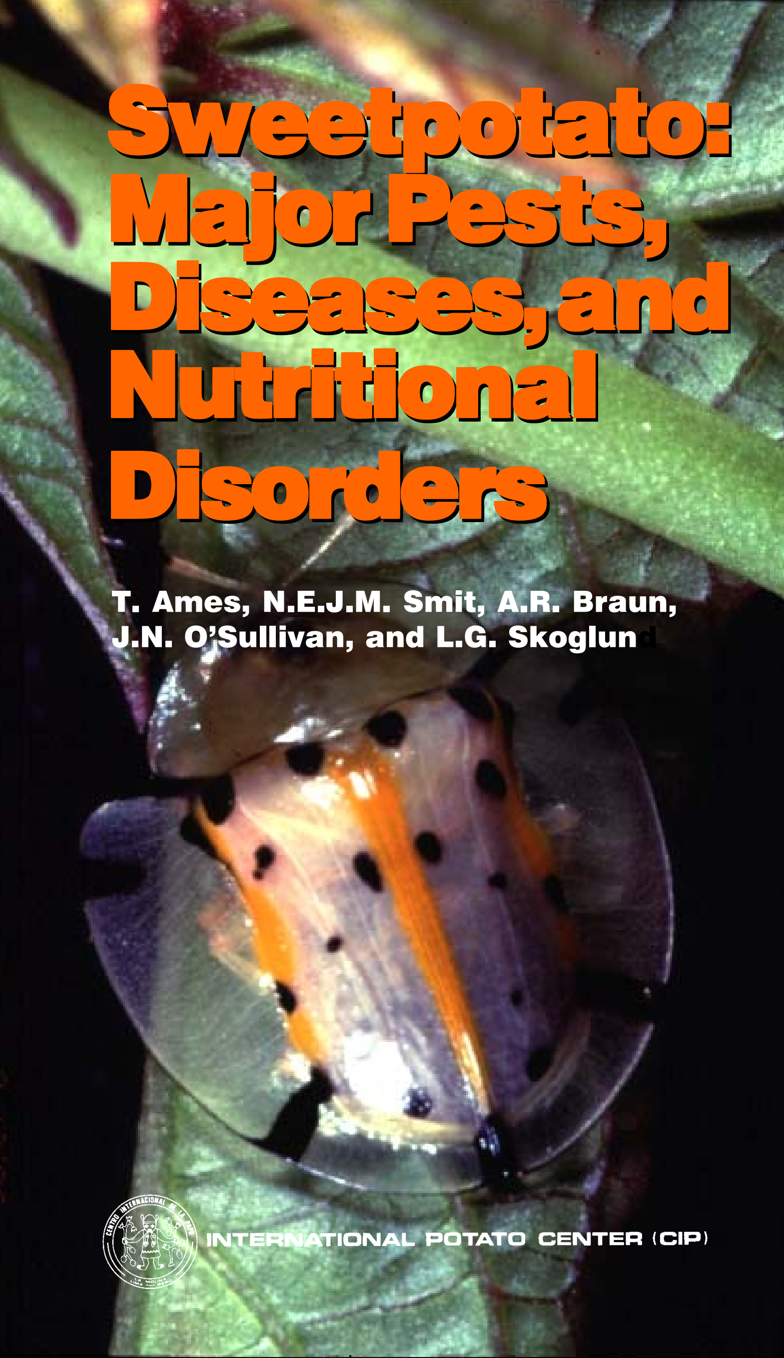


# Sweetpotato: Major Pests, Diseases, and Nutritional Disorders

T. Ames, N.E.J.M. Smit, A.R. Braun, J.N. O'Sullivan, and L.G. Skoglund

INTERNATIONAL POTATO CENTER (CIP)

# Sweetpotato: Major Pests, Diseases, and Nutritional Disorders

T. Ames, N.E.J.M. Smit, A.R. Braun, J.N. O'Sullivan, and L.G. Skoglund

International Potato Center (CIP)

The International Potato Center (CIP) is a scientific, nonprofit institution dedicated to the increased and more sustainable use of potato, sweetpotato, and other roots and tubers in the developing world, and to the improved management of agricultural resources in the Andes and other mountain areas. CIP is part of the global agricultural research network known as the Consultative Group on International Agricultural Research (CGIAR).

International Potato Center
Apartado 1558
Lima 12, Peru

ISBN 92-9060-187-6
Press run: 1000
Printed in Lima, Peru
August, 1997

Cover: Photo of chlorotic spots with and without purple margins induced by SPFMV (taken by S. Fuentes).

T. Ames, N.E.J.M. Smit, A.R. Braun, J.N. O'Sullivan, and L.G. Skoglund. 1996. Sweetpotato: Major Pests, Diseases, and Nutritional Disorders. International Potato Center (CIP). Lima, Peru. 152 p.

1. Sweetpotato – Insect pests. 2. Sweetpotato – Diseases. 3. Sweetpotato – Nutritional disorders. 4. Sweetpotato – Integrated management. I. International Potato Center.

# C O N T E N T S

# Foreword

This field guide presents information on common pests, diseases and nutritional disorders of sweetpotato. It is intended primarily as a tool for correct identification of these problems and ailments, as an essential first step in their control.

The principal entries in the guide are accompanied by photographs or illustrations, and pinpoint where specific problems occur. Additional information is provided on symptoms and recommended control practices, with emphasis on integrated crop management.

We believe that researchers, extension agents, students and farmers alike will find this guide useful, as it can assist them in controlling pests and diseases while safeguarding the natural environment needed for sustainable agriculture.

Wanda Collins
Deputy Director General for Research
International Potato Center

# Acknowledgments

The information on nutritional disorders of sweetpotato presented in this field guide was derived from a research project of the Australian Centre for International Agricultural Research (ACIAR). The author of the section on nutritional disorders, J.N. O'Sullivan, is a member of the project based at the University of Queensland, Australia.

We would like to thank virologist Richard W. Gibson of the Natural Resources Institute for contributing to the section on virus diseases.



# Introduction

The purpose of this field guide is to aid researchers and extensionists throughout the world in the identification of common pests, diseases, and nutritional disorders of sweetpotato (*Ipomoea batatas*). This guide is based on the authors' experiences with the crop in various regions of the world since 1990.

In contrast to most other major staple food crops, sweetpotato is able to produce a comparatively high yield under relatively adverse conditions; however, a number of pests, diseases, and nutritional disorders affect the crop. Among the pest and disease constraints, sweetpotato weevils (*Cylas* spp.) and virus diseases probably contribute the most to yield losses, although leaf-feeding insects, such as the sweetpotato butterfly (*Acraea acerata*), can cause significant losses during outbreaks. Nutritional disorders can cause slight to complete yield loss, and are the main factor limiting most unfertilized crops. They may also reduce tolerance of pests and diseases.

The basis for successful management of sweetpotato pests, diseases, and nutritional disorders is integrated crop management. This implies prevention of insect infestation and infection by pathogens through the use of adequate cultural practices, and the conservation of natural enemies. Adequate cultural practices include the selection of healthy planting material from well-adapted varieties, rotation, good field sanitation, and maintenance of soil fertility. Conservation of natural enemies involves avoidance of pesticide use, enhancement of natural enemy action through favorable cultivation practices, and the introduction of natural enemies if necessary.

Integrated crop management for sweetpotato is covered comprehensively in the *Farmer Field School Guide for Sweetpotato Integrated Crop Management*. This publication can be obtained from the CIP Regional Office for East and Southeast Asia and the Pacific or from CIP headquarters in Lima.[1] Nutritional disorders are covered comprehensively in the publication *Nutritional Disorders of Sweet Potato,*[2] available from the Australian Centre for International Agricultural Research.

The photographs in this publication were assembled from the collections of the authors and their colleagues, and are acknowledged as such.

[1] To order copies of the *Farmer Field School Guide for Sweetpotato Integrated Crop Management,* contact the CIP-ESEAP Regional Office, Fax: 62-251-316264; email: cip-bogor@cgnet.com or CIP headquarters, Fax: 51-1-435-1570; email: cip@cgnet.com .

[2] *Nutritional Disorders of Sweet Potato* is available from the Australian Centre for International Agricultural Research (ACIAR), GPO Box 1571, Canberra 2601, Australia, Fax: 61-6-2170501, email: aciar@aciar.gov.au .



# Insect Pests of Sweetpotato and Their Management

Many insect species attack sweetpotato and the importance of different species varies between agroecological zones. Within a zone, the importance of a species depends on the season; many insect pests are a problem mainly in dry periods.

In this guide, we divide pest species into three groups according to whether the damage is caused to leaves, stems, or roots. Defoliation reduces yield depending on the severity of infestation and the growth stage of the sweetpotato crop in which it occurs. In some areas, sweetpotato is grown for its foliage and leaf feeders can be a problem. In addition to feeding, certain insects, such as aphids and whiteflies, transmit viruses. Extensive stem damage can result in wilting or even in death of the plant. Damage to the vascular system caused by insect feeding and tunneling and pathogen invasion of the injured tissue can reduce the size and number of storage roots. Damage to storage roots, the plant part generally consumed by humans, is of two kinds. External damage results in a loss of quality. Although roots with external damage may bring a lower market price or be unsaleable, they can often still be consumed in the farm household. Internal damage often causes complete loss.

# Storage Root Feeders

## Sweetpotato Weevils

### *Cylas* spp. (Coleoptera: Curculionidae)

**Description.** Three species of the genus *Cylas* are pests of sweetpotato; they are commonly called sweetpotato weevils. All three species—*Cylas formicarius*, *C. puncticollis,* and *C. brunneus*—are found in Africa. *C. formicarius* is present in Asia and in parts of the Caribbean. The elongated ant-like adults of the three species can be distinguished from each other.

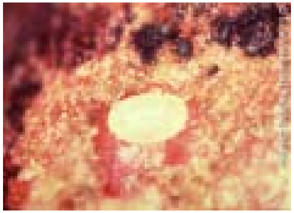
*Cylas puncticollis* is the easiest to distinguish because the adult is all black and larger than the other two (Fig. 1). *C. formicarius* has a bluish black abdomen and a reddish brown thorax. *C. brunneus* adults are small and not uniform in coloring. The most common type can easily be confused with *C. formicarius*.

In all species, the eggs are shiny and round (Fig. 2). The legless larvae (Fig. 3) are white and curved, and the pupae are white (Fig. 4).

**Damage.** Damage symptoms are similar for all three species. Adult sweetpotato weevils feed on the epidermis of vines and leaves. Adults also feed on the external surfaces of storage roots, causing round feeding punctures, which can be distinguished from oviposition sites by their greater depth and the absence of a fecal plug (Fig. 5). The developing larvae of the weevil tunnel in the vines and storage roots, causing significant damage. Frass is deposited in the tunnels. In response to damage, storage roots produce toxic terpenes, which render storage roots inedible even at low concentrations and low levels of physical damage. Feeding inside the vines causes malformation, thickening, and cracking of the affected vine (Fig. 6).



1



2

3

4

5

6

**Distribution and importance.** *Cylas* weevils are serious pests of sweetpotato worldwide, especially in drier agroecological zones. They are often the most significant sweetpotato pest.

**Distribution.** *C. formicarius* is an important pest in India and Southeast Asia, Oceania, the United States, and the Caribbean. In Africa, it has been found only in Natal, South Africa, and at one location in coastal Kenya. *C. puncticollis* and *C. brunneus* are confined to Africa.

**Biology.** All sweetpotato weevil species have a similar life history. The adult female lays eggs singly in cavities excavated in vines or in storage roots, preferring the latter. The egg cavity is sealed with a protective, gray fecal plug. The developing larvae tunnel in the vine or storage root. Pupation takes place within the larval tunnels. A few days after eclosion, the adult emerges from the vine or storage root. Because the female weevil cannot dig, she finds storage roots in which to lay her eggs by entering through soil cracks. Alternate hosts of sweetpotato weevils are *Ipomoea* spp. weeds.

Adults of all species may be conveniently sexed by the shape of the distal antennal segment, which is filiform (thread-like, cylindrical) in males and club-like in females. The males have larger eye facets than the females.

At optimal temperatures of 27–30°C, *C. formicarius* completes development (from egg to egg) in about 33 days. Adult longevity is 2 1/2 to 3 1/2 months and females lay between 100 and 250 eggs in this period. At suboptimal temperatures, development takes longer.



At 27°C, *C. puncticollis* has a total development time of about 32 days, whereas *C. brunneus* takes 44 days. Adults of the first species live an average of 100 days, whereas the latter dies after about 2 months. *C. puncticollis* females lay 90–140 eggs in their lifetime, whereas *C. brunneus* females lay 80–115.

**Control.** When sweetpotato weevil populations are high, no single control method provides adequate protection. The integration of different techniques, with emphasis on the prevention of infestation, provides sustainable protection.

***Cultural control.*** Cultural practices have proved to be effective against the sweetpotato weevil and should be the main basis of control. Cultural practices include:

- Use of uninfested planting material, especially vine tips.
- Crop rotation.
- Removal of volunteer plants and crop debris (sanitation).
- Flooding the field for 24 hours after completing a harvest.
- Timely planting and prompt harvesting to avoid a dry period.
- Removal of alternate, wild hosts.
- Planting away from weevil-infested fields.
- Hilling-up of soil around the base of plants and filling in of soil cracks.
- Applying sufficient irrigation to prevent or reduce soil cracking.

***Treatment of planting material.*** Dipping planting material in a solution of *Beauveria bassiana* or in an insecticide (such as carbofuran or diazinon) for 30 minutes prior to planting (Fig. 7) can control sweetpotato weevils for the first few months of the growing season.

***Less-susceptible varieties.*** Varieties with immunity or a high level of resistance are not available. Some varieties have low to moderate levels of resistance. Others escape weevil damage because their storage roots are produced deep in the soil or because they mature quickly and can be harvested early.

