectrum insecticide use.
- Consider introducing Cryptolaemus montrouzieri (mealybug destroyer) for scale insect control.

Some examples of:

— **Microbial Insecticides:**

***Bacillus thuringiensis* subsp. israelensis (Bti)**

Beauveria bassiana

— **Predatory Insects:**

***Cryptolaemus montrouzieri* (mealybug destroyer)**

— **Beneficial Nematodes:**

Heterorhabditis bacteriophora

Control with Plant Protection Products is possible as last resort.

Examples of systemic insecticides that can be used against scales include lambda-cyhalothrin, pyriproxyfen or acetamiprid.

When using chemical insecticides **always** follow label instructions for application rates and dilution ratios specific to the product and active ingredient and ensure local approval for use. The COLEAD crop protection database is accessible **here**. The database provides up to date information on Good Agricultural Practices (GAP), including data from COLEAD field trials of plant protection products (PPP), PPP manufacturers and scientific literature. Additional up-to-date information about Maximum Residue Levels (MRLs) in diverse target markets can be accessed via the pesticide registration toolkit of FAO.

Other control methods

There are several strategies to manage rhizome scale on ginger, including cultural control measures, physical control methods, exclusion techniques, and plant resistance. Cultural control involves sanitation by removing and destroying heavily infested plant material, pruning infested parts, and implementing crop rotation. Physical control includes using high-pressure water sprays and mechanical removal of scales. Exclusion methods involve using physical barriers such as netting or row covers. Plant resistance can be achieved by selecting resistant or tolerant ginger cultivars and optimizing cultural practices such as proper irrigation, nutrition, and spacing while avoiding over-fertilization.

7.3.2. BLACK CUTWORM, ALSO KNOWN AS DARK SWORD GRASS MOTH (AGROTIS IPSILON)

Description/identification

The term "cutworm" typically refers to the larvae of various moth species that are known for their habit of cutting through the stems of plants near the soil surface.

The black cutworm is a type of cutworm that can indeed pose a threat to a variety of crops, including ginger plants, under certain conditions.

The feeding habits of black cutworm caterpillars involve consuming the stems and leaves of plants, often by cutting through the stems near the surface of the soil. This behaviour can result in the complete severing of young seedlings or significant damage to well-established plants. While ginger plants are not their preferred host, they can still be affected if black cutworms are present nearby.

When black cutworms infest ginger plants during the seedling stage, it becomes a serious pest. It primarily targets the base of the ginger plants, causing tissue damage and leading to the withering of heart leaves (known as dead heart). Initially, the leaves turn yellow, and eventually, the affected plants suddenly collapse. The destructive impact of black cutworms on ginger plants is extensive, resulting in the complete destruction of the plant's core. The plants fall over and fail to produce adequately sized seed rhizomes. Furthermore, seedling plants fail to develop into robust and sturdy ginger plants.

Black cutworms undergo a transformation into moths with a black body and dark brown wings that can span 42-53mm when fully extended. The moths are visible and have a body length of 1.6-2.3 cm. The eggs of black cutworms are white and measure 5mm in length. As they develop, the eggs may acquire red spots and stripes. The pupa, which lacks any covering, is about 3/4 inches long and changes in colour from orange brown to black before incubation and eventually turns grey.

When fully grown, black cutworm caterpillars are dark-coloured and have a smooth body that measures approximately 3-4 cm (1.5 inches) in length. They typically appear grey or black, although their coloration can vary. The adult moths have a wingspan of about 4-5 cm (1.5 to 2 inches) and are characterized by their dull brown or grey colour.

Figure 45: Black cutworm larva, adult, and the related plant damage (Image credit: Iowa state university, naturespot.org.uk; Huntsbarger, W. M, respectively)

Quarantine organism

The black cutworm is currently not listed as a quarantine organism. For recent updates on quarantine status, refer to the EPPO global database.

Favourable conditions

Black cutworm larvae are primarily active at night and are commonly found in warm and moist environments. They thrive in temperatures ranging from 13-25°C. These caterpillars tend to have higher populations in wet areas of fields and fields that have been flooded. Their activity and development are closely tied to moisture levels in the soil.

The presence of black cutworm moths in an area is influenced by climate and seasonal patterns. They are migratory insects and are more likely to establish populations in regions with moderate to warm climates. The timing of their migration and the availability of suitable host plants can impact their population densities. Climate conditions play a crucial role in determining the extent of their presence and impact on crops.

Black cutworms show a preference for weedy and uncultivated areas as these locations provide shelter and food sources for both the moths and the caterpillars. These areas serve as breeding grounds, contributing to higher populations of the pest. Fields or gardens located in close proximity to weedy or uncultivated areas are at a higher risk of black cutworm infestations and should be carefully monitored.

Moisture and soil conditions play a crucial role in the life cycle and survival of black cutworms. These pests are more active and thrive in moist soil conditions. Poorly drained fields or areas with excessive irrigation can create favourable conditions for egg hatching, caterpillar survival, and overall population growth. The presence of crop residues or cover crops can attract and provide suitable habitat and food sources for black cutworms. If these residues or cover crops are not adequately managed or incorporated into the soil, they can serve as harbourage for the moths and caterpillars, further contributing to population growth.

The population dynamics of black cutworms are influenced by the availability of preferred host plants. These caterpillars are known to feed on a wide range of plants, including various crops, grasses, and weeds. The presence of preferred host plants, such as those from the Brassicaceae family (such as cabbage, broccoli, and mustard), as well as other susceptible crops, can contribute to higher populations of black cutworms.

Pest life cycle

The black cutworm undergoes multiple complete metamorphoses within a year, encompassing several generations. They have the ability to survive through winter cold periods. The initial generation of larvae primarily inflicts damage on ginger seedlings. Eggs laid by spring migrant moths are often deposited before crops are planted. The female moth places her eggs on grasses, weeds, and leftover crop remains.

Depending on the temperature, the eggs typically hatch within a span of 5-10 days. The larval stage, from hatching to pupation, lasts approximately 28-35 days, contingent on temperature conditions.

When the larva reaches maturity, it burrows into the soil and constructs a cell made of earth, in which it undergoes pupation. The pupal stage endures for around 12-15 days, completing the entire life cycle in 35-70 days. They are most active during nighttime.

Black cutworm moths possess migratory tendencies and can be found in diverse regions. They lay their eggs on the leaves of host plants, and within a week, the eggs hatch into caterpillars. These caterpillars experience several growth stages, known as instars, as they consume plant foliage and increase in size.

Surveillance / monitoring

The larvae hide in soil during the daytime and come out at night. Adult cutworms are monitored with both blacklight and pheromone traps, though light traps are not always reliable. Pheromone traps are more effective during the spring flight, when larvae present the greatest threat to young plants. White and yellow traps are more efficient than green traps. Cutworm larvae are sometimes difficult to observe as they burrow in the soil, though they can be sampled with bait traps. Sunflowers attract the larvae thereby allowing them to be picked up from the field.

Field scouting - conduct systematic field scouting to monitor black cutworm activity. This involves inspecting the crop field or garden regularly to observe signs of damage and the presence of caterpillars. Check for cut stems, wilting plants, and frass (insect excrement) near the base of plants, as these are indicative of black cutworm feeding.

Pheromone traps - pheromone traps can be used to monitor black cutworm adult moth activity and population trends. These traps release synthetic sex pheromones that attract male moths, allowing you to estimate their population density and monitor their flight patterns. Consult local agricultural authorities or entomologists for guidance on using pheromone traps effectively.

Light traps - light traps can be used to capture and monitor adult black cutworm moths. These traps utilize artificial light sources to attract and capture moths during their nocturnal flight. Monitoring the number of moths caught in light traps can help assess their population dynamics and activity levels.

Visual inspection - regular visual inspection of plants during the early morning or late afternoon can help identify black cutworm caterpillars. Look for the caterpillars themselves or signs of their feeding damage, such as notched leaves or cut stems.

Digging and soil sampling - black cutworm caterpillars usually hide in the soil during the day and emerge to feed at night. By gently digging near the base of affected plants, you may be able to find the caterpillars in the soil. Soil sampling can also help determine the presence and density of cutworm larvae by extracting soil samples and examining them for the presence of caterpillars.

Citizen science programs - some regions may have citizen science programs or pest monitoring networks that provide resources and protocols for monitoring black cutworms and other pests. These programs may involve collaboration with farmers, gardeners, or community members to collect data on pest populations and share information.

Cultural control

Effective management of black cutworms involves selecting healthy and pest-free planting material, regularly scouting for the pest, maintaining field cleanliness, and promptly responding to infestations. The control strategies employed depend on the pest's life cycle and the crop's growth stages. These strategies may include field sanitation, crop rotation, soil treatments before planting, and controlled weeding practices. Care should be taken to time tillage to avoid harming beneficial insects and to prevent excessive competition between crops and weeds.

Specific measures for controlling black cutworms in ginger cultivation are somewhat limited, but certain cultural control methods can be implemented to manage their populations. Crop rotation is advised to prevent ginger from being planted in areas where black cutworms have been problematic before, disrupting their life cycle and food source. To minimize accessibility of alternative hosts for the pests, regular weeding is essential to keep the ginger field free from unwanted plants. Maintaining proper field sanitation, such as removing crop debris after harvest, reduces hiding spots for black cutworms hinders their survival.

Employing appropriate tillage practices, for example, deep ploughing, can expose cutworm pupae to harsh conditions and natural predators, effectively reducing their population. Another useful technique involves planting trap crops that attract black cutworms more than ginger, thus diverting the pests away from the main ginger plants and facilitating targeted control measures.

Encouraging the presence of beneficial insects, such as ground beetles, parasitic wasps, and birds, can be advantageous for naturally suppressing the black cutworm population. Creating suitable habitats, such as hedgerows, flowering plants, and birdhouses, can attract these natural enemies and aid in the pest's management without resorting to chemical solutions. Avoiding mulching during infestations is recommended, while certain crops such as mustard, lamb's-quarter, and quack grass can be planted away from the main fields to prevent attracting the adult black cutworms.

Bioprotection

Biopesticides

Spinosad is an all-purpose natural insecticide that works well on cutworms. Products containing neem oil or pyrethrins (derived from chrysanthemum flowers) may also be effective but should be applied when the larvae are young.

Biocontrol agents

Hymenopteran (Wasp) Parasites

The hymenopteran parasites, including ichneumonids, chalcids, braconids, and sphecids, are the most important group of cutworm natural enemies.

Beneficial Parasitic Nematodes

Steinernema carpocapsae: Apply in the morning or evening for maximum effectiveness.

Parasitic Nematodes

Steinernema carpocapsae or Heterorhabditis bacteriophora

To be applied to the soil around the base of the ginger plants. Follow the manufacturer's instructions for application frequency, typically every 2-4 weeks.

Trichoderma species

Incorporate into the soil during planting or apply as a foliar spray.

Metarhizium anisopliae

Apply as a soil drench or foliar spray according to manufacturer's instructions, typically repeating every 7-14 days.

***Trichogramma* wasps**

Release Trichogramma wasps onto the ginger crop when black cutworm eggs are present. Repeat releases at weekly intervals as needed, following supplier recommendations.

Beauveria bassiana

Apply as a soil drench or foliar spray, according to manufacturer's instructions, typically repeating every 7-10 days.

Control with plant protection products

Persistent insecticides are commonly used to suppress black cutworms by applying them to plants and soil. However, it is preferable to apply these insecticides on the surface rather than below ground. Larvae can be controlled to some extent by using insecticide-treated bran and other baits. Another method involves applying systemic insecticides to rhizome seeds, which offers some protection against larval damage.

Potential products against black cutworm may for example include deltamethrin, lambda-cyhalothrin, cypermethrin, chlorantraniliprole, acetamiprid, and emamectin benzoate.

When using Chemical Insecticides – always follow label instructions for application rates and dilution ratios specific to the product and active ingredient and ensure local approval for use. The COLEAD crop protection database is accessible **here**. The database provides up to date information on Good Agricultural Practices (GAP), including data from COLEAD field trials of plant protection products (PPP), PPP manufacturers and scientific literature. Additional up-to-date information about Maximum Residue Levels (MRLs) in diverse target markets can be accessed via the pesticide registration toolkit of FAO.

Other control methods

Collars - Placing physical barriers, such as collars made of cardboard or plastic, around ginger plants can prevent black cutworms from reaching the stems and causing damage. This method physically blocks the worms from accessing the plants.

Sticky Traps - Setting up sticky traps near ginger plants can help capture adult black cutworm moths. This reduces their population and the number of eggs they can lay, thus controlling the pest's population.

Deep Ploughing - Performing deep ploughing or tilling of the soil before planting ginger disrupts the overwintering sites of black cutworm larvae. By disturbing their habitat, the number of larvae can be reduced. The recommended depth for ploughing is typically 15-20 centimetres (6-8 inches).

Light Traps - Using light traps can attract and trap adult moths by utilizing artificial light sources. This method helps to decrease the number of black cutworm adults in the vicinity of the ginger field.

7.3.3. NEMATODES - ROOT-KNOT, BURROWING AND LESION NEMATODES (MELOIDOGYNE SPP., RADOPHOLUS SIMILIS AND PRATYLENCHUS SPP.)

Description/identification

Nematodes, which are small organisms resembling worms, have the potential to harm plants such as ginger. Ginger plants can be affected by various nematode species, such as root-knot nematodes (Meloidogyne spp.) and lesion nematodes (Pratylenchus spp.). Infection of these nematodes can lead to stunted growth, leaf yellowing, root damage, and decreased ginger crop yield.

Figure 46: Root-knot and burrowing nematode and related ginger damage (Image credit: Stephen Ausmus, Australian Centre for Internation Agricultural Research)

Nematodes are microscopic organisms that reside in soil and roots, making it challenging to identify their presence on ginger plants. These soil diseases can significantly reduce ginger harvests and exacerbate fungal and bacterial infections.

Root-knot nematodes cause stunted growth, reduced vigour, chlorotic leaves with scorched tips, and yellowing. They feed on young roots and pseudostems, leading to rotting and water-soaking between fingers of rhizomes. Root-knot nematodes are economically significant as they invade plant roots and induce gall formation and abnormal growth stimulation.

Burrowing nematodes result in stunting, reduced vigour, chlorotic leaves with scorched tips, yellow leaves, fewer shoots, and stunted growth. Infected seed rhizomes develop small, water-soaked lesions that later turn brown and cause rot. Burrowing nematodes, also known as Radopholus nematodes, feed on the outer surface of roots, creating tunnels that disrupt water and nutrient flow to the plant.

Lesion nematodes severely damage roots and rhizomes, leading to yellowing of leaves, dry rot on seed rhizomes, and the formation of dark brown necrotic lesions. Lesion nematodes (Pratylenchus spp.) damage roots by causing necrotic lesions on the root surface and within tissues. Infested plants exhibit reduced vigour, stunted growth, and overall decline in health.

