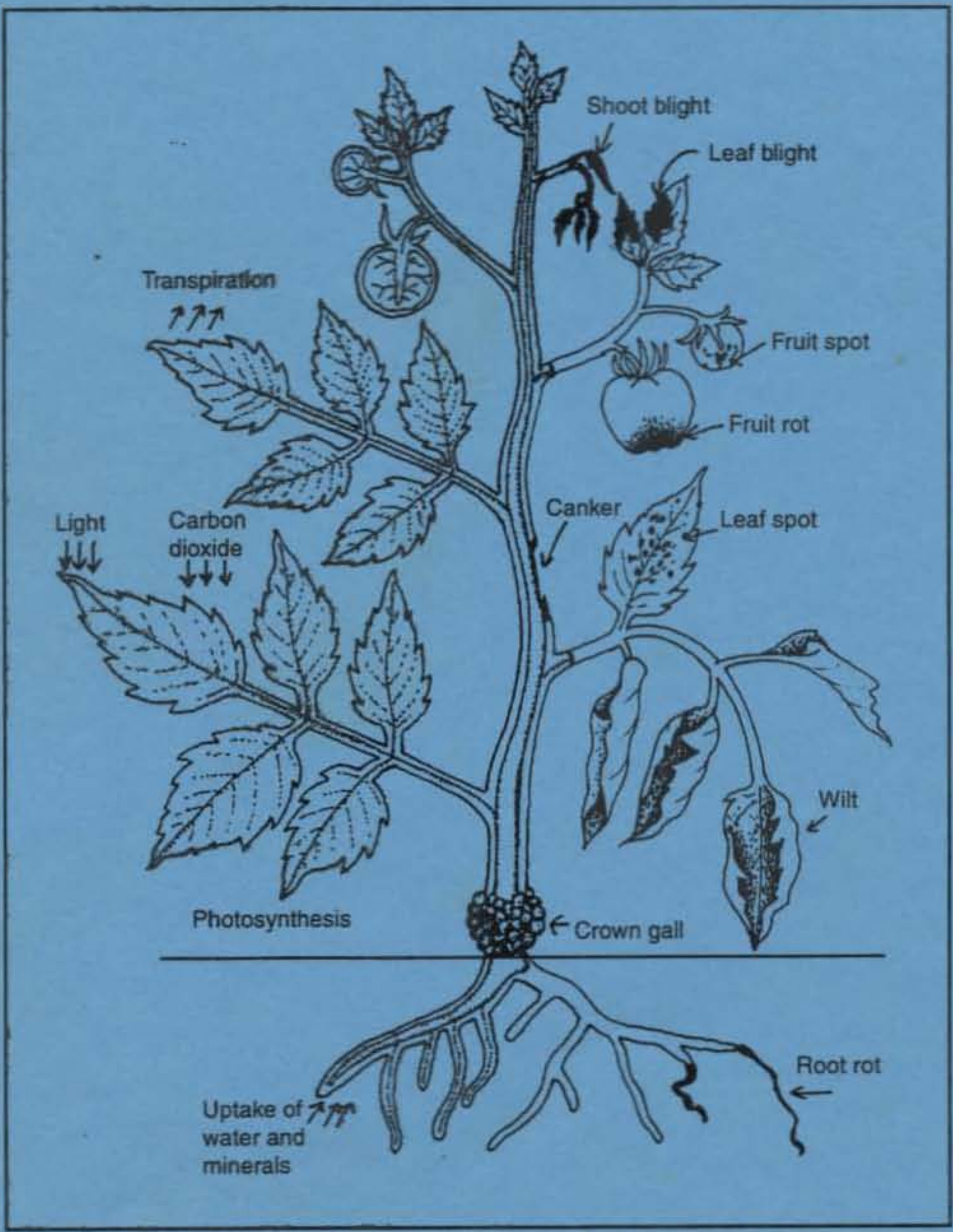
Agriculture Instructional Materials
ADAP 95-5

Crop Protection for Pacific Islands

Instructor Manual



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ADAP Directors:
SALEI'A AFELE-FA'AMULI
American Samoa Community College
CHIN T. LEE
University of Guam
ANITA SUTA
College of Micronesia
ANTONIO SANTOS
Northern Marianas College
NOEL P. KEFFORD
University of Hawai'i

Crop Protection For Pacific Islands - Instructor Manual

Prepared by:
MICHAEL T. HARRINGTON
AIMS Coordinator

AIMS Development Team:
AGNES VARGO
American Samoa Community College
DIANA GREENOUGH
American Samoa Community College
JOEL MILES
College of Micronesia, PCC
ILSE SCHREINER
University of Guam
DON NAFUS
University of Guam
GEORGE WALL
University of Guam

Computer Graphics and Layout:
MARY E.L. CONWAY and SERAPHIN COLOMANARES
Editing:
ARMANDO SOLANO
Pen and Ink Illustrations:
PETRA SCOTESE

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For additional copies, contact:
AIMS/ADAP Project
3050 Maile Way
Gilmore Hall, Room 213
University of Hawai'i
Honolulu, Hawai'i 96822
Tel: (808) 956-5294
Fax: (808) 956-3618

Crop Protection for Pacific Islands Instructor Manual

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I. INTRODUCTION

Lecture 1
DEFINITIONS AND BRIEF HISTORY

Introduction

Ever since people began growing food crops other living things have attempted to share in the harvest. Many types of insects, microorganisms and animals use the crop plants as food sources of their own. They find opportunities for multiplying in the presence of an increased food supply. Most types of plants find the land cleared by people to be ideal conditions. They grow well in the presence of fertilizers and irrigation water that farmers apply to their crops. However, farmers want their hard work to benefit themselves and therefore call these organisms pests and weeds. People spend large amounts of time and money to reduce the negative impacts these plants, insects and microorganisms have on food production.

This course will begin by considering the ecology of whole systems. Next, the various types of pest organisms will be described. A large part of this course is focused on pest control. The course provides information about different control methods to develop an integrated approach for managing the pest complex of a crop.

Objectives

Upon completion of this lesson, students will be able to:

A. Name the four major categories of pests.

B. Summarize the history of pest control in a written paragraph.

C. List three benefits and three limitations of the widespread use of pesticides.

D. Define the fifteen terms provided below.

Terms

BIOLOGICAL CONTROL - The use of living organisms to destroy, suppress, or regulate pest species.

CHEMICAL CONTROL - The use of pesticides for the management of pest species.

CULTURAL CONTROLS- The methods of manipulating crops, cropping practices and land for the management of insect, weed and disease problems.

ECOSYSTEM CONTAMINATION - The introduction of any substance that causes impurity in air, land, water or living things.

INSECT - An invertebrate organism of the animal kingdom, in the class Insecta or Hexapoda.

INTEGRATED PEST MANAGEMENT - The use of a combination of methods to reduce pest populations and keep them below economically damaging levels while minimizing ecological disturbance.

PHYSICAL CONTROL - Using mechanical practices and indirect methods that destroy pests or make the environment unsuitable for their entry, dispersal, survival, or reproduction.

ORGANIC PESTICIDE - A pesticide containing carbon based molecules.

PATHOGEN - An organism which causes disease in another organism. Common pathogens of plants are fungi, bacteria and viruses.

PEST- Any living organism not desired by humans, usually because it consumes a resource such as a crop. Whether an organism is a pest is entirely a human judgment, and not inherent in the organism itself.

PESTICIDE - A substance used to kill a pest.

PEST RESURGENCE - The pest population explosion that occurs when the natural predators and parasites of the pest have been killed by pesticides. When the pest re-invades the crop, its population grows rapidly because its natural enemies are gone.

RESISTANCE - The ability of an organism to overcome, completely or to some degree, the effect of a chemical, pathogen, or other damaging factor.

SECONDARY PESTS - Pests not normally seen in a field that become abundant because their predators and parasites have been killed by a pesticide.

WEED - A plant growing where it is not wanted.

Teaching Outline

A. Types of organisms often considered PESTS

1. INSECTS and mites

2. WEEDS

3. PATHOGENS - Fungi, bacteria, and viruses

4. Rodents

B. History of Pest Control

1. Traditional methods

a. No dependence on chemicals

b. High labor input

2. Invention of PESTICIDES - Arsenic, cyanide, and botanicals

3. Invention of ORGANIC PESTICIDES - DDT and hundreds of other chemicals currently in use

4. Widespread use of pesticides

a. Benefits

i. Reduced labor

ii. Quick control

iii. Availability

b. Limitations

i. RESISTANCE

ii. RESURGENCE

iii. SECONDARY PESTS

iv. ECOSYSTEM CONTAMINATION

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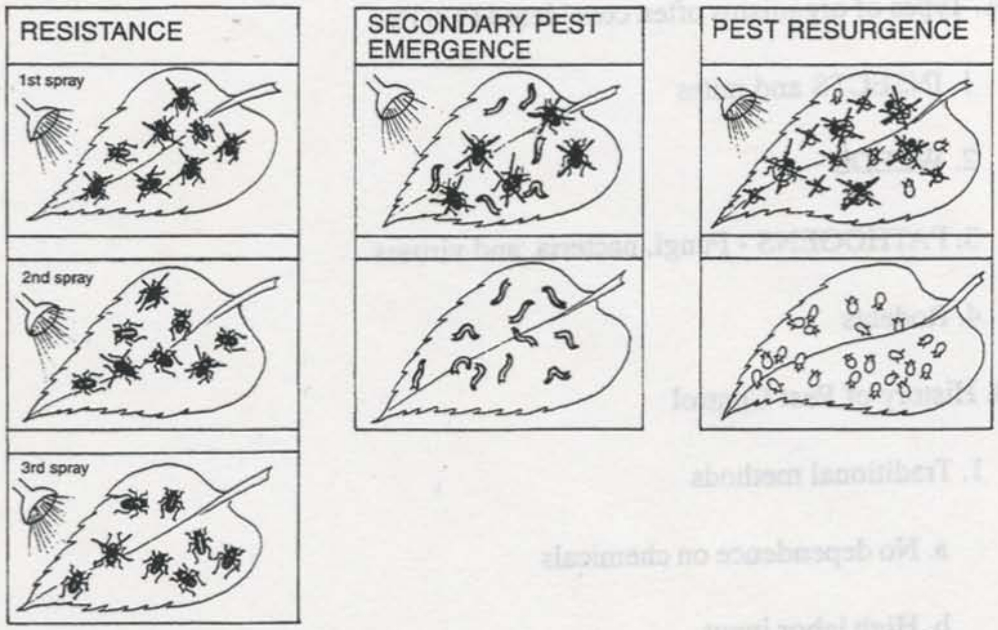


C. INTEGRATED PEST MANAGEMENT

1. BIOLOGICAL CONTROLS

2. CULTURAL CONTROLS

3. MECHANICAL CONTROLS

4. CHEMICAL CONTROLS

Reading Assignment

Student Information Sheet 1: Historical Perspective

Lecture 2
ECOLOGICAL FOUNDATIONS

Introduction

To manage pests effectively one must take a system approach. The system in this case is the crop, its surrounding environment, and the interactions of all the organisms within the site. Pests do not exist independent of the crop and the surrounding environment. Concentrating on controlling one pest may result in unforeseen side effects, and can sometimes lead to ecological or human disasters. In this lecture a few of the basic concepts of ecology are introduced to provide a foundation upon which the pest control concepts are developed in later units.

Objectives

Upon completion of this lesson, students will be able to:

A. Explain the concepts of an ecosystem and agroecosystem.

B. Explain the processes of energy flow and cycling of elements at the ecosystem level.

C. Draw a simple food web involving a familiar crop.

D. Describe ecological succession as it relates to crops and weeds.

E. List at least three additive and three subtractive processes influencing populations.

F. Describe two processes best studied at the level of individuals.

G. Describe at least five ecological modifications that have increased pest numbers in the Pacific islands.

H. Define the fifteen terms described below.

Terms

ABIOTIC FACTORS - The physical, non-living parts an ecosystem. These include water, air, minerals, and related processes such as rainfall, wind, erosion, etc.

AGROECOSYSTEM - The managed populations or communities of crops together with all of the organisms and environmental factors influencing them in a given ecosystem.

BIOTIC FACTORS - The living parts of an ecosystem including plants, animals, microorganisms, and the various processes such as oxygen production or decomposition that these organisms accomplish.

COMMUNITY - An assemblage of populations in a given area or ecosystem.

COMPETITION - The condition that occurs when a limited supply of resources are required by more than one organism.

ECOLOGICAL SUCCESSION - The process of changes in numbers and types of species within an ecosystem over time.

ECOSYSTEM - All living and non-living things in a given area that operate together through interaction and interdependence, forming a single unit.

FECUNDITY- The reproductive capacity of an organism.

FOOD CHAIN - The transfer of food energy from its source in plants through a series of organisms.

FOOD WEB - The interconnection of many food chains in a biotic community. Some organisms in a food chain may be both predators and the prey of other organisms.

HERBIVORE - An animal which eats plants.

HOST - An organism that serves as a food source for a parasite.

PARASITE - An organism that feeds on another without killing it. Many parasites can live on one host.

POPULATION - A group of individual organisms of a single species inhabiting a particular area or ecosystem.

PREDATOR - An animal or insect that lives by eating other organisms.

Teaching Outline

A. ECOSYSTEM and AGROECOSYSTEM

1. ABIOTIC FACTORS and BIOTIC FACTORS

2. Energy flow

3. Cycling of elements

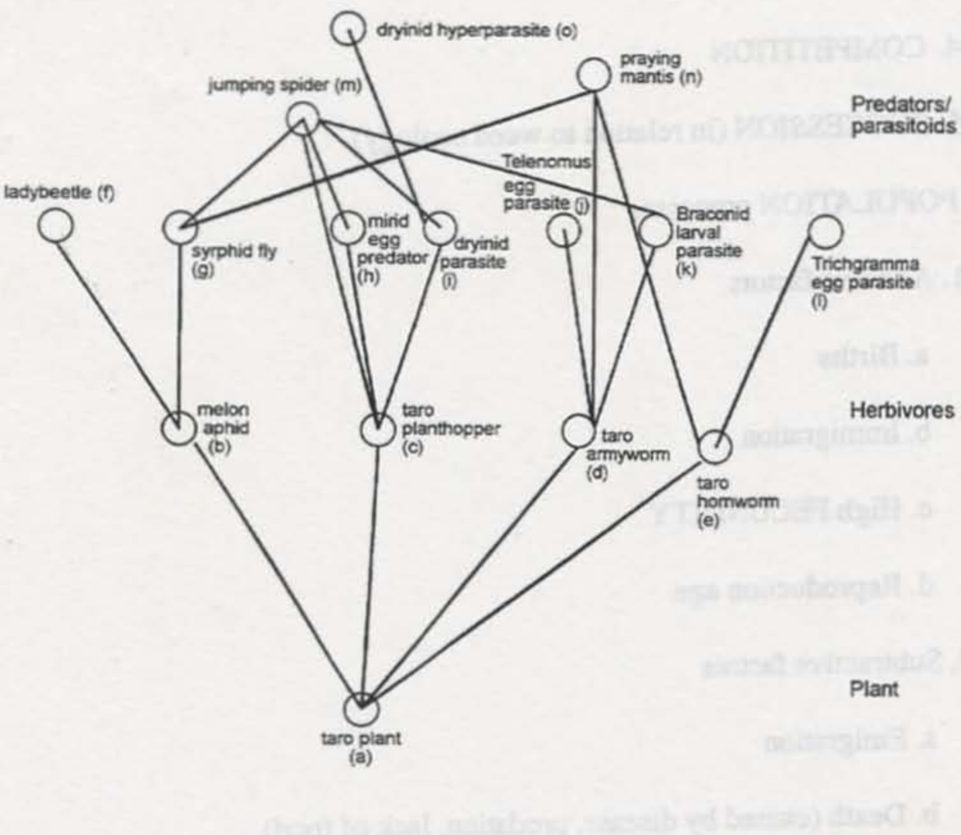
4. Biological relationships

B. COMMUNITY

1. FOOD CHAIN and FOOD WEB

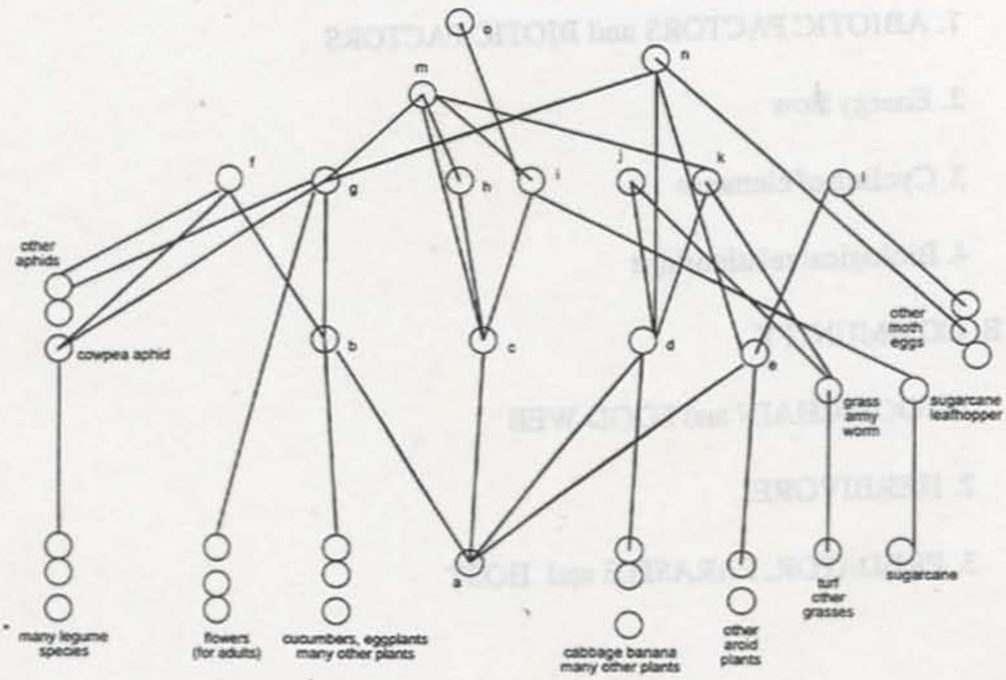
2. HERBIVORE

3. PREDATOR, PARASITE and HOST



Food web diagram showing host plant, herbivores, predators and parasites

Food web diagram showing more complete interactions within an ecosystem



4. COMPETITION

5. SUCCESSION (in relation to weed ecology)

C. POPULATION processes

1. Additive factors

a. Births

b. Immigration

c. High FECUNDITY

d. Reproduction age

2. Subtractive factors

a. Emigration

b. Death (caused by disease, predation, lack of food)

c. Reduced fecundity

d. Later reproduction or short reproductive lives

3. Population variability

a. Pesticide and disease resistance

b. Exploitation of new crops

D. Individual processes

a. Growth rates

b. Learning

i. Especially important for managing vertebrates

ii. Avoidance of poison

iii. Exploitation of new crops

E. Ecological modifications that have increased pests in the Pacific islands.

1. Monoculture leads to simplification of flora, partly by weed destruction.

2. Increased edibility makes plants more attractive to humans and pests.

3. Multiplication of suitable habitats by increased uniformity of landscape.

4. Irrigation allows year-round cropping in tropical dry season.

5. Reduced or eliminated fallow period when crop pests would decrease.

6. Change in host-parasite relationship allows local organisms to evolve and exploit newly introduced crops.

7. The spread of pests to new areas by increased human transportation

Reading Assignment

Student Information Sheet 2: Ecological Foundations of Pest Management

Student Activities

1. Food web game

   a. Make labels of organism in food web and give one to each student.

   b. Use string to connect creatures in web that eat or are eaten by another.

   c. Use string long enough to avoid cutting it and connect each organism to at least two others.

   d. Apply stimulus to one organism in food web; that person pulls all his her strings.

   e. Students holding strings that get pulled have to pull all their strings.

   f. Soon, the whole food web is jerking, showing that everything is connected (See food web illustrations for ideas).

2. Food web project

   a. Can be done in several laboratory sessions or as independent projects.

   b. Choose crop plant readily available near teaching facility.

   c. Look for insects, diseases, predators, and parasites for the purpose of drawing a food web for presentation.

   d. Rear various species of immature insects in bottles or vials to determine whether parasites are attacking them.

   e. Use microscope to find spider mites and small arthropods on leaves.

   f. Identify disease-causing organisms with local resources.

II. INSECTS

Lecture 3
ARTHROPODS

Introduction

A pest is any living organism not desired by humans. These organisms are often harmful or annoying to humans, their homes, their crops, and their animals. Identification of a suspected pest is an important first step in a successful control program. Only a small percentage of insects are pests; many insects are helpful as pollinators or as natural controls of other insects. Therefore, it is important to know which are helpful and which are harmful. Proper identification is also necessary for recommending an appropriate control strategy. When identifying a pest, it is useful to know about the larger group of living organisms to which it belongs. This lesson will focus on arthropods, a group of animals that contains many pest species.

Objectives

Upon completion of this lesson, students will be able to:

A. Describe the general characteristics of an arthropod.

B. List the five major arthropod classes and compare their body structures.

C. Describe the five distinguishing characteristics of an insect.

D. Compare the relative abundance of insects and arthropods to the total number of animal species.

E. Describe three tools or methods used to identify a specific insect.

F. Define the eight terms provided below.

Terms

ANTENNAE - Paired, flexible, and jointed sensory appendages on the head of some arthropods.

ARTHROPOD - An invertebrate animal with jointed legs and segmented body parts.

DICHOTOMOUS KEY - A method of identification using a series of choices grouped in pairs

HEXAPODA - Another name for the class of animals known as "insects." Literally means "six-legged."

INVERTEBRATE - An animal without a backbone.

PHYLOGENETIC - A system based on evolutionary relationships of structure and development.

SCIENTIFIC CLASSIFICATION - A method of categorizing all organisms.

SEGMENTED - Divided into smaller parts, this is used to describe an arthropod body and insect legs.

Teaching Outline

A. Hierarchical classification of insects

1. Kingdom: Animal

2. Phylum: Arthropoda

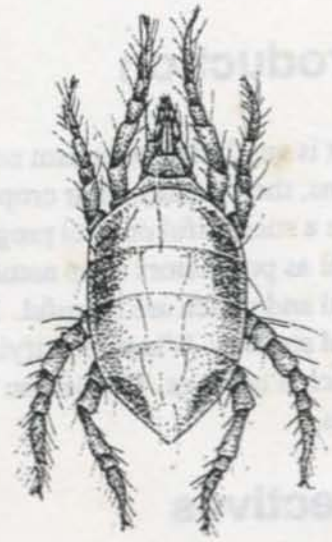
3. Class: Insecta or HEXAPODA

B. Characteristics of ARTHROPODS

1. INVERTEBRATES

2. SEGMENTED skeleton

3. Jointed appendages



Mite- a type of arachnid

C. Classes of Arthropods

1. Crustacea

   a. Two body parts: cephalothorax and abdomen

   b. Two pairs of ANTENNAE

   c. Five to seven pairs of legs

   d. Lobster, crayfish, shrimp and crab

2. Arachnida

   a. Two body parts: cephalothorax and abdomen

   b. No antennae

   c. Four pairs of legs, pedipalps, chelicerae

   d. Spiders, scorpion, mites and ticks

3. Chilopoda

   a. Many segmented body parts

   b. Head and flat segmented trunk

   c. One pair of antennae

   d. Two legs on each segment, poison appendages near the mouthparts

   e. Centipedes

4. Diplopoda

a. Many segmented body parts

b. Head and long tubular trunk

c. One pair of antennae

d. Four legs on each segment

e. Millipede

5. Insecta or Hexapoda

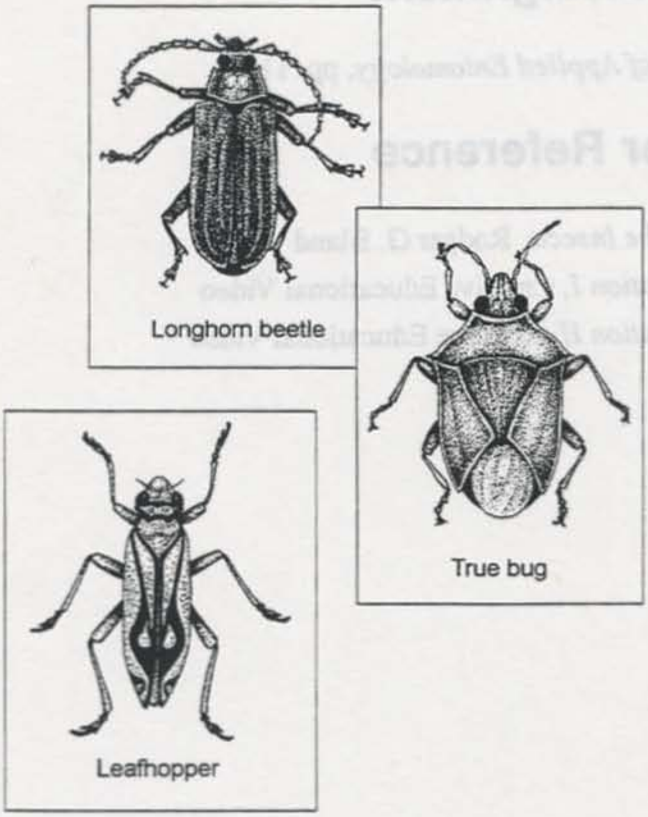
a. Three body parts: head, thorax, abdomen

b. One pair of antennae

c. Three pairs of legs on the thorax

d. Zero, one or two pairs of wings

e. Flies, butterflies, moths, true bugs, mealybugs, and beetles



Longhorn beetle

True bug

Leafhopper

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D. Relative abundance of major animal groups

1. Vertebrates 4%

2. Invertebrates 96%

a. Insects 72% (about 5/6ths of all known animal life)

b. Other Arthropods 15%

c. Other Invertebrates 9%

E. Insect identification

1. DICHOTOMOUS KEYS

a. PHYLOGENETIC arrangement

b. SCIENTIFIC CLASSIFICATION

2. Insect handbooks

3. Local insect collections

Reading Assignment

Fundamentals of Applied Entomology, pp. 11-17.

Instructor Reference

How to Know the Insects, Rodger G. Bland
Insect Identification I, Creative Educational Video
Insect Identification II, Creative Educational Video

Lecture 4
BASIC ANATOMY OF INSECTS

Introduction

Proper identification of a pest is necessary in order to control it. If a mistake is made in identification, a prescribed control method for the pest may be ineffective. A first step in identifying an insect is to look at the external characteristics of its body. This lesson begins with the major external characteristics that are needed for proper insect identification.

It is also important to know the major internal systems in order to understand how insects stay alive and function. Many methods of control are based on changing or manipulating conditions so that these internal systems will not work. This lesson will also detail the major characteristics of an insect's generalized internal anatomy.

Performance Objectives

Upon completion of this lesson, students will be able to:

A. List the major external parts of insects and describe the components and characteristics of each part.

B. List the characteristics of the major internal systems.

C. Compare the major types of insect mouthparts.

D. List various types of damage that an insect can do.

E. Give examples of damage from familiar tropical insect pests.

F. Define the twenty-nine terms provided below.

Terms

ACCESSORY GLAND - Part of the reproductive system of insects. In females, these glands coat the fertilized egg with a protective covering before laying the eggs.

AEDEAGUS - Reproductive structure of the male insect.

ALIMENTARY CANAL - A tube that makes up the digestive system of the insect which is usually coiled and extends from the mouth to the anus.

EJACULATORY DUCT - The end or terminal portion of the male sperm duct.

GANGLIA - A knot-like enlargement of a nerve, containing a coordinating mass of nerve cells.

Terms continued

HEMOLYMPH - The blood of an insect that contains plasma and blood cells. Its primary functions are to transport food, waste, and hormones. It is also an internal defense against disease pathogens.

HYPOPHARYNX- An insect mouthpart. In sucking insects the hypopharynx is the structure containing the salivary channel.

HORMONE- A chemical messenger that is carried throughout the body by the circulatory system.

LABIUM- The lower lip mouth part of an insect.

LABRUM- The upper lip mouth part of an insect.

MANDIBLES- The paired razor-like chewing mouth parts of an insect.

MAXILLAE- The paired mouth part structures right behind the mandibles.

MESOTHORAX- The center part of the insect thorax. In winged insects, one pair of wings is attached to this section.

METATHORAX- The third section of the insect thorax, furthest away from the head. In winged insects, one pair of wings, or a structure called halteres is attached to this section.

OOTHECA- The covering or case of an insect egg mass.

OPEN CIRCULATORY SYSTEM- The free-flowing circulatory system of an insect where blood flows freely throughout the body. There are no veins or arteries which hold the hemolymph.

OVARIOLES- The egg producing tubes of the ovary within the reproductive system of female insects

OVIPOSITION- The process of female insects laying eggs.

PHEROMONE- A substance given off by one individual that causes a specific reaction by other individuals of that same species.

PROTHORAX- The anterior of the three thoracic segments.

PROVENTRICULUS- The end part of the foregut of the insect digestive system with teeth-like projections that help grind food.

SCLERITES- A hardened body wall plate that makes up the exoskeleton of an insect.

SEMINAL VESICLE- A part of male reproductive systems that stores the sperm produced by the testes.

SPERMATHECA- A part of the female reproductive system that receives and stores the sperm from the male.

SPERMATOPHORE- A protective capsule containing sperm produced by the male insect.

SPIRACLE- An external opening of the respiratory system that acts as a breathing pore.

STYLET- One of the needle-like piercing structures in sucking mouth parts.

TRACHEA- The tube of the respiratory system of the insect that receives air at the spiracle opening and carries air through the tracheoles to the cells.

TRACHEOLES- The fine terminal or end branches of the respiratory tubes that delivers air to the cells.

Teaching Outline

A. Basic external anatomy of an insect

1. The head is like a hollow capsule formed by the fusion of a number of segments into plates called SCLERITES.

2. The thorax is made up of three segments; PROTHORAX, MESOTHORAX, and METATHORAX.

   a. There are a pair of legs on each thoracic segment.

   b. If present, wings are attached to the mesothorax and metathorax.

3. The abdomen consists of up to 11 ring-like segments.

   a. There is usually one SPIRACLE on each side of each segment.

   b. There are frequently appendages on the end of the abdomen.

B. Mouthparts of an insect

1. Chewing mouthparts

   a. Most common chewing mouthparts

      i. LABRUM

      ii. A pair of cutting, crushing or pinching MANDIBLES

      iii. A pair of AXILLAE

      iv. LABIUM

      v. A tongue-like HYPOPHARYNX

   b. Examples of insects with chewing mouthparts include: grasshoppers, dragonflies, beetles, bees, ants, wasps, lace wings and larvae of several orders.

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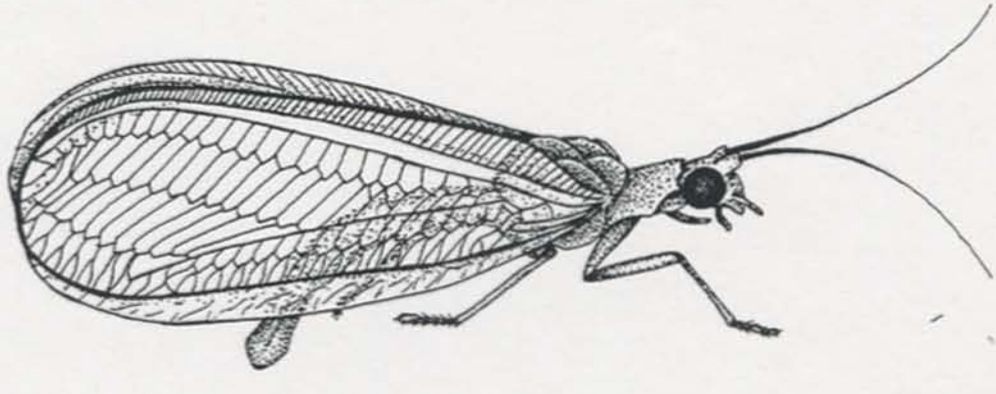
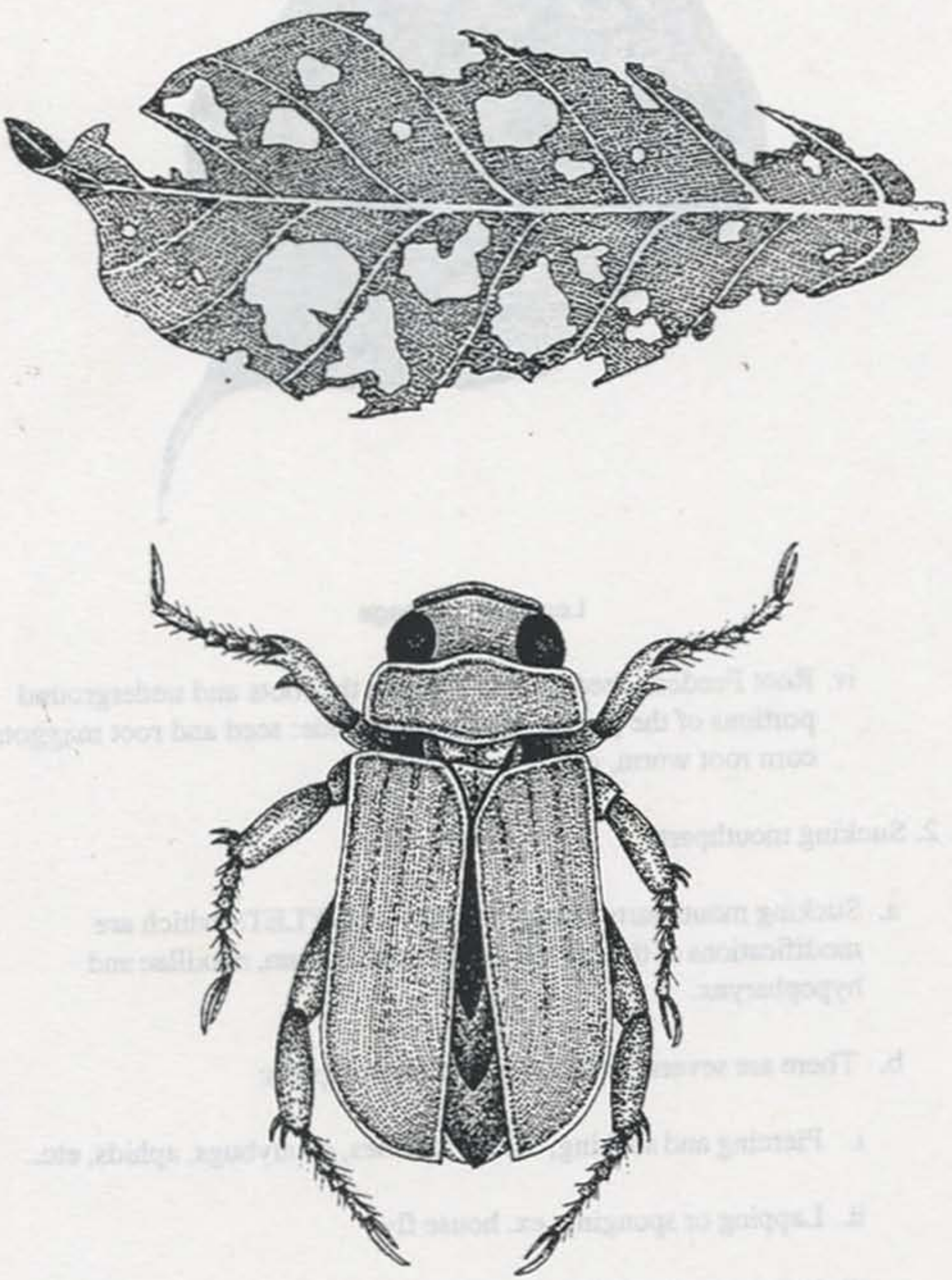


Lacewing

c. Damage from chewing insects

i. Borers: bore into stems, tubers, fruit trees, etc. Examples include banana weevil and fruit fly larvae.

ii. Defoliators: chew or strip portions of leaves or stems. Examples include: rose beetle, caterpillars, grasshoppers, rhinoceros beetle, and taro armyworm.



Rose beetle and leaf damage

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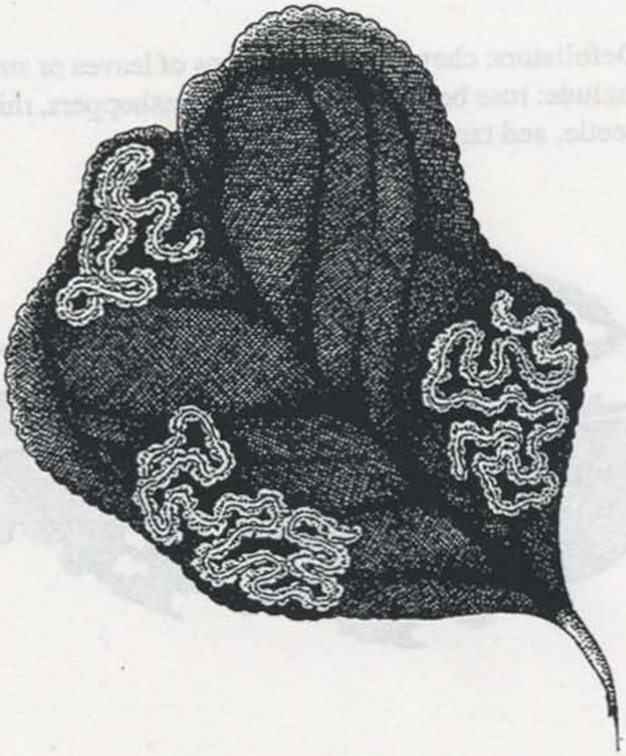
iii. Leaf Miners: bore into and then tunnel in between epidermal layers of the leaf. An example is the Serpentine leafminer.



Leafminer damage

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iv. Root Feeders: feed on and damage the roots and underground portions of the plants. Examples include: seed and root maggots, corn root worm, and wireworms.

2. Sucking mouthparts

a. Sucking mouthparts usually consist of STYLETS which are modifications of the mandibles, labrum, labium, maxillae and hypopharynx.

b. There are several types of sucking mouthparts:

i. Piercing and sucking, ex. mosquitoes, mealybugs, aphids, etc..

ii. Lapping or sponging, ex. house fly

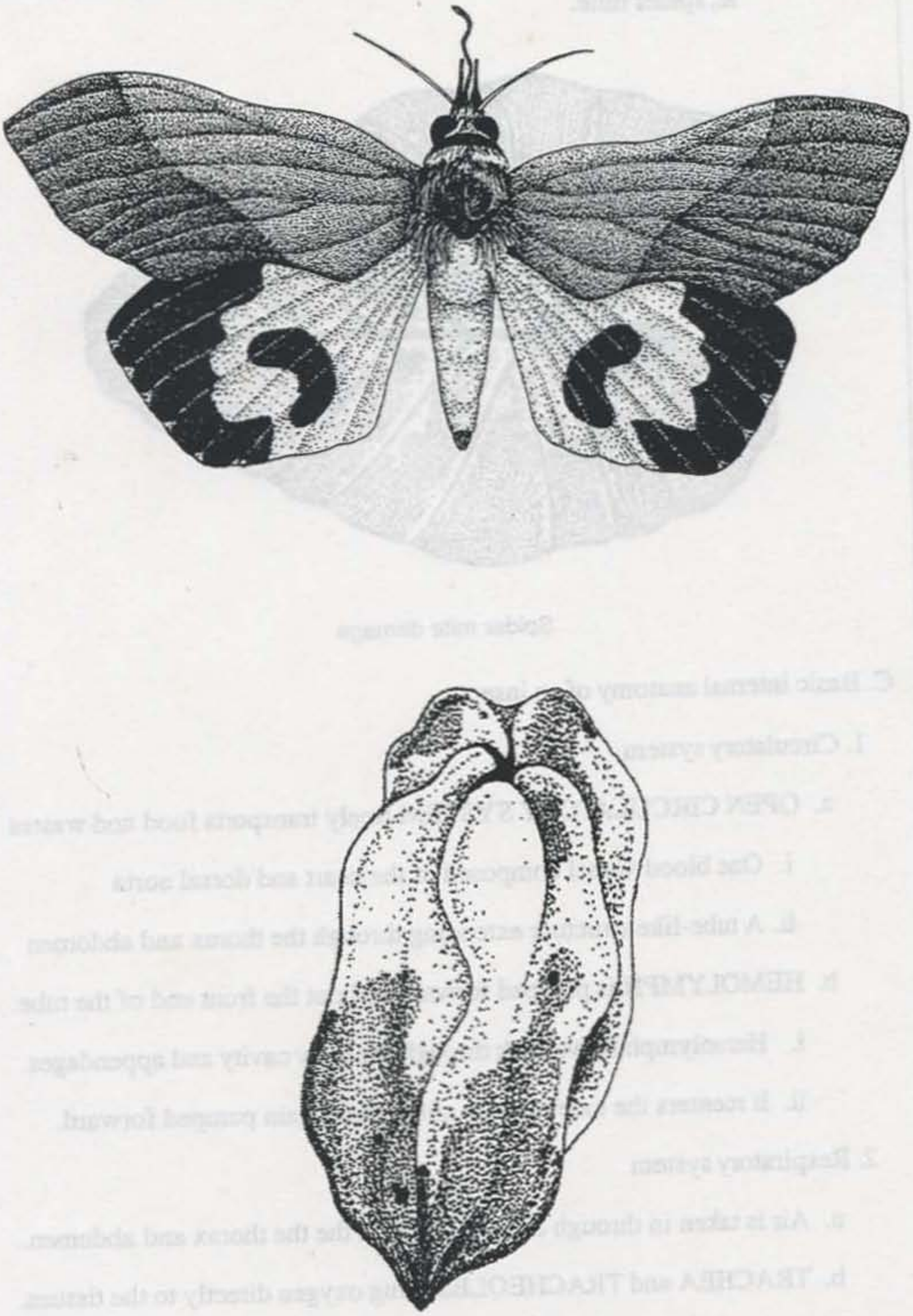
iii. Rasping and sucking, ex. thrips

iv. Siphoning, ex. moths and butterflies

v. Chewing and lapping, ex. bees

c. Damage from piercing and sucking insects

i. Distorted plant growth. Those pests that cause leaves, stems or fruit to wilt, curl or become distorted, ie. fruit piercing moth and true bugs.



Fruit piercing moth and fruit damage

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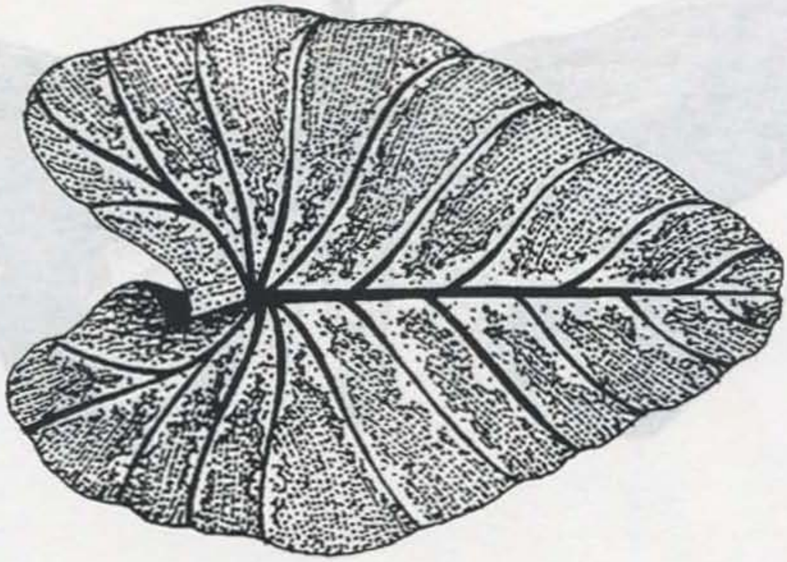
ii. "Burning" of leaves. These pests secrete toxic substances into the host tissue, causing foliage to appear burned. An example is the planthopper.

iii. Stippling effect on leaves. These pests may leave many small discolored spots on the leaves which eventually turn yellow. ie, spider mite.



Spider mite damage

C. Basic internal anatomy of an insect

1. Circulatory system

a. OPEN CIRCULATORY SYSTEM freely transports food and wastes

i. One blood vessel composed of the heart and dorsal aorta

ii. A tube-like structure extending through the thorax and abdomen

b. HEMOLYMPH is pumped forward and out the front end of the tube.

i. Hemolymph flows back through the body cavity and appendages.

ii. It reenters the tube through slits and is again pumped forward.

2. Respiratory system

a. Air is taken in through SPIRACLES on the the thorax and abdomen.

b. TRACHEA and TRACHEOLES bring oxygen directly to the tissues.

c. This system also takes CO_2 from tissue and then removes it from the body.

d. Some spiracles have valves that open and close.

3. Nervous system

a. A nerve cord is on the ventral (back) side of the body.

b. It connects to a "brain" in the head and series of GANGLIA throughout the body.

c. Nerve cells branch out to reach the muscles, organs and glands.

4. Digestive system

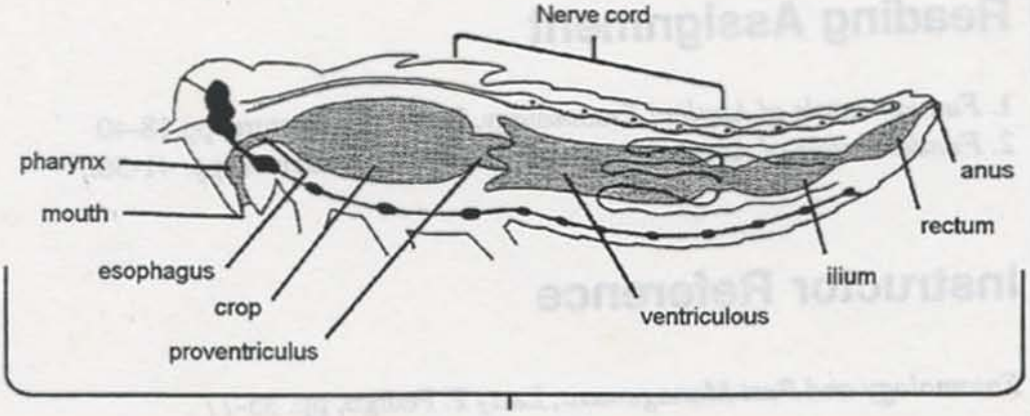
a. Food passes through the mouth and enters the ALIMENTARY CANAL.

b. It is pumped by the pharynx through the esophagus into a crop.

c. From the crop it moves to a stomach called the PROVENTRICULUS

d. Digestion continues in a mid-gut, an ilium, a colon, a rectum and the wastes are discharged from the anus.

e. This is a generalized form. There are many specialized digestive tracts found in insects because they eat different types of plants and animals.



Digestive System

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5. Reproductive system

a. Male insects

i. Sperm is produced in testes and stored in a SEMINAL VESICLE.

ii. ACCESSORY GLANDS secrete seminal fluid.

iii. Some species produce a SPERMATOPHORE.

iv. A EJACULATORY DUCT carries sperm to the AEDEAGUS.

b. Female insects

i. Eggs are produced by two ovaries in the OVARIOLES.

ii. Eggs are released into an oviduct.

iii. Sperm is stored in a pouch-like area called the SPERMATHECA.

iv. Eggs are released from the ovariole and sperm released from the spermatheca, then fertilization occurs in the oviduct.

v. ACCESSORY GLANDScoat the fertilized eggs with a protective covering called the OOTHECA before OVIPOSITION.

6. Endocrine system

a. HORMONES circulate in the hemolymph until they reach their target.

b. Hormones regulate growth, molting and other activities.

c. PHEROMONES are secreted externally to affect other members of the same species.

Reading Assignment

1. *Fundamentals of Applied Entomology*, External Structure, pp.18-40
2. *Fundamentals of Applied Entomology*, Internal Structure, pp. 41-56.

Instructor Reference

Entomology and Pest Management, Larry P. Pedigo, pp. 35-77 .

Lecture 5
INSECT LIFE CYCLES

Introduction

A life cycle is the period of time from birth, through maturity and reproduction, to death. Insects do not look exactly the same throughout their life. Some insects look similar except for changes in their size. Others look very different throughout the stages of their life. The differences may affect how they get their food and what food they eat. In this lesson we will learn about the different types of insect life cycles since they are important in understanding the stages when a pest can most easily be controlled.

Objectives

Upon completion of this lesson, students will be able to:

A. Describe and compare the differences between insects that undergo ametabolous, hemimetabolous and holometabolous metamorphosis.

B. Give at least two examples of insects that undergo each type of metamorphosis.

C. Discuss the relationship between types of metamorphosis and food sources.

D. Discuss how control of molting and metamorphosis is leading to new methods of pest management.

E. Describe the relationship between insect life cycles and feeding patterns and how this affects control.

F. Explain how juvenile hormone and molting hormone can be used to control insects.

G. Define the twelve terms provided below.

Terms

AMETABOLOUS INSECT - An insect that undergoes minimal metamorphosis with almost no change from immature instars to adult stages.

COCOON - A silken case inside which the pupa is formed.

HEMIMETABOLOUS INSECT - An insect that has a simple or incomplete type of metamorphosis in which the nymphs, resemble the adult except that they are smaller and have shorter wings.

HOLOMETABOLOUS INSECT - An insect that goes through complete metamorphosis in which larva hatches from the egg and goes through a pupal stage before becoming an adult. The larva looks completely different from the adult.

INSTAR - The insect stage between molts. The first instar occurs between hatching and the first molt.

JUVENILE HORMONE - A hormone that keeps an insect in its immature stage.

LARVA - A stage in the life of an insect undergoing holometabolous metamorphosis.

METAMORPHOSIS - A process of post embryonic change in shape and structure that most insects go through during their life cycle.

MOLTING HORMONE - A hormone that causes an insect to shed its cuticle.

NYMPH - The immature stage (following hatching) of an insect undergoing metamorphisis The nymph goes through a number of instars before becoming an adult.

PUPA - A stage in the life of an insect undergoing holometabolous metamorphosis that is usually a resting, non-feeding period between the larval and adult stages.

PUPARIUM - A case formed by the hardening of the next to last larval skin in which the pupa is formed.

Teaching Outline

A. Types of METAMORPHOSIS

1. AMETABOLOUS metamorphosis (minimal)

   a. Almost no change from immature INSTAR to adult stage.

   b. NYMPHS and adults are both wingless.

   c. Silverfish, fire brats, and book lice are examples.

2. HEMIMETABOLOUS metamorphosis (gradual or incomplete).

   a. Few changes occur between young and adult except in size

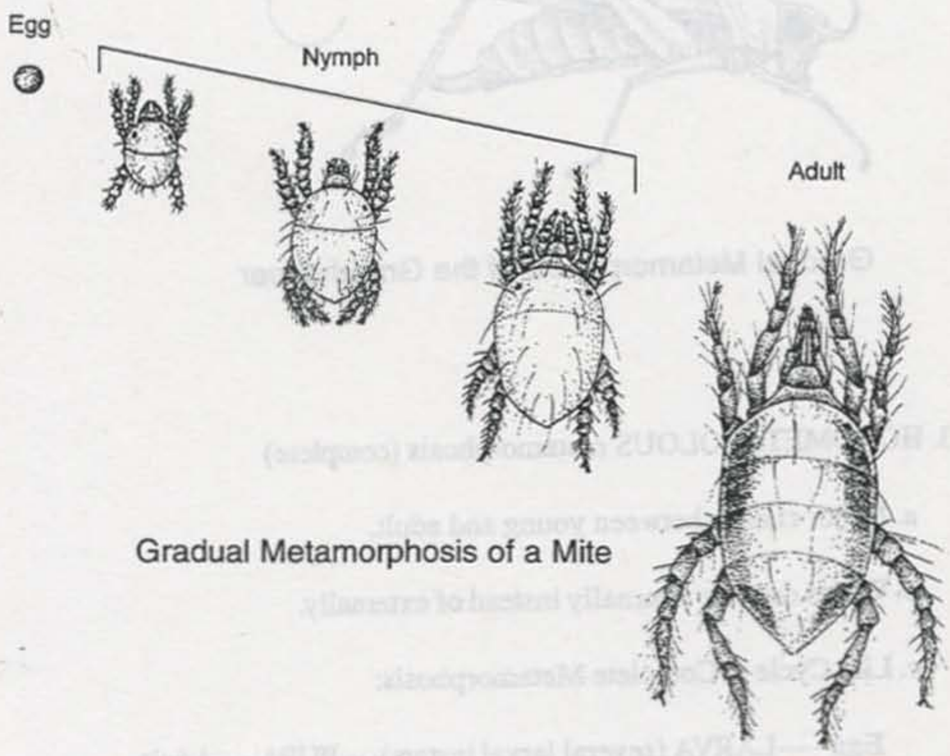
   b. Insects hatch from eggs as nymphs.

   c. They shed their skins or molt as they feed and grow

   d. Life cycle in gradual metamorphosis

      Egg-----Nymph (several nymphal stages)----Adult

   e. Grasshoppers, aphids, planthoppers, true bugs are examples.



Gradual Metamorphosis of a Mite

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f. Gradual metamorphosis of winged species is slightly different.

i. Wings first appear as pad-like buds on nymphs.

ii. Wings lengthen after each molt.

iii. Wings reach end of abdomen in adults.

iv. Instar stage between molts.

v. No resting period before adult stage.

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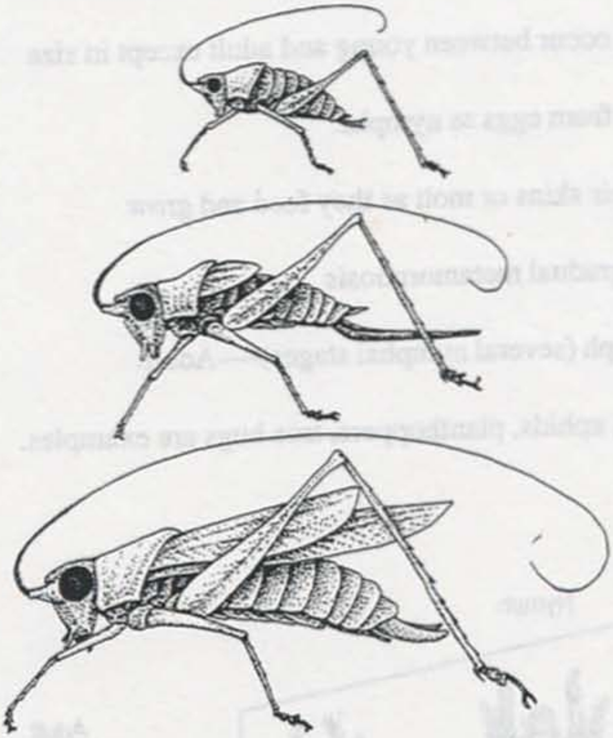


Gradual Metamorphosis of the Grasshopper

3. HOLOMETABOLOUS metamorphosis (complete)

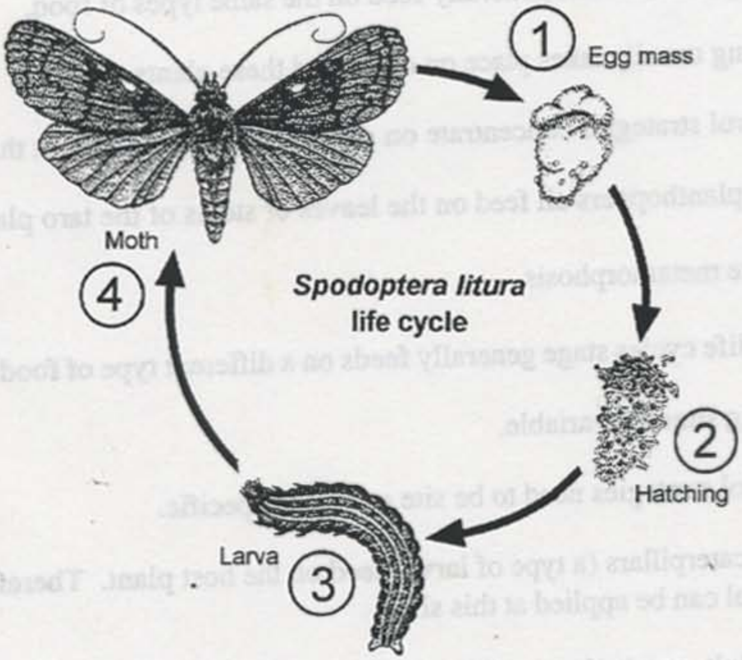
a. Major change between young and adult.

b. Wings develop internally instead of externally.

c. Life Cycle in Complete Metamorphosis:

Egg-----LARVA (several larval instars)----PUPA----Adult

i. The LARVAE grows as it feeds, sheds its skin, molting into a larger size larva. It does this several times before changing into a PUPA.



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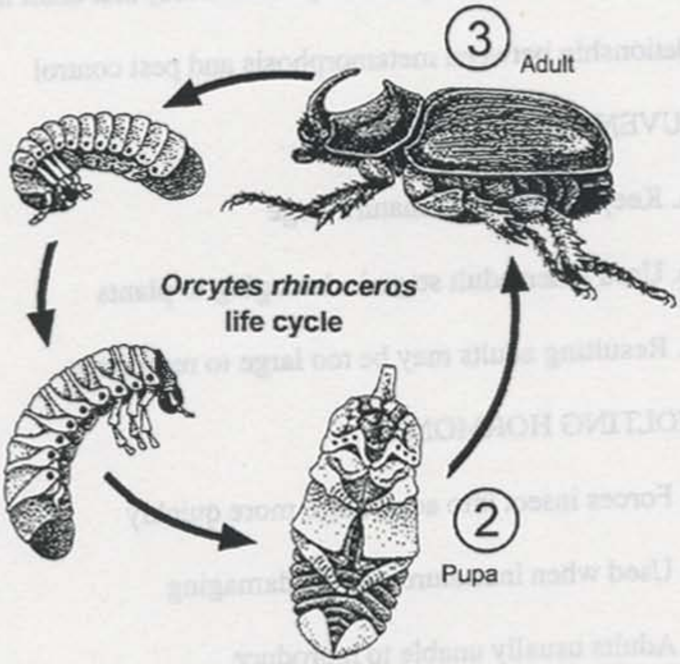
ii. Some kinds of larvae are caterpillars, maggots and grubs This is an active, feeding stage where chewing insects cause a lot of damage.



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iii. The pupa may take several forms: they can be exposed, contained in a capsule-like PUPARIUM or in a silken COCOON.

B. Relationship between metamorphosis, food sources and control strategies

1. Incomplete metamorphosis

a. Nymphs and adults generally feed on the same types of food.

b. Mating usually takes place on or around these plants.

c. Control strategies concentrate on suppressing populations at that site.

d. Taro planthoppers all feed on the leaves or stems of the taro plant.

2. Complete metamorphosis

a. Each life cycles stage generally feeds on a different type of food.

b. Mating sites are variable.

c. Control strategies need to be site and stage specific.

d. Most caterpillars (a type of larva) feed on the host plant. Therefore, control can be applied at this site.

e. The adult, not the larva, of the fruit piercing moth damages the crop.

i. Direct control measures need to focus on adult stage. ie, barriers.

ii. Indirect control can reduce the number of eggs or larvae by removing the plant (Erythrina trees) that adult moths lay eggs on.

C. Relationship between metamorphosis and pest control

1. JUVENILE HORMONE

a. Keeps insect at immature stage

b. Used when adult stage is damaging to plants

c. Resulting adults may be too large to reproduce

2. MOLTING HORMONE

a. Forces insect into adult stage more quickly

b. Used when immature stage is damaging

c. Adults usually unable to reproduce

Instructor Reference

Insect Metamorphosis and Structure, Creative Educational Video

Lecture 6
SITE SPECIFIC INSECTS

Introduction

It is important to become familiar with pests that affect tropical crops such as; coconut, taro, banana, sweet potato, breadfruit and papaya. Some pest species of temperate zone vegetable crops are also present in the tropical Pacific islands. These include pests of cucumber, Chinese cabbage, watermelon, green pepper, and tomato.

Objectives

Upon completion of this lesson, students will be able to:

A. List common pests of coconut, taro, banana, papaya, breadfruit, and sweet potato.

B. Name the type of life cycle and mouthparts of the important pests of each tropical crop.

C. List common pests of important vegetables crops grown in the Pacific islands.

D. Name the type of life cycle and mouthparts of common vegetable pests.

E. Identify the scientific names of the twenty-four pests presented in the terms section.

Terms

Banana aphid - *Pentalonia nigronervosa*
Banana thrips - *Chaetanophothrips signipennis*
Banana weevil borer - *Cosmopolites sordicus*
Cabbage cluster caterpillar - *Crocidolomia binotalis*
Coconut flat moth - *Agonoxena argaula*
Coconut hispid beetle - *Brontispa longissima*
Coconut scale insect - *Aspidiotus destructor*
Coconut stick insect - *Graeffea crouanii*
Coconut rhinoceros beetle - *Orcytes rhinoceros*
Cotton-melon aphid - *Aphis gossypii*
Cucumber beetle - *Aulocophera spp.*
Diamondback moth - *Plutella xylostella*
Fruit flies - *Bacticera spp.*
Fruit piercing moth - *Othreis fullonia*
Leaf-eating ladybird - *Epilachna spp.*
Leaf-footed bug - *Leptoglossis australicus*
Serpentine leafminer - *Liriomyza trifolii*
Spiraling white fly - *Aleurodicus dispersus*
Sweet potato weevil - *Cylas formicarius*
Taro armyworm - *Spodoptera litura*
Taro beetle - *Papuana huebneri*
Taro hornworm - *Hippotion celerio*
Taro planthopper - *Tarophagus proserpina*
Vegetable thrips - *Thrips palmi*

Teaching Outline:

A. Pests of the coconut palm

1. *Orcytes rhinoceros*, coconut rhinoceros beetle, Coleoptera

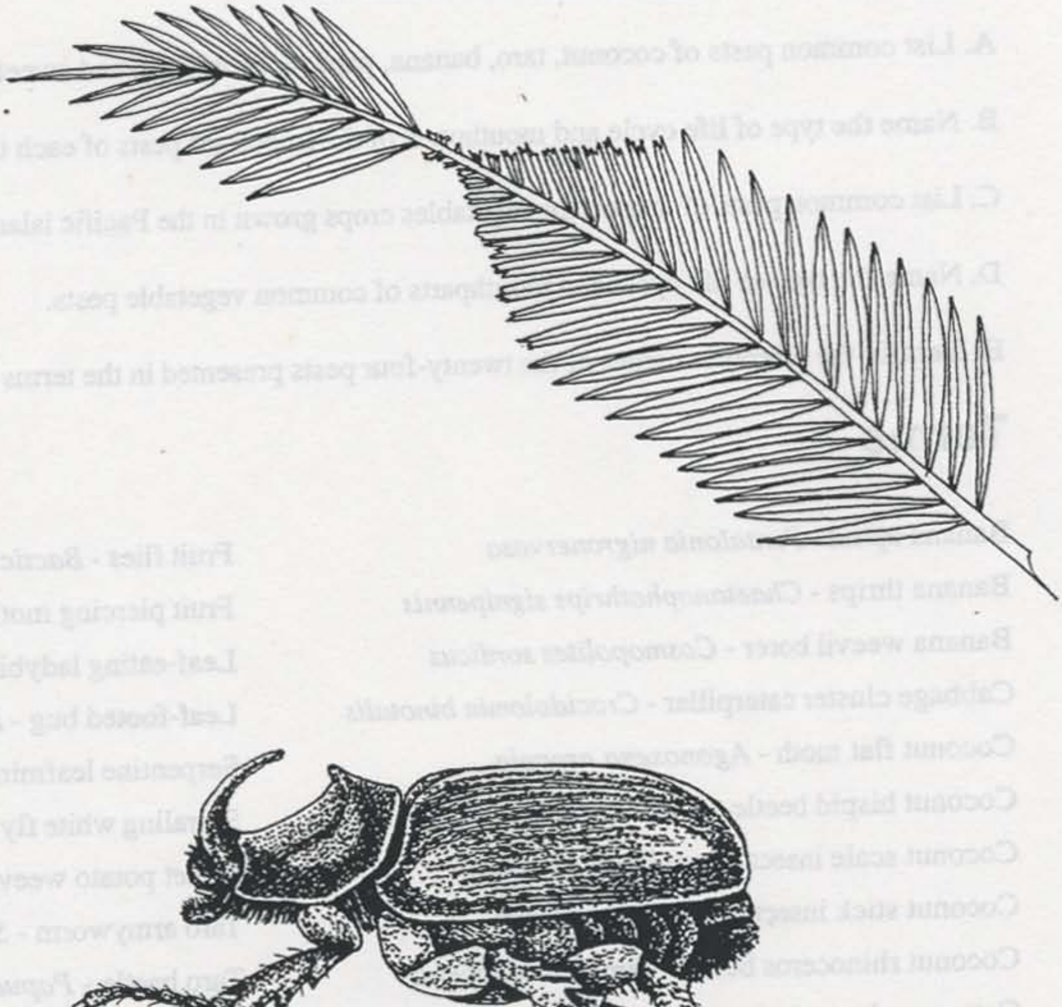
    a. Complete life cycle

    b. Chewing mouthparts

    c. Damage

        i. V-shaped cut in leaves.

        ii. Sometimes burrows into tree trunk



Rhinoceros beetle and leaf damage

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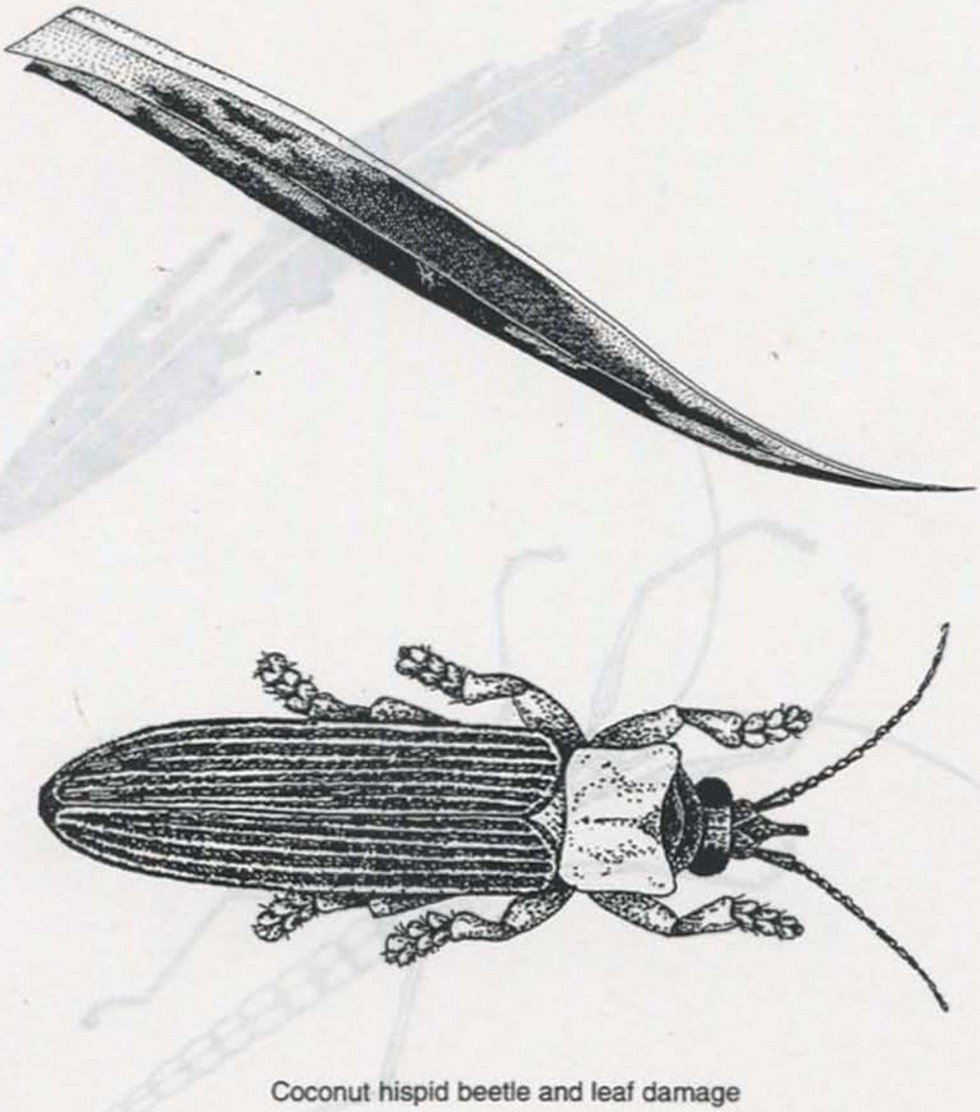
2. *Brontispa longissima,* coconut hispid beetle, Coleoptera

a. Complete life cycle

b. Chewing mouthparts

c. Scrapes epidermis of closed coconut frond and cause the appearance of "burnt" leaflets when frond opens.