***Sex pheromones.*** The species-specific pheromones of all three *Cylas* species that are released by female weevils and attract males have been identified. Pheromone lures for *C. formicarius* are commercially available. Pheromone traps are used as monitoring, training, and management tools. Many effective traps have been designed by farmers using locally available materials (Fig. 8). Traps are so sensitive that their failure to catch weevils is a good indication that the pest is not present.

***Microbial control.*** Promising biological control agents for sweetpotato weevils appear to be the fungi *B. bassiana* and *Metarrhizium anisopliae* and the nematodes *Heterorhabditis* spp. and *Steinernema* spp. The fungi attack and kill adult weevils, whereas the nematodes kill the larvae.

***Predators.*** Ants, spiders, carabids, and earwigs are important generalist predators that attack weevils. They are described more fully in the section on "Natural Enemies."



**7**


**8**

## West Indian Sweetpotato Weevil

*Euscepes postfasciatus*

(Coleoptera: Curculionidae)

**Description.** Adult weevils are reddish brown to blackish gray, and are covered with short, stiff, erect bristles and scales (Fig. 9). Eggs are grayish yellow to yellow. Larvae are white. Pupae are whitish and sedentary.

**Distribution.** *E. postfasciatus* is widespread in the Caribbean and South America, and is usually present in sweetpotato fields and storage.

**Damage.** Adults feed on sweetpotato stems and storage roots, and emerge by chewing exit holes (Fig. 10). Larvae feed deep in the plant tissues. Internally, flesh and stem tissues are severely damaged. Affected roots are not edible by humans or animals.

**Control.** Integrated pest management includes removal of infested sweetpotato vines and storage roots from the field after harvest, removal of alternate hosts, and use of uninfested planting material. Biological control with *B. bassiana* and the use of early-maturing varieties also reduces damage.

9


10

## Rough Sweetpotato Weevil

*Blosyrus* sp. (Coleoptera: Curculionidae)

**Description and biology.** Adult weevils are blackish or brownish and the surface of the elytra is ridged (Fig. 11). This makes them look like a lump of soil. Larvae are whitish and C-shaped. Adult weevils lay eggs underneath fallen leaves (Fig. 12). The larvae develop in the soil and pupate there. Adult weevils are found on the ground underneath foliage during the day.

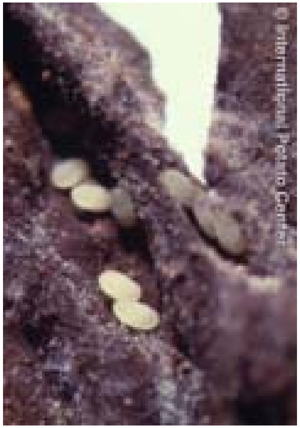
**Damage.** Adult weevils feed on foliage, but the larvae cause greater damage. While feeding under the soil surface, they gouge shallow channels on the enlarging storage roots (Fig. 13). These "grooves" reduce marketability. When extensively damaged, the skin of the storage root has to be thickly peeled before eating, because the flesh discolors just under the grooves.

**Distribution and importance.** This weevil is a common pest of sweetpotato in East Africa, and causes serious problems in some localities.

**Control.** Some of the cultural control measures used to control *Cylas* should be effective in reducing incidence of this pest, especially rotation and sanitation. The possibility of biological control is under investigation.




11




12


13

## Clearwing Moth

*Synanthedon* spp. (Lepidoptera: Sesiidae)

The larvae can tunnel through the vine into the storage roots. Usually, only the tip of the storage root is affected. This pest is discussed in detail in the section on "Stem-borers and Feeders."

## Peloropus Weevil

*Peloropus batatae*
(Coleoptera: Curculionidae)

The larvae of the *Peloropus* weevil can tunnel down the vines to the storage roots. This species is discussed in the section on "Minor Stemborers and Feeders."



## White Grubs

White grubs, the larvae of various species of scarabid beetles, live in the soil. In the larval stage, they are large and fleshy with swollen abdomens, well-developed head capsules, and large jaws and thoracic legs (Fig. 14). They usually adopt a C-shaped position. When they feed, white grubs gouge out broad, shallow depressions in sweet-potato roots. Most species attack a wide range of host plants. Control is not usually necessary. Handpicking of exposed grubs during land preparation and weeding is useful. Light trapping can be used to control white grubs when they become a chronic problem in a localized area.


**14**

# Stemborers and Feeders

## Clearwing Moth

*Synanthedon* spp.(Lepidoptera: Sesiidae)

**Description and biology.** Adults lay batches of 70–100 yellowish eggs on vines and leaf stalks. The larvae burrow into the vines soon after they hatch and tunnel downward. They are whitish, with transparent skin and a brown head capsule. They can grow up to 2.5 cm long. Pupation occurs in the main stem just above ground level and the grayish brown pupal case (Fig. 15) can be seen protruding from the swollen stem. The adult moth has distinctive transparent wings (Fig. 16).

**Damage.** The larvae burrow into the vines and sometimes into the storage roots. The vine base is characteristically swollen and traversed with feeding galleries. With heavy infestation, the vine breaks off easily at the base.

**Distribution and importance.** Three closely related species of *Synanthedon* are regularly found in sweetpotato, but they are prominent pests only in some localities in East Africa.

**Control.** Frequent earthing-up around the plant base reduces the incidence of this pest. Other cultural control measures, such as those practiced for sweetpotato weevil species, also help to control clearwing moths.



15


16

## Sweetpotato Stemborer
*Omphisia anastomasalis*
(Lepidoptera: Pyralidae)

**Description and biology.** Most eggs are laid individually along the underside of the leaves, along the leaf margins. Some are laid on the stem. The egg, larval, and pupal stages last an average of 55–65 days. There are six larval instars. A newly emerged larva has a brown head and a reddish or pinkish body. After a few days, it turns creamy with black markings. Full-grown larvae are 30 mm long (Fig. 17). Infested plants usually have a pile of brownish frass around their base. Before pupating, the larva makes an exit hole that is covered with the epidermis of the stem. Pupation lasts about two weeks and takes place in a web-covered cocoon within the tunnel (Fig. 18). The adults emerge by breaking through the dry papery covering of the exit hole. They live 5–10 days and the females lay an average of 150–300 eggs. The moths are 15 mm long and have reddish brown heads and bodies, and light brown wings (Fig. 19).

**Damage.** The larva bores into the main stem shortly after hatching and sometimes penetrates the neck of the storage root. Larval feeding results in enlargement and lignification of the stems at the base of the plant and in the formation of hollow cavities filled with frass. Plants may wilt and die. Attack during the early stages of plant growth may inhibit the formation of storage roots.



**17**

**18**

**Distribution and importance.** The stemborer is one of the most destructive pests of sweetpotato in trop-ical and subtropical Asia and the Pacific. It is widespread in the Philippines, Indonesia, India, Sri Lanka, Malaysia, Taiwan, Hawaii, and Vietnam, where it is a severe pest in the central region of the country. It also occurs in China, Japan, Cambodia, Laos, Burma (Myanmar), and Thailand. Infestation during the establishment phase of the crop can result in yield losses of 30–50% or more.

**Control.** Using planting material infested with stemborer eggs or planting a new field next to an infested one are often the main means of disseminating this pest. Treatment of planting material and crop rotation are valuable means of control. Hilling-up, often practiced to reduce damage from sweetpotato weevil, also contributes to the containment of a stemborer infestation. Hilling-up is effective when the holes, made to provide the adults with a means of exiting the stems, are covered with soil. Earwigs and ants may attack the larvae developing within sweetpotato vines. Sources of resistance have been identified by the Asian Vegetable Research and Development Center, Taiwan.



**19**

## Striped Sweetpotato Weevil
*Alcidodes dentipes* and *A. erroneus*
(Coleoptera: Curculionidae)

**Description and biology.** Adult *A. dentipes* is about 1.4 cm long and has conspicuous white stripes longitu-dinally along the elytra (Fig. 20). Adult *A.erroneus* is bigger than the former, and is brownish black with an irregular yellowish patch on each elytron. Larvae of both species are white, with an orange-brown head capsule, and are C-shaped. Larvae and pupae (Fig. 21) are found inside the sweetpotato vine, most often at the base. The adults eat their way out of the vine. The life cycle is very similar to that of sweetpotato weevils. Larvae and pupae also resemble those of immature *Cylas* weevils, but the *Alcidodes* later instars are much bigger.

**Damage.** The larvae bore into the vines and sometimes into the storage roots. The vine base swells up. Adult weevils girdle the vines, causing wilting.

**Distribution and importance.** *Alcidodes* spp. are minor pests throughout most of East and Central Africa.

**Control.** Control is not usually required. Frequent earthing-up around the plant base reduces the incidence of this pest. Other cultural control measures, such as the ones practiced for sweetpotato weevil species, also help to control *Alcidodes* spp.




20


21

## Sweetpotato Weevils

*Cylas* spp. larvae can do considerable damage to sweetpotato vine bases by tunneling. In East Africa, this damage can prevent a crop from establishing. This species is discussed in greater detail in the section on "Storage Root Feeders."



# Minor Stemborers and Feeders

## Peloropus Weevil

*Peloropus batatae* (Coleoptera: Curculionidae)

This reddish brown, compact, 3–4 mm weevil has been found inside stems and storage roots at some locations in East and Central Africa. The last instar of the white larva is longer than one would expect considering the small size of the adult. The larva makes long tunnels in the stem and can go down to the storage root via the storage root "neck." Pupae and adults are found at the end of the tunnels. The life cycle is long compared with that of other sweetpotato weevils—2 months or more. Because the larva enters via the storage root neck, storage roots that seem undamaged on the outside could be inedible because of several tunnels on the inside. Control is not usually required.

## Sweetpotato Bug

*Physomerus grossipes* (Hemiptera: Coreidae)

**Description and biology.** The sweetpotato bug lays groups of eggs on the undersides of leaves or on the stem. The mother bug guards her eggs (Fig. 22A,B) and the young gregarious nymphs (Fig. 23). The egg stage lasts about 15 days. There are 5 nymphal stages and total development takes about 85 days for males and 88 days for females. The adult is 20 mm long.

**Damage.** The nymphs and adults pierce the stems and petioles of the sweetpotato and suck the plant sap, thus causing wilting and stunting.

**Distribution and importance.** The sweetpotato bug is found in Southeast Asia, where it is a minor pest.

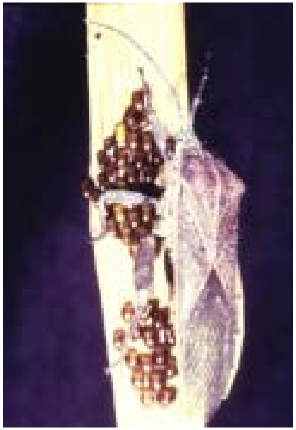
**Control.** Large numbers of bugs are usually found feeding together, making handpicking of the bugs or removal of the infested plants a feasible means of control.

## Long-Horned Beetle

A species of long-horned beetle (Coleoptera: Cerambycidae) has been found to attack stem bases in some localities in East Africa. The larvae are large, with big heads, and they are found inside the stem base. They cause severe swelling. Control is seldom necessary.




22A



22B


23

# Foliage Feeders

## Sweetpotato Butterfly

*Acraea acerata* (Lepidoptera: Nymphalidae)

**Description and biology.** Pale yellow eggs (Fig. 24) are laid in batches of 100–400 on both surfaces of the leaves. The caterpillars are greenish black and covered with branching spines. These larvae are concentrated in a protective webbing during the first 2 weeks after hatching. They then become solitary and hide from the sunlight on the ground during the day (Fig. 25). The pupae are yellowish and hang singly on the underside of leaves or on another support. The attractive adult butterfly has orange wings with brown margins (Fig. 26). The life cycle takes 27–50 days depending on temperature.

**Damage.** The caterpillars feed on the leaves. Young caterpillars feed on the upper leaf surface, whereas older larvae eat the whole leaf except for the primary midribs. Complete defoliation may result from severe attacks (Fig. 27).

**Distribution and importance.** The sweetpotato butterfly is a pest in East and Central Africa. It is an important production constraint in some localities. Outbreaks are sporadic and seasonal and usually occur at the beginning of the dry season.

**Control.** Sweetpotato fields should be observed for sweetpotato butterfly adults and damage early in the dry season. Webs containing young caterpillars should be collected and destroyed weekly. Early planting and harvesting enable the crop to escape severe attacks. In case of severe outbreaks, chemical control can be carried out with carbaryl, pyrethrum, etc.; however, effects on natural enemies should be considered. Various species of tachinid, braconid, and ichneumonid parasites attack the larval stage. *Beauveria bassiana* infects the sweetpotato butterfly.



24

25

26

27

## Tortoiseshell Beetles
*Aspidomorpha* spp. and others
(Coleoptera: Chrysomelidae)

**Description and biology.** Eggs are laid on the un- derside of the sweetpotato leaves or other Convolvulaceae in batches cemented to the leaves. The eggs of some species are concealed in a papery oothecum (Fig. 28). Larvae are characteristically flattened and spiny. In some species, the tail is held up over the back (Fig. 29A,B) and the larva may carry excreta and previous cast skins (Fig. 30). The pupa is less spiny than the larva, and is fixed inert to the leaf. The adults are broadly oval and may be bright and patterned (Fig. 31). Larvae, pupae, and adults are found on both sides of the foliage. Development from egg to adult takes 3-6 weeks depending on the species.

**Damage.** Both adults and larvae eat large round holes in the leaves. Attacks are sometimes sufficiently severe to completely skeletonize the leaves and peel the stems.