Nematode infestations can occur individually or in combination, with symptoms varying depending on the severity of the infestation, nematode species involved, and other environmental factors.

Quarantine organism

Meloidogyne spp are considered a regulated non-quarantine pest in Bahrain, and a quarantine/quarantine-recommended pest in parts of Europe (Turkey), Asia (China and Jordan) and America (Argentina).

Radopholus similis is widespread in many countries, and considered a regulated non-quarantine pest in Guinea, and a quarantine/quarantine-recommended pest in parts of Europe (Georgia, Norway, Ukraine, Turkey), Asia (China, Bahrain, Israel, Jordan, Uzbekistan, Jordan), Africa (Tunisia, Morocco, Egypt) and America (Argentina, Chile, Mexico, Paraguay, Uruguay).

Pratylenchus spp. is a quarantine-recommended pest in Bahrain, and a quarantine pest in China.

For other recent updates on quarantine status, refer to the EPPO global database.

Favourable conditions

Infestation and transmission of nematodes can occur through various means, including infected plant material, agricultural tools, rain and irrigation water, strong winds carrying infested soil particles, and contaminated soil carried on shoes or animal feet. Nematodes can survive in moist soil for extended periods (Meenu and Jebasingh, 2020). Weeds have also been found to be highly susceptible to root-knot nematodes, sustaining high-density levels in the soil throughout the year (Santos *et al.*, 2019). Proper weeding practices are therefore crucial in nematode management.

To reduce nematode infestation and transmission, you can consider the following measures:

Crop rotation - implement a crop rotation strategy that includes non-host crops or resistant varieties. Avoid continuous cultivation of susceptible host plants, such as ginger, as this provides a constant food source for nematodes and promotes population growth.

Sanitation - practice good sanitation in your farming operations. Clean and disinfect agricultural tools and equipment regularly to prevent the movement of nematodes between fields. Properly dispose of infected plant material to minimize the spread of nematodes.

Soil management - focus on improving soil health to strengthen plant defences against nematodes. Increase organic matter content through the addition of compost or organic amendments. Maintain balanced nutrient levels and promote the presence of beneficial microorganisms in the soil.

Water management - optimize irrigation practices to avoid excessive soil moisture that can favour nematode dispersal. Prevent waterlogging or water-saturated conditions, as these can limit oxygen availability and negatively impact nematode populations.

Weed control - implement effective weed management practices to minimize the presence of weed hosts that can sustain nematode populations. Regularly remove weeds from fields to reduce potential nematode reservoirs.

Monitoring and early detection - regularly monitor plants for signs of nematode infestation. Early detection can help implement control measures promptly, minimizing the spread of nematodes.

Resistant varieties: Whenever possible, choose plant varieties that are resistant or tolerant to nematodes. Resistant varieties can help minimize nematode damage and reduce the spread of nematode populations.

Pest life cycle

Nematode species can develop from egg to egg-laying adult within 3-4 weeks during hot weather, predominantly surviving as eggs in the soil between seasons. After hatching, the second-stage juveniles invade roots, while male nematodes later abandon the roots, leaving the females behind to lay their eggs. The egg-laying females form a mass that extends through the roots and into the soil. While sexual reproduction is common, some nematode species can reproduce asexually in some species.

Root-knot nematodes (*Meloidogyne* spp.)

Egg stage: Duration varies based on environmental conditions, ranging from a few days to a few weeks.

Juvenile stage: After hatching, juveniles go through four molts, with each stage lasting a few days to a few weeks. Adult stage: Upon completing the final molt, the juvenile nematode becomes an adult, which can last for several weeks or months, during which it reproduces and lays eggs. The complete life cycle of root-knot nematodes can range from 21 to 30 days under favourable conditions, but this can vary based on species and environmental factors.

Burrowing nematodes (*Radopholus* spp.)

Egg stage: Duration varies depending on temperature and other conditions, ranging from a few days to a few weeks. Juvenile stage: After hatching, juveniles go through several molts, with each stage lasting a few days to several weeks. Adult stage: After the final molt, the nematode reaches adulthood, which can last for several weeks or even months, during which it reproduces and lays eggs. The complete life cycle of burrowing nematodes can range from a few weeks to several months, depending on temperature, host availability, and environmental conditions.

Lesion nematodes (*Pratylenchus* spp.)

Egg stage: Duration varies from a few weeks to a few months, depending on environmental conditions.

Juvenile stage: After hatching, juveniles go through several moults, with each stage lasting a few weeks to several months. Adult stage: After the final molt, the nematode becomes an adult, which can last for several weeks or months, during which it reproduces and lays eggs. The complete life cycle of lesion nematodes can range from several weeks to several months, depending on factors such as temperature, host availability, and other environmental conditions.

Surveillance / monitoring

To monitor nematodes in the field, start surveillance after crop establishment and continue on a weekly basis:

- Collect representative soil samples (ca. 100-300 cm^3 or 200-300g) from the plant's root zone. Take multiple subsamples from different locations within the field. Combine them to create a composite sample. Send the samples to a nematology laboratory for analysis.
- Carefully unearth plant roots and inspect them for nematode infestation signs resembling galls, root-knots, lesions, discoloration, or abnormalities. Rinse the roots to remove soil, making it easier to spot signs of nematodes. Use a hand lens or microscope to identify nematode stages or damage.
- Monitor plants for symptoms associated with nematode infestations, such as stunted growth, wilting, yellowing, or general decline. Record any noticeable changes in plant health and growth stages. Analyse the correlation between these changes and nematode presence or population levels.
- Use the Baermann funnel technique to extract nematodes from soil or plant tissue. Place the sample in a funnel with water and let the nematodes migrate into the water through a fine mesh or filter. Collect, count, and identify the extracted nematodes.
- Use susceptible crops known to attract nematodes as a surveillance tool. Assess nematode population levels before rotating or removing the trap crop

Cultural control

To enhance the defence of ginger crops against nematode diseases, it is crucial to employ certain strategies and cultural control practices. Here are some effective measures:

Select healthy, pest-free planting material and prioritize host plant resistance. This helps in strengthening the crops' defence mechanisms against diseases. Treat rhizomes with hot water (51°C for 10 minutes) prior to planting to reduce nematode problems. After each harvest, promptly remove the roots of the crop and till the soil two to three times. This practice proves highly effective in combating nematodes.

Practice sanitation based on the pest's life cycle and crop stages. Integrate this with crop rotation using non-hosts and few antagonistic crops against nematodes. Implementing these practices for 1 or 2 years helps reduce nematode populations.

Implement solarization by covering ginger beds with a polythene sheet (45 gauge/0.45 mm) for three weeks before sowing or expose the beds to direct sunlight for 40 days during the hot season. This can also be done prior to planting. Solarization aids in controlling nematodes by creating unfavourable conditions for their survival. In case of infestation during rhizome development, uproot and destroy the infested plants.

Cultural control practices play a vital role in integrated pest management (IPM) strategies for nematode control. These measures create unfavourable conditions for nematodes, hindering their survival and spread. In addition to the above, consider the following practices:

- Rotate ginger with non-host or less susceptible crops over several years to break the nematode life cycle and reduce their populations. After uprooting and destroying infested plants, intercropping with cereal crops (e.g., marigold, Chrysanthemum, Sesbania, Crotalaria spp., Gaillardia, castor bean, and Desmodium spp.) can be done to control parasitic nematodes. Additionally, growing repellent border plants (e.g., Marigold, Gliricidia, Asparagus, Dahelia) as strips of rye grass, cover crops, and mulch beds (rove beetle) can be beneficial if feasible. Crop rotation with groundnut mustard effectively reduces M. incognita populations.
- Resistant or tolerant varieties: Cultivate ginger varieties that are bred to be resistant or tolerant to nematodes. These varieties exhibit genetic traits that make them less susceptible to nematode damage, minimizing losses.
- Remove and dispose of crop residues, roots, and infected plant materials after harvest. This eliminates potential sources of nematode populations. Clean and sanitize tools, machinery, and equipment to prevent nematode transfer among fields.
- Use sunlight and heat to control nematodes through soil solarization. Cover moist soil with clear plastic to trap solar radiation and increase soil temperatures to levels lethal to nematodes. This method is most effective in regions with high solar radiation during hot summer periods.
- Incorporate organic matter such as compost or well-rotted manure into the soil to improve its health and enhance beneficial microbial activity. Healthy soils with adequate organic matter content support a diverse microbial community that naturally suppresses nematode populations.
- Irrigation management: Optimize irrigation practices to avoid over-irrigation, as excessive moisture promotes nematode survival and movement. Proper irrigation scheduling prevents water stress, reducing plant susceptibility to nematode damage.
- Soil amendments such as dry or green crop residues, oil cakes, meals, sawdust, and farmyard nanure decompose in nematode-infested fields, reducing nematode populations and improving soil conditions for plant growth. Additionally, incorporating Gliricidia compost and neem cake enhances soil quality. Some soil amendments, such as biocontrol agents, organic amendments, or beneficial microorganisms exhibit suppressive effects on nematodes. Seek guidance from experts on specific soil amendments that have demonstrated efficacy against nematodes in your region.

Bioprotection

During rhizome development, asafoetida extract and turmeric are effective against plant pathogens, including nematodes, particularly in cases of infestation.

To combat M. incognita nematodes, several methods can be employed. These include applying neem (Azadirachta indica) seed cake before planting. Releasing and promoting existing natural enemies such as spiders, ladybird beetles, long-horned grasshoppers, Chrysoperla, earwigs, and biocontrol agents such as Paecilomyces lilacinus, Pasteuria penetrans, and Pseudomonas fluorescens have also shown effectiveness.

- Application of beneficial nematodes (e.g., *Steinernema* and *Heterorhabditis* species) can be considered and depends on the target nematode species and infestation severity. It is important to consult the product instructions or supplier for specific recommendations based on the nematode species and target crop.
- Application of *Trichoderma* fungi , and *Pasteuria penetrans* can also be considered.
- Application rates for soil amendments such as composts or biochar depend on the desired organic matter content and soil improvement goals. However, it is important to consider the specific composition and characteristics of the compost and consult local agricultural experts for site-specific advice.
- The application rates for rhizobacteria can also be considered, however always follow product instructions for accurate application rates.

Control with Plant Protection Products

Chemical products effective against nematodes may include: abamectin, emamectin benzoate, fluopyram, fosthiazate. Biological products may include Garlic extract, Cinnamaldehyde, Chitosan.

When using chemical plant protection products against nematodes – always follow label instructions for application rates and dilution ratios specific to the product and active ingredient and ensure local approval for use. The COLEAD crop protection database is accessible here. The database provides up to date information on Good Agricultural Practices (GAP), including COLEAD field trials of plant protection products (PPP), data from PPP manufacturers and scientific literature. Additional up-to-date information about Maximum Residue Levels (MRLs) in diverse target markets can be accessed via the pesticide registration toolkit of FAO.

Other control methods

No other control methods are reported for the control of nematodes on ginger.

7.3.4. SHOOT BORER (CONOGETHES PUNCTIFERALIS)

Description/identification

Also known as castor seed caterpillar, corn moth, peach pyralid, and yellow peach moth. *Conogethes punctiferalis*, one of the most damaging ginger pests, can cause up to a 50% loss in crop yield. The eggs, which are pink, oval, and flat, are laid individually on the budding parts, petioles, or in groups on leaves and other soft and delicate areas of the plant. The caterpillars tunnel into the central shoots of the plants and consume the growing buds, leading to the leaves turning yellow, drying up, and the shoots becoming withered and dried. When fully grown, the larvae are light brown and sparsely covered in hair. The adults are medium-sized moths with a wingspan of approximately 20mm, featuring orange-yellow wings adorned with tiny black spots. One characteristic sign of an infestation is the presence of a borehole on the pseudostem, through which frass is expelled, along with the appearance of withered and yellow central shoots.

Figure 47: Shoot borer and damage to ginger rhizome (Image credit: Tamil Nadu Agricultural University)

Quarantine organism

It is a quarantine pest in Africa (Morocco), America (Canada, Mexico, USA), Asia, Oceania (New Zealand), and recommended as a quarantine pest in Argentina, Brazil, Chile. More information on the quarantine status can be accessed here.

Favourable conditions

The pest thrives in temperatures ranging between 20-33°C and 60-90% relative humidity.

Pest life cycle

The eggs hatch in 2-6 days. The larvae are fully developed within 12- 16 days, having fed on internal tissues. Pupation takes place inside the seed or in the grass that collects after feeding, lasting about 7-10 days. Three generations are completed in a year.

Surveillance / monitoring

Pheromone traps (4-5/acre) for different pest stages are recommended. They should be erected on supporting poles approximately 0.3 m above the plant canopy, with a change of lures every month. The trapped moths should be counted weekly and destroyed (AESA, 2014).

Cultural control

One can apply green leaf mulch during the planting phase. Additionally, Vitex negundo leaves can be used around 40 and 90 days after planting. Control shoot borer infestation through an integrated approach, which involves several measures. These measures include collecting and eliminating larvae, egg masses, and adults, as well as trimming and removing newly infested shoots. To further reduce pest populations, prune and eliminate recently infested pseudostems at regular intervals, specifically during key periods every two weeks. During the rhizome stage of development, utilize attractant plants such as those from the carrot family, sunflower family, buckwheat, alfalfa, corn, and shrubs to promote natural biocontrol conservation. Utilize nectar rich plants with small flowers (e.g. mustard, anise, sunflower, caraway, dill, parsley) to attract natural enemies and repel pests, including, Chrysoperla zastrowi sillemi, coccinellids, king crow, wasps, dragonflies, spiders, robber flies, reduviid bugs, praying mantids, and fire ants, and entomopathogenic nematodes (EPN) of the genus Rhabditis/Oscheius and Hexamermis spp.

There are some other cultural control methods that are occasionally used as alternative or supplementary approaches to pest management. Their effectiveness and practicality may vary. For example:

- Creating physical barriers around ginger plants can help prevent pest infestations. This can include using fine mesh nets or screens to keep insects out, erecting fences to deter larger pests, or using row covers to protect against airborne pests.
- Certain plant species can repel or deter pests when grown alongside ginger. For example, planting marigolds, basil, or lemongrass near ginger crops may help repel insects. Similarly, intercropping ginger with plants that attract beneficial insects can promote natural pest control.
- Planting specific crops that are highly attractive to pests can be used as trap crops. The pests are lured to these plants, diverting them away from the ginger crop. This can help protect ginger from direct pest damage.
- For certain pests that are visible and easily accessible, physically removing them by hand can be an option. This can be practical for larger insects or pests such as snails and slugs. Regular scouting and manual removal can help reduce pest populations.
- Modifying cultural practices can contribute to pest control. For instance, proper spacing between ginger plants promotes good air circulation and reduces favourable conditions for certain fungal diseases. Adjusting irrigation and fertilization practices can also help create suboptimal conditions for pests.