Coconut hispid beetle and leaf damage

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3. *Agonoxena argaula,* coconut flat moth, Lepidoptera

a. Complete life cycle

b. Chewing mouth parts

c. Larvae feed on leaflets and leave longitudinal "window-hole" damage.

4. *Graeffea crouanii*, coconut stick insect, Orthoptera

a. Incomplete life cycle

b. Chewing mouthparts

c. Feeds on leaflets, often leaving only an exposed midvein

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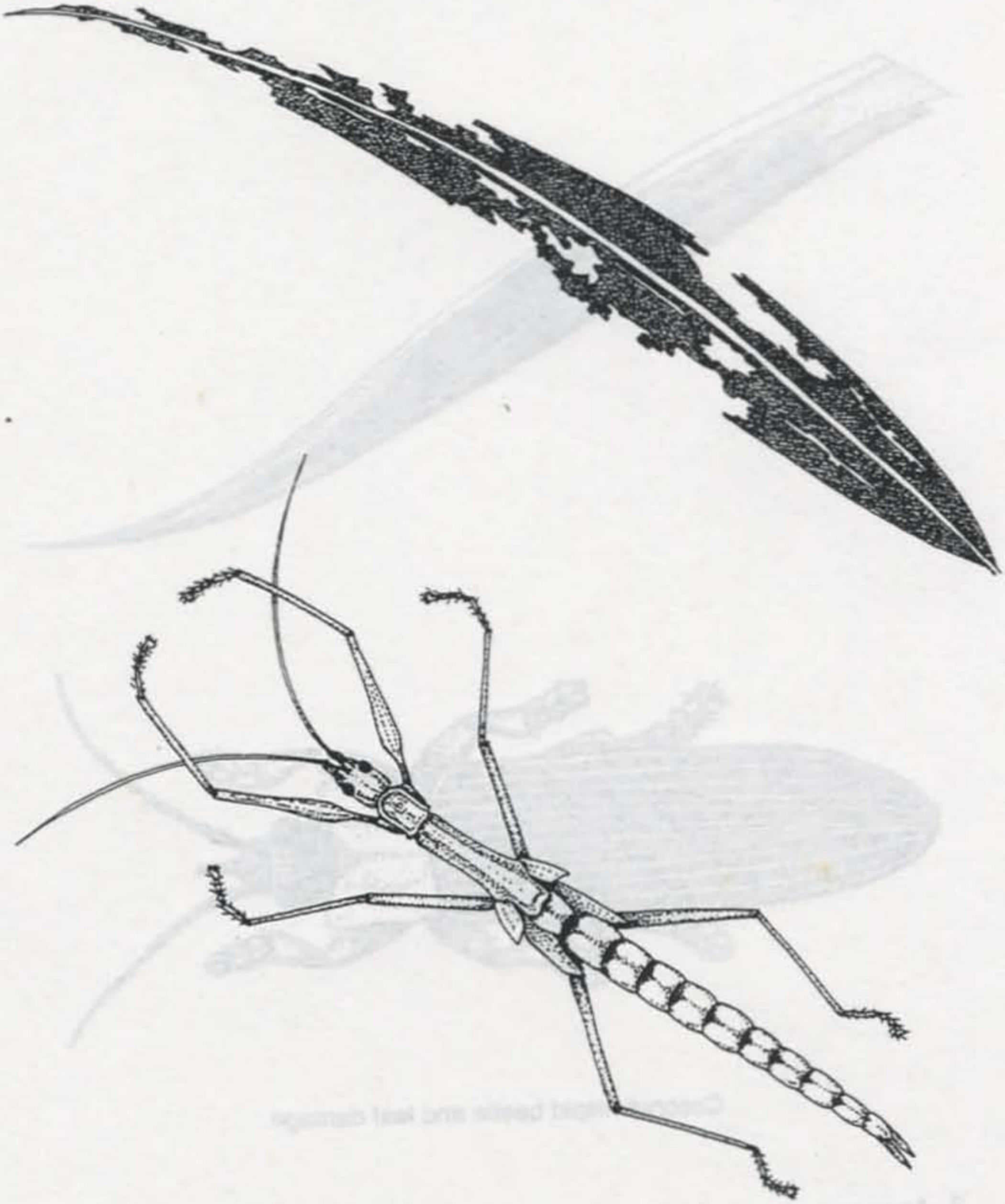


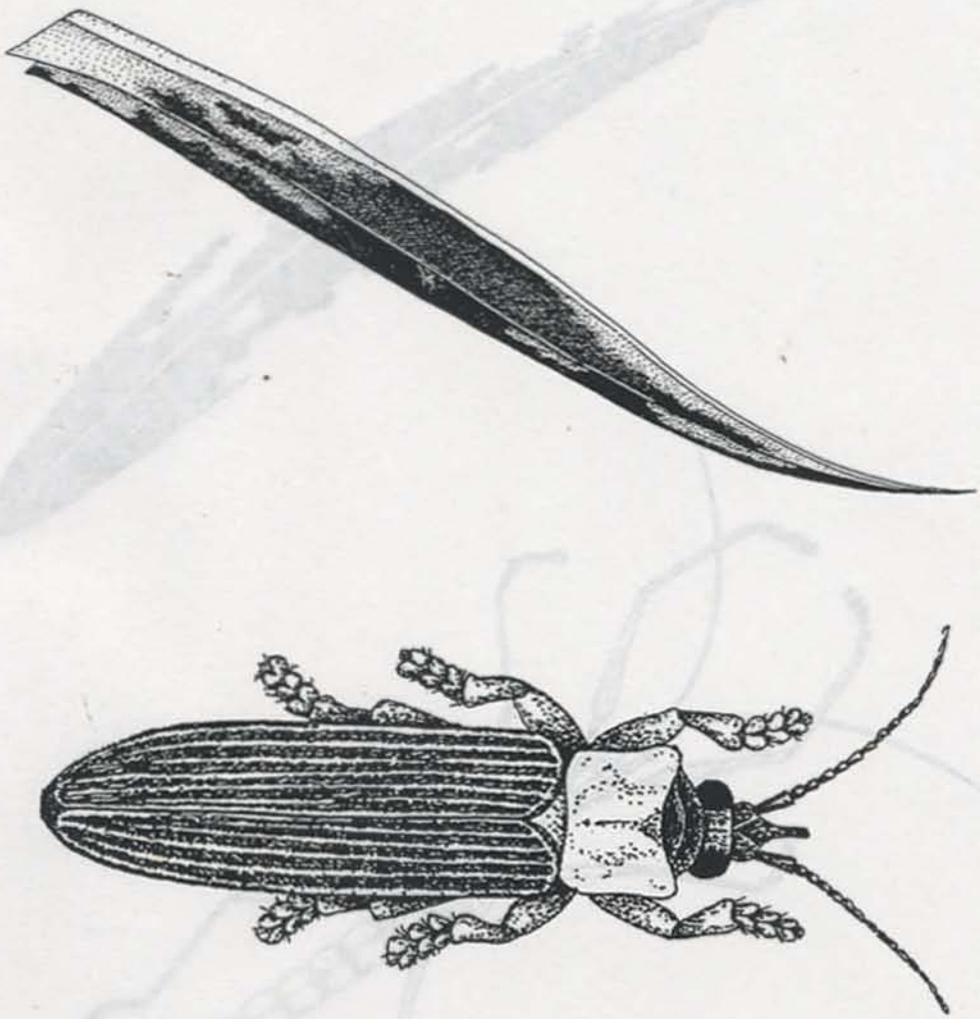
Coconut stick insect and leaf damage

2. *Brontispa longissima,* coconut hispid beetle, Coleoptera

a. Complete life cycle

b. Chewing mouthparts

c. Scrapes epidermis of closed coconut frond and cause the appearance of "burnt" leaflets when frond opens.



Coconut hispid beetle and leaf damage

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3. *Agonoxena argaula,* coconut flat moth, Lepidoptera

a. Complete life cycle

b. Chewing mouth parts

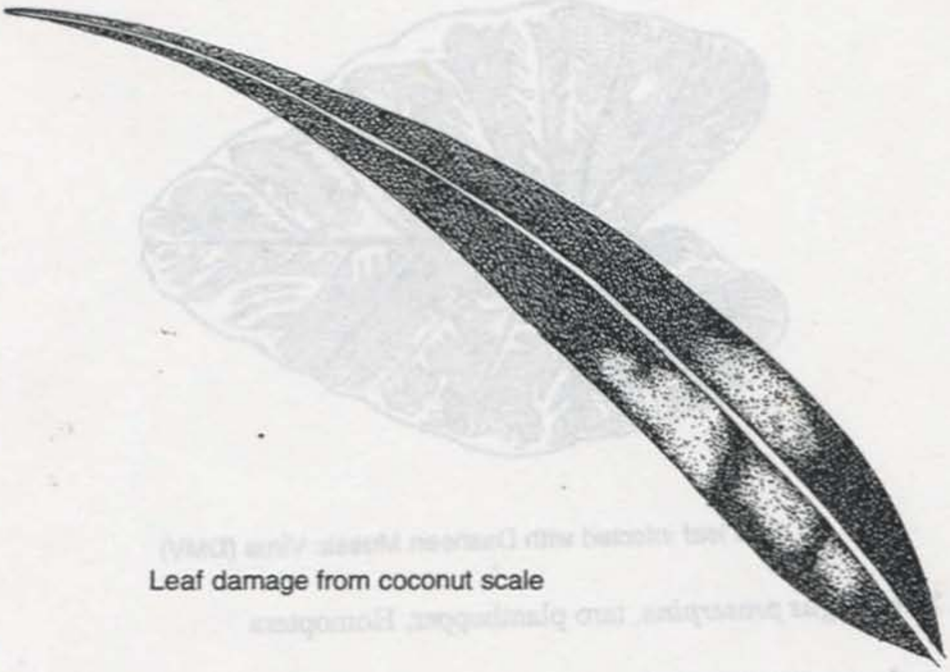
c. Larvae feed on leaflets and leave longitudinal "window-hole" damage.

5. *Aspidiotus destructor*, coconut scale insect, Homoptera

   a. Incomplete life cycle

   b. Sucking mouth parts

   c. Causes yellowing of leaves



Leaf damage from coconut scale

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B. Pests of Sweet Potato

1. *Cylas formicarius*, sweet potato weevil, Coleoptera

   a. Complete life cycle

   b. Chewing mouthparts

   c. Bores into tuber

C. Pests of Taro

1. *Spodoptera litura*, cluster caterpillar, taro armyworm, Lepidoptera

   a. Complete life cycle

   b. Chewing mouthparts

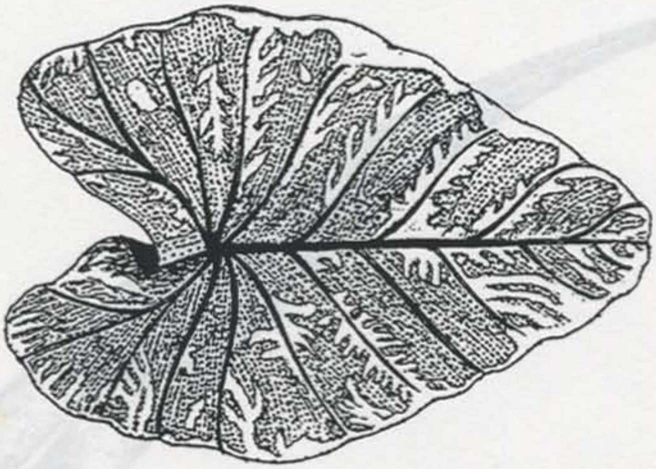
   c. Larvae feed on taro leaves and petioles, can devastate taro field

2. *Aphis gossypii*, cotton-melon aphid, Homoptera

a. Incomplete life cycle

b. Sucking mouthparts

c. Causes yellowing of leaves and transmits Dasheen Mosaic Virus (DMV)



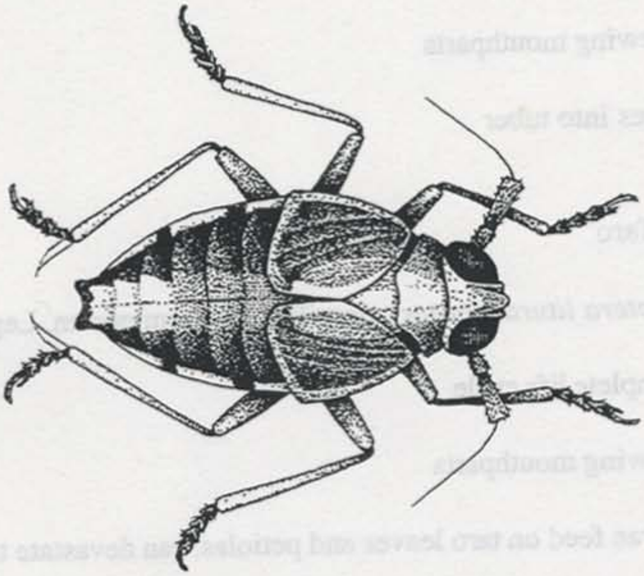
Taro leaf infected with Dasheen Mosaic Virus (DMV)

3. *Tarophagus proserpina*, taro planthopper, Homoptera

a. Incomplete life cycle

b. Sucking mouthparts

c. Causes yellowing of leaves and transmits Alomae and Bobone diseases.



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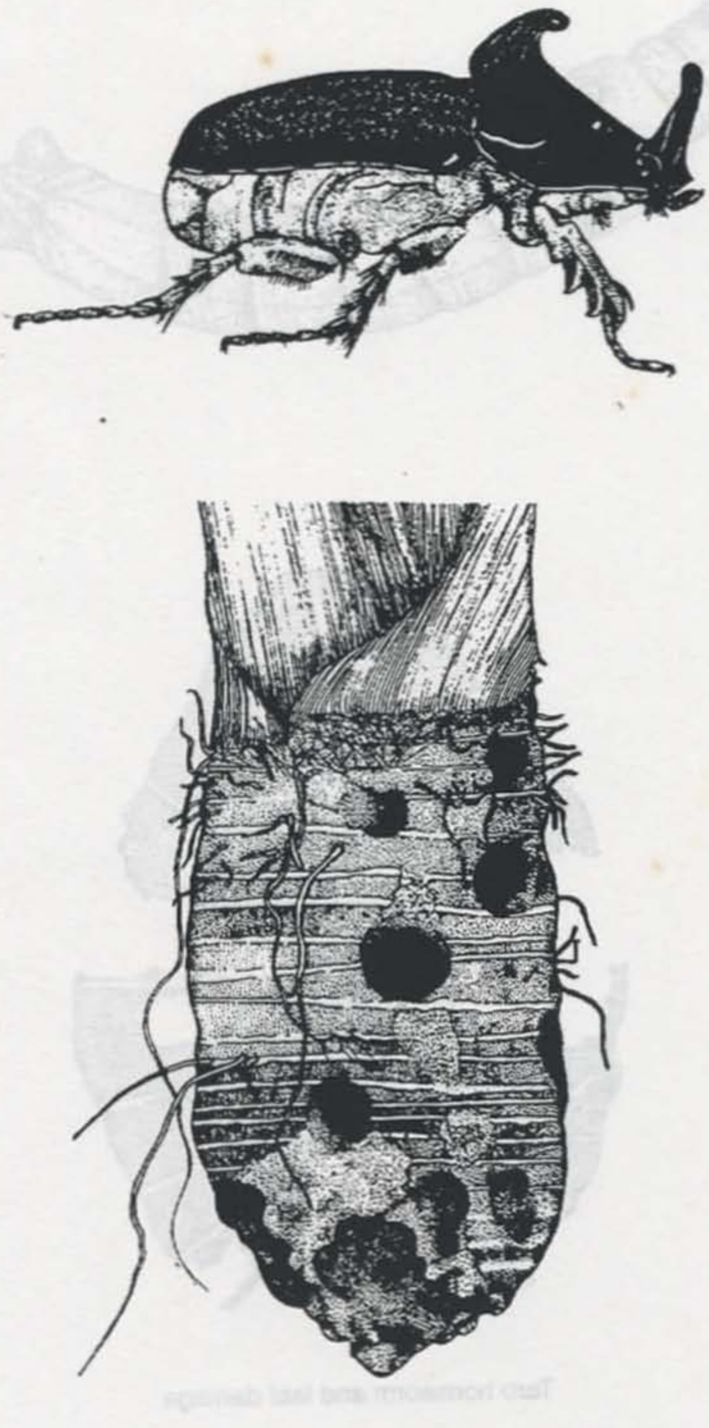
4. *Papuana huebneri*, taro beetle, Coleoptera

a. Complete life cycle

b. Chewing mouthparts

c. Bores into taro corm



Taro beetle and corm damage

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5. *Hippotion celerio*, taro hawkmoth, taro hornworm, Lepidoptera

a. Complete life cycle

b. Chewing mouthparts

c. Larvae feed on taro leaves

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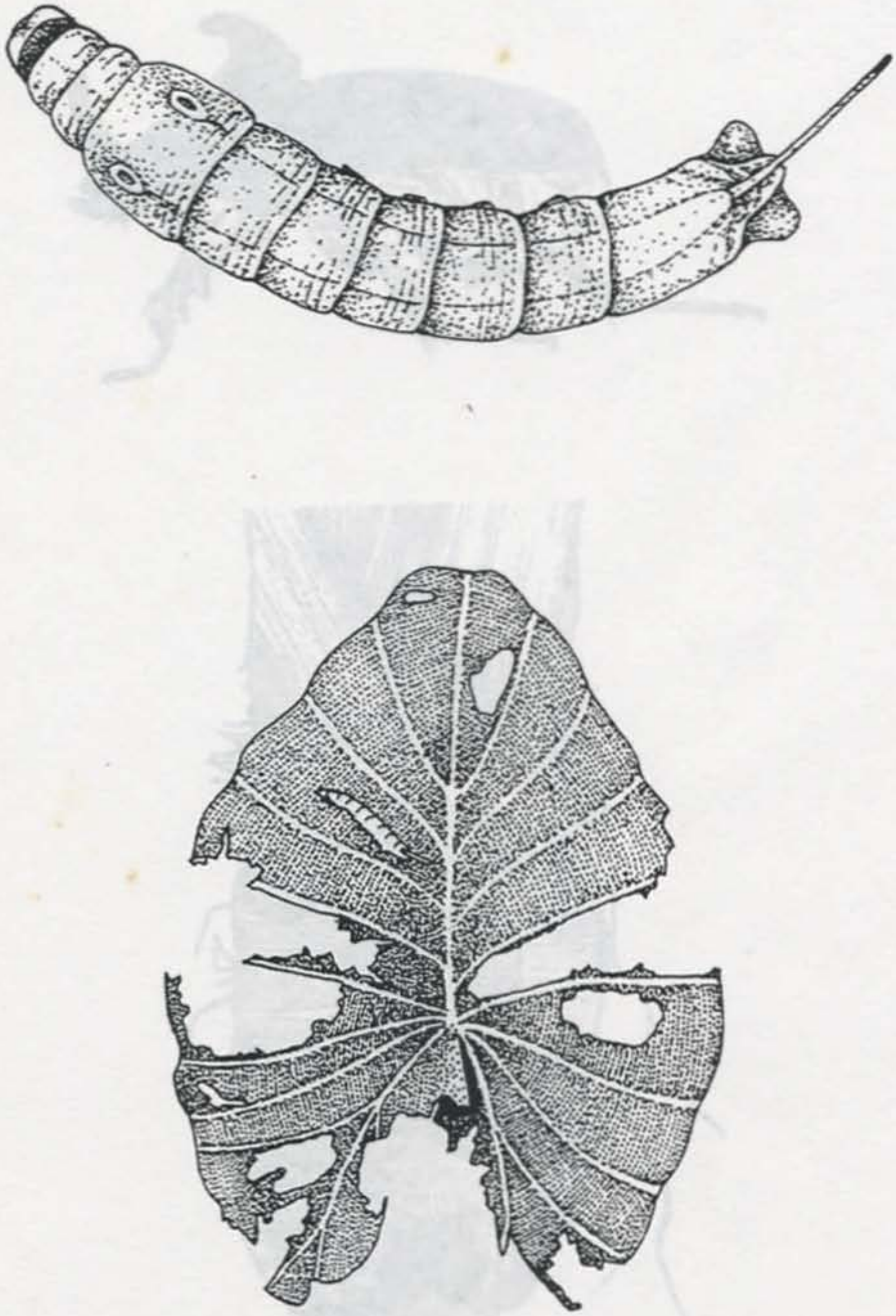


Taro hornworm and leaf damage

D. Pests of Papaya and Breadfruit

1. *Aleurodicus dispersus*, spiraling white fly, Homoptera

   a. Incomplete life cycle

   b. Sucking mouthparts

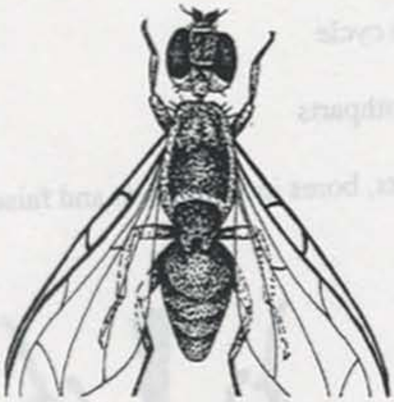
   c. Causes drying of leaves. Sugar secretion promotes sooty mold.

2. *Bacticera spp.*, fruit flies, Diptera

   a. Complete life cycle

   b. Chewing mouthparts

   c. Larvae bore into fruit



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E. Pests of Banana

1. *Pentalonia nigronervosa*, banana aphid, Homoptera

   a. Incomplete life cycle

   b. Sucking mouthparts

   c. Transmits "bunchy top" disease

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F. Pests of cabbage

1. *Plutella xylostella*, diamondback moth, Lepidoptera

   a. Complete life cycle

   b. Chewing mouthparts

   c. Larvae eat leaves and bore into stalk

2. *Crocidolomia binotalis*, cabbage cluster caterpillar, Lepidoptera

   a. Complete life cycle

   b. Chewing mouthparts

   c. Larvae eat leaves

G. Pests of cucumber and watermelon

1. *Epilachna spp.*, leaf-eating ladybird (28-spotted beetle), Coleoptera

   a. Complete life cycle

   b. Eats cucumber leaves consuming all but the veins.

2. *Leptoglossis australicus*, leaf-footed bug, Hemiptera

   a. Incomplete life cycle

   b. Sucking mouthparts

   c. Causes stunted and curved fruit

3. *Aphis gossypii*, cotton aphid, Homoptera

   a. Incomplete life cycle

   b. Sucking mouthparts

   c. Premature yellowing and drying of leaves

4. *Aulocophera spp.*, cucumber beetle, Coleoptera

   a. Complete life cycle

   b. Chewing mouthparts

   c. Eats leaves

5. *Thrips palmi*, vegetable thrips, Thysanura

a. Incomplete life cycle

b. Sucking mouthparts

c. Causes premature yellowing, drying of leaves, and plant death.

6. *Liriomyza trifolii*, serpentine leaf miner, Diptera

a. Complete life cycle

b. Chewing mouthparts

c. Larvae mine into leaves and decrease surface for photosynthesis.

H. Pests of tomato

1. *Othreis fullonia*, fruit piercing moth, Lepidoptera

a. Complete life cycle

b. Sucking mouthparts

c. Adults bore holes into fruit and cause secondary rotting

2. *Liriomyza trifolii*, as above

I. Pests of green pepper

1. *Othreis fullonia*, as above

2. *Liriomyza trifolii*, as above

3. Mites

Reading Assignment

Leaflets for locally important pests including:

1. *ADAP Agricultural Pests of the Pacific series,*
2. *SPC Pest Advisory Leaflets series,*
3. *SPC Quarantine Advisory Leaflets series.*

Lecture 7
RODENTS AND OTHER PESTS

Introduction

In addition to the major categories of pests such as insects, diseases and weeds, many other types of organisms can become pests in certain situations. The most common of these are rodents and mollusks. Other vertebrate pests include pigs, birds, chickens, etc.

Objectives

Upon completion of this lesson, students will be able to:

A. Name the four species of rodent pests in the Pacific islands.

B. Describe the most common habitats for the three kinds of rats.

C. Describe four methods of controlling rodents.

D. Describe at least four methods used to control mollusk pests.

E. Define the five terms provided below.

Terms

ANTICOAGULANT - A chemical which prevents blood from clotting and thus causes bleeding to death from cuts and hemorrhaging through small veins.

BAIT - A material used to attract a pest that is usually a food item mixed with poison.

MOLLUSK - Snails which have shells, and slugs which do not.

RODENTS - Rats, mice, and other vertebrate animals whose distinguishing characteristic is a pair of large continuously growing front incisor teeth.

VERTEBRATES - Animals with backbones such as birds and mammals.

Teaching Outline

A. RODENTS

1. Common problem in Pacific islands

2. Exotic species introduced by man

3. Few predators compared to mainland locations

4. Rat damage

    a. Young coconuts

    b. Vegetable crops, especially sweet corn

    c. Spread disease and cause unsanitary conditions

5. Polynesian rat

    a. Small size

    b. Found in native vegetation away from man

6. Roof or black rat

    a. Small to medium size

    b. More likely to be associated with man

    c. Often found in farm and plantation buildings

    d. Habitat overlaps that of Polynesian rat

7. Norway rat

    a. Largest size

    b. In Pacific region it is strictly associated with man

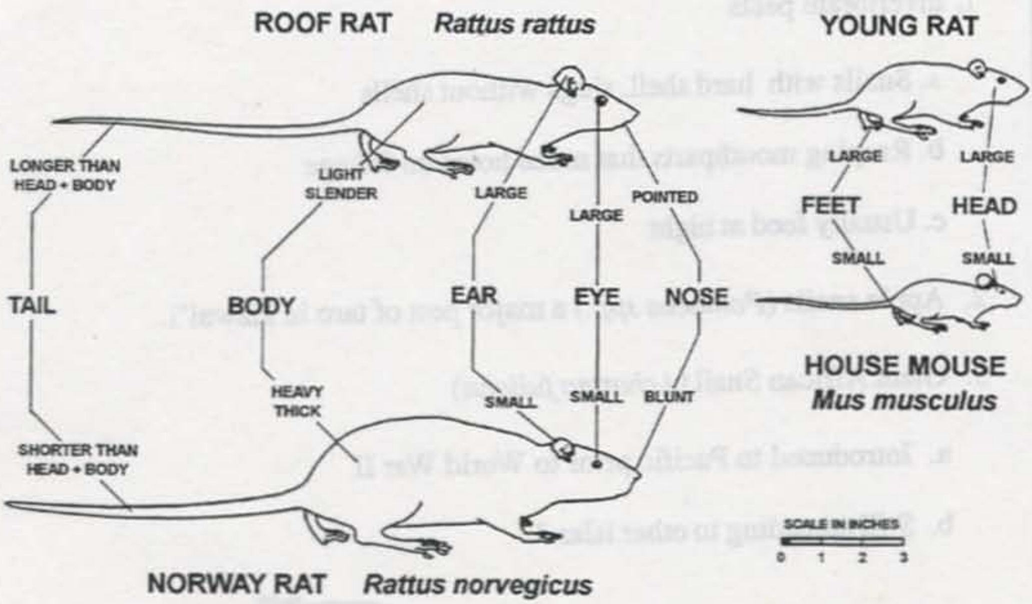
    c. Found mostly around docks and warehouses

8. House mouse

    a. Smaller than rats

    b. See identification chart

9. Identification of rodent pests



10. Rodent controls

a. Sanitation

i. Remove food sources (eg., crop and household waste)

ii. Eliminate habitat (clearing weeds and brush)

b. Snap traps, live traps, sticky traps

c. Barriers: Metal used on coconut trunks to prevent climbing

d. Poison BAIT

i. ANTICOAGULANT poisons take several days to cause death.

ii. Acute poisons are lethal in one dose

B. Other VERTEBRATE pests

1. Pigs damage root crops and native plants

2. Birds

a. Eat planted seeds

b. Damage fruit

3. Dogs, chickens, and humans

C. MOLLUSKS

1. Invertbrate pests

a. Snails with hard shell, slugs without shells

b. Rasping mouthparts that make holes on foliage

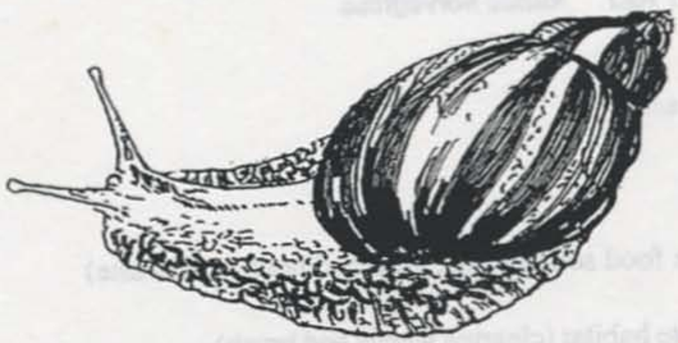
c. Usually feed at night

2. Apple snails (*Pomacea spp.*) a major pest of taro in Hawai'i

3. Giant African Snail (*Achatina fulicha*)

a. Introduced to Pacific prior to World War II

b. Still spreading to other islands



4. Mollusk controls

a. Eradication

b. Barriers such as roofing tin around garden plots

c. Biological controls

d. Molluscicides

e. Baits

i. Attract with chopped papaya stems and leaves

ii. Kill mollusks that congregate around bait

Reading Assignments

1. SPC Pest Advisory Series, Leaflet No. 6, *Giant African Snail.*

2. Taro Pest and Disease Leaflet No. 5, *Apple Snails in Wetland Taro;* in Pacific Islands Farm Manual, ADAP.

III. WEEDS

Lecture 8
WEED SCIENCE

Introduction

A weed is a plant that is considered a pest. Whether a specific plant is called a weed may depend on the situation and the plant's economic (or health) impacts. Some plants may have no economic value but also no negative impacts. Other plants may create allergic reactions such as hay fever. The most common weed plants interfere with agricultural operations, recreation, or lawn and ornamental plantings of homeowners.

Weed control is an agricultural problem for the producers of vegetables, fruits, flowers, field crops, livestock, trees and shrubs. Agricultural students and workers need to acquire the knowledge and skills that help them know when a plant should be considered a weed, what weed conditions are serious enough to require control, and what kind of action is best for the particular plant and its growing conditions.

Objectives

Upon completion of this lesson, students will be able to:

A. List at least eight ways in which weeds cause damage to agricultural production and/or human welfare.

B. List at least five ways in which weeds are considered beneficial.

C. Summarize the history of weed control practices.

D. Identify the scientific names of at least ten common weeds in the US affiliated Pacific islands.

Terms

Beggar's tick - *Bidens alba*
Garden spurge - *Chamaesyce hirta*
Graceful spurge - *Chamaesyce hypericifolia*
Nut sedge - *Cyperus rotundus*
Flora's paintbrush - *Emilia sonchifolia*
Goose grass - *Eleusine indica*
Primrose willow - *Ludwigia hyssopifolia*
Sensitive plant - *Mimosa pudica*
Wood sorrel - *Oxalis spp.*
T-grass - *Paspalum conjugatum*
Wild passionplant - *Passiflora foetida*
Blue rat's tail - *Stachytarpheta urticifolia*

Teaching Outline

A. Different descriptions of a "weed"

1. Unwanted plants

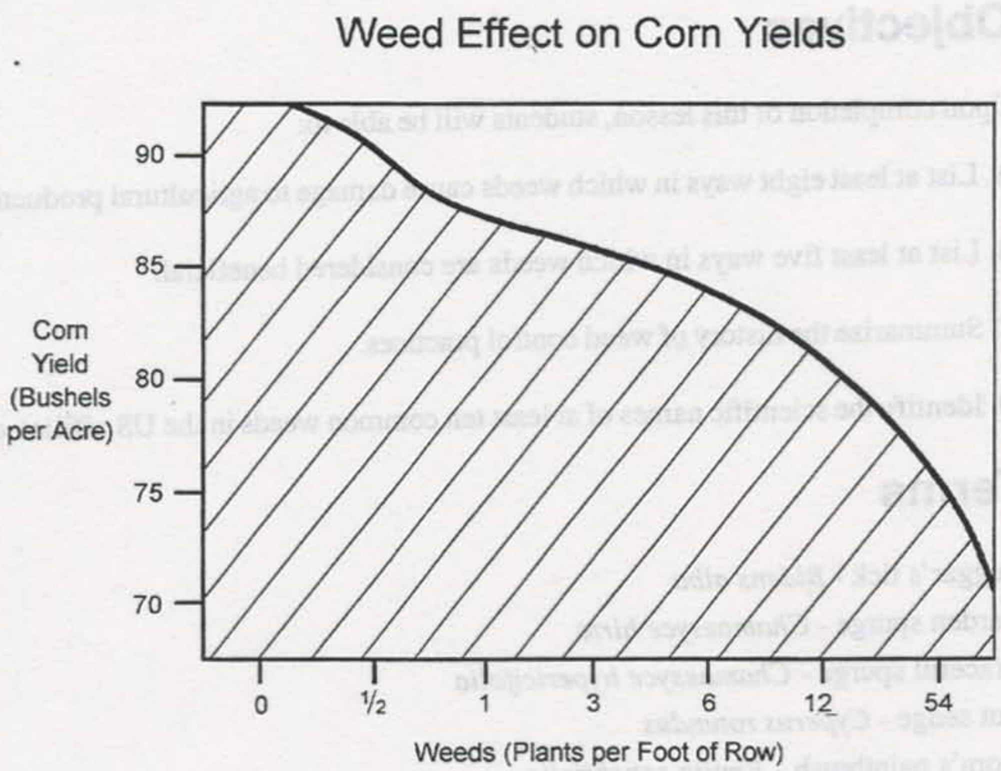
2. A plant growing where more desirable plants should be growing.

3. A plant out of place, e.g. a tomato growing in a field of Chinese cabbage.

B. Damage caused by weeds

1. Competition with more beneficial vegetation.

2. Reduced crop yield.



3. Interference with crop harvest.

4. Reduced quality of produce and/or animal products.

5. Habitat for other pests

   a. Insects, aphids and thrips

   b. Rodents and mollusks

   c. Plant diseases and viruses

6. Clog irrigation or drainage canals and interfere with water catchment

7. Directly harmful

   a. Poison ivy

   b. Allergenic plants

8. Irritating or poisonous to animals

C. Beneficial aspects of "weeds"

1. Prevent or reduce soil erosion

2. Add organic matter and nutrients to soil

3. Provide food and cover for wildlife

4. Yield useful drugs, foods, and delicacies

5. Beautify the landscape

D. Classification of weeds

1. Common names

   a. Can vary from place to place.

   b. Can vary for a specific plant (e.g., *Mimosa pudica*; known as sensitive plant, or sleeping grass, or vao fefe)

   c. Can be the same name for different plants (e.g., pigweed - in Hawaii *Portulaca oleracea*, in the continental United States any of several Amaranthus species).

   d. In 1984 the Weed Science Society of America published a list of almost 2,000 standardized common names.

2. Scientific names

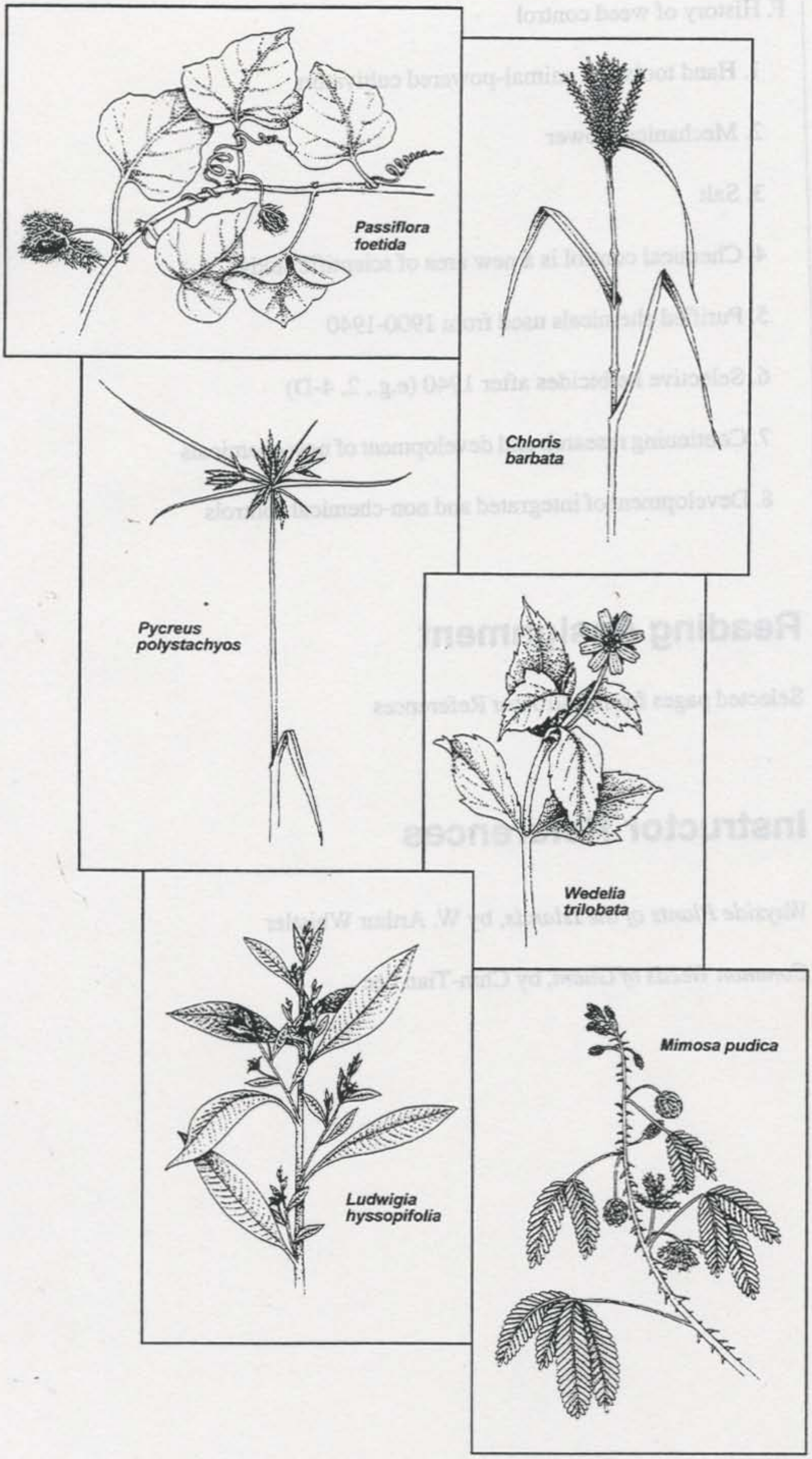
   a. The officially recognized, international classification system.

   b. Latin name of the genus and species (e.g., *Cyperus rotundus*).

   c. Shows the relationship of a plant (weed) to other plants in the same family and genus.

E. Some common weeds in the U.S. affiliated Pacific islands

	Samoa	**Guam**	**Belau**	**Pohnpei**	**Saipan**	**Hawaii**
Grasses and sedges						
Chloris barbata	x	x	x	x	x	x
Cyperus rotundus	x	x	x	x	x	x
Eleusine indica	x	x	x	x	x	x
Kyllinga nemoralis	x	x	x	x	x	x
Paspalum conjugatum	x	x	x	x	x	x
Pycreus polystachyos	x	x	x	x	x	x
Broadleaf weeds						
Bidens alba	x	x	x	-	x	x
Chamaesyce hirta	x	x	x	x	x	x
Chamaesyce hypericifolia	x	x	x	-	x	x
Costus speciosus	x	x	x	x	-	x
Emilia sonchifolia	x	x	x	x	x	x
Ludwigia hyssopifolia	x	x	x	x	-	x
Mimosa pudica	x	x	x	x	x	x
Oxalis spp.	x	x	x	x	x	x
Passiflora foetida	x	x	x	x	x	x
Polygala paniculata	x	x	x	x	-	x
Stachytarpheta urticifolia	x	x	x	-	x	x
Wedelia trilobata	x	x	x	-	-	x



Show transparencies 8.1, 8.2, 8.3, 8.4, 8.5, and 8.6

Weeds not pictured here are included as transparencies 8.7, 8.8, 8.9, and 8.10

F. History of weed control

1. Hand tools and animal-powered cultivators

2. Mechanical power

3. Salt

4. Chemical control is a new area of scientific study

5. Purified chemicals used from 1900-1940

6. Selective herbicides after 1940 (e.g., 2, 4-D)

7. Continuing research and development of new chemicals

8. Development of integrated and non-chemical controls

Reading Assignment

Selected pages from Instructor References

Instructor References

Wayside Plants of the Islands, by W. Arthur Whistler

Common Weeds of Guam, by Chin-Tian Lee

Lecture 9
WEED IDENTIFICATION

Introduction

Proper identification of weeds is basic to their management. Control methods appropriate for one weed species may be ineffective against another weed that is very similar in appearance. This is especially true for many herbicides. There are several ways to identify weeds including; pictures, preserved specimens, written descriptions, and keys. Weed handbooks have been produced which combine pictures and written descriptions. Some handbooks also contain a simple key to help place weeds in the proper family.

Objectives

Upon completion of this lesson, students will be able to:

A. Explain why weed identification is important.

B. State at least three identifying features of a monocot and dicot plant, with examples of each.

C. Correctly identify common weeds using a handbook of local weeds.

D. Recognize and identify fifteen of the most common local weeds, without using a handbook.

E. Define the fourteen terms provided below.

Terms

AURICLE - Ear-shaped appendages (parts) that project from either side of the collar.

COLLAR - Area on the outer side of the leaf where the blade and leaf sheath meet.

CROWN - The base of stems where roots originate.

DICOTYLEDON - A flowering plant with two seed leaves or cotyledons (also called a dicot).

INFLORESCENCE - A flower cluster or the arrangement of flowers on a plant.

LEAF BLADE - The main, central portion of a leaf.

LEAF SHEATH - Lower part of the leaf which wraps around the stem.

LIGULE - A membrane found at the junction of the leaf sheath and leaf blade.

MONOCOTYLEDON - A flowering plant with one seed leaf or cotyledon (also called a monocot).

NODE - The part of a stem where leaves emerge.

RHIZOME - An underground stem, usually with nodes and buds.

STOLON - A horizontal stem, usually rooting at above-ground nodes.

TILLER - An erect shoot which arises from the crown of a grass.

VERNATION - The arrangement of unfolding grass leaves in a bud shoot.

Teaching Outline

A. The importance of weed identification

1. Distinguish the desired crop from the weed: some weeds look similar to the early stages of desired plants.

2. Choose the correct weed control recommendations: some weeds look similar but have different control recommendations.

B. Identifying grassy weeds

1. Grasses are MONOCOTYLEDONS (monocots).

   a. The seeds have one cotyledon.

   b. The leaves are parallel-veined.

   c. The growing point is at the base of the plant (often below ground level).

   d. The flower parts are in threes.

2. Identifying part of a grass plant.

   a. INFLORESCENCE - the flower cluster may be a:

      i. Panicle (branching)

      - Open and loose

      - Compressed

      ii. Spike (unbranching)

      - Open or compressed

      - Narrow or broad

   b. LIGULE - a membrane found at the junction of the leaf sheath and leaf blade that may be:

      i. Membranous

      ii. Hairy

      iii. Absent

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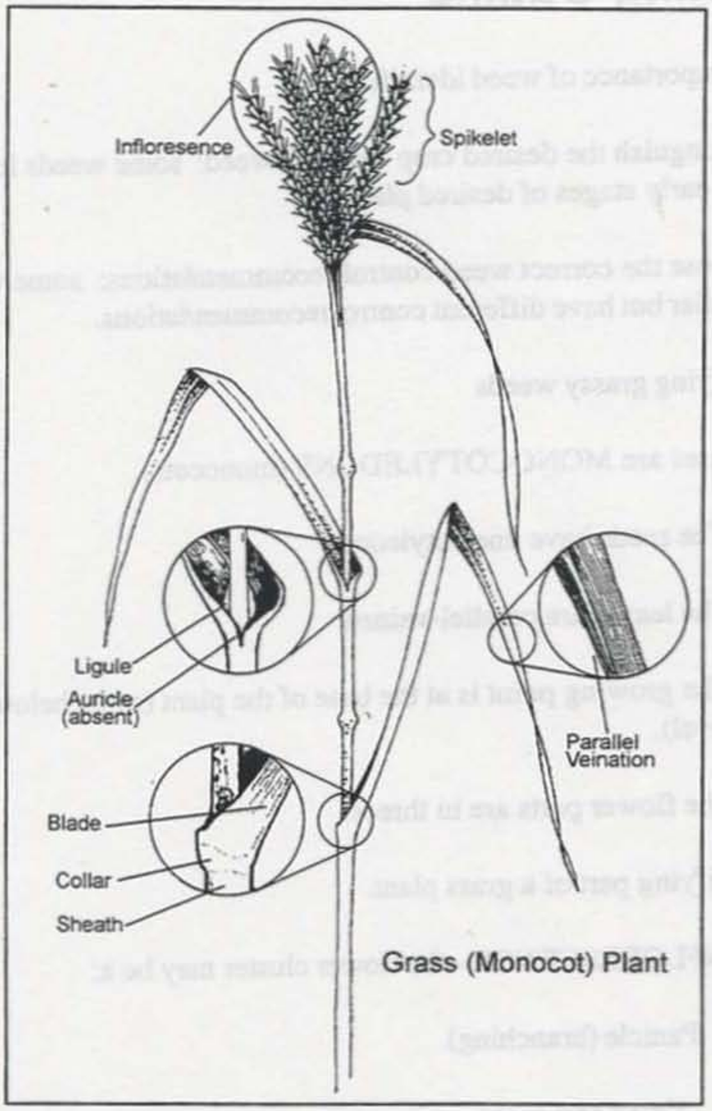


c. COLLAR - area on the outer side of the leaf where the blade and leaf sheath meet that may be:

i. Continuous

ii. Divided

iii. Narrow or broad

d. AURICLES - ear-shaped appendages that project from either side of the collar that may be:

i. Long and clasping

ii. Short

iii. Absent

e. LEAF BLADE - upper portion of the leaf that may be:

i. Narrow or wide

ii. Rough, smooth, or hairy

iii. Short or long

f. LEAF SHEATH - lower part of the leaf which wraps around the stem that may be:

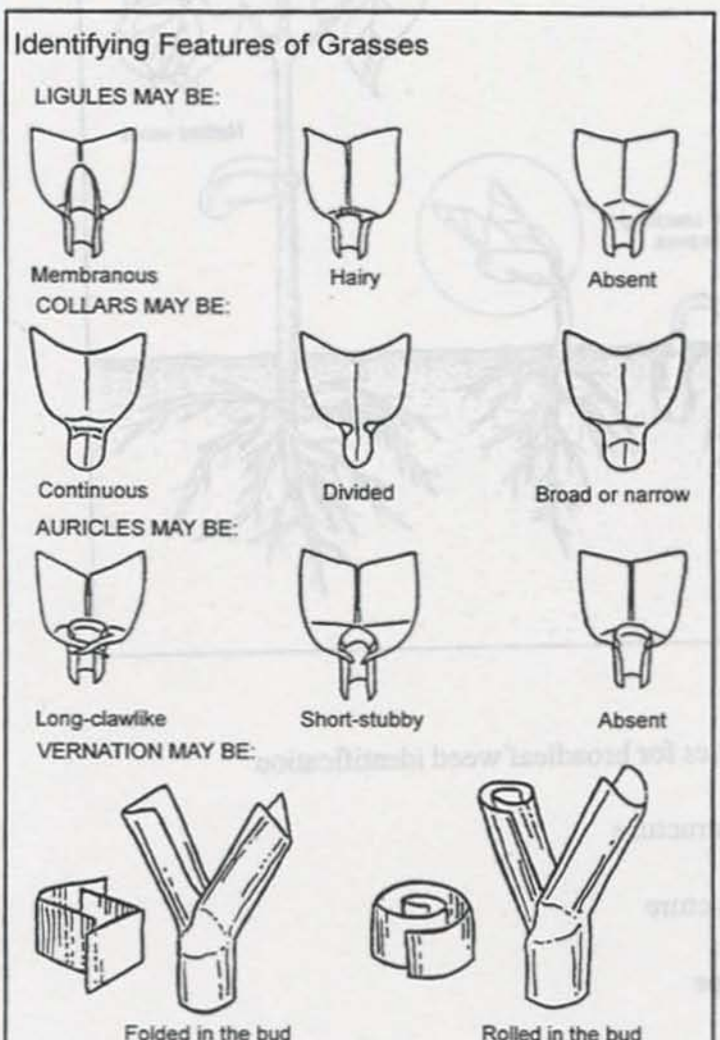
i. Rough or smooth

ii. Flat or compressed

g. VERNATION - the arrangement of unfolding grass leaves that may be:

i. Rolled

ii. Folded



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C. Identifying broadleaf weeds

1. Broadleaf weeds are DICOTYLEDONS.

   a. The seeds have two cotyledons.

   b. The leave are net-veined.

   c. The growing points are found at stem tips and leaf axils.

   d. The flower parts are in fours or fives.

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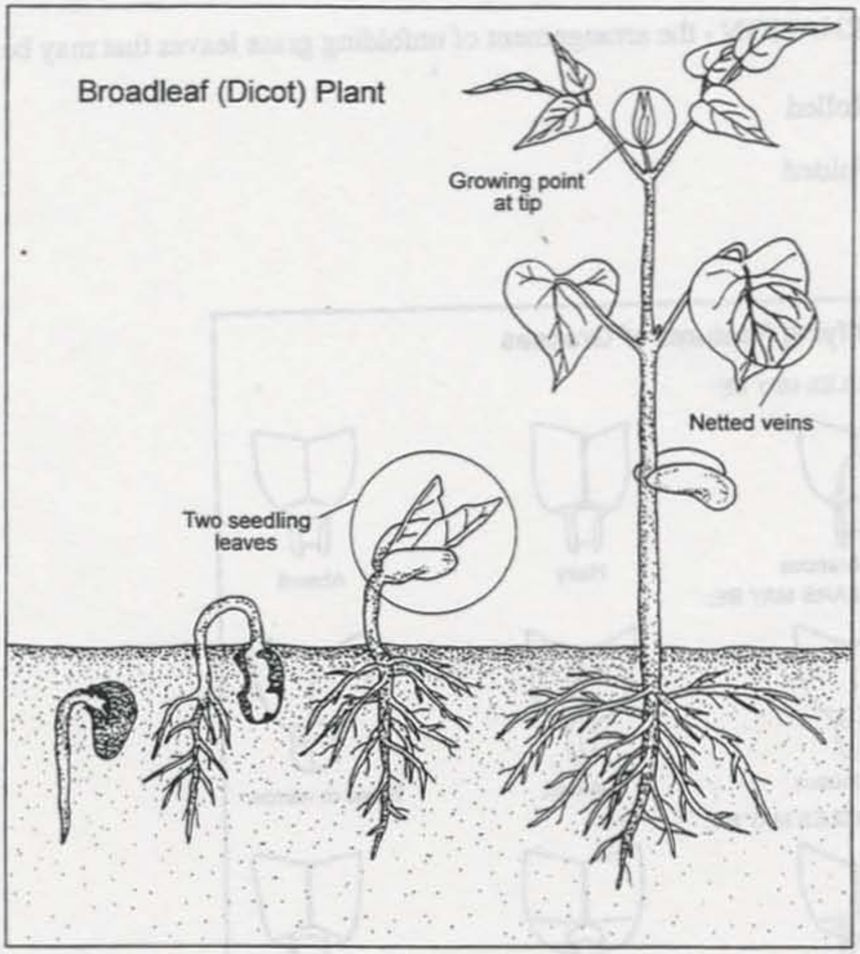
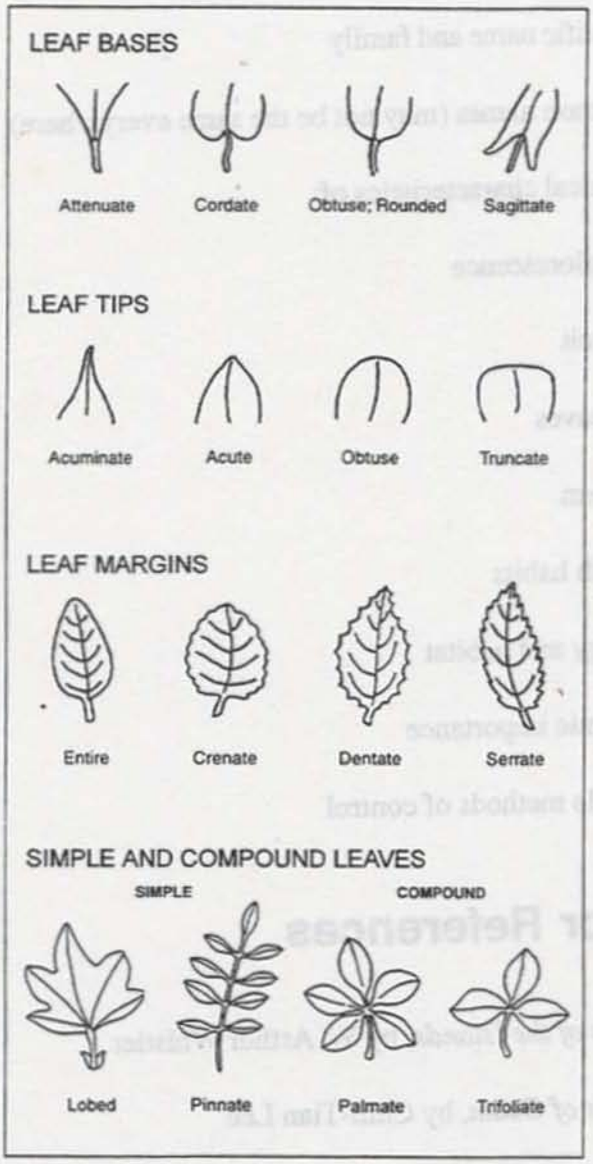


2. Characteristics for broadleaf weed identification

   a. Flower structure

   b. Fruit structure

   c. Leaf shape



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D. Weed identification methods and tools

1. Field observation

2. Herbarium collection

3. Dichotomous key

E. Weed handbooks

1. Identification aids for weeds are usually produced for a particular location, e.g. Hawaii, Guam, Western Polynesia, etc.

2. Contain drawings, photographs, and descriptions

3. Descriptions may include:

a. Scientific name and family

b. Common names (may not be the same everywhere)

c. Botanical characteristics of:

i. Inflorescence

ii. Fruit

iii. Leaves

iv. Stem

d. Growth habits

e. Ecology and habitat

f. Economic importance

g. Possible methods of control

Instructor References

Wayside Plants of the Islands, by W. Arthur Whistler

Common Weeds of Guam, by Chin-Tian Lee

Weed Handbook of Western Polynesia, by W. Arthur Whistler

Lecture 10
WEED ECOLOGY

Introduction

Weeds are a problem in many different environmental settings. They compete with other plants for water, nutrients, light, and space. Many weeds are quite aggressive and can adapt to a wide range of environmental conditions. This chapter deals with the factors that influence the establishment, growth, development, and distribution of weeds. Developing a weed control program requires knowledge of a weed's life cycle, methods of reproduction, and distribution.

Objectives

Upon completion of this lesson, students will be able to:

A. Explain five factors that determine the establishment, growth, and distribution of weeds.

B. Define and give two examples of annual and perennial plants.

C. Describe at least five ways weeds reproduce asexually.

D. Explain at least three reasons why some weeds are persistent.

E. List five ways weeds are distributed, with an example of each.

F. Define the ten terms provided.

Terms

ANNUALS - Plants which complete their life cycle in one year or less.

BULB - A highly compressed underground stem to which storage scales (modified leaves) are attached.

DORMANT - Not currently growing but capable of growing under proper conditions.

ESTABLISHMENT - The successful growth of an organism in a new environment.

PERENNIALS - Plants which normally live longer than two years.

RHIZOME - An underground stem usually horizontal and elongated, capable of producing new shoots.

STOLON - An above-ground creeping stem, rooting at the nodes, capable of producing new shoots.

TUBER - An enlarged, fleshy underground tip of a stem capable of regenerating a plant.

VIABILITY - The ability to grow.

WEED ECOLOGY - The relationship between weeds and their environment.

Teaching Outline

A. WEED ECOLOGY

1. Weeds require the same resources as other plants.
2. Weeds compete with other plants for water, nutrients, light, and space.
3. Crops with poor competitive ability often have larger weed populations

B. Environmental factors

1. Many weeds can become established in areas with environmental conditions unsuited to other plants.
2. Weeds that tolerate extreme or adverse conditions are often difficult to control.
3. Climatic factors
   a. Light
   b. Water
   c. Temperature
   d. Wind
4. Soil conditions
   a. Water
   b. Temperature
   c. Ph balances
   d. Salinity
   e. Fertility
   f. Depth of soil
   g. Drainage
   h. Compaction

5. Biological factors

a. Plants

b. Animals and humans

d. Diseases

e. Insects

C. Classification of weeds by life cycle.

1. ANNUALS

a. VIABLE seeds germinate when environmental conditions are met.

b. Seedlings mature into plants that produce new seed.

c. This life cycle is completed in one year or less.

d. Examples - Goose grass and Beggar's tick

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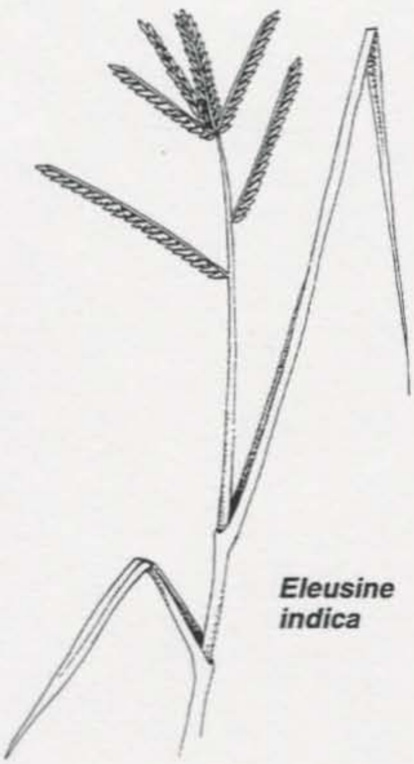


Eleusine indica

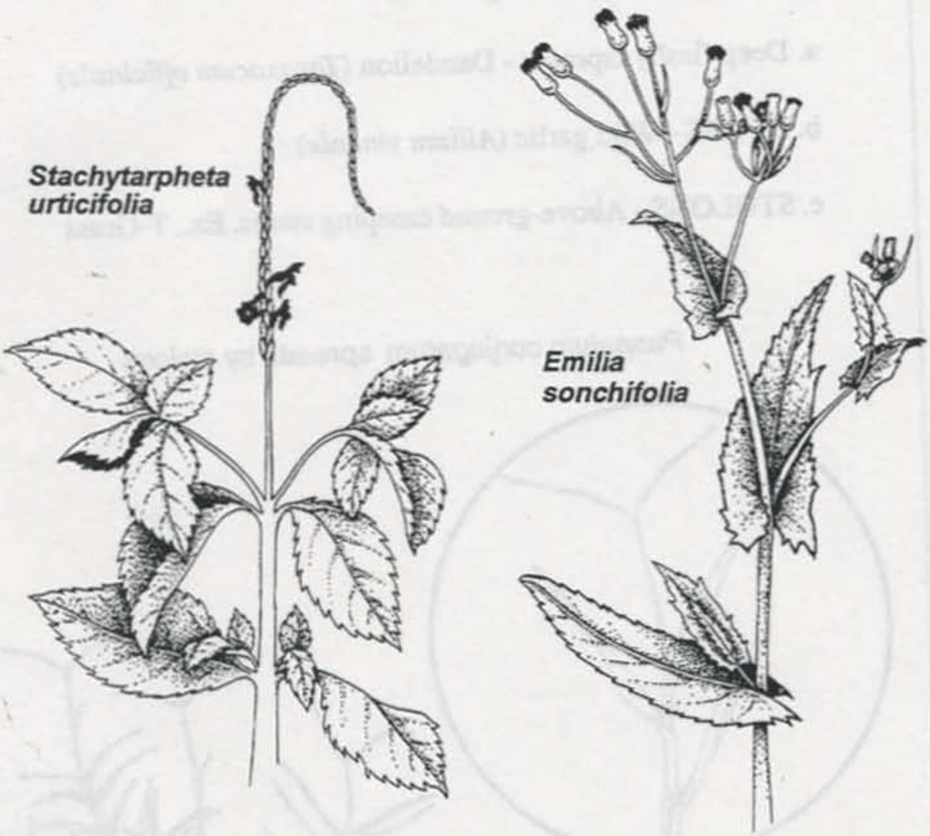
Bidens alba

2. Simple PERENNIALS

a. Plants normally live longer than two years.

b. May generate new plants by seed and VEGETATIVE REPRODUCTION

c. Examples - Blue rat's tail and Flora's paintbrush



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3. Creeping perennials

a. Reproduce vegetatively by rhizomes, stolons, creeping roots, etc.

b. Most also reproduce by seed.

D. Methods of Reproduction

1. Sexual reproduction

a. Annuals reproduce mainly by seeds

b. Some perennials can only reproduce by seeds

2. Asexual reproduction (vegetative)

a. Deep fleshy taproots - Dandelion (*Taraxacum officinale*)

b. BULBS - Wild garlic (*Allium vineale*)

c. STOLONS - Above-ground creeping stems. Ex., T-Grass

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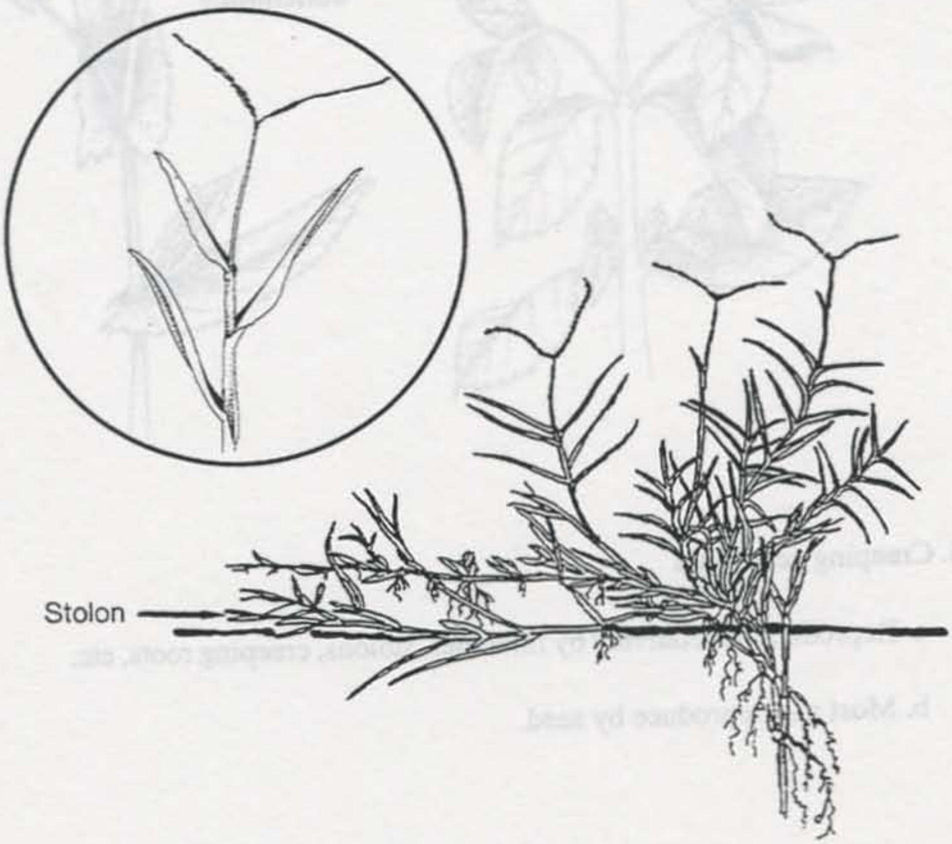
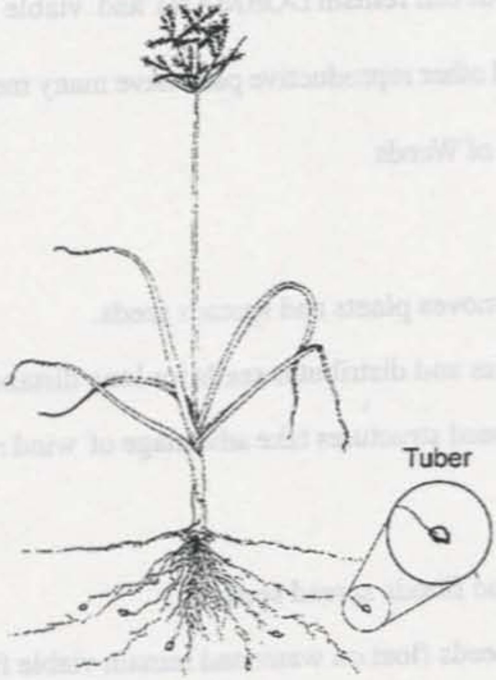
Paspalum conjugatum spreads by stolons



d. TUBERS - Enlarged fleshy, underground tip of a stem. Ex., Nut sedge

Cyperus rotundus reproduces by tubers



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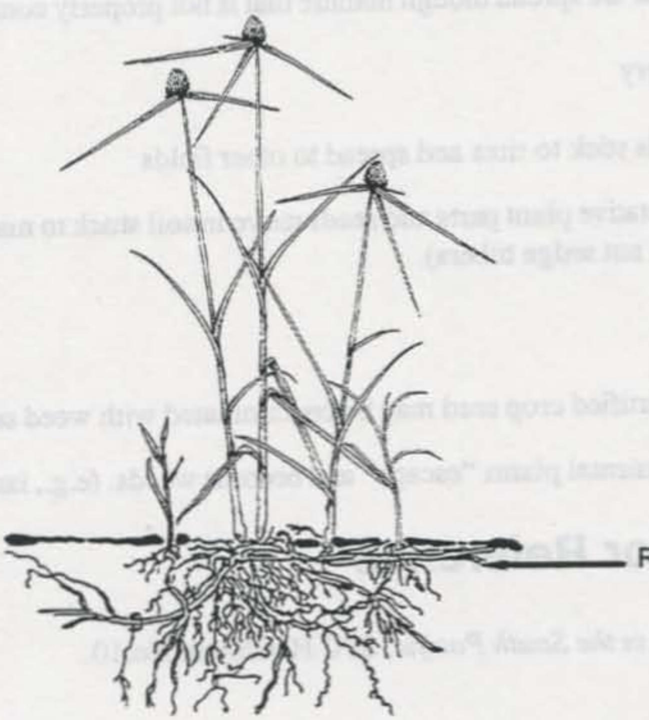
e. RHIZOMES - An underground horizontal, elongated stem.
Examples include; Wild sugarcane, Johnson grass, and Kyllingia.