**Distribution and importance.** Four species of *Aspidomorpha* and eight other Chrysomelidae have been recorded in Kenya on sweetpotato. Several species occur in Southeast Asia including *Cassia circumdata* and *C. obtusata*, the green tortoiseshells; *A. miliaris,* the spotted tortoiseshell; *A. elevata*, the golden tortoiseshell (Fig. 32A, B), and *A. amabilis*, with reddish brown elytra. Tortoiseshell beetles are widely distributed and often common. Although their damage is quite conspicuous, they seldom if ever cause yield losses.




28

29A

29B

30


31

**Control.** Control is rarely warranted. Removal of convolvulaceous weeds in the surrounding area may reduce their numbers. Several natural enemies including egg and larval parasites (*Tetrastichus* sp., Eulophidae; Chalcidae) and predators (*Stalilia* sp., Mantidae) have been reported.




32A


32B

## Sweetpotato Hornworm

*Agrius convolvuli* (Lepidoptera: Sphingidae)

**Description and biology.** The small, shiny eggs are laid singly on any part of the plant. The larvae have a conspicuous posterior "horn." They vary in color from green to brown and are marked with distinct striped patterns. The last instar caterpillars reach 9.5 cm in length (Fig. 33).

Hornworms are found mainly on young shoots. The larval period lasts 3–4 weeks. Pupation takes place in the soil and takes 5–26 days, depending on the temperature. The large, reddish brown pupa (Fig. 34)is characterized by a prominent proboscis, which is curved downward. Adults are large, gray hawkmoths with black lines on the wings. Wingspan is 8–12 cm.

**Damage.** Yield losses can occur if heavy defoliation takes place when the crop is young. A large caterpillar can defoliate a plant and a large population of late instar larvae can defoliate a field overnight. The larvae feed on the leaf blades, causing irregular holes, and may eat the entire blade, leaving only the petiole.

**Distribution and importance.** *A. convolvuli* occurs worldwide. It is not usually a serious pest, although severe outbreaks have been reported in Vietnam.

**Control.** Handpicking the larvae from the leaves is usually sufficient. Plowing the land between crops exposes the pupae. Light trapping can be used to monitor the population of adults. When a large increase in adult numbers occurs, manual removal of small larvae can prevent the buildup of an outbreak population of the voracious late instar larvae. Pesticide use disrupts the action of the egg and larval parasites of the hornworm.




33


34

## Armyworms

*Spodoptera eridania, S. exigua, S. litura*
(Lepidoptera: Noctuidae)

**Description.** Adult female moths of *S. eridania* are light brown with dark spots on their front wings (Fig. 35). Males are smaller with a black spot or a bar on the center of the front wings. Larvae in their first stages are gregarious and black and velvety with lateral yellow lines. In later stages, larvae are gray to olive green with two parallel dorsal lines (Fig. 36) and they disperse all over the plant.

The white eggs of *S. exigua* are laid in round or oval clusters and are covered with a layer of a felt-like substance (Fig. 37). The larvae are initially a grass-green color; they then become green or dark brown with yellowish stripes in later instars (Fig. 38). Pupation occurs in the soil and development from egg to adult takes about 23 days. *S. exigua* adults can lay 1000 eggs.

The eggs of *S. litura* are laid in clusters containing as many as 350 eggs. These are of variable shape and size and are covered with "felt." The caterpillars hatch after 3–5 days and take about 2 weeks to reach the pupal stage. The larvae (Fig. 39) possess two characteristic black crescents on the fourth and tenth abdominal segments, bordered by yellow lateral and dorsal stripes. The larvae prefer moist sites and may hide in the soil during the day, attacking plants at night. Pupation occurs in the soil. Female moths mate several times and produce a sex pheromone. The male moths are very sensitive to the pheromone on the fourth day after emergence. The female adults (Fig. 40) can lay as many as 2000–3000 eggs.

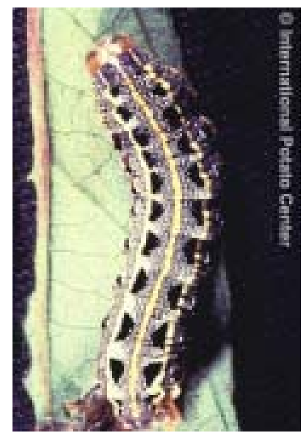
**Damage.** Early instar larvae feed by scraping and scarifying the leaf surface. From the third instar on, they



35

36


37



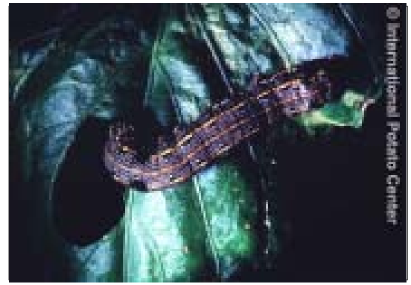

38

consume the parenchymal leaf tissue, leaving only the veins (Fig. 41). The late instars of *S. litura* are very voracious and may bore into sweetpotato roots when these are exposed.

**Distribution and importance.** Armyworms are widespread and feed on many host plants. *S. litura* is confined to Asia, the Pacific, and Australia.

**Control.** Weedy hosts should be eliminated. *Ipomoea reptans* (kankung) and several weeds (*Amaranthus* sp., *Passiflora foetida, Ageratum* sp.) are common alternate hosts in Asia. Collection of egg clusters or leaves infested with gregarious young larvae can be an effective means of control. Spot applications of insecticide or *Bacillus thuringiensis* can be made in the early larval stage when larvae are still gregarious. Formulations of nuclear polyhedrosis viruses are available. The green muscardine fungus, *Nomuraea rileyi*, is highly pathogenic to *S. litura*, and the virus *Borrelinavirus litura* can cause mortality after an incubation period of 4–7 days. Predatory bugs, carabid beetles, vespid wasps, and spiders attack the larvae, and more than 40 species of scelionid, braconid, ichneumonid, and tachinid parasites are known.






39


40

41

## Leaf Folders

*Brachmia convolvuli* (Lepidoptera: Gelechiidae), *Herpetogramma hipponalis* (Lepidoptera: Pyralidae), and others

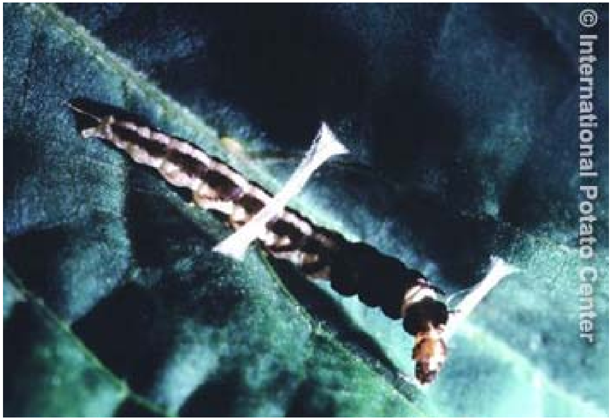
**Description and biology.** The larvae of the black leaf folder, *B. convolvuli* (Fig. 42), and the green leaf folder, *H. hipponalis* (Fig. 43), feed inside a folded leaf, leaving the lower epidermis intact. In most cases, only one larva is found per leaf fold. The black leaf folder lays yellowish white oval eggs singly on the leaves. The eggs hatch after 3–5 days and the five larval instars last 2–5 days each. The average total larval period is 11 days. The larva has prominent bland and white markings on the thorax and abdomen. The pupal period is 4–7 days. The female moth lives an average of 5 days. The green leaf folder lays eggs in groups on the upper surface of the leaf near the midrib. The eggs are shiny green, oblong, and covered with a scale-like gelatinous material. The eggs hatch after 3–5 days and there are five larval instars. The larva is greenish yellow with sparse brown setae and a dark brown head and prothoracic plate. The pupal period lasts 4–8 days. The adult is a yellowish brown moth with dark brown markings on its wings. The female moth lives about 3 days.

**Damage.** The leaf margin is folded once by *B. convolvuli*. *H. hipponalis* folds the leaf margin twice and produces some webbing. Leaf folder feeding results in a lace-like appearance of the leaf, with the main leaf veins left intact.

**Distribution and importance.** Leaf folders are widespread throughout Asia and Africa.

**Control.** A high rate of parasitism by braconid wasps is common. Earwigs and other generalist predators are also important in maintaining natural control. If natural






42


43

enemy action is not disrupted by pesticide use, control is rarely needed. The use of uninfested planting material is an effective means of reducing the incidence of leaf folders.

The brown leaf folder, *Ochyrotica concursa* (Lepidoptera: Pyralidae), and the pink-striped leaf folder, *Anticrota ornatalis* (Lepidoptera: Pyralidae), have been reported in the Philippines. The green larvae of the pyralid leafroller, *Tabidia aculealis*, scarify the mesophyll from the inner side of the rolled leaf. They prefer full-grown leaves and the pupae are found in leaf cases. Reported in Indonesia, they occasionally cause serious damage.



## Strobiderus Beetle
*Strobiderus aequatorialis*
(Coleoptera: Chrysomelidae)

This is a small, yellowish beetle, 5–7 mm long ocurring in East Africa. The adults perforate the leaves and cause damage similar to that of tortoiseshell beetles. Control measures are not usually necessary.

## Rough Weevil
*Blosyrus* sp. (Coleoptera: Curculionidae)

The adults feed on the leaves of sweetpotato in Africa, but their important pest stage is the larva, which affects the storage roots (see the section on "Storage Root Feeders").

## Sweetpotato Weevils
Cylas spp. (Coleoptera Curculionidae)

The adults feed on the leaves of sweetpotato, but are much more important as pests of the storage roots and stems (see the section on "Storage Root Feeders").

# Minor Leaf Feeders

## Grasshoppers and Locusts
## *Zonocerous variegatus* (Orthoptera: Pyrgomoriphidae), the variegated grasshopper and *Attractomorpha psitticina* (Orthoptera: Acrididae), the slant-faced grasshopper, and others

In Africa, both adults and nymphs of *Z. variegatus* can defoliate sweetpotato (Fig. 44). Outbreaks seldom occur and control is rarely needed.

An Asian species, the polyphagous slant-faced grasshopper is bright green and characterized by a pointed conical head and short antennae. It measures 30–40 mm in length.

The female taro grasshopper, *Gesonula zonocena mundata* (Orthoptera: Acrididae), is found in Southeast Asia. It bores through the petiole of the host plant to lay its eggs. These are covered with a reddish brown gummy substance. The pale brown to green adult is 30 mm long and has black stripes running from its eyes to the tips of its wings. The hind legs are black and the tibia are bluish with white-tipped spines. Taro and water hyacinth are also hosts.


**44**

# Virus Transmitters

## Aphids

*Aphis gossypii* and others
(Homoptera: Aphididae)

**Description and biology.** Aphids are soft-bodied insects, 1–2 mm long, yellowish green to black, with or without wings (Fig. 45). Aphids can multiply asexually, resulting in fast population buildup. Several generations occur per year.

**Damage.** Aphids damage plants by sucking sap from growing shoots. Symptoms of aphid attack are wrinkling, cupping, and downward curling of young leaves. During heavy infestation, plant vigor is greatly reduced.

As aphids feed and move from plant to plant in the field, they transmit viruses. The most important aphid-transmitted virus is sweetpotato feathery mottle virus. Winged forms may travel long distances and introduce viruses into new areas. *A. gossypii* has a wide host range, including cotton, cucur-bits, and many legumes.

**Distribution and importance.** Aphids are cosmopolitan. Their main impact in sweetpotato is as vectors of virus diseases.

**Control.** Control is rarely necessary. Predators such as ladybird beetles, lacewings (*Chrysoperla* sp.), and syrphids naturally reduce aphid populations. In case of heavy outbreaks, farmers tend to apply insecticides; however, these should be used with great caution since they reduce natural enemy populations and can contribute to further aphid outbreaks.




**45**

## Whiteflies

*Bemisia tabaci* (Homoptera: Aleyrodidae)

**Description and biology.** The female of *B. tabaci* lays eggs on the undersides of leaves. All the nymphal stages (Fig. 46) are greenish white, oval in outline, scale-like, and somewhat spiny. The adult (Fig. 47) is minute and covered with a white, waxy bloom. Development of one generation takes 3–4 weeks.

**Damage.** High whitefly populations may cause yellowing and necrosis of infested leaves. The pest is more important as a transmitter of viruses, especially sweetpotato mild mottle virus. *B. tabaci* has a wide host range, including cotton, tomato, tobacco, and cassava.

**Distribution and importance.** The main impact of *B. tabaci,* a cosmopolitan species, on sweetpotato is as a vector of virus diseases.

**Control.** Control measures are not usually needed. Controlling whiteflies is not usually an effective means of limiting the incidence of the viruses they transmit.




46


47

# Mites

## Erinose caused by Eriophyid mites, *Aceria* sp. (Acari: Eriophyidae)

**Description.** Vines and leaves become excessively hairy, beginning at the shoot tip (Fig. 48).

**Biology.** Erinose is present in East Africa and the United States. The problem is more pronounced at lower altitudes where the climate is hot and dry. Research suggests that yields may be reduced.

**Control.** Control is through selection of mite-free planting material and good field sanitation. This might not be effective enough, however, because mite populations can build up rapidly.

## *Eriophyes gastrotrichus* (Acari: Eriophyidae)

**Description.** Infested vines present pocket-like galls on leaves, petioles, and stems (Fig. 49). Initially, galls are light green, but they become brown afterwards. Several mites in every stage of development live together inside each gall. When heavy infestations occur, leaves become crinkled and lose their shape.

**Biology.** Erinose caused by the gall mite is present in the Philippines and Papua New Guinea.

**Control.** Mite-free planting material should be used together with good field sanitation and destruction of weeds that can act as hosts.