Bioprotection

Conserve natural biocontrol agents such as ladybird beetles, spiders, Chrysopids, Trichogrammatids, Bracon spp. (larval), myosoma spp. (larval), Apanteles spp. (larval), Xanthopimpla sp (larval and pupal) to assist with pest management. Introduce Trichogramma chilonis to enhance biological control. Alternatively, treat the affected area with Beauveria bassiana or Metarhizium.

Biopesticides may include Bacillus thuringiensis (Bt), neem-based products, or spinosad.

Control with plant protection products

Synthetic pyrethroids such as deltamethrin and cypermethrin are effective against a wide range of insect pests, including Conogethes punctiferalis. These insecticides work by disrupting the nervous system of insects. Neonicotinoids are systemic and can provide protection by being absorbed into plant tissues, affecting insects that feed on the plants. Organophosphates such as malathion are effective against many lepidopteran pests but should be used with caution due to their potential environmental and health impacts. Insect Growth Regulators (IGRs) like methoxyfenozide and tebufenozide mimic insect hormones and disrupt the development of larvae, preventing them from maturing into adults.

When using chemical plant protection products always follow label instructions for application rates and dilution ratios specific to the product and active ingredient and ensure local approval for use. The COLEAD crop protection database is accessible **here**. The database provides up to date information on Good Agricultural Practices (GAP), including COLEAD field trials of plant protection products (PPP), data from PPP manufacturers and scientific literature. Additional up-to-date information about Maximum Residue Levels (MRLs) in diverse target markets can be accessed via the pesticide registration toolkit of FAO.

7.3.5. DRY ROT (FUSARIUM OXYSPORUM F. SP. ZINGIBERI)

Description/identification

Also known as Fusarium yellows or yellows disease. Dry rot, caused by the fungus Fusarium oxysporum f. sp. Zingiberi, is a significant disease that affects ginger production.

Figure 48: Fusarium yellow wilt on ginger and damage caused to seed rhizomes (Image credit: Vikaspedia; Australian Centre for Internation Agricultural Research)

Dry rot primarily affects the rhizomes of ginger plants. Infected rhizomes exhibit symptoms such as brown discoloration, dryness, shrivelling, and rotting. The discoloration starts from the root tips and extends towards the centre of the rhizome. The intensity of the brown discoloration may vary. The infected rhizomes become dry, lightweight, and less firm, with a shrivelled appearance. The rotting process progresses as the disease advances, leading to soft, mushy rhizomes with a foul odour. Dry rot can also affect the foliage of ginger plants, causing yellowing of the leaves, starting from the lower ones, and leading to stunted growth.

To identify dry rot on ginger, visual inspection and laboratory analysis can be used. During visual inspection, carefully examine the rhizomes for discoloration, dryness, shrivelling, and rotting. Additionally, observe foliage symptoms such as yellowing and stunted growth. In some cases, laboratory analysis may be required for accurate identification. A plant pathologist or diagnostic laboratory can perform tests, including pathogen isolation and culturing from infected tissue, to confirm the presence of Fusarium oxysporum f. sp. Zingiberi.

Effective management of dry rot involves several measures. Start by selecting disease-free seed rhizomes for planting. Implement crop rotation to avoid continuous cultivation of ginger and reduce disease pressure. Proper sanitation practices, such as removing and destroying infected plant debris and disinfecting planting material, can help minimize disease spread. Additionally, ensure adequate spacing between ginger plants for good air circulation. Proper irrigation and fertilization practices should be followed to create suboptimal conditions for pests and diseases. Consider applying appropriate fungicides or biocontrol agents as recommended by local agricultural authorities to manage dry rot effectively.

Quarantine organism

Fusarium oxysporum f. sp. Zingiberi is currently not listed as a quarantine organism.

Favourable conditions

This disease is seed and soil borne, transmitted through diseased seed rhizomes and soil as oospores. Infected rhizome pieces and soil are the primary sources of inoculum. Thus, infected crop tissues left in the field act as a fungal reservoir. The pathogen thrives in warm, wet weather and high soil moisture. Development of the disease is favoured by high rainfall and poorly drained soil.

Dry rot can develop under specific favourable conditions:

- Dry rot thrives in warm temperatures. The optimal temperature range for disease development is typically between 25°C to 30°C (77°F to 86°F). High temperatures provide favourable conditions for the pathogen's growth and colonization of ginger plants.
- Moisture plays a crucial role in the development and spread of dry rot. Excessive moisture or prolonged periods of high humidity create a favourable environment for the fungus. Over-irrigation, waterlogged soils, or heavy rainfall can promote the disease's progression.
- Dry rot on ginger is favoured by slightly acidic to neutral soil conditions. A pH range of 5.5 to 7.0 is generally considered suitable for the disease. However, the specific pH preferences may vary slightly depending on the ginger variety and the local strain of the pathogen.
- The use of infected planting material, such as rhizomes or seed pieces, can introduce and spread dry rot within a ginger crop. It is crucial to source disease-free and healthy planting material from reliable sources to minimize the risk of introducing the pathogen.
- High planting densities or overcrowding of ginger plants can create a microclimate with reduced air circulation, leading to increased humidity and moisture retention. Such conditions favour the spread and severity of dry rot.
- Wounds or Injuries: Wounding or injuries to ginger rhizomes provide entry points

for the pathogen. Insects, nematodes, or mechanical damage during harvesting, handling, or other cultural practices can create openings through which the fungus can infect the plant.

Disease life cycle, crop stage

Understanding the life cycle and stages of dry rot is crucial for implementing effective management practices. Early detection, preventive measures, and timely intervention at each stage can minimize the disease's impact and maintain healthy ginger production.

Dry rot in ginger involves multiple stages throughout the crop cycle. The disease life cycle can be summarized as follows:

- The pathogen enters ginger rhizomes through wounds, injuries, or natural openings. Contaminated soil, infected plant debris, or planting material carrying fungal spores are often the primary sources of infection.
- Once inside the rhizome, the pathogen colonizes the vascular system, creating a network of fungal threads called mycelium. This mycelium spreads throughout the rhizome, causing discoloration, dryness, and rotting. Infections may start at the root tips and progress towards the centre of the rhizome.
- Infected rhizomes serve as a source of inoculum for further disease spread. The pathogen can produce spores or survive in dormant structures called chlamydospores within the rhizomes. These structures can persist in the soil or on infected plant debris, facilitating disease transmission to healthy plants in subsequent seasons.
- The pathogen can also infect the foliage of ginger plants as the disease progresses. It enters through wounds or natural openings on the leaves, leading to symptoms such as yellowing, wilting, and stunted growth.
- The severity and progression of dry rot depend on environmental conditions, cultural practices, and ginger varieties' susceptibility. The disease can continue spreading within a crop, resulting in more infected rhizomes and further deterioration of affected plants.
- Dry rot can infect and affect various stages of the ginger crop:
    - Infections can take place in the nursery or during the early stages of propagation. Contaminated planting material or nursery soils can lead to initial infections.
    - After transplanting to the field, ginger plants undergo vegetative growth, and the disease can progress. Rhizomes may display symptoms of dry rot, and foliage infection can affect plant growth and development.
    - As ginger plants mature, the rhizomes undergo further development and enlargement. Dry rot can continue spreading within the rhizomes during this stage, leading to rotting and degradation of quality.
    - Dry rot can be observed during the harvesting of ginger, as infected rhizomes exhibit visible symptoms of discoloration, dryness, and rot. Harvested rhizomes can also serve as a source of inoculum for subsequent crops.

Surveillance / monitoring

Periodic scouting of the field is required, particularly under favourable weather conditions. To effectively combat dry rot in ginger production, it is crucial to detect the disease early. Prompt action is necessary upon observing visible symptoms of dry rot on ginger rhizomes, such as brown discoloration, dryness, shrivelling, or rotting.

High incidence of dry rot within a ginger field, indicating a substantial number of infected plants or rhizomes, requires immediate action. A high disease incidence suggests a favourable environment for the pathogen and increases the risk of further spread. Assess the economic impact of dry rot on ginger production. If the disease is causing significant yield losses or compromising the quality of the ginger, it is crucial to take action to minimize financial losses and maintain marketable produce.

Monitor the spread and progression of dry rot within the field. If the disease is rapidly advancing, affecting a larger area or a higher number of plants, intervention becomes more urgent to prevent widespread damage.

Cultural control

To manage dry rot in ginger production, implement the following cultural control measures:

— Rotate ginger with non-host crops to break the disease cycle.
— Remove and destroy infected plant debris.
— Use disease-free ginger rhizomes.
— Avoid excessive moisture and ensure proper drainage. Planting ginger on raised beds or ridges can help for the latter.
— Allow for good air circulation and light penetration. For the latter, planting density should not be too high.
— Regularly manage weeds in and around the ginger field.
— Maintain soil health through testing and amendments of fertilizers and organic matter (e.g. compost or biochar).
— Handle plants carefully to avoid wounds.
— Practice cleanliness and disinfection protocols.
— Implementing these measures will create unfavourable conditions for the pathogen, reducing disease incidence.

Bioprotection

Selected biocontrol agents and biopesticides for managing dry rot in ginger production, along with their corresponding treatments and general application rates are listed:

— Trichoderma spp. can be applied through soil treatment or seed/rhizome treatment.
— Bacillus spp. can be applied through soil treatment or seed/rhizome treatment.
— Plant Growth-Promoting Rhizobacteria (PGPR) can be applied through soil treatment

or seed/rhizome treatment.

— For inoculant-based Products, follow recommended rates and application methods mentioned on the product label or provided documentation.

Control with plant protection products

Some fungicides used for controlling dry rot in ginger production may include:

— Azoxystrobin

— Metalaxyl-M

— Fludioxonil

— Pyraclostrobin

— Tebuconazole

When using chemical plant protection products always follow label instructions for application rates and dilution ratios specific to the product and active ingredient and ensure local approval for use. The COLEAD crop protection database is accessible **here**. The database provides up to date information on Good Agricultural Practices (GAP), including COLEAD field trials of plant protection products (PPP), data from PPP manufacturers and scientific literature. Additional up-to-date information about Maximum Residue Levels (MRLs) in diverse target markets can be accessed via the pesticide registration toolkit of FAO.

Other control methods

— Certain essential oils, including clove oil, cinnamon oil, and oregano oil, exhibit antifungal properties that may be effective against fungal diseases such as dry rot. These oils can be applied as foliar sprays or incorporated into soil treatments. However, further research is needed to determine their effectiveness and optimal application rates.

— Adding beneficial microorganisms or organic amendments to the soil can enhance the soil microbiome's health and suppress pathogen growth. Compost tea, vermicompost, and biochar are examples of amendments that can improve soil health, promote beneficial microbial activity, and potentially reduce disease incidence.

— Extracts from specific plants, such as neem (Azadirachta indica), garlic (Allium sativum), and ginger (Zingiber officinale), have demonstrated antifungal properties and may serve as biopesticides against dry rot. These extracts can be applied as foliar sprays or incorporated into seed or rhizome treatments. However, their efficacy and application rates may vary, necessitating further research for validation.

— Soil Solarization, which involves covering the soil with a transparent plastic sheet to trap solar heat and elevate soil temperatures to levels lethal for pathogens. Soil solarization can help reduce the population of soil-borne pathogens, including Fusarium species. It is typically carried out during hot summer months and requires precise timing and appropriate soil preparation.

— Planting companion crops or trap crops that possess natural resistance or deterrent effects against pathogens can decrease the occurrence of diseases such as dry rot. Marigold (*Tagetes* spp.) and mustard (*Brassica* spp.), for instance, exhibit biofumigation properties and can be used as companion plants to suppress soil-borne pathogens.

7.3.6. EYE ROT (PYTHIUM SPP.)

Description/identification

Also known as rhizome soft rot. Eye rot, caused by Pythium spp., can have a significant impact on ginger production. Pythium is a genus of water mould that causes various plant diseases, including eye rot in ginger.

Figure 49 : Eye rot on ginger plants and rhizomes (Image credit: Le *et al.*, 2014)

Quarantine organism

Pythium spp. is currently not listed as a quarantine pest.

Favourable conditions

Eye rot disease causes significant losses during warm and humid conditions. Nematode infestation also aggravates rhizome rot disease. Younger sprouts are the most susceptible to the pathogen. Nematode infestation aggravates rhizome rot disease. Temperatures above 30°C and high soil moisture are the important predisposing factors favouring the disease. Waterlogging in the field due to poor drainage also increases the intensity of the disease (Le *et al.*, 2014).

The following conditions are known to contribute to the occurrence and severity of the disease:

— *Pythium* species are water moulds and thrive in environments with high moisture levels.

— Inadequate soil drainage exacerbates the disease. Soils with poor drainage retain excess water, leading to waterlogged conditions. Regions or seasons with high humidity provide the necessary moisture for Pythium spp. to grow and infect ginger rhizomes. Increased humidity creates a suitable environment for the pathogen's spores to germinate and penetrate plant tissues.

— Pythium eye rot is favoured by high humidity levels. Increased humidity creates a suitable environment for the pathogen's spores to germinate and penetrate the plant tissues.

— Planting ginger in dense or overcrowded conditions can increase the likelihood of disease occurrence. Overcrowding restricts air circulation around the plants and slows down foliage and soil drying. Prolonged moisture promotes Pythium infection and spread, resulting in a higher incidence of eye rot.

— Using infected ginger rhizomes or planting material introduces Pythium spp. into the growing area. Infected rhizomes act as a source of inoculum, contributing to disease development. It is crucial to use healthy and disease-free planting material to minimize the risk of Pythium eye rot.

— Continuous cultivation of ginger or other susceptible crops in the same area can lead to an accumulation of Pythium spores in the soil. Crop rotation, whereby different crops are grown in succession, breaks the disease cycle by interrupting the availability of host plants for Pythium and reducing inoculum levels.

Disease life cycle

Pythium spp. are able to persist in soil for long periods as they have quite a wide host range. Consequently, susceptible crops may still be affected if replanted into an infested field years after fallows or rotations (Le et al., 2014).

— The persistence of Pythium in the soil or infected plant debris can vary. Oospores can remain viable for several months to years, while mycelium in plant debris may persist for a shorter period, typically a few months to a year or more.

— The timing of Pythium infection depends on factors such as soil moisture, temperature, and the presence of susceptible host plants. Once the rhizomes come into contact with the pathogen, infection can occur within hours to days.

— The duration of disease development can vary based on environmental conditions, ginger cultivar susceptibility, and the aggressiveness of the Pythium species involved. Symptoms of Pythium eye rot typically appear within days to a week after infection. The rate of disease progression and severity may depend on factors such as temperature, moisture levels, and overall plant health.