Kyllinga spp. spreads by rhizomes



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E. Persistence of Weeds

1. Some weeds produce hundreds of thousands of seeds per plant.

2. Some seeds can remain DORMANT and viable for years.

3. Seeds and other reproductive parts have many means of distribution.

F. Distribution of Weeds

1. Wind

   a. Wind moves plants and spreads seeds.

   b. It carries and distributes seeds for long distances.

   c. Some seed structures take advantage of wind movement

2. Water

   a. Rain and floods spread seeds

   b. Some seeds float on water and remain viable for long periods.

3. Animals

   a. Seeds travel by sticking to animals.

   b. Seeds pass through digestive tract of birds and other animals.

   c. Seeds are spread though manure that is not properly composted.

4. Machinery

   a. Seeds stick to tires and spread to other fields

   b. Vegetative plant parts and seeds move in soil stuck to machinery (e.g., nut sedge tubers).

5. Humans

   a. Uncertified crop seed may be contaminated with weed seeds.

   b. Ornamental plants "escape" and become weeds. (e.g., lantana)

Instructor Reference

Weed Control in the South Pacific, SPC Handbook No.10.

IV. DISEASES

Lecture 11

BRIEF HISTORY OF PLANT PATHOLOGY

Introduction

Plant pathology is the study of the cause, development, and control of plant diseases. It is built on the basic framework of botany and utilizes the associated disciplines of genetics, nematology, entomology, chemistry, virology, and bacteriology. Disease control requires an understanding of economic, environmental, cultural, genetic, and microbiological factors that determine crop development and use.

The study of plant diseases has been recorded since people first began growing crops. The modern science of plant pathology began in the learning centers of France, Germany, and England during the 18th century. It has since continued in the United States and Canada as well. This lesson will provide a brief historical overview.

Objectives

Upon completion of this lesson, students will be able to:

A. Explain the association of other disciplines to plant pathology.

B. Describe a historical perspective of plant diseases and their management.

C. Describe at least two specific plant disease epidemics that occurred in the past 100 years.

D. Define the eight terms provided below.

Terms

BACTERIA - Single celled plants capable of causing plant disease.

BLIGHT - A disease that causes the rapid death of leaves, flowers, stems and entire plants .

DISEASE- Malfunctioning of host cells and tissues caused by a pathogen or environmental factor.

EPIDEMIC- A widespread and severe outbreak of a disease.

FUNGUS - Plant-like organisms lacking chlorophyll and capable of causing disease.

MILDEW- A fungal disease of plants which produces a whitish growth on the host surface.

RUST- A fungal disease caused by a member of the *Uredinales* family.

SMUT- A fungal disease caused by a member of the *Ustilaginales* family.

Teaching Outline

A. Early recorded evidence of plant DISEASES and controls.

1. India (2000 B.C.) - Vedic records of fungicide for field and storage pests.

2. Sumeria (1700 B.C.) - Clay tablets refer to viral disease.

3. Ancient Israel

a. 621 B.C. - BLIGHT and MILDEW listed as dangers to crop production.

b. 500 B.C. - Reference to crop rotation in Exodus 23: 10-11: "For six years you shall sow your land and gather in its yield; but the seventh year, you shall let it rest and lie fallow, that the poor of your people may eat. And what they leave, the wild beasts may eat. You shall do likewise with your vineyard and with your olive orchard."

4. Ancient Rome (60 A.D.)

a. Recommendations by Rubigo, god of RUSTS

i. Early sowing of wheat and barley seed so plants ripen before cereal rust appears.

ii. Placing laurel branches in fields so rust attacks it instead of cereal.

b. To control mildew, Pliny advises soaking wheat seed in wine and crushed cypress leaves prior to planting.

B. Recent historical developments

1. France (1660): First known legal attempt to control disease; law passed requiring eradication of barberry bushes because of their apparent connection with cereal rust

2. England (1660): Salt water used as seed treatment after SMUT fails to develop in seed salvaged from shipwreck off Bristol.

3. France (1755)

a. Mathieu Tillet, amateur botanist, publishes results of three years of work on wheat bunt.

b. Demonstrates that smut is contagious; wheat dusted with spores becomes diseased more heavily than non-dusted wheat.

c. Seed treatment of salt and lime reduces percentage of diseased plants.

4. United States (1817)

   a. BACTERIAL blight of pear and apple a serious threat on East Coast.

   b. Pennsylvania Horticultural Society offer $500 for remedy.

5. Ireland (1840's)

   a. Soil-borne FUNGUS, *Phytopthora infestans*, causes potato blight .

   b. Destroys potato crop in field and storage.

   c. Famine - One million people die and one and a half million migrate.

   d. Major change in the population and culture of various countries to which the Irish people migrated, particularly the United States.

6. Germany/France (1850): While working with cereal rust, Anton Debary, "Father of Plant Pathology," discovers that fungus causes disease.

7. France (1880)

   a. Millardet publishes findings on using copper sulfate and quick lime to keep people from stealing vineyard grapes.

   b. Farmers notice that mixture protects plants from mildew.

   c. The mixture known as "Bordeaux Mix" is still used today.

8. Bengal, India (1940's)

   a. Soil-borne fungus, *Helminthosporum oryzae*, causes rice brown spot EPIDEMIC.

   b. Extensive loss of rice yields; the limited supply is too expensive for most people to afford.

   c. Farmers move to city hoping to find work and food; they find neither.

   d. Two million people die of starvation.

C. Other effects of plant disease outbreaks

1. United States (1970's)

   a. Soil-borne fungus, *Helminthosporum maydis*, causes Southern corn-leaf blight.

   b. Destroys 15% percent of corn crop and causes a billion dollar loss.

2. Eastern United States (1930's-1970's)

a. Fungus, *Ceratocystis ulmi*, causes Dutch Elm disease.

b. Destroys trees in forests and neighborhoods.

c. Causes economic hardship to individuals and municipalities, lowers environmental quality.

3. Both U.S. epidemics caused economic hardship and reduced quality of life but neither one led to famine or death.

4. Most plant diseases are restricted to discrete geographic areas such as farms, individual fields, or gardens.

Reading Assignment

Selections from instructor reference.

Instructor Reference

Plant Pathology, by George N. Agrios, pp. 8-26.

Lecture 12
DISEASES, DISORDERS, AND SYMPTOMOLOGY

Introduction

All species of wild and cultivated plants are subject to disease. Plant disease is a continuing process caused by pathogenic or non-pathogenic agent which leads to decreased plant growth, development, and yield. Disease differs from injury in that an injury is an irritant such as wounding, burning, or freezing.

Objectives

Upon completion of this lesson, students will be able to:

A. Distinguish between a plant disease and a plant injury.

B. Define basic plant pathology terms relating to symptoms and disease.

C. Discuss the causal agents and types of diseases and disorders that affect plants.

D. Define the nine terms provided below.

Terms

CANKER - Dead and discolored portions of bark, stems, pseudostems, or roots.

GALL - A swelling or overgrowth that results from a plant infection caused by certain pathogens.

LESION - A localized discolored area or a rupture in the surface tissue.

ROT - Decomposition of tissue caused by bacterial or fungal disease, may be dry or wet.

SUSCEPTIBLE - Lacking the ability to resist the damaging effect of a pathogen.

SYMPTOM - A visible result of an interaction between host and pathogen (eg., chlorosis, wilting, rot).

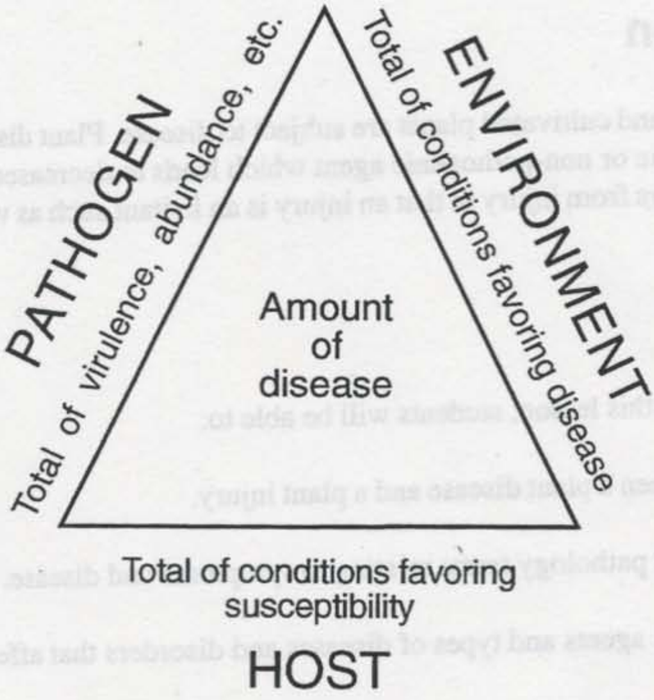
VIRUS - A nucleoprotein that multiplies in living cells of its host and has the ability to cause disease.

VIRULENCE - The degree of a pathogen's ability (from high to low) to cause disease.

WILTING - The condition of plant cells that have lost more water than they can absorb causing partial collapse of soft stems and leaves.

Teaching Outline

A. The disease triangle



1. Biological equilibrium in nature

    a. Between species

    b. Between individual cells

2. Factors that upset equilibrium and cause disease

    a. SUSCEPTIBLE plant host

    b. Pathogens - VIRULENCE and abundance

    c. Environmental changes

    d. Severity of damage depends on extent of change in equilibrium

3. Dynamic equilibrium

    a. Introduction of new organism does not necessarily lead to its establishment into local environment

    b. Local organisms usually able to maintain equilibrium

B. Pathogenic (biotic) causal agents

1. Disease caused by living organisms

2. Fungi, bacteria, VIRUSES, nematodes, viroids, and mycoplasmas

3. SYMPTOMS

a. Range from minor affects to death of; cells, tissues, or entire plant.

b. Decreased plant growth and yield

c. Some symptoms common to several causal agents. For example, WILTING can be caused by infection or by lack of water.

d. Plants are frequently attacked by more than one organism. The influence of each pathogen is difficult to determine.

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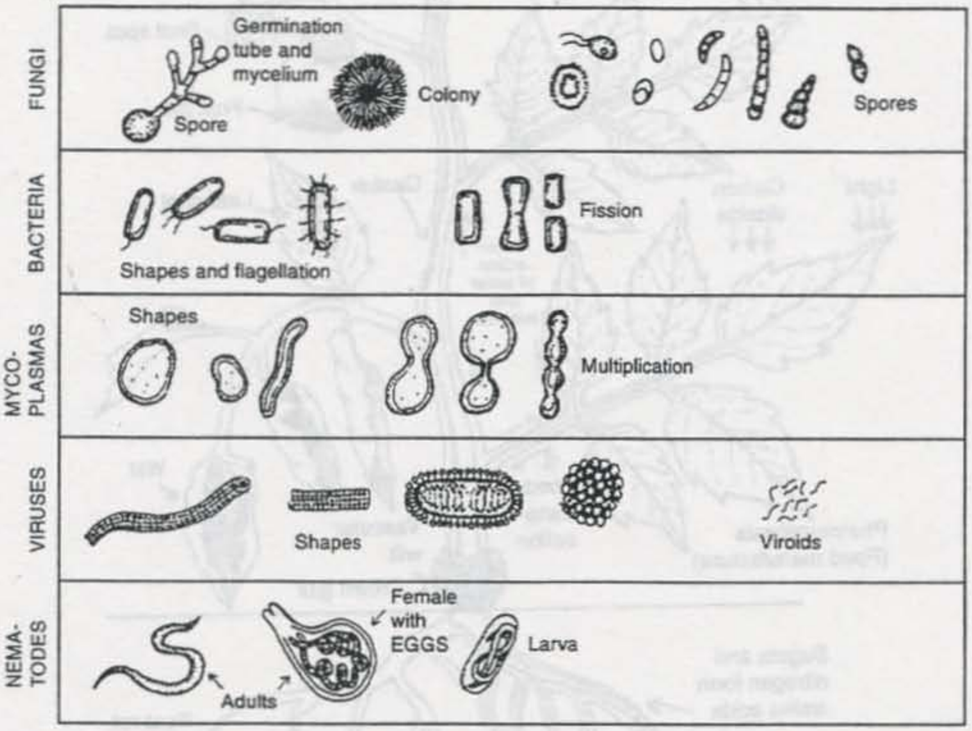


SHAPES AND REPRODUCTIVE STRUCTURES OF SOME OF THE GROUPS OF PLANT PATHOGENS

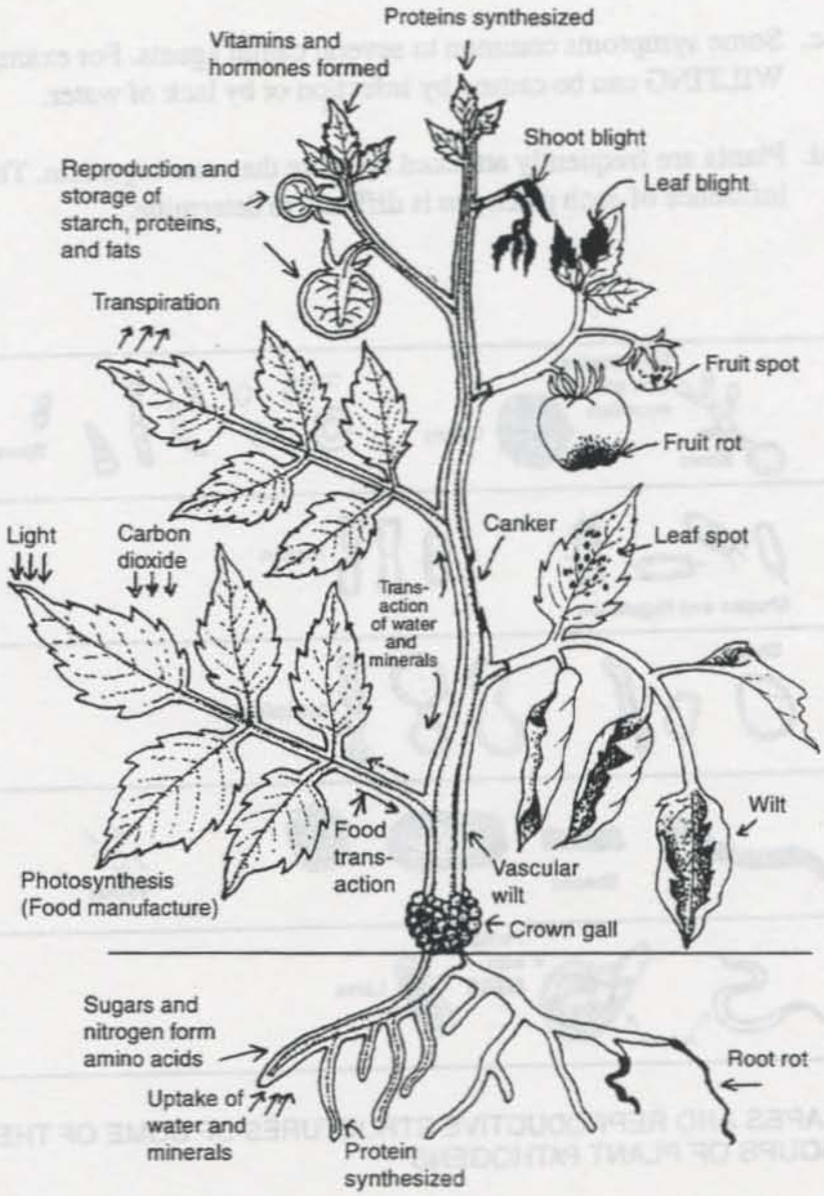
C. Diseases

1. Classified according to:

   a. Symptomology - leaf spots, rot, wilt

   b. Causal agent - fungi, bacteria, virus

   c. Plant parts affected; leaf, root, stem, pseudostem, fruit etc.



SCHEMATIC REPRESENTATION OF THE BASIC FUNCTIONS IN A PLANT (LEFT) AND OF THE INTERFERENCE WITH THESE FUNCTIONS (RIGHT) CAUSED BY SOME COMMON TYPES OF PLANT DISEASES

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2. Bacterial diseases

   a. Attack leaves, stems, fruits

   b. Symptoms can include:

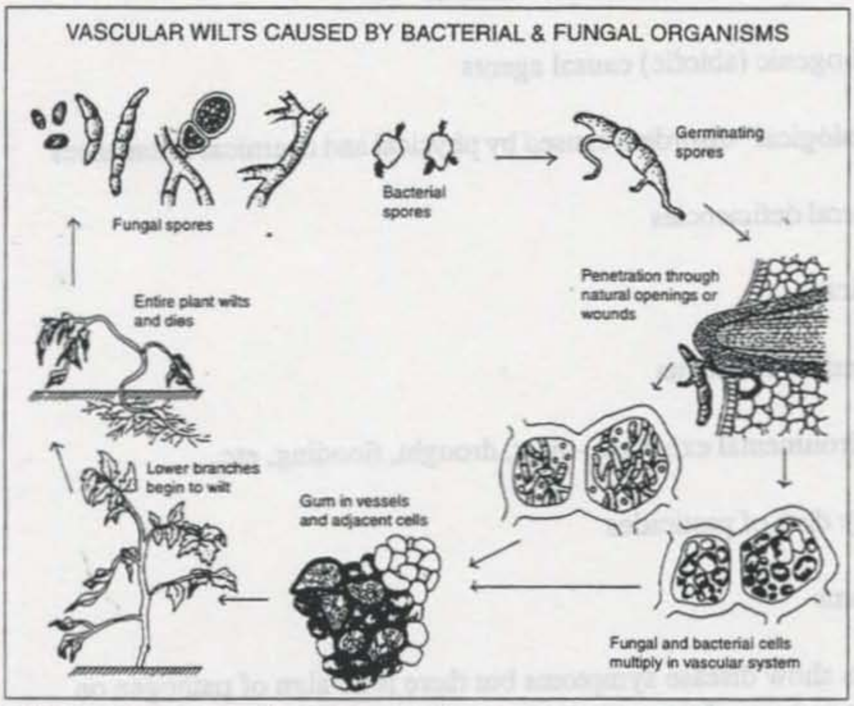
      i. Leaf spots and blights

      ii. Wet LESIONS

      iii. Cracked stems and bark

      iv. Wilting

      v. GALLS and CANKERS



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3. Fungal diseases

   a. Attack all parts of plant

   b. Symptoms can include:

      i. Damping off

      ii. Soft or hard ROTS

      iii. Seedling blights

      iv. Root rots

      v. Galls

      vi. Wilts

      vii. Suppression of photosynthesis

4. Viral diseases

a. Attack leaves, stems, fruits and become systemic

b. Symptoms can include:

i. Mosaic patterning

ii. Stunting

iii. Bunching

iv. Distorted and deformed terminals

D. Non-pathogenic (abiotic) causal agents

1. "Physiological" disorders caused by physical and chemical imbalances

a. Mineral deficiencies

b. Toxicity

c. Chemical pollutants

d. Environmental extremes - heat, drought, flooding, etc.

e. Spray drift of pesticides

2. Symptoms

a. Plants show disease symptoms but there is no sign of pathogen on plant or internal tissue

b. Symptoms mimic those caused by pathogenic agents

Reading Assignment

Selections from instructor references.

Lecture 13
BACTERIA AND MYCOPLASMAS

Introduction

Plant pathogenic bacteria have been known since 1882. They cause a variety of symptoms and are the best understood of the plant pathogenic PROKARYOTES. However, some species were not discovered until 1972; their properties and relationships to plants and other pathogenic bacteria are poorly defined or unknown at this time.

Approximately 1600 species of bacteria are known. Of these, 80 species cause plant diseases and many of these species have host specific PATHOVARS which are identified by the host plant that is attacked. Bacterial diseases of plants occur in every place that is reasonably warm or moist. They affect all kinds of plants and under favorable environmental conditions they can be extremely destructive.

Objectives

Upon completion of this lesson, students will be able to:

A. Explain the morphology, reproduction, and survival of bacteria in nature.

B. Describe the symptomology and control of bacterial diseases in plants.

C. Describe mycoplasma diseases and how they spread.

D. Define the five terms provided below.

Terms

FLAGELLUM - Whip-like structures that are used by bacterial to propel them in liquid.

MYCOPLASMA - Pleomorphic prokaryotic organisms lacking a cell wall.

PATHOVAR - Bacteria that can only infect plants in a certain genus or species.

PROKARYOTES - Single-cell organisms that have a cell membrane, cytoplasm and DNA; but no nucleus.

SAPROPHYTES - Organisms that live on dead organic matter.

C. Development and survival of bacteria

1. Most pathogenic bacteria develop as parasites in host plants.

2. Spread of bacteria

   a. Within same plant or between plants

   b. Spread by water, insects, humans, animals

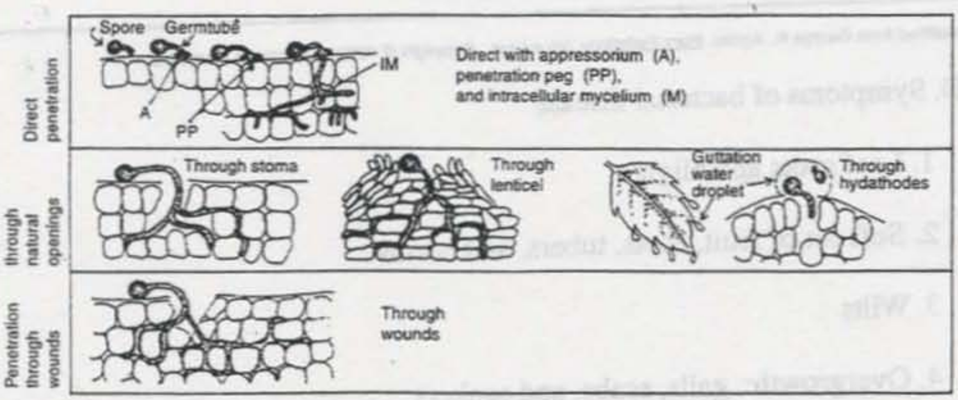
   c. Bacteria with flagellum only move short distance

3. Factors affecting development and survival

   a. Host genera

   b. Soil temperature and humidity

METHODS OF PENETRATION AND INVASION BY BACTERIA AND FUNGI



Modified from George N. Agrios, Plant Pathology, 3rd edition. Copyright © 1988 by Academic Press, Inc.

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4. Survive as SAPROPHYTES (eat dead organisms)

   a. Survival in soil

      i. In plant exudate

      ii. On insects

   b. Survival on plant

      i. Buds

      ii. Wounds

      iii. Exudates

      iv. Infected plant material

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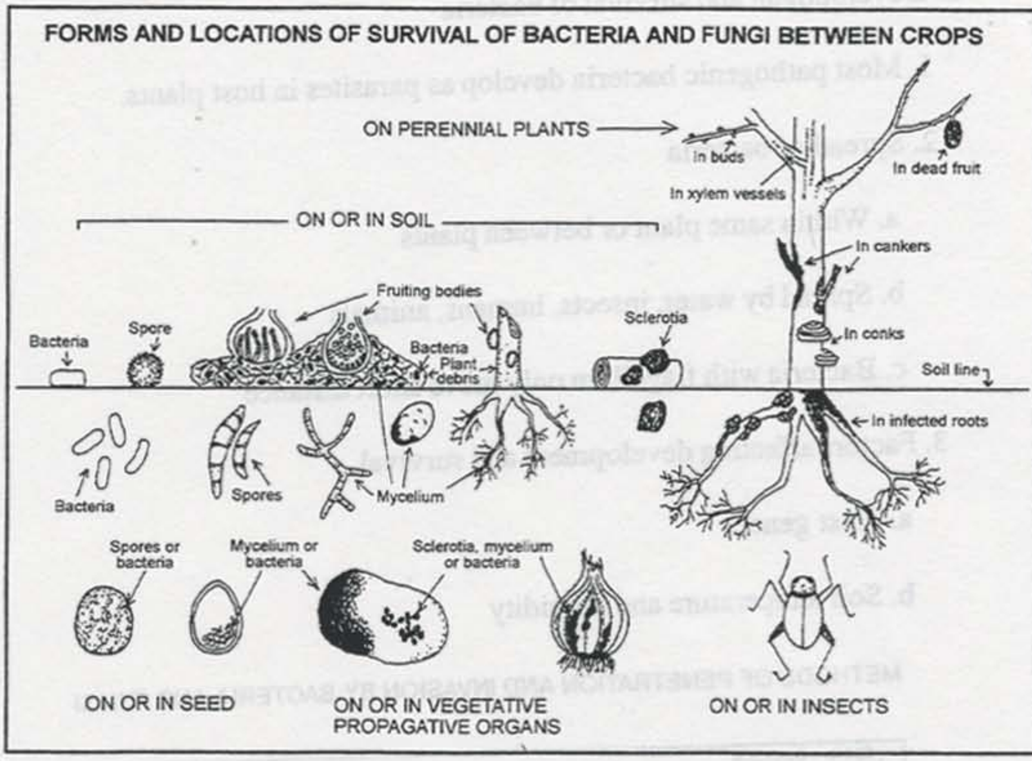


D. Symptoms of bacterial disease

1. Leaf spots and blights

2. Soft rot of fruit, roots, tubers, and corms

3. Wilts

4. Overgrowth: galls, scabs, and cankers

5. Symptoms vary from genera to genera

E. Common bacterial diseases

1. *Erwinia spp.*

a. Causes blights and cankers

b. Population increases in host plant and declines in soil

2. *Agrobacterium spp.* and *Pseudomonas spp.*

a. Cause galls and wilts

b. Live in soil and build up populations in host plant

c. Released into soil when host plant dies or is harvested

d. Survive if susceptible hosts are grown in infected soil

F. Bacteria identification

1. Lab methods

a. Eliminate fungal infection as causal agent

b. Grow pure cultures in agar or water with nutrients and components specific to bacteria

c. Identify bacteria genera and species

2. Characteristics used to identify bacteria genera and species

a. How colony grows

b. Colony color

c. Chemicals produced by bacteria

d. Test bacteria on host indicator plants to reproduce known symptomology

e. Serology: Antibody mixed with fluorescent compound for species and pathovar specific antisera

G. Control of bacterial disease

1. Difficult to control

2. Use combination of measures

a. Quarantine

b. Reduction of inoculum

c. Eradication

d. Resistant crop varieties

e. Vector control

f. Manipulation of production practices

H. MYCOPLASMAS

1. First seen with electron microscope in 1967 in phloem of plants infected with yellows-type disease

2. Viruses previously thought of as causal agent

3. Micoplasmas also seen in insect vectors of diseases

4. Susceptible to tetracycline but not penicillin

5. Responsible for 200 plant diseases affecting several hundred genera

6. Spread of organism

   a. Carried in plant sap and transmitted by psyllids and plant hoppers

   b. Grow and reproduce in vector

   c. Depending on temperature, transfer to healthy plant requires 10-45 day incubation time

Reading Assignment

Selections from instructor reference.

Instructor Reference

Plant Pathology, by George N. Agrios, pp. 510-595.

Lecture 14
FUNGI

Introduction

Fungi are EUKARYOTIC plant-like organisms that lack chlorophyll. They are usually microscopic but can be quite large, like bract fungi and puffballs. Approximately 100,000 fungus species are known. They are normally saprophytic; they live on dead organic matter which they help decompose. About 50 species cause diseases in humans and about as many cause diseases in animals. Most of them are superficial diseases of the skin. Around 8,000 species of fungi cause diseases in plants. Most plants are attacked by some type of pathogenic fungus and each fungus can attack more than one kind of plant.

Objectives

Upon completion of this lesson, students will be able to:

A. Describe the morphology, colonization, reproduction, and survival of fungal pathogens.

B. Describe at least five general symptoms of fungal diseases with specific crop examples.

C. Explain at least six common practices for managing fungal diseases of crop plants.

D. Define the ten terms provided below.

Terms

COENOCYTIC - Containing many nuclei.

EUKARYOTES - Organisms with true nuclei

GAMETE - Male or female reproductive cell of fungi nuclei "parent cell."

HYPHAE (MYCELIA) - Individual branches or filaments of a mycelium.

MYCELIUM - The mass that makes up the body of a fungus.

OBLIGATE - A parasitic life form that can only live on or in its host.

SEPTA - Cross-wall separating nuclei and cells of some fungi.

SPORE - The reproductive unit of fungi, (similar to a seed in a vascular plant).

ZOOSPORE - Spore with flagella and capable of moving in water.

ZYGOSPORE - Sexual spore produced by the fusion of two similar gametes.

Teaching Outline

A. Morphology

1. MYCELIUM in the plant-like vegetative body

   a. Some fungi have bodies of many cells with one or two nuclei per cell.

   b. COENOCYTIC body in some fungi

      i. Contains many nuclei

      ii. Entire body is one continuous tubular cell

   c. SEPTA separates cells and nuclei of some fungi

2. HYPHAE (or MYCELIA) make up the body

   a. Elongated, continuous, branched, microscopic filaments with cell walls

   b. Thickness and length vary among genera

   c. Some species have mycelial strands several meters long

   d. Growth occurs at tips of hyphae

   e. Lower fungi

      i. Some lack true hyphae

      ii. Produce naked amoeboid plasmodium or simple system of varying strands

B. Fungi Reproduction

1. Reproduction by means of SPORES, specialized reproductive bodies consisting of one or more cells.

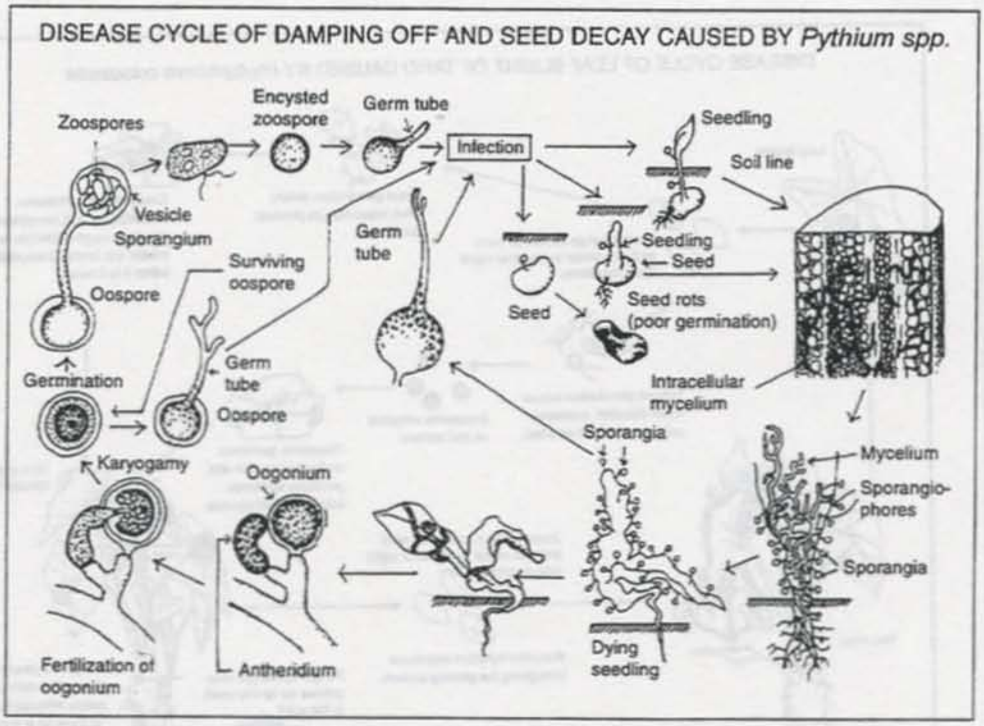
2. *Pithium* and *Phytopthora* produce ZOOSPORES with flagella.

3. *Conidia* has spores at ends or sections of hyphae.

4. Asexual reproduction

   a. Some fungi produce asexual spores inside a sac.

   b. *Imperfecti* and *Deuteromycetes* produce some of the most destructive diseases.



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5. Sexual reproduction

   a. GAMETES of similar size and appearance produce zygospores

   b. ZYGOSPORES receive half nuclei from each parent

   c. Meiosis - chromosome division

   d. Self-fertilization - Male and female gametes sometimes produced in same mycelia.

   e. Gametes can change sex depending on need

   f. Flexibility is an important characteristic of fungal reproduction

6. When no gametes exist, hyphae unite and form specialized structures specific to the fungal family

   a. *Ascomycetes* form ascospores

   b. *Basidiomycetes* form basidiospores

C. Colonization

1. Majority of pathogenic fungi

   a. Spend life partly on host plant and partly in soil or plant debris

   b. Remain inactive until carried to new host

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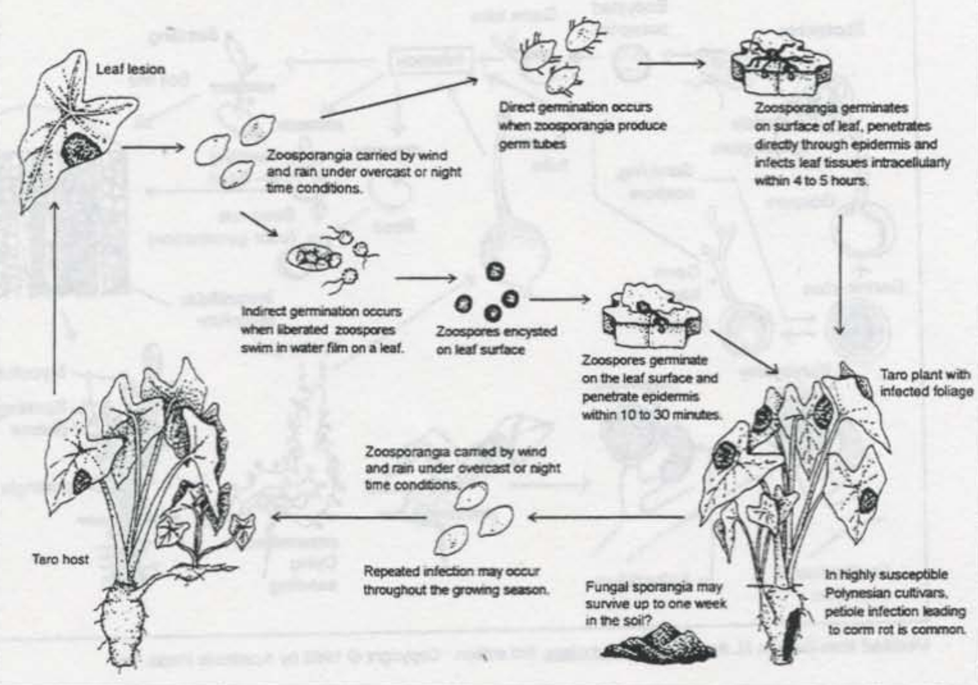
DISEASE CYCLE OF LEAF BLIGHT OF TARO CAUSED BY *Phytophthora colocasiae*



2. Host specific fungi

   a. Spend part of lives on the host as parasites

   b. Part of life in dead matter to complete life cycle in nature

   c. Do not grow on any other kind of organic matter

3. Soil-borne fungi

   a. Grow parasitically on host

   b. Live, grow, and multiply on dead tissue

   c. Move into soil or other decaying plant material

   d. Live as saprophytes on organic material in soil

   e. Have many hosts and can survive for years in absence of host

4. Locations of parasitic growth

   a. Outside the plant surface

      i. Sends haustoria feeding organs into epidermal cells of plant

      ii. An example is "powdery mildew"

b. Between cuticle and epidermal cells

c. Between cells

d. In cells throughout entire plant and cause systemic infections

5. OBLIGATE fungi

a. Do not feed on dead cells

b. Must remain on host plant for nutrients or critical life function

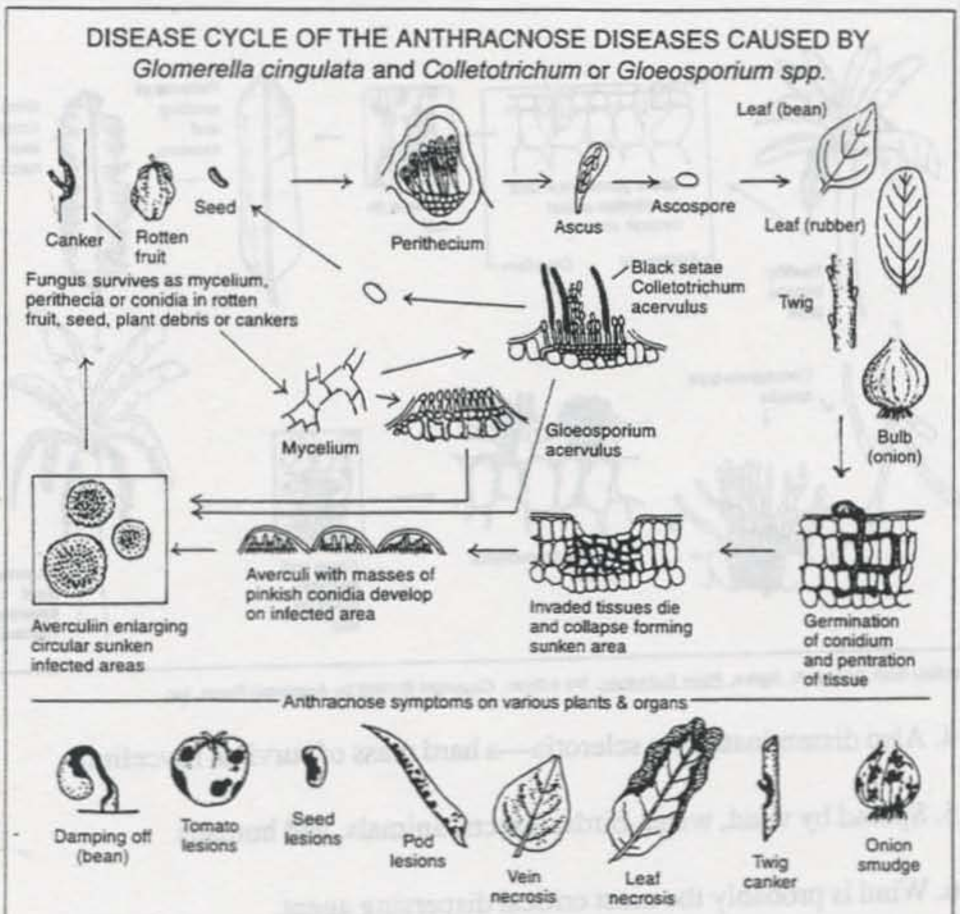
6. Non-obligate fungi

a. Require host for part of life cycle

b. Can multiply in both living and dead matter

c. Mycellium enzymes kill the living plant cells on contact

d. Reproductive spores produced near surface of host tissue



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D. Survival and dissemination

1. Depend upon temperature and moisture

2. Free mycellium

   a. Survive only within -5° C to 45° C temperature range

   b. Must be in contact with moist surfaces inside or outside host

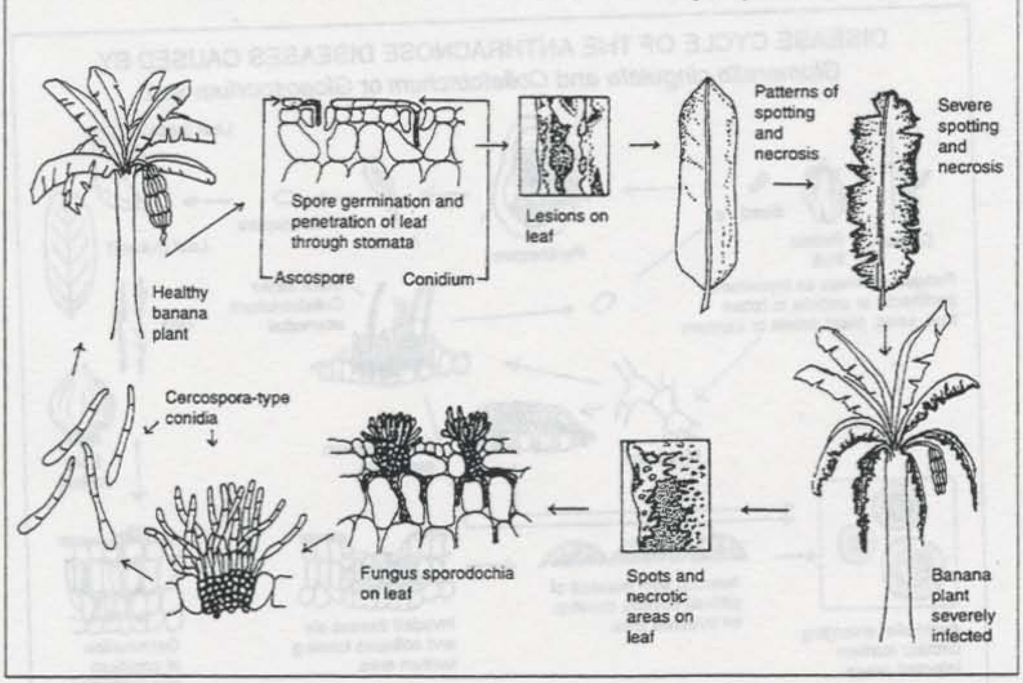
3. Spores

   a. Primary form of dissemination for fungi

   b. Spores can withstand broad range of temperature and moisture

   c. Remain inactive when environment is not favorable

   d. Zoospores with flagella require free water for production, movement, and germination.



4. Also disseminated via sclerotia—a hard mass of survival mycelium

5. Spread by wind, water, birds, insects, animals, and humans

6. Wind is probably the most critical dispersing agent.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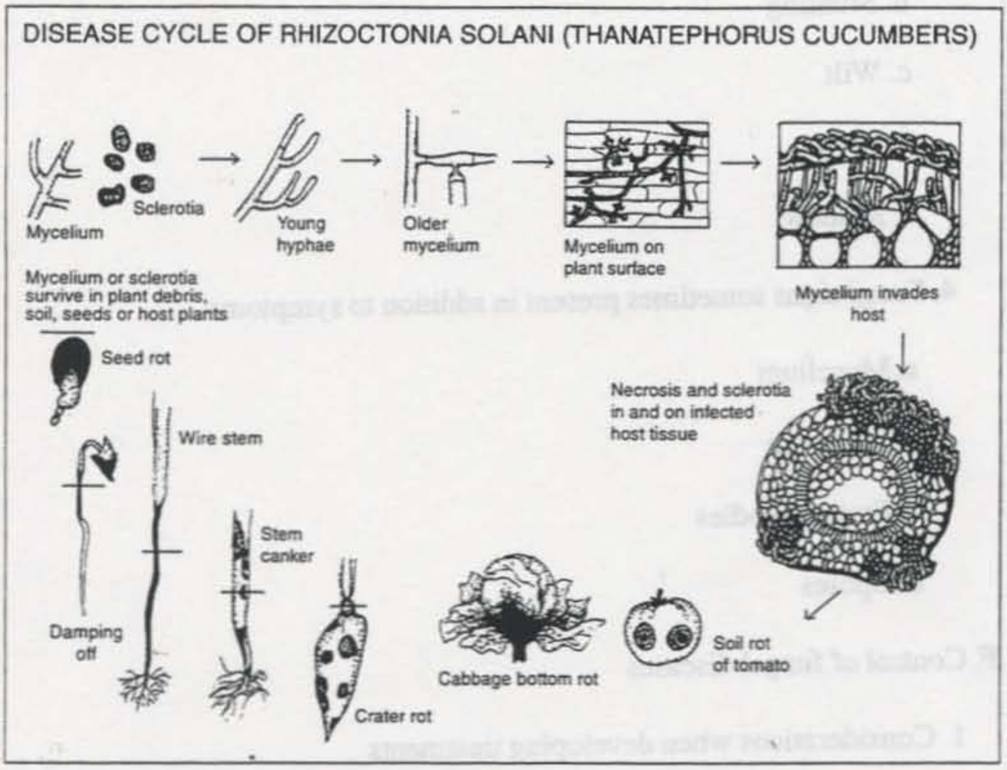

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E. Symptomology

1. Local or general systemic symptoms on hosts

2. Occurrence

   a. On different hosts

   b. Simultaneously on same host

   c. Following one another on same host

3. General symptoms

   a. Necrotic symptoms

      i. Leaf spots

      ii. Blight

      iii. Canker

      iv. Root rot

      v. Damping off

      vi. Decline

b. Stunting

c. Wilt

d. Rust

e. Mildew

4. Fungi signs sometimes present in addition to symptoms

a. Mycelium

b. Sclerocia

c. Fruiting bodies

d. Spores

F. Control of fungal diseases

1. Considerations when developing treatments

a. Fungus life cycle

b. Habitat

c. Performance under environmental conditions

2. Common practices

a. Hot water and chemical treatment to make pathogen-free seed

b. Elimination of inoculum in plant debris

c. Good sanitation practices; clean tools and containers

d. Crop rotation

e. Resistant varieties

f. Fungicides and chemical soil sterilants

Reading Assignment

Selections from instructor reference.

Instructor Reference

Plant Pathology, by George N. Agrios, pp. 265-507.

Lecture 15
PATHOGENIC VIRUSES AND NEMATODES

Introduction

A virus is a NUCLEOPROTEIN, a particle composed of nucleic acid surrounded by a protein protective coating. Viruses are too small to be seen with a light microscope. They multiply only in living cells and cause disease in plants as well as animals. Plant viruses cannot infect animals. All viruses are obligate parasites, which means they require living tissue to survive. They live in the cells and cause a multitude of diseases to all living things from single-celled microorganisms to large plants and animals.

The total number of viruses known to date is about 2,000 and about one-fourth of those attack and cause diseases of plants--500 viruses! One virus may infect one or dozens of species of plants and each species of plant is usually attacked by many different kinds of viruses. A single plant may be attacked by more than one kind of virus.

Nematodes are roundworm organisms that belong to the animal kingdom. The average size of plant nematodes is about 1 mm. There are many nematodes that are not plant parasitic. Those that are plant parasitic possess a stylet in their mouth and use it to pierce plant cells and suck out their juices.

Objectives

Upon completion of this lesson, students will be able to:

A. Describe the morphology of plant viruses.

B. Explain the transmission and infection processes of plant viruses.

C. Describe at least five symptoms of virus infection.

D. Describe at least five means of virus control.

E. Describe the morphology of nematodes.

F. Explain the disease cycle and symptomology of nematodes.

G. Describe at least seven means of nematode control.

H. Define the thirteen terms provided.

Terms

CAPSID - The protein coating of viruses that forms the closed shell or tube containing nucleic acid.

CIRCULATIVE VIRUSES - Viruses that are acquired by vectors through their mouth parts, accumulate internally, and are later introduced to plants via the mouth parts of the vectors. Also called persistent viruses.

ECTOPARASITIC - Nematodes that live outside the root tissue.

ENDOPARASITIC - Nematodes that live inside root tissue.

GALLS - Overgrowths caused by the action of pathogens on plants. Root-knot nematodes cause root galls on infested plants.

MOTTLE - An irregular pattern of light and dark areas.

MOSAIC - Intermingled patches of normal green and light green, or yellowish color.

NEMATODES - Organisms belonging to the animal kingdom that may possess a stylet in their mouth used to pierce plant cells and suck out their juices.

NONPERSISTENT VIRUSES - Also known as stylet-borne viruses. They are carried by their insect vectors in their mouth parts or stylets.

NUCLEOPROTEIN - An organism composed of nucleic acid surrounded by a protein protective coating.

STYLET - A long, slender, hollow feeding structure found in the mouth of nematodes and some insects.

VECTOR - An organism that spreads virus particles from an infected plant to a healthy one. Insects, fungi, and nematodes are examples of vectors.

VIRUS - A nucleoprotein that is too small to be seen with a light microscope; it multiplies only in living cells of its host and has the ability to cause disease.

Teaching Outline

A. VIRUSES

1. Virus Morphology

a. Viruses do not have cells; they take over the cells of the host

b. Made of nucleic acid molecules containing genetic information

c. Encased in protein coating called CASPID

d. Live and reproduce inside infected cells

e. Diseases spread throughout plant (systemic)

f. Difficult to treat diseases without hurting host plant

2. Symptoms of viral diseases

a. MOSAIC or MOTTLE patterns

i. Varying shades of green on leaves

ii. Some viruses cause yellow and green colors

b. Other abnormal growth patterns

i. Excessive branching or witch's broom

ii. GALLS

iii. Infected plants have reduced growth rates and yields

3. Virus transmission

a. Particles cannot move by themselves

b. Insect VECTORS spread many viruses

i. Aphids feed on infected plants

ii. Spread virus while feeding on healthy plants

c. CIRCULATIVE VIRUSES

d. NONPERSISTENT VIRUSES

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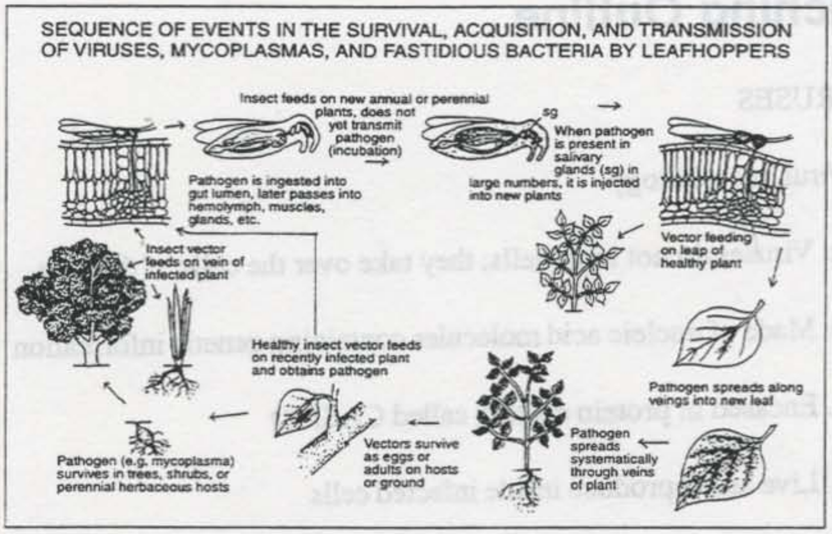

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e. Mechanical inoculation via people and animals

f. Seed transmission

i. Seeds from infected plants produce plants with virus.

ii. Blackeye cowpea mosaic virus (BCMV) infects "yard-long beans".

iii. Dasheen mosaic virus (DMV) infects taro corms.

g. Grafting

i. Plant pathogens are not transmitted through grafting.

ii. Viral nature of a disease can be demonstrated this way.

4. Virus controls

a. Most effective technique is to use resistant varieties

b. Use virus-free seed to avoid seed transmission

c. Cannot use chemical means to control viral disease

d. Can use chemicals to control insect vectors

e. Remove weed hosts for several hundred meters around crop plants

f. Rogue (pull out) and remove infected plants

g. Floating crop covers

i. Used to exclude aphids and other vectors from vegetable crops

ii. Remove at time of flowering to allow pollination to occur

B. NEMATODES

1. Morphology

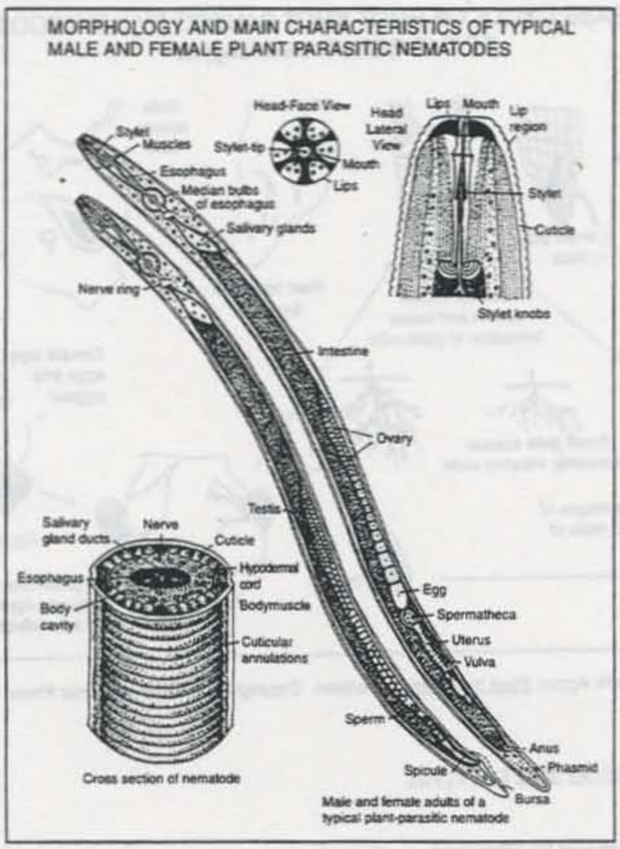
a. Microscopic round worms (also known as eel worms)

b. Most live in the soil

c. Free-living (non-parasitic) nematodes live on dead organic matter in soil

d. Parasitic nematodes live on plants and animals.

e. Plant-parasitic nematodes possess a STYLET



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2. Disease cycle and symptoms

a. Most nematodes attack plant roots but some attack above ground parts

b. Affected roots weaken and die prematurely

c. Above ground parts show stress symptoms, slowed growth, leaf loss, an unthrifty appearance, and wilting

d. Below-ground symptoms vary according to plant species

e. Root-knot nematodes

i. Most common type of nematode

ii. Cause large tumors or galls on roots of infected plants

iii. Females lay thousands of eggs in tumors

iv. Males look for females in soil near roots

v. Larvae find a feeding site, molt, and become reproductive adults

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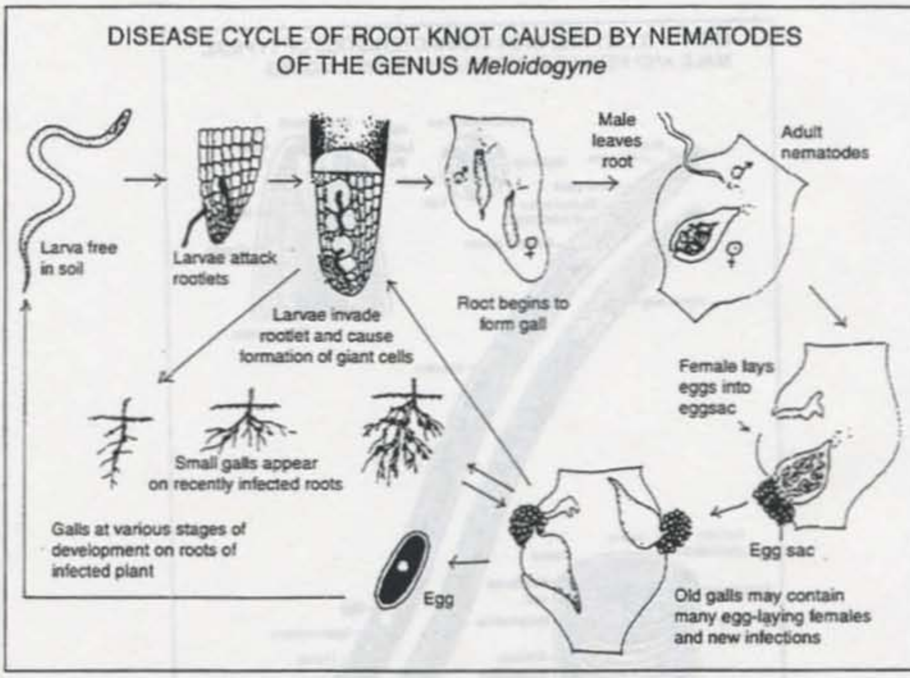

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3. Dissemination and survival

a. Spread mainly through soil and water movement

b. Farmers spread nematodes by sharing tractor implements or tools containing infected soil.

c. Some nematodes slow down their metabolism to survive during drought and temperature extremes

d. Some form protective cyst coatings

4. Habitat and identification

a. ECTOPARASITIC or ENDOPARASITIC

b. Most identification done by expert nematologists

c. Requires high quality compound microscope

d. Specimens permanently mounted on microscope slide for mailing

e. Identification based on morphological characteristics

i. Shape and size of stylet

ii. Esophagus

iii. Glands and genitals

iv. Tail shape and size

f. Good pictorial guide is helpful

5. Nematode control

a. Tomatoes and peppers are cultivar resistant to root-knot nematode

b. Crop rotation

c. Cultivation

d. Antagonist crops

i. Claims made for using marigolds against root-knot nematode

ii. Similar claims for castor beans

e. Chemical treatments

f. Soil sterilization for seedling beds and greenhouses

g. Biological agents

i. Nematode-trapping fungi occur in some soils

ii. Bacterium, *Bacillus penetrans*, parasitizes nematodes

iii. Fungus, *Dactylella oviparasitica*, parasitizes eggs

Reading Assignment

Selections from instructor reference.

Instructor Reference

Plant Pathology, by George N. Agrios, pp. 622-713.

Lecture 16
OTHER PLANT PATHOGENS

Introduction

In addition to the four major categories of plant pathogens, there are others of minor importance because they are less common. They include phanerogams, protozoa, MLO's, rickettsiae, and viroids.

Objectives

Upon completion of this lesson, students will be able to:

A. Describe each of the five pathogens discussed in this lecture, using regional examples of each one.

B. Define the six terms provided below.

Terms

FASTIDIOUS VASCULAR BACTERIA - Microorganisms similar to bacteria but only capable of multiplying inside host cells. Also known as rickettsiae.

HAUSTORIA - A projection of hyphae into a host plant that acts as an absorbing organ.

MLO's - Mycoplasma-like organisms that are found in the phloem of plants affected by certain diseases.

PHANEROGAMS - Parasitic higher plants similar to other plants in general morphology.

PROTOZOA - Unicellular animals possessing true nuclei. The protozoa that cause disease on plants are flagellated microorganisms.

VIROID - Virus-like pathogenic entities that have no protein capsid surrounding the nucleic acid.

Teaching Outline

A. PHANEROGAMS

1. Dodders

a. General description

i. Leaves, stems, flowers, and fruits; but some do not have chlorophyll or roots.

ii. Reproduce by seed but rely on the host for nutrition.

iii. Infect broad range of genera in higher plants

iv. Send HAUSTORIA forcefully into host tissues to extract nutrients

v. Can transmit viruses from infected plants to healthy ones

b. Cuscutta dodder

i. Yellow spaghetti-like appearance

ii. Very prolific; produces masses of small white flowers and seeds.

iii. Easily torn by pulling

iv. Affects annuals

c. Casytha dodder

i. Found along beaches

ii. Often green in color

iii. Vines are thicker and tougher than those of Cuscuta

iv. Does not flower as profusely

v. Parasitizes perennials

2. Mistletoe

a. Small leathery leaves

b. Produces flowers and sticky fruit disseminated by birds

c. Parasitizes tree branches for food and anchorage

3. Witchweed

a. Common in Africa and Asia

b. Parasitizes root systems of corn, sorghum, and sugarcane

c. Host plants wilt and die

d. Very small seed may contaminate crop seed, thus a quarantine danger.

4. Broomrape

a. Present in Africa, Asia, and the U. S.

b. Small plants with fleshy stems and scaly leaves

c. Produces flowers directly on the stem

d. Attacks root of tobacco, tomato, potato, hemp, and other plants

B. PROTOZOA (Phytomonas spp.)

1. It is suspected that all protozoa pathogens are vectored by insects.

2. Can be transmitted by root grafts on coffee; no insect vector identified in coffee phloem necrosis.

3. Causes coconut "heartrot" and sudden wilt of oil palms

C. MLO's (Mycoplasma like organisms)

1. Different from free living mycoplasmae or those parasitic to animals

2. Few plant diseases caused by MLO's

3. Corn stunt

a. Caused by helical spiroplasma

b. Vectored by grasshoppers

4. Lethal yellowing of palms

a. Unknown vector; planthopper probably involved

b. Has killed thousands of coconut and other palms in Florida, U.S.A.

D. FASTIDIOUS VASCULAR BACTERIA (also known as rickettsiae)

1. Obligate cellular parasites

2. Clavibacter

   a. Ratoon stunting of sugarcane

   b. Stunting of Bermuda grass

3. Xyllela spp.

   a. Pierce's disease of grapes

   b. Citrus greening

4. All are gram-negative except for Clavibacter

E. VIROIDS

1. Nucleic acid molecules without a protective protein coating

2. Similar to viruses

3. *Cadang-cadang* disease of coconuts

   a. Occurs in the Philippine islands

   b. Produces stippling of leaflets

   c. Possibly transmitted by pollen and/or mechanical transmission

4. *Tinangaja* disease of coconuts

   a. Occurs on Guam

   b. Causes small nuts with no flesh before all fruit production stops

5. Symptoms common to both diseases

   a. Slow decline

   b. Scarred fruit

   c. Tapering trunk

   d. Sterile inflorescences

   e. Finally, no inflorescence and death of trees

Lecture 17
DIAGNOSING PLANT DISEASES

Introduction

There are many possible causes of plant diseases. In order to determine the cause of a specific problem, it is necessary to take an orderly approach. Begin by eliminating the incorrect reasons and continue until you reach the right conclusion based on the evidence available.

Objectives

Upon completion of this lesson, students will be able to:

A. Explain the process involved in plant disease diagnosis.

B. Describe the symptoms associated with the most common nutrient deficiencies of plants.

C. Determine whether or not a particular malady is caused by an infectious agent.

D. Define the four terms provided below

Terms

CHLOROSIS - Lack of chlorophyll development leading to pale green or yellow discoloration of leaves.

DEFICIENCY - An insufficient amount of a nutrient required for normal growth and development.

INTERVEINAL - The area between the leaf veins.

PHYTOTOXIC - A description of a substance that will kill a plant.

Teaching Outline

A. Diagnosing a plant disease

1. Identify plant species

2. Observe symptoms

a. On overall scale

b. On individual plant basis especially in case of crops

3. Observe environmental conditions during onset of disease

a. Moisture conditions in soil and atmosphere

b. Temperature

c. Light intensity

d. Nature of affected site

4. Consider possible causes and compare symptoms

a. Infectious organisms

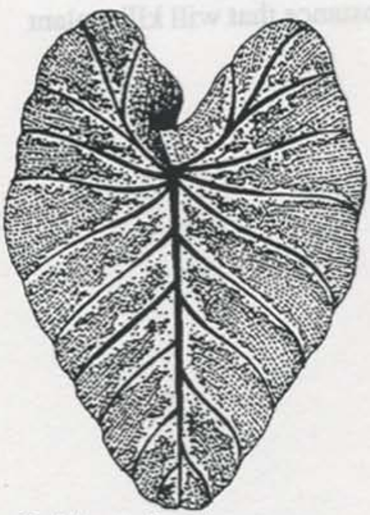
b. Physiologic agents

c. Plant damage caused by pests

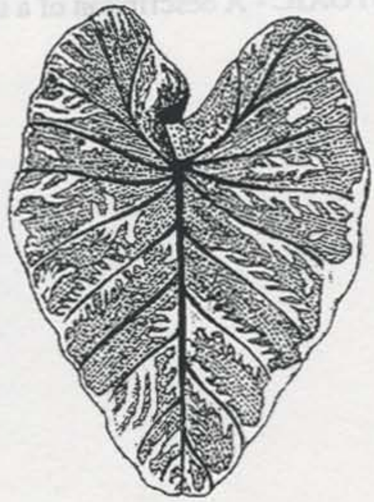
i. Rodents

ii. Birds

iii. Insects: Look for evidence such as frass, molts, or insects.



Spider mite damage



Dasheen mosaic virus

B. Water related diseases

1. Excess soil moisture reduces air available at roots

a. Roots suffocate

b. Susceptible to infection by root-rot organisms

c. Infection by soil fungus *Phytophthora* if plant collars are too wet

2. Lack of water

a. Wilted leaves are first symptom

b. Scorched leaf margins and tips if lack of water is frequent

c. Wilted plants can recover but long drought causes permanent damage

3. Salinity

a. Excess salts in water absorbed by plant

b. Scorched leaf margins and tips due to salt accumulation

C. Nitrogen DEFICIENCY

1. Symptoms

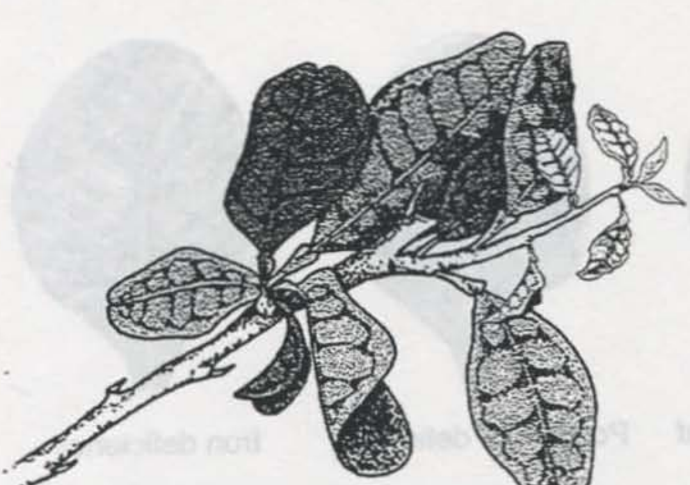
a. Leaves show signs of CHLOROSIS

i. Pale green to yellow color of older leaves

ii. Spreads to young leaves during acute phase

b. Stunted growth of entire plant begins with smaller young leaves

2. Cure: Apply nitrogen as foliar spray or some other form of fertilizer



Nitrogen deficiency in citrus

D. Phosphorus deficiency

1. Symptoms

a. Reduction in growth rate

b. Purple discoloration of old leaves depending on plant type

c. Normal green color becomes dull or bluish instead

2. Phosphorus deficiency is better prevented than cured

3. Phosphorus fertilizer

a. Apply below root area before planting and/or use as sidedress

b. Foliar spray not well absorbed and PHYTOTOXIC

E. Potassium deficiency

1. Symptoms

a. Marginal spotting, chlorosis, or mesophyll collapse

b. Scorched margins of older leaves. Margins curl up or down.

c. Differs from salt damage which causes scorched young leaves

2. Prevention

a. Apply potassium fertilizer below root area before planting

b. Foliar application can be phytotoxic

Normal cabbage leaf   Potassium deficiency   Iron deficiency

F. Iron deficiency

1. Can occur when there is an actual lack of iron in soil
2. Excess calcium or potassium may prevent iron absorption
3. Symptoms
    a. INTERVEINAL chlorosis of young leaves
    b. Uniform yellowing in some species
    c. Plant becomes progressively yellow or white as condition worsens
4. Correct with iron chelates or foliar sprays

G. Manganese deficiency

1. Interveinal chlorosis starts on young leaves, may spread to old leaves
2. Correct with foliar sprays

H. Chemical damage

1. Symptoms
    a. Spots on leaves - may appear as a spray pattern.
    b. Burn spots have irregular shapes and sharp margins.
2. Household chemicals with a strong solvent base
3. Agricultural chemicals
    a. Caused by improper use, mixing, and/or application
    b. Easy to damage sensitive plant species
    c. Interview people to determine type and amount of chemical applied.