48

49

# Natural Enemies

The natural enemies of sweetpotato pests have received limited research attention. What little is known of their biology and ecology relates mostly to generalist predators, such as ants, and to fungal pathogens of the sweetpotato weevils.

Generalist predators are often the most important group of biological control organisms in agricultural systems because they can switch from one prey type to another. Their flexible food habits allow them to respond as one pest re-places another in terms of relative abundance. Herbivorous species that cause little or no economic damage play an important ecological role in agricultural systems by providing food to maintain populations of beneficial species at levels that can prevent damaging pest outbreaks.

In Asia, where sweetpotato is often grown in rotation with rice, many of the generalist predators commonly found in rice fields persist in the sweetpotato crop that follows (for more information on these, see Shepard et al. 1987).



## Earwigs

Earwigs (Dermaptera: Forficuliidae) have a characteristic hind pair of forceps-like pincers that are used for defense. Adults can live for several months and are most active at night. They enter stemborer tunnels in search of larvae. Occasionally they climb the foliage to prey on leaf folder larvae. They can consume 20–30 prey daily.

## Spiders

The importance of spiders as predators has been clearly demonstrated for rice, but their role has not been studied adequately in many other crops and little is known about their contribution to biological control of sweetpotato pests.

The lynx spider *Oxyopes* sp. and the wolf spider *Lycosa* sp. are abundant in sweetpotato fields. These do not spin webs but rather hunt prey directly. Web-spinning spiders are also common.

## Pheidole and Other Predacious Ants

Cuban farmers practice augmentation of *Pheidole megacephala* (Myrmicinae) and *Tetramorium guinensis* (Myrmicinae) to control the sweetpotato weevil, *C. formicarius*. Several ants—*Pheidole* sp. (Fig. 50), *Iridomyrmex anceps* (Dolichoderinae), and *Anoplolepis longipes* (Formicinae)—have been confirmed as predators of the sweetpotato weevil in Indonesia. Although their role as predators of other sweetpotato pests is unknown, *Pheidole* ants are known to attack small prey stages such as eggs and early instar insect larvae.

A number of other ant species are reported from sweetpotato fields in Indonesia (*Tetramorium* sp., *Monomorium* sp., *Odontoponera transversa*, *Dolichero-derus thoracicus*, *Polyrachis* sp., *Camponotus maculatus*, *Diacamma* sp., *Myrmicaria* sp., *Leptogenys* sp., *Pachy-dondyla* sp., and *Odontomachus simillimus*), Uganda (*Myr-micaria* sp.), and Vietnam (*Solenopsis geminata* and *Paratrechina* sp., found in tunnels made by *Omphisia anas-tomasalis*). Although these ants have not been confirmed as predators of sweetpotato pests, the literature contains references suggesting a predacious behavior for several species. An example is *Myrmicaria* sp., often found attack-ing caterpillars in agricultural fields and dragging them to their nests.




50

## Beetles

Carabids are one of the most important families of predatory beetles. The majority of carabids in agricultural systems are ground-dwelling species that feed on other insects that live or pupate in or on the soil. An example of a predatory carabid identified from sweetpotato fields in Indonesia is *Pheropsopus* sp. A few carabids climb foliage and can be found within the chambers made by leaf folders.

The staphylids are another common family of scavengers and generalist predators. Of these, *Paederus* spp. (Fig. 51) are common in many crop environments, including sweetpotato. *P. fusciceps* occurs in Indonesia.

The Coccinellidae, or ladybird beetles, are a large family, nearly all of which are predacious. Their main prey are aphids, mealybugs, and scale insects, but they also feed on insect eggs or on the slow-moving early instars of some Lepidoptera. Both the larvae (Fig. 52) and the adults are predacious. Adult females deposit distinctive yellow cigar-shaped eggs in groups of 5–30 on plants, mostly near colonies or groups of prey. Ladybird larvae forage on the plant and pupate on the foliage.




**51**


**52**

## Flies and Parasitic Wasps

Hover flies (Syrphidae) are brightly colored and frequently visit flowers to feed on pollen and nectar. The adult flies (Fig. 53) lay their elongated white eggs singly on plants, often near aphid colonies, which serve as prey for their white, maggot-like offspring. Syrphid larvae are active mostly at night and feed mainly on aphids. Syrphids, cocinellids, and parasitic wasps form a natural enemy complex that plays an important role in regulating aphid populations.

Tachinid flies (Fig. 54) mostly attack medium-to-late instar caterpillars. Some species deposit their eggs directly on a host. Others lay eggs on the plant close to where the host is feeding. The eggs are consumed by the host but remain intact and develop within the host's body. Other species lay incubated, fully developed eggs on the leaves; the newly hatched larvae search for a host and penetrate its cuticle. Caterpillars parasitized by tachinids can be recognized by the presence of dark spots on the cuticle, or by discoloration and deformation. Adult tachinids visit flowers for nectar and survive for several weeks.

The tachinid *Zygobothria ciliata* is a larval parasite of the sweetpotato hornworm. *Cuphocera varia*, a larviparous species, and *Blepharella lateralis* are common parasites of armyworms, and are widespread throughout Southeast Asia. The larvae of *C. varia* are deposited on leaves near the feeding sites of their hosts and rapidly bore into the side of a host between the segments. The host caterpillar attempts to dislodge the attached parasite by twisting and turning violently. *B. lateralis* lays it eggs on the leaves and the flies often emerge from the host pupa. *Carcelia kockiana*, a highly polyphagous species, parasitizes armyworms in Indonesia. *Carcelia normula* parasitizes the sweetpotato butterfly in Uganda.




53


54

The wasp *Telenomus spodopterae* (Scelionidae) is a common egg parasite of *S. litura*. The encyrtids *Anastatus dasyni* and *Oencyrtus malayensis* are egg parasites of *Physomerus grossipes*. Development of *A. dasyni* takes 16 -18 days and the females live for about one month. As many as 8 adults of *O. malayensis* emerge from an egg of *P. grossipes*. The wasps are able to attack eggs within one day of emergence, and live for about one month. The eulophid *Tetrastichus* sp. has been reported as a pupal parasite of the green tortoiseshell beetle. *Brachymeria* sp., a chalcid, parasitizes the green leaf folder. *Trichogramma minutum* (Trichogrammatidae) is an egg parasite of the sweetpotato hornworm. *Charops* sp. (Ichneumonidae) has been reported from the sweetpotato butterfly. The adult is slender with a long, stalked abdomen, which is flattened laterally. The adult also has a characteristic stalked and barrel-shaped pupal cocoon.

Many of the host insects of braconid parasites live in protected sites such as tunnels, mines, and folded leaves (Fig. 55), or under webbing. Some examples are *Macrocentrus* sp., a parasite of the black leaf folder; *Microbracon cylasovorus* and *Bassus cylasovorus,* parasites of *C. formicarius*; and *Meteorus* sp., a parasite of sweetpotato butterfly larvae.

**55**



## Viruses

Nuclear polyhedrosis viruses are common on armyworms. The larvae become infected by eating virus-contaminated foliage. As infection develops in a larva, it becomes sluggish and stops feeding. Later the larva turns whitish and then black and hangs from the foliage by its prolegs. The fluid oozing from its body contaminates foliage and continues the disease cycle.

Granulosis viruses attack lepidopteran larvae. Hornworm species are often affected. Host larvae that eat contaminated foliage move sluggishly and then stop feeding. After 1-2 weeks, the body becomes constricted, giving a segmented appearance. Infected larvae turn yellow, pink, or black and become soft.

## Fungal Pathogens

### *Metarrhizium anisopliae* and *Beauveria bassiana*

Sweetpotato weevils are among the insect species attacked by *M. anisopliae*. Spores germinate on the body of a host insect under conditions of prolonged high humidity. The fungus penetrates the insect and uses its internal body contents as a substrate for proliferation. When the host dies, the fungus emerges through joints in the insect exoskeleton, appearing first as a white growth. When spores are formed, the fungus turns green. Spores emerging from the dead host are spread to new hosts by wind or water.

*Beauveria bassiana* (Fig. 56) attacks stemborers, leaf folders, and bugs among others, and is a confirmed pathogen of sweetpotato weevils and the sweetpotato butterfly. Like other fungal diseases, it requires conditions of prolonged high humidity for the air-or waterborne spores to germinate. The fungus invades the soft tissues and body fluids of the host and grows out of the body to sporulate. Affected insects appear to be covered with a powdery, white substance.

Other pathogens that may play a role in the biological control of pests in sweetpotato fields include the fungi *Hirsutella* spp. and *Nomuraea rileyi*, and the nematodes *Heterorhabditis* spp. and *Steinernema* spp.




56

# Diseases and Pathogens of Sweetpotato and Their Management

A number of pathogenic organisms affect sweetpotato. Most appear to be widespread, but damage levels vary.

In this guide, we include viral, fungal, and bacterial diseases, as well as those caused by nematodes. Each group of pathogens is covered in a separate section. Pathogenic bacteria, although not very common, are responsible for important economic losses. They affect vascular tissue as well as storage and fibrous roots, thus causing vine wilting and rots. Fungal pathogens are classified according to the type of disease they cause, such as foliar, stem, storage root, and postharvest diseases. In general, foliar and stem diseases are mild and cause little damage, except for scab, which is a very important disease in Southeast Asia. These diseases contribute to lower yields by reducing photosynthetic area and transport of nutrients and products to the storage roots. In some countries, storage rots do not cause much damage because sweetpotatoes are consumed shortly after harvest. Tuber-rot pathogens, however, are present in the field and can cause significant losses. Plant parasitic nematodes are included as the cause of serious damage to storage roots both in the field and during storage.

Although the symptoms of virus diseases appear in the foliage, these have been accorded a separate section because of their importance. Of all the sweetpotato pathogens, viruses appear to contribute the most to yield losses.

# Viral Diseases

## Sweetpotato Feathery Mottle Virus (SPFMV)

Aphid-transmitted potyvirus

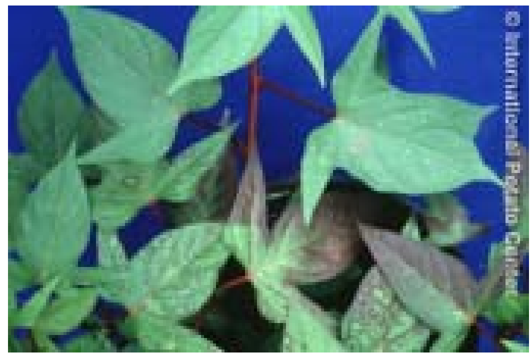
**Symptoms.** Symptoms of SPFMV on the foliage of sweetpotato are generally slight or absent. If present, they appear as faint, irregular chlorotic spots occasionally bordered by purplish pigment. Chlorosis (feathering) along midribs (Fig. 57) and faint-to-distinct chlorotic spots with or without purple margins occur in some cultivars (Fig. 58). Symptom visibility on foliage is influenced by cultivar susceptibility, degree of stress, growth stage, and strain virulence. Increased stress can lead to symptom expression, whereas rapid growth may result in symptom remission. Symptoms on storage roots depend on the strain of SPFMV and the sweetpotato variety. The common strain causes no symptom on any variety, but the "russet crack" strain causes external necrotic lesions or internal corking on certain varieties (Fig. 59). SPFMV can be latent in vines.

**Biology.** SPFMV is transmitted by a wide range of aphid species in the nonpersistent manner through brief feeds of only 20–30 seconds. Both colonizing species of aphids and winged aphids of noncolonizing species may transmit the disease. It is also perpetuated between cropping cycles in infected cuttings, but the lack of symptoms in the foliage makes it difficult for farmers to select SPFMV-free cuttings. In Uganda, symptom-free cuttings were mostly virus-free. SPFMV is found with SPSVV (see next section) in some countries; the combination results in a severe disease known as sweetpotato virus disease (SPVD).

**Distribution and importance.** Occurs worldwide.

**Control.** Aphid control is not economically feasible. The main controls are avoidance of use of diseased plants for cutting material, sanitation, and use of resistant varieties.


57




58


59

## Sweetpotato Sunken Vein Virus (SPSVV)

Whitefly-transmitted closterovirus

**Symptoms.** The symptoms reported for SPSVV vary geographically; in East Africa, the disease may cause stunting and color change in leaves (reddening or yellowing usually) depending on the variety. Elsewhere, symptoms include mild vein yellowing, some sunken seconday veins on adaxial leaf surfaces, and swollen veins on abaxial surfaces. The disease may also cause no symptoms.

**Biology.** SPSVV is transmitted by the whitefly *B. tabaci* in the semipersistent manner, needing feeds of several hours to acquire or transmit efficiently. It may also be perpetuated through cropping cycles via infected cut-tings. SPSVV is generally identified in combination with SPFMV, causing the severe disease SPVD (see next section).

**Distribution and importance.** By itself, SPSVV may cause only small yield losses, but combined infection with SPFMV causes SPVD, a severe disease associated with almost complete loss of yield. SPSVV occurs in Kenya, Uganda, and Nigeria, and has been reported in Asia, Argentina, Brazil, Peru, and the United States.

**Control.** The main controls are avoidance of diseased plants as sources of planting material and use of resistant varieties.



## Sweetpotato Virus Disease (SPVD)

**Symptoms.** Diseased plants become severely stunted and the leaves become small and narrow (straplike), often with a distorted edge. Puckering, vein-clearing, and mottling may occur. The mottling is often pale so that the whole plant may appear chlorotic.

**Biology.** This disease seems to be caused by a synergistic combination of SPFMV and SPSVV; it is unclear whether other virus combinations are involved.

**Distribution and importance.** SPVD is common in Africa, where it is the main virus disease of sweetpotato in Nigeria, Cameroon, Ghana, and Uganda. It causes virtually total yield loss in affected plants. It may be identical to a severe disease reported in the Americas. SPVD has also been reported in Argentina, Brazil, Peru, Kenya, the United States, and Taiwan.