— Pythium eye rot produces spores, including zoospores, as infected ginger rhizomes decay. Spore production and release generally occur within a week to a few weeks after infection. Spores can be disseminated through water movement, irrigation, rain, or other means, initiating new infections on healthy plants.

— The duration and spread of the disease within a field depend on factors such as environmental conditions, proximity of susceptible plants, and the availability of inoculum. Secondary infections can occur within days to weeks after spore dissemination.

- When adverse conditions, such as drought or cold temperatures occur, Pythium may enter a dormant phase. Dormancy can last from weeks to months or even longer until favourable conditions for growth and infection are restored.
- On ginger, Pythium often occurs in combinations or as a complex with maggots. The Pythium-maggot complex is a destructive disease-pest interaction, where the combined action of Pythium species (soilborne oomycetes) and maggots (larvae of root-feeding flies) results in significant damage to the crop. Pythium spp. infect the rhizomes, causing rot and soft tissue breakdown, which attracts flies that lay eggs near the infected tissue. The emerging maggots feed on the decayed rhizomes, exacerbating the damage and accelerating secondary infections. Symptoms include water-soaked lesions, soft rot of rhizomes, foul odor, and plant stunting or death. Favorable conditions for this complex include waterlogged soils, high humidity, and warm temperatures, which promote the activity of both pathogens and pests. Effective control involves integrated management practices, including improving soil drainage, using raised beds, applying fungicides to suppress Pythium, and employing insecticides or biological controls to target maggots. Additionally, using disease-free planting material and practicing crop rotation can help reduce the prevalence of this challenging complex.

Surveillance / monitoring

Surveillance and monitoring for Pythium in ginger involve a combination of field inspections, soil sampling, and laboratory analysis to detect early signs of the disease and prevent its spread. Regular field inspections should be conducted, focusing on symptoms such as water-soaked lesions on rhizomes, wilting, and yellowing of leaves, which indicate potential Pythium infection. Soil sampling from different areas of the ginger field is crucial, especially in low-lying or poorly drained sections where Pythium thrives. These samples should be analyzed in a laboratory to identify the presence of Pythium species. Additionally, implementing the use of baiting methods, such as placing ginger slices in the soil and observing them for infection, can help in early detection. Monitoring environmental conditions, including soil moisture and temperature, is also important, as Pythium is more likely to proliferate in wet and warm conditions. By integrating these surveillance methods, farmers can effectively monitor for Pythium and take timely management actions to mitigate its impact on ginger

Cultural control

Cultural practices such as seed selection, crop rotation, organic amendment, tillage, ridging, drainage, and quarantine practicing in ginger plantation not only control the disease but also limit the spread of Pythium spp. Planting disease-free seed rhizomes is the best method to prevent the disease. However, it is important to note that a combination of good practices is needed to prevent and manage the disease.

Some key practices to consider:

- Avoid continuous cultivation of ginger in the same field. Rotate ginger with non-host crops to break the disease cycle and reduce the buildup of Pythium inoculum in the soil. Ideally, rotate with crops that are not susceptible to Pythium species causing eye rot.

- Maintain good soil health and fertility by implementing practices such as organic matter addition, proper nutrient management, and soil pH adjustment. This creates optimal growing conditions and promotes healthy ginger plants that are more resilient to disease, including Pythium infections.
- Manage irrigation practices carefully to avoid excessive soil moisture, which creates a favourable environment for Pythium growth. Ensure proper drainage to prevent waterlogging and stagnant conditions. Use irrigation methods that deliver water directly to the root zone without wetting the foliage excessively.
- Practice good sanitation measures to reduce the spread and survival of Pythium eye rot. Remove and destroy infected plant debris, including ginger rhizomes showing symptoms of the disease. Properly clean and sanitize tools, equipment, and machinery to prevent contamination and movement of the pathogen.
- Treat ginger seed rhizomes before planting to reduce the risk of Pythium eye rot. Dip the seed rhizomes in a fungicide solution recommended for Pythium control, following the manufacturer's instructions, and ensuring thorough coverage of the rhizomes.
- Whenever possible, choose ginger varieties that are resistant or tolerant to Pythium eye rot. Consult local agricultural experts or plant breeders for information on resistant varieties suitable for your growing region.
- Manage weeds effectively in and around the ginger field. Weeds can serve as alternative hosts for Pythium eye rot, contributing to disease spread. Regularly remove weeds to minimize the risk of infection and provide a cleaner environment for the ginger plants.
- Optimize the planting density and spacing of ginger plants. Avoid overcrowding, as it can lead to increased humidity and reduced airflow, creating conditions favourable for disease development. Provide adequate spacing between plants to promote good air circulation and reduce the risk of infection.
- Maintain good field hygiene practices by keeping the field free of debris, excess vegetation, and unnecessary plant materials. This helps reduce potential sources of infection and provides a cleaner growing environment for ginger plants.
- Intercropping ginger with certain companion plants that possess natural repellent or allelopathic properties may help deter Pythium eye rot. For example, marigold (Tagetes spp.) and garlic (Allium sativum) have been suggested as companion plants with potential antifungal properties.
- Regularly monitor the field for signs of Pythium eye rot. Conduct thorough inspections of the plants and rhizomes to detect early symptoms. Promptly remove and destroy any infected plants or rhizomes to prevent further disease spread.

Bioprotection

Examples of biocontrol agents for the management of Pythium eye rot in ginger may include:

- Beneficial fungi products (including Trichoderma spp. and others).
- Beneficial microorganisms, such as Streptomyces spp., Trichoderma spp. Gliocladium spp., and Chaetomium spp., have shown potential in suppressing Pythium spp. and controlling Pythium eye rot. These biocontrol agents can be applied as soil drenches or incorporated into the planting medium
- Bacillus spp.
- Plant growth-promoting rhizobacteria (PGPR)
- Pseudomonas spp.

Some plant extracts and essential oils have also demonstrated antifungal properties and may have potential for managing Pythium eye rot. Examples include extracts from neem (Azadirachta indica), cinnamon (Cinnamomum spp.), garlic, and tea tree (Melaleuca alternifolia).

Control with plant protection products

To manage the yellow disease, the use of fungicides may be considered as last resort. Potential products include:

- COC (Concentrated Oil Emulsion):
- Metalaxyl-M
- Azoxystrobin
- Propamocarb
- Fluopicolide

When using chemical plant protection products always follow label instructions for application rates and dilution ratios specific to the product and active ingredient and ensure local approval for use. The COLEAD crop protection database is accessible **here**. The database provides up to date information on Good Agricultural Practices (GAP), including COLEAD field trials of plant protection products (PPP), data from PPP manufacturers and scientific literature. Additional up-to-date information about Maximum Residue Levels (MRLs) in diverse target markets can be accessed via the pesticide registration toolkit of FAO.

Other control methods may be considered or combined:

- Adopt an integrated approach treating seeds and soil with biocontrol agents such as Trichoderma harzianum, Trichoderma hamatum, and Gliocladium virens. This combination can effectively reduce disease incidence.
- Certain soil amendments, such as biochar or specific organic matter additions,

have been explored for their potential to suppress Pythium spp. and improve soil health. These amendments can enhance beneficial microbial populations and create an environment less favourable for the pathogen. However, the efficacy and optimal application methods may vary, and further research is needed.

— Cover soil with a transparent plastic sheet to trap solar heat. Duration typically ranges from 4-6 weeks during hot summer months.
— Rotate ginger with non-host crops for at least one growing season.
— Remove and destroy infected plant debris and disinfect tools and equipment. Implement proper sanitation practices throughout the growing season.
— Maintain proper spacing, irrigation management, and avoid overfertilization. Implement cultural practices according to recommended guidelines.
— Incorporate organic materials for anaerobic decomposition. Application rates may vary depending on the organic material and specific recommendations.
— Intercrop ginger with companion plants, for example, marigold or garlic.

7.3.7. LEAF SPOT (PHYLLLOSTICTA ZINGIBERI)

Description/identification

Leaf spot in ginger is a common disease characterized by the appearance of spots on the leaves, which can lead to significant damage to the plant if not managed properly. These spots can vary in color, shape, and size depending on the causative agent. The disease can affect the photosynthetic capability of the plant, reducing yield and quality.

Leaf spot, a prevalent plant disease, arises from a variety of fungal and bacterial pathogens. Among the culprits responsible for leaf spot are Phyllosticta spp. and more particularly Phylllosticta zingiberi. This group of pathogens has the capacity to afflict a broad spectrum of plants, encompassing ornamentals, vegetables, and crops alike.

Figure 50: Leaf spot on ginger (Image credit: Tamil Nadu Agricultural University/COLEAD)

The disease typically starts as water-soaked spots and later turns white with dark brown margins and a yellow halo. The lesions enlarge, and adjacent lesions may coalesce, forming necrotic areas. Symptoms often appear first on younger leaves, and as the disease progresses, fresh leaves also become infected. In severe conditions, the affected leaves become shredded and disfigured, leading to extensive desiccation. Leaf spot disease is becoming increasingly important in many parts of India due to the severe leaf rot and blight it causes.

Quarantine organism

These disease species are currently not listed as quarantine species.

Favourable conditions

During rainfall, spore dispersal occurs, and high precipitation and wind lead to greater spore dispersion on leaves. Prevailing temperature, relative humidity, and rainfall significantly influence disease incidence.

Temperatures between 23-28°C with intermittent rain favours the occurrence of the disease, while leaf spot disease incidence is lower in plants grown under partial shade, and higher when ginger is continuously cultivated without crop rotation. Optimum conditions for pathogens such as Phyllosticta spp. vary, but generally involve specific temperature, moisture, and pH preferences for each group.

Disease life cycle

The spread of the disease occurs through wind dispersal, rain splashes, and infected seed and plant debris. High soil moisture and soil temperatures are crucial factors influencing disease development, with increased severity observed in areas with heavy clay soil and poor drainage during rainfall or seed rhizome planting (Farm Africa, 2021).

- Infection by Phyllosticta spp. typically occurs within a few hours to several days after pathogen contact.
- Phyllosticta spp. colonizes plant tissues and causes disease symptoms over several days to weeks.
- Spore production by Phyllosticta spp. on infected plant tissues usually happens within a few days to a couple of weeks.

Surveillance / monitoring

To effectively monitor and manage diseases on ginger, the following actions can be taken:

- Regularly visually inspect plants and plant tissues for disease symptoms, employing trained personnel to identify signs of infection or damage.
- Systematically examine crops or plant populations to identify and quantify disease incidence and severity through random sampling or targeted assessments.
- Analyse plant samples in laboratories using techniques such as microscopy, DNA-based tests (PCR), or immunological assays (ELISA) to confirm the presence of pathogens.

- Utilize satellite imagery or drones with specialized sensors to gather data on crop health and disease outbreaks by monitoring changes in plant reflectance or vegetation indices.
- Gather and process information on disease incidence, severity, and spread, recording symptoms, mapping affected areas, and analysing data to identify patterns or trends.
- Monitor weather conditions to predict disease outbreaks and assess disease risk, utilizing weather stations or online databases for disease forecasting.
- Establish strategically located plots or specific plants to monitor disease presence and serve as an early warning system for potential disease outbreaks.
- Engage farmers, gardeners, and community members in disease surveillance through reporting disease observations, symptoms, or outbreaks, contributing to broader monitoring efforts.

For the four pathogens affecting ginger and causing leaf spot (i.e. Fusarium spp. Phyllosticta spp.), the following action thresholds may be applied:

- If leaf spot symptoms caused by Phyllosticta spp. affect over 20% of ginger leaves, apply fungicides and implement cultural practices – for example, proper plant spacing, airflow, and removal of infected leaves to minimize disease severity.

Cultural control

Cultural control practices to manage Phyllosticta spp. on ginger:

- Maintain adequate plant spacing to ensure good airflow and reduce humidity levels, minimizing Phyllosticta spp. infection.
- Remove and destroy infected leaves, especially those showing visible symptoms of Phyllosticta spp., to reduce inoculum levels in the field.
- Minimize the use of overhead irrigation methods that can promote leaf wetness and create favourable conditions for Phyllosticta spp. growth.

Biocontrol

Biocontrol agents from the genus Trichoderma and Bacillus are commonly used beneficial microbes against soft rot and root rot caused by pathogens on ginger (Mersha and Ibarra-Bautista, 2022).

Some application recommendations for each biocontrol agent are outlined:

Bacillus amyloliquefaciens

Seed Treatment: Use a few grams of the biocontrol agent per kilogram of seeds. Soil Drench/Foliar Spray: Apply 1-5 kilograms per hectare (refer to product label for specific recommendations).

Bacillus subtilis

Seed Treatment: Use a few grams of the biocontrol agent per kilogram of seeds. Soil Drench/Foliar Spray: Apply 1-5 kilograms per hectare (refer to product label for specific recommendations).

Trichoderma harzianum

- Seed Treatment: Use a few grams of the biocontrol agent per kilogram of seeds.
- Soil Drench/Foliar Spray: Apply 1-10 kilograms per hectare (refer to product label for specific recommendations).

Streptomyces spp.

- Seed Treatment: Use a few grams of the biocontrol agent per kilogram of seeds.
- Soil Drench/Foliar Spray: Apply 1-5 kilograms per hectare (refer to product label for specific recommendations).

Pseudomonas fluorescens

- Seed Treatment: Use a few grams of the biocontrol agent per kilogram of seeds.
- Soil Drench/Foliar Spray: Apply 1-5 kilograms per hectare (refer to product label for specific recommendations).

Gliocladium spp.

- Seed Treatment: Use a few grams of the biocontrol agent per kilogram of seeds.
- Soil Drench/Foliar Spray: Apply 1-10 kilograms per hectare (refer to product label for specific recommendations).

Control with plant protection products

Some plant protection products used for disease control on ginger:

Fungicides

Azoxystrobin, metalaxyl, fluazinam and copper-based fungicides.

Botanical Extracts

Neem oil (Azadirachtin), garlic extract, citrus extract

When using chemical plant protection products always follow label instructions for application rates and dilution ratios specific to the product and active ingredient and ensure local approval for use. The COLEAD crop protection database is accessible **here**. The database provides up to date information on Good Agricultural Practices (GAP), including COLEAD field trials of plant protection products (PPP), data from PPP manufacturers and scientific literature. Additional up-to-date information about Maximum Residue Levels (MRLs) in diverse target markets can be accessed via the pesticide registration toolkit of FAO.

Other control methods

Here are a few examples of additional tools that can be considered in disease management strategies. While their efficacy may vary and they may not be widely adopted, they are worth considering:

Essential Oils - Certain essential oils, such as oregano oil, thyme oil, and cinnamon oil, have shown potential antifungal and antibacterial properties. They can be diluted and applied as foliar sprays or incorporated into the soil to help suppress disease development. However, their effectiveness may vary depending on the specific pathogens and conditions.