I. Herbicides

1. Non-target plants damaged by wind born chemicals
2. Symptoms
    a. Distorted/elongated growth caused by hormonal herbicides (eg. 2-4-D)
    b. Burning caused by strong contact herbicides (eg. Gramoxone)

J. Environmental factors

1. Symptoms of environmental factors are usually uniform for species in area

2. Potential causes

a. Insufficient or excess water

b. Salts in irrigation water, on soil surface, or from ocean spray

c. Overcrowding and transplanting shock

K. Infectious agents

1. Symptoms of disease infection usually appear as non-uniform patterns.

2. Analysis of symptoms and diseased tissue

a. Identification is the first step in diagnosis.

b. Use a magnifying glass or microscope to look for signs.

c. Inspect more than one disease site before reaching a conclusion.

d. Secondary invaders often present on diseased tissue.

Reading Assignment

Selections from instructor reference.

Instructor Reference

Plant Pathology, by George N. Agrios, pp. 31-35, and 147-154.

V. INTEGRATED PEST MANAGEMENT

LECTURE 18
INTEGRATED PEST MANAGEMENT

Introduction

We depend on the earth's natural resources to survive. These resources include air, soil, water, plants and animals. Other living things compete for the same resources that we do. These organisms we call pests. Even though pests are annoying, it is important to remember that each organism has it's role in nature.

We can devise methods to reduce the number or harmful effects of pests. We can change the environment to make things less acceptable to the pest or more acceptable to its natural enemies. We can grow crops at different times of the year when the pest is not present. We can hand remove pests.

Integrated pest management methods were introduced in the first lecture of this course. These methods minimize the use of pesticides by considering them as a last alternative for pest management. This helps reduce pollution and protects the health of people and animals. The following five lessons will detail some IPM methods and practices which manage pests effectively, economically, and ecologically.

Objectives

Upon completion of this lesson, students will be able to:

A. List at least six IPM methods.

B. List at least four benefits of using an IPM program.

C. Describe at least six components of an IPM program.

D. Explain at least four benefits of an IPM program.

E. Discuss the relationship between IPM, sustainable agriculture, and traditional agricultural practices in the Pacific islands.

F. Discuss at least six steps in the IPM problem solving approach.

G. Define the ten terms provided below.

Terms

ECOLOGY - The study of the interrelationships between organisms and their environment.

ECONOMIC CROP PROTECTION - Managing pests at a low cost by applying management practices only when they are needed.

ENERGY CONSERVATION - The wise use of all energy related resources.

ERADICATE - To abolish or completely get rid of; to destroy.

INTERCROPPING - growing two or more crops in a given area at the same time.

IPM EVALUATION - Assessment of an IPM practice to see how well the treatment is working.

IPM PREDICTION - The process of forecasting pest outbreaks by using information gained from identification and monitoring.

MONITORING - Routinely observing and counting the populations of key species over the growing period of a crop.

SUSTAINABLE AGRICULTURAL PRACTICES - The farming methods used to maintain land so that it will continue to be productive and healthy for future generations.

TRADITIONAL AGRICULTURAL PRACTICES - The food production methods that have been developed over many generations to maintain the land and manage pest problems.

Teaching Outline

A. Integrated pest management (IPM) is the use of a combination of methods to reduce pest populations and keep them below economically damaging levels while minimizing ecological disturbance.

1. Pest management means limiting the number of pests and/or the ways pests can be harmful.

2. It does not imply the complete removal or eradication of pest species from an area.

B. IPM can include many methods

1. Mechanical control methods

2. Cultural control methods

3. Host plant resistance methods

4. Biological control methods

5. Regulatory control methods

6. Chemical control methods

C. Reasons for using an IPM program

1. Acceptable level of management: IPM can result in an acceptable level of pests by relying on several management practices.

2. ECONOMIC CROP PRODUCTION: IPM programs apply management measures only when they are needed. This usually results in managing pests at a low cost.

3. Reduced hazards: IPM can decrease the exposure of people and the environment to pesticides. This reduces the chance of possible harmful side effects.

4. ENERGY CONSERVATION: Farm operations like cultivation, pesticide spraying, and fertilizer application use energy from fossil fuels. IPM programs can reduce agricultural energy use by:

   a. Using fewer agricultural chemical inputs.

   b. Using less farm machinery, such as spraying equipment and tractors.

D. Six components of an IPM Program

1. Identification of:

   a. Pests and beneficial organisms

   b. Physical factors: soil, slope, water, etc.

   c. Environmental factors: rainfall and temperature

2. Use of preventative practices that may keep pest populations from developing. These practices include:

   a. Land preparation

   b. Use of pest resistant species

   c. Timing of practices

   d. Protection of parasites and other natural enemies

3. MONITORING: Pest and predator populations should be counted and watched.

   a. Scouts count the numbers of key species in a given area.

   b. Monitoring should be done regularly, weekly or bi-weekly, during the growing period of the crop.

4. PREDICTION

   a. The information gained by monitoring is used to predict pest outbreaks.

   b. When the number of pests begin to increase over normal levels the grower is alerted to a potential outbreak.

5. Decision making

   a. Information from identification, monitoring, and prediction is combined with economic factors.

   b. The grower can make a decision whether or not to take additional control measures.

6. EVALUATION

   a. It is important to assess the outcome of the control measures to see how well the treatment is working.

   b. Evaluation (like steps 3, 4, and 5) is a continuous process.

E. Benefits of an IPM Program

1. Reduced costs due to less pesticide usage.

2. Reduced risk of exposure to pesticides by farmers and consumers.

3. Reduced pollution of water, air, soil and biota.

4. Balance of nature reestablished or maintained.

F. Relationship between IPM, SUSTAINABLE AGRICULTURE and TRADITIONAL AGRICULTURE

1. Sustainable practices minimize the use and dependence on chemical inputs (eg., pesticides and inorganic fertilizers) that may cause pollution.

2. Traditional agricultural methods have been used for centuries by Pacific island farmers. Due to land and resource constraints these methods have generally developed with an emphasis on sustainability.

3. All three systems use a variety of practices to manage pests.

a. Prevention

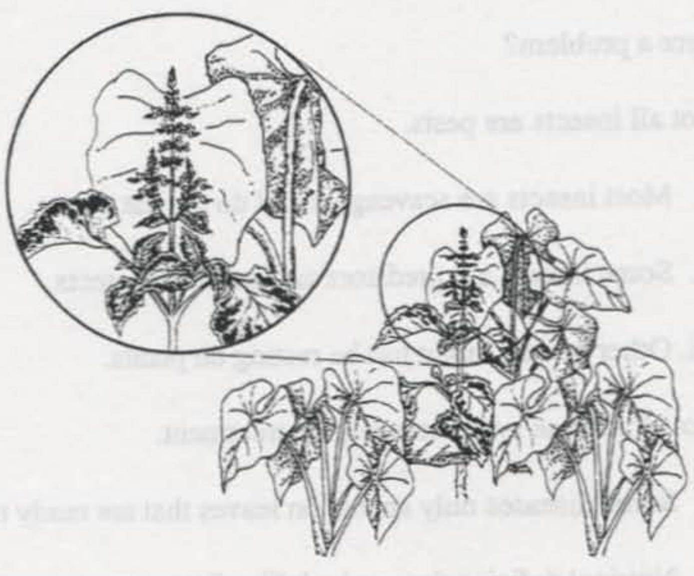
i. Planting resistant varieties of crops.

ii. Planting crops at certain times of year.

iii. INTERCROPPING to prevent the quick spread of pests.

iv. Agroforestry, or planting crops among trees.

iv. Using plants to manage pest problems.



Interplanting coleus with taro to reduce armyworm damage

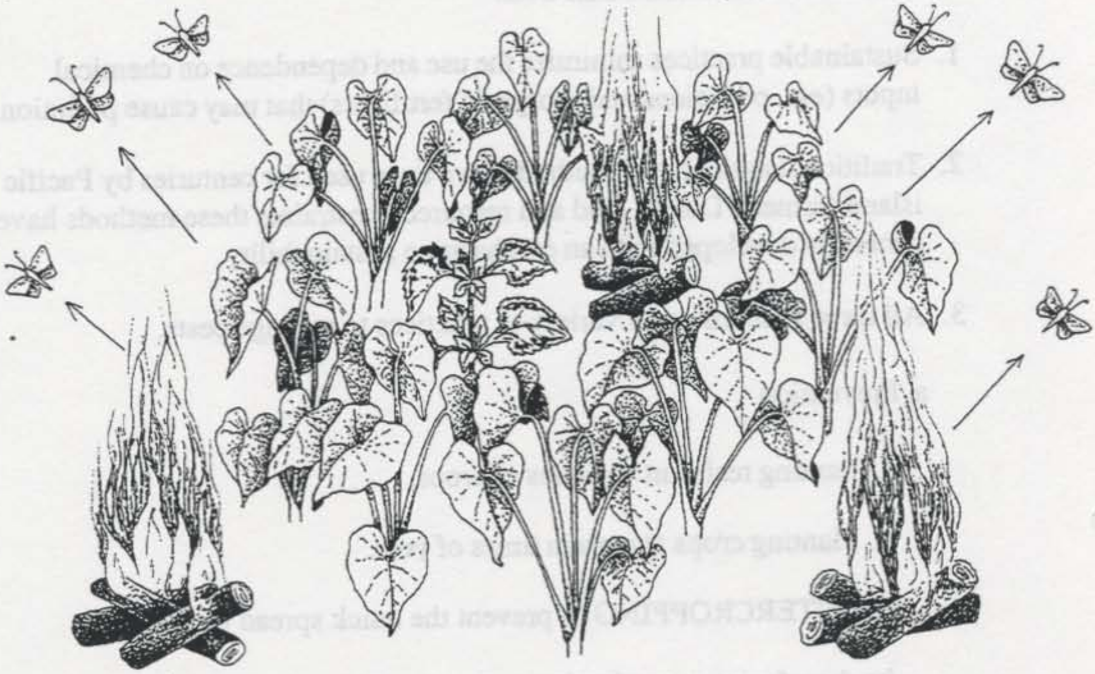
b. Pest Management

i. Handpicking pests from crops

ii. Applying ashes to caterpillar pests

iii. Raising chickens to feed on caterpillars

iv. Using smouldering fires around crops to repel pests



H. The IPM problem solving approach

1. Is there a problem?

a. Not all insects are pests.

i. Most insects are scavengers and do not eat plants.

ii. Some insects are predators and eat other insects.

iii. Other insects might just be resting on plants.

b. Not all disease symptoms require treatment.

i. Some diseases only appear on leaves that are ready to drop.

ii. Nutrient deficiencies can look like disease symptoms.

2. Is the pest population increasing or decreasing on its own?

a. Natural enemies can control pests, it is very important to know the interactions between different species.

b. Example (Serpentine leaf miner- *Liriomyza trifolii*)

i. Miners are abundant on many vegetable crops during early growth.

ii. Close observation shows that most miners are killed by parasites.

iii. Spraying kills parasites instead of the pest.

iv. Pesticide application increases the problem.

3. Is pest/disease present in sufficient amount to cause economic damage? (Lecture 19 discusses economic damage in detail)

4. Is there a better solution than applying a pesticide?

a. Pesticides often only provide a short-term solution.

b. Complete pest eradication may be possible without pesticides.

i. Example 1: Yams

- Yams growing on trellis are attacked by rose beetle *(Adoretus versutus).* Beetles do not attack yams growing on the ground.

ii. Example 2: Cucumbers

- Powdery mildew is a serious problem in the tropics. A susceptible crop must be treated repeatedly with fungicide to prevent losses.

- Powdery mildew resistant cultivars are available from seed companies. Growing these may eliminate the need for spraying.

5. If a chemical is the best control, is it legal to use on the target crop?

a. This section applies where Environmental Protection Agency (EPA) regulations concerning pesticide use are operative. However it should also be considered in other locations.

b. Strict controls govern EPA chemical registration because of risks to public health and ecosystem contamination.

c. Cost of EPA registration

i. Registration fees are at least $50,000; due to cost of studies regarding effectiveness, health, and environmental impacts.

ii. Cost prohibits registration for some Pacific island crops and pests, thus legal and safe chemicals may not be available.

6. What is the most economical way to use chemicals?

   a. Some farmers use a routine or calendar spraying method.

   b. Many Pacific island farmers take a casual approach and don't notice the problem until it has become serious.

   c. Importance of regular monitoring

      i. Insects and diseases are easier to control in early stages.

      ii. Even occasional monitoring is valuable when precise monitoring is not possible.

   d. Example: Guam research concerning routine spraying

      i. Guam farmers routinely apply pesticides to prevent thrips on melons and cucumbers.

      ii. Researchers found that only two out of six unsprayed fields in their study had any thrips damage.

      iii. Pesticides which control thrips are extremely toxic.

      iv. Farmers waste time and risk health by using unnecessary chemicals.

Reading Assignment

Fundamentals of Applied Entomology pp. 113-116 and 123-132.

Lecture 19
PEST MANAGEMENT AND EFFECT ON YIELD

Introduction

Before trying to control a pest, it is important to know the effect it is having on a crop. The impact can vary from no damage to severe problems. One of the fundamental concepts of integrated pest management is that each control method has a definite cost. In general, the greater the desired degree of control, the greater the cost and effort required to achieve it. It is necessary to decide whether the control effort is worth the cost. That decision depends upon knowledge about the extent of pest damage and the cost of the control measures. Sampling is an important aspect of a pest management system because it provides a quick and simple means of measuring current pest population density.

Objectives

Upon completion of this lesson, students will be able to:

A. Explain the differences between direct and indirect pest damage with examples of each.

B. Describe four potential relationships between pest infestation and crop yield with examples of each.

C. Explain the interactions between economic damage, economic injury level, and economic threshold in relation to examples provided by the instructor.

D. List the steps in developing an economic pest management program.

E. Define the eight terms provided below.

Terms

ECONOMIC DAMAGE - The amount of pest injury that justifies the cost of applying pest controls.

ECONOMIC INJURY LEVEL - The lowest number of pests that will cause economic damage.

ECONOMIC THRESHOLD - The pest population density at which pest control is needed to prevent reaching the economic injury level.

KEY PESTS - Members of a pest population with an average density above the economic injury level.

OCCASIONAL PESTS - Members of a pest population with density commonly well below economic injury level but exceeding that level at some times.

RANDOM - The distribution of objects in a population such that there is an equal chance of any object being sampled.

SAMPLING - The statistical measuring of a portion of a population to deduce properties about the whole population.

SUBECONOMIC PESTS - Members of a pest population with density well below economic injury level at all times.

Teaching Outline

A. Types of pest damage

1. Direct damage

a. Applies mostly to insect and vertebrate pests.

i. Pests eat or spoil usable part of crop such as fruit, edible leaves, seeds, roots or tubers.

ii. A single insect can make a whole fruit unusable.

b. Same impact from some diseases

c. Weeds are unlikely to cause direct damage.

2. Indirect damage

a. Pests eat unusable parts of a crop plant

b. Possible effect on yield

B. The effects of pests on crop yield

1. No effect on yield

a. There may be no effect on crop yield if pest numbers are low.

b. If disease damages older plant leaves, photosynthesis may not be greatly reduced.

c. When foliage is damaged, some plants produce extra carbohydrates in remaining leaves.

d. Pests may not damage plant parts that influence crop yield, eg. damage to male flowers

e. Some plants produce extra fruit to compensate for losses.

2. Decrease in yield

a. Yield decreases as pest numbers increase.

b. Damage and effect on yield varies according to crop and type of pest.

c. Age of plant

i. Weeds do not affect yield of taro after plants are four months old.

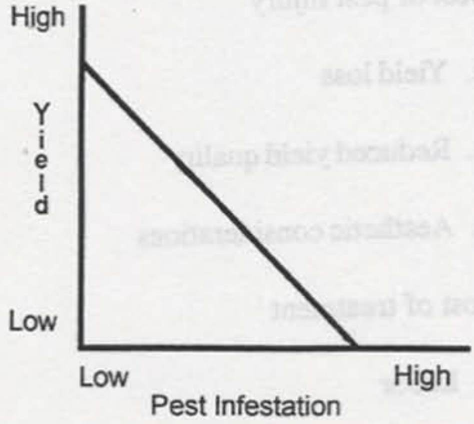
ii. No effect on yield when bean plants lose up to 33% of leaves before flowering, but yield decreases with leaf loss of 10% after flowering.

Relationships Between Pest Infestation and Crop Yield

A. Effect on Yield in Proportion to Number of Pests

Example: The effect of cutworms on cabbage.

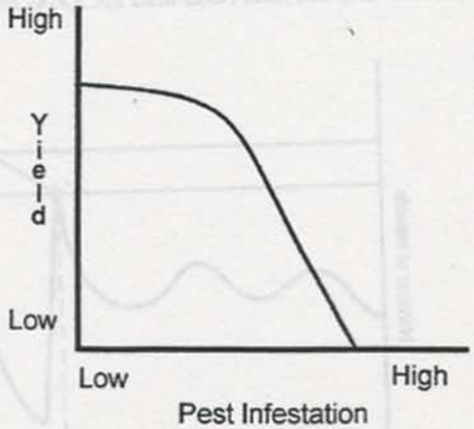
Each seedling removed by a cutworm is one less plant to produce the total yield.



B. Effect on Yield When Few Pests Are Present

Little effect on yield until the threshold is reached.

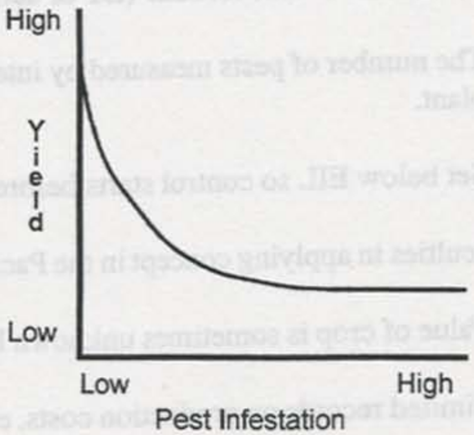
Then decrease in proportion to increasing number of pests.



C. Effect on Yield When Many Pests Are Present

Loss in proportion to number of pests until level when pests have no further influence.

Example: 20 leaf miners cause all leaves to drop, so 10 more pests have no effect.



C. Economic decision making

1. Cost of pest injury

   a. Yield loss

   b. Reduced yield quality

   c. Aesthetic considerations

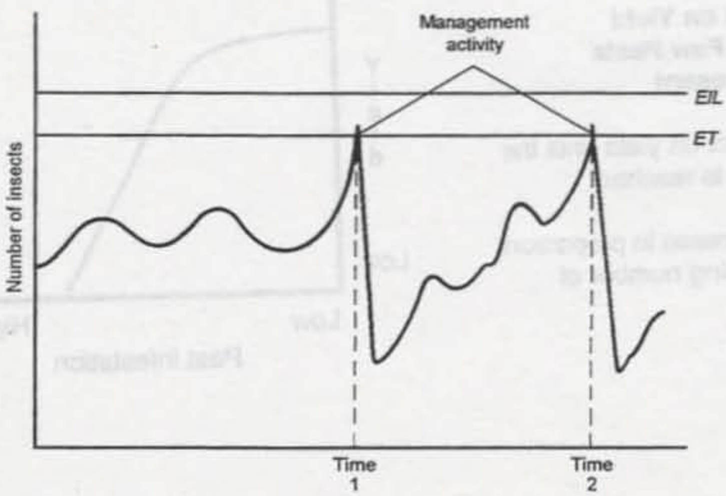
2. Cost of treatment

   a. Labor

   b. Chemicals

   c. Prorated cost of equipment use

3. ECONOMIC DAMAGE and ECONOMIC INJURY LEVEL (EIL)



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4. ECONOMIC THRESHOLD (ET or action threshold)

   a. The number of pests measured by intensity or density, eg. insects per plant.

   b. Set below EIL so control starts before pests cause economic damage.

5. Difficulties in applying concept in the Pacific region

   a. Value of crop is sometimes unknown because it is not sold.

   b. Limited records on production costs, especially labor.

   c. Limited knowledge available about pests and their effect on yield for many Pacific island crops

D. Developing an economic pest management program

1. Start the new management program even without all exact information.

2. Stop using a spray routine or calendar.

3. Begin to identify, monitor, and predict crop and pest interactions.

4. Gather advice from experienced farmers and extension agents.

   a. Information about when to start treatment

   b. Thresholds that are more accurate than just presence/absence of pests.

5. Use SAMPLING techniques to determine pest presence and avoid unnecessary use of insecticides.

6. Differentiate between non-pests and:

   a. SUBECONOMIC PESTS:

      i. Control of these pests will cost more than loss from their damage.

      ii. A few subeconomic pests together may reach economic injury level

   b. OCCASIONAL PESTS: Populations may rise to a destructive level and require control.

   c. KEY PESTS:

      i. These pests will cause damage every season.

      ii. Any pest management program must concentrate on their control.

E. Sampling techniques

1. Statistical considerations

   a. RANDOM selection

   b. Lack of bias

   c. Sample size

2. Estimating pest incidence and damage

   a. Determine type and amount of damage to measure

   b. Select sample plot that has 1-5 individuals per unit

   Examples: Cucumbers with melon worms, eggplants with flea beetles, or recently-plowed area infested with nutsedge.

   c. Count samples and make graphs

3. Methods

a. Direct counts

b. Trapping

i. Sweep nets

ii. D-Vac suction method

iii. Steiner traps for fruit flies

iv. Dishes of beer for slugs

v. Ring samples used to inundate parts of turf and bring up pests

4. Examples

a. Sweep-net method

i. Student teams each take fifty sweeps from lawn area

ii. Note distance covered by each team

iii. Kill and count samples

iv. Compare results

b. Estimating weed coverage

i. Run point transects across plot

ii. Lay out measuring tape across plot every 10 cm.

iii. Lower stick with pin at end and count whatever pin touches (the finer the pin the more accurate the estimate)

iv. Repeat 100 times, percent cover equals number of hits in 100 times

Reading Assignment

Selections from instructor reference.

Instructor Reference

Entomology and Pest Management, by Larry P. Pedigo, pp. 205-278; 288-295.

Lecture 20
CULTURAL CONTROL

Introduction

Cultural control refers to methods of manipulating crops, cropping practices, and land for the management of insect, weed and disease problems. These methods are often used to make the environment unfavorable for pests. Cultural practices may also provide a more favorable environment for the natural enemies of pests. They help reduce or eliminate pest damage.

Many practices can be applied to achieve cultural control. Two of the most important practices are the use of resistant varieties and crop rotation. Other methods employ the strategic scheduling of planting, tillage, irrigation, fertilizer applications and fallow periods. Some of these practices are labor intensive, however they are generally dependable and can reduce the need for insecticides. Cultural methods are readily available to the farmer and in most cases do not require an extra investment in equipment.

Objectives

Upon completion of this lesson, students will be able to:

A. Describe four primary uses of cultural controls.

B. Explain at least two important steps in disinfestation and phytosanitation with examples of how these methods are used.

C. Describe at least twelve cropping practices used as cultural controls, with reference to traditional uses in Pacific islands.

D. Explain why some cropping practices may not be appropriate as cultural control in specific conditions.

E. Define the fifteen terms provided below.

Terms

CROP COMPETITION - Use of practices favoring the establishment and growth of crops over pests.

CROP DENSITY - The relationship between the quantity of plants and the size of the planting area.

CROP ROTATION - Planting different types of crops in succession on the same piece of land.

CULTURAL CONTROL - The methods of manipulating crops, cropping practices and land for the management of insect, weed, and disease problems.

DISEASE RESISTANCE - The ability of an organism to exclude or overcome, completely or to a degree, the effect of a pathogen.

DISINFESTATION - Using basic sanitation practices when handling plant material.

FALLOW - The condition of land without a crop growing on it; absence of agricultural planting in a field.

INTERCROPPING - Growing two or more crops in a given area at the same time.

IRRIGATION - The application of water to a crop or area by means other than natural rainfall.

MULCH - Any material that is spread over the soil surface to control weed growth and/or erosion.

PHYTOSANITATION - The removal and destruction of infested materials and alternative hosts from a crop field or the surrounding area.

SOLARIZATION - Using clear plastic mulch over moist soil in direct sunlight to raise soil temperature to a level where weeds and pathogens are controlled.

SHIFTING CULTIVATION - An agricultural land use system that involves rotation between cropping an area and leaving it fallow while a different area is grown in crops.

TRAP CROPPING - Attracting pests to small planting areas which are then destroyed or sprayed with a chemical pesticide.

TRELLISING - The practice of providing support for climbing plants and "training" them to use it.

Teaching Outline

A. CULTURAL CONTROLS

1. Reduce the spread of pests

2. Disrupt the reproductive cycle of pests

3. Remove food source(s) of pests

4. Make a habitat more suitable for natural enemies of pests

B. Cultural Methods

1. DISINFESTATION

a. Clean knives and machetes used in grafting, pruning, cutting, and harvesting. Dip in a 10% bleach solution or a milk bath.

Ex. Clean machetes after cutting down banana plants infected with Bunchy Top to avoid transferring the disease to other plants.

c. Wash mud off foot wear before going between fields or entering a greenhouse.

d. Clean tractor tires to prevent spread of diseases and weed seeds.

e. Wash hands after smoking to prevent spread of tobacco mosaic virus.

2. PHYTOSANITATION

a. Destroy sources of disease inoculum, insect pests, or vectors.

b. Never use diseased materials as mulch

i. In W. Africa, removal of old cocoa pods after harvest is strongly recommended to control the spread of black pod disease.

Ants use old pods as nest sites and are the most common vector of black pod disease. Infested pods are used as building material by ants who then transfer infected pod material to healthy pods.

ii. In Samoa, fallen coconut logs or piles of rotting vegetation are breeding sites for rhinoceros beetles and should be destroyed.

iii. The aphid that transmits bunchy top disease, lives in red ginger as its alternate host. Farmers should not plant this ginger near bananas plantations.

3. Adjusting planting schedules

a. Plant crops during the time of year when the there are fewer pests likely to be present, eg. dry or wet season.

b. *Thrips palmi* is a serious insect pest of cucurbits during dry seasons. It is better to grow a different crop at that time of year.

4. Cropping practices

a. Appropriate cropping practices provide suitable conditions for plant growth while reducing the potential for pest problems.

b. DISEASE RESISTANT crop varieties

i. Some tomato cultivars are bacterial wilt resistant.

ii. Certain cultivars of banana are less susceptible to bunchy top or black leaf streak diseases.

c. CROP COMPETITION

i. Selection of aggressive crop varieties

ii. Proper preparation of soil

iii. Use of seedlings or other well established planting material

iii. Proper planting depth, population, and timing

d. CROP ROTATION

i. Prevents build up of crop specific diseases and insect pests in a field.

ii. Common crop rotations include grasses followed by legumes then root crops in the same area.

iii. Soilborne fungi, bacteria and nematodes are also controlled with 2-4 year rotations of non-host crops.

iv. In the Imperial Valley of California, sugar beet cyst nematode is controlled when sugar beets are grown no more that 2 years in succession and not more than 5 years in 10

e. SHIFTING CULTIVATION

i. A traditional practice on nearly all Pacific islands

ii. Utilizes a FALLOW period that reduces the number of most crop pests and allows time for the restoration of soil nutrients.

f. TRAP CROPPING

i. Treatment of the trap plants generally controls the pest without residues on the crop or harm to beneficial natural enemies.

ii. A disadvantage of this technique is the expense of producing and destroying a crop that brings no income.

iii. In Hawaii, squash and melon fields are often surrounded by a few rows of corn to attract large numbers of melon flies.

g. INTERCROPPING can limit pest damage in several ways. Additional crops may:

i. Act as physical barriers or chemical barriers (repellants) to pests.

ii. Act as alternative hosts, diverting pests from the crop at most risk.

iii. Provide a suitable habitat for natural enemies

iv. Provide shade to decrease weed growth.

v. On many Pacific islands, taro (*Colocasia esculenta*) is intercropped with bananas, coconut, papaya, and other crops. Intercropped areas appear to experience less incidence of armyworm and planthopper outbreaks than do areas planted only with taro.

h. High CROP DENSITY is not always appropriate

i. Close plant spacing can help control weeds. As the plants grow, leaves will form a canopy that shades the ground reducing weeds.

ii. Close spacing can increase the humidity surrounding crop plants which allows some diseases and insects to reproduce more rapidly.

i. Proper fertilization

i. A healthy plant is less susceptible to attack by insects and disease.

ii. Healthy, fast-growing plants can compete with weeds.

iii. Excess fertilizer (particularly nitrogen) results in too much leaf growth. The succulent leaves are more easily damaged by insects, and increased humidity around crop may favor pests and disease.

j. MULCHING is traditionally practiced with many Pacific island crops.

ii. In Palau, banana leaves are worked into the taro patch by hand for soil improvement. Taro is planted in the patch and additional leaves on the surface used to reduce weed growth.

iii. In Aunuu, American Samoa, different leaves are used as mulch to obtain different textures of swamp taro.

iii. SOLARIZATION is a new practice with potential for Pacific islands. Clear plastic mulch is laid on bare, moist soil to raise the temperature and kill certain pests.

Mulching with breadfruit leaves

Mulching with cardboard

k. Increasing soil ORGANIC MATERIAL

i. Improves drainage and prevents waterlogged conditions.

ii. Reduces problems of root rot and crown rot.

iii. Reduces seedling "damping off" problems from *Phytophthora*.

l. IRRIGATION

i. Water droplets can splash on leaves and spread disease organisms.

ii. Using drip irrigation carries water to crop not weeds.

iii. Water can be used to deter pests.

iv. In Hawaii, overhead irrigation of watercress interferes with mating of the Diamondback moth, thereby reducing incidence of that pest on the crop.

m. TRELLISING is not always an appropriate practice.

i. Keeps plants off the ground where diseases may be a problem.

ii. May increase insect pest problems

Ex. Research in Micronesia has shown that a serious insect pest of cucumbers, the Leaf-footed bug (*Leptoglossus australis*), is found in high number on trellised plants from flowering until the last harvest. No bugs were encountered on cucumber plants crawling on the ground on top of mulch.

n. Smoke is traditionally used to repel agricultural pests.

Reading Assignment

Selections from instructor reference.

Instructor Reference

1. *Entomology and Pest Management,* by Larry P. Pedigo, pp.331-356.
2. *Plant Pathology*, by George N. Agrios, pp, 8-26.

Lecture 21
PHYSICAL CONTROL

Introduction

Physical controls include mechanical practices and indirect methods that destroy pests or make the environment unsuitable for their entry, dispersal, survival, or reproduction. Some physical controls are rarely used in "modern" agriculture due to high labor costs. However, in many circumstances these methods can be a suitable alternative to chemical forms of pest control. They are most useful when incorporated with other methods into an integrated pest management program.

Objectives

Upon completion of this lesson, students should be able to:

A. Describe at least one mechanical practice used to control insects, weeds, and diseases; including an example of each.

B. Explain how barriers, adhesives, and traps are used to discourage pests.

C. Describe at least two types of heat treatment and how they are used to control crop diseases.

D. Define the three terms provided below.

Terms

MECHANICAL PRACTICES - Direct removal of pests; e.g. hand-pulling weeds, smashing insects, etc.

PHYSICAL CONTROL - Using mechanical practices and indirect methods that destroy pests or make the environment unsuitable for their entry, dispersal, survival, or reproduction.

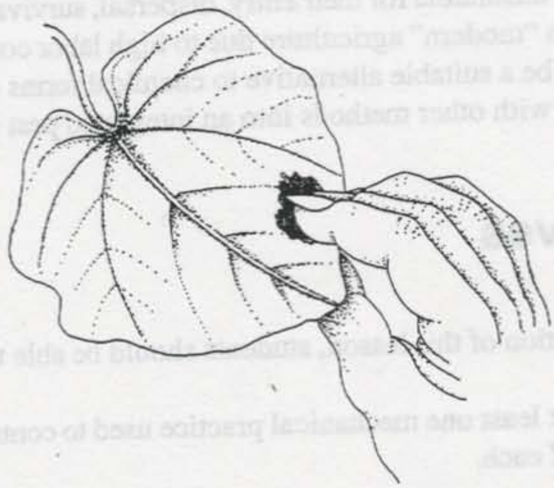
TILLAGE - The practices used to cultivate soil and prepare land for planting.

Teaching Outline

A. Insects

1. MECHANICAL PRACTICES

a. Hand picking insects or smashing egg masses.



b. TILLAGE

i. Deep ploughing may bring insect larvae and pupae to the soil surface disturbing their life cycle by exposure to sunlight, rain, etc.

ii. Disturbed pests in the soil may also be killed by; predators, bad weather, mechanical injury, or starvation.

2. Other PHYSICAL CONTROLS

a. Barriers

i. Sticky bands around trunks can prevent non-flying pests from climbing trees.

ii. Chicken wire or other sharp borders around a garden will keep out snails and slugs.

iii Screens keep out mosquitoes, flies and others insects.

b. Adhesives

i. Paper strips coated with sticky adhesive catch house/barn flies.

ii. Yellow plastic or wooden strips covered with adhesive attract and entangle aphids, leafminers and other pests.

c. Traps and Attractants: pheromones, papaya leaves, or baits that will attract pests so they can be captured and destroyed.

d. Insects respond to some types of artificial sound vibrations.

i. Attract insects to a trap

ii. Repel them from specific areas

iii. "Jam" or interfere with their natural communication systems

B. Weeds

1. Mechanical practices

a. Hand weeding and mowing

i. Prevents weeds from flowering and setting seed

ii. Can be used to deplete the weed's root reserve

iii. Effective on tall weeds but not low growing plants

iv. A temporary measure

b. Tillage

i. Weeds on the surface can be uprooted and killed

ii. Buried weed seeds, tubers, and rhizomes may be brought to the surface and germinate.

iii. Potential for soil erosion is increased compared to hand weeding.

c. Screens placed in irrigation pipes and ditches can reduce the movement of weed seed into irrigated cropland.

C. Diseases

1. Removing diseased plants is a mechanical practice

a. Roguing entire plants, eg., bunchy top and papaya ringspot

b. Removing injured leaves, eg., black leaf streak and taro blight

2. Soil sterilization is commonly used for potting soil to prevent the transmission of "damping off" and other diseases.

3. Hot water treatment of planting material, such as banana corms, can kill diseases and nematodes that may otherwise be transfered to new locations.

Reading Assignment

Selections from instructor reference.

Instructor Reference

1. *Entomology and Pest Management,* by Larry P. Pedigo, pp.340-344, 463-474

2. *Plant Pathology,* by George N. Agrios, pp. 192- 194.

Lecture 22
BIOLOGICAL CONTROL

Introduction

One of the most desirable ways of controlling pests is to make use of the many organisms in the environment that eat other living things. Almost every species in the world is food for some other organism. Biological controls are used to establish conditions that allow these organisms to maintain pests numbers below the economic injury level.

The needed predators or parasites may already be present in the location where the pest is a problem. In these cases, changing management of the crop may give the predators and parasites a better chance to control the pest. In other cases, especially when the pest has been introduced from elsewhere, the biological controls may be lacking. The needed organisms may be found in the native home of the pest and brought to the new location.

Weeds also have their own predators, called herbivores. In some cases herbivores eat sufficient quantities of the weeds to control them. Even plant disease organisms have other microorganisms which feed on them, or at least compete with them, and prevent economic injury to the target crop.

Many plants are resistant to the effects of some insects and diseases because of their physical/chemical characteristics, or their ability to sustain damage without serious injury. Plant resistance to pests can be used by farmers through the selection of traditional and improved varieties. The development of new resistant varieties is a field of increasing importance to agricultural scientists.

Objectives

Upon completion of this lesson, students will be able to:

A. Describe classical biological control of insects and reasons why it should be undertaken by professionals.

B. List three methods that can increase the native parasites and predators in a crop field.

C. List at least three advantages and three disadvantages of biological control of insects.

D. Describe four method of biological control of weeds.

E. Describe three methods of biological control of plant pathogens.

F. Give at least two examples of tolerance and antibiosis in plant resistance.

G. Describe the process by which a resistant variety is developed.

H. Define the twelve terms provided below.

Terminology

ANTIBIOSIS - Plant characteristics that reduce the growth and survival of pests feeding on it.

CROSS PROTECTION - The infection of a plant with a virus that protects it from infection by other strains of the same virus.

EXOTIC PEST - A pest that is native to a part of the world other than where it is currently found.

HORIZONTAL RESISTANCE - Resistance achieved by small changes in many genes, summed together.

HOST SPECIFIC - An herbivore or predator that only eats a particular host.

HYPERPARASITE - A parasite that feeds on other parasites.

PARASITOID - An organism similar to a parasite, but it eventually kills the host so it is also similar to a predator.

RESISTANCE - The collective inheritable characteristics of a plant which influence the ultimate degree of damage done by a pest.

SUPPRESSIVE SOIL - Soil that prevents soil borne pathogens from causing disease in a susceptible plant.

SUSCEPTIBLE - A plant which is easily injured by the effects of a specific pest.

TOLERANCE - Ability of a host to withstand pest injury that would damage a susceptible plant.

VERTICAL RESISTANCE - A high degree of resistance caused by a change in only one or two genes.

Teaching Outline

A. Biological control of insects

1. Classical method

   a. Introduce predators, parasites, PARASITOIDS, or diseases of a pest

      i. Target is often an EXOTIC PEST

      ii. Biocontrol is tested, introduced, and monitored

      iii. Highly successful in many cases

   b. Should only be undertaken by professionals

      i. Pest and control agent must be correctly identified

      ii. Ensure that predator or parasite is HOST SPECIFIC

      iii. Avoid general predators (such as cane toad or mongoose)

      iv. Do not introduce any HYPERPARASITES

   c. Examples of successful programs

      i. Control of transparent scale by predators

      ii. Control of coconut rhinoceros beetle by a virus

      iii. Control of spiraling whitefly by a parasite

   d. Examples of unsuccessful programs

      i. Introduction of mongoose to Hawai'i

      ii. Introduction of toads into American Samoa

      iii. Introduction of parasitic snails that consume native snails

2. Management of native predators and parasites

   a. Reduce pesticides that damage predator/parasite populations

   b. Improve habitat for predators and parasites (e.g., flowers as a nectar source, alternate hosts in hedgerows)

3. Augmentative biological control

   a. Obtain mass reared native or exotic parasites and release as a biological control.

   b. Quarantine restrictions and distance from suppliers has limited this method in the Pacific islands.

4. Advantages and disadvantages of biological control of insects.

   a. Advantages

      i. Low cost

      ii. No residues

      iii. No inputs by farmer except in augmentative control

      iv. Long term benefits (unless disrupted by pesticides, etc.)

   b. Disadvantages

      i. Slow action compared to chemical control

      ii. Difficult to find a natural enemy for all pests

      iii. Introduced biocontrol can remain in ecosystem forever (if unexpected affect on non-target species)

      iv. May not be compatible with chemical control of other pests

B. Biological control of weeds

1. Introduced invertebrate herbivores

   a. Introduction must be host specific

   b. Requires competition by a desirable plant/crop to replace weed species

   c. Successful programs; Lantana and Opuntia cactus control in pastures

2. Introduced vertebrate herbivores

   a. Pigs or chickens remove certain propagative structures from soil before planting

   b. Ducks, geese, cows and other vertebrates control weeds in row or paddy crops after planting

3. Allelopathy - certain plants produce substances that suppress weeds.

4. New technology is being developed to use host specific disease organisms sprayed on weeds to control them.

C. Biological control of plant pathogens

1. SUPPRESSIVE SOILS

a. High organic matter in soil encourages non-pathogenic competitors

b. Viruses of soil pathogens build up in some conditions

c. Fungi that feed on nematodes

2. Bioprotectants

a. Commercial products (e.g.. *Bacteria subtilis)* applied to plant

b. Non-pathogen bacteria on surface prevents pathogen establishment

c. Used to protect seeds, and experimentally for post-harvest storage

3. CROSS-PROTECTION

a. Weak strains of virus injected into SUSCEPTIBLE plants at early stage

b. Prevents them from becoming infected by virulent stains later

D. RESISTANCE to pest problems

1. Use of traditional varieties

2. Improved varieties

a. Disease resistance is common in named varieties.

b. Insect resistance is rarely bred into plants.

3. Types of resistance

a. TOLERANCE

i. The ability of a plant to sustain pest effects without serious injury.

- Regenerate damaged tissues (root rot resistant beans)
- Extra strength against physical damage (borer resistance crops)
- Not sensitive to toxins (some leafhopper resistant cottons)

ii. Tolerant characteristic does not affect the pest population.

b. ANTIBIOSIS

i. Physical characteristics of plant (e.g., waxiness, hairiness)

ii. Chemistry of plant (e.g., toxins, nutrient imbalances)

iii. Hypersensitivity

4. Sources of genes for increasing resistance

   a. Adapted types: Crop cultivars that have desired resistance are very rare.

   b. Unadapted types: Semicultivated varieties that need considerable breeding improvement to become widely acceptable.

   c. Wild species in same genus as crops: Highest level of resistance but many years of breeding improvement to make an acceptable variety

   d. Genetic engineering.

      i. VERTICAL RESISTANCE

      ii. HORIZONTAL RESISTANCE

5. Advantages and disadvantages of increased resistance methods

   a. Advantages

      i. Small cost to farmer

      ii. Compatible with almost all forms of pest management

   b. Disadvantage

      i. Farmer cannot produce seed

      ii. Sometimes pests overcome resistance

Reading Assignment

Selections from instructor reference.

Instructor Reference

1. *Entomology and Pest Management,* by Larry P. Pedigo, pp.301-330.
2. *Plant Pathology,* by George N. Agrios, pp. 189-192.

Lecture 23
PESTICIDE FORMULATIONS AND APPLICATION

Introduction

Pesticides always contain an active ingredient which is the material that kills the target pest. Most pesticides also have other ingredients that are often called "inert" because they are not the active ingredient. These are used to make the pesticide more effective, or to make it; safer, easier to measure, mix, or apply. The pesticide is usually diluted with water or a petroleum based material if it is a liquid, or with clay if it is a granule. A product may also include substances such as wetting agents and surfactants.

The mixture of active and inert ingredients is called a formulation. Some formulations are ready to be used and others must be further diluted before they can be applied. A single active ingredient can be sold in a variety of formulations. The effectiveness of different formulations may vary when used on different pests. What formulation should be applied will also depend on the equipment available for applying the pesticide.

Objectives

Upon completion of this lesson, students should be able to:

A. Describe four common types of pesticides with at least two examples of each.

B. List four common ingredients in pesticide formulations.

C. Describe dry and liquid formulations with at least four examples of each.

D. List advantages and disadvantages of using dust/granule versus spray formulations.

E. Explain why pesticides are sometimes combined and four reasons one must check for compatibility when doing so.

F. Describe eight different pesticide application methods.

G. Define the twenty-two terms provided.

Terms

ACTIVE INGREDIENT - The chemical in a pesticide formulation responsible for the toxic effect.

AEROSOL - An extremely fine mist or fog made of liquid particles suspended in air.

ANTIBIOTIC - A substance which kills bacteria.

BOTANICAL INSECTICIDE - A plant derived substance which kills insects.

BROADCAST - A uniform application to an entire, specific area.

CARRIER - A gas, liquid or solid used to dilute, propel, or suspend a pesticide while it is being applied.

CHEMIGATION - Use of irrigation systems for applying pesticides.

CONTACT HERBICIDE - A herbicide that is phytotoxic when applied to plant tissue.

DILUENT - A substance used to reduce the concentration of an active ingredient in a formulation.

EMERGENCE - The growth of weed and/or crop seedlings above the soil surface.

EMULSIFIABLE CONCENTRATE - A concentrated formulation containing substances to facilitate the formation of an emulsion when mixed with water.

EMULSION - A suspension of microscopic droplets of one liquid in another.

FORMULATION - A pesticide preparation supplied by a manufacturer for practical use.

FUMIGATION - Application of a pesticide in a gaseous state into an enclosure and/or the soil.

GRANULES - Small coarse particles covered with or containing the active ingredient of a pesticide.

MICROBIAL INSECTICIDE - A substance produced by microbes (bacteria or virus) which kills insects.

MYCOHERBICIDE - A fungal disease of weeds that is packaged and sold as a herbicide.

SELECTIVE - A substance that is more toxic to some species of plants and animals than others.

SOLUBLE - The ability to dissolve in a liquid.

SURFACTANT - A material which interacts with waxy or oily surfaces so that water will stick to them.

SYSTEMIC - A substance that is taken up and translocated throughout the system of a plant or animal.

WETTABLE POWDER - Finely ground particles easily suspended in water.

Teaching Outline

A. Types of pesticides

1. Insecticides

   a. BOTANICALS: pyrethrum, rotenone, nicotine

   b. Organics: Carbamates, organophosphates, pyrethroids

   c. MICROBIALS: *Bacillus thuringensis*, *B. popillae*, NPV viruses

2. Fungicides

   a. Inorganics: Bordeaux mixture, lime-sulfur, and copper sulfate

   b. Organics: Sulfur compounds and organic phosphates

   c. MYCOHERBICIDES

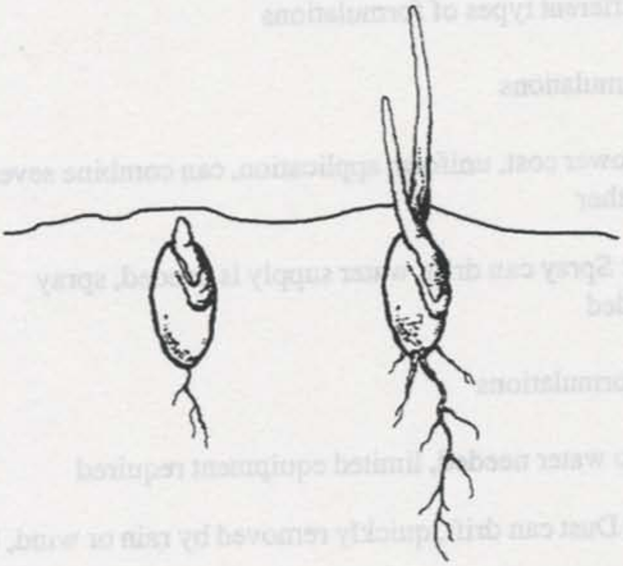
3. ANTIBIOTICS: Streptomycin, Tetracyclines

4. Herbicides

   a. SYSTEMIC versus CONTACT

   b. SELECTIVE versus non-selective

   c. Pre-EMERGENCE versus post-emergence



Pre-emergence and Postemergence

B. FORMULATIONS of pesticides

1. Ingredients in pesticides

a. ACTIVE INGREDIENTS

b. DILUENTS

c. SURFACTANTS; may also be added to tank mixture

d. CARRIER

2. Liquid formulations

a. EMULSIFIABLE CONCENTRATES (EC OR E)

b. Water SOLUBLE Liquids (WSL or L)

c. Flowables

d. AEROSOLS

3. Dry formulations

a. Dusts (D)

b. GRANULES (G)

c. Wettable powders (WP)

d. SOLUBLE powders (SP)

C. Reasons for using different types of formulations

1. Liquid (spray) formulations

a. Advantages: Lower cost, uniform application, can combine several chemicals together

b. Disadvantages: Spray can drift, water supply is needed, spray equipment needed

2. Dust or granular formulations

a. Advantages: No water needed, limited equipment required

b. Disadvantages: Dust can drift, quickly removed by rain or wind, bulky materials

D. Combining different chemicals in the same tank

1. May save time (and money) by controlling more than one pest in a single application.

2. Small amounts of two different herbicides can be as effective as larger amount of one kind.

3. Never use herbicide spray equipment for any other purpose.

4. The compatibility of chemicals to be mixed must be checked.

   a. Possible dangerous interactions

   b. Herbicides may react with each other resulting in increased toxicity.

   c. One chemical may inactivate the other

   d. May cause clogging of spray equipment

E. Application Methods

1. Foliar treatment for plant leaves

   a. Spray

   b. Dust

2. Soil treatment

3. BROADCAST

   a. Pesticide applied to entire area

   b. Costly but often more effective

4. Band application

   a. Pesticide applied in bands over crop

   b. Less pesticide needed, less costly, but may not give sufficient control

5. Spot treatment for specific areas

6. Injection

   a. Injector or capsule carries systemic pesticide into the target

   b. Control is not long lasting in tropical environment

c. Uses of injection methods

i. Killing woody perennials with herbicide

ii. Treating ornamentals for insect infestation

iii. Treating yellows disease in palms

7. CHEMIGATION

a. Pesticide is injected into main irrigation stream with positive displacement pump.

b. Only effective in areas of field receiving irrigation water

c. Can only apply chemicals that do not settle when mixed with water and will not clog irrigation equipment

8. FUMIGATION

a. Target object is tented and gas is injected

b. Extremely toxic, complete control is obtained

c. Only way to kill deeply imbedded insects

d. Very dangerous, must be done by trained personnel

e. Many fruits, vegetables, and ornamentals are damaged by gas

Reading Assignment

Applying Pesticides Correctly, University of Hawai'i CES, pp. 17-25.

Instructor Reference

1. *Plant Pathology*, by George N. Agrios, pp.205-227.

2. *Entomology and Pest Management*, Larry P. Pedigo, pp. 365-398.

Lecture 24
EQUIPMENT AND CALIBRATION METHODS

Introduction

Pesticides are applied with equipment especially made for the task. Successful safe pest control depends upon choosing the proper type of equipment and taking good care of it. Correct calibration assures that chemicals are applied safely in the proper amount as directed on the label. This lecture covers the various types of spray equipment used in the Pacific islands.

Objectives

Upon completion of this lesson, students will be able to:

A. Describe at least six pieces of protective clothing /equipment required for safe pesticide application.

B. Describe at least five types of equipment used to apply liquid pesticides.

B. Describe the seven main parts of a tank sprayer.

C. Describe at least four types of nozzles and a specific use of each one.

D. Describe at least four types of equipment used to apply dust or granular formulations.

E. Explain the importance of equipment calibration and solve a variety of practice problems.

F. Define the six terms provided below.

Terms

AGITATION - The process of stirring or mixing in a spray tank.

BACKPACK SPRAYER - A sprayer shaped so the operator can wear the tank on his/her back.

CALIBRATION - The adjustment of application equipment to a specified rate of flow.

CANISTER SPRAYER - A hand-pumped cylindrical sprayer used for small jobs.

MISTBLOWER - A motorized sprayer that disperses formulations as a fine mist.

NOZZLE - A device on the application end of a pesticide sprayer that has an opening which shapes the spray pattern.

Teaching Outline

A. Protective clothing and equipment

1. Waterproof rain hat or hard hat
2. Face shield or goggles
3. Mask or respirator
4. Rubber or polyethylene gloves
5. Watertight coveralls
6. Waterproof boots or footwear

B. Equipment used for applying liquid formulations

1. Wiping devices used especially for herbicides
2. Hose-end sprayers
3. Hand operated pumps
   a. CANISTER SPRAYER
   b. BACKPACK SPRAYER
4. Motorized sprayers
5. MIST BLOWERS

C. Parts of a tank sprayer

1. Tank
   a. Corrosion-resistant
   b. Large opening for easy cleaning
   c. Strainer to keep formulation clean
2. Pump
   a. Sufficient capacity to AGITATE mix and provide required pressure
   b. Corrosion and abrasion resistant
   c. Valves should be easily accessible

3. Filter

4. Hoses

a. Burst strength greater than peak operating pressure

b. Resistance to solvents

5. Pressure regulator and pressure gauge

a. Regulator capacity must match that of pump

b. Gauges must be checked for accuracy since they regulate the rate at which materials is sprayed.

6. Agitators

7. NOZZLES

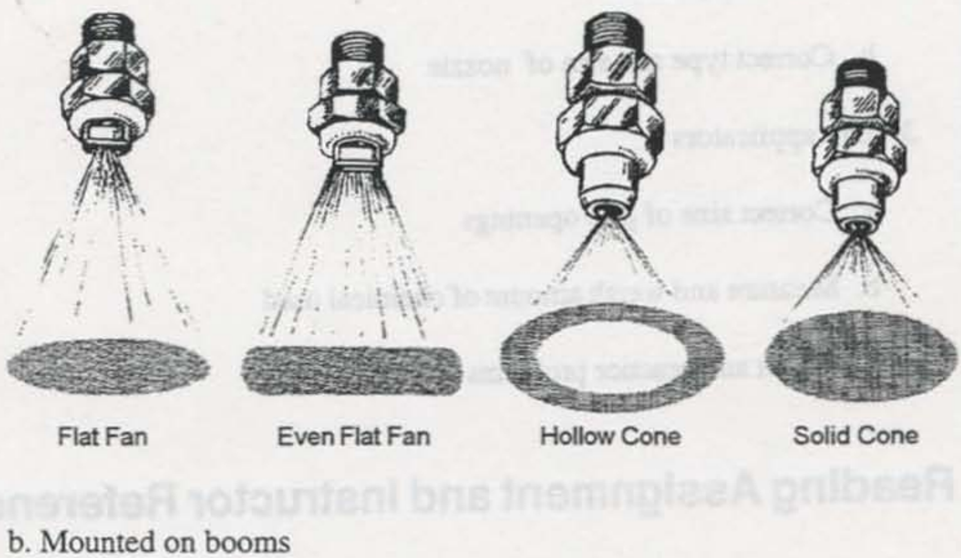
a. Different spray patterns for different uses

i. Flat fan

ii. Even flat fan

iii. Hollow cone

iv. Solid cone



b. Mounted on booms

i. Consider spray overlap when using multiple nozzles.

ii. Herbicide application may require different types of nozzles.

D. Equipment for applying solid materials

1. Dusts

    a. Hand dusters

    b. Power-operated dusters

2. Granules

    a. Spinning disks similar to fertilizer spreaders

    b. Multiple gravity-fed outlets similar to lawn spreaders or grain drills

    c. Forced air

    d. Soil injectors

E. CALIBRATION

1. Determining the proper amount of pesticide to apply on a specific area

    a. Methods depend on the type of equipment to be used

    b. Equipment must move at a constant speed

2. Sprayers

    a. Constant pressure

    b. Correct type and size of nozzle

3. Dry applicators

    a. Correct size of gate openings

    b. Measure and weigh amount of chemical used

4. Equations and practice problems

Reading Assignment and Instructor Reference

Applying Pesticides Correctly, University of Hawai'i CES, pp. 31-32, 38-48.

VI. PESTICIDE SAFETY

Lecture 25
HANDLING, STORAGE, AND DISPOSAL

Introduction

Pesticides are poisons. They are intended to kill weeds, plant pathogens, and insect pests. If handled improperly they can also harm or kill other living things, including humans. Every pesticide must have a label containing important information for it's safe handling and use. This lecture will describe pesticide labels, the procedures for the safe transport, storage and disposal of chemicals and their containers, as well as how to handle accidental leaks or spills.

Performance Objectives

Upon completion of this lesson, students will be able to:

A. Explain why pesticide labels are important and four times when they should always be read.

B. Describe the ten key parts of a pesticide label.

C. Explain at least five safety precautions for transporting pesticides in a vehicle.

D. Describe eight components of a safe storage site.

E. Describe four alternative actions when a pesticide container leaks.

F. List at least ten important actions to safely manage a pesticide spill.

G. Explain three alternative ways to dispose of excess pesticides that are still usable.

H. Explain the five steps in proper disposal of empty pesticide containers.

I. Define the seven terms provided below.

Terminology

CAUTION - The pesticide label signal word for materials of low toxicity.

DANGER - The pesticide label signal word for materials of high toxicity.

INGREDIENT STATEMENT - The pesticide label information that tells the percentage of active ingredient(s).

LABEL - The written, printed and graphic information on, or attached to, the pesticide container or device.

MSDS - The Materials Data Safety Sheet that must be kept with each stored pesticide.

PRACTICAL TREATMENT - The recommended first aid actions to take if a pesticide is swallowed, inhaled, gotten in the eyes, or on skin.

WARNING - The pesticide label signal word for materials of moderate toxicity.

Teaching Outline

A. Pesticide LABELS

1. Importance of the label

   a. What is inside the container

   b. How to use the pesticide properly

   c. Safety hazards, emergency actions, and first aid treatment

2. Read the label

   a. Before buying the pesticide

   b. Before mixing and applying the pesticide

   c. Before storing the container

   d. Before disposal of the pesticide and/or the container

3. Main parts of a standardized label

   a. Product name

   b. INGREDIENT STATEMENT

   c. Statement of use classification

   d. Signal words and symbols

      i. CAUTION

      ii. WARNING

      iii. DANGER

   e. Statement of PRACTICAL TREATMENT

   f. Precautionary statements

   g. Directions for use

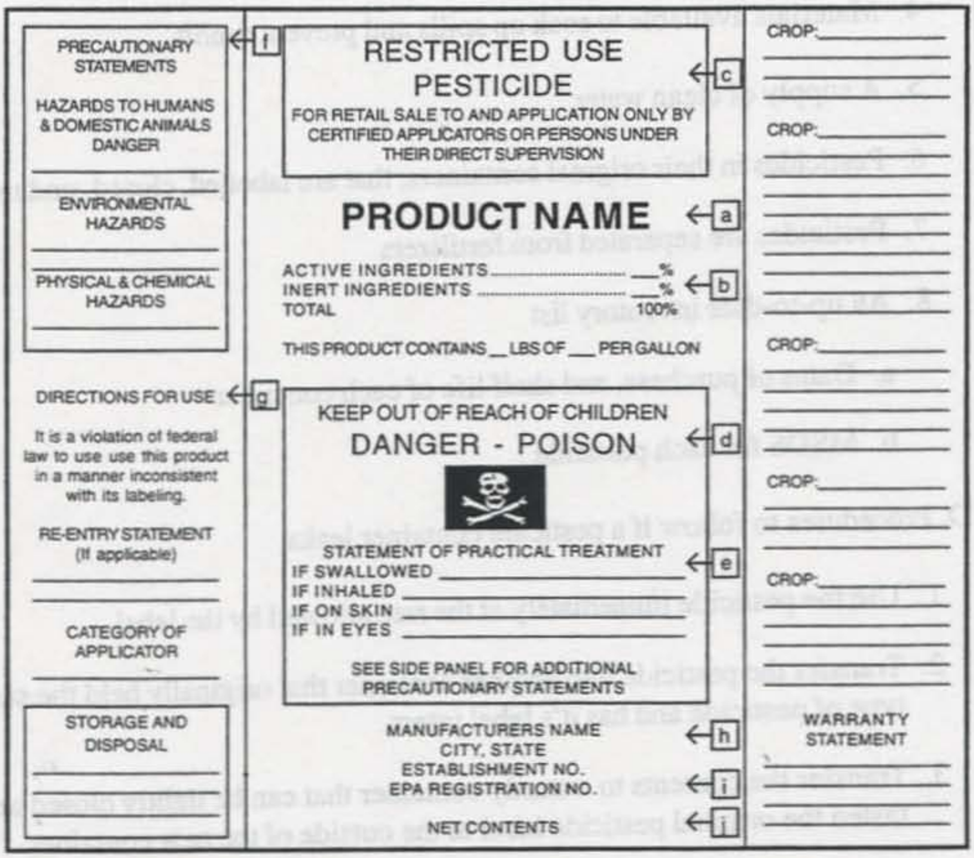
      i. Directions for storage, disposal, re-entry, etc; and a misuse statement

      ii. The pests that can be controlled on specific crops, animals, and sites

   h. Manufacturer name and location

   i. EPA registration number

   j. Net contents



A sample standardized pesticide label

Show transparency 25.1

B. Safety precautions for transporting pesticides

1. Never carry pesticides in the passenger section of a car, truck, or bus.

2. Never allow children, other passengers, or pets to ride with pesticides.

3. Never transport pesticides with food, clothing, or anything that will come in contact with people or animals.

4. Never leave your vehicle unattended if transporting pesticides in an unlocked trunk or open-bed truck.

5. Consider transporting highly volatile pesticides in separate trips from other chemicals.

C. Components of a safe pesticide storage site

1. A locked cabinet, cage, or building to keep out unauthorized personnel

2. A sign at the entrance: *DANGER PESTICIDE STORAGE AREA*

3. A controlled environment

   a. Dry

   b. Well ventilated

   c. Cool

4. Materials available to soak up spills and prevent runoff

5. A supply of clean water

6. Pesticides in their original containers, that are labelled, closed, undamaged

7. Pesticides are separated from fertilizers

8. An up-to-date inventory list

   a. Dates of purchase, and shelf life of each container

   b. MSDS for each pesticide

D. Procedures to follow if a pesticide container leaks

1. Use the pesticide immediately at the rate allowed by the label.

2. Transfer the pesticide into another container that originally held the same type of pesticide and has it's label intact.

3. Transfer the contents to a sturdy container that can be tightly closed and fasten the original pesticide label to the outside of the new container.

4. Place the entire damaged container with its contents and label into a suitable larger container.

E. Procedures for safe management of pesticide spills.

1. Wear the appropriate protective clothing before contacting the spill or breathing its fumes.

2. Stop the source of the spill.

3. Keep children, other unprotected people, and animals away from the site.

   a. Rope off the site if necessary.

   b. Warn people to keep out of reach of any drift or fumes.

   c. Don't allow fire or smoking on site as the chemicals may be flammable.

4. Stay at the site until a correctly protected person arrives to replace you.

5. Contain the spill.

   a. Make a dike of soil or plant materials to stop further movement of spill.

   b. Use absorbent material to soak up the chemical.

   c. Prevent spill from entering bodies of water, ditches gutters, and sewers.

6. Prevent dusts, powders, or granules, from becoming airborne.

   a. Sweeping compound

   b. Plastic cover

   c. Very light mist of water

7. Dry pesticide spill

   a. Sweep up the chemical for reuse if possible.

   b. If the dry spill has become wet or full of debris, it must be swept up and placed in a heavy-duty plastic drum or bag for disposal.

8. Liquid pesticide spill

   a. Sweep up the absorbent materials containing the pesticide.

   b. Place all materials into a heavy-duty plastic drum or bag for disposal.

9. Neutralize the site after pesticide is removed.

   a. Mix full-strength bleach with hydrated lime and work this mixture into the spill site with a coarse broom.

   b. Spread fresh absorbent material over the spill site to soak up the bleach and lime mixture.

   c. Sweep up absorbent materials and place in drum or bag for disposal.

10. Decontaminate yourself

    a. Wash thoroughly with detergent and water.

    b. If shoes or clothing are saturated with pesticide, they should be properly disposed of in a landfill.

11. Decontaminate equipment and vehicles by washing with a strong mixture of chlorine bleach, dishwashing detergent, and water.

F. Procedures for using excess pesticide

1. Apply it to a crop and site listed on the label.

2. Find someone else who can legally use it.

3. Return it to the dealer, manufacturer or appropriate disposal agency.

G. Care and disposal of empty pesticide containers

1. Return all empty containers to the pesticide storage area or the container holding area when you finish your task.

2. If containers are rinsable, rinse them as soon as they are empty. Types of containers that are rinsable:

   a. Glass, metal and plastic containers

   b. Plastic-lined paper or cardboard containers

   c. Unlined paper or cardboard containers that can withstand rinse process

3. Triple rinse the container

4. Crush, break, or puncture empty containers that cannot be refilled, reconditioned, recycled or returned to the manufacturer.

5. Dispose of containers in accordance with labeling directions and local laws or regulations that apply.

Reading Assignment and Instructor Reference

Applying Pesticides Correctly, University of Hawai'i CES, pp.25-28 and 35-38.

Lecture 26
USING PESTICIDES SAFELY

There are two main reasons for using pesticides safely; to keep yourself and others from being poisoned and to avoid environmental damage. The topics of poisoning and ecosystem contamination by pesticides will be discussed in separate, upcoming lessons. This lesson will cover the general safety practices and conditions that are required whenever pesticides are used.

Performance Objectives

Upon completion of this lesson, students will be able to:

A. List the eight basic safety questions to ask before applying pesticide.

B. List at least six consequences of incorrect use of pesticides.

C. List four factors to consider when choosing among different formulations.

D. Explain five conditions at the application site that affect decisions regarding pesticide use.

E. Describe the safety precautions to take when mixing or loading pesticides.

F. Describe three ways to determine whether pesticides can be safely mixed together for application.

G. List the six safety procedures to follow each time you apply a pesticide.

H. Describe nine pesticide application tasks that require more personal protection than found on the label.

I. Explain four ways to avoid heat stress when applying pesticides.

J. List the seven procedure to follow after mixing, loading, and application activities are finished.

K. Describe what to do with rinsates from equipment cleanup.

L. Describe five steps on personal cleanup after pesticide handling.

M. Explain four benefits of record-keeping.

Teaching Outline

A. Basic safety questions to answer before using pesticides

1. Have you read the label?

2. How can exposure to pesticides be avoided?

3. Is the required personal protective equipment available?

4. Is the application equipment ready and safe?

5. Are conditions correct to prevent the accidental spread of pesticides?

6. Has preparation been made for any emergencies?

7. Are people and animals out of the area?

B. Consequences of incorrect use of pesticides

1. Possible immediate and long-term harmful effects to humans and other living things

2. Damage to the target site and surrounding environment

3. Killing the natural enemies of a pest that can lead to worse outbreaks

4. Failure to control the pest

5. Wasted pesticide material

6. Loss of money

   a. Pesticides are expensive; using them incorrectly can be costly

   b. Misuse of pesticides can result in fines and legal actions charging you with liability for damages.