**Control.** The main controls are avoidance of diseased plants as sources of planting material and use of resistant varieties. Farmers usually avoid diseased planting material because symptoms are so severe.

## Sweetpotato Mild Mottle Virus (SPMMV)

Whitefly-transmitted potyvirus

**Symptoms.** The predominant symptoms associated with SPMMV are leaf mottling and stunting (Fig. 60). Vein clearing and distortion may also occur. None of these symptoms is easily diagnosed in the field and the virus can be latent.

**Biology.** SPMMV is transmitted nonpersistently by the whitefly *B. tabaci.* It is also carried in infected cuttings. There is some evidence that SPMMV forms a complex with SPFMV, but this is unclear.

**Distribution.** It has been identified in Kenya, Uganda, Tanzania, and Indonesia, but yield effects are unknown.

**Control.** Some sweetpotato varieties appear to be immune and others are tolerant. Sanitation and selection by farmers of symptomless planting material also help achieve control.

**60**



# Other Viral Diseases

Other viruses have been identified through serological identification techniques, such as sweetpotato latent virus (SPLV), reported in Taiwan, Japan, Kenya, China, and Israel; sweetpotato chlorotic fleck virus (SPCFV), present in south-east Africa, Indonesia, the Philippines, China, Japan, and Central and South America; sweetpotato caulimo-like virus (SPCV), found in Puerto Rico, Madeira, New Zealand, Papua New Guinea, the Solomon Islands, and Kenya; sweetpotato ring spot virus (SPRSV), reported in Papua New Guinea and Kenya; and cucumber mosaic virus (CMV), found only in Israel, Kenya, and the United States. Sweetpotato chlorotic stunt virus (SPCSV) (Fig. 61) is found in Kenya and the Caribbean.


**61**

# Bacterial Diseases

## Bacterial Stem and Root Rot

*Erwinia chrysanthemi*

**Symptoms.** Aerial symptoms are water-soaked brown to black lesions on stems and petioles. One or two branches may wilt, and eventually the entire plant collapses (Fig. 62). Localized lesions on fibrous roots may also be present. On fleshy roots, localized lesions with black margins can be observed on the surface, but more frequently the rotting is internal, with no evidence outside (Fig. 63).

**Biology.** The pathogen has several other hosts in warm, humid areas of the world, where it remains in the soil on plant debris and weeds. Infection occurs through wounds.

**Distribution and importance.** This disease is found worldwide. Losses can be economically important.

**Control.** Cuttings for transplanting should be taken above the soil line. Using less-susceptible cultivars and taking care to avoid wounding can reduce disease incidence.




62


63

## Bacterial Wilt
*Pseudomonas solanacearum*

**Symptoms.** Infected stands usually contain some wilted plants (Fig. 64A). The disease starts at the base of the stem as yellowish water-soaked lesions that soon turn brown. The vascular bundles of affected stems and sprouts are discolored (Fig. 64B). In storage roots, vascular discoloration is also present, but mainly longitudinal brown streaks appear as well as brown water-soaked lesions on the surface (Fig. 64C). Slightly affected fleshy roots, when stored, can rot completely and develop a distinctive odor (Fig. 64D).

**Biology.** The bacterium is soil-borne, but it is usually carried with the propagative material. Once the soil is infested, the bacterium can persist from one to three years. Dissemination in the field can also occur via irrigation water.

**Distribution and importance.** The disease is important in some areas of southern China when susceptible varieties are grown.

**Control.** The use of less-susceptible varieties and disease-free planting material reduces disease incidence. When the bacterium is already present in the soil, flooding and crop rotation with graminaceous hosts are recommended.




64

## Soil Rot
*Streptomyces ipomoea*

**Symptoms.** The first indication of the disease is an extensive chlorosis and bronzing of the foliage as a consequence of the destruction of fibrous roots (Fig. 65). On storage roots, besides dark brown necrotic lesions, we frequently find cracks radiating from the center and malformations such as dumbbell-shaped roots (Fig. 66).

**Biology.** Soil rot causes more damage in dry alkaline soils. The pathogen can survive in soil for long periods.

**Distribution and importance.** This disease reduces yield and can be destructive in some areas of the United States and Japan.

**Control.** Planting material should come from areas where the disease is not present. Maintaining soil moisture helps reduce disease incidence. Using sulfur to reduce soil pH is another alternative, but large amounts of this element are required.




65


66

# Foliar and Stem Diseases Caused by Fungi

## Leaf and Stem Scab

*Elsinoe batatas, Sphaceloma batatas*

**Symptoms.** Brown to tan raised corky lesions, with purple to brown centers, appear along the stems (Fig. 67). Coalescing tiny lesions cover the leaf veins, thus making them shrink and causing the leaves to curl (Fig. 68).

**Distribution and importance.** The disease is important in Southeast Asia and the South Pacific Islands, where the pathogen causes serious losses from poor formation of fleshy roots. The disease is also present in Brazil.

Little is known about the biology of the pathogen. Humid weather, however, favors the disease.

**Control.** Good levels of varietal resistance are available. Pathogen-free planting material of the most resistant varieties and good sanitation practices should be used. The resistance of native and introduced material is being evaluated in Southeast Asia and the Pacific.


67

68

## Alternariosis, Anthracnose, Blight
*Alternaria bataticola*

**Symptoms.** Brown lesions with a typical bull's-eye appearance of concentric rings occur on leaves, especially older leaves. Black lesions appear on petioles and stems (Fig. 69). Bases and middle sections are more affected than the vine terminals. Death of vines can occur. The ground under affected vines is often carpeted with blackened leaf debris (Fig. 70).

**Biology.** Disease and lesion size increase with altitude. High relative humidity or free water is necessary for infection and sporulation. The fungus survives in debris, and the spores are spread through infected planting material, wind, splashing rain, and water.

Although *Alternaria* spp. can be found infecting sweetpotato in all agroecological zones, the form known as alternariosis or anthracnose occurs at mid to high elevations.

**Distribution and importance.** Published information and experience point to Alternaria blight as the most important fungal disease in East Africa and Brazil.

**Control.** Susceptibility to the pathogen varies among varieties. Pathogen-free planting material of the more resistant varieties and good sanitation practices will help control the disease.



69


70

## Phomopsis Leaf Spot (Phyllosticta Leaf Spot)

*Phomopsis ipomoea-batatas (Phyllosticta batatas)*

**Symptoms.** Whitish to tan to brown lesions, usually less than 10 mm in diameter, form on the upper and lower surfaces of leaves. The lesions usually have a dark brown or purple margin (Fig. 71). Pycnidia are visible in the center of the lesions (Fig. 72).

**Biology.** The fungus survives in debris and is not known to have other hosts. Spores spread through infected planting material, wind, splashing water, and possibly insects.

**Distribution and importance.** The disease is widespread and occurs in all agroecological zones. It is not known to depress yield, but it can reduce the quality of vines for planting material and fodder.

**Control.** No control measures are known. Control is not normally necessary.




71

72

## Minor Leaf Spot Fungi

Other fungi cause leaf spots and can be identified by inspecting spores with a microscope. These fungi are *Alternaria* spp., *Cercospora* sp. (Fig. 73), *Septoria* sp., *Ascochyta* sp., *Curvularia* sp., *Colletotrichum* sp., and *Pestalotia batatae*.

**Control.** No control measures are known. Control is not usually needed.




73

## Chlorotic Leaf Distortion

*Fusarium lateritium*

**Symptoms.** The first noticeable sign or symptom is a white, waxy (crusty) mucilaginous layer, which contains mycelium and sporodochia, that covers newly expanded leaves (Fig. 74). Microscopic observation reveals it on apical meristems and axillary buds. As the leaves age, the waxy covering spreads along the leaf margin and eventually disappears. In some cultivars and environments, leaves become chlorotic. Occasionally, leaves become distorted and plants are stunted (Fig. 75).

**Biology.** The pathogen may be present on the entire surface of the aerial part of the plant and it can be transmitted through true seed. It cannot be eliminated by surface disinfection of the seed. Symptoms are more severe in hot, dry weather. There is a long latent period (3–6 weeks) from infection to symptom expression.

**Distribution and importance.** The disease has been found in Peru, a few areas of East and Central Africa—primarily at low altitudes where it is hot and dry—and in the United States. It is not known to cause economic damage in its less-virulent form. When stunting and distortion occur, losses should be expected.

**Control.** Pathogen-free planting material is essential. Varietal differences in susceptibility are observed. Use vegetative planting material from plants free of symptoms. Do not harvest true seed from diseased plants, especially if the seed is to be shipped to areas where chlorotic leaf distortion is not present. No chemical control is known.




74


75

## Fusarium Wilt

*Fusarium oxysporum* f. sp. *batatas*

**Symptoms.** The first indication of this disease is a dullness and yellowing of the leaves, followed by wilting and death of the vine. Affected vines show the vascular discoloration typical of this disease (Fig. 76).

**Biology.** The fungus is soil-borne and specific to sweetpotato and a few close relatives, and barley and flue-cured tobacco. It can survive in the soil and in debris for several years. Though tip cuttings are usually pathogen-free, roots and cuttings from the base of the vine can be infected. Movement of infested soil on tools and by animals can lead to outbreaks in new areas. The disease occurs under a variety of environmental conditions. Yield reduction depends on the stage of plant growth when disease occurs.

**Distribution and importance.** This disease is found in most areas where sweetpotato is grown and is more important in temperate areas than in the tropics.

**Control.** Good sanitation will help reduce the impact of the disease and limit its spread. Some varietal resistance has been observed, and breeding programs in some countries have released resistant varieties.



**76**

## Violet Root Rot
*Helicobasidium mompa*

**Symptoms.** Affected plants become chlorotic and may defoliate. Fibrous roots rot and become covered with thick whitish threads of mycelium that soon become pink and finally violet (Fig. 77). Storage roots start rotting apically and then they completely decay and are covered by the same mycelial mat as the fibrous roots. At the same time, flat black sclerotia are formed. This violet mat of coarse mycelium and sclerotia may be found on the ground in places where plants have rotted. Rotted storage roots have a characteristic smell of alcohol.

**Biology.** The fungus has a wide host range besides sweetpotato. It can survive in the soil for at least 4 years as mycelium or as sclerotia. Infected transplants and irrigation water can disseminate the fungus. Temperature is not a limiting factor for disease development, but considerable moisture in the soil favors the disease.

**Distribution and importance.** The disease is present in several areas of Asia and the Americas. It can cause serious losses in Asia.

**Control.** Planting material should come from healthy plants. Early maturing varieties can escape the disease. Rotation with cereals can also help prevent the disease.




**77**

## Sclerotial Blight and Circular Spot
*Sclerotium rolfsii*

**Symptoms.** Sclerotial blight and circular spot are two diseases caused by the same pathogen.

Blight symptoms start in both seedbeds and newly planted stands. Shoots emerging from the mother root suddenly collapse and die. Affected shoots are easily pulled and separated from the rest of the plant. A mat of white mycelium and numerous round brown sclerotia resembling rapeseed are found at the base of affected plants (Fig. 78). Circular spots are observed only in fleshy roots. Symmetric brown sunken lesions that sometimes show crackings are present (Fig. 79).

**Biology.** The fungus attacks several plant species. It is soil-borne and survives for long periods as sclerotia. Moisture and organic matter in the soil favor attack.

**Distribution and importance.** This disease is common in tropical and subtropical regions of the world. Losses are not usually serious.

**Control.** Disease incidence can be reduced by avoiding growing sweetpotato in infected soils and using disease-free planting material. The use of good sanitation and less-susceptible cultivars also helps to reduce the disease.



78

79

## Black Rot
*Ceratocystis fimbriata*

**Symptoms.** Dark to black sunken cankers in the lower part of the stem are the most distinctive symptom. In severe infections, yellowing, wilting, and plant death can occur. Affected storage roots develop black to gray sunken areas (Fig. 80) on which black spine-like structures of the fungus can be seen protruding from the surface of roots. A smell of alcohol resembling that of fermenting sugar is frequent.

**Biology.** The use of infected cuttings for planting perpetuates the disease. Transmission occurs through wounds made by sweetpotato weevils (such as *Cylas* spp.), wireworms, crickets, and mice. The fungus is a soil inhabitant that can remain 1–2 years in crop debris. Moisture does not affect disease development.

**Distribution and importance.** The disease is particularly important in Southeast Asia and Oceania where it reduces yield and quality of fleshy roots.

**Control.** Cuttings for transplants should come from pathogen-free planting material. In places where it is difficult to find healthy mother plants, cuttings should be made 2 cm above the soil line to avoid infected portions of the plant. Rotate with nonhost plants for at least 2 years and use good sanitation practices. Cure during the 5 days following harvest at 30–35°C and 85–90% relative humidity.




80

# Storage Root and Postharvest Diseases

## Foot Rot

*Plenodomus destruens*

**Symptoms.** Brown lesions form on the stem at or below the soil line. Wilting and death occur in severe cases. Black pycnidia can be seen (Fig. 81). A canker extends down the stem and affects the proximal end of the storage root (Fig. 82). This decay is dark brown, firm, and dry.

**Biology.** The fungus does not survive well in the soil except in infected roots and stems. It is spread by infected cuttings, especially those from the base of the vine, and by contact with spores from infected roots in storage. Other hosts include members of the Convolvulaceae. Diseased roots should not be stored.

**Distribution and importance.** This disease is found in Peru, Brazil, and Argentina. Storage damage can reduce marketability.

**Control.** Sanitation and the use of healthy vine tips for planting are the best means of control in the field.




81


82

## Java Black Rot

*Lasiodiplodia theobromae*
(*Diplodia gossypina*)

**Symptoms.** This rot is firm and moist initially, but storage roots soon become totally blackened and mummified. Rot starts at either or both ends of the storage root and is initially brown, before turning black. Eruptive black stromatic masses that bear pycnidia are a diagnostic feature (Fig. 83).