Compost Tea - Compost tea is a liquid solution made by steeping compost in water. It contains beneficial microorganisms and nutrients that can promote soil health and suppress certain diseases. Applying compost tea as a foliar spray or soil drench can contribute to plant vigor and disease suppression.

Plant Extracts and Juices - Extracts and juices from various plants, such as aloe vera, papaya, and ginger itself, have been explored for their potential antifungal and antibacterial properties. These extracts can be prepared and applied as foliar sprays or incorporated into the soil. However, more research is needed to determine their efficacy and optimal application methods.

Biochar - Biochar is a form of charcoal produced by heating organic matter in the absence of oxygen. It can be incorporated into the soil to improve soil structure, water retention, and nutrient availability. Some studies suggest that biochar amendments may also have disease-suppressive effects by altering soil microbiota and reducing pathogen survival. However, further research is needed to fully understand its effects on specific ginger pathogens.

7.3.8. ANTHRACNOSE (COLLETOTRICHUM SPP.)

Disease Overview and Symptoms

Anthracnose, caused by various Colletotrichum species, is a significant fungal disease that affects ginger (Zingiber officinale). The pathogen primarily attacks the leaves and stems, manifesting as small, water-soaked lesions that expand into large, irregular, brown-to-black necrotic patches. Small round to oval light yellow spots on leaves, increase in size and often coalesce to form large discoloured areas. Holes can occur in the leaf or leaf drop. As the disease progresses, leaves may wither, dry, and drop prematurely, while stems can exhibit dark streaks and become brittle. In severe cases, anthracnose can lead to stunted growth, reduced yield, and compromised quality of rhizomes, making it a critical concern for ginger growers.

Favorable Conditions

The disease thrives in warm, humid environments, with temperatures ranging between 25–30°C and prolonged leaf wetness due to rain, overhead irrigation, or dew. High humidity levels above 85% and poor air circulation create ideal conditions for spore germination and infection. Wet soils, dense planting, and mechanical damage to plants further exacerbate the disease. Anthracnose often spreads through infected planting material, splashing water, and contaminated tools, making sanitation and environmental conditions key factors in its development.

Control Methods

Effective management of anthracnose involves an integrated approach combining cultural, chemical, and biological practices. Cultural controls include using disease-free planting materials, maintaining proper plant spacing for better air circulation, and avoiding overhead irrigation to minimize leaf wetness. Crop rotation with non-host plants and removing infected plant debris from the field can reduce inoculum levels. Chemical control measures, such as applying fungicides containing copper, or azoxystrobin, can be used preventively or at the first signs of infection. Biological control with antagonistic organisms like Trichoderma species offers a sustainable alternative. Additionally, selecting resistant varieties and implementing good field hygiene practices can help reduce the disease's impact over time.

7.3.9. RHIZOME ROT (RHIZOCTONIA SPP)

Disease Overview and Symptoms

Rhizome rot, caused by Rhizoctonia solani and related species, is a devastating fungal disease affecting ginger. The disease primarily targets the rhizomes, causing them to rot and become soft, watery, and discolored. Early symptoms include yellowing of the lower leaves, wilting, and stunted growth of the plants. As the infection progresses, rhizomes emit a foul smell and develop dark brown or black lesions, rendering them unsuitable for consumption or planting. Severe infestations can lead to total crop loss, significantly impacting ginger production. Rhizoctonia species are soilborne fungi that infect plants through the soil or plant debris, causing elongated lesions on the leaves. The lesions may appear water-soaked at first and later turn brown or black. In severe cases, the spots may merge, leading to extensive damage.

Favorable Conditions

The disease thrives in warm, humid climates, with temperatures ranging from 25–30°C, and is exacerbated by waterlogged or poorly drained soils. High soil moisture and heavy rainfall provide ideal conditions for the fungus to infect and spread. Other contributing factors include planting infected rhizomes, excessive nitrogen fertilization, and mechanical injuries to the rhizomes during planting or harvesting. The pathogen can persist in the soil for long periods, making it challenging to eradicate once established.

Control Methods

Managing rhizome rot requires an integrated approach that combines cultural, chemical, and biological methods. Cultural practices include using disease-free planting material, improving soil drainage, and avoiding waterlogging through raised beds or furrow irrigation. Ensure adequate field drainage to prevent waterlogged conditions, which can favor the development of Rhizoctonia spp. Maintain proper plant spacing to promote air circulation and reduce rhizome-to-rhizome contact, aiding in disease spread. Utilize soil solarization techniques before planting to reduce the population of Rhizoctonia spp. in the soil. Crop rotation with non-host plants and solarization of the soil before planting can reduce pathogen levels. Chemical control involves treating rhizomes with fungicides before planting. Biological control measures, such as incorporating Trichoderma species or Pseudomonas fluorescens into the soil, can suppress the pathogen naturally. Adopting proper field hygiene, including removing infected plant debris and sterilizing tools, further reduces the risk of infection and ensures healthier ginger crops.

7.3.10. MOSAIC VIRUS (CMV)

Disease Overview and Symptoms

Mosaic virus is a viral disease that affects ginger, caused by pathogens such as the Cucumber mosaic virus (CMV). The disease primarily manifests on the leaves, showing symptoms of irregular, light green to yellow mosaic patterns interspersed with dark green areas. Infected plants may exhibit distorted or stunted growth, reduced vigor, and abnormal leaf shapes. Over time, the infection can lead to significant yield losses as it hampers the plant's photosynthetic efficiency and overall health. Rhizomes from affected plants are often undersized and of poor quality, reducing their marketability.

Favorable Conditions

The spread of mosaic virus in ginger is favored by the presence of vector organisms, particularly aphids, which transmit the virus through feeding. Warm temperatures, dense planting, and the presence of weeds that serve as alternative hosts for the virus or its vectors increase the risk of infection. The use of infected planting material is another critical factor contributing to disease spread. Once established, the virus persists in infected plants and surrounding vegetation, making control difficult.

Control Methods

Managing mosaic virus in ginger requires an integrated approach focusing on prevention and vector control. Using virus-free planting material is critical to preventing initial infections. Regular monitoring and control of aphids through the application of insecticides or the introduction of biological control agents, such as predatory insects, can help reduce virus transmission. Eliminating weeds and alternative host plants in and around the ginger fields minimizes sources of infection. Planting resistant or tolerant ginger varieties, if available, is another effective strategy. Since there is no cure for infected plants, removing and destroying symptomatic plants promptly helps prevent the spread of the virus. Maintaining proper field sanitation and crop rotation with non-host plants further supports long-term disease management.

7.3.11. CHLOROTIC FLECK VIRUS (GCFV)

Disease Overview and Symptoms

Chlorotic fleck virus is a viral disease that affects ginger, and caused by the Ginger chlorotic fleck virus (GCFV). The disease is characterized by the appearance of small, chlorotic (yellow) flecks or spots on the leaves. Over time, these flecks may coalesce, leading to extensive yellowing and reduced photosynthetic capacity. Affected plants may show stunted growth, reduced vigor, and poor rhizome development. In severe infections, the disease can result in significant yield losses and diminished quality of rhizomes.

Favorable Conditions

The spread of chlorotic fleck virus is typically facilitated by infected planting material and vector organisms, such as aphids or other sap-feeding insects. Warm, humid conditions that favor the proliferation of these vectors increase the risk of disease outbreaks. Dense planting and the presence of alternate host plants or weeds near ginger fields can also contribute to the spread of the virus. Once introduced, the virus persists in infected plants and can spread rapidly through vegetative propagation if not managed properly.

Control Methods

Effective management of chlorotic fleck virus involves preventive and cultural practices. The use of virus-free, certified planting materials is the first step in controlling the disease. Regular monitoring and management of vector populations, particularly aphids, through insecticides or biological control agents, are crucial to prevent virus transmission. Field sanitation practices, such as removing and destroying infected plants and controlling weeds that serve as alternate hosts, reduce the inoculum source. Crop rotation with non-host plants and the maintenance of proper plant spacing improve airflow and reduce conditions conducive to vector activity. While resistant varieties may not always be available, ongoing research and careful field management can help mitigate the impact of the disease over time.

7.3.12. BACTERIAL WILT (RALSTONIA SOLANACEARUM FORMELY PSEUDOMONAS SOLANACEARUM)

Ginger bacterial wilt, also referred to as brown rot of potato and moko disease, is a severe disease that can cause substantial yield losses in ginger farming. Unfortunately, there are currently no chemical treatments that have proven effective against bacterial wilt in ginger. As a result, the primary focus is on preventive measures and cultural practices to manage the disease.

Figure 51: Symptoms of bacterial wilt on ginger plants and rhizomes (Image credit: Plant Village; Tamil Nadu Agricultural University)

Description/identification

Bacterial wilt, also known as brown rot of potato and moko disease, is a significant threat to ginger cultivation. The disease primarily spreads through contaminated soil, infected planting material, and contaminated farming tools. It is caused by a soil-borne bacterium, Ralstonia solanacearum, which can persist in the soil for several years, posing challenges for control efforts.

An overview of the symptoms associated with bacterial wilt on ginger:

- The disease initially manifests as light yellowing of the lower leaf tips, gradually progressing to the leaf blade and sheath edges. This yellowing extends to all leaves, resulting in drooping and drying out.
- The collar region of ginger roots exhibits a water-soaked translucent brown coloration. Infected plants can be easily uprooted from the seed rhizomes, and the infection gradually spreads from the collar to the rhizome.
- Leaves tend to droop and wilt, particularly in the early morning when sunlight is absent. This symptom is quite common in infected plants.
- The base of the pseudostem (stem-like structure) turns grey and becomes water-soaked and soft. This can be observed near the soil line.
- When the ginger rhizome is cut, a milky substance may be exuded from the cut end.
- Bacterial wilt can spread rapidly, leading to significant losses. Due to the persistent nature of the bacterium in the soil, prevention and cultural practices play a crucial role in managing the disease. It is essential to be aware of these symptoms, as they may vary based on ginger variety, environmental conditions, and the stage of infection. Accurate identification of bacterial wilt can be confirmed through laboratory testing, considering the presence of multiple symptoms.

Quarantine organism

Ralstonia solanacearum has been listed as a quarantine pest in Africa (Guinea), America

(Argentina, Brazil), Europe (Georgia, Switzerland, Ukraine and UK), and is a quarantine pest in Africa (Morocco and Tunisia), and Asia (China). More information is accessible here.

Favourable conditions

Bacterial wilt thrives in warm temperatures, typically ranging from 25°C to 30°. Higher temperatures within this range promote the growth and multiplication of the bacterium, accelerating the development of the disease.

The survival and spread of Ralstonia solanacearum are facilitated by moist soil conditions. Excessive rainfall, over-irrigation, or poorly drained soils create a favourable environment for the pathogen. Waterlogged or saturated soil allows the bacterium to move easily and infect the roots of susceptible plants.

Soil with a high organic matter content provides a conducive environment for the survival and multiplication of the disease. Organic matter serves as a nutrient source and creates a favourable microenvironment for the bacterium to thrive.

Bacterial wilt can occur in soils with a wide pH range, but it is more prevalent in slightly acidic to neutral soils (pH 5.5 to 7.0).

Ralstonia solanacearum has a broad host range, affecting various plant species, including ginger. The presence of susceptible host plants in the vicinity contributes to the survival and spread of the bacterium.

The pathogen enters plants through wounds, such as cuts, bruises, or natural openings. Injuries caused by cultivation practices, insect feeding, or other factors create entry points for Ralstonia solanacearum, facilitating its colonization and infection.

Disease life cycle

Ralstonia solanacearum can persist in soil, plant debris, and biofilms, even without a host. It enters plants through wounds, natural openings, or roots via contaminated soil or plant material. It multiplies in the plant's vascular tissues, obstructing water transport. Symptoms include wilting, yellowing leaves, and plant death, depending on factors such as, host susceptibility and environmental conditions. It can spread within fields through soil, water runoff, and contact between infected and healthy plants. Long-distance dissemination occurs via contaminated material or equipment. It remains viable in soil debris or as dormant cells, waiting for suitable conditions to initiate new infections.

Surveillance / monitoring

Regular monitoring of field is important to avoid spread of diseases. Removal of infected plants at the initial appearance of symptoms and subsequent can effectively control field contamination.

To effectively monitor bacterial wilt caused by Ralstonia solanacearum throughout the growing season, follow these recommended practices. Before planting, assess the field's history and potential risk, checking for host weeds and evaluating soil health. During the early growth stage, regularly inspect plants for wilting or stunted growth. Continuously monitor for symptoms of bacterial wilt as the crop progresses, conducting thorough visual inspections. Even during the harvest period, remain vigilant and check harvested plants for signs of internal discoloration or decay. After harvest, evaluate disease incidence, conduct soil testing, and plan future measures based on the results.

Cultural control

To manage bacterial wilt in ginger cultivation, follow these key recommendations:

— Rotate crops with non-host plants.

— Plant resistant or tolerant ginger varieties.

— Practice sanitation and hygiene.

— Manage irrigation properly.

— Control weeds effectively.

— Use disease-free seed and planting material.

— Maintain balanced soil fertility and organic matter.

— Minimize plant injuries.

Biocontrol

To prevent disease occurrence in ginger cultivation, consider the following practices:

— Apply plant growth-promoting rhizobacteria (PGPR) and biocontrol agents – for example, *Pseudomonas* spp., *Bacillus* spp., and *Trichoderma* spp. at recommended rates as seed treatments or soil drenches.

— Use enzymes, antimicrobial peptides, or natural compounds to disrupt biofilms. Apply at appropriate rates.

— Apply biocontrol agents producing antimicrobial compounds as seed treatments, soil drenches, or foliar sprays. Follow recommended application rates specific to the product and crop.

— Specific bacteriophages targeting *Ralstonia solanacearum* can be applied to reduce bacterial populations. Dilute beneficial bacteriophages in water and apply as a foliar spray or through irrigation systems.

Control with plant protection products

Some plant protection products are outlined:

Chemical plant protection products

Copper-Based bactericides like Copper Hydroxide or Copper Oxychloride can be considered.

When using chemical plant protection products always follow label instructions for application rates and dilution ratios specific to the product and active ingredient and ensure local approval for use. The COLEAD crop protection database (e-GAP) is accessible **here**. The database provides up to date information on Good Agricultural Practices (GAP), including COLEAD field trials of plant protection products (PPP), data from PPP manufacturers and scientific literature. Additional up-to-date information about Maximum Residue Levels (MRLs) in diverse target markets can be accessed via the pesticide registration toolkit of FAO.

Other control methods may include:

Soil Solarization with Plastic Mulching and Biofumigation:

Timing: During hot seasons or summer months.

Application: Cover soil with plastic for 4-6 weeks to heat the soil and control pathogens. Optionally, incorporate biofumigant plant materials.

Biochar Amendment:

Timing: During soil preparation or planting.

Application: Incorporate biochar into soil at recommended rates.