C. Factors to consider when choosing a specific pesticide and formulation

1. Risk to applicator, workers and other people likely to be involved

2. Will the formulation cause unwanted harm to plants, animals in the application site.

3. Application equipment that is available and best suited for the job

4. Hazard of drift or runoff. Do weather (windy) conditions or environmental conditions (excess water) prevent use?

D. Site conditions that must be considered before applying pesticides

1. Surface characteristics

   a. Granules are good on flat soil surfaces

   b. Wettable powder on porous surfaces

   c. Narrow upright leaves prevent contact with the entire surface

   d. Waxy leaves cause spray solution to form droplets and run off

2. Cleanliness of the surface

   a. Organic matter may absorb pesticides and reduce amount available to control the target pest

   b. A factor on both the soil or leaf surface

3. Surface moisture

   a. Excess water may keep pesticide from adequately contacting surface

   b. Dryness may prevent the pesticide from spreading evenly over the surface and contacting the target pest

4. Temperature, sunlight, and humidity

   a. Low temperature can slow down or stop the activity of some pesticides. It can also cause pests to move slower, eat less, or even change into another form.

   b. High temperature can break down pesticides before they affect the pest. High temperature with low humidity can cause vaporization of the pesticide.

   c. Humidity influences pesticides in different ways. Herbicides work best when weeds are growing fast--usually in high humidity and optimum temperature. However, these same conditions can make the crop more likely to be injured by the herbicide.

5. Air movement

   a. Do not apply when wind speed in greater than 10 miles per hour.

   b. Do not use nozzles which dispense fine droplets because the chemical will drift more easily.

E. Safety when mixing and loading pesticides

1. Personal protection

a. Front protection; apron, gloves and hat

b. Face protection; face shield or goggles

c. Dusts and vapors; Appropriate respirator or mask

2. Preventing water pollution

a. Keep water pipe or hose above the level of the pesticide mixture

i. Prevents contamination of the hose

ii. Prevents pesticides from back siphoning into the water source

b. Do not mix or load pesticides in areas where a spill, leak, or overflow could allow pesticides to get into the water system.

F. Only certain pesticides can be combined

1. Check the pesticide label; it may list the chemicals that are compatible with the formulation.

2. Get a compatibility chart which may be available from several sources.

3. Test a small amount of mixture before mixing large quantities of the pesticide together.

G. Safety procedures to follow each time you apply a pesticide

1 Deliver the pesticide to the target site

2. Check the delivery rate

3. Check for appearance

4. Avoid nontarget organisms

5. Avoid nontarget surfaces

6. Operate equipment safely

H. Tasks requiring more personal protection than specified on the label.

1. Hand carrying application equipment
2. Entering the path of the released pesticide
3. Walking into a just treated area
4. Using high exposure methods where the pesticide may engulf you
5. Applying pesticides in enclosed spaces
6. Adjusting pesticide application equipment
7. Immersing hands and forearms in pesticides
8. Applying into or across air currents
9. Applying concentrated pesticides

I. Avoiding heat stress

1. Gradually accustom yourself to working in hot conditions.
    a. Do short periods of light work for several days in a row
    b. Increase the amount of time working in protective gear each day
2. Schedule frequent breaks when risk of heat stress is high
3. Drink plenty of fluids before spraying
4. Choose protective equipment designed to be cool as possible.

J. Procedures after mixing, loading and application activities are finished

1. Post a warning sign in the area where you have sprayed
2. Wash your pesticide equipment before removing protective equipment
3. Return equipment to its designated place
4. Safely store or dispose of all pesticide materials and other chemicals that you have used
5. Remove protective equipment and wash yourself thoroughly
6. Be sure that your work site presents no hazards to people or to the environment
7. Make a record of what you have applied and the conditions at the application site

K. Proper care of rinses from equipment cleanup

1. Collect the rinsate

2. Reuse it or dispose of it as excess pesticide

L. Personal cleanup after handling pesticides

1. Wash the outside of your gloves before taking them off

2. Carefully peel back your personal protective equipment to avoid getting pesticides on your skin

3. Remove any other clothing that has pesticides on it

4. If possible, take a shower right away. Otherwise, use a mild detergent and warm water to wash your face, hands, forearms, and any other area that may have pesticides on it.

5. No later than the end of the work day, wash your whole body thoroughly with a mild liquid detergent and plenty of warm water.

M. Benefits of record keeping

1. Records can establish proof of good use.

2. Good records can save you money by improving your pest-control practices and your efficiency.

3. Records can help you reduce mistakes or misuse.

4. Records can reduce carry over by helping you to buy only the amount of pesticides that you will need.

Lecture 27
PESTICIDE POISONING

Introduction

According to the World Health Organization, in developing countries one person is poisoned by pesticides every minute. A pesticide-caused death occurs every hour and 45 minutes, totaling more than 5,000 deaths a year.

Pesticides can enter the body through the eyes, mouth, nose, and skin. Some pesticides are highly toxic to humans; only a small amount in the mouth or on the skin can cause extremely harmful effects. Other pesticides are less toxic, but too much exposure will cause harmful side effects. Poisoning can be detected by specific signs and symptoms. First aid procedures have been developed to treat pesticide exposures. This lesson will familiarize students with details on all of these subjects

Objectives

Upon completion of this lesson, students will be able to:

A. Name the four routes through which pesticides can enter the body.

B. Explain how exposure to a pesticide relates to its absorption, clearance, symptoms and effects.

C. Compare the degree of dermal absorption by different parts of body.

D. Describe five potential causes of dermal exposure and at least three preventative measures.

E. Explain five steps in first aid following dermal exposure.

F. Describe four potential causes of oral exposure and at least four preventative measures.

G. Explain six steps in first aid following dermal exposure.

H. Define the eleven terms provided below.

Terms

ABSORPTION - The process by which a pesticide is taken into a plant or animal following exposure.

ACUTE EFFECTS - Sickness, injury, or death that occurs immediately after exposure to a pesticide.

CHRONIC EFFECTS - Illnesses, injury, or death that occurs after a long time, usually several years, following exposure to a pesticide (i.e., tumors, cancer, birth defects, etc.).

CLEARANCE - The natural processes of eliminating a substance from a body after it has been absorbed or ingested.

DERMAL EXPOSURE - Exposure to pesticides through the skin.

PESTICIDE EXPOSURE - Direct contact by plants or animals with a pesticide that has potential for absorption.

INHALATION EXPOSURE - Exposure to pesticides by breathing a substance into the respiratory system.

OCULAR EXPOSURE - Exposure to pesticides through the eyes.

ORAL EXPOSURE - Exposure to pesticides through the mouth or by swallowing.

SIGN - Evidence of pesticide poisoning that is visible to another person (i.e., fainting, eye dilation, etc.).

SYMPTOMS - Evidence of pesticide poisoning that only the person who has been poisoned can notice (i.e., headache, stomach pain, etc).

Teaching Outline

A. PESTICIDE EXPOSURE

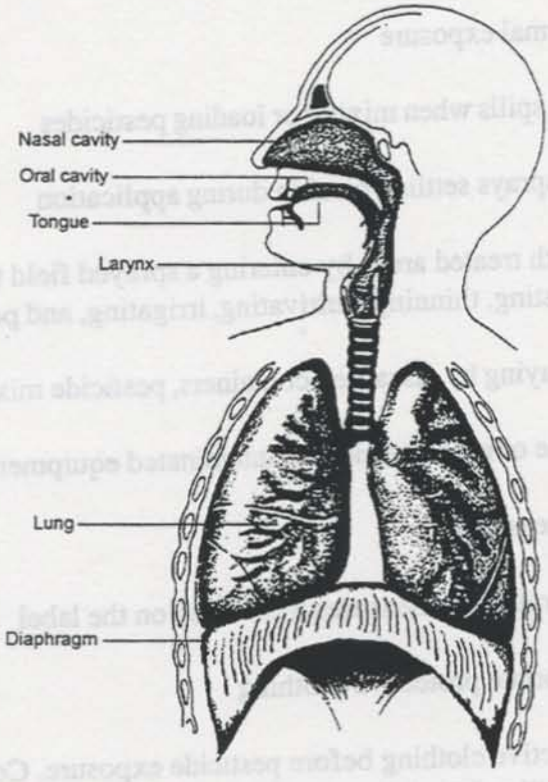
1. There are four routes of pesticide exposure

   a. DERMAL EXPOSURE

   b. ORAL EXPOSURE

   c. OCULAR EXPOSURE

   d. INHALATION EXPOSURE



The human respiratory system

2. Exposure results in ABSORPTION and CLEARANCE

   a. The amount of pesticide that can be absorbed is that which is not intercepted by clothing or other protective equipment.

   b. The rates of absorption and clearance are highly variable depending on the specific chemical substance.

3. Exposure is not an illness, but can result in ACUTE EFFECTS or CHRONIC EFFECTS.

4. Poisoning by exposure is identified by SIGNS and SYMPTOMS.

B. Dermal exposure

1. The most common way for pesticides to enter the body

2. Parts of the body differ in their rate and amount of absorption

   a. 35% Scalp
   b. 40% Forehead
   c. 50% Ear Canal
   d. 8% Forearm
   e. 10% Palm
   f. 20% Abdomen
   g. 99% Scrotum
   h 15% Foot

3. Causes of dermal exposure

   a. Accidental spills when mixing or loading pesticides

   b. Dusts and sprays settling on skin during application

   c. Contact with treated areas by entering a sprayed field too soon, i.e. hand harvesting, thinning, cultivating, irrigating, and pest scouting

   d. Children playing by discarded containers, pesticide mixes, or spill areas

   e. Maintenance or repair work on contaminated equipment

4. Preventative measures

   a. Follow all protective measures mentioned on the label

   b. Wear appropriate protective clothing

   c. Put on protective clothing before pesticide exposure. Covering up afterwards will only quicken absorption into the skin.

5. First aid following dermal exposure

   a. Drench skin and clothing with water

   b. Remove clothing

   c. Wash skin, hair, and nails thoroughly with soap and water. It is very important to start washing quickly to reduce the extent of injury.

   d. Dry the victim and wrap in blanket

   e. Call physician if exposure was severe or symptoms are present

C. Oral exposure

1. The most common route of exposure for children

2. Causes of oral exposure

   a. Dusts or liquid accidently entering the mouth when mixing or spraying

   b. Drinking pesticides accidentally from an unlabeled or contaminated container

   c. Eating contaminated food

   d. Eating or smoking with contaminated hands

3. Preventative measures

   a. Wear a full face shield or mask when mixing and spraying pesticides

   b. Never eat or drink when mixing or spraying

   c. Do not wipe mouth with hands, forearm, or clothing

   d. Wash thoroughly with soap and water imediately after spraying

4. First aid following oral exposure

   a. Call a physician immediately

   b. Bring the pesticide label to the phone to describe the "statement of practical treatment" and/or antidote to the poison

   c. If you must take the victim to the hospital take the container with you, but don't carry it in the passenger compartment of the vehicle

   d. Keep the victim warm, calm, and moving as little as possible

   e. Do not induce vomiting if:

      i. Patient is in a coma or unconscious

      ii. Patient is in convulsions

      iii. Patient has swallowed petroleum products such as kerosene, gasoline, or lighter fluid

      iv. Patient has swallowed a corrosive poison (strong alkaline or acid product), or symptoms include a burning sensation in the mouth or throat

f. If patient can swallow after ingesting a corrosive poison, give the following substances by mouth:

i. For acid poisons: Milk, water, or milk of magnesia; one tablespoon to one cup of water.

ii. For alkaline poisons: Milk or water. For patients 1-5 years old, 1-2 cups. For patients 5 years and older, up to one quart.

D. Signs and symptoms

1. It's important to know what to look for in case you or your co-workers are exposed.

2. The acute effects may be mild or severe depending on:

a. Type of chemical

b. Amount absorbed

3. Indications of mild pesticide exposure

a. General: weakness, headache, and fatigue

b. Dermal: skin irritation, burning, heavy sweating

c. Oral: nausea, vomiting, stomach cramps, burning in mouth and throat

d. Inhalation: cough, difficulty breathing, chest tightness and pain

e. Ocular: itching, burning and/or watering eyes

f. Nervous system: dizziness, blurred vision, confusion, muscle twitching

Reading Assignment

Applying Pesticides Correctly, University of Hawai'i CES, pp. 28-31.

Instructor Reference

1. *Applying Pesticides Correctly*, University of Hawai'i CES, pp.28-31.
2. *Entomology and Pest Management,* by Larry P. Pedigo. pp.399-405.

Lecture 28
PESTICIDES IN THE ECOSYSTEM

Introduction

The ecosystem includes all the living and non-living things in a given area. It includes not only the natural elements but also people and the man-made components of our world. It is the air, soil, water, plants, animals, houses, restaurants, office buildings, factories, and all they contain. Anyone who uses a pesticide, indoors or outdoors, in a city or in the country, must consider how that pesticide will affect the parts of the surrounding ecosystem. This lesson will discuss the potential for ecosystem contamination by pesticides and ways that it may be prevented.

Objectives

Upon completion of this lesson, students will be able to:

A. Distinguish between point sources and non-point sources of contamination by pesticides.

B. Describe five ways pesticides can move in the environment.

C. Explain four major factors that affect groundwater contamination by pesticides.

D. Explain two major factors that affect ecosystem contamination by pesticide drift.

E. Describe at least six applicator practices that may contribute to ecosystem contamination.

F. Describe six problems that result from ecosystem contamination by pesticides.

G. Define the eleven terms provided below.

Terms

BIOMAGNIFICTION - The increased concentration of a pesticide in animal tissue related to that organisms level in the food chain.

CARRYOVER - Accumulation or persistence of pesticide in soil from one cropping period to the next.

DRIFT - Pesticide spray blown through the air that can affect organisms other than the intended pest.

GROUNDWATER - Water that fills the pores of material underlying the water table.

LEACHING - The downward movement through the soil of a chemical or nutrient carried by water.

NON-POINT-SOURCE POLLUTION - Contamination originating from a wide area rather than a single identifiable location.

NONTARGET ORGANISMS - Living things that are not intended to be controlled, injured, killed, or affected in any way by an applied pesticide.

RESIDUES - Any amount of chemical remaining on or in crops or animals that were treated with pesticides.

RUNOFF - The movement of soil, chemicals, or nutrients carried by the flow of surface water.

PERSISTENT - A material that does not break down quickly under normal environmental conditions.

POINT-SOURCE POLLUTION - Contamination originating from a specific, identifiable location.

Teaching Outline

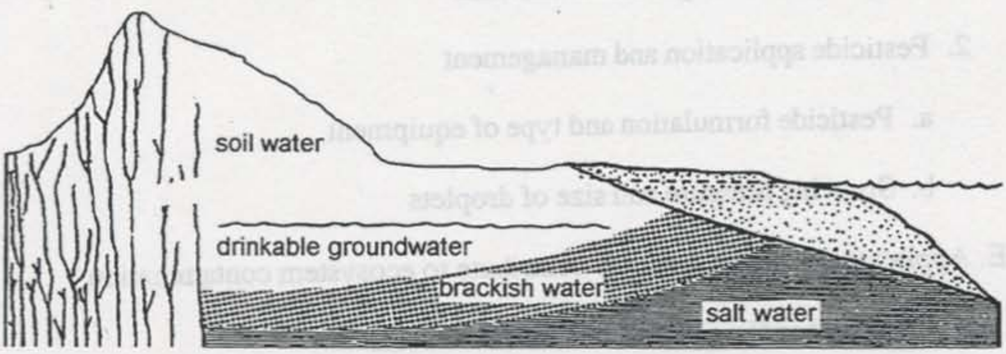
A. Ecosystem contamination

1. POINT SOURCE POLLUTION: e.g., a pesticide spill that moves into a sewer

2. NON-POINT-SOURCE POLLUTION: e.g., movement of pesticides from a crop field into a stream

B. How pesticides move in the environment

1. DRIFT from sprays with droplet size of less than 100 microns
2. Non-drift airborne movement
3. RESIDUES
4. RUNOFF
5. LEACHING .



Relationships of land and water on a high island

C. Major factors affecting GROUNDWATER contamination by pesticides

1. Properties of soil

   a. Soil texture; coarse, sand and gravel soils allow quick drainage

   b. Organic matter; will hold chemicals and nutrients longer

   c. Subsurface drainage

2. Conditions at the site

   a. Depth from surface to groundwater

   b. High rainfall or extensive irrigation

   c. Steepness of slopes will increase the amount of runoff

3. Properties of the pesticides

a. High solubility

b. Poor binding to soil

c. PERSISTENCE

4. Pesticide application and management

a. Injection or soil incorporation

b. Poor timing: heavy rain or irrigation immediately after application

D. Major factors affecting ecosystem contamination by drifting pesticides

1. Environmental conditions

a. Wind speed and direction

b. Patterns of air movement: daily changes and seasonal trade winds

c. Valleys, buildings, and windbreaks

2. Pesticide application and management

a. Pesticide formulation and type of equipment

b. Spraying pressure and size of droplets

E. Applicator practices that may contribute to ecosystem contamination

1. Careless handling of concentrated chemicals

2. Using pesticides in ways not approved on the label

3. Application to areas along ditches and streams

4. Backflow contamination of main water line

a. When filling sprayer tank

b. When applying pesticides in irrigation water

5. Improper care of leaking containers

6. Improper disposal

a. Containers

b. Excess spray mix

c. Rinsate from cleaning equipment

F. Problems resulting from ecosystem contamination by pesticides

1. Direct kill of nontarget organisms

   a. In the target area

   b. Off site of target area

   c. Label warnings

      i. Bees and other beneficial insects

      ii. Birds

      iii. Fish

2. Secondary poisoning

   a. Birds

   b. Predators of poisoned rodents

3. Pesticide residues

   a. Legal application rate and waiting period

   b. Over application and illegal uses

   c. Food plants and by-products

   d. Feed and forage plants

   e. Animal products: meat, milk, eggs

   f. Ornamental plants

4. BIOMAGNIFICTION

5. Pest resistance

   a. Insects

   b. Plants

   c. Pathogens

6. CARRYOVER

   a. Phytotoxicity symptoms in the following crop cycle

   b. Illegal residues in the crops grown next

7. Direct chemical damage to crops

a. Lethal vs. nonlethal dosage

b. Symptoms of herbicides damage vary widely

i. Malformed leaves

ii. Discolored leaves; regular and irregular patterns

iii. Leaf and fruit drop

iv. Stunted growth

v. Don't confuse these symptoms with pest damage or the effects of adverse environmental conditions

c. Causes

i. Plants cannot tolerate the pesticide active ingredient or solvent

ii. Spray mixture too concentrated

iii. Pesticide used on immature plants

iv. Plants stress caused by pests, or lack of water or nutrients

v. Air temperature and humidity too high at time of application

vi. An incompatible mixture of pesticides (and/or adjuvants)

Reading Assignment

Applying Pesticides Correctly, University of Hawai'i CES, pp. 33-34

Instructor Reference

Plant Pathology, by George N. Agrios, pp.381-383, and 527-542.

Lecture 29

PESTICIDE LAWS AND REGULATIONS

Introduction

Many pesticides can have extremely negative effects if not handled and applied properly. Careless handling or misuse of pesticides have resulted in crop loss, property damage, surface and groundwater contamination, worker and applicator poisonings, as well as kills of fish, wildlife and beneficial insects. Nearly all of these incidents could have been avoided if applicators were properly trained and careful about pesticide use.

International, national, and local governments have adopted codes of conduct or enacted laws and regulations to insure that pesticides are used by people trained in the correct procedures. The primary purpose of these regulations is to protect human life and the ecosystems we live in. This lesson will review a range of pesticide laws and regulations focusing on those that apply in the U.S. affiliated Pacific islands.

Objectives

Upon completion of this lesson, students will be able to:

A. Distinguish between a code of conduct, law, and regulation.

B. Explain the general purposes of the UNFAO International Code of Conduct on the Distribution and Use of Pesticides.

C. Describe a brief history of U. S. national laws related to pesticides enacted between 1910 and 1972.

D. Explain the role of the EPA and the 1972 amendment to FIFRA.

E. Describe local laws and regulations regarding pesticide use.

F. Define the eight terms provided below.

Terms

CUMULATIVE PESTICIDES - Pesticides that concentrate in an organism and cause chronic effects once a certain level is reached.

USEPA - United States Environmental Protection Agency.

FDCA - Food, Drug, and Cosmetic Act.

FIFRA - Federal Insecticide, Fungicide, and Rodenticide Act.

GENERAL USE PESTICIDE - Pesticides that the general public can use without being certified.

RESTRICTED-USE PESTICIDE - Pesticides that may only be sold to certified applicators and must only be used by those applicators or by persons working under their direct supervision.

TOLERANCE - The maximum amount of a pesticide that may remain on a raw agricultural commodity.

UNFAO - United Nations Food and Agriculture Organization.

Teaching Outline

A. Codes of conduct, laws, and regulations

1. Codes of conduct are voluntary standards established by an institution or agency charged with the protection or oversight of others.

2. Laws are enacted by nations, states, territories and commonwealths as a requirement to be followed in areas under their jurisdiction.

3. Regulations describe how laws are to be interpreted and enforced.

B. International

1. UNFAO adopted the International Code of Conduct on the Distribution and Use of Pesticides in 1985.

2. Describes the shared responsibilities of national governments, international regions, private industry and public institutions to derive benefits from the necessary and acceptable use of pesticides while preventing adverse effects.

3. Addresses the need for a cooperative effort between governments of exporting and importing countries to promote practices that ensure safe use while minimizing health and environmental concerns.

C. United States national laws

1. Federal Insecticide Act (1910) protected farmers from substandard or fraudulent products.

2. Pure Food and Drug Act was amended in 1938 to forbid the presence of harmful residues of pesticides on food.

3. FIFRA (1947) replaced the Federal Insecticide Act by increasing the types of pesticides covered and requiring their approval by USDA.

   a. Required labeling (amended to be more specific in 1964)

   b. Burden of proof on the manufacturer prior to marketing a new product

4. The Miller Pesticide Amendment (1954) to the Federal Food, Drug and Cosmetic Act (FDCA) formalized TOLERANCE setting procedures.

   a. TOLERANCE is usually measured in parts per million or ppm.

      i. Persistent pesticides

      ii. CUMULATIVE PESTICIDES

   b. As a matter of policy, the USDA registered only pesticide uses that would result in no residue or residue levels declared safe by USDA.

5. A 1958 amendment to the FDCA included the Delaney Clause which prohibits any residue of cancer causing chemicals.

6. The EPA was created in 1970 and regulates pesticide usage through the 1972 amended FIFRA (also known as the Federal Environmental Pesticide Control Act of 1972).

   a. Requires pesticides to be classified according to their potential hazard.

      i. GENERAL USE PESTICIDES

      ii. RESTRICTED USE PESTICIDES

   b. Restricted-use pesticides applicators must be certified through a process approved by the EPA.

7. Other important US laws involving pesticide use

   a. Worker Protection Standard

   b. Endangered Species Act

   c. Clean Water Act

D. Local Laws and Regulation within the U.S. affiliated Pacific islands

1. Must follow all national laws but may strengthen related regulations and policies.

2. May enact additional local laws. Examples include:

   a. Hawai'i Pesticides Law (1974) identifies the state Department of Agriculture for pesticide certification and law enforcement.

   b. American Samoa Pesticide Act (1979) makes the local EPA responsible for certification and enforcement of laws.

3. In Hawai'i and American Samoa, the Cooperative Extension Service conducts pesticide applicator certification training programs.

Reading Assignment

Applying Pesticides Correctly, University of Hawai'i CES, pp. 48-50

Instructor Reference

Entomology and Pest Management, Larry P. Pedigo, pp. 405-412.

VII. INSTRUCTOR REFERENCES and STUDENT READINGS

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Crop Protection for Pacific Islands
Information Sheet 1 : HISTORICAL PERSPECTIVE

Traditional Agriculture

Traditional forms of agriculture rely on a variety of pest control techniques that differ for each region and crop. Many traditional farming practices help control pests even when it is not the main purpose of the activity. For example, burning, mulching, or letting the land lie fallow all reduce weed problems.

The traditional practices of growing sweet potatoes in Yap, are a good specific example. Farmers there plant sweet potatoes in raised beds. After harvesting they allow pigs to forage in the area, then they bury the beds under a deep layer of soil and organic matter. This traditional treatment gets rid of the remaining sweet potatoes and bits of stem which carry sweet potato weevils from one crop to the next.

Changes in Pacific Island Agriculture

Traditional farmers before the 1900's rarely worried about pests other than weeds. However, agriculture in the Pacific islands has changed dramatically during this century. Today's farmers, particularly those who grow crops for sale, find that disease and insect control are very important parts of their agricultural operation. One reason for this change has been the introduction of new crops. Another reason is that increased transportation in the Pacific region has introduced pests which cause problems with both traditional crops and new crops.

Many types of vegetable plants have been introduced. These are highly marketable crops but traditional practices for growing them do not exist. The crops originate in temperate overseas locations where there are fewer pest problems. When planted in the Pacific islands, they become susceptible to the year-round insect and disease problems of the tropics.

In adopting non-traditional farming techniques, many farmers adopt the "modern" solutions to pest control. This includes the use of insecticides, fungicides, and herbicides. These practices have some positive effects but they also cause problems which can be avoided by considering the whole farming system. Some reasons for using pesticides and negative consequences of their misuse are described in more detail below.

Reasons for Using Insecticides

1. Quick kill: Insecticides are attractive solutions because they promise quick results. Apply the pesticide and the pest is killed immediately.

2. Versatility: There are pesticides that can control almost any pest problem. Some of the problems cannot be controlled easily with any other method.

3. Reduced labor: One farmer using pesticides can often control the pest problems that would require many people to accomplish with traditional methods.

Negative Consequences of Pesticide Misuse

The following conditions can result from over-reliance and overuse of pesticides:

1. Resistance: Intense insecticide use increases the risk of an insect population becoming resistant to that insecticide. Over 500 insect species are resistant to at least one insecticide. Diamondback moths and serpentine leaf miners are resistant to most insecticides on the market. They can develop a resistance to new products within one crop cycle.

   Resistance is also a problem with disease control. Among plant pathogens, banana leaf streak is well known for rapidly becoming resistant to new products.

   The time and labor, or machinery required for tillage and other weed clearing operations sometimes makes herbicides the most cost-effective control method. Relying on a single type of weed control, whether it be tillage or herbicides, can result in a resistant weed community. Susceptible weeds are eliminated but the remaining ones increase in number. After some years, a field may become unusable because the weeds are so dense.

2. Pest Resurgence: Insecticides almost always kill a wide variety of insects. They often kill the predators and parasites of the pests as readily as the pests themselves. If most of the targeted pests are killed, the remaining predators will go elsewhere for food. Since no pesticide application is 100% effective, the surviving pests begin to multiply rapidly.
3. Secondary Pests: Some insects are known pests. Others can become pests if they are abundant but their natural predators and parasites keep their numbers down. Insecticides may kill their natural enemies resulting in the appearance of a secondary pest which now requires control. The new pest is probably resistant to the insecticide so it is more difficult to control than the original pest. This situation has been observed with serpentine leaf miners and melon thrips in melon plantings on Hawaii and other islands. Fungicides and herbicides can cause similar problems.

4. Contamination: Pesticides can add impurities to living and nonliving things in the ecosystem. This was a serious problem several decades ago when there was widespread use of persistent insecticides like DDT. Modern insecticides break down more readily but their use can still cause contamination. Some of the most serious cases occur when pesticides enter the groundwater. Exposure to pesticides by humans is another form of contamination. In the tropics, pesticide applicators sometimes refuse to wear their protective gear because it is hot and uncomfortable. This is an example of the improper safety practices that increase the chances of being poisoned.

Conclusion

Changes in Pacific island agriculture have increased pest problems. Pesticides are useful products that can help control these problems. To avoid the overuse of pesticides a variety of control methods are required. Integrated Pest Management (IPM) promotes the wise use of pesticides as a last alternative to other practical, economical, non-chemical pest control methods.

Crop Protection for Pacific Islands
Information Sheet 2 : ECOLOGICAL FOUNDATIONS

Background Concepts

Individual organisms of a species live together in groups called populations. The populations occupying an area form a community which is influenced in various ways by the physical environment. An ecosystem is all of the living and nonliving things in a given area that operate together through interaction and interdependence, forming a single unit. Any area of convenient size may be considered an ecosystem; a forest, a stream, or an agricultural field. Agroecosystems are ecosystems in which agricultural crops play an important part. They range from the vast wheat monocultures of the mainland United States to agroforestry systems on Pacific islands where crops and the forest are mixed together.

Properties of Life Observed at the Ecosystem Level

1. Movement of Energy: The sun provides energy which is captured by plants. Plants use solar energy, water, and carbon dioxide to create carbohydrates through photosynthesis. Carbohydrates provide energy for the non-photosynthetic organisms in the ecosystem. These organisms include people, animals and many microorganisms that consume plants. Plant consuming organisms are often eaten by other organisms that may in turn be eaten by another higher level consumer. In this way energy flows through the ecosystem on a one way trip. In the process it is transformed into heat which is not an energy source that organisms can use to sustain life. At some point there is not enough energy remaining to support another level of consumers.

2. Cycling of Elements: Chemical elements such as nitrogen, phosphorus, and potassium cycle through ecosystems. They are released from rocks or organisms, absorbed by plants, and made into proteins, vitamins, and other nutrients. When organisms eat the plants, these elements continue moving through the ecosystem by the processes of digestion, excretion, and decomposition which return them to the soil to be reabsorbed by plants. Soil erosion and leaching can move elements to new locations. Agricultural practices can also move these substances between different ecosystems. When crops are harvested they are often taken to a new location. Fertilizers and pesticides are common additions to the element cycle in agroecosystems. The man-made materials enter into the natural cycling of elements and end up in areas where they were not originally found.

3. Food Webs: A food chain shows how energy (and elements) are transferred from plants through a series of organisms. A food web is the interconnection of many food chains in a biotic community. Portions of an ecosystem can be diagrammed by food webs. They show the feeding relationships among various members of the ecosystem.

4. Pest Management in Agroecosystems: All living organisms in an ecosystem are connected to each other through feeding and other relationships. Farming practices such as pest management affect the community structure of an agroecosystem. Changes in practices may have unexpected results. Failure to consider the dynamics of the whole system can lead to negative consequences.

Properties of Life Observed at the Community Level

Community interactions include any process involving two or more types of organisms. Some of these processes are very important in pest management.

1. Herbivory: Herbivores affect the plants they feed on. By removing resources from the plant, herbivores prevent the plant from developing properly or producing as much fruit. The relationships between herbivores and the plants they eat are often complex.

2. Predation/Parasitism: These are two consumer relationships in food chains. The consumer is often the prey of another organism. These relationships keep plant eating organisms such as insects, nematodes, and rats from becoming too numerous.

3. Competition: This interaction occurs when two or more organisms require the same limited resource(s). For example, the relationship between crops and weeds is competitive. They both strive to obtain all the light, water, and nutrients needed for maximum growth. The weaker competitor may not grow as well. Crops that are bred for taste and high yield can lose their ability to compete effectively with other plants.

   Proper management of the pests and diseases that compete with crops requires a detailed understanding of food webs in the agroecosystem. Adding or removing a species often creates unintended damage. Removal of predators can create uncontrollable outbreaks of insects and diseases. Introduced predators without any natural controls can become pest problems themselves.

4. Ecological Succession: This is the natural process of changes in the numbers and types of species within an ecosystem over time. When an area is cleared of vegetation, plants move in to use the available resources. If the area remains undisturbed, species of plants will gradually replace each other until the community resembles what was there before the clearing occurred. Succession can be affected by agricultural practices such as pest control. For example, tillage and/or herbicides may lead to alternate plant communities including weed species more resistant to the control practices.

   Succession is managed in agroecosystems to varying degrees depending on the type of farming system. A multi-crop agroforestry system contains a large degree of the diversity and stability found in a natural ecosystem and requires only a limited management of succession. A monoculture system that aims to produce a single crop species creates a very unstable community. Succession must be highly managed to control pests and provide the inputs needed by the target species.

Properties of Life Observed at the Population Level

1. Population Growth and Regulation: A combination of additive and subtractive factors affect species populations. The balance between these factors determines the total number of organisms present. Additive factors promote births, immigration, high fecundity, long life, and generally add to population size. Subtractive factors may increase deaths or emigration, lower fecundity, or shorten life expectancy; reducing the size of a population.

Subtractive factors can be density dependent or density independent. Density dependent factors respond to population size, either increasing or decreasing in effect as the population grows. For example, disease usually claims a greater percentage of victims as the population grows more dense. Density independent factors, such as predation, exert a constant force on a population. They can also vary independently of target population density. For example, typhoons and hurricanes have density independent effects on plant and animal populations.

2. Population Variability: Populations are composed of individuals that each carry a unique set of genes. Some organisms reproduce asexually in which case the population consists of groups of organisms with the same genetic background. Sexual reproduction results in genetic recombination with the opportunity for mutations and increased variability. The variability of a population influences the pest potential of certain organisms. For example, some weed species have seeds that vary in their ability to germinate over time. This results in "seed banks" in the soil. In these species, some seeds may continue to sprout every time the soil is tilled for many years after the adult plants have been removed.

   Variability is also evident when a population is exposed to a mortality factor such as a pesticide. Differences in how the individuals respond to that factor provide the basis for evolutionary changes. Pests may develop a tolerance to pesticides that previously controlled them. Plant pathogens may overcome the resistance in a strain of plants bred to be resistant to that particular disease.

Properties of Life Observed at the Individual Level

1. Growth Rates: The growth rate of individuals is important in pest management. Most often one is interested in the growth of the crop plant. However weeds can also become very large and individual large weeds may decrease yields without being part of a pest population. Growth rates of individuals are influenced by the supply of light, water, nutrients, and the presence of parasites or other debilitating factors.

2. Climatic Adaptations: Determining the climate suitable for an organism is generally done by measuring the response of individuals to various physical factors. Climatic adaptation may include the tendency towards dormancy, soil and water requirements, needs for specific daylength or temperature to set seed, and so on. In determining the pest potential of a given species, it is necessary to know about its climatic adaptations.

3. Learning: For vertebrates learning is an important part of how they deal with the world. With larger vertebrates, individual animals rather than populations are likely to be pests. Their management must be carried out on a case by case basis. Even smaller vertebrates such as rats may learn bait avoidance which influences how they will be managed.

APPLY PESTICIDES CORRECTLY

Cooperative Extension Service

College of Tropical Agriculture
and Human Resources

University of Hawaii

Other Study Material for Hawaii

This manual contains general information about using pesticides correctly. Other (supplemental) study materials contain specific information for Hawaii. Usually, they are given to you along with this manual. Make sure you have them.

ACKNOWLEDGEMENT: This manual was prepared by reprinting the major portion of a University of Georgia guide, *Apply Pesticides Correctly* (Special Bulletin 15, September 1981) which was prepared by Emmett D. Harris, Jr., Extension Entomologist & Pesticide Chemical Coordinator, Cooperative Extension Service, University of Georgia, College of Agriculture.

The section of the text describing Georgia State laws and regulations was left out. The Table of Contents was edited to reflect the deletion. Page numbers following the deleted section were changed to preserve continuity.

DISCLAIMER

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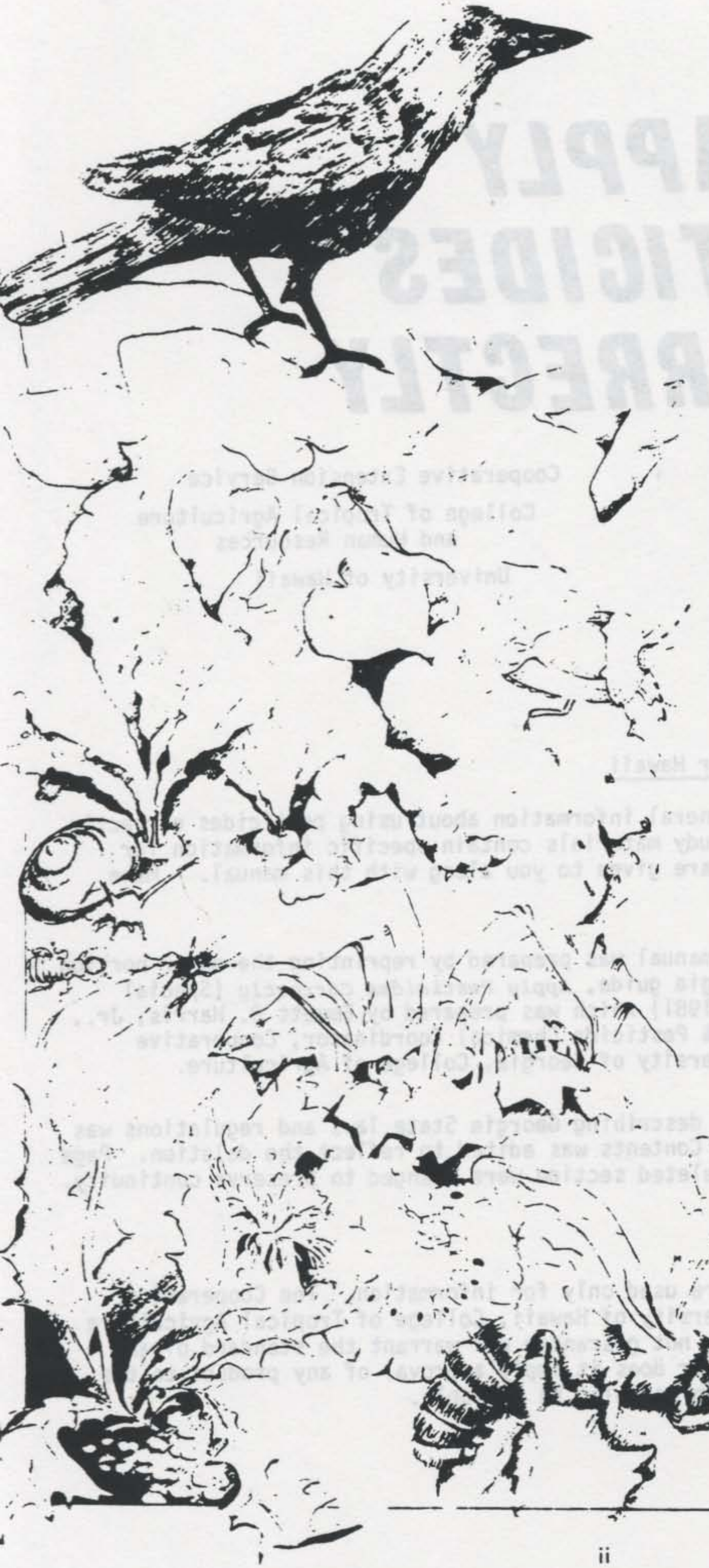


PREFACE

This manual will partially prepare you to meet U.S. Environmental Protection Agency and State requirements for Certified Pesticide Applicators. If you are to be certified as a Commercial Pesticide Applicator, you must also study a companion manual in each category of pest control in which you will apply Restricted Use pesticides.

Restricted Use pesticides can be used only by or under the supervision of Certified Applicators. Certain pesticides have been classified for Restricted Use because they are extremely hazardous to man and/or the environment. As restricted use classification is actually an alternative to the denial or cancellation of registration, misuse of these pesticides could result in their being banned. In some instances, the misuse of a Restricted Use pesticide will involve greater penalties than those associated with other pesticides.

However, all pesticides are potentially hazardous and none should be misused or used carelessly. In fact EPA has not yet gotten around to classifying many pesticides that eventually will be classified for restricted use only.

APPLY PESTICIDES CORRECTLY

A Guide for Commercial Applicators

Prepared by:

Emmett D. Harris, Jr.
Extension Entomologist & Pesticide Chemicals Coordinator
Cooperative Extension Service
The University of Georgia College of Agriculture

CONTENTS

ACKNOWLEDGMENTS

The present guide was prepared by adapting and expanding a guide of the same title which was developed by The Pesticides Operations Division, U.S. Environmental Protection Agency and the Extension Service, U.S. Department of Agriculture under the editorship of Gerald T. Weekman, North Carolina State University.

Mr. J.R. Conley, Georgia Department of Agriculture, and the members of the Georgia Pesticide Applicators Training Steering Committee (PATSC) reviewed the manuscript and made many valuable suggestions: PATSC members are Thomas J. Delaney, Georgia Department of Agriculture and Walter C. Hammond, Norman E. McGlohon, James F. Miller, Ralph E. Motsinger, Charles W. Swann and Herbert Womack, The University of Georgia Cooperative Extension Service. PATSC chairman Dr. Burton R. Evans, The University of Georgia Cooperative Extension Service, deserves special recognition for many valuable suggestions, coordination and guidance in preparation of this manual.

INTRODUCTION

Federal regulations set general and specific standards that you must meet before you can use certain pesticides. This guide contains basic information to help you meet the *general* standards. Because the guide is for use by all categories of applicators, some parts of it may not concern you. The guide does not include the things you need to know to meet *specific* standards required for your job by federal regulations or state law. Your State Pesticide Regulatory Agency and your Cooperative Extension Service can give you this additional information.

This guide will tell you:

- the most common features of pests, how they develop, and the kinds of damage they do,
- methods you can use to control pests and how to combine these methods for the best results,
- how pesticides work,
- how pesticide labels can help you,
- how to use pesticides so they will not harm you or the environment,
- how to choose, use, and care for equipment, and
- the federal and state laws that apply to the things you do on the job.

The test for certification will be based on:

- general information, and
- problems and situations that occur in the specific kinds of pest control jobs you do.

You will have to show that you know:

- the pests you control, and
- how to use the pesticides and application equipment needed in your job.

PESTS

The first step in solving any problem is to understand what is causing it. So the first step in your job is to recognize the pests you need to control.

We favor certain plants and animals that provide us food and fiber. But we also provide good growing conditions for other plants and animals that harm them. These living things that compete with us for food and fiber, or attack us directly are *pests*. The living plant or animal a pest depends on for survival is called the *host*.

Pests can be put into five main groups:

- insects (plus mites, ticks, and spiders),
- snails and slugs,
- vertebrates,
- weeds, and
- plant disease agents.

Most applicators know most of the pests they see on the job. But sometimes unfamiliar pests may appear. You can get identification aids, publications, and pictures to help find out what they are, but the best thing to do is to contact local experts. Ask the Cooperative Extension Service or a competent consultant to help you.

INSECTS

Insects thrive in more environments than any other group of animals. They live not only on the earth's surface but within the soil and in water. They are at home in deserts, rain forests, hot springs, snow fields, and dark caves. They eat the choicest foods on man's table. They can even eat the table.

Many types of insects affect crops. They cause damage in a variety of ways. They may:

- feed on leaves,
- tunnel or bore in stems, stalks, and branches,
- feed on and tunnel in roots,
- feed on and in seeds and nuts,
- suck the sap from leaves, stems, roots, fruits, and flowers and
- carry plant disease agents.

The plants are damaged, weakened, or killed. This causes reduced yields, lowered quality, and ugly plants or plant products that cannot be sold. Even after harvest, insects continue their damage in the stored or processed products. Insects also feed on and in man and other animals. Some of these pests carry disease agents which have caused millions of deaths to man and livestock.

Most insects are not pests. Some help man by doing such things as pollinating plants or feeding on other insects that are pests. Essentially all insects are important food sources for other animals.

RECOGNIZING COMMON FEATURES OF INSECTS

All adult insects have two things in common—they have six jointed legs and three body regions. But how do you tell one insect from another? The most important parts to look at are *wings* and *mouthparts*. Some insects have no wings; others have two or four. The wings vary in shape, size, thickness, and structure. Insects with chewing mouthparts have toothed jaws that bite and tear the food. Insects with piercing-sucking mouthparts have a long beak which they force into a plant or animal to suck out fluids or blood.

Almost all insects change in shape, form, and size during their lives. This change is called *metamorphosis*. Distinct shapes and forms are called *stages*.

An insect's skin also serves as its skeleton. It is an *exoskeleton*. The exoskeleton will only stretch so much so the developing insect must shed it periodically in order to grow larger. This shedding is called a *molt*. The interval prior to the first molt or between two molts is an *instar*. The instar number is used to describe an immature insect's age.

Some insects change only in size as they develop. They have *no metamorphosis*. The adult lays *eggs*. A *nymph* which looks like a tiny *adult* hatches from the egg and goes through several instars. These nymphs change into wingless adults.

Some insects change form slightly. They have *gradual metamorphosis*. Their nymphs hatch from *eggs*. These *nymphs*, which have no wings, go through several instars. They change into winged *adults*.

Other insects change completely. They have *complete metamorphosis*. They go through four stages. The *larva* hatches from an *egg*. It is a worm, caterpillar, grub, or maggot. This is the stage in which these insects feed the most and grow. When full-grown, the larger larva changes into a *pupa*. During this stage it changes into the *adult*. The adult stage usually has wings.

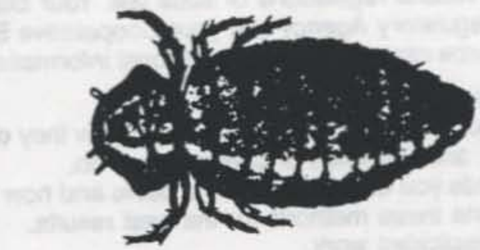
Here are the insect groups that include most of the insects which man considers pests. You should be familiar with the characteristics of each group that you control and the type of damage each group does.

BRISTLETAILS

- No wings.
- Chewing mouthparts.
- Usually have two or three long tails.
- Young and adult look alike (no metamorphosis) Adults about ½ inch long.
- Usually found in houses, libraries and other buildings.
- Feed on all starches including sized fabric and paper. They frequently damage bookbindings and wallpaper.
- Silverfish and firebrats belong in this group.

CHEWING LICE

- No wings.
- Chewing mouthparts.
- Broad head.
- Young and adult look alike (no metamorphosis). Adults less than ¼ inch long.
- Usually found on birds. They cause skin irritation and reduced weight gain and egg production.

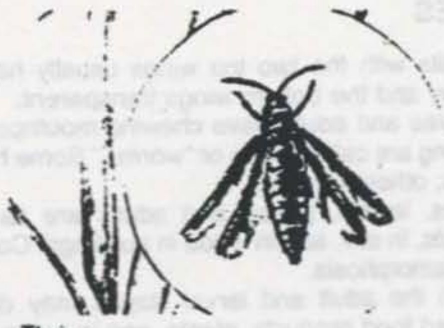


SUCKING LICE

- No wings.
- Piercing-sucking mouthparts.
- Narrow head.
- Young and adults look alike (no metamorphosis). Adults less than ¼ inch long.
- Some feed on livestock.
- Some carry disease agents.
- Their bites may be painful and cause itching.
- Human body, head, and pubic (crab) lice belong in this group.

THRIPS

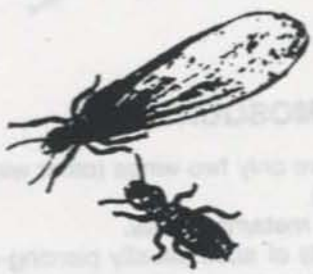
- Some adults have four narrow, fringed wings; others have no wings.
- Combination of chewing (rasping) and sucking mouthparts.
- Young and adults similar (gradual metamorphosis). Adults rarely longer than ¼ inch.
- Usually found in flowers or buds of plants.
- May cause speckled, misshapen or poorly developed flowers, buds, fruits, and leaves.



Thrips

TERMITES

- Swarming termites have four wings of equal size, other adults and the nymphs are white and have no wings.
- Chewing mouthparts.
- Young and adults similar (gradual metamorphosis). Adults usually less than ½ inch long.
- Usually feed on wood products such as fence posts, timbers, and flooring.
- Damage to the wood in homes and other structures is common.



GRASSHOPPERS, CRICKETS, AND COCKROACHES

- Some adults have wings; some do not have fully developed wings. Top pair of wings is leathery.
- Chewing mouthparts.
- Young and adults similar (gradual metamorphosis). Adults ½ to 2 inches long.
- Grasshoppers usually feed on plant leaves and stems.
- Crickets are found in the field or indoors. They feed on plants and occasionally almost anything made from plants.
- Cockroaches often occur in restaurants, houses, stores, and offices. They are scavengers, feeding on a large variety of foods.

BUGS

- Some adults have wings; some do not. Top pair of wings is part leathery and part transparent. These are the only true bugs.
- Piercing-sucking mouthparts.
- Young and adults similar (gradual metamorphosis).
- Suck the juice from plants and blood from man and animals.
- Reduce the vitality and yield of plants and animals, and may carry plant and animal disease agents.
- Bed bugs, stink bugs and chinch bugs are in this group.

APHIDS, LEAFHOPPERS, SPITTLEBUGS, WHITEFLIES AND SCALE INSECTS

- Some adults have wings; some do not.
- Piercing-sucking mouthparts.
- Young of aphids, leafhoppers, and spittlebugs are similar to adults (gradual metamorphosis).
- Nymphs and adult female scale insects are scale-covered and stay in one place on the plant. Adult males have wings.
- Adult whiteflies are tiny moth-like insects. Nymphs are flat, oval and stationary.
- Suck the juices from plants.
- Reduce the vitality and yield of plants.
- Some carry plant disease agents.
- Many secrete honeydew, a syrupy substance that attracts ants and supports sooty mold.

MOTHS AND BUTTERFLIES

- Most adults have four large wings with many scales that rub off easily.

- Most moths are dull brown and active at night. Most butterflies are brightly colored and active by day.
- Mouthparts of adults are lacking or are a coiled tube used for sucking.
- Four distinct stages: egg, larva, pupa and adult (complete metamorphosis).
- Larvae are caterpillars, usually with six jointed legs and ten soft, fleshy legs. Often called "worms," but they are not true worms.
- Larvae have chewing mouthparts.
- Larval stages are important pests of many plant and animal products as well as many crops. They damage leaves, stems, tubers, fruits, grains and fabrics.
- Clothes moths, peachtree borers, armyworms and eastern tent caterpillars are in this group.

FLEAS

- Adults are small (1/16 to 1/8 inch long), brownish-black, hard bodied, wingless insects that jump.
- Body with many spines and flattened from side to side.
- Adults have piercing-sucking mouthparts; larvae have chewing mouthparts.
- Adults suck blood of warm-blooded animals, larvae live on ground, in floor cracks, bedding or carpets and feed on dead skin that drops from the animal.
- Complete metamorphosis.
- Adults can be very irritating to animals or man and also spread diseases such as bubonic plague and murine typhus.

BEETLES

- Adults with the two top wings usually hard and shiny and the bottom wings transparent.
- Larvae and adults have chewing mouthparts.
- Young are called grubs or "worms." Some have no legs; others have six.
- Eggs, larvae, pupae and adults are found on plants, in soil, and in wood in buildings. Complete metamorphosis.
- Both the adult and larval stages may damage stored food products, plants, and in some cases, animals and animal products.
- Japanese beetles, wireworms, white grubs, shothole borers and carpet beetles are in this group.

FLIES AND MOSQUITOES

- Adults have only two wings (other winged insects have four).
- Complete metamorphosis.
- Mouthparts of adult usually piercing-sucking, but may be sponging, rasping, or chewing.
- Young (except mosquitoes) are maggots.
- Heads of maggots usually not well-defined; mouthparts are usually small, dark, and hooklike.
- Young mosquitoes live in water. They have a well-developed head with chewing mouthparts. They are often called wrigglers.
- Maggots usually feed on plant seedlings and roots, in organic matter, in water, and in other damp places.
- Some maggots feed on animals.
- Some adults spread diseases such as encephalitis and malaria.
- Some flies or mosquitoes in large numbers reduce the production efficiency of animals.
- Mosquitoes, house flies, seed corn maggots and horse flies belong to this group.

BEES, WASPS, ANTS, AND SAWFLIES

- Most adults have a narrow waist; sawflies are an exception.
- Some adults have four transparent wings; some have none.
- Chewing mouthparts.
- Complete metamorphosis.
- Most young are wormlike with no legs. The young of sawflies are caterpillar-like.
- Young usually in nests in soil, or in nests made of mud, paper, or wax. Sawfly larvae feed on plants.
- Painful sting of many adults makes some of these a pest. Others may damage wood products.

MITES, TICKS AND SPIDERS

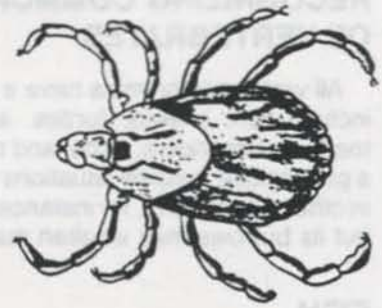
Mites, ticks, and spiders are closely related to insects. The main differences are that the adults have eight jointed legs instead of six and have two body regions instead of three. They do not have wings.

MITES

- Adults and nymphs have eight legs; the newly hatched young, which are called larvae, have six.
- Very small—about the size of the period at the end of this line.
- No wings.
- Sucking mouthparts.
- Soft-bodied.
- Injury they cause usually is noticed before the mites are found.
- When present on plants in large numbers, their feeding speckles foliage and buds with whitish, reddish, or brown spots. Severely damaged leaves wither and die. Some may scar fruit.
- Some mites make thin webs on plants.
- On animals, they cause severe skin irritation, redness, scabs, and scaliness.
- Chiggers (also called jiggers and red bugs) are mites that attack man.

TICKS

- Adults and nymphs have eight legs; larvae have six.
- Leathery or soft (sometimes colored) oval body without a distinct head.
- Less than ½ inch long.
- Piercing-sucking mouthparts with which they firmly attach themselves to the host animal.
- Parasitic on animals, including man.
- Must have blood to complete their life cycle.
- Some carry disease agents to man and animals. Some tick transmitted diseases are tularemia, Rocky Mountain spotted fever, Colorado tick fever and Texas cattle fever.



SPIDERS

- Eight legs.
- Biting mouthparts.
- Vary in length from a fraction of an inch to 5 or 6 inches.
- Useful to man because they eat insects, but webs and excretions may be a nuisance.
- Black widow and brown recluse bites are dangerous to man.

SNAILS AND SLUGS

Snails and slugs are members of a large group of animals called mollusks. Snails have a hard shell; slugs have no shell. They have rasping mouthparts that leave holes in plant foliage. They usually feed at night. They are pests in lawns, landscape plantings, and greenhouses. Snails and slugs leave a silvery trail.

VERTEBRATES

RECOGNIZING COMMON FEATURES OF VERTEBRATES

All vertebrate animals have a jointed backbone. They include fish, snakes, turtles, alligators, lizards, frogs, toads, salamanders, birds, and mammals. What may be a pest animal in some situations may be highly desirable in others. A muskrat, for instance, is a fur-bearing animal, but its burrows may weaken man-made earthen dams.

FISH

Man has caused most fish problems. We have put some kinds where they normally would not have been. We think some fish are undesirable because they are not useful for sport or for food. Some compete with or feed on more desirable species. Some complicate the recreational or commercial harvest of desirable species. Some fish are intermediate hosts for parasites of man.

REPTILES AND AMPHIBIANS

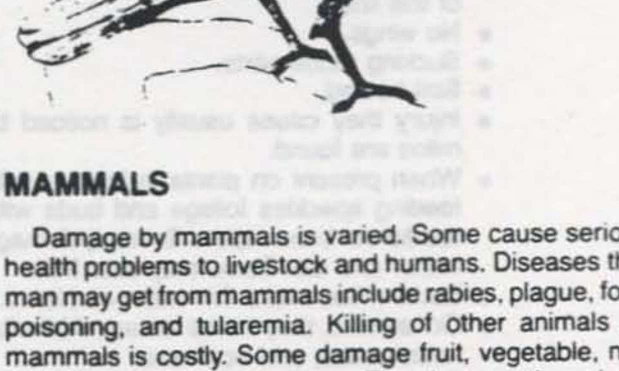
Reptiles (snakes, lizards, turtles, and alligators) and amphibians (frogs, toads, and salamanders) may cause local problems. Although most of them do little damage, many people fear or dislike them. Poisonous snakes can be a real problem. So can snakes and turtles in fish hatcheries or waterfowl production areas.

BIRDS

Bird damage can be quite varied. It includes:

- structural damage by woodpeckers,
- destruction of feed and of fruit, nut, grain, timber, and vegetable crops by seed- and fruit-eating birds,
- hazards to animal and human health caused by birds like pigeons and parakeets, which may harbor certain diseases and
- annoyance caused by birds roosting near dwellings.

Peck marks, location of damage, tracks, feathers, and droppings are signs of bird damage.



MAMMALS

Damage by mammals is varied. Some cause serious health problems to livestock and humans. Diseases that man may get from mammals include rabies, plague, food poisoning, and tularemia. Killing of other animals by mammals is costly. Some damage fruit, vegetable, nut, grain, range, and tree crops. The damage they do to dams and ditches can be very costly. They damage such things as lawns, clothing, furniture, and buildings by gnawing and burrowing. Mice and rats annoy us and endanger our health by living in our homes, offices, and factories.

How do you tell what mammal caused the damage? You can eliminate some suspects if you know:

- which animals are found in your part of the country,
- what kinds of places they live in, and
- what their habits are.

Animal signs (tracks, droppings, toothmarks, diggings, burrows, hair, and scent) plus the type of damage will give you further clues.

WEEDS

A weed is simply "a plant out of place." Weeds are a problem because:

- they reduce crop yields,
- they increase costs of production,
- they reduce quality of crop and livestock products,
- some cause skin irritation and hay fever. Some are poisonous to man, his livestock, and wildlife, and
- they spoil the beauty of turf and landscape plants.

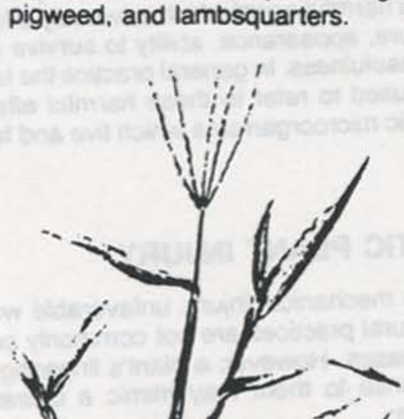
RECOGNIZING COMMON FEATURES OF WEEDS

Before you can control weeds, you need to know something about how they grow. One important feature is the length of their life cycle.

ANNUALS

Plants with a one-year life cycle are *annuals*. They grow from seed, mature, and produce seed for the next generation in one year or less. They may be grasslike (crabgrass and foxtail) or broadleaved (pigweed and cocklebur).

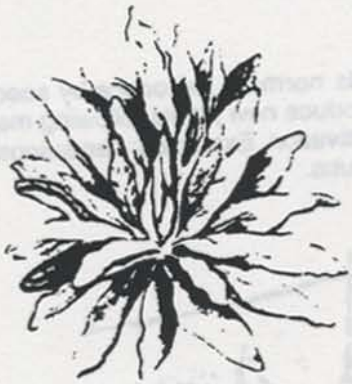
Summer annuals are plants that result from seeds which sprout in the spring. They grow, mature, produce seed, and die before winter. Examples: crabgrass, foxtail, cocklebur, pigweed, and lambsquarters.



Winter annuals are plants that grow from seeds which sprout in the fall. They grow, mature, produce seed, and die before summer. Examples: cheat, henbit, and annual bluegrass.

BIENNIALS

Plants with a two-year life cycle are *biennials*. They grow from seed and develop a heavy root and compact cluster of leaves the first year. In the second year they mature, produce seed, and die. Examples: mullein, burdock, and bull thistle.

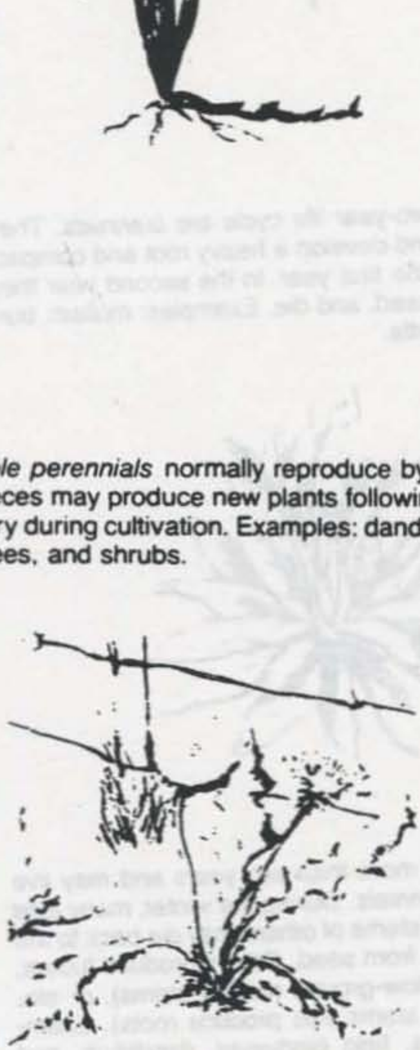


PERENNIALS

Plants which live more than two years and may live indefinitely are *perennials*. During the winter, many lose their foliage and the stems of others may die back to the ground. Some grow from seed. Others produce tubers, bulbs, rhizomes (below-ground rootlike stems), or stolons (above-ground stems that produce roots). Examples: Johnson grass, field bindweed, dandelion, and plantain.

Creeping perennials produce seeds but also produce rhizomes and stolons. Examples: Bermuda grass, Johnson grass, and field bindweed.

Simple perennials normally reproduce by seeds. But root pieces may produce new plants following mechanical injury during cultivation. Examples: dandelions, plantain, trees, and shrubs.



Bulbous perennials may reproduce by seed, bulblets, or bulbs. Wild garlic, for example, produces seed and bulblets above ground and bulbs below ground.

PLANT DISEASES

A plant disease is a continuing process in a plant in response to some harmful agent which adversely affects its growth, structure, appearance, ability to survive and reproduce, or its usefulness. In general practice the term disease may be used to refer to those harmful effects caused by parasitic microorganisms which live and feed on or in plants.

NON-PARASITIC PLANT INJURY

Things such as mechanical injury, unfavorable weather and poor cultural practices are not commonly considered to be diseases. However, a plant's lingering or progressive response to them may mimic a disease. Some of these are:

- nutrient deficiency,
- extreme cold or heat,
- toxic chemicals (air pollutants, some pesticides, salts, too much fertilizer),
- mechanical injury, and
- lack of or too much water.

None of the above are pests and they cannot move from one plant to another. However, anyone who attempts to identify a plant pest should be familiar with non-parasitic agents and the plant's response to them. An important part of disease diagnosis is being able to identify non-parasitic plant injury.

PARASITIC PLANT DISEASES

These are caused by living agents which live and feed on or in plants. They can be passed from one plant to another. The most common causes of parasitic diseases are:

- fungi,
- bacteria,
- viruses, viroids and mycoplasmas,
- nematodes.

Insects, which were discussed earlier, can be another cause. A few seed-producing plants and some microbes can cause plant diseases, too.

Three things are required before a parasitic disease can develop:

- a susceptible host plant,
- a parasitic agent, and
- an environment favorable for parasite development.

Fungi are plants that lack green color (chlorophyll). They cannot make their own food. There are more than 100,000 kinds of fungi of many types and sizes. Not all are harmful, and many are helpful to man. Many are microscopic; but some, such as the mushrooms, may become quite large. Most fungi reproduce by spores, which function about the same way seeds do. Fungi may attack a plant both above and below the soil surface.

Fungus diseases include apple scab, anthracnose of beans, smut in corn, and powdery mildew on landscape plants.

In addition to attacking growing plants, fungi are important pests of stored foods, wood and other useful items.

Smut

Attacked foods often deteriorate to an inedible mess. Some fungi that infest food or feed, such as aflatoxins, are extremely toxic and sometimes fatal to man and animals. Wood may rot and lose structural strength or be badly stained. Mildew is an unsightly growth in damp areas.

Bacteria are microscopic, one-celled plants. They usually reproduce by simply dividing in half. Each half becomes a fully developed bacterium. Bacteria can build up fast under ideal conditions. Some can divide every 30 minutes. Fireblight of pears, halo blight of beans, and bacterial leaf spot on peaches are caused by bacteria.

Leaf Spot

Viruses are so small that they cannot be seen with the unaided eye or even with an ordinary microscope. They are generally recognized by their effects on plants. Many viruses that cause plant disease are carried by insects, usually aphids or leafhoppers. Viruses are easily carried along in bulbs, roots, cuttings, and seeds. Some viruses are transmitted when machines or men touch healthy plants after touching diseased plants. A few are transmitted in pollen. At least one virus is transmitted by a fungus. A few are transmitted by nematodes. Wheat streak mosaic, tobacco mosaic and corn dwarf are diseases caused by viruses.

Dwarf Virus

Nematodes are small, usually microscopic, roundworms, also called eelworms. Many nematodes are harmless. Others may attack crops planted for food, fiber, or landscape purposes. Some species attack the above-ground plant parts, such as leaves, stems, and seeds; but most species feed on or in the roots. They may feed in one location, or they may constantly move through the roots. Nematodes usually do not kill plants, but reduce growth and plant health. They may weaken the plant and make it susceptible to other disease agents.

All nematodes that are parasites on plants have a hollow feeding spear. They use it to puncture plant cells and feed on the cell contents. Nematodes may develop and feed either inside or outside of a plant. Their life cycle includes an egg, four larval stages, and an adult. Most larvae look like adults, but are smaller. The females of some, such as root knot and cyst nematodes, become fixed in the plant tissue. Their bodies become swollen and rounded. The root knot nematode deposits its eggs in a mass outside of its body. The cyst nematode keeps part of its eggs inside its body after death. They may survive there for many years.

DEVELOPMENT OF PLANT DISEASES

A parasitic disease depends on the life cycle of the parasite. The environment affects this cycle greatly. Temperature and moisture are especially important. They affect:

- the activity of the parasite,
- the ease with which a plant becomes diseased, and
- the way the disease develops.

The disease process starts when the parasite arrives at a part of a plant where infection can occur. This step is called *inoculation*. If environmental conditions are good, the parasite will begin to develop. The entrance of the parasite into the host is called *penetration*. If the parasite gets into the plant and starts drawing nutrients from it, the stage called *infection* starts. The period from infection to the appearance of symptoms is called the *incubation period*. The plant is diseased when it responds to the parasite.

The three main ways a plant responds to a parasite are:

- overdevelopment of tissue, such as galls, swellings, and leaf curls,
- underdevelopment of tissue, such as stunting, lack of chlorophyll, and incomplete development of organs, and
- death of tissue, such as blights, leaf spots, wilting, and cankers.

IDENTIFYING PLANT DISEASES

You cannot always tell one plant disease from another just by looking at the plant itself. Because many disease agents cause similar injury, you need other evidence. Identifying the cause is a better way to identify the disease. You usually need a microscope or magnifying lens to see such things as fungus spores, nematodes or their eggs, and bacteria. You need more training to find and identify the cause of a disease than you need to observe the effects. The help of a competent plant pathologist is often essential.

PEST CONTROL

To solve pest problems, you must:

- Identify the pest.
- Know what control methods are available.
- Evaluate the benefits and risks of each method or combination of methods.
- Choose the methods that are most effective and profitable and that will cause the least harm to you and the environment.
- Know the correct use of the methods, and
- Know local, state, and federal regulations that apply to the situation.

PRINCIPLES OF PEST CONTROL

The use of a combination of methods to control pests is basic to all pest control. Modern pest control is:

- using all available and acceptable methods to keep pests below economically harmful levels, and
- damaging the environment as little as possible in the process.