**Biology.** Java black rot is spread by infested soil, infected storage roots, and contaminated storage boxes, baskets, or tools. Infection occurs via wounds, especially the cut stem end. Though the pathogen can infect stems, it grows very little and is seldom a problem. Yields can be reduced in the field or through storage losses.

**Distribution and importance.** This disease is distributed worldwide. It is one of the most important storage diseases of sweetpotato.

**Control.** Timely harvesting can reduce losses. Good sanitation and care in handling to reduce wounding are important.




**83**

# Charcoal Rot

*Macrophomina phaseolina*

**Symptoms.** This disease is found only on fleshy roots during storage. The fungus does not attack other plant parts. Infection starts on the surface of the root and progresses through the vascular ring toward the pith.

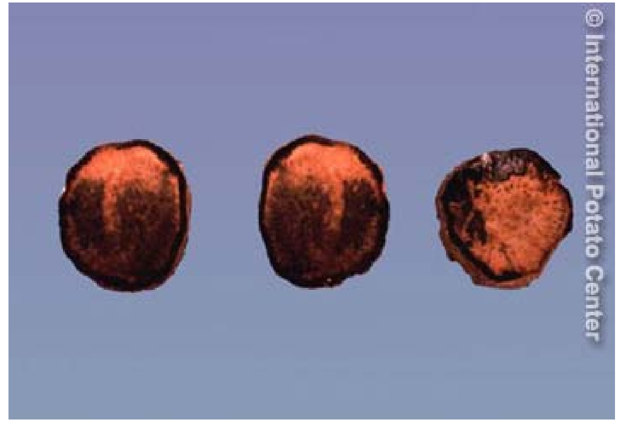
Three distinct zones are found in a cross section of an infected root: an unblemished periderm, an inner zone about 6 mm wide of reddish brown tissue where a crusty layer of sclerotia is found, and the inner part of the root with light tan tissue. Sometimes the center of the pith splits and the entire root becomes mummified (Fig. 84).

**Biology.** The fungus is distributed worldwide and attacks several plant species. It is soil-borne and can survive saprophytically on plant debris or freely as sclerotia.

**Distribution and importance.** This disease is found in tropical and subtropical areas of the world. Losses are seldom serious.

**Control.** No control measures are known.






84

## Soft Rot
(*Rhizopus stolonifer, Mucor* sp.)

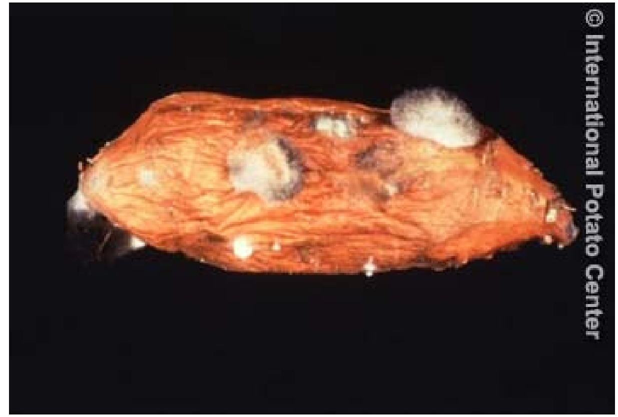
**Symptoms.** Soft rotting occurs after harvest. Storage roots become soft, wet, and stringy, often starting at one end. A strong alcohol-like odor is produced. These fungi are commonly seen sporulating on the surface of rotting storage roots (Fig. 85).

**Biology.** The disease is spread by infested soil or air-borne spores that enter wounds. Optimum relative humidity and temperature for progress of infection and disease vary by variety, but are usually high. Soft rot can destroy harvested roots in 48 hours if they are left unprotected under sunlight.

**Distribution and importance.** This disease is found worldwide in sweetpotato and other crops. It attacks the fleshy organs of plants that are rich in sugar or starch.

**Control.** Washing storage roots is especially conducive to rot. Care in handling and proper curing can reduce disease incidence. So far, no resistance has been found, but some varieties rot faster than others because they are more susceptible. Curing is accomplished by storing after harvest at 29–32°C and 95–100% relative humidity for 5–7 days with adequate ventilation (at least 8 cubic feet of air per ton per day). Subsequent storage is best at around 13°C and 95% relative humidity.






85

# Diseases Caused by Nematodes

## Root-Knot Nematode
*Meloidogyne* spp.

**Symptoms.** Affected plants become stunted, foliage turns yellow and flagging, and flower production is abnormal. On fibrous roots, round to spindle-shaped swellings (galls) are produced together with egg masses on the surface (Fig. 86). Large portions of the root system can become necrotic. The storage roots of some varieties react with longitudinal cracking (Fig. 87), whereas in others, blister-like protuberances emerge through the epidermis (Fig. 88).

**Biology.** *Meloidogyne* spp. are distributed worldwide on several hosts, such as potato and tomato. These nematodes survive in the soil as egg masses and in plant debris as infective juveniles. They can be transported by irrigation water and disseminated through infested propagating material.

**Distribution and importance.** This root-knot nematode is one of the most destructive on sweetpotato because of its wide distribution and damage caused to storage roots.

**Control.** Resistance, crop rotation (such as with rice in Asia), and selected nematode-free planting material can help to control this disease. In East Africa, nematodes are rarely associated with sweetpotato and no control measures are needed.




86


87


88

## Brown Ring
*Ditylenchus destructor, D. dipsaci*

**Symptoms.** Fleshy roots, some time after they are stored, show symptoms as depressed areas (Fig. 89). In cross sections, initial infections appear as necrotic isles of brown tissue scattered throughout the flesh. In advanced stages, the pulp becomes completely blackened, slightly soft, and corky (Fig. 90). These nematodes affect fleshy roots only during storage. No symptoms have been found in the field.

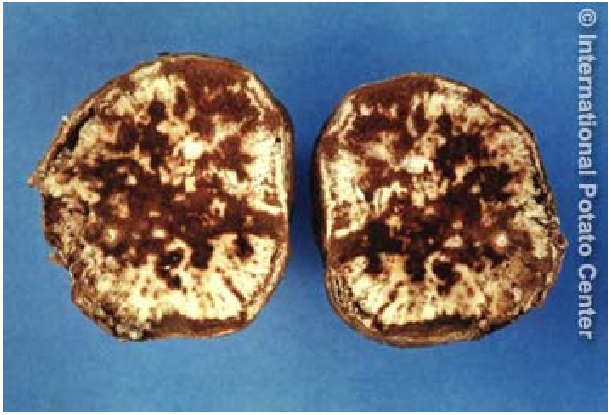
**Biology.** The two species of *Ditylenchus* are distributed worldwide and have a vast host range. They are migratory endoparasites.

**Distribution and importance.** On some occasions, storage losses can be serious.

**Control.** No control measures are known.



89



90

## Reniform Nematode
*Rotylenchulus reniformis*

**Symptoms.** Symptoms are not distinctive and can be confused with those caused by other nematodes. Affected plants are stunted because of destruction of fibrous roots. Foliage becomes chlorotic and transitorily wilted. Fleshy roots, when attacked early, develop cracks that enlarge as the roots grow. In mature roots, deep suberized cracks are the most noticeable symptom (Fig. 91).

**Biology.** This nematode can survive in dry soil and live and infect roots under dry conditions.

**Distribution and importance.** The nematode mainly occurs in western and northern Africa, India, the Caribbean islands, the United States, and some Pacific islands. Crop yield and quality can be affected.

**Control.** Rotation with nonhost crops is recommended to reduce the soil population of the nematode.




91

# Lesion Nematode

*Pratylenchus* spp.

**Symptoms.** Affected plants are stunted because of a reduced feeder root system. On fibrous roots, lesion nematodes produce small, brown necrotic lesions. Affected fleshy roots also show blackish brown lesions that are often invaded by saprophytic fungi and bacteria (Fig. 92).

**Biology.** Different species of these nematodes are found worldwide parasitizing several plant species. They are migratory endoparasites and leave the roots when the lesions they produce are parasitized by secondary organisms. Damage is more severe in sandy soils with high temperature.

**Distribution and importance.** Although it is dis-tributed worldwide, this nematode has caused significant losses only in Japan.

**Control.** Organic amendments such as manure increase the natural enemies of the nematode in the soil and reduce its population. The use of resistant varieties is also recommended.




**92**

# Disorders of Unknown Origin

## Fasciation

Cause unknown

**Symptoms.** Vines become very broad and flattened—fasciated (Fig. 93). This symptom becomes more pronounced toward the shoot tip.

**Biology.** Plants have been known to exhibit spontaneous remission of symptoms. It has been suggested that this is a physiological disorder or that it is caused by a bacterium of the *Rhodococcus* genus.

**Distribution and importance.** Fasciation is found throughout the world wherever sweetpotato is grown. It is not known whether yields are affected.

**Control.** No control is known.




93

# Nutritional Disorders and Their Management

Plant nutrients are chemical elements that are essential to plant tissue. For healthy growth, plants require an adequate supply of each of these elements. The most abundant elements in plants—carbon, oxygen, and hydrogen—are obtained from the air and water. The others are referred to as mineral nutrients, and are supplied by the mineral and organic components of the soil. They are divided into two groups, according to their abundance in plants. The macronutrients—nitrogen (N), potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), and sulfur (S)—comprise from 1 g to 60 g per kg of dry plant material. The micronutrients, including iron (Fe), boron (B), manganese (Mn), zinc (Zn), copper (Cu), and molybdenum (Mo), make up 0.1–100 mg per kg of dry weight.

A deficiency of any particular nutrient results in reduced growth rate and yield. It can only be corrected by increasing the supply of that nutrient; therefore, accurate diagnosis of nutritional disorders is essential for efficient corrective treatment. Supplying a nutrient in excess of crop requirements is costly and of no benefit.

Many mineral nutrients (such as boron, manganese, and copper) are toxic to plants if present at high concentrations. Other elements, which are not essential nutrients, may also cause toxicity, such as aluminum, in acid soils, and sodium.

## Causes of Nutritional Disorders

Supply of a mineral nutrient to a plant is influenced by

- its total abundance in the soil,
- the proportion of the total in an available form at any time, and
- the plant's ability to capture it.

Usually only a small proportion of the total nutrient is available for uptake. Availability may be affected by soil pH—at high pH (alkaline soil), the solubility of many micronutrients is greatly reduced, and the crop may experience deficiencies such as iron, zinc, or manganese. At low pH (acid soil), the solubility of macronutrients, particularly phosphorus, is reduced, while that of aluminum and manganese may be increased to toxic levels. Disorders such as aluminum toxicity, which inhibits root development, reduce the plant's ability to capture nutrients and water, and may induce symptoms of secondary disorders such as magnesium deficiency or water stress. It is important to recognize the primary agent in such cases.

Deficiencies of macronutrients, particularly nitrogen, phosphorus, and potassium, are often associated with a fertility decline following sequential cropping. They are taken up in such large quantities that the soil's reserves become depleted. High cropping intensity increases dependence on external supplies of these nutrients. In low-intensity agriculture, supplies may be replenished by

- fallow periods, which allow time for weathering of mineral particles;
- redistribution of nutrients into the crop's root zone from below; and
- accumulation in plant material of nutrients, which become available to the crop when it decomposes or is burned.



Burning fallow makes nutrients immediately available to the following crop, but they are easily lost by rain leaching and some, particularly N and S, are lost into the atmosphere. Burning decreases the soil's ability to continue supplying nutrients, as there is less organic material to decompose.

Deficiencies of micronutrients are usually associated with low natural abundance in the soil, or unfavorable soil conditions that cause insolubility of these nutrients. Correction of a micronutrient deficiency usually requires only a few kg per ha, and may be effective for a number of years. Such inputs are likely to be cost-effective, even when the application of nitrogen or phosphorus fertilizers is not.

## Diagnosing Nutritional Disorders

Plants respond to a deficiency of any nutrient first by decreasing growth rate. Specific symptoms, which may allow the deficient nutrient to be identified, usually occur only at relatively severe levels of deficiency. Nevertheless, such symptoms are often the first thing to alert the grower that there is a problem, and they are very useful for diagnosis. Chemical analysis of the plant tissue provides a second diagnostic tool, which can be quite valuable when available.

If a soil is deficient in several nutrients, the plant usually shows symptoms of the deficiency that is most limiting to growth. If that nutrient is supplied, growth rate will increase until it is limited by the next most scarce nutrient, and a new set of symptoms may develop. It is difficult to establish from plant symptoms or tissue composition which nutrients are deficient other than the most limiting one. Soil tests may provide some guidance, but they must be calibrated for the crop and soil type at each location.

If a nutrient deficiency is suspected, the best way to confirm it is by observing a positive response to fertilizer containing that nutrient, and preferably no other (for example, urea, containing N, is preferred to ammonium sulfate, containing N and S, for confirming N deficiency). When testing a fertilizer response, it is important to have a control area for comparison, such as an area treated in exactly the same manner, except for the omission of the nutrient being tested.

## Correcting Nutritional Disorders

Nutrient deficiencies are alleviated by increasing the supply of the deficient nutrient. Applying chemical fertilizers is one way of doing this. Another may be to add organic material such as animal manure, if it contains an appropriate balance of the required nutrients. Other approaches aim to change the soil properties, in order to increase the availability of nutrients already present, or to reduce the supply of elements causing toxicity. The pH of acid soils may be increased by adding lime. Improved drainage may be necessary to reduce denitrification, to reduce the production of toxic forms of manganese, or simply to ensure that roots receive enough air to function well.