Soil Bioaugmentation with Beneficial Microbes

Timing: Before or during planting.

Application: Introduce beneficial microorganisms through seed treatments, soil drenches, or inoculants.

Soil Amendments with Antagonistic Plants or Extracts

Timing: During soil preparation or planting.

Application: Incorporate antagonistic plant materials or extracts at recommended rates.

7.3.13. STORAGE ROTS DURING POST-HARVEST STAGE (PYTHIUM SPP., FUSARIUM SPP. AND VERTICILLIUM SPP.)

Storage rots caused by Pythium spp., Fusarium spp., and Verticillium spp. are common fungal diseases that affect plants and crops during storage after harvest. Implementing good agricultural practices in the field and during post-harvest handling is vital to prevent these storage rots.

Figure 52: Pythium infected plants and ginger rhizome and rot (Image credit: Bighaat.com; COLEAD)

Description/identification

Seed rhizomes stored for seed and commercial purposes face serious postharvest losses in ginger (Sharma et al., 2017). The disease is primarily identified by above-ground symptoms which include wilting and yellowing. During storage, symptoms start as watery, brown lesions on above-ground parts at the rhizome-stem intersection or "collar." These losses are influenced by various biotic and abiotic factors. Pythium ultimum, Fusarium oxysporum, and Verticillium chlamydosporium are the main culprits behind most storage rots. Fungi and bacteria attack seed rhizomes during storage, causing softening. Here is more information about each fungus:

Pythium spp.

- Water moulds thriving in wet conditions.
- Infect vegetables, fruits, and ornamentals.
- Cause root and crown rot, as well as post-harvest decay.
- Symptoms include soft, water-soaked lesions leading to plant death or decay in storage.

Fusarium spp.

- Soilborne fungi surviving in plant debris or soil.
- Infect cereals, vegetables, fruits, and ornamentals.
- Cause diseases, Fusarium wilt, root rot, and storage rot.
- Symptoms include dry, sunken lesions with pink or orange discoloration.
- Some produce harmful mycotoxins.

Verticillium spp.

- Soilborne fungi persisting in the soil.
- Infect vegetables, fruits, and field crops such as potatoes and tomatoes.
- Cause vascular wilt disease, affecting water and nutrient transport.
- During storage, result in dry, brownish discoloration of internal tissues.

Quarantine organism

Only Fusarium species are regulated non-quarantine pests in the UK and Switzerland

Favourable conditions

Pythium survive in plant debris. Severity of disease is influenced by high rainfall and when rhizomes are planted in heavy clay soil with poor drainage. The optimum temperature favouring the germination of P. aphanidermatum and P. myriotylum spores is 34°C is optimum.

Disease life cycle

The fungi are carried in seed-pieces or soils which are the source of primary infection. The secondary spread of the disease can also take place through irrigation water and by mechanical means.

Surveillance / monitoring

Soft rot poses a complex disease challenge, requiring the implementation of multiple methods for effective management and control. Fungal inoculum is carried over from season to season through infected rhizomes and soil. The disease can persist in the soil for extended periods, remaining viable for many years. Phytosanitation becomes necessary when soft rot symptoms appear in ginger fields.

Cultural control

To control storage rots cultural control needs to be implemented in the field prior to harvest and measure must be taken for safe storage:

- Practice crop rotation and diversify crops to reduce pathogen buildup.
- Manage soil health and fertility through proper nutrient management and organic matter incorporation.
- Implement appropriate irrigation practices to avoid excess moisture.
- Harvest ginger at the right maturity stage and handle it carefully to prevent damage.
- Maintain proper sanitation by promptly removing and disposing of infected plant material.

- Store ginger in cool, dry, and well-ventilated conditions with good air circulation.
- Sort and grade ginger, separating healthy rhizomes from diseased ones.
- Regularly inspect stored ginger and remove any infected rhizomes promptly.

Biocontrol

Trichoderma spp. is the best biocontrol agent for soft rot.

Control with plant protection products

Plant protection products can be used as part of an integrated approach to control storage rots in ginger in the field and post-harvest. Here are some commonly used products:

Fungicides - Apply fungicides specifically labelled for use on ginger to control fungal pathogens causing storage rots. Follow the product label instructions for proper application rates and timing. Some commonly used fungicides for ginger include those containing active ingredients - azoxystrobin, metalaxyl, and fluazinam.

Bactericides - If bacterial pathogens are involved in storage rots, bactericides labelled for ginger can be used (e.g. Copper-based formulations like Copper Hydroxide or Copper Oxychloride can be considered). Follow the instructions on the product label for proper application rates and timings.

Biofungicides/Biological Control Agents - Consider using biofungicides or biological control agents that are commercially available for controlling storage rots in ginger (see also other sections above). These products contain beneficial microorganisms or natural compounds that can suppress fungal pathogens. Follow the label instructions for accurate rates and application methods.

When using chemical plant protection products always follow label instructions for application rates and dilution ratios specific to the product and active ingredient and ensure local approval for use. The COLEAD crop protection database is accessible **here**. The database provides up to date information on Good Agricultural Practices (GAP), including COLEAD field trials of plant protection products (PPP), data from PPP manufacturers and scientific literature. Additional up-to-date information about Maximum Residue Levels (MRLs) in diverse target markets can be accessed via the pesticide registration toolkit of FAO.

Other control methods

Additional guidelines for key ginger producing countries employing biocontrol for managing pests and diseases are summarised below (Table 2).

Table 7. Example of practices considered to contribute to sustaining ginger production, including suitable cover crops, beneficial organisms, and crop rotation observed in key ginger producing regions (Divyashree et al., 2023; Rajkumar et al., 2023; TNAU Agritech portal; Yanagawa et al., 2022)

COUNTRY	SUITABLE COVER CROPS	BENEFICIAL ORGANISMS TO CONTROL KEY PESTS AND DISEASES	OPTIONAL CROPS TO ROTATE WITH	AVOID ROTATING WITH THESE CROPS
INDIA	Legumes such as cowpea (Vigna unguiculata), lablab bean (Lablab purpureus), or green gram (Vigna radiata) Sesbania rostrata, horse gram (Macrotyloma uniflorum), and cluster bean (Cyamopsis tetragonoloba).	Trichoderma spp. for managing fungal diseases, Bacillus thuringiensis (Bt) for caterpillar control.	Legumes (pigeon pea, black gram, soybeans), rice, maize, pearl millet, mustard greens, fenugreek, coriander.	Turmeric or cardamom.
NIGERIA	Pigeon pea (Cajanus cajan) or mucuna (Mucuna pruriens), cowpea (Vigna unguiculata), lablab (Lablab purpureus), sunn hemp (Crotalaria juncea), velvet bean (Mucuna pruriens).	Beauveria bassiana for managing insect pests, Trichoderma spp. for fungal disease control. African marigold (Tagetes erecta) as a trap crop for nematodes, neem (Azadirachta indica) extracts for insect pest management.	Maize, cowpea, sorghum, cassava, yam, okra.	Turmeric or cardamom.

COUNTRY	SUITABLE COVER CROPS	BENEFICIAL ORGANISMS TO CONTROL KEY PESTS AND DISEASES	OPTIONAL CROPS TO ROTATE WITH	AVOID ROTATING WITH THESE CROPS
CHINA	Chinese milk vetch (Astragalus sinicus), hairy vetch (Vicia villosa), or clovers (Trifolium spp.).	The predatory mite, Neoseiulus cucumeris, Steinernema spp. for controlling soil-dwelling pests, Bacillus thuringiensis (Bt) for caterpillar control. Chinese chives (Allium tuberosum) as a companion plant to repel aphids and spider mites, garlic extracts for insect pest management.	Maize, soybeans, sesame, sweet potatoes, wheat, barley, oats, rapeseed.	Turmeric or galangal (Alpinia officinarum).
NEPAL	Sesbania species (Sesbania rostrata or Sesbania aculeata) or alfalfa (Medicago sativa).	Trichoderma spp. for fungal disease control, Steinernema spp. for managing soil-borne pests. French marigold (Tagetes patula) as a trap crop for nematodes, ash-based formulations for insect pest management: Aphidius colemani, a parasitic wasp, can be introduced to manage aphid populations in ginger fields.	Maize, cowpea, millet, buckwheat, wheat, barley, lentils, radish.	Turmeric or cardamom.
INDONESIA	Mucuna, soybeans (Glycine max), or sword bean (Canavalia gladiata).	Metarhizium anisopliae, a naturally occurring fungus, can be used as a biological control agent against insect pests such as beetles and weevils. Beauveria bassiana for insect pest control, Trichoderma spp. for managing fungal diseases. Tithonia (Tithonia diversifolia) as a trap crop for aphids, chili and garlic extracts for insect pest management.	Maize, soybeans, rice, peanuts, cabbage, cucumbers, watermelon.	Galangal or turmeric.

COUNTRY	SUITABLE COVER CROPS	BENEFICIAL ORGANISMS TO CONTROL KEY PESTS AND DISEASES	OPTIONAL CROPS TO ROTATE WITH	AVOID ROTATING WITH THESE CROPS
THAILAND	Sunn hemp (Crotalaria juncea), velvet bean (Mucuna pruriens), or cowpea.	Phytoseiulus persimilis, a predatory mite, can be employed for biological control of spider mites that infest ginger plants. Bacillus thuringiensis (Bt) for caterpillar control, Steinernema spp. for managing soil-borne pests. Thai basil (Ocimum basilicum var. thyrsiflora) as a companion plant to repel pests, botanical extracts for insect pest management.	Maize, peanuts, winged bean, sugarcane, taro, rice.	Turmeric or galangal.
PERU	Peruvian sunflower (Tithonia diversifolia), lupine (Lupinus spp.), or common vetch (Vicia sativa).	Chrysoperla spp. (green lacewings) are beneficial insects that feed on aphids and other soft-bodied pests, offering natural pest control in ginger fields. Marigold (Tagetes spp.) as a companion plant to repel pests, botanical extracts for insect pest management.	Maize, beans, quinoa, amaranth, potatoes, fava beans, barley.	Turmeric, cardamom.
BRAZIL	Sunn hemp, Lablab purpureus, velvet bean (Mucuna pruriens), Canavalia ensiformis	Cryptolaemus montrouzieri, Beauveria bassiana for insect pest control, Steinernema spp. for managing soil-borne pests.	Maize, beans, peanuts, cassava, sorghum, sunflowers, jute.	Turmeric or cardamom.

COUNTRY	SUITABLE COVER CROPS	BENEFICIAL ORGANISMS TO CONTROL KEY PESTS AND DISEASES	OPTIONAL CROPS TO ROTATE WITH	AVOID ROTATING WITH THESE CROPS
VIETNAM	Cowpea, hairy vetch, or soybeans.	Entomopathogenic nematodes (e.g., Steinernema carpocapsae) can be employed as biological control agents against soil-dwelling insect pests such as grubs and weevils. Trichoderma Tspp. for fungal disease control, Bacillus thuringiensis (Bt) for caterpillar control. Vetiver grass (Vetiveria zizanioides) as a companion plant to repel pests, neem-based formulations for insect pest management.	Maize, peanuts, soybeans, mung beans, sweet potatoes, corn.	Turmeric or cardamom.

8

HARVESTING GINGER

Commercial quality

Harvesting is performed by simply lifting the rhizomes from the soil, cleansing them, followed by drying. Harvesting ginger during periods of rain or when there is dew should be avoided (Farm Africa, 2021). The European market offers good opportunities for exporters who can comply with EU/UK regulations. Special attention on harmful organisms, pesticide residues, toxic heavy metals, food additives and food fraud is needed. In general, dried ginger powder should have a characteristic taste and flavour free from musty odour or rancid or bitter taste, and should be free from mould, living and dead insects, insect fragments, and rodent contamination.

Mandatory requirements

All foods, including dried ginger, sold in the EU should be safe, as specified in the General Food Law. This applies to imported products as well. Additives should be approved, and harmful contaminants, such as pesticide residues, and excessive levels of mycotoxins or preservatives are banned. Operated by the European Commission, the rapid alert system for food and feed (RASFF, accessible here) serves to exchange information on identified hazards between Member States, whilst the TRACES database (accessible here) aims to enhance traceability, information exchange and risk management across food systems on plant health. More information can be accessed via COLEAD dashboards.

8.1. WHEN TO HARVEST

8.1.1. TIMING (MATURITY INDICATORS)

The purpose for which the ginger is produced determines the stage of harvest. The ginger plant grows between 60 - 120cm. Mature ginger seed rhizomes are harvested when plant tops begin to turn yellow, wilt and die (Fig. 54), and the desired root size has been reached. The seed rhizomes should be plump, with a dry, bright yellow-brown skin colour, and a gloss. Ginger is also harvested according to commercial standards and/or customer specifications, observing chemical (or other) application harvest intervals for plant protection products (PPP). Ginger can be harvested at two different stages of maturity (young and mature). For dry ginger markets, harvest fully mature ginger at 8 - 9 months after planting, whereas targeting fresh markets, young or baby ginger can be harvested at around 6 months. Baby ginger (Fig. 54) is harvested between 5 - 7 months after planting and has a low fibre content. This ginger is not recommended to be used as planting material, since it dehydrates rapidly and does not produce good quality shoots.

Figure 53: Harvest maturity indicator: yellow foliage (Image credit: leafyplace.com)

8.2. HARVESTING TOOLS AND ANCILLARY EQUIPMENT

Ginger is mostly harvested manually with a garden fork or similar implement. When manually harvested, a sharp knife is used to trim roots from the rhizome, so potential damage is reduced. Ginger can also be harvested mechanically, but the process is more complex and less common than manual harvesting due to the delicate nature of the ginger rhizomes and the requirements for careful handling to prevent damage. Mechanical harvesting is generally more feasible on larger commercial farms where labor costs and efficiency are significant concerns.

8.3. FIELD HANDLING

8.3.1. CONTAINER TYPES

Immediately after uprooting, place ginger rhizomes in clean baskets/dry jute sacks/trailers/ well-aerated containers to transport to the processing facility. When using plastic containers (Fig. 55), it is worth paying attention to moisture build up that could lead to mould growth.

Figure 54: Harvested ginger placed in lined field trays (Image credit: Discover Agriculture)

8.4. GOOD PRACTICES

8.4.1. PREPARATION (TOOLS, METHODS, HYGIENE, MANPOWER)

To precipitate an early harvest of mature ginger, it is suggested to trim the tops of the plants off two (2)or three (3) weeks prior to harvest (Fig. 56). Motorized mechanical trimmers are available in many different capacities and models, appropriate for the scale of ginger production.