The challenge lies in our ability:

- to control pests so that injury caused by them is held to an acceptable level,
- to recognize when direct action, such as a pesticide application, is necessary, and
- to obtain the most cost effective pest control.

PEST CONTROL METHODS

Many pest control methods have been known and used for years. But some methods, what we call them, and the way we put them together are new. Here are the most important pest control methods:

IMMUNE, RESISTANT OR TOLERANT PLANTS AND ANIMALS

Some plants and animals and also some plant and animal products are less likely than others to be damaged by certain pests. This may result from their ability to escape attack or their ability to tolerate or repair the damage resulting from a pest attack. However, the plant, animal or product that is immune, resistant or tolerant to one pest may be readily damaged by another. By knowing the pests that are likely to be encountered, one can utilize those plants, animals or products that are less likely to be damaged. In some instances a completely different kind of plant, animal or product may be grown or used. In others an immune, resistant or tolerant variety or breed of the same crop or animal may be utilized. The proper application of this pest control method makes it easier, less expensive and safer to keep pest populations below harmful levels.

Examples:

- Some tomato varieties are resistant to certain diseases and nematodes.
- Cotton fabrics and other plant products are not attacked by clothes moths and carpet beetles; animal products are.
- Cypress lumber is resistant to certain fungus rots.

BIOLOGICAL CONTROL

Biological control is the reduction or management of pests by other living organisms (predators, parasites and disease agents). It usually occurs naturally but it can be favorably or unfavorably influenced by human activities. Biological control can sometimes be encouraged by releasing a pest's natural enemies into the target area, but the maintenance of a favorable environment is usually more effective. Apply pesticides only when necessary and then in such a manner as to hurt the biological control agents as little as possible. The choice of pesticides, dosages, timing and method of application can be extremely important. Biological control agents may also be encouraged by judicious crop rotation, cover crops and other cultural control methods.

The introduction of natural enemies from other areas or countries improves biological control, especially of introduced pests, in some instances. However, there is grave danger of the parasite, predator or disease agent itself proving to be a pest unless it is extensively investigated prior to introduction.

Some important biological control agents are:

- Lady beetles.
- Aphidlions.
- Polyhedrosis virus disease of cabbage loopers.
- Various wasps.

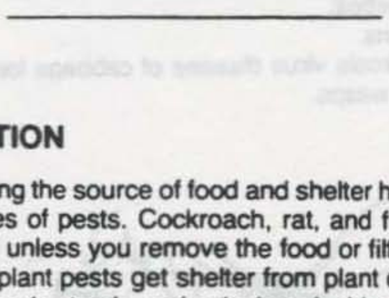
CULTURAL CONTROL

Planting, growing, harvesting, and tillage practices may help or harm pests. Cultivating is harmful to weeds and some other pests but may result in the spread of diseases and nematodes and even some weeds. Other practices such as crop rotation, methods of construction, time of planting, irrigation or drainage and fertilization all affect pests.

MECHANICAL-PHYSICAL CONTROL

Some physical methods and examples of their use are:

- traps for rats, mice, and birds,
- barriers to protect against termites, rodents, and flies,
- light to attract or repel pests,
- sound to kill, attract, or repel pests,
- heat or cold to kill pests, or retard activities,
- radiation to sterilize or kill pests, and
- electrocution to kill pests.



SANITATION

Removing the source of food and shelter helps control some types of pests. Cockroach, rat, and fly control is often hard unless you remove the food or filth they feed on. Many plant pests get shelter from plant debris, crop refuse, weeds, trash and misplaced objects such as flower pots, wooden boards and tools. Farming equipment such as plows and harvestors can harbor pests. Animal pests often get food and shelter from manure.

LEGAL CONTROL

Legal controls result from federal, state, or local laws and regulations. They include such things as:

- quarantines,
- inspections,
- embargoes, and
- compulsory crop or product destruction.

PESTICIDES

Pesticides often must be used. Other methods cannot always prevent harmful pest levels. Use pesticides:

- where they are needed, and
- where they can be used safely.

Select and use pesticides so they work with other methods. Be careful not to harm yourself or the environment. Using pesticides along with other methods is often better than using any one method by itself.

PUTTING IT ALL TOGETHER

The combination of methods you choose will depend on the *kind* and *amount* of control you need. The three main types of controls are:

PREVENTION

Keeping a pest from becoming a problem. Includes use of such things as:

- sanitation,
- resistant plants, animals, or wood,
- treated seed,
- pesticides,
- cultural controls,
- quarantines, and
- seed certification.

SUPPRESSION

Reducing pest numbers or damage to an acceptable level. Includes use of such things as:

- sanitation,
- resistant plants, animals, or wood,
- pesticides, and
- cultural controls.

ERADICATION

Destroying or removing a pest completely from a crop, an area, or a geographic region.

For most pests and environments, eradication is not necessary or even possible. It is often feasible to eradicate certain pests (cockroaches, ants, rats and mice, fleas, lice, termites, stored product insects, etc.) from individuals, structures, containers or commodities that can be reasonably protected from reinfestations. A few pests, usually newly introduced ones, have been eradicated from the United States. However, eradication or complete control is generally unnecessary, unobtainable and possibly undesirable.

Remember, the most important principle of pest control is:

- Use a pest control method only when that method will prevent the pest from causing more damage than is reasonable to accept or when it is otherwise a good production or maintenance practice.

Even though a pest is present, it may not do very much harm. It could cost more to control the pest than would have been lost because of the pest's damage.

INTEGRATED PEST MANAGEMENT (IPM)

Integrated pest management (IPM) is a principle or concept that has been practiced for centuries. However, the term "integrated pest management" has been coined in recent years and the approach has been reemphasized and greater sophistication has been added. *Management* refers to the concept of keeping a pest population or its damage at an acceptable level instead of reducing it to zero or an unnecessary level. This usually involves observations to determine if pest control is actually needed instead of using control methods routinely. However, this should not imply that certain preventive measures are not needed. *Integrated* means using all available and acceptable methods in controlling a pest and methods that are compatible or supportive to those used in managing other pests as well as the production or maintenance, health and use of a crop or other object that requires pest management. The goal is to obtain maximum benefits with minimum costs and risks.

There is a tendency to consider the concept of integrated pest management as being applicable to only the production of plant and animal crops. This is far from true. IPM is applicable in almost any situation where pests may be a problem. For example rat and mouse control in buildings can utilize cats (biological control); the removal or trimming of nearby plants that might provide shelter or accessibility (cultural control); traps as well as screens, doors, and other barriers (mechanical-physical control); the removal of food, filth and harborage areas (sanitation); and pesticides (chemical control).

PESTICIDES

After considering all available control methods, you may decide that a pesticide is needed. Here are some things you should know in order to choose the right pesticide and use it most effectively.

Pesticides are chemicals used to destroy, prevent, or control pests. They also include:

- chemicals used to attract or repel pests, and
- chemicals used to regulate plant growth or remove or coat leaves.

Here are the types and uses of pesticides:

Insecticide: controls insects.
Miticide: controls mites.
Acaricide: controls mites, ticks, and spiders.
Nematicide: controls nematodes.
Fungicide: controls fungi.
Bactericide: controls bacteria.
Herbicide: controls weeds.
Rodenticide: controls rodents.
Avicide: controls birds.
Piscicide: controls fish.
Molluscicide: controls mollusks, such as slugs and snails.
Predacide: controls vertebrate pests.
Repellent: keeps pests away.

Attractant: lures pests.

Plant Growth Regulator: stops, speeds up, or otherwise changes normal plant processes.

Defoliant: removes unwanted plant growth without killing the whole plant immediately.

Dessicant: dries up plant leaves and stems, and insects.

Antitranspirant: coats the leaves of plants to reduce unwanted water loss (transpiration).

A pesticide will often control organisms other than those implied by the type name. For example, many insecticides will also kill mites.

THE NATURE OF PESTICIDES

Pesticides can be grouped according to their chemical nature. The groups are:

INORGANIC PESTICIDES

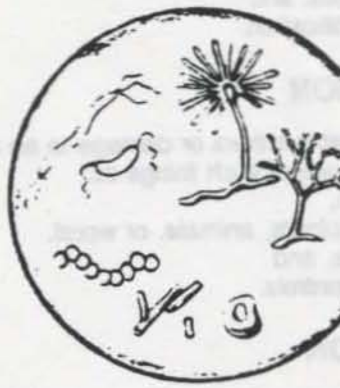
These are made from minerals. Minerals used most often are arsenic, copper, boron, lead, mercury, sulfur, tin, and zinc. Examples: lead arsenate, Bordeaux mixture, and Paris green.

SYNTHETIC ORGANIC PESTICIDES

These are man-made pesticides. They contain carbon, hydrogen, and one or more other elements such as chlorine, phosphorous, and nitrogen. Examples: 2,4-D; atrazine; captan; parathion; and malathion.

MICROBIAL PESTICIDES

These are microscopic living organisms such as viruses, bacteria, and fungi that are cultured, packaged and sold. Some multiply and spread after application. Others do not. Some become established in the target environment. Examples: the bacterium *Bacillus thuringiensis*, and the polyhedrosis virus.



PLANT-DERIVED ORGANIC PESTICIDES

These are made from plants or plant parts. Examples: rotenone, red squill, pyrethrins, strychnine, and nicotine.

PHEROMONES

These are sex attractants from special glands of one or both sexes of an animal. Synthesis by man is usually necessary to obtain usable quantities. They are very, very selective and usually effective for a single species. Although they show some promise as control agents, they are usually used to monitor pest populations. An example is codelure, a codling moth attractant.

HORMONES

Hormones are chemicals normally produced by an organism that affect its metabolism, development or behavior. They usually must be synthesized by the chemist to obtain usable quantities. They tend to be more selective than most other pesticides, but less selective than pheromones. An example is methoprene, which prevents mosquito larvae and certain other insects from developing into adults.

HOW PESTICIDES WORK

Pesticides also can be grouped according to what they do. Many synthetic organic pesticides work in more than one way. Read the label to find out what each pesticide will do. The major groups are:

Protectants: applied to plants, animals, structures, and products to prevent entry or damage by a pest.
Sexual Sterilants: makes pests unable to reproduce.
Sterilants: Kill all organisms in the treated area.
Contact Poisons: kill pests simply by touching them.
Stomach Poisons: kill when swallowed.
Systemics: taken into the blood of an animal or sap of a plant.
Translocated herbicides: kill plants by being absorbed by leaves, stems, or roots and moving throughout the plant.
Fumigants: gases which kill when they are inhaled or otherwise absorbed by the pest.
Anticoagulants: prevent normal clotting of the blood.
Selective: more toxic to some kinds of plants or animals than to others.
Nonselective: toxic to many plants or animals.
Attractants: lure pests.
Repellents: keep pests away.

USING PESTICIDES

Many terms describe when and how to use pesticides. They are used in labeling. They also are found in leaflets and bulletins that you may get from your local Cooperative Extension agent or others at your land-grant university. You should know and understand these terms. They will help you get the best results from your pesticides with the least possible harm to you and the environment.

WHEN TO USE

Terms that tell you when to use the pesticide product:
Preplant: used before the crop is planted.
Preemergence: used before crop or weeds emerge. May also refer to use after crops emerge or are established, but before weeds emerge.
Postemergence: used after the crop or weeds have emerged.

Terms such as *dormant, pre-bloom, bloom, post-bloom* and *post-harvest* are also applicable.

Preemergence and Postemergence

HOW TO USE

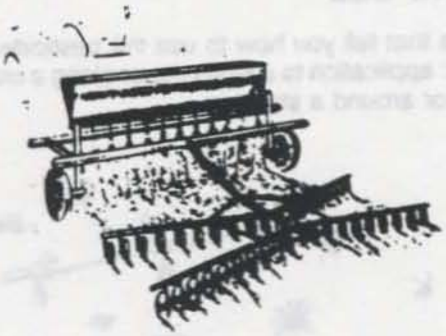
Terms that tell you how to use the pesticide product:
Band: application to a strip over or along a crop row or on or around a structure.

Band

Basal: application to stems or trunks at or just above the ground line.
Broadcast: uniform application to an entire, specific area.
Crack and crevice: application in structures to cracks and crevices where pests may live.
Dip: complete or partial immersion of a plant, animal, or object in a pesticide.
Directed: aiming the pesticide at a portion of a plant, animal, or structure.

Directed

Drench: soaking the soil with a pesticide or oral treatment of an animal with a liquid pesticide.
Foliar: application to the leaves of plants.
In-furrow: application to or in the furrow in which a plant is planted.
Incorporation: mixing the pesticide with soil or some other substance.
Injection: application beneath the surface of the soil or another substance.
Over-the-top: application over the top of the growing crop.
Pour-on: pouring the pesticide along the midline of the back of livestock.
Sidedress: application along the side of a crop row.
Soil application: application to the soil rather than to vegetation.



Soil Incorporation

Space: dispersal into the air.
Spot treatment: application to small area.

ACCURACY IS IMPORTANT

The *rate* and *time* of application of pesticides are critical. Most pesticides work at very low rates. If you use too much, they can harm or even kill the plant or animal you wish to protect. Pesticides work best when applied at specific times. Applying them before or after the correct time reduces or even eliminates their effectiveness.

Since all these chemicals work in small amounts, be careful to treat only the intended target. Avoid getting them on anything else as a result of drift or of residue in application equipment or soil.

FACTORS AFFECTING PESTICIDE ACTIVITY

SOIL FACTORS

Organic matter in soils limits pesticide activity. Soils with high organic matter content may need higher rates of pesticides for good pest control. Follow label instructions.

Soil texture also affects the way pesticides work. Soils with fine particles (silts and clays) provide the most surface area. They may need higher rates. Coarser soils (sands) have less surface area. Use lower rates on them. Follow label instructions.

Soil moisture affects pesticides. Soil pestcides usually work best with moderate soil moisture. Effectiveness is decreased when pesticides adhere tightly to dry soil particles. Moisture tends to make the pesticide more effective but less persistent.

CLIMATIC FACTORS

Rain may cause soluble pesticides to leach down through the soil. This may increase the effectiveness of pesticides applied to the soil surface but it increases the risk of groundwater contamination. Rain during or soon after an application may wash pesticides from the intended target and contaminate other areas through runoff.

Humidity and temperature also affect the way pesticides work. Herbicides work best when plants are growing fast. High relative humidity and optimum temperatures usually cause this fast growth. High temperatures cause the rapid loss of some pesticides. Low temperatures may slow down or stop the activity of some pesticides. Extreme temperatures and humidities can increase risk of injuring plants or animals.

Light may break down some pesticides.

Wind accelerates the loss of many pesticides and increases risk of environmental contamination from drift.

SURFACE CHARACTERISTICS

Porosity, smoothness, oiliness, waxiness and other surface characteristics may affect the effectiveness and persistence of a pesticide. Cleanliness is often important. For instance, the removal of grease and other dirt from household surfaces may increase the effectiveness of a pesticide against pests such as ants, cockroaches, or microorganisms.

PESTICIDE RESISTANCE

The ability of pests to resist poisoning is called *pesticide resistance.* Consider this when planning pest control programs that rely on the use of pesticides.

Rarely does any pesticide kill all the target pests. Each time a pesticide is used, it selectively kills the most sensitive pests. Some pests avoid the pesticide. Others are able to withstand its effects. Pests that are not destroyed pass along to their offspring the trait that allowed them to survive.

When we use one pesticide repeatedly in the same place, the pest population sometimes builds up its resistance. Some pests have become practically immune to poisoning by certain pesticides.

Not every pesticide failure is caused by pest resistance, however. Make sure that you have:

- used the correct pesticide,
- used the correct dosage, and
- applied the pesticide correctly.

Your Cooperative Extension Service or other qualified persons can help you find out why you did not get the desired results.

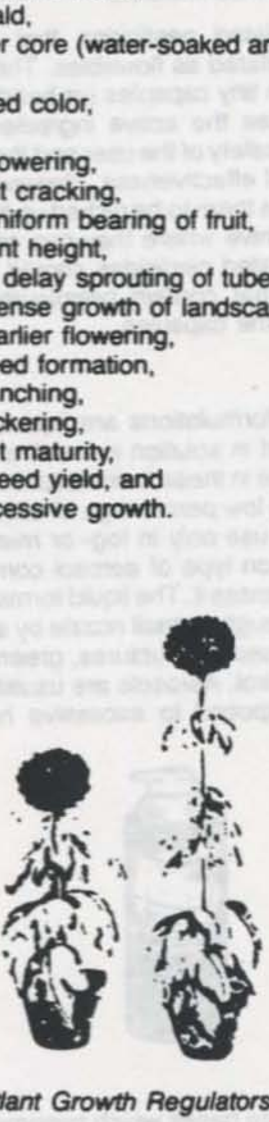
PLANT GROWTH REGULATORS, DESICCANTS, DEFOLIANTS AND ANTITRANSPIRANTS

Plant growth regulators, desiccants, defoliants, and antitranspirants change normal plant processes.

PLANT GROWTH REGULATORS

All plant parts are made up of tiny cells which continually multiply and grow. Plant growth regulators speed up, slow down, or otherwise affect cell growth and reproduction. Here are some ways they are used:

- decrease preharvest drop,
- increase fruit firmness,
- reduce scald,
- delay water core (water-soaked area around core of fruit),
- increase red color,
- thin fruit,
- increase flowering,
- reduce fruit cracking,
- promote uniform bearing of fruit,
- control plant height,
- prevent or delay sprouting of tubers,
- promote dense growth of landscape plants,
- promote earlier flowering,
- prevent seed formation,
- induce branching,
- reduce suckering,
- hasten fruit maturity,
- increase seed yield, and
- control excessive growth.



Plant Growth Regulators

DESICCANTS AND DEFOLIANTS

These often are called harvest-aid chemicals, because they help the farmer harvest his crop. Both are used to get rid of leaves, stems, and weeds in such crops as cotton, soybeans, and potatoes.

Defoliated Cotton

ANTITRANSPIRANTS

By reducing water loss, they can:

- prevent winter damage,
- maintain color in evergreens,
- protect against salt damage,
- help protect transplants, and
- prevent needle drop on Christmas trees.

TYPES OF FORMULATIONS

Active ingredients are the chemicals in a pesticide product that do the work. Active ingredients can rarely be used in their original form. They usually must be mixed with other substances to make them usable. These are the inert ingredients. This mixture of active and inert ingredients is called a *pesticide formulation*. Some formulations are ready for use. Others must be diluted with water or a petroleum solvent. The directions for use will tell you how to use a pesticide formulation.

Each type of pesticide formulation has both advantages and disadvantages. Your choice should depend on such things as the site of application, safety to man and the environment, type of application equipment available and cost. Information on the suitability of formulations can be obtained from Cooperative Extension Service publications, county Extension agents and other qualified advisors.

Here are the most common types of liquid and dry formulations. The abbreviations are included because Cooperative Extension Service recommendations and the labels and labeling may refer to the formulations in this way.

LIQUID FORMULATIONS

EMULSIFIABLE CONCENTRATES (EC OR E)

An emulsifiable concentrate can be mixed with water to form an emulsion. It contains active ingredient(s), petroleum solvent(s) and emulsifier(s). Each gallon of an EC usually contains 2 to 8 pounds of active ingredient. Diluted ECs usually need little agitation in the spray tank.

ECs can damage some crops. These crops may require a different formulation of the active ingredient such as a wettable powder or a dust.

ULTRA LOW VOLUME CONCENTRATES (ULV)

These formulations contain little if anything in addition to the active ingredient. They are intended for application in undiluted form at a total volume not exceeding one-half gallon per acre. They are usually more hazardous to handle and more likely to damage crops and cause other environmental damage than other formulations.

SOLUTIONS (S)

These consist of the active ingredient dissolved in a petroleum solvent (usually a highly refined oil) or in some instances the active ingredient only. The active ingredient content ranges from a fraction of one percent to essentially 100 percent. Some are to be mixed with a petroleum solvent before use; others are not. These materials are highly flammable and they should not be exposed to excessive heat and should not be used near open flames, such as pilot lights. Some uses are:

- controlling household and industrial pests,
- mothproofing,
- as livestock sprays, or
- as space sprays in barns.

WATER SOLUBLE LIQUIDS (WSL OR L)

The chemical properties of some active ingredients permit them to be dissolved in water-soluble solvents such as alcohols to form water soluble liquids. They require little if any agitation when diluted with water for application.

FLOWABLES (F OR L)

The nature or intended use of some active ingredients prevents them from being formulated as an emulsifiable concentrate, water soluble liquid or a solution. In such cases the active ingredient or a wettable powder containing it may be finely ground and mixed with a liquid to form a creamy appearing suspension. They contain a substance to prevent settling and make them mix readily with water. When mixed with water they remain in suspension with moderate agitation.

ENCAPSULATED PESTICIDES

Those encapsulated pesticides that are currently available are formulated as flowables. The active ingredient is enclosed in tiny capsules (or beads) of a plastic material that release the active ingredients gradually. This increases the safety of the user and the environment plus the duration of effectiveness. However, the size of the capsules causes them to be picked up by honey bees and carried to the hive where they can cause massive bee kills. Encapsulated pesticides should not be mixed with formulations that contain petroleum solvents as these will dissolve the capsules.

AEROSOLS (A)

These pesticide formulations are liquids that contain the active ingredient in solution in a solvent. More than one pesticide may be in these formulations. Most aerosol formulations have a low percentage of active ingredient. They are made for use only in fog- or mist- generating machines. A common type of aerosol comes in a container that also dispenses it. The liquid forms fine droplets when it is driven through a small nozzle by a pressurized gas. Aerosols are used in structures, greenhouses, and barns for insect control. Aerosols are usually flammable and explosive if exposed to excessive heat or open flame.

FUMIGANTS

Some fumigants are gases which become liquid when placed under pressure. This type of formulation is stored under pressure. The pressure may be either high or low, depending on the product. Some nematicides, insecticides, fungicides, and rodenticides are formulated this way. These formulations are applied by:

- injecting them directly into the soil,
- releasing them under tarps, or
- releasing them into a structure such as a grain storage elevator.

Some other active ingredients remain liquid in an ordinary container, but turn into a gas or vapor as or after they are applied. These formulations do not require storage under pressure. They must be put into the soil or confined in a space before they turn to gas. Otherwise, they could be lost into the air. Most fumigants are highly flammable and explosive. Some react violently with other substances, such as certain metals.

DRY FORMULATIONS

DUSTS (D)

Most dust formulations are ready to use and contain:

- an active ingredient, plus
- a very fine or powdered dry inert substance such as talc, clay, nut hulls, or volcanic ash.

The amount of active ingredient usually ranges from 1 to 10 percent.

All the ingredients are ground into fine, uniform particles. Inert ingredients are often added so the formulation will store and handle well. Some active ingredients are prepared as dusts because they are safer for crops in that form. Dusts always must be used dry. They can easily drift into non-target areas. They leave visible residues that may be objectionable. You can get dusts for use on seeds, plants, and animals. Dusts are often used for crack and crevice treatments in structural pest control.

GRANULES (G)

Granular formulations are dry. Most are made by applying a liquid formulation of the active ingredient to coarse particles (granules) of some porous material. Often used are clay, corn cobs, or walnut shells. Granule particles are much larger than dust particles. The pesticide is absorbed into the granule, or coats the outside of it, or both. Inert ingredients may be added to make the formulation handle well. The amount of active ingredient ranges from 2 to 40 percent. Granular formulations are usually safer to apply than sprays or dusts. Granules are less likely to drift than other formulations. They are most often used as soil treatments. They may be applied either directly to the soil or over plants. They do not cling to plant foliage, but they may be trapped in the whorls of some plants. Granular formulations, like dusts, should always be used dry. Never mix them with water.

Pellets are granules that are more uniform in size, shape and weight to achieve greater precision of application.

WETTABLE POWDERS (WP OR W)

These are dry, finely ground pesticide formulations. They look like dusts. But, unlike dusts, they are made to mix with water. Most wettable powders are much more concentrated than dusts. They contain 15 to 95 percent active ingredient—usually 50 percent or more. Wettable powders form a suspension rather than a true solution when added to water. Good agitation is needed in the spray tank to maintain the suspension. Good wettable powders spray well and do not clog nozzles. Wettable powders are abrasive to pumps and nozzles. Most wettable powders are safer for use on plants than ECs are. They leave a visible residue that may be objectionable in some environments.

WATER DISPERSIBLE GRANULES

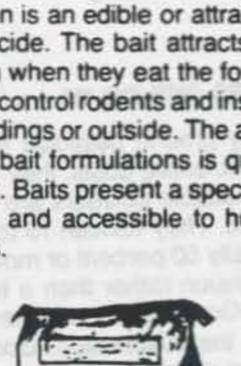
These have the same general characteristics as wettable powders with the exception that they are in the form of granules or pellets which break apart when placed in water. Water dispersible granules are less hazardous than wettable powders because they are less apt to be inhaled or to contaminate skin or other surfaces before dilution.

SOLUBLE POWDERS (SP)

Soluble powders also are dry formulations. But when they are added to water, they form true solutions. Agitation in the spray tank may be needed to get them to dissolve. After that, no more agitation usually is needed. The amount of active ingredient in an SP is usually above 50 percent.

BAITS (B)

A bait formulation is an edible or attractive substance mixed with a pesticide. The bait attracts pests and the pesticide kills them when they eat the formulation. Baits usually are used to control rodents and insect pests. They can be used in buildings or outside. The amount of active ingredient in most bait formulations is quite low, usually less than 5 percent. Baits present a special hazard when they are attractive and accessible to humans or other non-target animals.



FERTILIZER MIXTURES

Fertilizers which contain relatively small concentrations of pesticides are frequently available. It is also possible to specify the addition of a pesticide when you order a fertilizer.

PESTICIDE MIXTURES

It is more economical and convenient to apply a mixture of two or more active ingredients when a wide range of pests must be controlled. Some products, particularly many of those intended for home garden and home orchard use, already contain two or more active ingredients. In most instances the user must add separate formulations to the spray tank. It is important that the pesticide products be compatible with one another. Incompatibility can cause:

- lumps, globs, sediments and separated liquids which cause poor distribution and clogged equipment.
- loss of effectiveness.
- increased toxicity to humans, animals and plants.
- damage to treated plants, animals and objects.

A list of compatible pesticide active ingredients is included on the label of many pesticide products. Compatibility charts and other information are available. But these must be used with some caution. Usually there is information for a mixture of only two active ingredients. There is usually no information provided for a mixture of three or more active ingredients nor for the compatibility of ingredients other than the active ingredients. When trying new mixtures the pesticide user should mix up only a pint or quart of the spray to see that it mixes properly. The mixture should be tried initially on a small scale and treated plants, animals or objects observed for a few days. In general one should avoid mixing different types of formulations, *e.g.* WPs with ECs.

ADJUVANTS

An adjuvant is a substance that is included in a pesticide formulation or is added to the tank mix to facilitate mixing or otherwise improve the application. Most adjuvants are also called surfactants. Most pesticide products contain enough adjuvant for general use but the pesticide user may need to add additional adjuvant for specific situations. The user should be certain that an adjuvant is chosen that gives the desired results. Most adjuvants will have more than one effect. Some types of adjuvants are:

Wetting Agents - help powders mix with and remain suspended in a water carrier and also increase the ability of the water to wet a treated surface.

Emulsifiers - help droplets of a petroleum-based liquid to remain separated and suspended in water or a similar liquid. Many will also act as wetting agents.

Invert Emulsifiers - help droplets of water or a similar liquid remain separated and suspended in petroleum-based liquids.

Spreaders - increase the area that a given volume of liquid will cover on a solid or liquid surface. Also called *film extenders*. Wetting agents and emulsifiers usually act also as spreaders.

Stickers - increase the retention of spray or dust deposits on plants and other surfaces. Also called *adhesives*. Some will also act as wetting agents or emulsifiers.

Penetrants - help a pesticide pass beneath the surface of a treated object.

Foaming agents - cause a liquid to mix with air to form many small bubbles when used in the proper equipment. The main purpose is to reduce drift.

Foam suppressants - reduce the foam or entrapped air in a liquid which is usually caused by excessive amounts of other adjuvants.

Compatibility agents - reduce the injurious effects caused by mixing two or more incompatible substances.

pH adjusters - change and stabilize the acidity or alkalinity of a substance. Usually used to decrease excessive alkalinity which causes the rapid deterioration of certain pesticides in water.

Surfactant - a substance that affects the interface of two substances that are not soluble with each other. Many adjuvants are surfactants (surface active agents).

LABELS AND LABELING

Each time you buy a pesticide, you also receive instructions that tell how to use it. Those instructions are the labeling.

What is labeling? What is a label? These words seem alike but they do not mean the same thing.

Labeling is all information that you receive from the company or its agent about the product. Labeling includes such things as:

- the label on the product,
- brochures,
- flyers, and
- a supplemental label accompanying the product.

The *label* is the information printed on or attached to the container of pesticides. This label does many things:

- To the manufacturer, the label is a "license to sell."
- To the state or federal government, the label is a way to control the distribution, storage, sale, use, and disposal of the products.
- To the buyer or user, the label is a main source of facts on how to use the product correctly and legally.
- The label is a way to tell users about special safety measures needed.
- The label contains information on first aid and treatment for poisoning.

Some labels are easy to understand. Others are complicated. But all labels will tell you how to use the product correctly. This section will explain the items that must be on a label.

PARTS OF THE LABEL

BRAND NAME

Each company has brand names for its products. The brand name is the one used in ads. The brand name shows up plainly on the front panel of the label. It is the most prominent name on the product.

There are two types of brand names. One is the name that is given to an active ingredient by its manufacturer. This is often a reliable name for identifying the active ingredient. However, a single active ingredient may have two or more brand names. Dursban and Lorsban are brand names for chlorpyrifos. Nudrin and Lannate are brand names for methomyl. Sevin is the brand name for carbaryl.

The other type of brand name is the name that an individual distributor or formulator uses for his product. This is usually a poor way of recognizing active ingredients. Essentially the same formulation may be sold under many brand names. In addition, the active ingredients of some products may be changed without changing the brand name.

TYPE OF FORMULATION

Different types of pesticide formulations (such as liquids, wettable powders, and dusts) require different methods of handling. The label will tell you what type of formulation the package contains. The same pesticide may be available in more than one formulation.

COMMON NAME

Many pesticides have complex chemical names. Some have been given another name to make them easier to identify. These are called *common names*. For instance, carbaryl is the common name for l-naphthyl N-methylcarbamate. A chemical made by more than one company will be sold under several *brand names*, but you may find the same *common name* or chemical name on all of them.

INGREDIENT STATEMENT

Every pesticide label must list what is in the product. The list is written so that you can see quickly what the active ingredients are. However you must often distinguish the actual pesticide from certain solvents, such as petroleum hydrocarbons, aromatic petroleum distillate or xylene, and some other ingredients of doubtful or limited pesticide value that may be listed as active ingredients.

The amount of each *active ingredient* is given as a percentage by weight. In addition, the pounds of the actual pesticide per gallon of a liquid concentrate will usually be given at the bottom of the ingredient statement. The pesticide can be listed in the ingredient statement by either the chemical name or the common name.

The *inert ingredients* need not be named, but the label must show what percent of the contents they make up.

NET CONTENTS

The net contents number tells you how much is in the container. This can be expressed in gallons, pints, pounds, quarts, or other units of measure.

NAME AND ADDRESS OF MANUFACTURER

The law requires the maker or distributor of a product to put the name and address of the company on the label. This is so you will know who made or sold the product.

REGISTRATION AND ESTABLISHMENT NUMBERS

A registration number must be on every pesticide label. It shows that the product has been registered with the federal government. It usually is found on the front panel of the label and will be written as "EPA Registration No. 0000." The establishment number tells what factory made the chemical. This number does not have to be on the label, but will be somewhere on each container.

SIGNAL WORDS AND SYMBOLS

To do their job, most pesticides must control the target pest. By their nature, they are toxic. Therefore, some may be hazardous to people. You can tell the toxicity of a product by reading the *signal word* and looking at the *symbol* on the label.

SIGNAL WORDS

One of the most important parts of the label is the *signal word*. It tells you approximately how toxic the material is to people.

Signal words are based on five criteria of toxicity to laboratory animals. These are the dosages that will cause death (1) when swallowed, (2) when applied to the skin, (3) when inhaled; and irritation or corrosiveness to (4) the skin and (5) the eye. The criterion for which the product is graded the most toxic will determine the signal word that must appear on the label. The signal words and the estimated human toxicity that each represents are listed below:

SYMBOL

One of the best ways to catch a person's eye is with symbols. This is why a skull and crossbones symbol is used on all highly toxic materials along with the signal word DANGER and the word POISON.

Pay attention to the symbol on the label. It is there to remind you that the contents could make you sick, or even kill you.

PRECAUTIONARY STATEMENT

HAZARDS TO HUMANS (AND DOMESTIC ANIMALS)

This section of the label will tell you the ways in which the product may be poisonous to man and animals. It also will tell you of any special steps you should take to avoid poisoning, such as the kind of protective equipment needed.

If the product is highly toxic, this section will inform physicians of the proper treatment for poisoning.

ENVIRONMENTAL HAZARDS

Pesticides are useful tools. But wrong or careless use could cause undesirable effects. To help avoid this, the label contains environmental precautions that you should read and follow.

Here are some examples:

- "This product is highly toxic to bees exposed to direct treatment or to residues on crops."
- "Do not contaminate water when cleaning equipment or when disposing of wastes."
- "Do not apply where runoff is likely to occur."

Labels may contain broader warnings against harming birds, fish, and wildlife.

PHYSICAL AND CHEMICAL HAZARDS

This section will tell you of any special fire, explosion, or chemical hazards that the product may pose.

Signal Words	Toxicity	Approxiate Amount Needed to Kill the Average Adult when Swallowed
DANGER	Highly toxic	a taste to a teaspoonful
WARNING	Moderately toxic	a teaspoonful to two tablespoonfuls
CAUTION	Low toxicity or Comparatively free from danger	an ounce to more than a pint

All products must bear the statement "Keep out of reach of children."

PRECAUTIONARY STATEMENTS

HAZARDS TO HUMANS (& DOMESTIC ANIMALS)

DANGER

ENVIRONMENTAL HAZARDS

PHYSICAL OR CHEMICAL HAZARDS

DIRECTIONS FOR USE

It is a violation of Federal law to use this product in a manner inconsistent with its labeling

RE-ENTRY STATEMENT (If Applicable)

CATEGORY OF APPLICATOR

STORAGE AND DISPOSAL

STORAGE

DISPOSAL

CROP

RESTRICTED USE PESTICIDE

FOR RETAIL SALE TO AND USE ONLY BY CERTIFIED APPLICATORS OR PERSONS UNDER THEIR DIRECT SUPERVISION, AND ONLY FOR THOSE USES COVERED BY THE CERTIFIED APPLICATOR'S CERTIFICATION.

PRODUCT NAME

ACTIVE INGREDIENT %

INERT INGREDIENTS %

TOTAL 100.00 %

THIS PRODUCT CONTAINS LBS OF PER GALLON

KEEP OUT OF REACH OF CHILDREN

DANGER — POISON

STATEMENT OF PRACTICAL TREATMENT

IF SWALLOWED

IF INHALED

IF ON SKIN

IF IN EYES

SEE SIDE PANEL FOR ADDITIONAL PRECAUTIONARY STATEMENTS

MFG BY

TOWN, STATE

ESTABLISHMENT NO

EPA REGISTRATION NO

NET CONTENTS

CROP

CROP

CROP

CROP

CROP

WARRANTY STATEMENT

STATEMENT OF PRACTICAL TREATMENT

If swallowing or inhaling the product or getting it in your eyes or on your skin would be harmful, the label will tell you emergency first aid measures. It also will tell you what types of exposure require medical attention.

The pesticide label is the most important information you can take to the physician when you think someone has been poisoned.

STATEMENT OF USE CLASSIFICATION

Every pesticide label must show whether the contents are for general use or restricted use. EPA puts every product use into one of these two classes. The classification is based on:

- the hazard of poisoning,
- the way the pesticide is used, and
- its effect on the environment.

RESTRICTED USE

A restricted use pesticide is one which could cause some human injury or environmental damage even when used as directed on the label. The label on these products will say: "*Restricted use pesticide for retail sale to and application only by certified applicators or persons under their direct supervision and only for those uses covered by the Certified Applicator's Certification.*"

The restricted use statement must be at the top of the front panel of the label.

DIRECTIONS FOR USE

The instructions on how to use the pesticide are an important part of the label for you. This is the best way you can find out the right way to apply the product.

The use instructions will tell you:

- the pests the product is registered to control (Labels use common names for pests. Knowing these names will help you choose the proper pesticide and find control information).
- the crop, animal, or other item the product can be used on,
- whether the product is for general or restricted use,
- .n what form the product should be applied,
- how much to use,
- where the material should be applied, and
- when it should be applied.

MISUSE STATEMENT

This section will remind you that it is a violation of federal law to use a product in a manner inconsistent with its labeling. Do not use a product on a crop or site not listed on the label. Do not use it at more than the recommended rate. Before the product could be registered, EPA required the manufacturer to conduct many tests to be sure the label directions were correct. By following them exactly, you will:

- get the best results the product can give, and
- avoid breaking the law.

REENTRY STATEMENT

If required for the product, this section will tell you how much time must pass before a pesticide-treated area is safe for entry by a person without protective clothing. Consult local authorities for special rules that may apply.

CATEGORY OF APPLICATOR

If required for the product, this section will limit use to certain categories of commercial applicators.

STORAGE AND DISPOSAL DIRECTIONS

Every pesticide should be stored and disposed of correctly. This section will tell you how to store and dispose of the product and empty containers.

USING PESTICIDES SAFELY

There are two good reasons for using pesticides safely:

- to keep yourself and other people from being poisoned, and
- to avoid harming the environment.

PROTECTING MAN

HOW PESTICIDES HARM MAN

Pesticides can cause injury. They are *toxic*. The product's *hazard*—the danger that injury will occur to man—depends on the toxicity of the active ingredient plus the exposure to the product.

There are two general types of toxicity, *acute* and *chronic*. *Acute toxicity* refers to the ability of a pesticide to cause injury, sickness or death as the result of a single or short term exposure. *Chronic toxicity* refers to the ability of a pesticide to cause injury, sickness or death as the result of a long term exposure.

Before a pesticide is marketed many acute and chronic toxicity studies must be conducted on animals to show that it does not cause unreasonable adverse effects to man or the environment when used as directed on the label. However, for many reasons it is impossible to prove that any pesticide is absolutely safe even when directions are followed explicitly. Therefore, it is important not to needlessly expose yourself or others to any pesticide.

Most pesticides can cause severe illness, or even death, if misused. But every registered pesticide can be used with reasonable safety if you use proper care.

The pesticide user must be protected from pesticide poisoning, but must also be concerned with the safety of others, particularly children. Children under 10 are the victims of at least half of the accidental pesticide deaths in this country. If pesticides were always cared for correctly, children would never touch them.

Pesticides enter the body by three main routes, being swallowed, being inhaled and penetrating the skin. Many accidental pesticide deaths are caused by eating or drinking the product. But some mixers, loaders, and applicators die or are injured when they breathe a pesticide vapor or get a pesticide on their skin. Repeated exposure to small amounts of some pesticides can cause sudden severe illness.

Most pesticides can enter the body through the skin. You may get more into your body this way than you would accidentally swallow or inhale while working. With some pesticides, skin contact alone can cause death.

You should help prevent *all* accidents with pesticides:

- by using and storing pesticides away from children and other untrained persons, and
- by taking care to follow directions when using them.

Products for restricted use need special care. The label is your guide.

SYMPTOMS OF PESTICIDE POISONING

You should know what kinds of sickness are caused by the pesticides you use. You also should know the conditions under which each one may make you sick.

There are two kinds of symptoms to pesticide poisoning. Some are feelings that only the victim can notice—such as nausea or headache. Others, like vomiting, also can be noticed by someone else. So you should know:

- what your own feelings might mean, and
- what signs of poisoning to look for in your co-workers and others who may have been exposed.

All pesticides in the same chemical group cause the same kind of sickness. This sickness may be mild or severe, depending on the pesticide and the amount absorbed. But the *pattern* of illness caused by one type of pesticide is always the same. Having some of the signs and symptoms does not always mean you have been poisoned. Other kinds of sickness may cause similar signs and symptoms. Headache and a feeling of being unwell, for example, may signal the start of many kinds of illness. It is the *pattern of symptoms* that makes it possible to tell one kind of sickness from another.

Get medical advice quickly if you or any of your fellow workers have unusual or unexplained symptoms starting at work or later the same day. If you suspect a person has been poisoned, do not leave him alone. Do not let yourself or anyone else get dangerously sick before calling your physician or going to a hospital. It is better to be too cautious than too late. Take the container (or the label) of the pesticide to the physician. Do not carry the pesticide container in the passenger space of a car or truck.

SYNTHETIC ORGANIC PESTICIDES

Organophosphates - Most of these are insecticides, miticides or nematicides. Some common ones are parathion, azinphosmethyl (Guthion), monocrotophos (Azodrin) and diazinon. They injure the nervous system by inhibiting cholinesterase, an enzyme. The signs and symptoms go through stages. They normally occur in this order:

Mild Poisoning

- fatigue
- headache
- dizziness
- blurred vision
- too much sweating and salivation
- nausea and vomiting
- stomach cramps or diarrhea

Moderate Poisoning

- unable to walk
- weakness
- chest discomfort
- muscle twitches
- constriction of pupil of the eye
- earlier symptoms become more severe

Severe Poisoning

- unconsciousness
- severe constriction of pupil of eye
- muscle twitches
- secretions from mouth and nose
- breathing difficulty
- death if not treated.

Illness may be delayed a few hours. But if symptoms start more than 12 hours after you were exposed to the pesticide, you probably have some other illness. Check with your physician to be sure.

Repeated slight exposures to organophosphates and other cholinesterase inhibiting pesticides can cause a progressive and gradual reduction of cholinesterase activity. Only slight, if any, indications appear before severe symptoms occur suddently from a slight exposure. Symptoms of such a gradual poisoning are weakness, poor appetite and a vague feeling of discomfort or uneasiness.

Gradual poisoning by organophosphates and carbamates can be detected early by periodic blood tests for cholinesterase activity. The initial test should follow several weeks of no exposure to these pesticides to obtain a normal value. Such a pre-exposure test may be of value in diagnosing poisonings even if periodic tests are not made.

Carbamates - The only carbamates likely to make you ill on the job act almost like organophosphates. Some common carbamates are aldicarb (Temik), carbofuran (Furadan), methomyl (Lannate, Nudrin) and carbaryl (Sevin). They produce the same symptoms as organophosphates if you are poisoned by them. But the injury they cause can be corrected more easily by a physician. For this reason, most carbamates are safer than organophosphates. The label will warn you of the danger.

Organochlorines - Some common organochlorines are Aldrin, endosulfan (Thiodan), toxaphene, chlordane, chlorobenzilate and DDT. Not many organochlorines (chlorinated hydrocarbons) other than endrin have poisoned applicators.

Early symptoms of poisoning include:

- headache
- anxiety
- excitability
- dizziness
- disorientation
- weakness
- muscle twitching

With more severe poisoning, convulsions follow. They may even appear without the warning symptoms. Coma may follow the convulsions.

Nitrophenols and Pentachlorophenol - Nitrophenols are used as herbicides but sometimes as insecticides or fungicides when their usual phytotoxicity is not a factor. Some common ones are dinoseb (DNBP), dinitroorthocresol (DNOC, DNC) and dinoprop. Pentachorophenol is used mostly as a wood treatment.

These pesticides may be moderately toxic to the skin and cause:

- redness,
- burning, and
- blisters

They may also cause poisoning by being inhaled, absorbed through the skin or swallowed. Yellow staining of the eyeballs and urine indicate that the body contains potentially toxic amounts of nitrophenols. Weight loss may indicate protracted exposure to small amounts of nitrophenols or pentachlorophenol. Symptoms of nitrophenol or pentachlorophenol poisoning include:

- heavy sweating
- headache
- thirst
- weakness or tiredness
- nausea or vomiting
- flushed warm skin
- fast heartbeat
- fever (Do not use aspirin)
- manic behavior
- collapse and
- coma

Severe poisoning usually runs a rapid course. One usually dies or is almost well within 24 to 48 hours.

Fumigants and Solvents - Too much exposure to these compounds may make a person seem drunk. The symptoms are:

- poor coordination,
- slurring words,
- confusion, and
- sleepiness
- nausea or vomiting

Repeated exposure to the fumigant methyl bromide has caused permanent internal injury without early signs or symptoms of poisoning. You can absorb a fatal dose of it before symptoms appear.

INORGANIC PESTICIDES

Large single doses of most inorganic pesticides cause vomiting and stomach pain. The signs and symptoms depend on the mineral from which the pesticide is made.

PLANT-DERIVED PESTICIDES

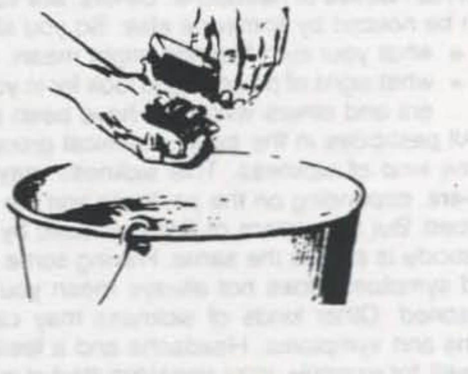
Some plant-derived pesticides are very toxic. Technical pyrethrum may cause allergic reactions. Some rotenone dusts irritate the respiratory tract. Nicotine is a fast-acting nerve poison about as dangerous as parathion. Some other plant-derived pesticides are strychnine, ryania and red squill.

FIRST AID PROCEDURES

Read the directions in the "Statement of Practical Treatment" on each label. These instructions can save your life and the lives of your employees.

If you get a pesticide on your skin:

- Remove the pesticide as quickly as possible. Remove all contaminated clothing. Prompt washing may prevent sickness even when the spill is very large. Don't forget your hair and fingernails. Wettable powders and other solid formulations or suspensions are easy to remove with plain water. So are most emulsifiable concentrates and emulsions. However, soap or detergent should be used if readily available and its use does not delay washing with water. Solutions of pesticides in petroleum oil or other solvents are harder to remove without soap or a detergent. Detergents work better. Washrooms and emergency field washing facilities should have detergents rather than plain soap.



If you inhale a pesticide:

- Get to fresh air right away.

If you splash a pesticide into your mouth or swallow it:

- Rinse your mouth with plenty of water.
- Drink large amounts of milk or water.
- Go or be taken to a physician immediately.
- It is sometimes dangerous to cause vomiting; follow label directions.

If you get a pesticide in your eyes:
- Flush eyes thoroughly with clear water.
- Go or be taken to a physician immediately.

PROTECTING YOUR BODY

Pesticides can enter the body in many ways. The main ones are:
- getting the pesticide on your skin or in your eyes,
- inhaling it, and
- swallowing it.

To prevent this, you must wear protective clothing and equipment. No safety recommendations can cover all situations. Your common sense should tell you to use more protection as the toxicity of the pesticide or the chance of exposure increases. The pesticide label will tell you the kind of protection you need.

Remember to bathe, using a detergent, when you finish working with pesticides or pesticide-contaminated equipment. Any time you spill a pesticide on yourself, wash immediately.

PROTECTIVE CLOTHING

Body Covering - Any time you handle pesticides, you should wear at least:
- a long-sleeved shirt and long-legged trousers, or
- a coverall type garment.

They should be made of closely woven fabric. When handling pesticide containers or very toxic materials, you also should wear a liquid-proof raincoat or apron. Wear trousers *outside* of the boots to keep pesticides from getting inside.

Gloves - When you handle concentrated or highly toxic pesticides, wear liquid-proof neoprene gloves. However, some fumigants are readily absorbed by neoprene. The label will tell you what kind of gloves to use. They should be long enough to protect the wrist. Gloves should not be lined with a fabric. The lining is hard to clean if a chemical gets on it. Sleeves should usually be *outside of* the gloves to keep pesticides from running down the sleeves and into the gloves. If spray is being directed upward by handgun then the gloves should be outside the sleeves.

Hat - Wear something to protect your head. A wide-brimmed, waterproof hat will protect your neck, eyes, mouth and face. It should not have a cloth or leather sweatband. These sweatbands are hard to clean if chemicals get on them. Plastic "hard hats" with plastic sweatbands are good. They are waterproof and are cool in hot weather.

Boots - Wear unlined neoprene boots. However, some fumigants are readily absorbed by neoprene boots. Follow label instructions. Trousers should be worn outside boots.

Goggles or Face Shield - Wear goggles or a face shield when there is any chance of getting pesticides in your eyes. Your eyes will absorb many pesticides. Even relatively non-toxic pesticides can severely damage the eyes. You can wear goggles alone or with a respirator.

Care of Clothing - Wear clean clothing daily. If clothes get wet with spray, change them right away. If they get wet with pesticide concentrates or highly toxic pesticides, destroy them. They are hard to get clean by normal methods. Do not store or wash contaminated clothing with the family laundry. Wash hats, gloves, and boots daily, inside and out. Hang them to dry. Test gloves for leaks by filling them with water and gently squeezing.

Wash goggles or face shields at least once a day. Elastic fabric headbands often absorb pesticides and are difficult to clean. Have some spares so you can replace them often, or use neoprene headbands.

RESPIRATORY PROTECTIVE DEVICES

The respiratory tract—the lungs and other parts of the breathing system—is much more absorbent than the skin. You *must* wear an approved respiratory device when the label directs you to do so. Enclosed cabs on trucks, tractors and other application equipment do not ordinarily provide adequate respiratory protection. Follow the label instructions on respiratory protection.

You probably will need a respirator:
- if you will be exposed to a pesticide for a long time,
- if the pesticide you are using is highly toxic, or
- if you are working in an enclosed area.

Chemical Cartridge Respirator - You should wear this kind of respirator:
- when you are exposed to intermittent concentrations of a toxic pesticide. It is usually adequate for outdoor pesticide applications.

The inhaled air comes through both a filter pad and a cartridge made to absorb pesticide vapors. Most harmful vapors, gases, and particles are removed. These half-face masks cover the mouth and nose. To cover the eyes also, use one that is combined with goggles or wear separate goggles.

Cartridge Respirator

Chemical Canister Respirator (Gas Mask) - You should wear this kind of respirator:

- when you are exposed to a continuous concentration of a toxic pesticide.

The canister has longer-lasting absorbing material and filters than a cartridge respirator. Gas masks usually protect the face better than cartridge types. Neither kind will protect you during fumigation or when the oxygen supply is low, as in a silo.

Canister Respirator

Supplied Air Respirator - You may use this kind of respirator when mixing or applying pesticides:

- when the oxygen supply is low,
- when you are exposed to high concentrations of highly toxic pesticides in enclosed areas, as in fumigation,
- when your work can be done close to a supply of clean air.

Clean air is pumped through a hose to the face mask.

Supplied Air Respirator

Self-Contained Breathing Apparatus - You should wear this kind of respirator under the same conditions as the supplied air respirator. It does about the same thing. The difference is that you carry cylinders of air or oxygen with you, usually on your back. This lets you move more freely and over a wider area than you can with a supplied air respirator.

Self-contained Breathing Apparatus

Positive Pressure Respirator Helmet - Your head, face and eyes as well as the lungs are protected from pesticide exposure without the uncomfortably tight fit and breathing difficulty experienced with cartridge and canister respirators. The pressure from air that is drawn through the filtering system by an electric powered fan provides a barrier against unfiltered air entering the helmet. The power can be provided by a lightweight battery pack which can be carried by the applicator or it can be provided by a vehicle's generator.

Selection and Maintenance - Specific types of cartridges and canisters protect against specific chemical gases and vapors. Be sure to choose one made for the pesticides you are using. Use only those approved by the National Institute for Occupational Safety and Health (NIOSH), or the Mining Enforcement and Safety Administration (MESA).

With the exception of the positive pressure respirator helmet the respirator must fit the face well. Long sideburns, a beard, or glasses may prevent a good seal. Read the manufacturer's instructions on the use and care of any respirator and its parts before you use it.

When applying pesticides change filters, cartridges, and canisters if you have trouble breathing, or if you smell pesticides. Remove and discard filters, cartridges, and canisters after use. (Follow the manufacturer's recommendations on the maintenance and care of positive pressure respirator helmets.) Then wash the face piece with detergent and water, rinse it, and dry it with a clean cloth. Store it in a clean, dry place away from pesticides.

The useful life of a cartridge or canister depends on:

- the amount of absorbent material,
- the concentration of contaminants in the air,
- the breathing rate of the wearer, and
- the temperature and humidity.

If you have trouble breathing while wearing a respiratory device, see your physician to find out whether you have a respiratory problem.

PROTECTING THE ENVIRONMENT

The "environment" is our surroundings and its many forms of life. Every plant or animal is affected by other plants or animals in the environment. Factors like rain, temperature, and wind are part of the environment. We cannot do much about them. But we can control some other things, including the use of pesticides.

Many people consider pesticides a tool for preserving or improving the environment. Others feel that they cause pollution. As a weed is a "plant out of place," a pesticide sometimes can be a "tool out of place." Correct use prevents pollution by pesticides.

HOW PESTICIDES HARM THE ENVIRONMENT

Using pesticides in a way other than as directed on the label can:

- injure plants and animals,
- leave illegal residues, and
- damage the environment in many other ways.

Any pesticide can cause harm if not chosen and used with care. Here are some ways damage can occur.

DIRECT KILL OF NON-TARGET ORGANISMS

Do not let a pesticide contact anything except the target area. Drift from herbicides can kill nearby crops and landscape plants. You may kill bees and other pollinators if you treat a crop while they are working in a field. Or you could kill parasites and predators that help control harmful insects.

Pesticides are sometimes applied over a large area. Targets are such things as mosquitoes, forest insects, and weeds. Many non-target plants and animals within the treated area may be harmed. Plan area projects with great care so you will not do irreparable damage to the environment.

Runoff from a sprayed field can kill fish in a nearby stream or pond. Life in streams can be wiped out by careless tank filling or draining and improper container disposal.

All of these kills can result in lawsuits, fines, and loss of certification.

If more than one pesticide will control your target pest, choose the one that is the least hazardous to the environment and most useful for your situation. Ask your Cooperative Extension agent to help you make this choice.

PERSISTENCE AND ACCUMULATION

Not all pesticides act the same after you apply them. Most are in one of these two groups:

Pesticides that break down quickly remain on the target or in the environment only a short time before being changed into harmless products. Some are highly toxic. Others are fairly harmless.

Pesticides that break down slowly may stay in the environment without change for a long time. Often this is good, because you get long term control. These are called *persistent pesticides.* Most of them:

- are not broken down easily by microorganisms, and
- are only slightly soluble in water.

Some persistent pesticides can injure sensitive crops planted on the same soil the next year. But they seem to be of little hazard to the environment beyond the treated soil. Other persistent pesticides can build up in the bodies of animals, including man. They may build up until they are harmful to the animal itself or to the meat eater that feeds on it. These are called *accumulative pesticides.*

PESTICIDE MOVEMENT IN THE ENVIRONMENT

Pesticides become problems when they move off target. This may mean:

- drifting out of the target area as mist or dust,
- moving with soil through runoff or erosion,
- leaching through the soil,
- being carried out as residues in crops and livestock, or
- evaporating and moving with air currents.

SOIL AND PESTICIDES

Persistent pesticides may limit future planting. You can plant only crops which the pesticide will not kill or contaminate.

Even pesticides directed at plants or animals can move to the soil. They may be washed or brushed off. They may be worked into the soil with dead plant parts.

AIR AND PESTICIDES

Pesticides in the air cannot be controlled. The pesticides can settle into water, crops, trees, houses, or barnyards. The wind can carry them hundreds of miles. Even gentle breezes can carry them away from the target.

WATER AND PESTICIDES

Water is necessary for all life. But it is not safe to drink or bathe in polluted water.

Most fish and other aquatic life can survive only slight changes in their environment. Even tiny amounts of many pesticides can harm them or destroy the food they live on. They may die at once, or there may be chronic effects. The behavior of an animal can be changed so that predators can more easily catch and kill it. Pesticide-contaminated eggs may not hatch.

Pesticides in water also may harm other wildlife. Polluted irrigation water can harm crops, soil, and livestock. It can cause illegal residues in crops, milk, and meat.

Pesticides contaminate water in many ways. They are applied directly to water when controlling some pests. Your state may require a permit for this. It can be done safely if you:

- choose the pesticides carefully,
- make sure they are registered for the use intended, and
- apply them when and as directed.

But water can be polluted if you use the wrong pesticide or apply it carelessly. Pesticides also can reach water directly as a result of:

- drift,
- spills,
- application to waterways (ditches and streams),
- incorrect handling, use and disposal methods, and
- incorrect loading and cleaning of application equipment

Pesticides also may reach water indirectly. This happens because of erosion, runoff, and leaching. In fact, most pesticide movement through air or soil ends up in water.

BENEFITS OF CAREFUL USE

Pesticides help the environment when they are used correctly. Most importantly, they can help produce better quality and higher yields of food, fiber, and timber by reducing damage from pests.

Weigh carefully the advantages and disadvantages of each pesticide use. If it is necessary to apply a pesticide choose the one that will do the least damage while giving good control. Finally, plan each part of the job carefully from beginning to end.

Be a responsible pesticide applicator.

SAFE USE PRECAUTIONS

Most parts of your job may involve some risk of pesticide injury:

- hauling pesticides,
- storage,
- mixing,
- calibrating equipment before use,
- loading,
- applying,
- repairing equipment,
- working in pesticide-treated crops and buildings,
- cleaning application equipment after use,
- disposing of surplus pesticides and empty containers,
- cleaning up spills, and
- cleaning protective clothing and equipment.

Some of these things are done indoors. Many are done outdoors. Each one requires some safety measures to prevent harm to people, animals, and plants as well as to the soil and water both inside and outside the target area.

You can prevent harm from pesticides if you follow safety precautions and use common sense. Here are the *minimum* safety steps you should take.

BEFORE YOU BUY A PESTICIDE

The first and most important step in choosing a pesticide is to know what pest you need to control. Then find out which pesticides will control it. You may have a choice among several. You may need help to guide you. Common sources of information are your Cooperative Extension Service, most agricultural schools, the U.S. Department of Agriculture, and pesticide manufacturers and dealers.

AT THE TIME OF PURCHASE

Read the label of the pesticide you intend to buy to find out:

- restrictions on use,
- if this is the correct chemical for your problem,
- if the product can be used safely under your conditions,
- environmental precautions needed,
- if the formulation and amount of active ingredient are right for your job,
- if you have the right equipment to apply the pesticide,
- if you have the right protective clothing and equipment, and
- how much pesticide you need.

BEFORE YOU APPLY THE PESTICIDE

Read the label again to find out:

- the protective equipment needed to handle the pesticide,
- the specific warnings and first aid measures,
- what it can be mixed with,
- how to mix it,
- how much to use,
- safety measures,
- when to apply to control the pest and to meet residue tolerances,
- how to apply,
- the rate of application, and
- special instructions.

TRANSPORTATION OF PESTICIDES

You are responsible for the safe transport of your pesticide.

- The safest way to carry pesticides is in the back of a truck. Fasten down all containers to prevent breakage and spillage.
- Keep pesticides away from food, feed, and passengers.
- Pesticides should be in a correctly labeled package.
- Keep paper and cardboard packages dry.
- If any pesticide is spilled in or from the vehicle, clean it up right away. Use correct cleanup procedures.
- Do not leave unlocked pesticides unattended. You are responsible if accidents occur.

PESTICIDE STORAGE

The label will tell you how to store the product.

As soon as pesticides arrive, correctly store them in a locked and posted place. Children and other untrained persons should not be able to get to them.

The storage place should keep the pesticides dry, cool, and out of direct sunlight. It should have enough insulation to keep the chemicals from freezing or overheating.

The storage place should have:

- fire-resistant construction, including a cement floor,
- an exhaust fan for ventilation,
- good lighting,
- a lock on the door, and
- warning signs on doors and windows

Keep the door locked when the building is not in use.

The storage building should be away from where people and animals live. This will avoid or minimize harm to them in case of fire.

Store all pesticides in the original containers. Do not allow labels to be removed or become unreadable.

Do not store pesticides near food, feed, seed, or animals.

Check every container often for leaks or breaks. If one is damaged, transfer the contents to a container that has held *exactly* the same pesticide. Clean up any spills correctly. Water, detergent, cleaning equipment and a fire extinguisher should be readily available.

Keep an up-to-date inventory of the pesticides you have.

MIXING AND LOADING PESTICIDES

Do all of your mixing and loading of pesticides away from ponds, streams, wells and other areas where water could be contaminated. When adding water to the spray tank, keep the opening of the filler hose or pipe well above the water level in the tank to prevent back-siphoning back into the water supply. An anti-siphon device on pipes or hoses, and particularly on well outlets, is a desirable added precaution. However, this is no substitute for constant observation to keep the hose or pipe above the water level and to avoid overfilling the tank to the extent that contaminated water spills out the filler opening of the tank.

Keep livestock, pets, and people out of the mixing and loading area.

Do not work alone, especially at night.

Work outdoors. Choose a place with good light and ventilation. Do not mix or load pesticides indoors or at night unless there is good lighting and ventilation.

Before handling a pesticide container, put on the correct protective clothing and equipment.

Each time you use a pesticide, read the directions for mixing. Do this before you open the container. *This is essential.* Directions, including amounts and methods, are often changed.

Do not tear paper containers to open them. Use a sharp knife. Clean the knife afterward, and do not use it for other purposes.

When taking a pesticide out of the container, keep the container and pesticide below eye level. This will avoid a splash or spill on your goggles or protective clothing. Do the same thing when pouring or dumping any pesticide.

If you splash or spill a pesticide while mixing or loading:

- Stop right away.
- Remove contaminated clothing.
- Wash thoroughly with detergent and water. *Speed is essential.*
- Clean up the spill.

When mixing pesticides, measure carefully. Use only the amount called for on the label. Mix only the amount you plan to use.

When loading pesticides, stand so the wind blows across your body from the right or left to avoid contaminating yourself.

To prevent spills, replace all pour caps and close containers after use.

Closed handling systems nearly eliminate exposure to pesticide liquid concentrates when transferring the concentrate from the container to the spray tank. The use of these systems is limited by their relative unavailability and the lack of uniformity among pesticide containers. Some solid pesticides are available in water soluble containers that can be placed in the spray without being opened and thereby reducing the chance of exposure.

PESTICIDE APPLICATION

Wear the correct protective clothing and equipment.

To prevent spillage of chemicals, check all application equipment for:

- leaking hoses, pumps, or connections, and
- plugged, worn, or dripping nozzles.

Use water to correctly calibrate spray equipment before use. Before starting an indoor or field application, clear all people, pets or livestock and objects such as clothing, toys or dishes that would present a contamination problem from the area to be treated.

Structures should be well ventilated during indoor applications unless labeling instructions call for a closed structure. Many pesticides and solvents that are used indoors are highly flammable and should not be placed or used near excessive heat or open flames, including pilot lights on ranges and other appliances.

REDUCE DRIFT

Drift is the movement of spray droplets or dust particles away from the target area. Drift increases:

- as droplet or particle size decreases, and
- as wind speed increases.

It can be minimized if you:

- spray at low pressure,
- use the largest practical nozzle openings,
- spray during the calmer parts of the day,
- avoid air currents from fans and heating or air conditioning outlets,
- use a method of application or formulation that results in less drift.

Vaporization is the evaporation of an active ingredient during or after application. Pesticide vapors can cause injury far from the site of application. High temperatures increase vaporization. You can reduce vaporization by:

- choosing nonvolatile chemical formulations, and
- spraying in the cooler parts of the day.

REDUCE RUN-OFF

Run-off occurs when water or another liquid flows off a field or another surface. Pesticides can leave the target area by being dissolved or suspended in the run-off liquid or attached to soil particles or other debris from the treated surface. *Leaching* occurs when water or some other liquid seeps through soil or some other medium. In some instances wells and ground water can be contaminated with pesticides, especially water soluble ones, through leaching. You can reduce the amount of pesticide that leaves the target through run-off or leaching by:

- not making outdoor applications immediately preceding expected rainfall. The treated surface should have had time to dry off before the rain begins.
- not applying a spray to the point of excessive run-off.
- avoiding excessive irrigation.
- using insoluble pesticides in critical situations.

MINIMIZE EFFECT OF OFF-TARGET PESTICIDES

You must do your best to reduce the amount of pesticide that leaves the target area. However, you should realize that some of this is inevitable and you should minimize the hazard by:

- maintaining a reasonable buffer zone from sensitive areas such as unprotected people and animals, residences, public facilities, water and wells, non-target crops, etc.
- notifying occupants or owners of sensitive areas before application.
- spraying when the wind is blowing away from sensitive areas.
- spraying when nearby roads, schools, churches, houses etc. are unoccupied.
- using a pesticide that is less hazardous in a particular situation.
- avoiding planting a crop that requires high pesticide use in a sensitive environment.

PROTECT HONEYBEES

There are two important reasons to protect honeybees. They are a source of income for the beekeeper and they are essential as pollinators in the production of many valuable fruits and vegetables. Where there is danger of killing bees you should:

- use a pesticide that is least toxic to bees, especially on flowering plants that attract bees.
- use the least hazardous method of application. Granules are usually harmless. Sprays are less likely to drift into bee sensitive areas than dusts are. In general, avoid encapsulated pesticides as bees are likely to take capsules back to the hive.
- time pesticide applications. Do not apply pesticides when honeybees are active in a crop. Applications in the late afternoon or night are least likely to harm bees. Do not apply pesticides when plants are in flower unless absolutely necessary.
- avoid pesticide drift into apiaries or areas where crops or wild plants are flowering. Plant crops that require heavy pesticide applications in non-sensitive areas.
- notify nearby beekeepers several days before you apply a pesticide.

CLEANING EQUIPMENT

Mixing, loading, and application equipment must be cleaned as soon as you finish using it. Clean both the inside and outside, including nozzles. Only trained persons should do this job. They should wear correct protective clothing.

Sometimes you may need to steam clean equipment or use special cleaning agents. In other cases, hot water and detergent may be enough.

Have a special area for cleaning. It is best for the area to have a wash rack or concrete apron with a good sump. This will catch all contaminated wash water and pesticides. Dispose of sump wastes by burning or burial as you would excess pesticides. Keep drainage out of water supplies and streams.

Equipment sometimes must be repaired before it is completely cleaned. Warn the person doing the repairs of the possible hazards.

DISPOSAL

Many pesticide applicators may be required to dispose of pesticide containers, excess pesticide and excess pesticide dilutions according to regulations under the Federal Resources Conservation and Recovery Act. They should check with their EPA regional headquarters and state enforcement agencies. Farmers are exempt from these regulations if they triple rinse containers and dispose of pesticide residues on their own farms according to instructions on the pesticide label.

EXCESS PESTICIDES

EPA recommends ways to dispose of excess pesticides. Consult local authorities for procedures in your area. If you have excess pesticides:

- Use them up as directed on the label.
- Burn them in a specially designed pesticide incinerator if they are organic and do not contain mercury, lead, cadmium or arsenic.
- If you do not have access to proper facilities for burning, or if the pesticides contain mercury, lead, cadmium or arsenic or they will not burn, bury them in a specially designated landfill.
- If you cannot either burn or bury them right away, store the pesticides until you can.