Increasing the organic content of the soil has a number of beneficial effects. The gradual decomposition of this material provides a steady supply of available nutrients. The organic particles may also provide a suitable substrate for the soil's nutrients to be held in an available form. Organic matter increases the soil's ability to resist acidification. It also increases water retention so that soil takes longer to dry out, and gives the soil an open texture so that more air can get to the roots, which need oxygen. Organic matter is increased by leaving crop or fallow residue



on the field, without burning, or by bringing plant material from another site. If the need for field sanitation requires removal of crop residues, then these may be composted and returned later, or used to mulch another crop that is not at risk from a specific pest or disease.

Where fertilizers and water are readily available and cheap, growers may aim to maximize crop potential by eliminating nutritional stress. Where fertilizers are unavailable or expensive, the aim may be to optimize use of resources in the agroecosystem, in order to obtain an adequate and sustainable economic return. At whatever level of operation, it is important to recognize the limitations of the resource base. A traditional cropping system may become unsustainable through intensification; however, intensification is frequently paralleled by a shift from subsistence to cash cropping. At some point in that progression, the purchase of inputs may become profitable. Growers and their advisers should remain aware of these options, even if they are not currently cost-effective.

## Nutrient Requirements of Sweetpotato

Sweetpotato is regarded as tolerant of low fertility because it may give adequate yields on soils where few other crops do. Tolerance, however, comes at a cost, and often large increases in yield can result from a modest increase in nutrient supply. The nutrient requirement of the crop depends on what yield is considered adequate.

Most of the nutrients taken up by a sweetpotato crop are removed from the site when the crop is harvested. The amount of nutrients removed depends on the yield, and on whether the vines are removed from the field as well as the roots. Table 1 gives the approximate rates of nutrient removal for crops yielding 12 t/ha of storage roots (the global average) and 50 t/ha (a high yield). In an intensive farming system, those nutrients for which the soil has limited reserves may be replaced by fertilizers; in addition to crop removal, nutrient losses through leaching, soil erosion, and fixation will determine the actual fertilizer requirement. In less intensive systems, the rate of cropping that is sustainable will depend on the time required for mobilization of soil reserves or decomposition of organic material to replenish the nutrient pools in the soil.

In the following sections, we describe briefly the most common nutritional disorders of sweetpotato.



**Table 1.** Estimated removal of nutrients from the soil by sweetpotato crops of 12 t/ha (average) and 50 t/ha (high), for a situation in which only storage roots are harvested and both roots and vines are removed.

| Nutrient | Nutrient removal[1] (kg/ha) by crop with root yield of: | | | |
|---|---|---|---|---|
| | 12 t/ha | | 50 t/ha | |
| | Roots alone | Roots & vines[2] | Roots alone | Roots & vines[2] |
| Nitrogen | 26 | 52 | 110 | 215 |
| Phosphorus | 6 | 9 | 25 | 38 |
| Potassium | 60 | 90 | 250 | 376 |
| Calcium | 3.6 | 16 | 15 | 65 |
| Magnesium | 3 | 6.5 | 12.5 | 27 |
| Sulfur | 1.8 | 4.3 | 7.5 | 18 |
| Iron | 0.060 | 0.160 | 0.250 | 0.670 |
| Boron | 0.024 | 0.074 | 0.100 | 0.310 |
| Manganese | 0.024 | 0.175 | 0.100 | 0.730 |
| Zinc | 0.036 | 0.062 | 0.150 | 0.260 |
| Copper | 0.018 | 0.037 | 0.075 | 0.155 |
| Molybdenum | 0.004 | 0.006 | 0.015 | 0.023 |

[1] Concentrations of nutrients in sweetpotato roots and tops vary considerably. Quantities given are based on representative concentrations from a number of sources, converted to a fresh weight basis assuming 70% moisture in storage roots and 86% moisture in vines.

[2] A vine to root weight ratio of 0.6 was assumed. Actual ratios may vary from 0.3 to 1.4.

## Nitrogen Deficiency

**Occurrence.** Nitrogen deficiency is very common, especially on sandy soils, soils with little organic matter, and any soils that have been repeatedly cropped without replacing nitrogen. Marshy areas are particularly prone, as waterlogging encourages denitrification by soil bacteria.

**Symptoms.** Nitrogen-deficient plants grow slowly and have small, pale green, dull leaves (Fig. 94). In many cultivars, red pigmentation is increased on the petioles and veins of young leaves; this may be more visible on the underside of the leaf. The oldest leaves may die prematurely as their nitrogen is remobilized for new growth. They usually turn uniformly yellow before wilting and drying (Fig. 95).

**Correction.** Nitrogen may be added in the form of inorganic fertilizers, animal manure, plant compost, or mulch, or by growing leguminous plants in the field, intercropped or in rotation with sweetpotato.

Various nitrogen-containing fertilizers are available, including urea, ammonium sulfate, calcium nitrate, or combined NPK fertilizers. All supply nitrogen in a form that is immediately available to plants. The choice should be made on the basis of cost per kg of nitrogen, and whether the other elements contained in the preparation, such as calcium or sulfur, will be beneficial. As nitrogen is easily lost from the soil by leaching and microbial activity, split application is preferred, with a smaller dose at planting and the larger proportion after the crop is well established (6–8 weeks), when its roots are more able to intercept it.




**94**

Rates of nitrogen fertilizers in excess of crop requirements may reduce yields in sweetpotato by causing vigorous growth of vines at the expense of storage roots. The optimum level of nitrogen supply varies among cultivars.

Animal manures are a rich source of nitrogen, although the quantity of manure needed will be much higher than for chemical fertilizers; it also depends on the ratio of dung to straw and the moisture content. Plant material is also beneficial, but it has a lower nitrogen content.

Leguminous plants fix nitrogen from the atmosphere, which becomes available to the sweetpotato crop when the legume material breaks down. These plants may be grown either in rotation with sweetpotato or as an intercrop. They perform best if crop residue is left on the field or incorporated into the soil. Alternatively, leafy prunings from leguminous trees growing on other sites may be applied as a mulch. The labor required is significant, as quantities on the order of 20–40 t/ha are needed to supply sufficient nitrogen to maximize yield.




95

## Phosphorus Deficiency

**Occurrence.** Phosphorus compounds in the soil have a low solubility, so that only a small proportion of the soil's phosphorus is available to plants. As a result, phosphorus is often the most limiting nutrient for plant growth. Many plants, including sweetpotato, form a symbiotic association with root-infecting fungi (known as mycorrhizae), which increase their ability to extract phosphorus from the soil.

Oxisols, ultisols, and many volcanic ash soils have a great capacity to bind, or "fix," phosphorus, making it unavailable to plants. On these soils, very high rates of phosphorus fertilizers may be required to maximize the yield response of the crop. After several years of such applications, however, the binding capacity will become saturated, and much lower rates are then adequate to maintain fertility.

**Symptoms.** Phosphorus deficiency can reduce plant growth considerably without inducing visible symptoms. Therefore, this disorder is difficult to recognize until it is quite severe. An experienced grower may note a darker than normal color, together with poor growth rate.

The first visible symptom in many cultivars is the development of red-brown or purple pigmentation on the older leaves (Fig. 96). As the oldest leaves begin to die, yellowing develops unevenly, spreading from diffuse spots, the tip region, or one half of the blade (Fig. 97). Bright autumnal colors may develop with yellow and orange combining with the purple pigment (Fig. 98).



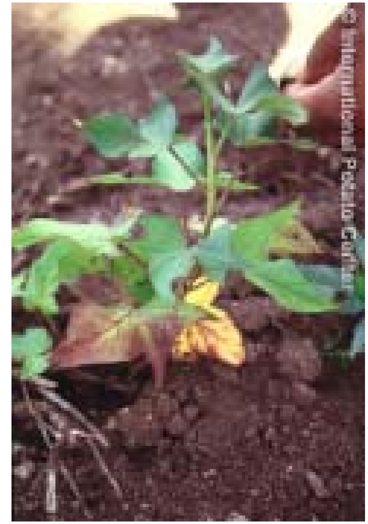

**96**


**97**

On some cultivars, purple pigmentation may appear or be increased on the young leaves. Nitrogen deficiency may produce a similar symptom, but in the case of phosphorus deficiency, the whole plant is not pale, but dark green.

**Correction.** Phosphorus is usually applied as superphosphate (single or triple) or in combined NPK fertilizers. Because it is relatively slow to dissolve and has low mobility in the soil, it may be applied at planting. Band or spot application close to the plants is usually more efficient than broadcasting, especially on phosphorus-fixing soils. Rock phosphate may be an effective source on acid soils. Liming of acid soils may increase the availability of native soil phosphorus.

Phosphorus is also contained in animal manures and plant material. Increasing the organic content of the soil also increases availability of phosphorus to plants, and applying plant mulch in conjunction with inorganic phosphorus fertilizer may increase its efficiency. Organic matter in the soil may also reduce the effects of acidification.




98

## Potassium Deficiency

**Occurrence.** Potassium deficiency is common on sandy soils and on leached oxisols and ultisols, whereas many volcanic ash soils are well supplied with potassium. Sweetpotato and other root crops remove much more potassium from the soil than do cereals or pulse crops. A 15 t/ha sweetpotato crop removes approximately 80 kg/ha of potassium. If the vines are also removed, the additional loss is 30–50 kg/ha. Therefore, it is not surprising that potassium deficiency is a common problem on soils that have been continuously cropped without potassium fertilization.

**Symptoms.** Visible symptoms often appear when the crop is a few months old, at a time when the developing storage roots are placing increasing demand on potassium supplies.

The first signs may appear on mature leaves, which develop a light green chlorosis between the fine veins (Fig. 99). The oldest leaves become yellow, particularly around the margin and in areas between the main veins. The yellow tissue eventually dies, usually turning dark brown and brittle.

**Correction.** Potassium may be supplied in organic material or as inorganic fertilizer. Plant material can be applied either as compost or as a surface mulch. It should be noted that, if a whole region is potassium deficient, then locally grown plant material will have a low potassium concentration. Inorganic fertilizers include potassium chloride (muriate of potash) or potassium sulfate, or combined NPK fertilizers. A split application, at planting and after 4–6 weeks, is often most effective.




**99**

## Magnesium Deficiency

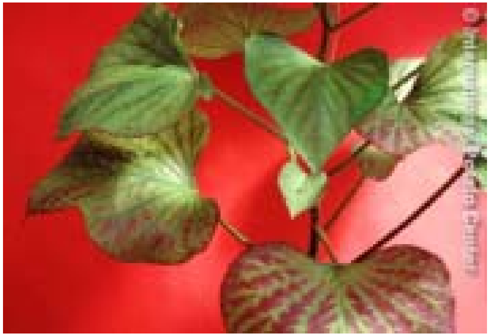
**Occurrence.** Magnesium deficiency is most likely to occur on sandy soils and on volcanic soils of high potassium status, as high concentrations of potassium tend to inhibit magnesium uptake. In strongly acid soils, magnesium deficiency may be induced as an effect of aluminum toxicity.

**Symptoms.** The crop tends to have a generally pale color and vines become thin and twining. Older leaves develop pale green to yellow interveinal chlorosis, in which the main veins retain a margin of 1–3 mm of darker green tissue (Fig. 100). Affected leaves are often slightly wilted and drooping. Red or purple pigmentation may appear on the upper surface of older leaves, over interveinal patches (Fig. 101), or on the lower surface, where the minor veins may become red. On the oldest leaves, yellow areas become brown and necrotic, but usually remain soft. The entire leaf then turns yellow and wilts (Fig. 102).

**Correction.** On acid soils where magnesium deficiency is known to be a problem, dolomitic lime or magnesium oxide (20–50 kg/ha Mg) may be incorporated into the soil. To correct symptoms in an existing crop, magnesium sulfate (10–40 kg/ha Mg, as a band application or foliar spray) is preferred as it is more rapidly soluble. Kieserite, a naturally occurring form of magnesium sulfate, is available in some countries.



100



101

102

## Boron Deficiency

**Occurrence.** Sweetpotato seems to be more susceptible to boron deficiency than many other crops. Boron deficiency of sweetpotato has been observed in diverse environments, such as on highly weathered ultisols in the Papua New Guinea highlands, on granitic sands in northern Australia, and on clayey river flats in Malawi. Dry or cold conditions, which restrict root development, seem to exacerbate boron deficiency; recovery may occur following rains or warmer weather.

**Symptoms.** Boron deficiency affects actively growing tissue of both the shoot and roots. Young leaves become small, thickened, and brittle, and often puckered (Fig. 103). Tips of lobes may curl under and petioles may twist. On the vines, internode length is reduced in most, but not all, cultivars. In many cultivars, young leaves also become pale, either uniformly or with a diffuse interveinal pattern (Fig. 104). In severe cases, the shoot tip shrivels and dies.

Storage roots are often short and blunt-ended or spherical, and may split and overgrow, resulting in deformities (Fig. 105). The cut root exudes less white sap than normal, and flesh may be mottled or corky in places. The flavor is less sweet, or even bitter.

**Correction.** Boron deficiency can be controlled by fertilizing with borax or other borates at around 1 kg/ha B on sandy soils, to 3 kg/ha B on clay soils. Foliar application is often recommended for other crops, but appears to give a poor response in sweetpotato. Boron is not transported within the plant from vines to roots. Although the tops may appear healthy after foliar spraying, symptoms persist on the storage roots.




103

104

105

## Iron Deficiency

**Occurrence.** Because iron becomes less soluble with increasing alkalinity (that is, as pH increases above 7), iron deficiency is a common disorder on calcareous soils. It may also be induced by overliming or excessive use of phosphate fertilizers. It may be a secondary symptom of other disorders that impair root function, including calcium deficiency and heavy metal toxicities.