Figure 55: Mechanical trimming of ginger placed in lined field trays (Image credit: Discover Agriculture)

Figure 56: Manual harvesting tools for ginger (Image credit: Rabees et al., 2020)

Figure 57: Manual harvesting of untopped ginger (Image credit: Discover Agriculture)

Figure 58: Manual harvesting of Trimmed, freshly harvested ginger, China

Figure 59: Manual harvesting of ginger (Image credit: agrifarming, India, 2015)

Figure 60: Manually harvesting of baby ginger (Image credit: mofga.org)

Figure 61: Mechanical harvesting and transporting of field grown ginger (Image credit: Discover Agriculture))

The following images highlight harvesting operations at different scales and context (Figs. 56 - 61).

Ensure harvesters and machineries are clean and properly adjusted to reduce contamination from soil and other materials. For baby ginger, loosen the soil approximately 30 cm (12 inches) from the base of the plant with a shovel or with a garden fork. Then grasp the stems near the ground and pull the entire plants gently by their stalks, avoiding foreign matter is mixed with the harvested rhizome.

Once uprooted, trim the foliage about a centimeter (half inch) above the spot where it meets the rhizome (Fig. 62).

Leaving a longer stem helps in drying of seed rhizomes faster. Discard rotten and damaged seed rhizomes at harvest, packing, transportation, storage and processing to avoid contamination and quality losses. If harvest occurs in wet conditions, seed rhizomes should be transported as soon as possible to a clean drying shed. To ensure traceability, affix labels/identification to the packaging, detailing ginger variety, place of production, harvest date, and grower information.

Figure 62: Freshly harvested ginger (Image credit: top left, commons.wikimedia.org); and topped baby ginger at harvest, top right, horticulture magazine; bottom left: and right: COLEAD)

8.5. YIELDS

8.5.1. OPTIMUM YIELDS FOR KEY GINGER VARIETIES

Ginger yields vary across and within countries, depending on varietal tolerance to pests and diseases, genotypic yield potential, cropping techniques, agronomic practices, prevailing growing conditions and maturity. Average yields in central Jamaica are 13-18 MT/ Ha of green ginger, being lower in sandy soils. In India, yield of the main types planted is similar to Jamaica. In Hawaii, 44 MT/ Ha are reported, using their larger green ginger types. In Nigeria, yields range between 13 – 27 MT/Ha and 13-18 MT/ Ha in China. It is good practice to monitor both quantity and quality of yields to assess trends over time.

CHECKLIST TO REMEMBER WHEN PREPARING FOR HARVESTING

- Ensure ginger has reached right stage of maturity for the market, and respect harvest intervals when using chemical inputs
- Prepare your harvest materials and tools (fork, non-abrasive trays or baskets)
- Trim the plants before harvesting
- Locate the base of the ginger hand when uprooting carefully
- Ensure clean and sharp tools are used, including clean harvest and transport containers
- Provide crates or bags to facilitate transportation for harvested crop
- Document, monitor and benchmark yields

9

POSTHARVEST MANAGEMENT OF GINGER

9.1. INTRODUCTION

Adopt Good Practices for all postharvest operations. Procedures are required to ensure produce is able to consistently meet standards and customer expectations. Good practices reduce the risk of contamination of fresh and processed ginger during handling, packing, storage and transportation. Adoption of Good Manufacturing or Processing practices (GMP) during operations increases market competitiveness and access to high-end (export) markets and global food chains. Processing operations meanwhile include all aspects of handling to achieve high-quality and safe produce. During operations, there should be sufficient monitoring and control activities to inspect the infrastructure and personnel , evaluate samples during handling, allowing for corrective actions where needed.

9.1.1. GOOD HYGIENE AND HANDLING PRACTICES

Ensure that the containers are appropriately washed, sterilized and dried between different harvests / loads. Remove soil from the rhizomes by washing with clean water, air dry in a well-ventilated shaded area and then allow for the curing process to take place.

9.1.2. SUNLIGHT PROTECTION

Harvested mature ginger must be placed in cool area away from direct sunlight. Exposure to sunlight scorches the ginger and increases the heat within the batch. Further, young ginger dehydrates very easily and so should also be protected from direct sun.

9.1.3. WASHING

Uncleaned ginger is typically sold on the local markets. Batches for export will require further cleaning to remove debris before packing the ginger, so extending shelf-life. Rhizomes should be washed using potable or treated water immediately after harvesting and prior to storage. Following washing, the ginger should be air dried before packing.

9.1.4. PRE-COOLING

Pre-cooling conditions for ginger ranges from 12 to 14 °C. Cooling is carried out to decrease residual heat from the field.

9.2. CURING

9.2.1. TIME/TEMPERATURE/RELATIVE HUMIDITY CONSIDERATIONS

After washing, the ginger should be placed on racks in a well-ventilated room for 3 to 5 days to allow all exposed, cut or damaged tissues to heal and become firm before storage and/or marketing. This process is referred to as “curing”. Curing also helps to reduce postharvest weight loss and decay. When ginger is intended for storage, it should be cured by air-drying at 22 - 26°C and 70 - 75% RH for up to 14 days, to allow the skin to thicken and the cut surfaces to heal. There are several techniques for drying. Sun drying is a natural method whereby solar radiation supplies the heat required to dry the product and is the most common practiced technique. In solar drying, the product is directly exposed to solar radiation through a transparent cover, generally a polymer. Solar drying is preferred to sun drying, as it helps to maintain a more consistent rhizome quality and can reduce the incidence of microbial contamination. Proper curing of the seed rhizomes after harvesting is also a good pre-storage requirement to manage nematodes, rhizome bruises and external pathogens (Farm Africa, 2021).

9.3. TRANSPORT

Good transport practices involve ensuring the carrier or vehicle transporting the ginger is clean, dry, well ventilated (if not refrigerated) and of good hygiene standards (free from previously harvested plant products and other foreign materials). Ginger should not be transported with other commodities that may contaminate or taint the product, or that are incompatible with the desired ginger crop temperature/humidity regime.

Desirable conditions in transport containers are 12°C and between 65 to 75 %RH. When exporting by sea, it is recommended to add 5% more weight to compensate for the weight loss of ginger during this period. Immature roots have increased respiration, thus face more rapid weight loss.

9.4. ON-FARM / OFF-FARM STORAGE

9.4.1. GOOD STORAGE PRACTICES

Effective storage practices for ginger involve several factors, including grading, appropriate storage conditions, temperature, relative humidity, and ventilation. When good postharvest handling and storage procedures are followed, good quality ginger can be stored successfully for several months.

It's important to note that storing ginger at the optimal temperature is crucial to avoid chilling injury, which can result in the loss of bright skin colour and skin pitting. In severe cases of chilling damage, internal breakdown may occur. On the other hand, holding ginger at ambient temperatures leads to rapid moisture loss, surface shrivelling, and sprouting.

In line with maintaining good hygiene practices (GHP) and good transport practices (GTP), harvested seed rhizomes should be stored in clean and dry conditions, free from pests, and protected from livestock and domestic animals. In case of infection observed during monitoring, destroy any soft rot/ bacterial rot infected seed rhizomes. This set of practices is referred to as Good Storage Practices (GSP). Dehydration can occur when ginger is stored at humidity levels below 65%, while humidity levels above 90% can encourage mould infections. There are different scales and requirements for ginger storage during the preharvest-postharvest continuum...

9.4.2. ON-FARM PIT STORAGE

Good quality harvested seed rhizomes can be stored within on-farm pits dug under shade. The floor of the pit should be lined with sand or saw dust (Fig. 63). Further, it is advisable to line the pit with layers of leaves, such as Glycosmis pentaphylla (Panai), and cover the pits with for example coconut fronds for long-term storage. Monitoring for pests and disease should take place every two weeks (or more often depending on observations), and any diseased seed should be removed and destroyed.

Figure 63: On-farm pit storage of ginger seed (Image credit, Kathmandu Post, 2022)

Examples of small scale and medium scale commercial storage in net sacks, and cardboard boxes, in ambient temperature (Fig. 64) and cold storage (Fig. 65), respectively, are illustrated below.

Figure 64: Bulk storage of mature ginger (Source: 21Food)

Figure 65: Storage of ginger in cold control rooms (Image credit: TAN Logistics)

9.4.3. COMPENSATE WEIGHT LOSS IN STORE

Dehydration can occur when ginger is stored at humidity levels below 65%. In preparation for sea freight, where the product may take several weeks on a reefer, it is recommended to add 5% extra weight to unit loads to compensate for the potential weight loss of ginger occurring during storage through respiration. Good quality fresh ginger can store for 4 - 6 months.

9.4.4. LABELLING

Identification of ginger batches when passing through seed, planting, harvesting, storage, and transportation phase up to marketing by labelling packages is essential for traceability from farm to consumption. Labelling technologies may be simple (e.g. sticky label, marked with pen), or more sophisticated, (e.g. packaging incorporating pre-printed and/or QR coded boxes). The latter is more common for larger ginger marketing operations, where demand is reasonably predictable. Brand labelling packages can aid in advertising and promotion for the producer or packer.

9.5. PROCESSING

9.5.1. PACKHOUSE REQUIREMENTS

Packhouse operations encompass various activities, including cleaning, sorting/ grading, pre-treatments, packing, cooling, storing, and dispatching to the market. When considering packhouse area requirements, a general guideline is to allocate a minimum of 20 m^2 of floor area per ton of produce. Additional space is necessary for equipment, containers, storage, washing stations, passageways, waste disposal, lavatories, and vehicle parking.

The packhouse plays a vital role in conducting quality assurance activities to ensure that ginger meets market requirements in terms of both quality and quantity. It also helps minimize losses during transportation and distribution to markets. It's worth noting that ginger producers in developing countries often face significant postharvest losses, ranging from 20 - 40% of production. By implementing a well-managed farm-packhouse-market organization, business opportunities can be maximized, while postharvest quality and physical losses can be minimized.

Packhouse reception

Upon receiving the produce, it is important to record the farm source and produce weight for purposes such as yield monitoring, traceability, and accounting. Recordkeeping plays a crucial role in introducing smallholder farmer groups or associations to Good Business Practices, especially when they expand into quality or niche markets.

Sorting and grading

Sorting and grading are essential packhouse operations for ginger. The desired quality characteristics include skin colour, plumpness of tuber pieces, sheen on the skin, and the absence of sprouts, blemishes, soil, and insect injury. Young or "baby" ginger, which is bright yellow to brown, should have a high sheen with greenish-yellow vegetative buds but no sprouts. Ideally, baby ginger should have very little or no fibre. When packaging ginger for export, it should be arranged uniformly, and the internal flesh should not show any dark spots or sprouting. Fibreboard cartons with good ventilation are commonly used for exporting ginger.

Postharvest treatments

Postharvest treatments for ginger are limited. Cleaning reduces microbial contamination and physical damage, while selecting healthy seed rhizomes prevents fungal and bacterial infections during storage. Postharvest technologies, for example, grading tables, flotation tanks, and screens optimize final marketable yields. Air screen separators remove insects and extraneous matter.

The permissibility of post-harvest fungicide applications for ginger varies depending on local regulations, export requirements, and consumer preferences. In many cases, such applications may be discouraged or strictly regulated due to concerns about food safety, chemical residues, and compliance with maximum residue limits (MRLs) set by importing countries or global standards.

If post-harvest pesticides are allowed, they must be used in compliance with regulations, ensuring that:

- The pesticide is approved for use on ginger.
- Application rates and timing adhere to recommended guidelines.
- Residues fall within the acceptable MRLs.

When post-harvest pesticides are not permitted, alternative practices such as:

- Hot water treatment to reduce fungal load.
- Proper drying and storage to lower humidity levels.
- Use of biocontrol agents or natural antifungal treatments. can effectively minimize post-harvest losses due to fungal diseases.

Proper curing and storage at 12 - 14°C control quality. Steam sterilization is the best method to address microbiological contamination, although it may affect ginger's taste. European buyers often require this procedure. For ginger growers or exporters, it is essential to check with relevant agricultural or food safety authorities to ensure compliance with applicable laws and market requirements.

Packaging

Packaging plays a crucial role in ginger storage by containing seed and mature rhizomes and preventing contamination, at the same time, allowing the rhizomes to breath. Packaging is a key packhouse operation following curing and grading and suboptimal packaging can result in significant postharvest losses. The choice of packaging materials (e.g. Figs. 67 – 68) used depends on handling, storage duration and facilities, transport modalities, and customer requirements. Irrespective of the chosen packaging material, it is important to use clean containers with adequate ventilation to minimize condensation, and maintaining suitable moisture. Such conditions are the fundamental principles of good packaging and storage. These measures help preserve the quality and freshness of the ginger.

Figure 66: Ginger bulk storage (Image credit: Shree Agro Fresh Ulo Cold Storage)

Effective packaging techniques involve filling the containers to their optimal capacity. Under-packing can lead to increased damage caused by vibrations and movements, while overpacking can exert excessive compression forces that damage the seed rhizomes. Once packed, the ginger should be securely stacked in a well-ventilated area.

Figure 67: Ventilated cardboard packaging for ginger (Image credit: AgriFoods, Brazil)

If ginger needs to be stored for extended periods, it is advisable to develop an inspection plan. Chemical sprout inhibitors are generally ineffective, and sprouted seed rhizomes are more susceptible to mould. Additionally, wounded rhizomes are prone to premature sprouting. While irradiation at 25 to 50Gy can inhibit sprouting during long-term storage, it is worth noting that many European export markets do not favour this method. Baby ginger is perishable and will store for only about two weeks in cold storage.

In the case of dried ginger, it is crucial to ensure that moisture levels are maintained at 10% or below. Proper storage involves placing the dried ginger in a cool, dark space and using airtight containers to preserve its quality.

9.5.2. CARBON DIOXIDE BUILD UP IN STORE

Fresh ginger has a tendency of self-heating and therefore increase in carbon dioxide concentrations (CO^2) in the store due to respiration. This necessitates that ventilation measures are taken. CO^2 concentration during transport or storage should not exceed 0.4% by volume.

9.5.3. GINGER SAFETY STANDARDS (PESTICIDES RESIDUES, MYCOTOXINS, HEAVY METALS, MICROBIOLOGICAL ORGANISMS AND FOOD ADDITIVES)

EU food legislation strongly emphasizes on food safety. Ginger and turmeric must comply with the General Food Law (Regulation (EC) 178/2002). The FAO standard for ginger (CODEX STAN 218-1999) defines technical parameters for quality, packaging, hygiene, and phytosanitary aspects. EU Organic ginger has additional requirements for the European organic market (Regulation (EU) 2018/848).

Food additives must meet specific legislation, listing permitted substances. European traders and consumers prefer additive-free spices. Food fraud, including ginger adulteration, is a serious concern. European buyers conduct rigorous testing using various methods to detect fraud.

EU regulations govern materials and articles in contact with food to protect food composition and human health (Regulation (EC) 1935/2004). Compliance with microbiological criteria is essential.

9.5.4. PHYTOSANITARY REGULATIONS

The "European Directive 2019/523" on protective measures against the introduction of organisms harmful to plants or plant products and against their spread within the community requires all imported produce to go through plant health checks before entering the European Union. The plant health inspection must take place in the country of origin and the shipment must be accompanied by a phytosanitary certificate.