These recommendations also tell you how to dispose of excess diluted liquid pesticides. Add these and rinse liquids to spray mixtures in the field when you can. If you cannot use excess diluted pesticides, follow the disposal instructions for excess pesticides.

CONTAINERS

To prepare containers for disposal:

1. Empty the container into the spray tank. Let it drain an extra 30 seconds.
2. Fill it one-fifth to one-fourth full of water.
3. Replace the closure and rotate the container. Upend the container so the rinse reaches all the side surfaces.
4. Drain the rinse water from the container into the tank.
5. Repeat steps 2 through 4 at least two more times for a total of three rinses.

Remember to empty each rinse solution into the spray tank.

The EPA recommendations divide containers into three groups. They tell you how to dispose of each kind. You should also check the label for disposal instructions.

Group I Containers - These are containers which will burn, and:

- held organic or metallo-organic pesticides, but not organic mercury, lead, cadmium, or arsenic compounds.

Here are ways to dispose of them:

- You may burn them in a special pesticide incinerator.
- You may bury them in a specially designated landfill.
- You may burn small numbers of them as directed by state and local regulations.
- You may bury them singly in open fields. Bury them at least 18 inches below the surface. Be careful not to pollute surface or subsurface water.

Group II Containers - These are containers which will *not* burn, and:

- held organic or metallo-organic pesticides, but not organic mercury, lead, cadmium, or arsenic compounds.

Here are ways to dispose of them:

- Rinse the containers three times.
- Many large containers in good shape can be re-used by your supplier. Return them to the pesticide manufacturer or formulator, or drum reconditioner.
- You can send or take them to a place that will recycle them as scrap metal or dispose of them for you.
- All rinsed containers may be crushed and buried in a sanitary landfill. Follow state and local standards.
- You may bury them in the field.

If the containers have not been rinsed:

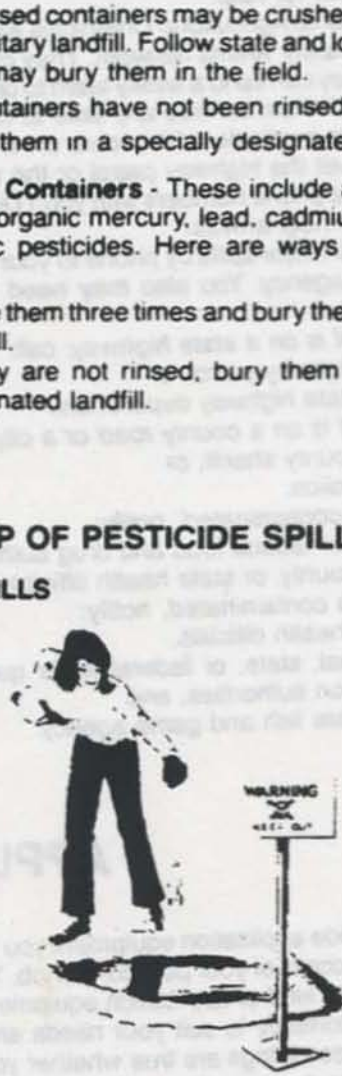
- Bury them in a specially designated landfill.

Group III Containers - These include any containers which held organic mercury, lead, cadmium, or arsenic, or inorganic pesticides. Here are ways to dispose of them:

- Rinse them three times and bury them in a sanitary landfill.
- If they are not rinsed, bury them in a specially designated landfill.

CLEANUP OF PESTICIDE SPILLS

MINOR SPILLS



Keep people away from spilled chemicals. Rope off the area and flag it to warn people. Do not leave unless someone is there to warn of the danger.

If the pesticide was spilled on anyone, give the correct first aid.

Confine the spill. If it starts to spread, dike it up with sand or soil.

Use an absorbent material to soak up the spill. You can use soil, sawdust, or a special product made to do this. Shovel all contaminated material into a leakproof container for disposal. Dispose of it as you would excess pesticides. Do not hose down the area. This spreads the chemical.

Put something on the spill to stop the chemical action. You may be able to use common household bleach or a solution of lye or ammonia. If you are not sure what to use, call the chemical manufacturer. Always work carefully. Do not hurry.

Do not let anyone enter the area until the spill is all cleaned up.

MAJOR SPILLS

The cleanup job may be too big for you to handle. You may not be sure of what to do. In either case, keep people away, give first aid, and confine the spill. Then call the manufacturer for help.

The National Agricultural Chemicals Association has a Pesticide Safety Teams Network. They can tell you what to do. Or they can send a safety team to clean up the spill. You can call them toll-free any time at (800) 424-9300.

If a major pesticide spill occurs on a highway, have someone call the highway patrol or the sheriff for help. (Carry these phone numbers with you.) Do not leave until responsible help arrives.

Report all major spills by phone to your state pesticide regulatory agency. You also may need to notify other authorities:

If the spill is on a state highway, call:

- the highway patrol, or
- the state highway department.

If the spill is on a county road or a city street, call:

- the county sheriff, or
- city police.

If food is contaminated, notify:

- state or federal food and drug authorities, or
- city, county, or state health officials.

If water is contaminated, notify:

- state health officials,
- regional, state, or federal water quality or water pollution authorities, and
- the state fish and game agency.

REENTRY TIMES

It may be hazardous to enter an area soon after a pesticide has been applied. Reentry times and other protective measures for workers in the agricultural environment are set forth in federal regulations. Here is a summary of the regulations:

Workers and other persons, except those knowingly involved in applying a pesticide, must be vacated from the field or area during application.

No worker who is not wearing protective clothing shall be permitted to enter a treated field or area until sprays have dried or dusts have settled. Some pesticides require a longer reentry time. Ethyl parathion, methyl parathion, demeton (Systox), Azodrin, carbophenothion (Trithion), MetaSystox-R, Bidrin and endrin have reentry times of 48 hours. Guthion, phosalone (Zolone), EPN and ethion have reentry times of 24 hours. The labels of other pesticides may contain reentry times, also. In addition to these requirements, workers must not be permitted in treated areas if special circumstances indicate a hazard. Protective clothing means at least a hat, long-sleeved shirt and longlegged pants or coveralls of closely woven fabric, shoes and socks.

Workers must be adequately warned about areas or fields which cannot be entered without protective clothing, how long they should be vacated and what to do if accidentally exposed.

If labeling instructions and restrictions are followed, public pest control programs, greenhouse treatments, animal treatments and non-agricultural uses are exempt from these regulations.

Some states or localities have more stringent and more inclusive standards than those in the federal regulations. You should check with state and local authorities.

Although the federal regulations are meant only for the agricultural environment the general principles set forth, along with labeling instructions and restrictions, should serve as a useful guideline in non-agricultural situations. Remember that these are minimum requirements and that additional measures may be necessary or desirable. For instance, even though a person is wearing protective clothing he should not be permitted in a treated area before the reentry time has elapsed unless it is required by his assigned task.

APPLICATION EQUIPMENT

The pesticide application equipment you use is important to the success of your pest control job. You must first select the right kind of application equipment. Then you must use it correctly to suit your needs and take good care of it. These things are true whether you use hand-carried, tractor-drawn, self-propelled, or aircraft-mounted equipment. Here are some things you should know about choosing, using, and caring for equipment.

SPRAYERS AND OTHER LIQUID APPLICATORS

Your sprayer or other liquid applicator should be:

- designed to do the job you want to do,
- designed to minimize hazards to man and the environment.

- durable, and
- convenient to fill, operate, and clean.

MANUALLY OPERATED SPRAYERS

Hand operated sprayers are for professional application of pesticides in structures and for spot treatments. They can be used for small jobs around the home and garden. You can use them in restricted areas where a power unit would not work. They range in size from hand held sprayers of less than one pint capacity to wheelbarrow sprayers that hold 25 gallons or more.

Advantages
- economical
- simple
- easy to use, clean, and store

Limitations
- frequent lack of good agitation and screening for wettable powders. Keep WPs in suspension by shaking the sprayer.
- impractical for treating larger areas

Certain types of manually operated sprayers present special hazards. Spray liquid may spill from the top of *knapsack* or *backpack* sprayers onto the applicator. *Hose end sprayers*, which operate by siphoning pesticide into a stream of water from a garden hose can back-siphon pesticides into water pipes and water supplies if not handled properly. *Pressurized aerosol cans* (aerosol bombs) can explode if exposed to excessive heat.

SMALL POWER SPRAYERS

These range from electric spray guns with tanks that hold less than a quart of spray liquid to gasoline engine powered estate sprayers that have 50 gallon tanks. They require less labor than hand sprayers in jobs where a larger sprayer would be impractical because of inaccessibility or economic considerations.

LOW PRESSURE FIELD SPRAYERS

These sprayers are designed to deliver low to moderate volume at 15 to 50 psi. Most of them are used for treating field and forage crops, pastures, fence rows, and structures. They also may be used to apply fertilizer-pesticide mixtures.

Advantages
- medium to large tanks
- low cost
- lightweight
- versatility
- usually result in less drift than high pressure sprayers

Limitations
- low gallonage output limits their use when high volume is required
- low pressure limits pesticide penetration
- agitation is usually limited

HIGH PRESSURE SPRAYERS

These are often called hydraulic sprayers. They are designed to deliver large volumes at high pressure. They are used to spray fruits, vegetables, trees, landscape plants, and livestock. When fitted with the correct pressure regulators, they can be used at low pressures. Applications usually are made at high gallonages (usually 100 or more per acre). Even though very large tanks are used, they may need to be filled often.

Advantages
- well built
- usually have mechanical agitation
- last a long time even when using wettable powders

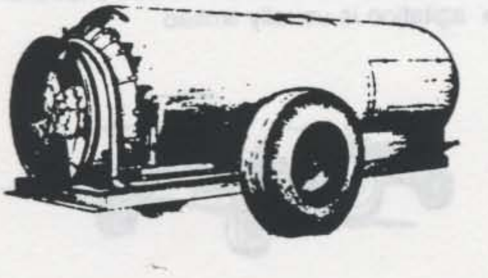
Limitations
- high cost
- large amounts of water, power, and fuel needed
- high tire loads
- high pressure which makes a spray that drifts easily

AIR BLAST SPRAYERS

These units use a high speed, fan-driven air stream to break the nozzle output into fine drops which move with the air stream to the target. The air is directed to either one or both sides as the sprayer moves forward. These sprayers are used in applying pesticides to landscape plants, fruits, and vegetables, and for biting fly control. Most air blast sprayers can be adapted to apply either high or low volumes of spray.

Advantages
- good coverage and penetration
- low pump pressures
- mechanical agitation

Limitations
- drift hazards
- chance of overdosages
- difficult to use in small areas
- hard to confine discharge to limited target areas



MIST BLOWERS

Mist blowers are air blast sprayers that are designed to apply lower volumes of more highly concentrated sprays. Mist blowers tend to be smaller than conventional air blast sprayers, some being small enough to be carried and operated by one person. Others must be mounted on a truck or pulled by a tractor.

Advantages
- water, time and fuel requirements low
- more maneuverable than conventional airblast sprayers
- some types can project sprays to great heights

Limitations
- drift hazard increased
- greater hazard to operator from high concentrations
- poor agitation in tanks of some units
- air currents more disruptive to spray pattern

AEROSOL GENERATORS AND FOGGERS

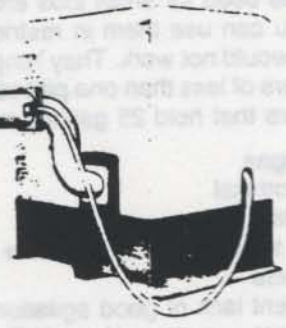
These applicators are used in situations where it is desirable to fill an air space, including cracks, crevices and dense foliage, with many tiny droplets of pesticide and leave little if any residue on exposed surfaces.

Aerosol generators work by using:
- atomizing nozzles,
- spinning disks, and
- small nozzles at high pressure.

Fogs are usually generated by thermal generators using heated surfaces.

Advantages
- usually no residue problems
- efficient distribution of liquid pesticides in enclosed spaces
- efficient distribution of liquid pesticides into cracks, crevices and dense foliage
- some devices automatic in operation

Limitations
- aerosols and fogs extremely sensitive to drift
- repeated application needed to maintain effectiveness
- risks of explosion in enclosed areas



SELECTION

Choose an aerosol generator according to where you will use it—indoors or outdoors. Aerosol and fog generators are manufactured for many special uses. Truck- and trailer-mounted machines are for use outdoors. Most hand-operated or permanently mounted automatic machines are for use indoors.

USE AND MAINTENANCE

In general, use and care for an aerosol generator as you would a sprayer. They do require special precautions. Be sure that the pesticides used in them are registered for such use. Keep them on the target. Because of the effects of weather conditions during application, follow special use instructions. The operator, other humans, and animals must be kept out of the fog or smoke cloud.

ULTRA LOW VOLUME (ULV) SPRAYERS

Deliver undiluted pesticides or highly concentrated sprays from the air, on the ground, or in buildings. In outdoor applications, one-half gallon or less of spray per acre is considered to be ULV.

Advantages
- little if any water or other diluent is needed
- equal control with less pesticide
- faster
- fuel use reduced

Limitations
- does not provide for thorough wetting
- hazards of using high concentrates
- chance of overdosage
- small number of pesticides that can be used this way

ELECTROSTATIC APPLICATORS

Specially designed nozzles are fitted with electrodes that place an electrical charge on spray droplets. The charged droplets repel each other to produce a better spray pattern and are also attracted to plants, and other grounded targets, thereby enhancing pesticide deposition. The end result is less drift and better coverage, including the underside of leaves.

Advantages
- less drift
- better coverage
- less pesticide required

Limitations
- costly
- not readily available
- operation complicated
- not adaptable to most types of sprayers at present

SPINNING DISC APPLICATORS

These applicators introduce the spray liquid onto a rapidly spinning disc that breaks it up into uniform sized droplets by centrifugal force. Droplet size can be changed by varying the speed of the disc. This nozzle system can be used on handheld sprayers that contain a single unit as well as larger sprayers that contain several units.

Advantages
- uniform droplet size
- no small nozzle openings to clog
- pumps and other equipment required for high pressures not needed

Limitations
- high cost
- not suitable for windy conditions
- not adaptable to all types of applications

SWABBING APPLICATORS

The diluted pesticide is squirted or sprayed onto ropes, pads, rollers or sheets of an absorbent material which is being dragged over vegetation. The pesticide is wiped onto the vegetation. These applicators are used to apply herbicides to weeds that extend above the crop plant.

Advantages
- no drift
- reduces amount of pesticide used
- herbicide damage to non-pest plants unlikely

Limitations
- limited uses
- difficult to calibrate

CHEMIGATION

Chemigation is a process in which the pesticide is metered into the water stream and applied during irrigation. It is a very economical application method when irrigation is needed, but if not done properly poses a great risk to health and to the environment from run-off, leaching from the target and back-siphoning into the water supply. Both the injector and the irrigation line must be properly equipped with anti-siphoning devices as well as automatic shut-off valves and switches, and the operation must be closely watched. Chemigation has been utilized in center pivot overhead irrigation and drip irrigation.

Advantages
- combines farming operations to reduce labor, fuel and equipment costs
- may reduce drift problems
- phytotoxicity hazard reduced because of dilution
- better penetration of pesticide into soil

Limitations
- usually requires special pesticide formulations or additives
- some pesticides not suitable
- needs more research for adaptability to specific pests, crops and cropping practices

SPRAYER PARTS

TANKS

Tanks should have large openings for easy filling and cleaning. They should allow straining during filling and have mechanical or hydraulic agitation. The tank should be made of corrosion-resistant material such as stainless steel or glass reinforced plastic. If not, it should have a protective plastic lining or coating. The tank should have a good drain. The outlets should be sized to the pump capacity. If you use dual tanks, make sure the plumbing allows for agitation and adequate withdrawal rates in both tanks. All tanks should have a gauge to show the liquid level.

Flush out the tank, pump, lines, and nozzles after each day's use and each separate pesticide use. If switching to another pesticide where contamination must be prevented, wash out with detergent and water two or three times and then flush with water. Phenoxy herbicides such as 2,4-D are hard to remove. After using them, either follow the special cleaning procedures noted on the pesticide label or avoid using the same sprayer for any other product. Keep tank clean inside and out. Tighten or repair all leaky tank seals or fittings. Make sure sight gauges can be read.

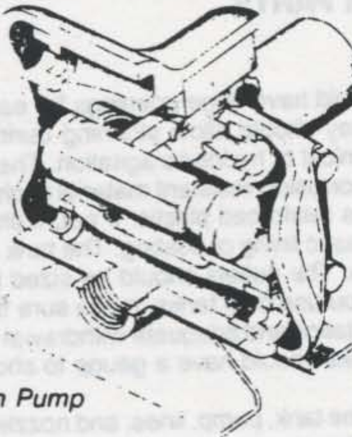
PUMPS

The pump must be adequate for all the spraying pressures you use. It must provide enough flow to:
- supply all nozzles,

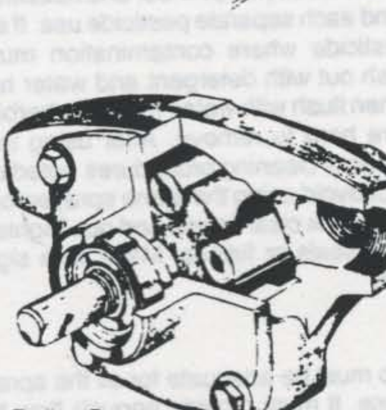
Centrifugal Pump

- allow for hydraulic agitation when needed, and
- leave a reserve to allow for loss of flow due to wear.

Pumps should resist corrosion and abrasion. Centrifugal pumps provide high volume at low pressure. They are not self-priming. Piston and diaphragm pumps provide moderate to high volumes at high pressure. They are self-priming. Roller and gear pumps provide moderate volume at low to moderate pressure. They are self-priming in most equipment. Do not use wettable powder formulations in gear pumps. If you need pressures above 75 psi, piston pumps are more likely to provide them over a long period of time.



Piston Pump



Roller Pump

You will damage a pump if you operate it dry or with a restricted inlet. Follow the manufacturer's recommendations for pump operation. Keep all shields in place.

STRAINERS (FILTERS)

Proper filtering of the pesticide:

- protects the working parts of the sprayer, and
- avoids time loss and misapplication due to clogged nozzle tips.

Filtering should be progessive, with the largest mesh screen in the suction line between the tank and the pump. Put a smaller mesh screen in the high pressure line between the pump and the pressure regulator. Put the finest mesh screen nearest the nozzles. Do not use a screen in the suction line of a centrifugal pump.

Clean strainers after each use. Replace them if you see deterioration. Strainers are your best defense against nozzle and pump wear and nozzle clogging. Use nozzle screens as large as nozzle sizes permit. Screen opening should be less than nozzle opening.

Strainer

HOSES

Select synthetic rubber or plastic hoses that:

- have burst strength greater than the peak operating pressures,
- resist oil and solvents present in pesticides, and
- are weather-resistant.

Suction hoses should resist collapse. They should be larger than pressure hoses. All fittings on suction lines should be as large as or larger than the line itself.

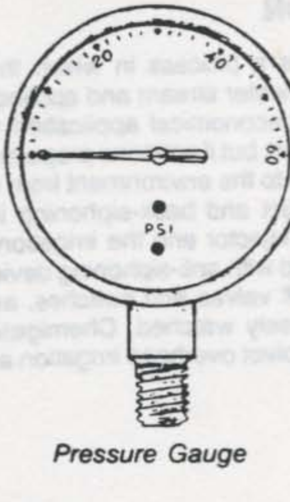
Keep hoses from kinking or being rubbed. Rinse them often, inside and outside, to prolong life. Remove and store hoses during off season, or at least store unit out of sun. Replace hoses at the first sign of surface deterioration.

Hose

PRESSURE GAUGES

These serve as the monitors of your spraying job. They must be accurate and have only the range needed for your work. For example, a 0-60 psi gauge with 2-pound gradations would be enough for most low pressure sprayers.

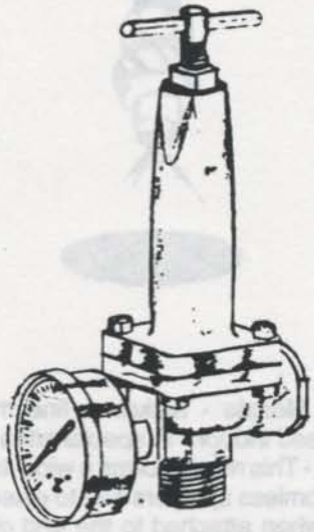
Check frequently for accuracy against an accurate gauge. Do not use them under too much pressure. Keep glass faces clean and intact. Use gauge protectors to protect against corrosive pesticides and pressure surges.



Pressure Gauge

PRESSURE REGULATORS

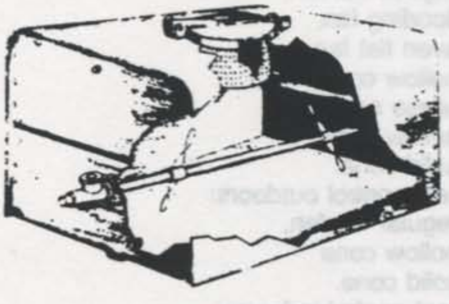
The pressure regulator must have a working range that is about the same as the range of pressure you plan to use.



Pressure Regulator

AGITATORS

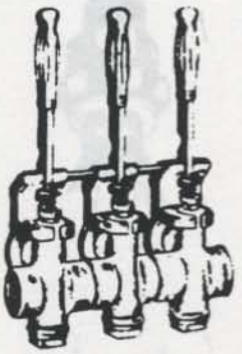
Make sure your sprayer has enough agitation. If it does not, your pesticide application rate may vary greatly as the tank is emptied. Bypass agitation may be good enough for solutions and emulsions. Use a jet agitator or mechanical agitator for wettable powders. Mechanical agitation is the surest way to get good agitation. It is expensive initially and is harder to maintain. Hand sprayers must be shaken frequently.



Agitator

CONTROL VALVES

These should be large enough so as not to restrict flow. They should be easy for you to reach. On-off action should be quick and positive. You need to be able to cut off all flow or flow to any section of the spraying system. There are many different kinds of control valves. Be sure you know how to operate and maintain the ones on your equipment.



Valve

NOZZLES

The nozzle helps control the rate and pattern of distribution. These things depend on:

- the nozzle design or type,
- its operating pressure,
- the size of the opening,
- its discharge angle, and
- its distance from the target.

Nearly all nozzles share the disadvantage of producing droplets that vary more in size than is desirable for most uses. Larger droplets do not provide adequate distribution; smaller droplets drift or fail to reach the target.

There are six basic nozzle types. They are:

Solid Stream - A type used in handguns to spray a distant target and for crack and crevice treatment in buildings. Also a type used in a nozzle body to apply pesticides in a narrow band or inject them into the soil.

Flat Fan - There are three types of flat fan nozzles:

- The regular flat fan nozzle makes a narrow oval pattern with lighter edges. It is used for broadcast spraying. This pattern is designed to be used on a boom and to be overlapped 30 to 50 percent for even distribution.

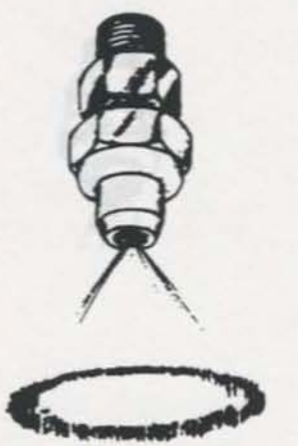
- The even flat fan nozzle makes a uniform pattern across its width. It is used for band spraying and for treating walls and other surfaces.

- The flooding nozzle makes a wide-angle flat spray pattern. It works at lower pressures than the other flat fan nozzles. Its pattern is fairly uniform across its width. It is used for broadcast spraying.

Hollow Cone - There are two types of hollow cone nozzles:

- the core and disk, and
- the whirl chamber.

The pattern is circular with tapered edges and little or no spray in the center. It is used for spraying foliage.



Solid Cone - This nozzle produces a circular pattern. The spray is well-distributed throughout the pattern. It is used for spraying foliage.

Atomizing Nozzle - Makes a fine mist from liquid pesticides. Used indoors in special situations.

Broadcast - This nozzle forms a wide flat fan pattern. It is used on boomless sprayers and to extend the effective swath width when attached to the end of a boom.

Many spraying jobs could be done by more than one nozzle type or pattern. Here are some general guidelines.

For weed control:

- regular flat fan,
- flooding fan,
- even flat fan,
- hollow cone.

For disease control:

- hollow cone,
- solid cone.

For insect control outdoors:

- regular flat fan,
- hollow cone
- solid cone.

For insect control indoors:

- even flat fan,
- solid stream,
- atomizing.

To minimize drift:

- flooding fan,
- whirl chamber hollow cone,
- keep operating pressures below 30 psi.

You can get nozzles in many materials. Here are the main features of each kind.

Brass:
- inexpensive,
- wears quickly from abrasion,
- probably the best material for limited use.

Stainless steel:
- will not corrode,
- resists abrasion, especially if it is hardened.

Plastic:
- resists corrosion and abrasion.
- swells when exposed to some solvents.

Aluminum:
- resists some corrosive materials,
- is easily corroded by some fertilizers.

Tungsten carbide and ceramic:
- highly resistant to abrasion and corrosion,
- expensive.

Keep nozzles in good working condition. For most boom applications, select nozzles of uniform type and size.

Nozzle caps should not be over-tightened. Adjust nozzle distance and spacing to suit the target. Follow the nozzle manufacturer's instructions and the pesticide label. Allow for crop or weed height if necessary. Check each nozzle for uniform flow using water and a jar marked in ounces. Replace any whose flow is five percent more or less than the average. Replace any nozzles having faulty spray patterns. A good check is to spray on asphalt pavement. Watch for streaks as you increase speed or as spray dries.

Clean nozzles only with a toothbrush or wooden toothpick.

OPERATION AND MAINTENANCE

Always read and follow the operator's manuals for all your spray equipment. They will tell you exactly how to use and care for it. After each use, rinse out the entire system. Remove and clean nozzles, nozzle screens, and strainers. Check for leaks in lines, valves, seals, and tank both after filling with water and during running.

Be alert for nozzle clogging and changes in nozzle patterns. If nozzles clog or other trouble occurs in the field, be careful not to contaminate yourself while correcting the problem. Shut off the sprayer and move it to the edge of the field before dismounting. Wear protective clothing while making repairs.

Store sprayers correctly after use. But first, rinse and clean the system. Then fill tank almost full with clean water. Add a small amount of new light oil to the tank. Coat the system by pumping tank contents out through nozzles or handgun. Drain the pump and plug its openings or fill the pump with light oil or antifreeze. Remove nozzles and nozzle screens and store in light oil or diesel fuel.

DUSTERS AND GRANULAR APPLICATORS

HAND DUSTERS

Like hand operated sprayers, hand dusters are for professional use in structures and can be used in gardens. They may consist of a squeeze bulb, bellows, tube, or shaker, a sliding tube, or a fan powered by a hand crank.

Advantages
- the pesticide is ready to apply
- good penetration in confined spaces

Limitations
- high cost for pesticide
- hard to get good foliar coverage
- dust is subject to drifting

POWER DUSTERS

Power dusters use a powered fan or blower to propel the dust to the target. They range from knapsack or backpack types to those mounted on or pulled by tractors. Their capacity in area treated per hour compares favorably with some sprayers.

Advantages
- simply built
- easy to maintain
- low in cost

Limitations
- drift hazards
- high cost of pesticide
- application may be less uniform than with sprays

SELECTING A DUSTER

Look for a power duster that is easy to clean. It should give a uniform application rate as the hopper is emptied. Look for both hand and power dusters that keep the dust cloud well away from the user.

GRANULAR APPLICATORS

These include:
- hand-carried knapsack and spinning disk types for broadcast coverage,
- mounted equipment for applying bands over the row in row crops, and
- mounted or tractor-drawn machines for broadcast coverage.

Advantages
- eliminates mixing
- is low in cost
- minimizes drift
- is less hazardous to applicator

Limitations
- high cost for pesticide
- limited use against some pests because granules won't stick to most plants
- need to calibrate for each granular formulation
- poor lateral distribution, especially on side slopes

SELECTING A GRANULAR APPLICATOR

Choose a granular applicator that is easy to clean and fill. It should have mechanical agitation over the outlet holes. This will prevent bridging and keep flow rate constant. Application should stop when drive stops even if outlets are still open.

USE AND MAINTENANCE OF DUSTERS AND GRANULAR APPLICATORS

Both dusters and granular applicators are speed-sensitive, so maintain uniform speed. Do not travel too fast for ground conditions. Bouncing equipment will cause the application rate to vary. Stay out of any dust cloud that may form.

Watch banders to see that band width stays the same. Small height changes due to changing soil conditions may cause rapid changes in band width.

Clean equipment as directed by the operator's manual.

FUMIGANT APPLICATORS

This equipment is of two types:
- that needed to handle low pressure fumigants, and
- that needed to handle high pressure fumigants which are kept liquid only by storage in pressure vessels.

The low pressure fumigators are gravity or pump fed units. Most high pressure units use the pressure generated by the fumigant or a compressed gas to force the fumigant into the soil or space being fumigated.

SELECTION

Choosing equipment to apply low pressure fumigants is similar to choosing a low pressure sprayer. But corrosion-resistant pumps, tanks, fittings, nozzles, and lines are essential. Some metals such as aluminum, magnesium, potassium and sodium and their alloys react violently with certain fumigants. High pressure fumigators must be able to withstand the internal pressure created by the fumigant. Select equipment with pressure or flow regulators that assure constant delivery rates.

USE AND MAINTENANCE

Keep the units in good repair. Make sure there are no leaks. Replace hoses and fittings as soon as you see signs of deterioration. Lines and fittings should not be located near the operator. Empty all lines after application. To avoid contamination and corrosion, flush the units after use. Carefully follow all precautions on the fumigant label.

SPECIALIZED EQUIPMENT

Some types of application equipment are too specialized and not generally enough used to be included in this manual. Where appropriate, their care and use will be discussed in commercial category certification manuals. Otherwise those using such equipment should consult operator manuals, dealer's and manufacturer's representatives and qualified individuals such as Cooperative Extension Service workers.

CALIBRATION

Calibration is simply adjusting your equipment to apply the desired rate of pesticide. You need to do this so that you can be sure you are using each pesticide as directed on the label. Too much pesticide is dangerous; too little will not do a good job. Only by calibrating correctly can you safely get the best results.

There are many ways to calibrate equipment. The preferred methods differ according to the kind of equipment you use. Your Cooperative Extension Service personnel can show you how to calibrate your equipment. Here is one basic method for sprayers and another for dusters and granular applicators.

SPRAYERS

To apply a pesticide evenly and accurately, your sprayer must move at a constant speed. It also must operate at a constant pressure. Each nozzle must be clean and at the right height. All nozzles must be of the correct type and size for the job. Each nozzle in the system must deliver its rated amount of pesticide.

If you have made the correct choice of nozzles, pressure and speed for the job, the amount of liquid that you apply per acre or other unit of treated area will almost always fall within an acceptable range. As long as the concentration of pesticide does not exceed that permitted by the label and the right amount of pesticide is evenly distributed on the treated surface the amount of total spray liquid that you apply is usually unimportant. Precise calibration is necessary if the pesticide product is not intended for dilution. Otherwise your primary goal in calibrating a sprayer is to determine the exact amount of pesticide that should be added to the tank in order to apply the recommended amount of pesticide per acre or other designated unit of treated area.

First, choose the speed, pumping pressure, and nozzle or nozzles that you want to use. Fill the spray tank with water and operate the sprayer in place to fill the plumbing. Top off the tank and spray a measured area as if you were applying the pesticide. Measure the amount of water needed to refill your tank. This is the application rate per unit of area. If it takes 8 gallons to refill the tank after spraying one acre, you are spraying at the rate of 8 gallons per acre. If your sprayer has a tank of more than 100 gallons capacity, you should spray an area large enough to use at least 10 percent of the tank capacity.

If your sprayer is delivering more or less spray than the label directs, you can change the rate three ways:

- You can change the pressure. Lower pressure means less spray delivered; higher pressure means more spray delivered. This is not a good method, because a pressure change may change the nozzle pattern and droplet size. Pressure must be increased fourfold to double the output.

- You can change the speed of your sprayer. Slower speed means more spray delivered, faster speed means less spray delivered. This method is practical for small changes in delivery rate. If you drive half as fast, you double the delivery rate.

- You can change the nozzle tips to change the amount delivered. The larger the hole in the tip, the more spray delivered. This is the best method for making major changes in the delivery rate of sprayers. Always select nozzles for the job you want done. Use the manufacturer's performance charts to make your selection.

After making a change, you must recalibrate your sprayer to make sure the rate is correct.

You have adjusted your sprayer and you know how many gallons of spray per unit of area your equipment will apply. Next you must find out how much pesticide to put in the tank to apply the correct dosage of pesticide. To do this you need to know two more facts:

- How much your sprayer tank holds.
- The amount of formulation to be used per unit of area. This will be given on the label.

Suppose your tank holds 50 gallons of spray. The directions say to apply one pint of formulation on each acre. In our example, you found that your sprayer applies 8 gallons per acre. First find the number of acres one tank load will spray. Divide 50 gallons by 8.

$$\frac{\text{50 gallons per tankful}}{\text{8 gallons per acre}} = \text{6 1/4 acres per tankful}$$

To find the amount of formulation you must add to your tank so you can spray 6¼ acres with one pint per acre, multiply one pint by 6¼

1 pint per acre × 6 1/4 acres per tankful
= 6 1/4 pints per tankful.

Suppose you want to apply two pounds of a wettable powder per acre.

2 pounds per acre × 6 1/4 acres per tankful
= 12 1/2 pounds per tankful.

Add the proper amount of pesticide

You should add the 12½ pounds of wettable powder to a small amount of water in a clean bucket. Stir until it is mixed well and then add this mixture (called a slurry) to the partly filled tank. Remember to operate the sprayer's agitator while adding the slurry and filling the tank.

Even after your sprayer is calibrated, you should recheck it often. Be sure you are spraying the same size area for each tankful as you figured on. If you are spraying more or less acres than you planned, stop spraying and refigure the amount of pesticide per tankful or recalibrate. If you have figured wrong or your sprayer changes its delivery rate, you will be able to catch it before you make a major mistake.

Make a slurry

DUSTERS AND GRANULAR APPLICATORS

- Read the manufacturer's operator's manual. Follow these instructions to set the gate openings for the product you are going to use. CAUTION: always set the openings from the same direction, such as from closed to open. This will minimize variations in settings.
- Fill each hopper to an easily determined level.
- Operate the equipment over a measured area or distance at your normal working speed. The area should be large enough to use one-fourth of the hopper contents.
- Refill the hopper to the same level, weighing the amount of pesticide needed to replace what was used.
- The amount of pesticide it takes to refill the hopper is the amount applied to the measured area. If the amount applied does not fall within five percent of the recommended dosage per unit of area, reset the gate opening and repeat the previous three steps.
- Keep a record of the area treated with each filling of the hopper. This will let you see any slight change in rate of application and make the necessary adjustments.

LAWS AND REGULATIONS

Without pesticides, we would not have the food, fiber, and landscape plants we need. There would also be a great increase in the incidence of discomfort, sickness and deaths caused by pests and diseases transmitted by pests. But because pesticides can be dangerous, Congress has passed laws affecting pesticide use. These laws try to balance the need for pesticides against the need to protect people and the environment from their misuse.

FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE ACT (FIFRA), AS AMENDED

You are taking this training because of a law passed by Congress in 1972. It amended an already existing law, the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) of 1947, which primarily regulated only the registration and labeling of pesticide products that were being shipped from one state to another state. The 1972 law broadened FIFRA to regulate the registration and labeling, manufacture, transportation and use of pesticides as well as the disposal of excess pesticides and pesticide containers. FIFRA has been further amended by Congress several times since 1972. FIFRA as amended requires you to show that you know the correct way to handle pesticides.

Here are the parts of the law which concern you the most:

- It says that all pesticide uses must be *classified* as either general or restricted.
- It requires you to be *certified* as competent to use any of the pesticides classified for restricted use.
- It says that it is illegal, *"to use any registered pesticide in a manner inconsistent with its labeling."*
- It provides *penalties* (fines and jail terms) for people who do not obey the law.

Congress chose October 21, 1976, as the date for certification to go into effect. The Environmental Protection Agency (EPA), acting under federal law, has by regulation set minimum standards of competency for all commercial applicators. Your state has developed a plan for certification of competency that meets minimum national standards. The certification plan in your state is administered by a branch of your state government.

CLASSIFICATION OF PESTICIDES

Manufacturers must register every pesticide with EPA. By regulation, when each pesticide is registered, all its uses must be classified. EPA must decide whether each use is a general or a restricted one.

Under the law, pesticide uses that will damage the environment very little or not at all when done as the label directs can be classified as *general uses*.

Uses that could cause damage even when done as directed on the label must be classified as *restricted uses*. They may be carried out only:

- by someone who is certified, or
- under a certified person's supervision.

Some uses may be general under some conditions and restricted under others.

CERTIFICATION OF APPLICATORS

What is certification? It is proof that you know the safe and correct way to carry out restricted uses. Both private and commercial applicators will have to meet state and national standards. Your state has its own program for seeing that you meet these standards.

PRIVATE APPLICATOR

This is a certified applicator who uses or supervises the use of a restricted use pesticide to produce any agricultural commodity on personally owned or rented property or on property owned or rented by his or her employer. A private applicator may apply a restricted use pesticide on the property of another agricultural producer if it is done with no compensation other than an exchange of personal services. Some examples are: farmers, ranchers, Christmas tree growers, floriculturists and nurserymen.

COMMERCIAL APPLICATOR

Any certified applicator who uses or supervises the use of a restricted use pesticide and does not qualify as a private applicator is a commercial applicator. Individuals who use or supervise the use of restricted use pesticides for demonstration or research purposes as well as those who apply them to golf courses, lawns, landscape plants, etc., must be certified.

A commercial applicator can use or supervise the use of a restricted use pesticide only for uses within a category in which he or she is certified. EPA has designated ten categories of which one has two sub-categories. Categories designated by EPA are:

(1) Agriculture
  (i) *Plant*
  (ii) *Animal*
(2) Forest Pest Control
(3) Ornamental and Turf Pest Control
(4) Seed Treatment
(5) Aquatic Pest Control
(6) Right-of-Way Pest Control
(7) Industrial, Institutional, Structural and Health Related Pest Control
(8) Public Health Pest Control
(9) Regulatory Pest Control
(10) Demonstration and Research Pest Control

PROHIBITED ACTIONS

FIFRA as amended names many things you cannot do. These two concern you most:

- You may not use a pesticide other than as the label or labeling directs except when permitted by FIFRA as amended or by special regulations. As long as you otherwise follow the directions on the labeling, FIFRA allows you to:
  - apply a pesticide at any dosage, concentration or frequency less than that specified on the labeling.
  - apply a pesticide against any pest not listed on the labeling if the use is on a crop, animal or site that is listed and if the labeling does not prohibit use against an unlisted pest.
  - use any method of application which is not prohibited by the labeling.
  - mix a pesticide with a fertilizer if the mixture is not prohibited by the labeling.
- You may not dispose of any pesticide or its container except as the label or labeling directs.

You also should know your state and local laws. They may prohibit more actions than the federal law does.

The applicator is responsible for proper pesticide use.

PENALTIES

If you violate the FIFRA, you are subject to civil penalties. They can be as much as $5,000 for the commercial applicator and $1,000 for the private applicator for each offense. Before EPA can fine you, you have the right to ask for a hearing in your own city or county. Violations of the law may also subject you to criminal penalties. They can be as much as $25,000 or one year in prison, or both, for commercial applicators. They can be as much as $1,000 or 30 days imprisonment, or both, for private applicators.

OTHER FEDERAL REGULATIONS

TRANSPORTATION

Shipment of pesticides and other dangerous substances across state lines is regulated by the Federal Department of Transportation (DOT). DOT issues the rules for hauling these materials.

DOT standards tell you which pesticides:

- are dangerous to man, and
- create a health hazard during transportation.

If you ever haul pesticides between states, you should know that:

- they must be in their original packages. Each package must meet DOT standards.
- the vehicle must have a correct sign. Manufacturers must put the correct warning signs on each package.
- the pesticides may not be hauled in the same vehicle with food products.
- you must contact DOT right away after each accident
  a) when someone is killed,
  b) when someone is injured badly enough to go to a hospital, or
  c) when damage is more than $50.000.
- you must tell DOT about all spills during shipment.

State and local laws may require you to take additional precautions.

AERIAL APPLICATION

Application of pesticides from airplanes is also regulated by the Federal Aviation Administration (FAA) and may be regulated by your state. FAA judges:

- the flying ability of pilots, and
- the safety of their aircraft. FAA rules, too, say that an aerial applicator may not apply any pesticide except as the label directs.

WORKER SAFETY

The Occupational Safety and Health Act of 1970 is administered by the Occupational Safety and Health Administration (OSHA) in the Department of Labor (DOL). It requires anyone with 11 or more workers to keep records and make reports. The records must include all *work-related* deaths, injuries, and illnesses. Minor injuries needing only first aid treatment need not be recorded. But a record must be made if the injury involves:

- medical treatment,
- loss of consciousness,
- restriction of work or motion, or
- transfer to another job.

RESIDUES

The pesticide that stays in or on raw farm products or processed foods is called a *residue*. EPA sets residue *tolerances* under regulations authorized by the Federal Food, Drug, and Cosmetic Act. A tolerance is the concentration of a pesticide that is judged safe for human use. Residues in processed foods are considered to be food additives and are regulated a such.

Tolerances are expressed in "parts per million" (ppm). One ppm equals one part (by weight) of pesticide for each million parts of farm or food product. Using pounds as a measure, 50 ppm would be 50 pounds of pesticide in a million pounds of the product. The same pesticide may have a different tolerance on different products. It might be 50 ppm on grapes and 25 ppm on apples.

If too much residue is found on a farm or food product, the product may be seized or condemned.

The label will tell you how many days before harvest the pesticide may be applied. Follow the label exactly. Then you can be sure you are not breaking the law.

Residues

TERMS USED IN PEST CONTROL

Some of these words have several meanings. Those given here are the ones that relate to pest control.

Abrasion: The process of wearing away by rubbing.

Abscission: The separation of fruit, leaves, or stems from a plant.

Absorption: The process by which a chemical is taken into plants, animals, or minerals. Compare with *adsorption*.

Activator: A chemical added to a pesticide to increase its activity.

Adherence: Sticking to a surface.

Adjuvant: Inert ingredient added to a pesticide formulation to make it work better.

Adsorption: The process by which chemicals are held on the surface of a mineral or soil particle. Compare with *absorption*.

Adulterated: Any pesticide whose strength or purity falls below the quality stated on its label. Also, a food, feed, or product that contains illegal pesticide residues.

Aerobic: Living in air. The opposite of anaerobic.

Aerosol: An extremely fine mist or fog consisting of solid or liquid particles suspended in air. Also, certain formulations used to produce a fine mist.

Agitation: The process of stirring or mixing in a sprayer.

Alkaloids: Chemicals present in some plants. Some are used as pesticides.

Anaerobic: Living in the absence of air. The opposite of aerobic.

Animal Sign: The evidences of an animal's presence in an area.

Antagonism: The loss of activity of a chemical when exposed to another chemical.

Antibiotic: A substance which is used to control pest microorganisms.

Antidote: A substance used in practical treatment for poisoning, including first aid.

Aqueous: A term used to indicate the presence of water in a solution.

Arsenicals: Pesticides containing arsenic.

Aseptic: Free of disease-causing organisms.

Bait Shyness: The tendency for rodents, birds, or other pests to avoid a poisoned bait.

Bipyridyliums: A group of synthetic organic pesticides which includes the herbicide paraquat.

Botanical Pesticide: A pesticide made from plants. Also called plant-derived pesticides.

Broadleaf Weeds: Plants with broad, rounded, or flattened leaves.

Brush Control: Control of woody plants.

Carbamate: A synthetic organic pesticide containing carbon, hydrogen, nitrogen, and sulfur.

Carcinogenic: Can cause cancer.

Carrier: The inert liquid or solid material added to an active ingredient to prepare a pesticide formulation.

Causal Organism: The organism (pathogen) that produces a specific disease.

Chemosterilant: A chemical that can prevent reproduction.

Chlorinated Hydrocarbon: A synthetic organic pesticide that contains chlorine, carbon, and hydrogen. Same as organochlorine.

Chlorosis: The yellowing of a plant's green tissue.

Cholinesterase: A chemical catalyst (enzyme) found in animals that helps regulate the activity of nerve impulses.

Compatible: When two or more chemicals can be mixed without affecting each other's properties, they are said to be compatible.

Concentration: The amount of active ingredient in a given volume or weight of formulation.

Contaminate: To make impure or to pollute.

Corrosion: The process of wearing away by chemical means.

Crucifers: Plants belonging to the mustard family, such as mustard, cabbage, turnip, and radish.

Cucurbits: Plants belonging to the gourd family, such as pumpkin, cucumber, and squash.

Deciduous Plants: Perennial plants that lose their leaves during the winter.

Deflocculating Agent: A material added to a suspension to prevent settling.

Degradation: The process by which a chemical is reduced to a less complex form.

Dermal: Of the skin; through or by the skin.

Dermal Toxicity: Ability of a chemical to cause injury when absorbed through the skin.

Diluent: Any liquid or solid material used to dilute or carry an active ingredient.

Dilute: To decrease concentration by adding water, another liquid, or a solid.

Dispersing Agent: A material that reduces the attraction between particles.

Dormant: State in which growth of seeds or other plant organs stops temporarily.

Dose, Dosage: Quantity of a pesticide applied.

Emulsifier: A chemical which aids in mixing one liquid in another.

Emulsion: A mixture in which one liquid is suspended as tiny drops in another liquid, such as oil in water.

Fungistat: A chemical that keeps fungi from growing.

GPA: Gallons per acre.

GPM: Gallons per minute.

Growth Stages of Cereal Crops: (1) Tillering—when additional shoots are developing from the young plants. (2) Jointing—when stem internodes begin elongating rapidly. (3) Booting—when upper leaf sheath swells due to the growth of developing spike or panicle. (4) Heading—when seed head is emerging from the upper leaf sheath.

Hard (water): Water containing soluble salts of calcium and magnesium and sometimes iron. Alkaline water usually.

Herbaceous Plant: A plant that does not develop woody tissue.

Hydrogen-Ion Concentration: A measure of acidity or alkalinity, expressed in terms of the pH of the solution. For example, a pH of 7 is neutral, from 1 to 7 is acid, and from 7 to 14 is alkaline.

Immune: Not susceptible to a disease or poison.

Impermeable: Cannot be penetrated. Semipermeable means that some substances can pass through and others cannot.

Lactation: The production of milk by an animal, or the period during which an animal is producing milk.

LC50: The concentration of an active ingredient in air or water which is expected to cause death in 50 percent of the test animals so treated. It is generally expressed as milligrams or micrograms per liter, as parts per million (ppm) or as parts per billion (ppb).

LD50: The dose of an active ingredient taken by mouth or absorbed by the skin which is expected to cause death in 50 percent of the test animals so treated. It is usually expressed as milligrams per kilogram of the animal's weight. If a chemical has an LD50 of 10 milligrams per kilogram (mg/kg) it is more toxic than one having an LD50 of 100 mg/kg.

Leaching: Movement of a substance downward or out of the soil as the result of water movement.

Mammals: Warm-blooded animals that nourish their young with milk. Their skin is more or less covered with hair.

Miscible Liquids: Two or more liquids that can be mixed and will remain mixed under normal conditions.

MPH: Miles per hour.

Mutagenic: Can produce genetic change.

Necrosis: Localized death of living tissue such as the death of a certain area of a leaf.

Necrotic: Showing varying degrees of dead areas or spots.

Nitrophenols: Synthetic organic pesticides containing carbon, hydrogen, nitrogen, and oxygen.

Noxious Weed: A plant defined as being especially undesirable or troublesome.

Oncogenic: Can cause tumors.

Oral: Of the mouth; through or by the mouth.

Oral Toxicity: Ability of a pesticide to cause injury when taken by mouth.

Organic Compounds: Chemicals that contain carbon.

Organochlorine: Same as chlorinated hydrocarbon.

Organophosphate: A synthetic organic pesticide containing carbon, hydrogen, and phosphorus; parathion and malathion are two examples.

Ovicide: A chemical that destroys eggs.

Pathogen: Any disease-producing organism.

Penetration: The act of entering or ability to enter.

Phytotoxic: Harmful to plants.

Pollutant: An agent or chemical that makes something impure or dirty.

PPB: Parts per billion. A way to express the concentration of chemicals in foods, plants, and animals. One part per billion equals one pound in 500,000 tons.

PPM: Parts per million. A way to express the concentration of chemicals in foods, plants, and animals. One part per million equals 1 pound in 500 tons.

Predator: An animal that destroys or eats other animals.

Propellant: Substance in self-pressurized pesticide products that forces the active ingredient from the container.

PSI: Pounds per square inch.

Pubescent: Having hairy leaves or stems.

RPM: Revolutions per minute.

Safener: A chemical added to a pesticide to keep it from injuring plants.

Seed Protectant: A chemical applied to seed before planting to protect seeds and new seedlings from disease and insects.

Soil Sterilant: A chemical that prevents the growth of all plants in the soil. Soil sterilization may be temporary or permanent, depending on the chemical.

Soluble: Will dissolve in a liquid.

Solution: Mixture of one or more substances in another in which all ingredients are completely dissolved.

Solvent: A liquid which will dissolve a substance to form a solution.

Spreader: A chemical which increases the surface area that a given volume of liquid will cover on a solid or on another liquid.

Sticker: A material added to a pesticide to increase its adherence.

Surfactant: A chemical which increases the emulsifying, dispersing, spreading, and wetting properties of a pesticide product.

Susceptible: Capable of being diseased or poisoned; not immune.

Suspension: Finely divided solid particles mixed in a liquid.

Synergism: The joint action of two or more pesticides that is greater than the sum of their activity when used alone.

Target Pest: The pest at which a particular pesticide or other control method is directed.

Tolerance: (1) The ability of a living thing to withstand adverse conditions, such as pest attacks, weather extremes, or pesticides. (2) The amount of pesticide that may legally remain in or on raw farm products at time of sale.

Toxicant: A poisonous chemical.

Trade Name: Same as brand name.

Vapor Pressure: The property which causes a chemical to evaporate. The higher the vapor pressure, the more easily it will evaporate.

Vector: A carrier, such as an insect, that transmits a pathogen.

Viscosity: A property of liquids that determines whether they flow readily. Viscosity usually increases when temperature decreases.

Volatile: Evaporates at ordinary temperatures when exposed to air.

Wetting Agent: A chemical which causes a liquid to contact surfaces more thoroughly.

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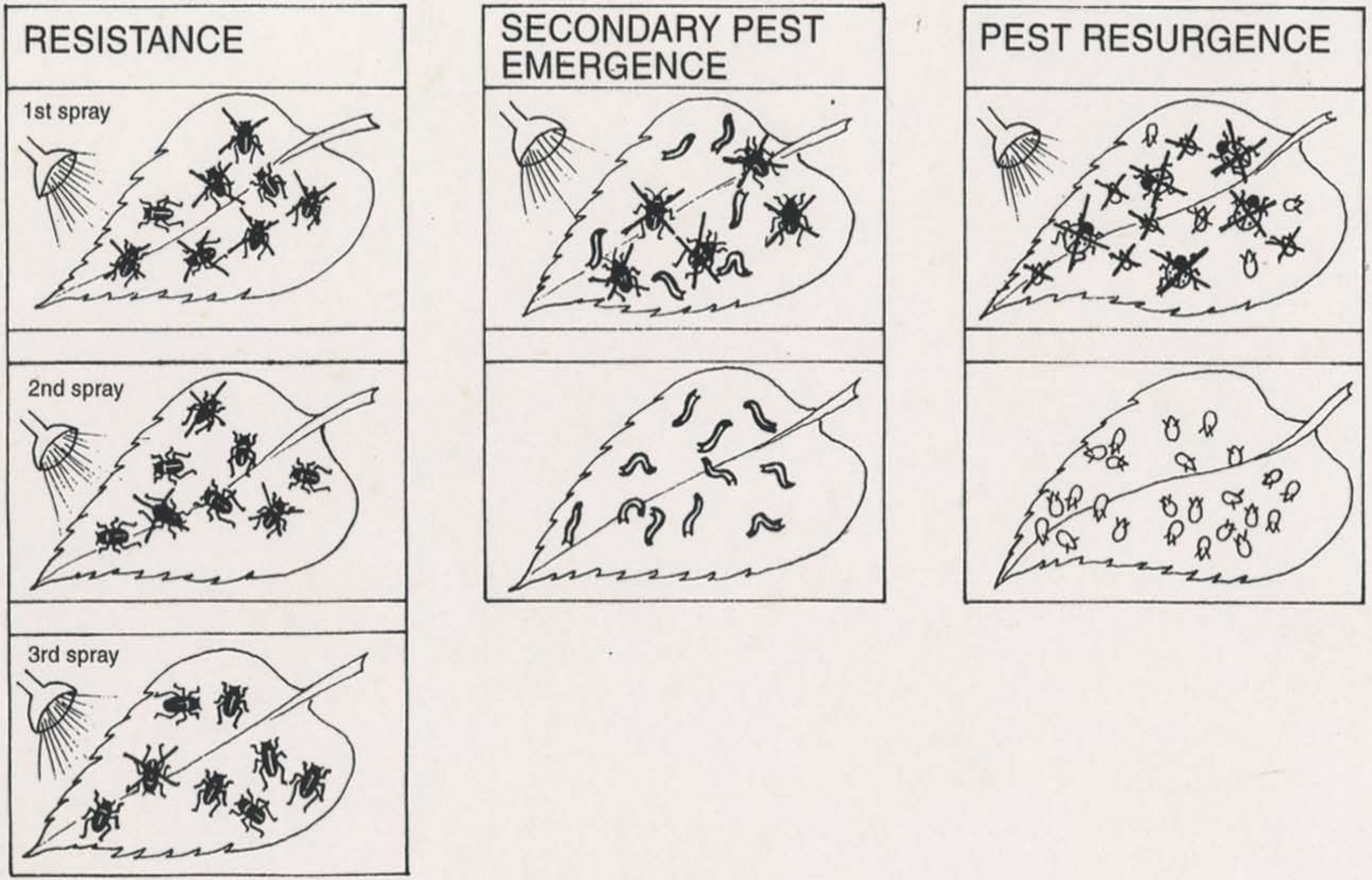
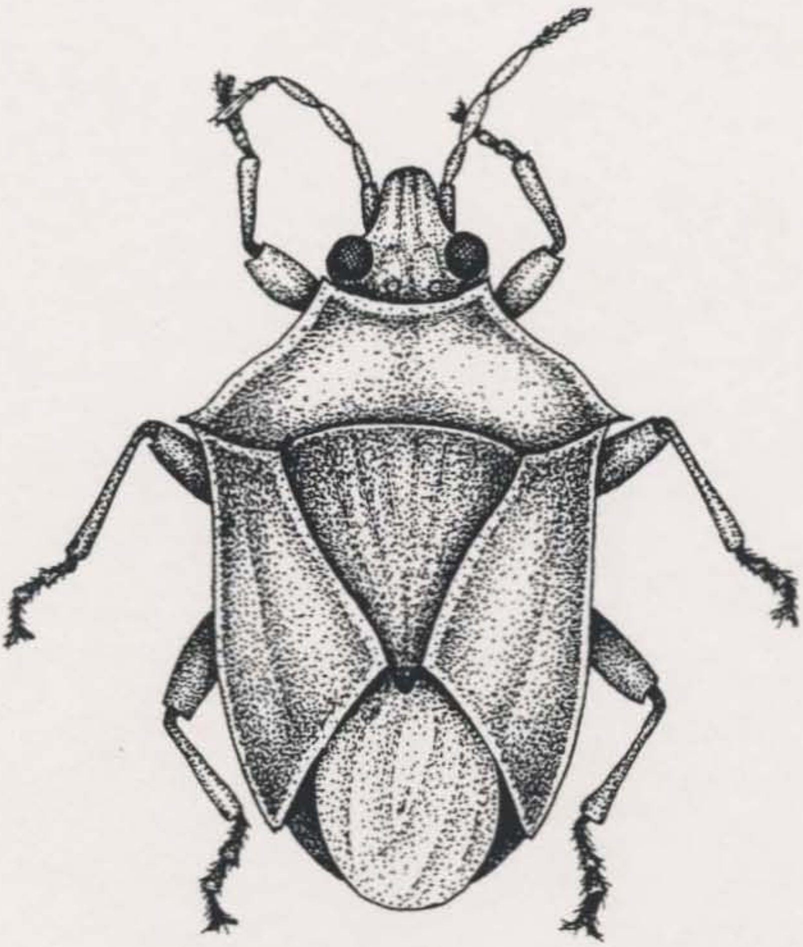
VIII. TRANSPARENCY MASTERS


RESISTANCE
1st spray
2nd spray
3rd spray
SECONDARY PEST EMERGENCE
PEST RESURGENCE