**Symptoms.** Symptoms are conspicuous and distinctive. Young leaves become yellow or almost white, with green veins sharply contrasting (Fig. 106). In severe cases, the young leaves become necrotic and the tip and axillary buds may die (Fig. 107). Diagnosis can be confirmed by painting a chlorotic leaf with a 1% solution of ferrous ammonium sulfate, which will cause regreening after a few days (Fig.108).

**Correction.** Soil application of iron compounds on alkaline soil is inefficient due to precipitation of the iron. Burying small pieces of scrap iron, such as nails and tin cans, in the mound before planting can reduce severity. Foliar sprays of iron chelate or ferrous ammonium sulfate solution are recommended for treatment of an iron-deficient crop.




106


107


108

## Acid Soils and Aluminum Toxicity

**Occurrence.** Acidity (low soil pH) is very common on tropical crop land and tends to increase over a period of cropping if not amended. Acidity causes reduced availability of macronutrients, particularly phosphorus, while the solubility of aluminum (and manganese in some soils) may be increased to toxic levels.

**Symptoms.** Aluminum toxicity is the most common disorder associated with acid soils. It impairs root growth (Fig. 109A, no Al added; Fig. 109B, 50 mM Al added), and the visible symptoms on vines are often secondary consequences of poor root function. Symptoms of water stress are common. Uptake of nutrients, particularly calcium and magnesium, is impaired, and symptoms of calcium or magnesium deficiency may develop. Phosphorus deficiency may be evident on acid soils as a result of reduced solubility of phosphate.

**Correction.** Soil pH is elevated by incorporating lime or dolomite into the soil. The amount required depends on the soil type; overcorrection can lead to micronutrient deficiencies associated with alkalinity. Maintaining high soil organic matter levels helps to slow acidification and to detoxify aluminum (see introductory section).



109A

109B

## Salinity

**Occurrence.** Salinity is usually a problem of irrigated land in arid to semiarid environments. It arises either by contamination of the topsoil by saline groundwater or by accumulation of salts contained in irrigation water. Other areas, such as coastal plains, may be affected by salinity.

**Symptoms.** Salt-affected plants may show symptoms of water stress despite adequate moisture in the soil. Older leaves may develop brown necrotic spots, turn yellow, and fall off (Fig. 110). In severe cases, the stem below the tip may shrivel and die.

**Correction.** If the problem is associated with saline groundwater, improved drainage is recommended. More efficient use of irrigation water can slow salination and prevent groundwater from rising. Often, the most useful strategy is to select a more salt-tolerant cultivar of sweetpotato.




110

# Literature Consulted

**Allard, G.B. 1993.** Integrated control of arthropod pests of root crops: Annual report. CAB International Institute of Biological Control, Kehya Station, Nairobi, Kenya. 95 p.

**Amalin, D.M. and E.A. Vasquez. 1993.** A handbook on Philippine sweetpotato arthropod pests and their natural enemies. International Potato Center (CIP), Los Baños, Philippines. 82 p.

**Arene, O.B. and A.O. Nwankiti. 1978.** Sweetpotato diseases in Nigeria. PANS 24(3):294-306.

**Autrique, A. and D. Perreaux. 1989.** Maladies et ravageurs des cultures de la region des grand lacs d'Afrique Centrale. Administration Generale de la Cooperation au Développement. Brussels, Belgium. 232 p.

**Bradbury, J.H. and W.D. Holloway. 1988.** Chemistry of tropical root crops: Significance for nutrition and agriculture in the Pacific. ACIAR Monograph No. 6, Canberra, Australia. 201 p.

**Bradley, J.D. 1968.** Two new species of clearwing moth (Lepidoptera, Sesiidae) associated with sweetpotato (*Ipomoea batatas*) in East Africa. Bull. Entomol. Res. 58:47-53.

**Castineiras, A. 1988.** Relaciones de *Pheidole megacephala* (Hymenoptera: Formicidae) con *Cylas formicarius elegantulus* (Coleoptera: Curculionidae) en el cultivo del boniato, *Ipomoea batatas*. Cienc. Tec. Agric. (Cuba) 18:15-19.

**COPR (Centre for Overseas Pest Research). 1982.** Pest control in tropical root crops. PANS Manual No. 4. England. 235 p.

**Chiu, Ren-jong. 1976.** Sweetpotato diseases of non-viral origin. ASPAC Tech. Bull. (Taipei) 28:1-14.

**Clark, C.A. and J.W. Moyer. 1988.** Compendium of sweetpotato diseases. The American Phytopathological Society, St. Paul, MN, USA. 74 p.

**Clark, C.A., R.A. Valverde, J.A. Wilder-Ayres, and P.E. Nelson. 1990.** *Fusarium lateritium*, causal agent of sweetpotato chlorotic leaf distortion. Phytopathology 80:741-744.

**Cuthbert, F.P. Jr. 1967.** Insects affecting sweetpotatoes. U.S.D.A. Agric. Handb. 329 p.

**Franssen, C.J.H. 1935.** Insect pests of the sweetpotato crop in Java: Korte Meded. Inst., Pezickt, Buctenzong 10:205-225. (In Dutch.) (Translation published, 1986, Asian Vegetable Research and Development Center, Shanhua, Taiwan.)

**Fresa, R. and F. Corvalio. 1966.** Podredumbre del pie de la batata *Plenodomus destruens*. Rev. Investig. Agropecu., Serie 5, Patol. Veg. INTA Argentina 3(6):47-50.

**Harter, L.L. 1944.** Sweetpotato diseases. U.S.D.A. Agric. Farmer's Bull. No. 1059. 26 p.

**Hildebrand, E.M. and H.T. Cook. 1959.** Sweetpotato diseases. U.S.D.A. Farmer's Bull. No. 1059. 28 p.

**Hill, D.S. 1983.** Agricultural insect pests of the tropics and their control. 2nd ed. Cambridge University Press, Cambridge, UK. 746 p.

**IIBC (International Institute of Biological Control). 1991.** Sweetpotato management in Kenya. A.S. Abubaker, G.B. Allard, and D.K. Langi (eds.). Proceedings of a national workshop held in Mombasa, Kenya, 7-11 May 1990. 90 p.

**Jansson, R.K. and K.V. Raman (eds.). 1991.** Sweetpotato pest management: A global perspective. Westview Press, Boulder, CO, USA. 458 p.

**Jatala, P. 1991.** Biology and management of plant parasitic nematodes on sweetpotato. In: R.K. Jansson and K.V. Raman (eds.). Sweetpotato pest management. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, India. p. 359-378.

**Kalshoven, L.G.E. 1981.** Pests of crops in Indonesia. Revised and translated by P.A. van der Laan. P.T. Ichtiar Baru-van Hoeve, Jakarta. 701 p.

**Kibata, G.N. 1973.** Studies on varietal susceptibility and pest control of sweetpotato (*Ipomoea batatas*) in Central Kenya. In: Proceedings of the 1st East African Conference on Entomology and Pest Control. p. 93-98.

**Kusuma Hendarto, Bayu. 1996.** Inventarisasi predator kumbang ubi jalar *Cylas formicarius* Fab. (Coleoptera: Curculionidae). Thesis. Faculty of Plant Pests and Diseases, Bogor Agricultural University. Bogor, Indonesia. 51 p.

**Lenné, J.M. 1991.** Diseases and pests of sweetpotato: South-East Asia, the Pacific and East Africa. Natural Resources Institute Bull. No. 46. viii + 116 p.

**Lenné, J.M. 1994.** Morphological and pathogenic characterization of *Elsinoe batatas*: Causal agent of sweetpotato scab. 4th International Conference on Plant Protection in the Tropics, 28-31 March 1994. Kuala Lumpur, Malaysia. p. 64-66.

**Loebenstein, G. and I. Harpaz. 1960.** Virus diseases of sweetpotatoes in Israel. Phytopathology 50:100-104.

**Macfarlane, R. and G.V.H. Jackson. 1989.** Sweetpotato weevil. Pest Advisory Leaflet 22. South Pacific Commission, Suva, Fiji. 4 p.

**Maitai, W.M. 1958.** Annotated list of insects associated with the sweetpotato (*Ipomoea batatas*). East African Agric. J. April:290-291.

**McClure, T.T. 1959.** Rhizopus decay of sweetpotatoes as affected by chilling, recurring and hydrowarming after storage. Phytopathology 49:359-361.

**Moyer, J.W. and L.F. Salazar. 1989.** Viruses and virus-like diseases of sweetpotato. Plant Dis. 73:451-455.

**Palomar, M.K., A.D. Solis, and H.S. Bandala. 1980.** Sweetpotato tuber rot disease in the Philippines. Ann. Trop. Res. 2:111-121.

**Scott, L.E. and J.C. Bouwkamp. 1974.** Seasonal mineral accumulation by the sweet potato. HortScience 9:233-235.

**Sheffield, F.M.L. 1954.** Erinose of sweetpotato. Empire J. Exp. Agric. 22:97-102.

**Sheffield, F.M.L. 1957.** Virus diseases of sweetpotato in East Africa. I. Identification of the viruses and their insect vectors. Phytopathology 47:582-590.

**Shepard, B.M., A.T. Barrion, and J.A. Litsinger. 1987.** Helpful insects, spiders and pathogens. International Rice Research Institute (IRRI), Los Baños, Philippines. 136 p.

**Skoglund, L.G. and N.E.J.M. Smit. 1994.** Major diseases and pests of sweetpotato in eastern Africa. International Potato Center (CIP), Lima, Peru. 67 p.

**Talekar, N.S. 1988.** How to control sweetpotato weevil: A practical IPM approach. International Cooperator's Guide AVRDC 88-292. Asian Vegetable Research and Development Center (AVRDC), Tainan, Taiwan. 6 p.

**Talekar, N.S. and Ko Wen Cheng. 1987.** Nature of damage and source of resistance to sweetpotato vine borer (Lepidoptera: Pyralidae) in sweetpotato. J. Econ. Entomol. 80:788-791.

**Talekar, N.S. and G.V. Pollard. 1991.** Vine borers of sweetpotato. In: Jansson, R.K. and K.V. Raman (eds.). Sweetpotato pest management: A global perspective. Westview Press, Boulder, CO, USA. 458 p.

**Théberge, R.L. (ed.). 1985.** Common African pests and diseases of cassava, yam, sweetpotato and cocoyam. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 108 p.

**Vasquez, E.A. and C.E. Sajise. 1990.** Pests of sweetpotato: Insects, mites and diseases. Philippine Root Crops Information Service, Philippine Root Crops Research and Training Center. 65 p.

**Wambugu, F.M. 1991.** In vitro and epidemiological studies of sweetpotato (*Ipomoea batatas* (L.) Lam.) virus diseases in Kenya. Ph.D. thesis. University of Bath, UK. 271 p.

**Waterhouse, D.F. and K.R. Norris.1987.** Biological control Pacific prospects. Australian Centre for International Agricultural Research, Inkata Press, Melbourne, Australia.

**Wheatley, P.E. 1961.** The insect pests in the coast province of Kenya. III. Sweetpotato. East African Agric. Forest. J. April:228-229.

**Wilson, J.E., P. Taufatofua, P. Pole, and N. Smit. 1990.** Breeding leaf scab-resistant sweetpotatoes in Tonga. In: R.H. Howeler (ed.). Proceedings of the 8th Symposium of the ISTRC, Bangkok,Thailand, Oct. 1988. Centro Internacional de Agricultura Tropical (CIAT), Bangkok, Thailand. p. 491-499.



# About the Authors

**Teresa Ames** is a pathologist at the International Potato Center, Apartado 1558, Lima 12, Peru; e–mail: t.icochea@cgnet.com

**Nicole Smit** is an integrated pest management specialist at the International Potato Center, Liaison Office Uganda, P.O. Box 7878, Kampala, Uganda; e–mail: nsmit@imul.com

**Ann Braun** is a former integrated pest management specialist at the International Potato Center, Regional Office for East and Southeast in Indonesia, and is currently with the Centro Internacional de Agricultura Tropical, Apartado Aero 6713, Cali, Colombia; e-mail: a.braun@cgnet.com

**Jane O'Sullivan** is a soil scientist at the University of Queensland, Brisbane Qkl 4072 Australia; e–mail: j.osullivan@mailbox.uq.oz.au

**Linnea Skoglund** is a plant pathologist at the Colorado State University, Plant Pathology Department, Fort Collins, CO 80523, USA; e-mail: skoglund@lamar.colostate.edu

# Photo Credits

C. Asher–99; T. Ames– 83; F. P.C. Blamey–101; A. Braun–14,17-19, 22 A, B, 23, 28, 29A,B, 32 A, B, 38, 39, 42, 43, 51-56; G. Chang–73, 75; CIP archives–33, 45,47; C. A. Clark–63, 65, 78, 79, 81, 82, 88, 91; A. Dowling–106;V. Duarte–62; E. R. French–49, 67, 68; S. Fuentes–57, 58, 60; E. Guevara–86, 89, 90; V. P. Ila'ava–110; IIBC –1-4, 20; G. W. Lawrence–84; W. J. Martin–61, 85; J. W. Moyer–59, 66; T. Nishizawa–92; J. O'Sullivan–94-98, 100, 102-105, 107-109; M. Palacios–8-10; M. Shepard– 37, 40; L. G. Skoglund–48, 69-72, 93; N. E. J. M. Smit–5,6,11-13, 15,16, 21,24-27, 30,31,34, 44, 46; *Sweeetpotato cultivation in China*, 76,77; SON–87; N. S. Talekar–7; H. Van den Berg–50; A. Vera–35, 36, 41



# I N D E X

**A publication of the**
International Potato Center (CIP)

**Editing**
Bill Hardy

**Design and layout**
Rubén D. Gutiérrez
Nini Fernández-Concha Bernales
Milton Hidalgo

**Printed by**
The Communications Unit-CIP

ISBN 92-9060-187-6