Besides internationally recognised standards, private voluntary standards such as social and environmental standards, and certifications such as GLOBALG.A.P., GRASP, SMETA and BSCI have often become an additional precondition for the import of fresh ginger into the EU, for example.

CHECKLIST FOR POSTHARVEST MANAGEMENT OF GINGER

- Damaged seed rhizomes are more susceptible to sprouting and molds during storage
- Pack and store pest and disease-free ginger for optimum quantity and quality
- Store under optimum conditions for maximum shelf-life
- Adopt Good Storage Practices
- Be aware of target market and customer SPS standards
- Document all operations and periodically review for trends, and thus improved management

COLEAD CROP PROTECTION DATABASE

When using Chemical Insecticides – always follow label instructions for application rates and dilution ratios specific to the product and active ingredient and ensure local approval for use. The COLEAD crop protection database is accessible **here** (https://resources.colead.link/en/vue-substance-active-culture). The database provides up to date information on Good Agricultural Practices (GAP), including data from COLEAD field trials of plant protection products (PPP), from PPP manufacturers and from scientific literature. This database includes MRLs set by the EU and Codex Alimentarius for key horticultural crops in ACP countries. It also brings together the Good Agricultural Practices (dose, interval between treatments, pre-harvest intervals, etc.) that ensure compliance with these MRLs. Additional information such as the type of pesticide, the authorization status of the active substance in the EU and ACP countries, the World Health Organisation (WHO) recommended classification and the resistance group (FRAC code for fungicides; IRAC classification for insecticides) is also available. Additional up-to-date information about Maximum Residue Levels (MRLs) in diverse target markets can be accessed via the pesticide registration toolkit of FAO. (https://www.fao.org/pesticide-registration-toolkit/information-sources/maximum-residue-limits/en/)

REFERENCES/ BIBLIOGRAPHY

1. Australian Awards Short Courses: Agribusiness (2018). Nigerian Ginger Value Chain. University of Queensland (UQ) CRICOS Provider No 00091C. Australie.
2. Australian Awards Short Courses: Agribusiness (2018). Nigerian Ginger Value Chain. University of Queensland (UQ) CRICOS Provider No 00091C. Australia.
3. Bacterial wilt: ginger. The crop diseases of sikkim himalayas. https://bioinformaticssikkim.gov.in/Crop%20Diseases/GINGER%202.html
4. CABI Compendium. (2016, June). Zingiber officinale (ginger). https://doi.org/10.1079/cabicompendium.57537
5. CBI Ministry of Foreign Affairs. (2022, 6 December). Entering the European market for dried ginger. Consulted on 25.01.22 on http.//www.cbi.eu/market-information/spices-herbs/dried-ginger/market-entry
6. Chandrashekhar, G. (2021). Just Agriculture Agricultural Newsletter Vol.1 Issue 10. Article ID: 33. e-ISSN: 2582-8223. Accessed
7. Cioni, Franco & Maines, Gianfranco. (2010). Weed Control in Sugarbeet. Sugar Tech. 12. 243-255. 10.1007/s12355-010-0036-2.
8. Collinge, B.D.; Jensen, F.D.; Rabiey, M.; Sarrocco, S.; Shaw, W.M.; Shaw, H.R. Biological control of plant diseases—What has been achieved and what is the direction? Plant Pathol. 2022, 71, 1024–1047.
9. Dafni, A. & Böck. B. (2019). Medicinal plants of the Bible—revisited. Journal of Ethnobiology and Ethnomedicine, 15(57). 1-14. https://doi.org/10.1186/s13002-019-0338-8
10. Dewanarayana, T. B. & Wimalaratana, W. (2019). Challenges and prospects of ginger farming in Sri Lanka with special Referenec to Plogahawela Divisional Secretariat division. International Journal of Business, Economics and Law, 17(3). https://www.semanticscholar.org/paper/challenges-and-prospects-of-ginger-farming-in-sri-Dewanarayana/744fb3a2919e6ecd3dB4f44db30f56cc9133f75
11. Divyashree N, Poojashree S, Venukumar S, et al. (2023) Sustainable Ginger Production through Integrated Nutrient Management. Ginger - Cultivation and Use. IntechOpen
12. Divyashree, N., Poojashree, S., Venukumar, S. & Vishwanath, Y.C. (2022). Sustainable Ginger Production through Integrated Nutrient Management. IntechOpen. http://dx.doi.org/10.5772/intechopen.107179
13. FAO. (2018). The 1o Elements of Agroecology: Guiding the Transition to Sustainable Food and Agricultural Systems. http://www.fao.org/3/19007en.pdf
14. FAO. 2019. Ginger farming guide – GCP/RAS/296/JPN. Bangkok.
15. Farm Africa. (2021, April). Management of Ginger Bacteria Wilt and Leaf Spot Disease; A manual for Agriculture Extension Workers and Practitioners. Ethiopia. Farm Africa.
16. Ginger Production. http://www.agriculture.gov.vc/agriculture/images/stories/PDF_Documents/Ginger-Production.pdf
17. Horita, M., Kobara, Y., Yano, K., Hayashi, K., Nakamura, Y., Iiyama, K., Oki, T. (2023). Comprehensive Control System for Ginger Bacterial Wilt Disease Based

on Anaerobic Soil Disinfestation. Agronomy, 13, 1791.

18. Integrated pest and disease management in ginger (2008). (IPM)/State Bio Control Lab, Food Security and Agriculture Development, Department / Horticulture and Cash Crops Development Department. Tadong, Gangtok, East Sikkim.

19. Integrated Pest and Disease Management in Ginger. https://www.sikkimagrisnet.org/General/UploadedFiles/RecentPublications/22.pdf

20. Köhler's Medizinal-Pflanzen in naturgetreuen Abbildungen mit kurz erläuterndem Texte : Atlas zur Pharmacopoea germanica, austriaca, belgica, danica, helvetica, hungarica, rossica, suecica, Neerlandica, British pharmacopoeia, zum Codex medicamentarius, sowie zur Pharmacopoeia of the United States of America.

21. Lalitha, K., Venkatesan, S., Balamuralikrishnan, B. and Shivakumar, M. (2022). Isolation and biocontrol efficacy of entomopathogenic nematodes Steinernema carpocapsae, Steinernema monticolum and Rhabditis blumi on lepidopteran pest Spodoptera litura. Biocatalysis and Agricultural Biotechnology, 39, 1'15. **https://doi.org/10.1016/j.bcab.2022.102291**.

22. Li, L., Chen, F., Yao, D., Wang, J., Ding, N. & Liu, X. (2010). Balanced Fertilization for Ginger Production– Why Potassium Is Important. Better Crops with Plant Foods, 94 (1)

23. Lujiu Li, Fang Chen, Dianli Yao, Jiajia Wang, Nan. (2010). Balanced fermentation for ginger production – why potassium is important. Better Crops/Vol. 94 (2010, No. 1). http://www.ipni.net/publication/bettercrops.nsf/0/16493F0A984F8C5385257980006ED7C0/$FILE/Better%20Crops%202010-1%20p25.pdf

24. Manpreet, J., Kaur, R., & Seema, S. (2018). Scientific Cultivation of Ginger (Zingiber officinalis). In book: Advances in Vegetable Agronomy (pp.191-197). Publisher: Director Indian Agricultural Research Institute New Delhi–110 012, India & Indian Council of Agricultural Research Department of Agricultural Research and Education Ministry of Agriculture, Government of India New Delhi–110 001, India

25. Marsh, L. E., Ali, M., Smith, B. D., and McKenzie-Reynolds, P. (2023). High-tunnel Organic Ginger: Response to Propagation Material, Fertilizer, and Prepropagation Rhizome Storage. HortScience, 58(4), 419-427.

26. Meenu, G. & Jebasingh, T. (2020). Diseases of ginger. In H. Wang (Ed.), Ginger Cultivation and its antimicrobials and pharmacological potentials (pp. 1-32). IntechOpen

27. Mersha, Z, Ibarra-Bautista, M.A. (2022). Evaluation of Selected Biological and Chemical Treatments against Soil-Borne Diseases of Ginger in High Tunnel Production. Horticulturae, 2022, 8(870). https://doi.org/10.3390/horticulturae8100870

28. Mersha, Z. & Ibarra-Bautista, M. A. (2022). Evaluation of Selected Biological and Chemical Treatments against Soil-Borne Diseases of Ginger in High Tunnel Production. Horticulturae, 8(870), 1-14. https://doi.org/10.3390/horticulturae8100870

29. Mohansingh, R. (2016, May). Ministry of Agriculture, Land a& Fisheries, Trinidad & Tobago. Ginger Production. https://agriculture.gov.tt/publication/ginger-production

30. Organic farming horticulture crops: Ginger. (2008). TNAU Agritech portal. https://agritech.tnau.ac.in/ta/org_farm/orgfarm_ginger.html. Accessed March 2023.

31. Paull, R.E. & Chen, C. C. (2015). Ginger: Postharvest Quality-Maintenance

Guidelines Vegetable and Root Crops, VC-2 (pp. 1-2). https://www.ctahr.hawaii.edu.oc/freepubs/pdf/VC-2.pdf

32. Phu Le, D., Smith, M., Hudler, G. W. & Aitken, E. (2014). Pythium soft rot of ginger: Detection and identification of the causal pathogens, and their control. Crop Protection, 65, 153-167. http://dx.doi.org/10.1016/j.cropro.2014.07.021

33. Prasath D, Matthews A, O'Neill WT, Aitken EAB, Chen A. (2023). Fusarium Yellows of Ginger (Zingiber officinale Roscoe) Caused by Fusarium oxysporum f. sp. zingiberi Is Associated with Cultivar-Specific Expression of Defense-Responsive Genes. Pathogens. 12(1):141. https://doi.org/10.3390/pathogens12010141

34. Ram, C. & Govind, S. (2015). Effect of mulching on yield of ginger (Zingiber officinale Rosc.). Journal of Spices and Aromatic Crops 10

35. Rashid Pervez, Rajkumar,, ... T.I. Olabiyi, Rahman Khan, Mujeebur, Quintanilla, Marisol , in Nematode Diseases of Crops and their Sustainable Management, (2023). Chapter 20 - Nematode problems in major spice crops and their sustainable management. PB - Academic Press.

36. Reddy, J. (2018, 13 November). Ginger Cultivation Project Report, Farming Economics. https://www.scribd.com/document/505783751/Ginger-Cultivation-Project-Report-Farming-Economics-Agri-Farming

37. Rural Agricultural Development Authority (RADA), Government of Jamaica. Growing Ginger in Jamaica. Consulted on 01.03.2023 on https://www.rada.gov.jm/growing-ginger-jamaica

38. Saravanakumar, D. (2021). A guide to good agricultural practices for commercial production of ginger under field conditions in Jamaica. Kingston, FAO. https://doi.org/10.4060/cb3365en

39. Satyagopal, K., Sushil, S.N., Jeyakumar, P., Shankar, G., Sharma, O.P., Sain, S.K., Boina, D.R., Srinivasa Rao, N., Sunanda, B.S., Ram Asre, Kapoor, K.S., Sanjay Arya, Subhash Kumar, Patni, C.S., Chattopadhyay, C., Jacob, T.K., Jadav, R.G., Abhishekh Shukla, Usha Bhale, Singh, S.P., Khan, M.L., Sharma, K.C., Dohroo, N.P., Suseela Bhai, K., Santosh J. Eapen, Hanumanthaswamy, B.C., Srinivas, K.R., Thakare, A.Y., Halepyati, A.S., Patil, M.B. & Sreenivas, A.G. (2014). AESA based IPM - Ginger. National Institute of Plant Health Management, Rajendranagar, Hyderabad – 500 030, India.

40. Shyka, P. Growing Ginger, Winter 2011-2012. https://www.mofga.org/resources/herbs/growing-ginger/. Accessed 10/04/2023.

41. Singh, A., Singh, R., Singh, A., Singh, V., Rawat, S., Mehta, K., Kumar, A., Gupta, M., & Thakur, S. (2014). Bio-mulching for ginger crop management: Traditional ecological knowledge led adaptation under rainfed agroecosystems. Indian journal of traditional knowledge. 130210. 111-122.

42. SureChain. (2020, December). Value Chain Analysis Nigeria Ginger, DRAFT REPORT - VCA Ginger In Nigeria. http://www.cbi.eu/sites/default/files/market_information/researches/2020%2oVCA%20Nigeria%20Ginger.pdf

43. Thakur, N. & Sharma, G. C. (2020). Status of Plant Parasitic Nematodes in Ginger

Fields of Himachal Prdesh. International Journal of Science, Environment and Technology, 4(4), 976 – 979.

44. Thankamani, C. K., K. Kandiannan, S. Hamza and K. V. Saji. (2016). Effect of mulches on weed suppression and yield of ginger (Zingiber officinale Roscoe). Scientia Horticulturae 207 125-130.

45. The Centre for the Promotion of Imports from developing countries (CBI). (2020, December). Value Chain Analysis Nigeria Ginger – Draft Report. Accessed on 01.03.2023 on https://www.cbi.eu/market-information/spices-herbs/vca-nigeria-ginger-2020

46. USAID-Feed the Future. (2019, May). Avocado Production Manual. Accessed on 02.02.2023 https://fintracu.fintrac.com/sites/default/files/tech_manuals/Fintrac%20U_Avocado%20Production%20Manual.pdf

47. Walsh, M., Salter, W. and Coleman, G. (2022). May Site-specific weed control for ginger cropping systems. AgriFutures Australia project no. PRJ-011627.

48. Yanagawa A, Krishanti NPRA, Sugiyama A, Chrysanti E, Ragamustari SK, Kubo M, Furumizu C, Sawa S, Dara SK, Kobayashi M. Control of Fusarium and nematodes by entomopathogenic fungi for organic production of Zingiber officinale. J Nat Med. 2022 Jan;76(1):291-297. doi: 10.1007/s11418-021-01572-4. Epub 2021 Oct 5. PMID: 34609693.

49. Yuliar, Nion YA, Toyota K. Recent trends in control methods for bacterial wilt diseases caused by Ralstonia solanacearum. Microbes Environ. 2015;30(1):1-11. doi: 10.1264/jsme2.ME14144. Epub 2015 Mar 26. PMID: 25762345; PMCID: PMC4356456.

50. Yusong Jiang, Qinhong Liao, Honglei Li, Yong Zou. (2018). Ginger: Response to pathogen-related diseases, Physiological and Molecular Plant Pathology,Volume 102, Pages 88-94, ISSN 0885-5765. https://doi.org/10.1016/j.pmpp.2017.12.003.. (https://www.sciencedirect.com/science/article/pii/S0885576517302904)

GROWING PEOPLE

AOÛT 2025

colead.link