1.1

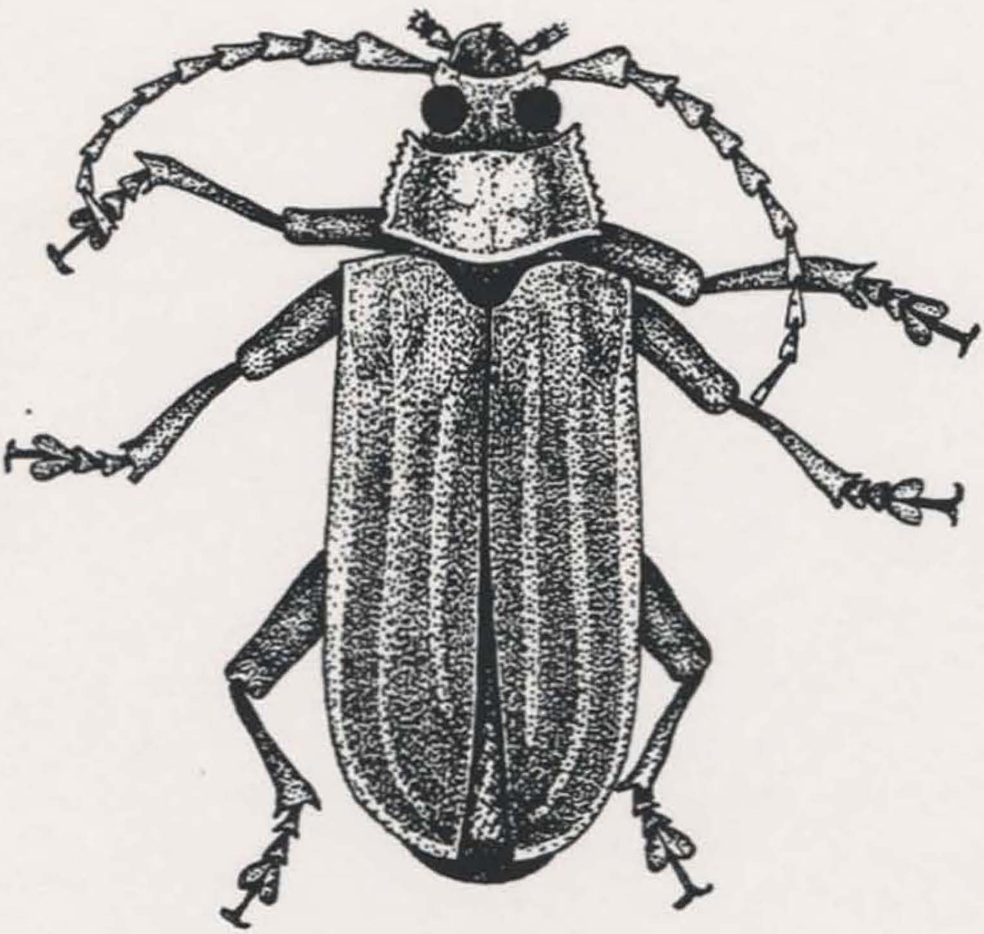


True Bug

Order: Hemiptera
Suborder: Heteroptera

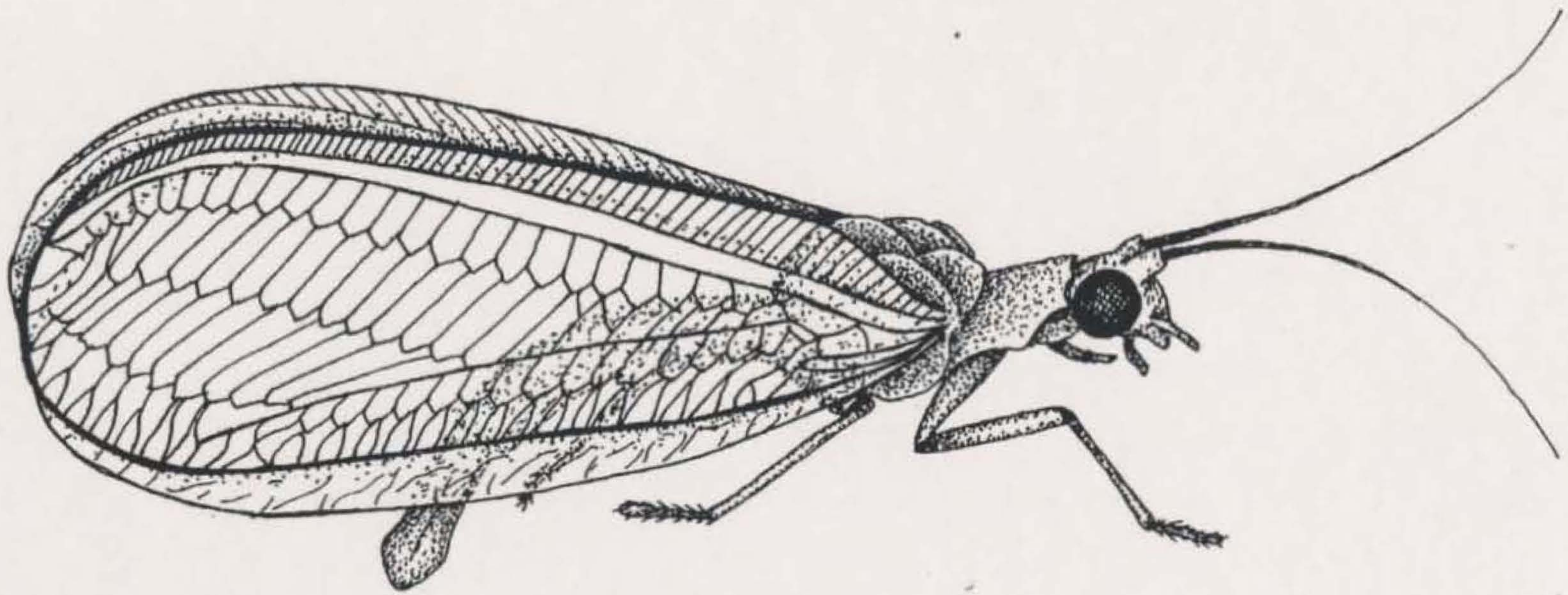
Leafhopper

Family: Cicadellidae



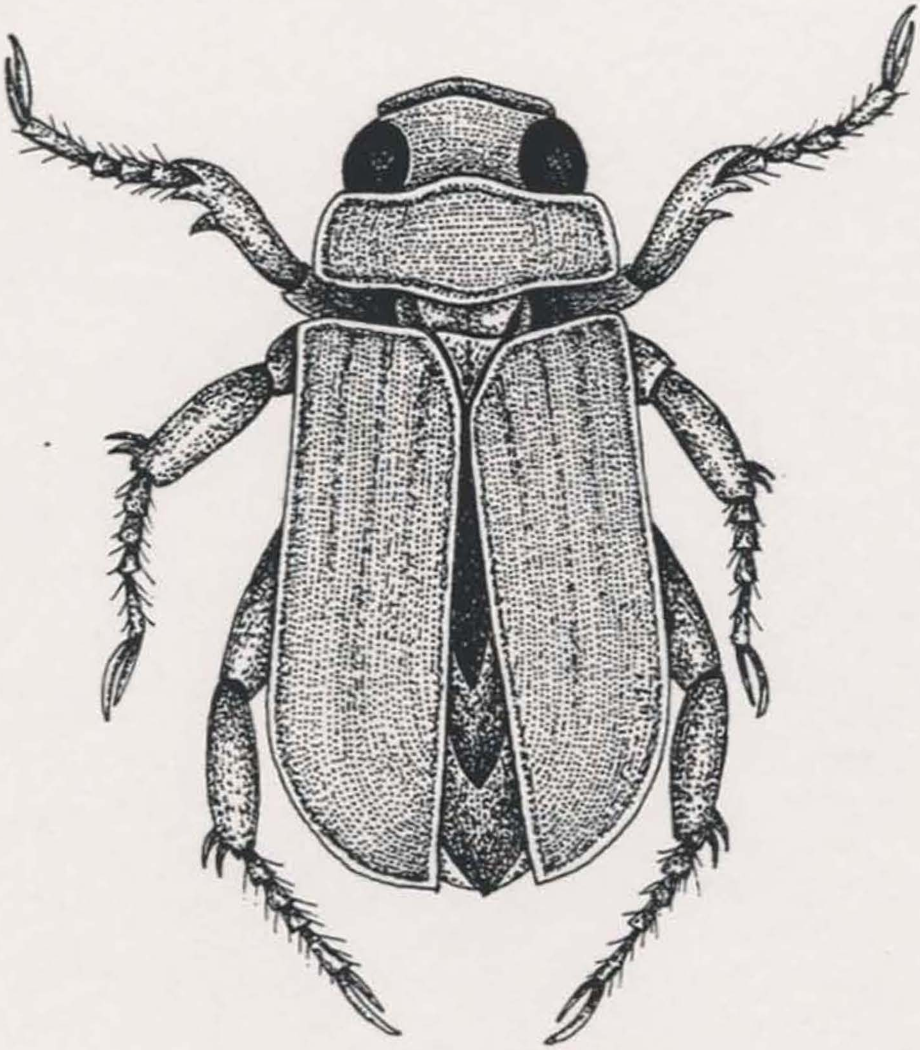
Longhorned beetle

Family: Cerambycidae

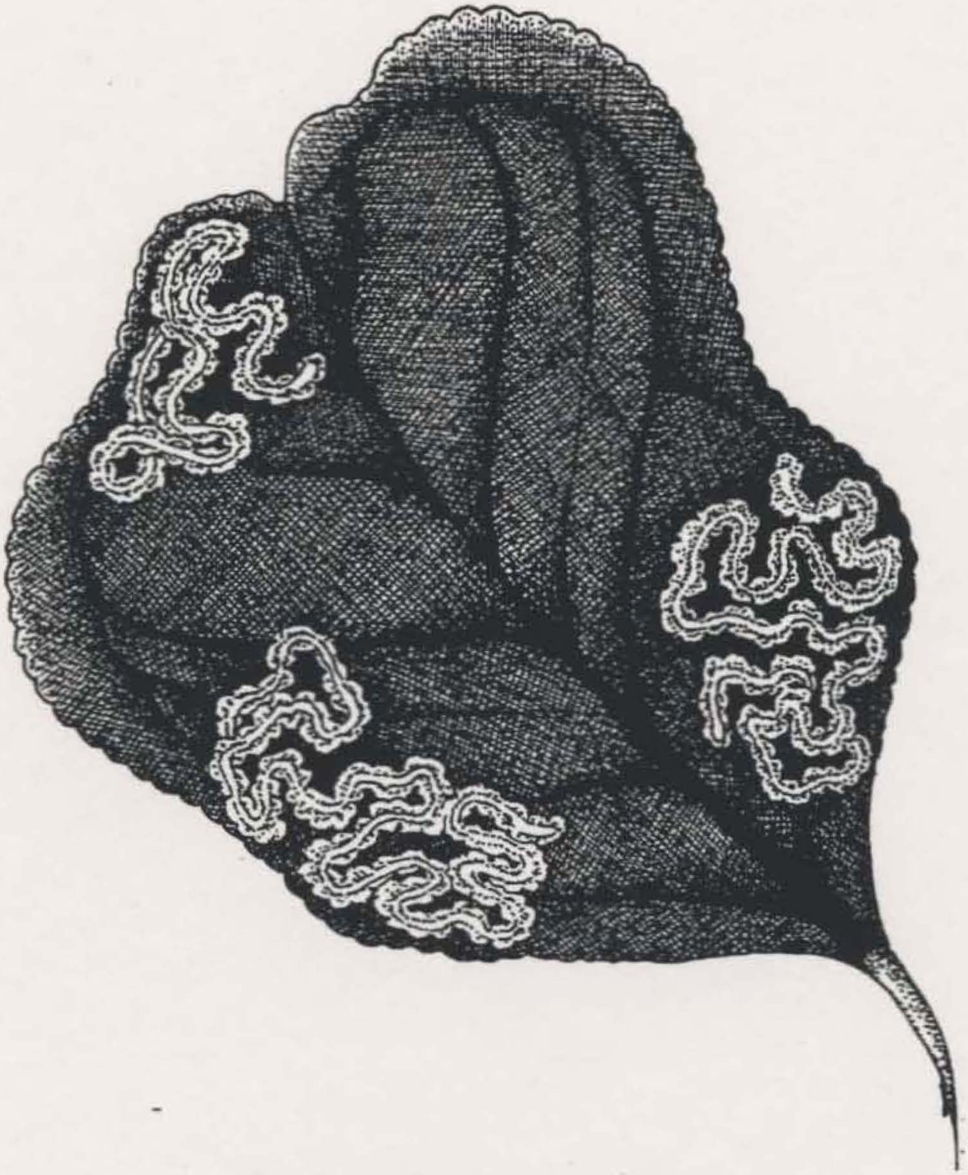


Lacewing

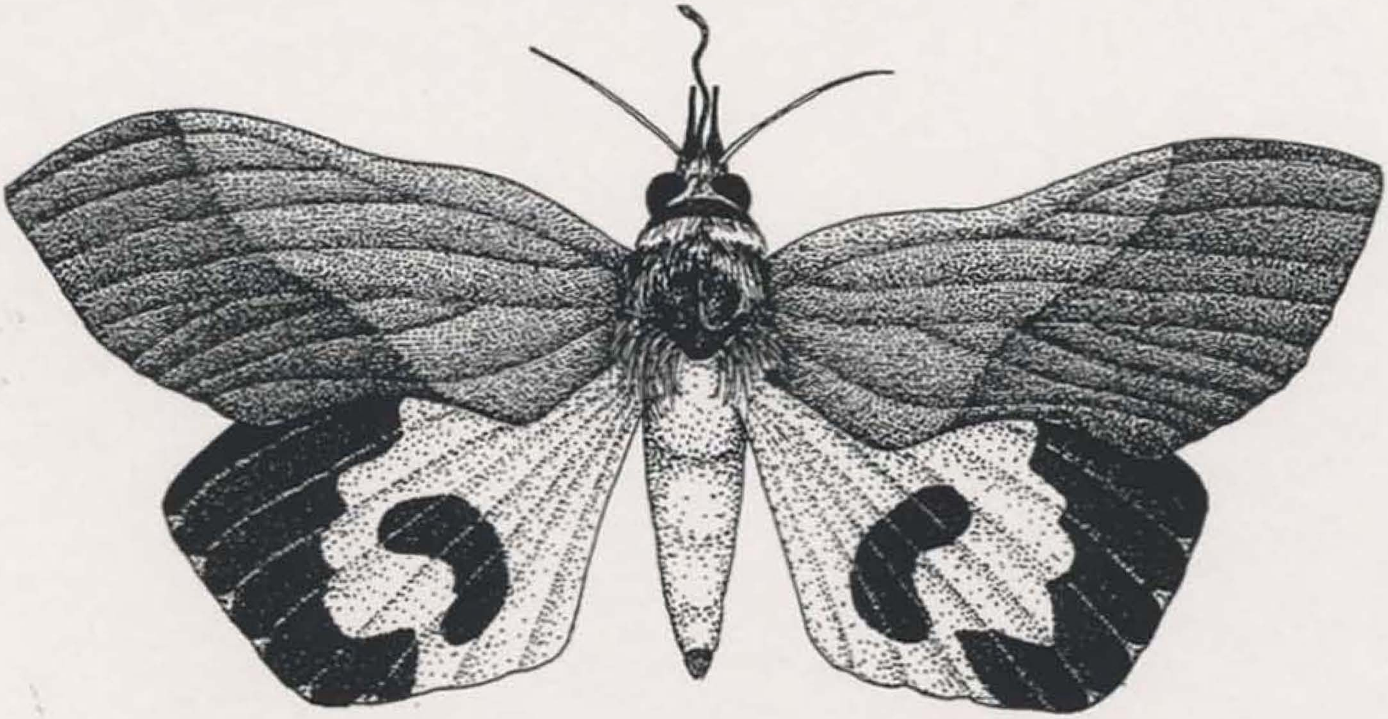
Family: Chrysopidae



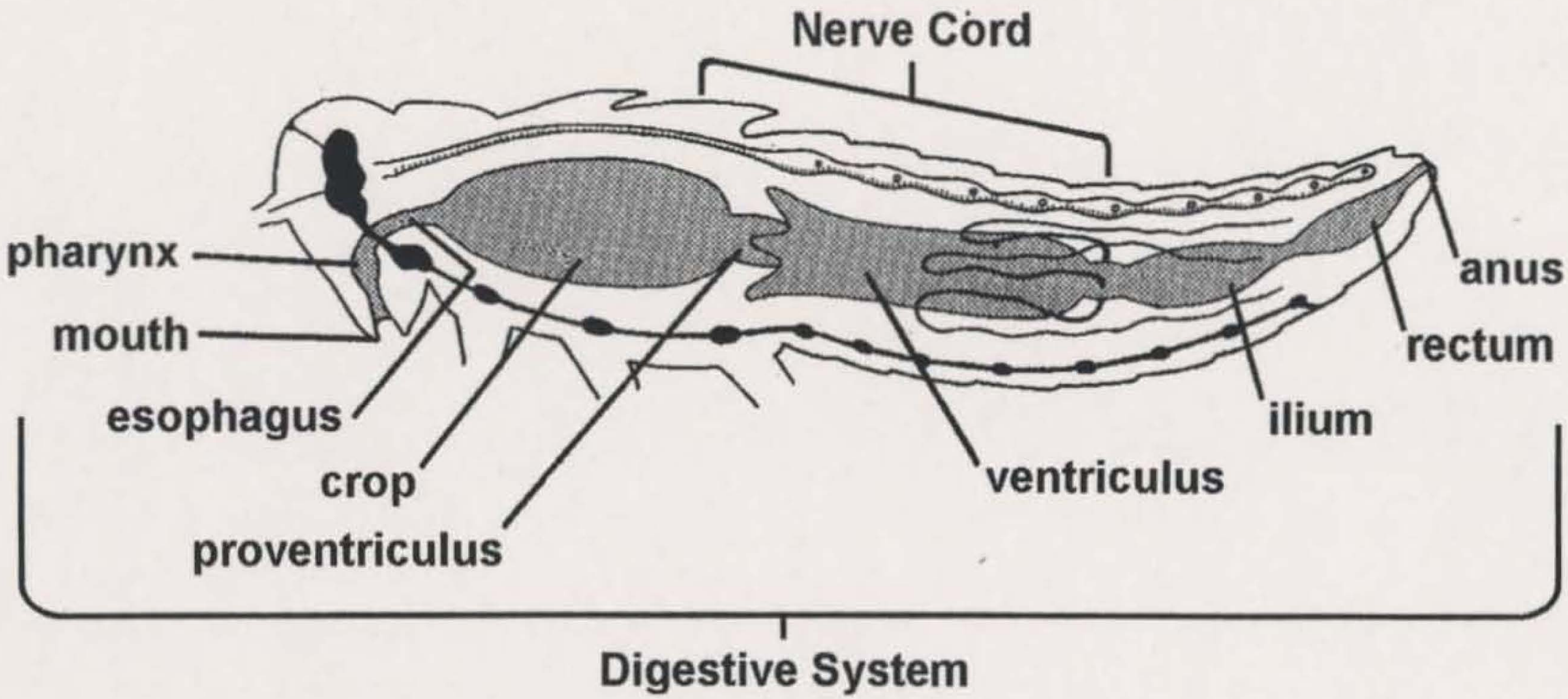
Adoratus versutus



Liriomyza trifolii

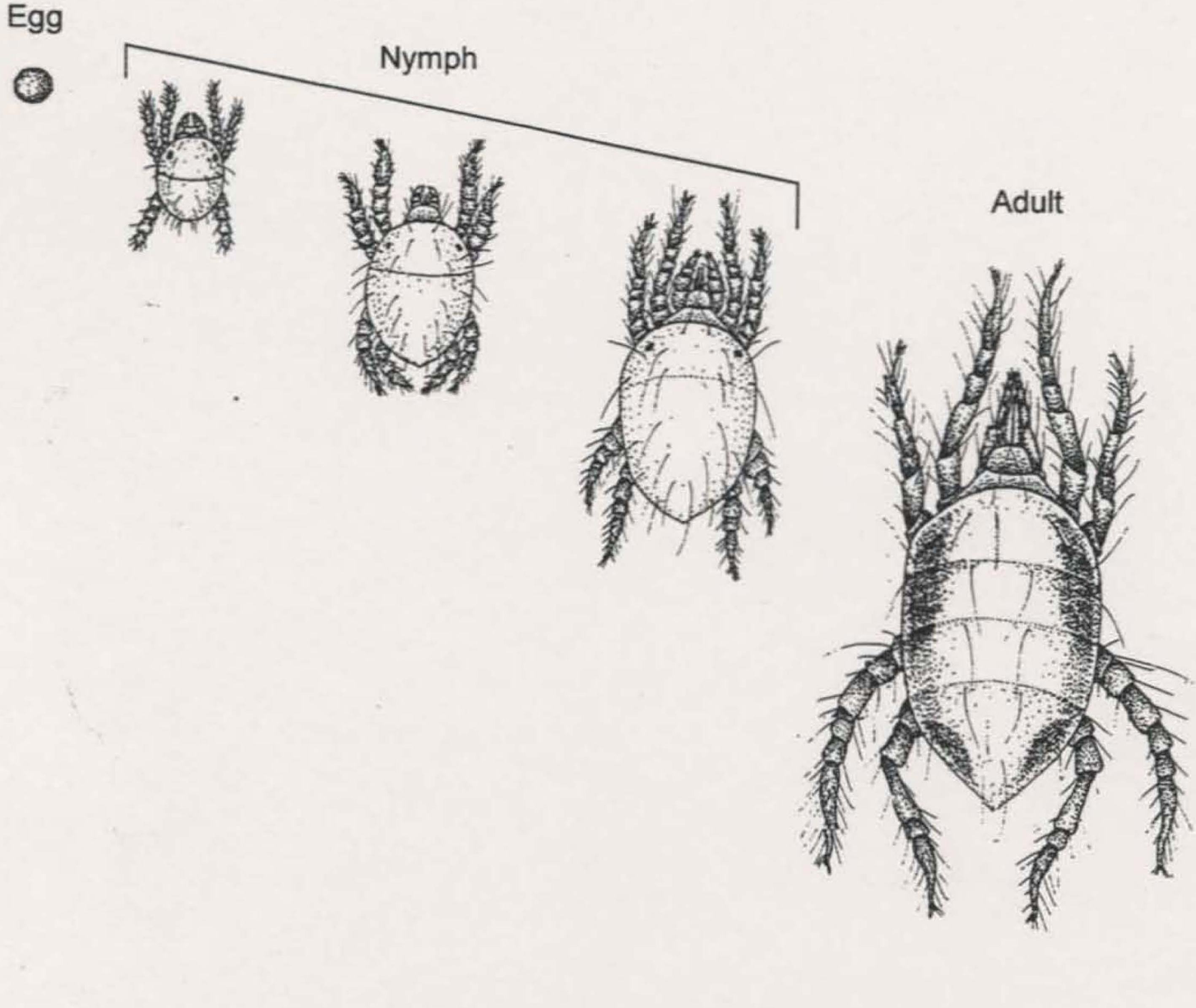


Othreis fullonia



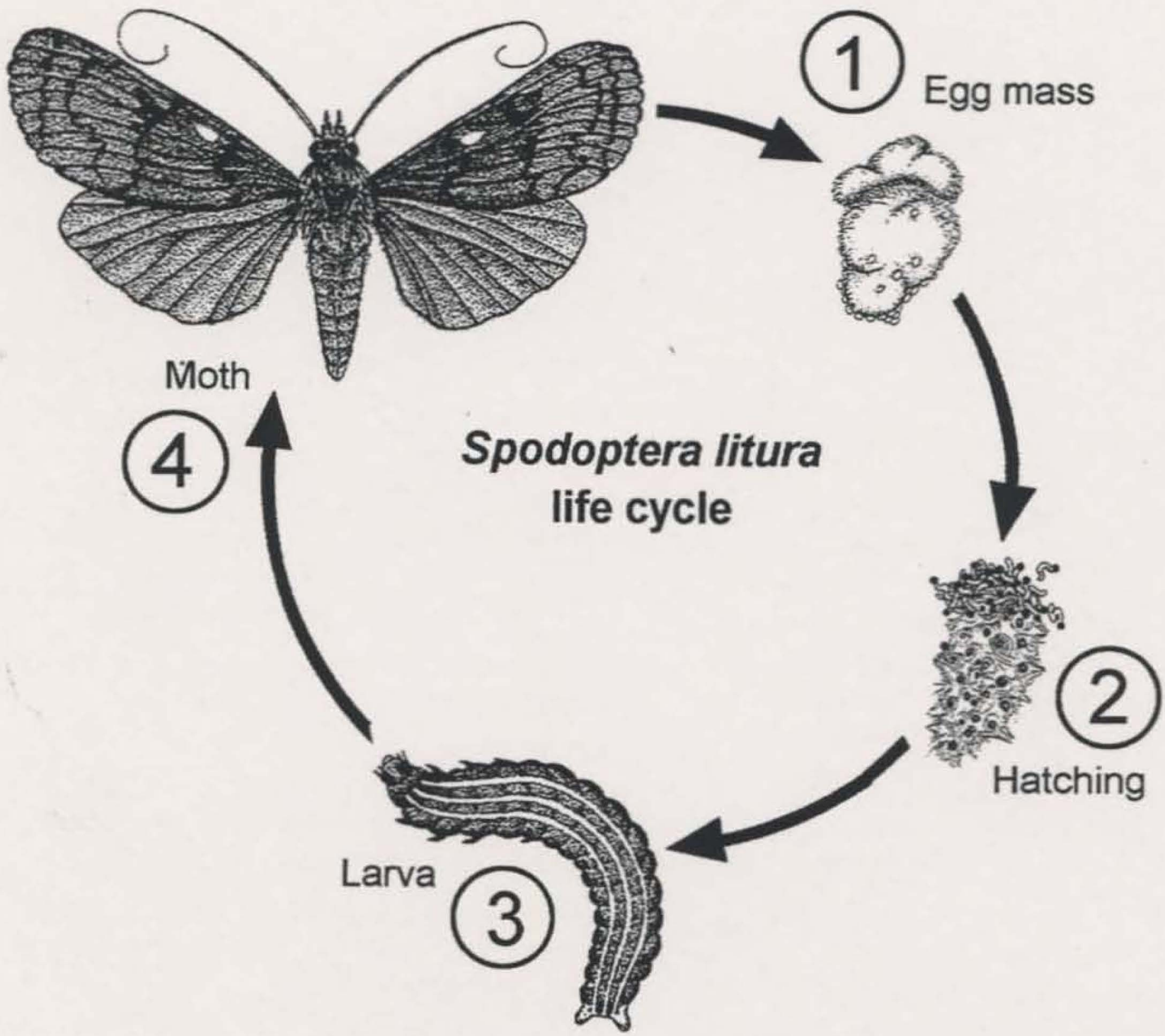
Internal anatomy of an insect

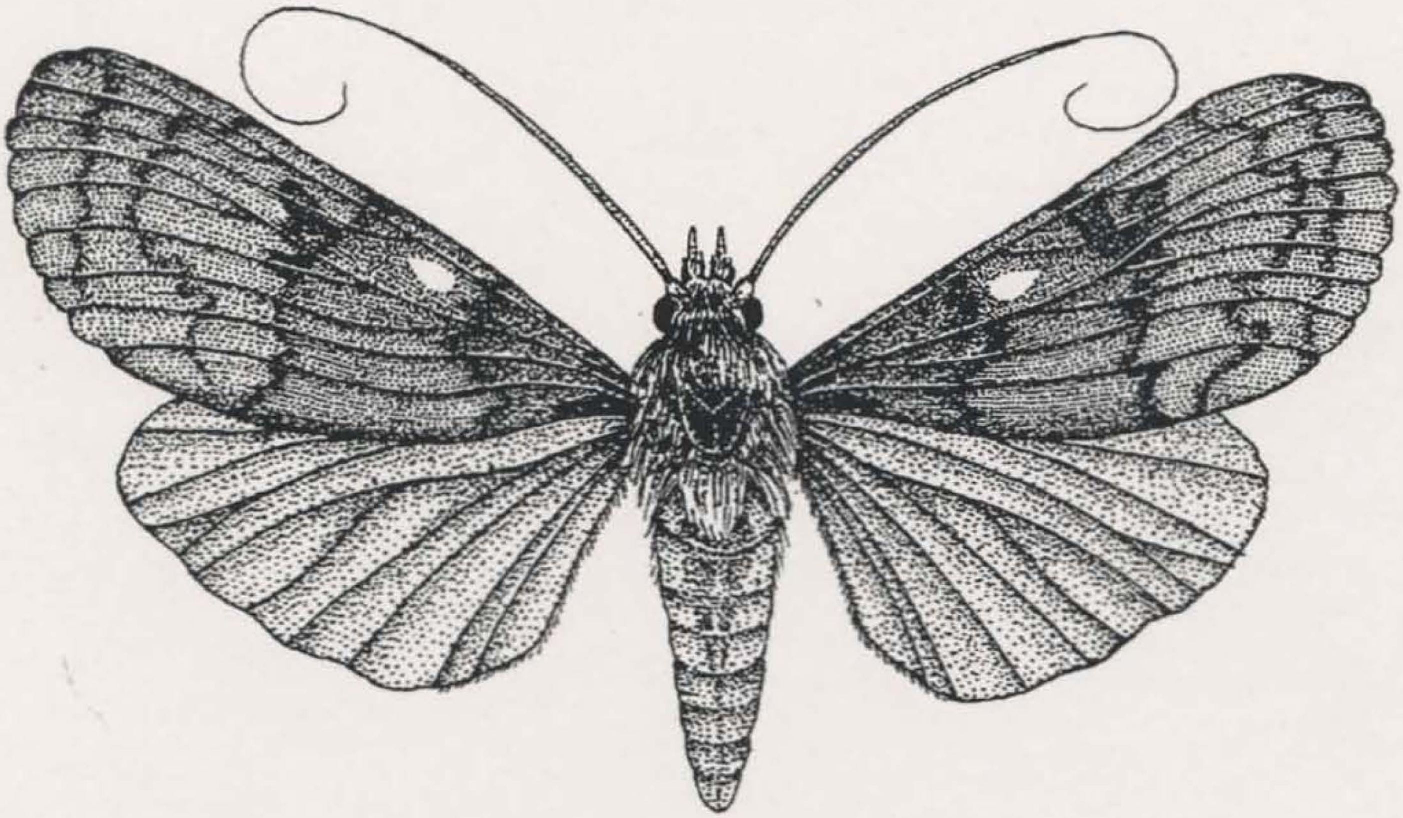
4.5



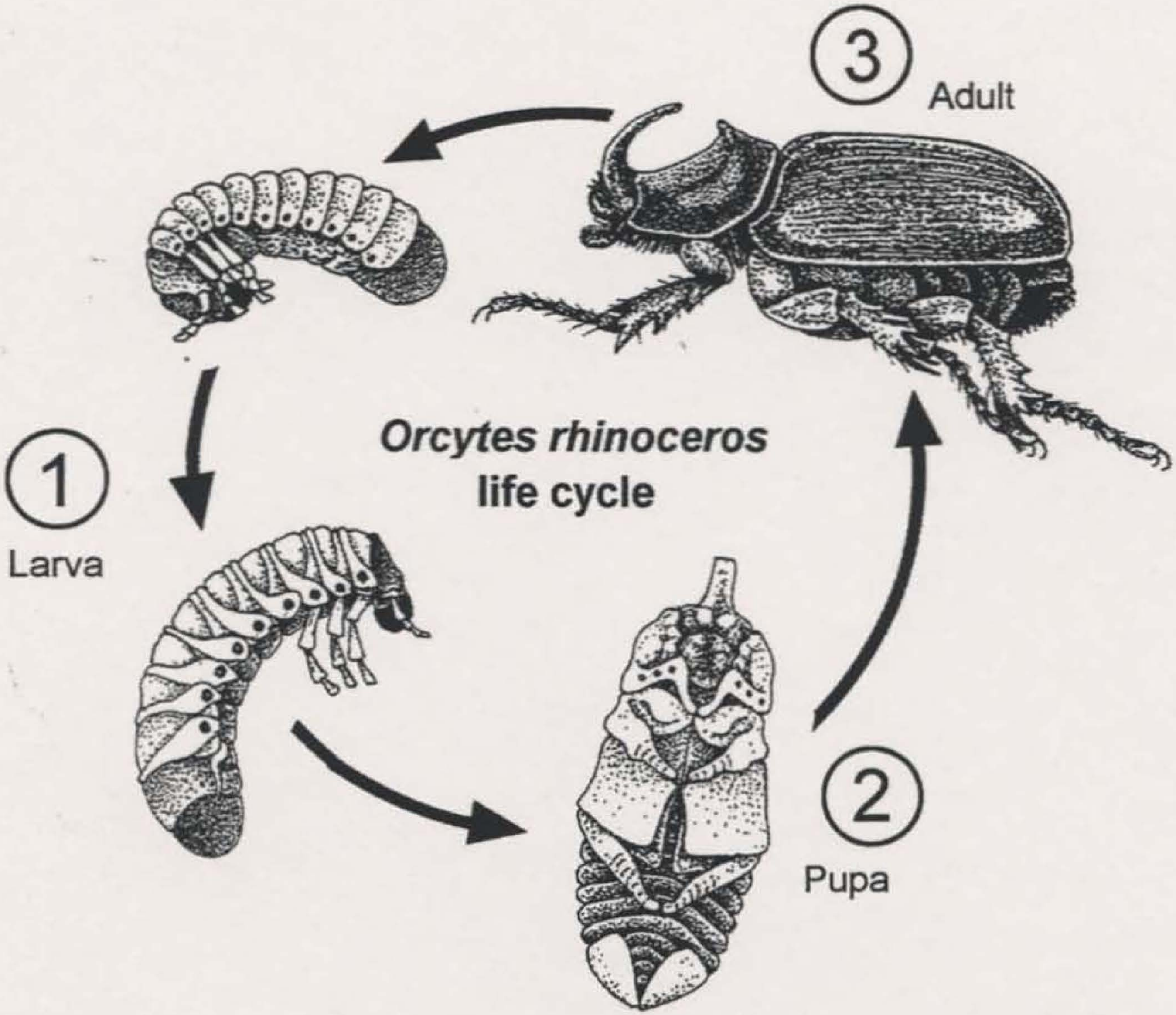
Gradual Metamorphosis of a Mite

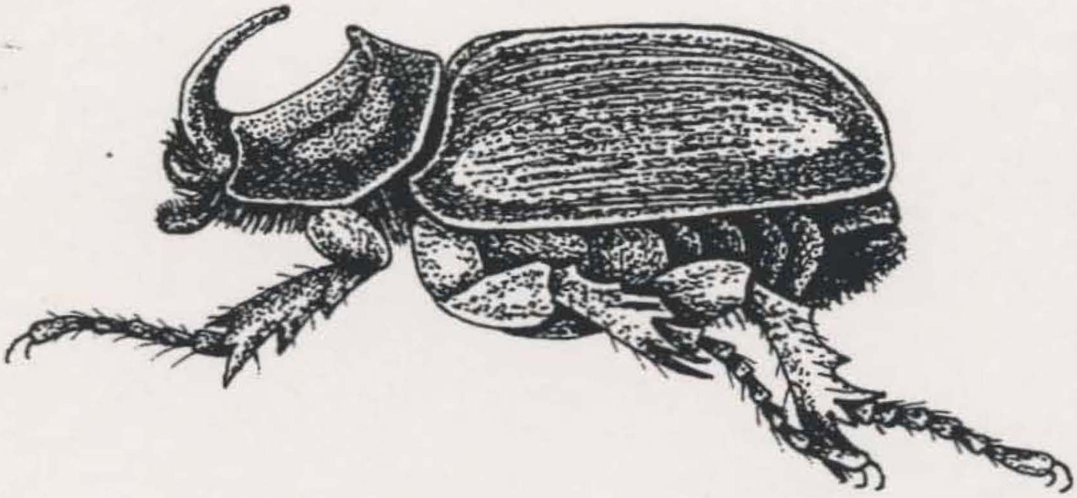
Gradual Metamorphosis of the Grasshopper


1
Egg mass
Moth
4
Spodoptera litura
life cycle
2
Hatching
Larva
3



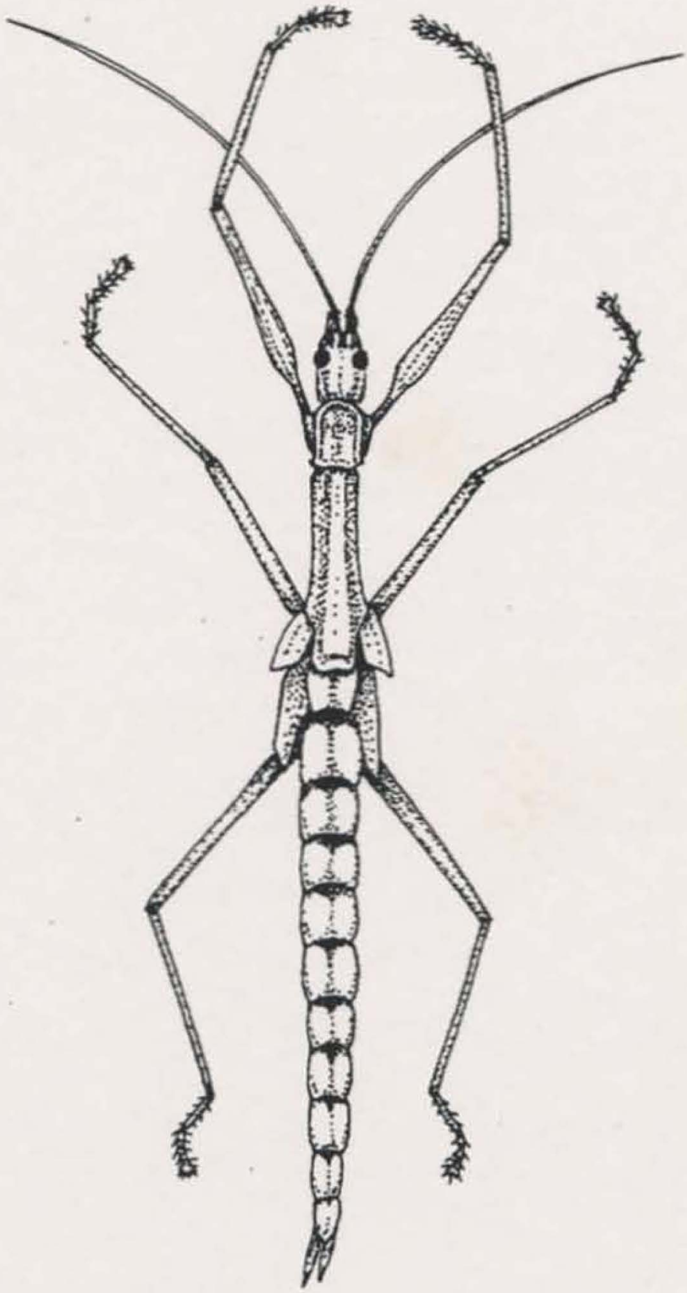
Spodoptera litura


3
Adult
Orcytes rhinoceros
life cycle
1
Larva
2
Pupa



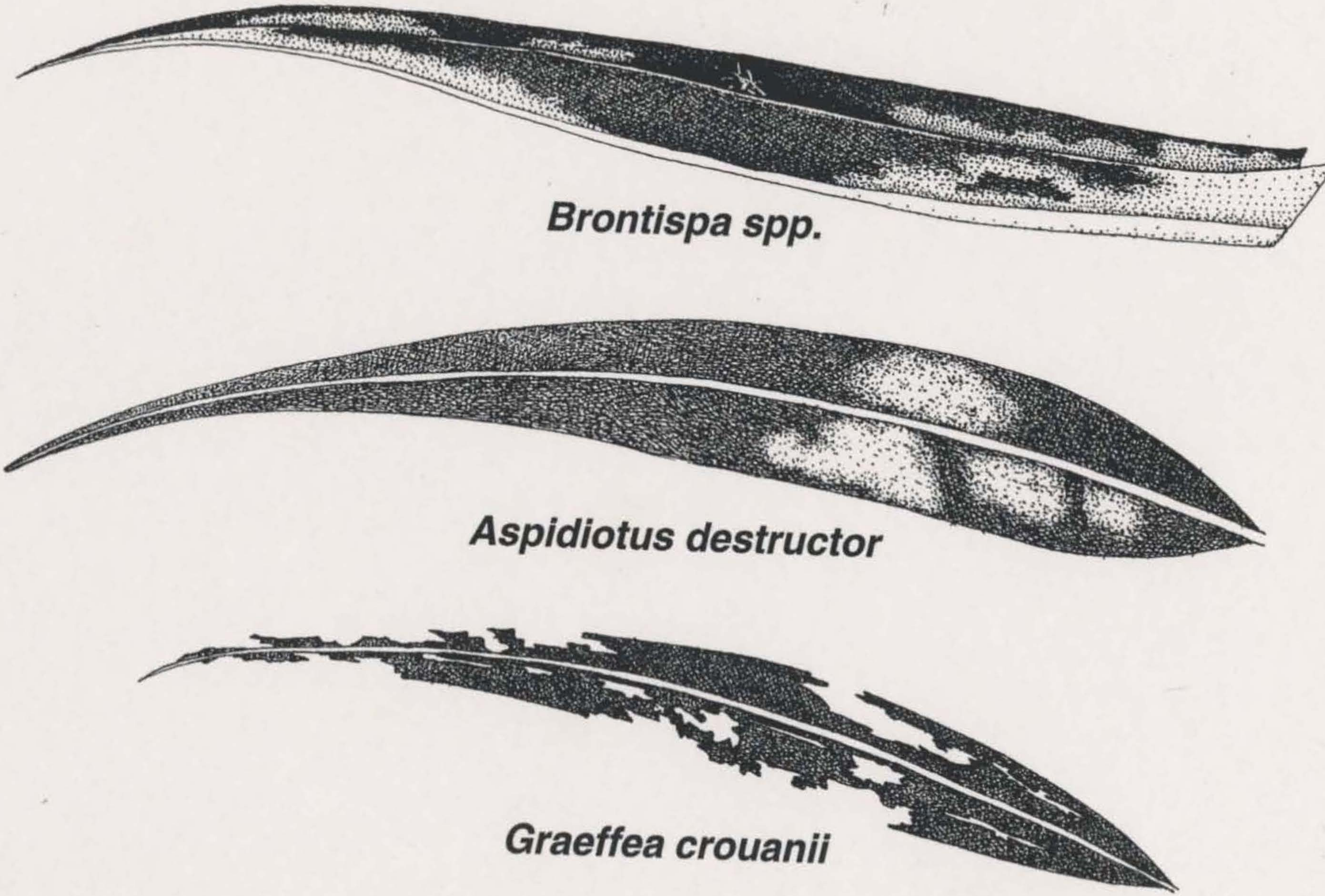
Orcytes rhinoceros

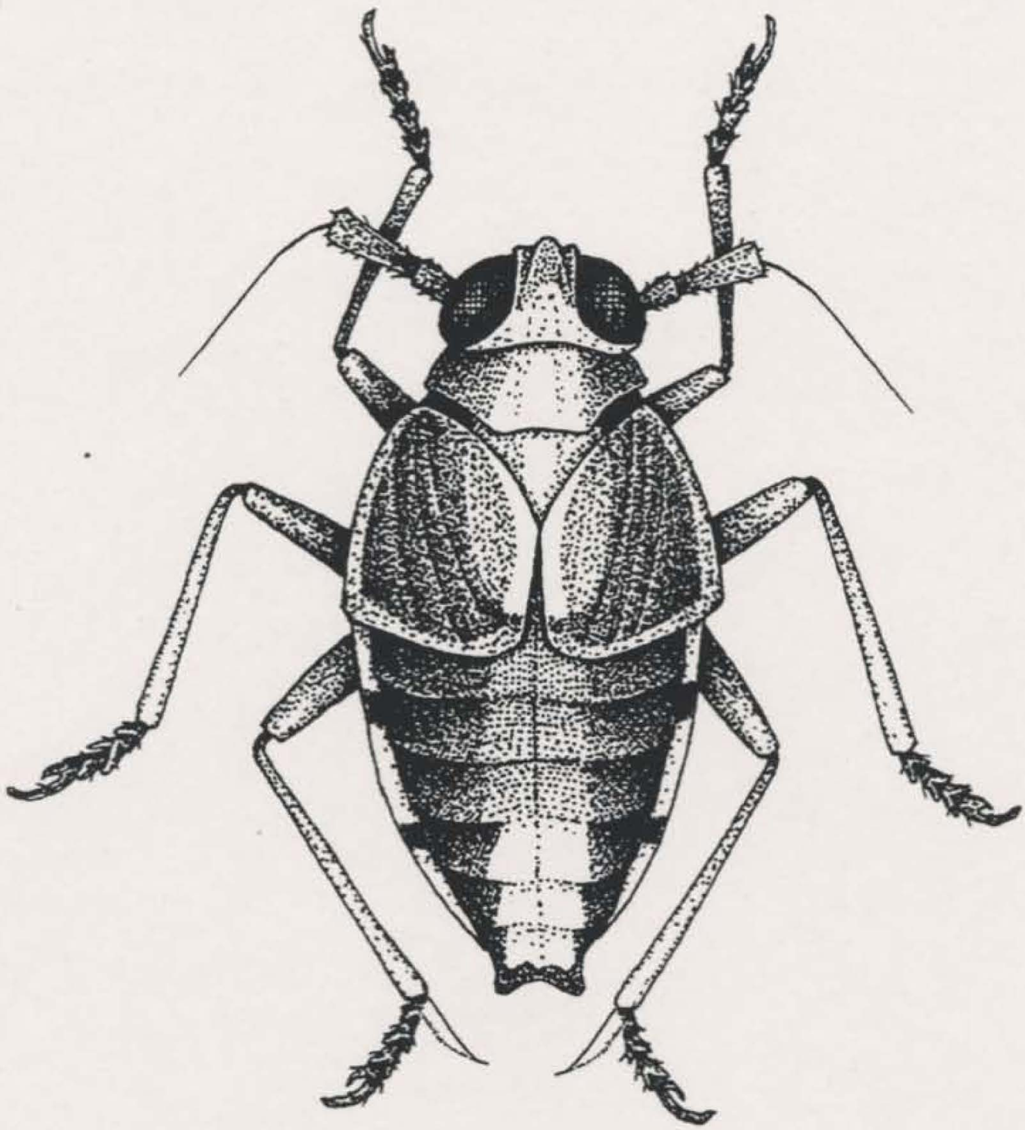
Brontispa longissima



Graeffea crouanii

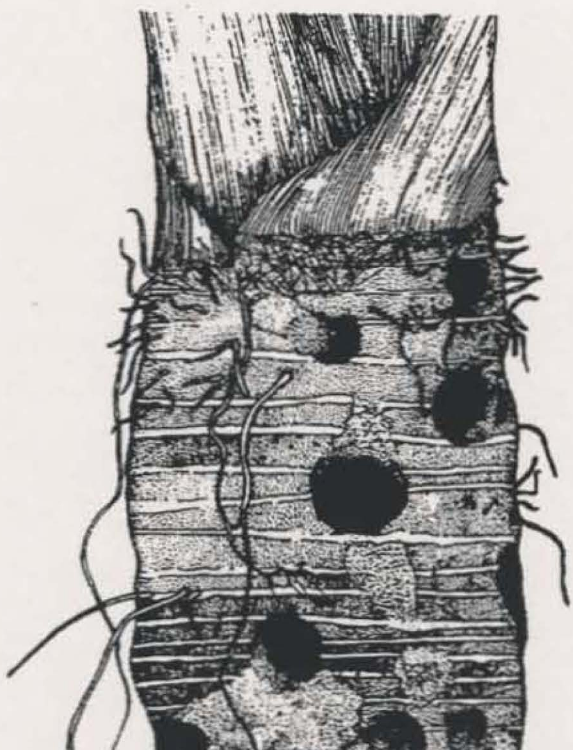
Damage caused by...



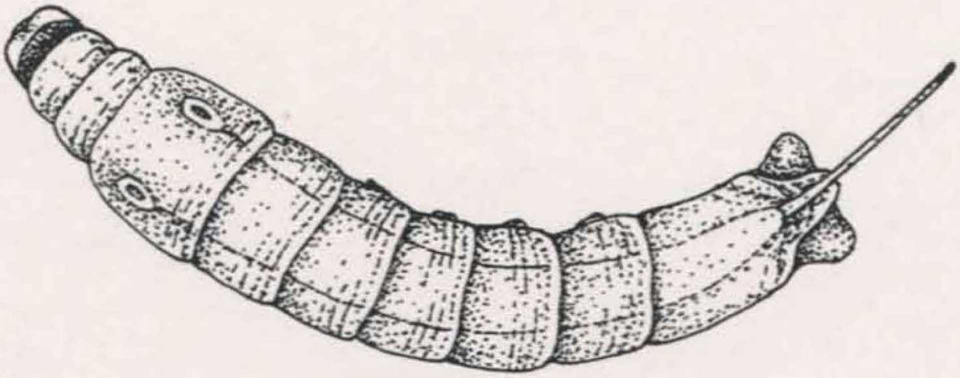


Tarophagus proserpina

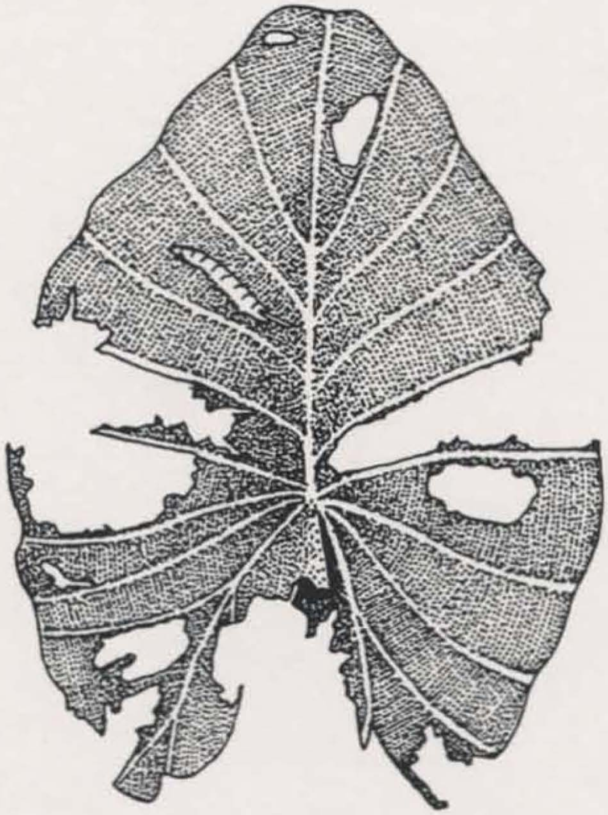
Papuana huebneri



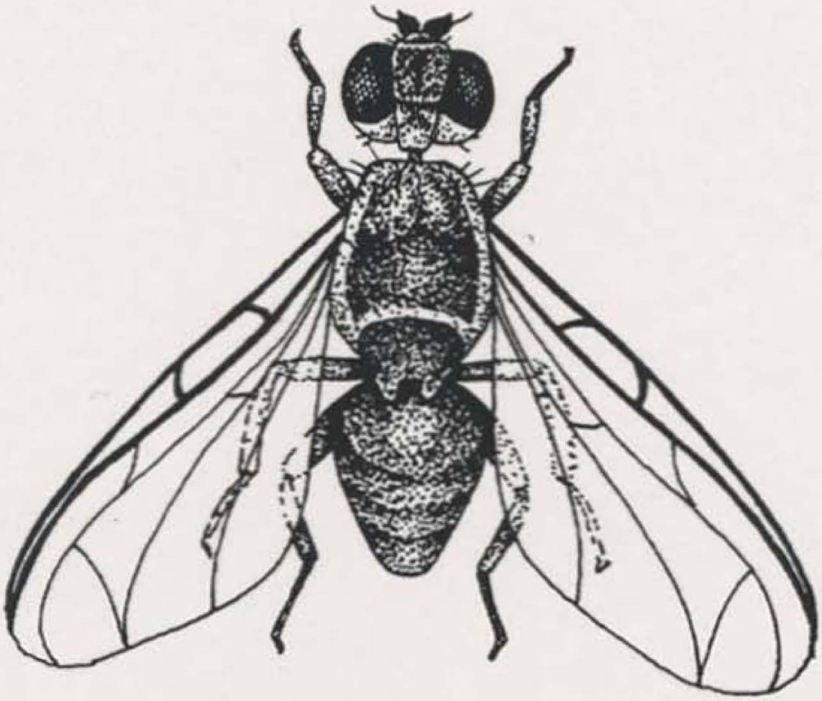
Damage on corn



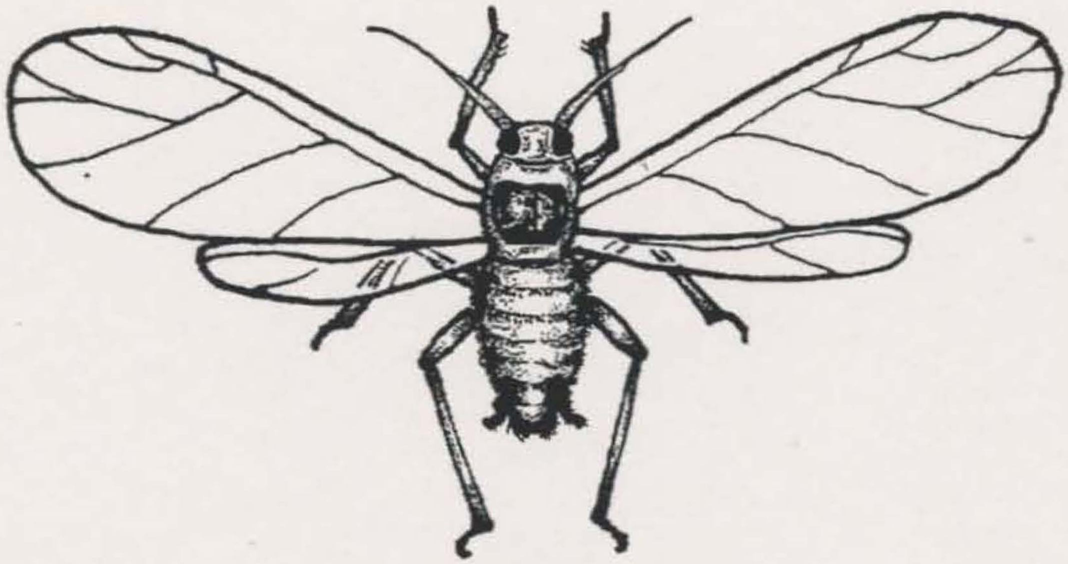
Hippotion celerio



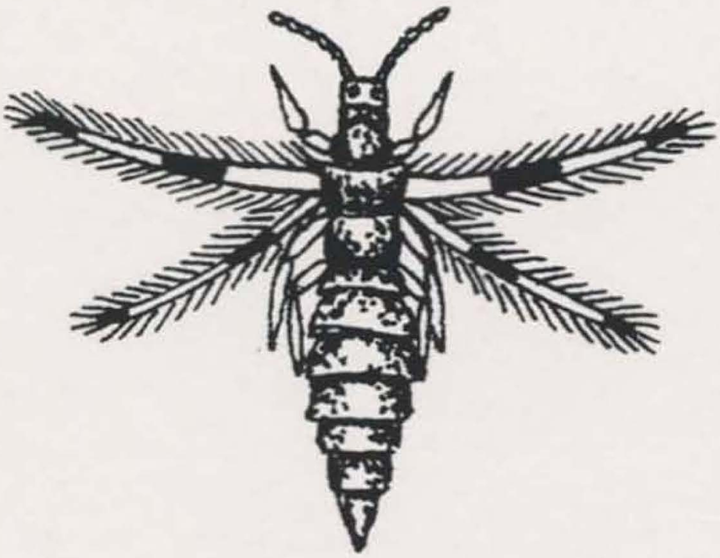
damage on taro leaf



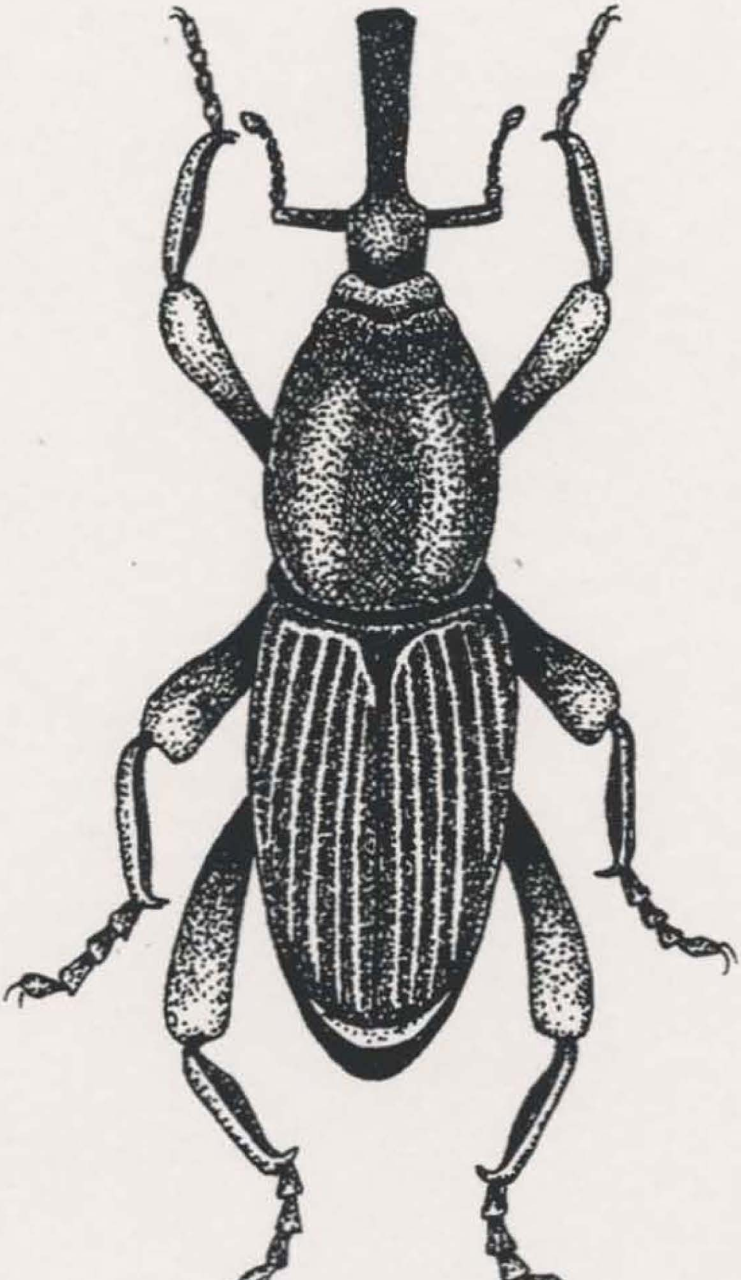
Bacticera spp.



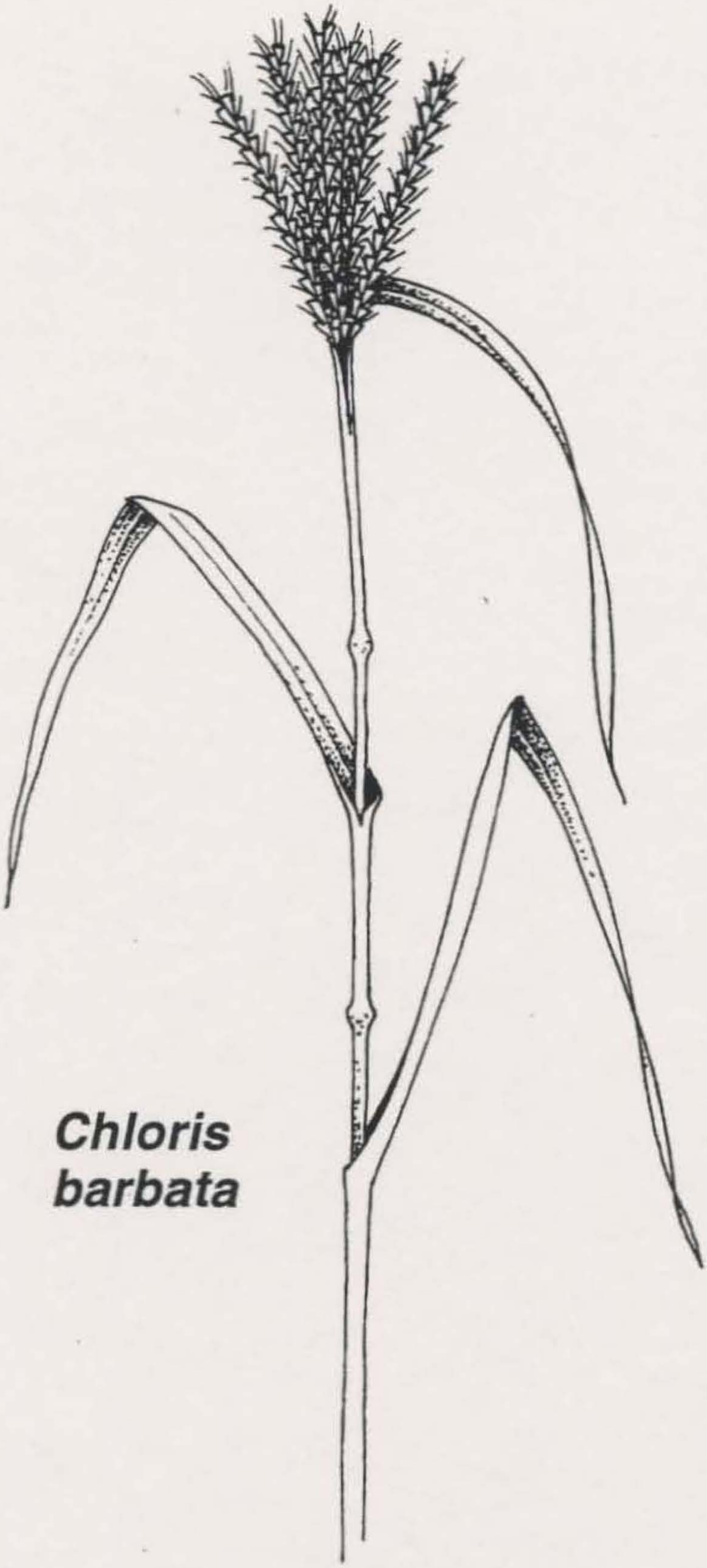
Pentalonia nigronervosa



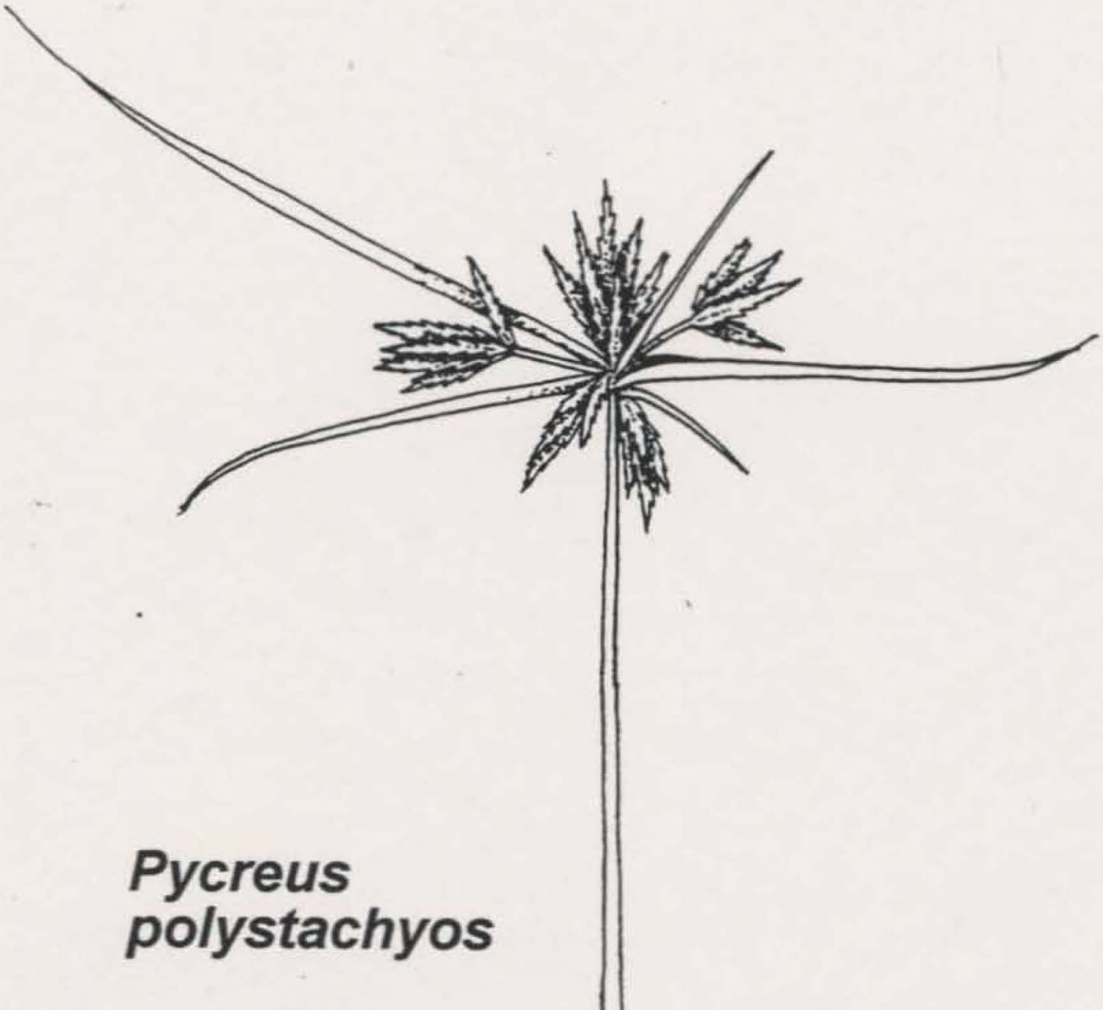
Chaetanophothrips signipennis



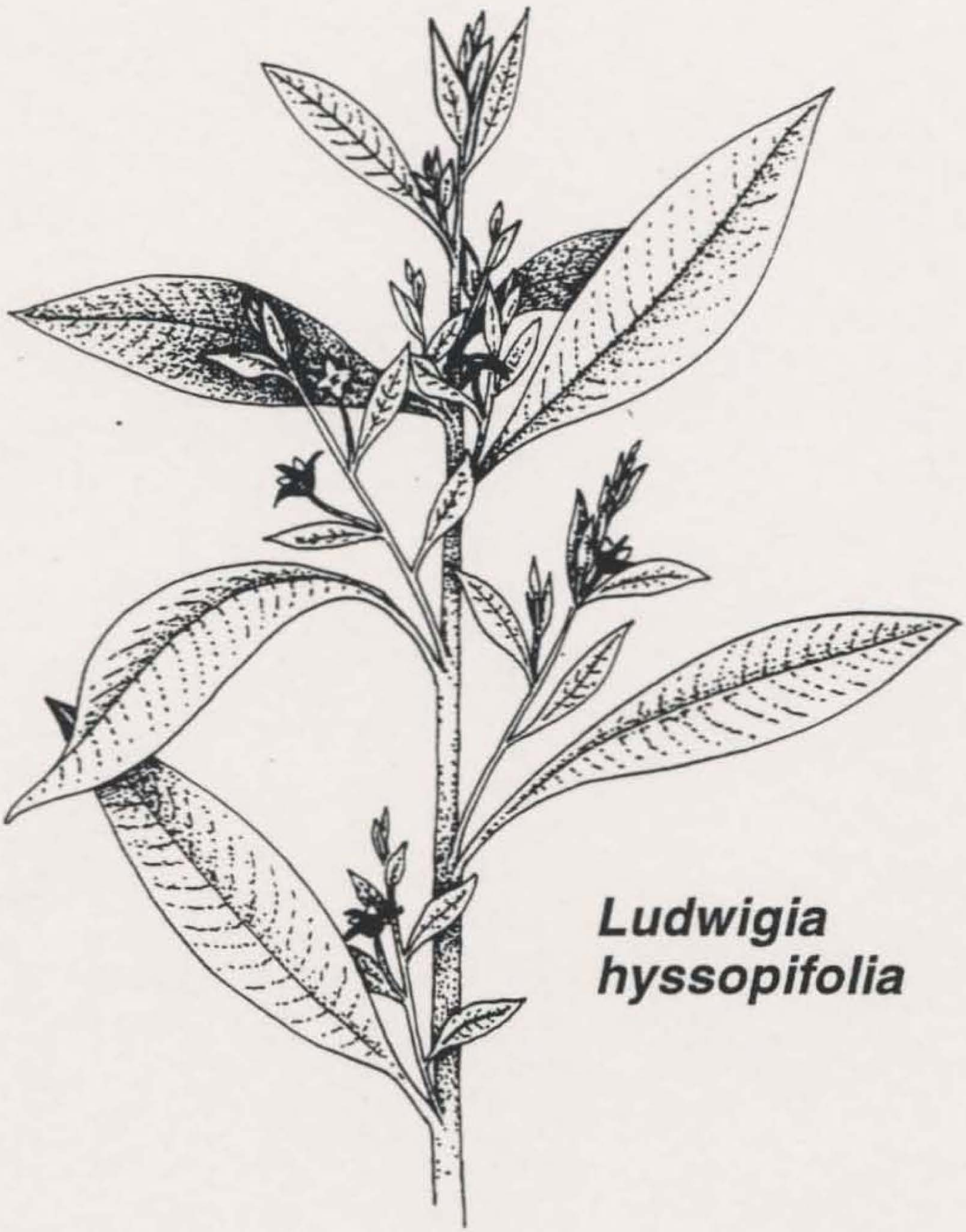
Cosmopolites sordicus



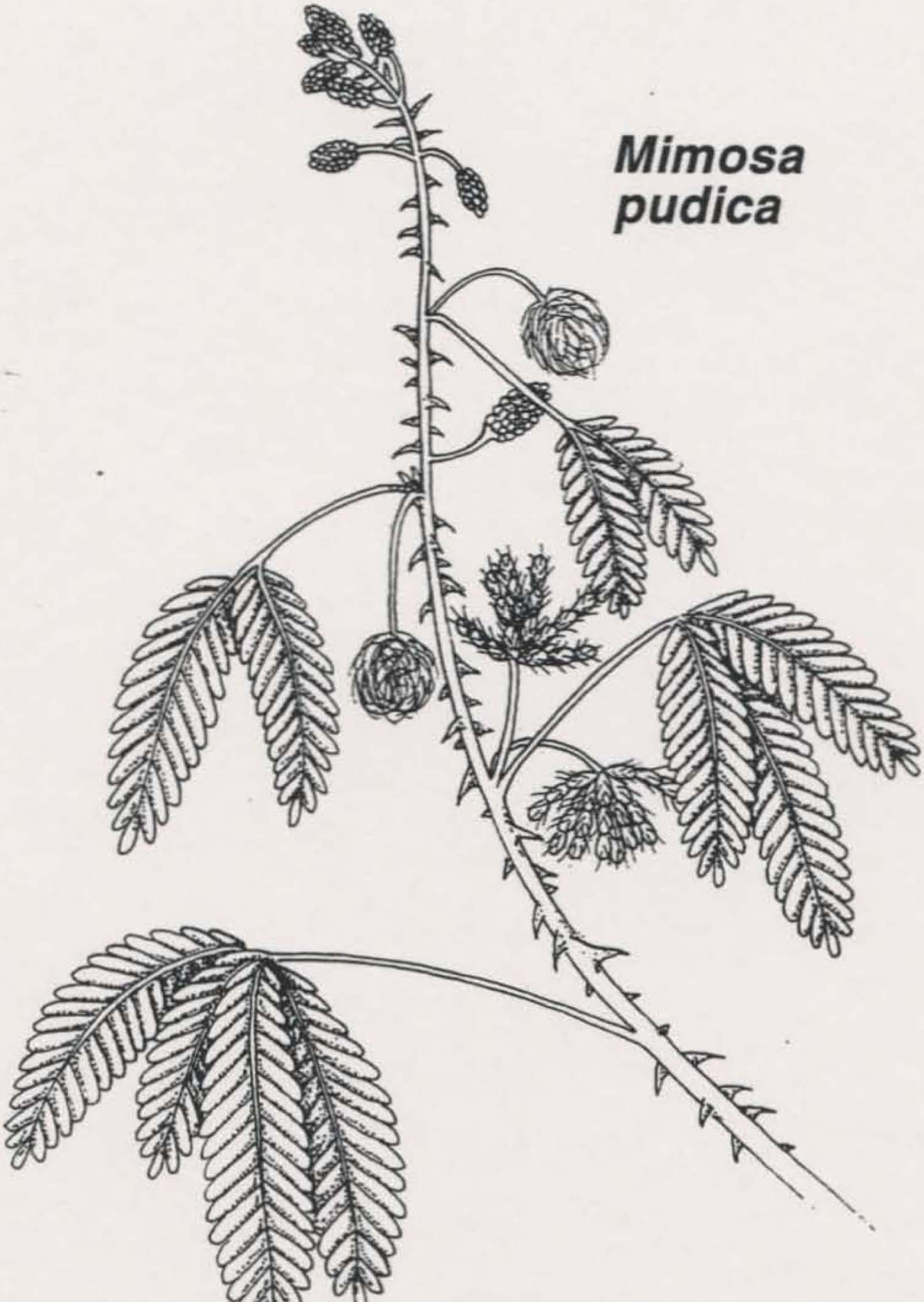
Chloris barbata



Pycreus polystachyos



Ludwigia hyssopifolia



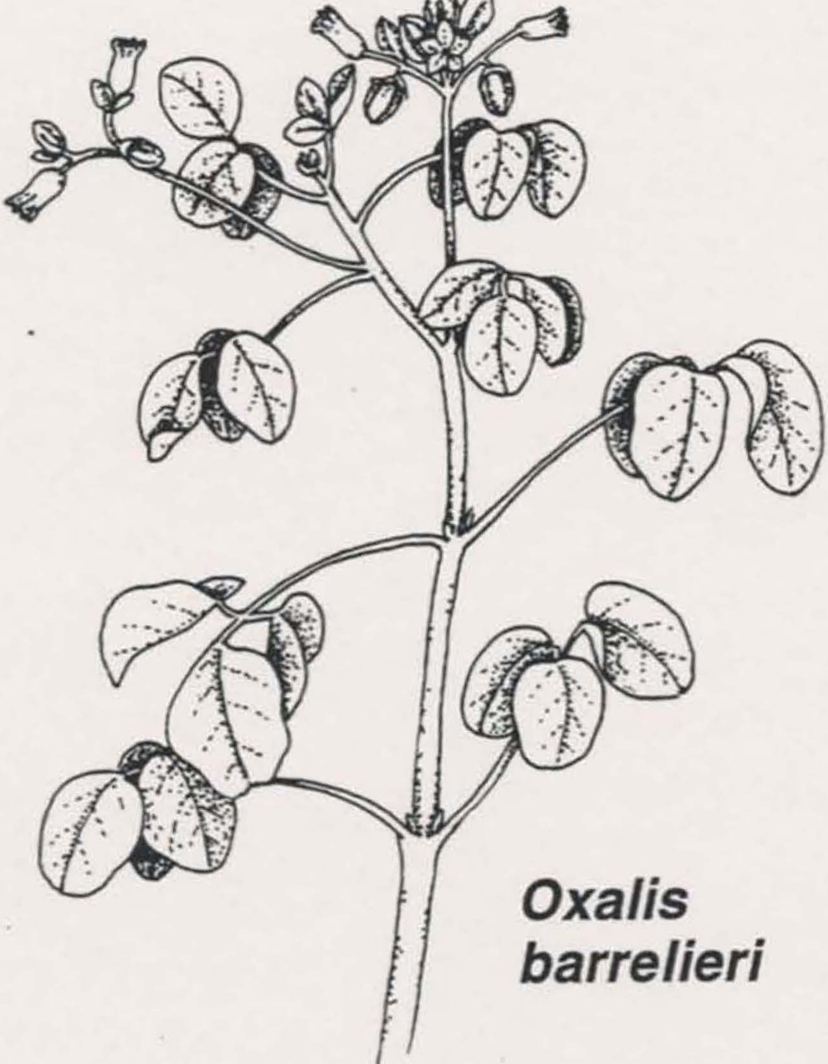
Mimosa pudica

Passiflora foetida

Wedelia trilobata

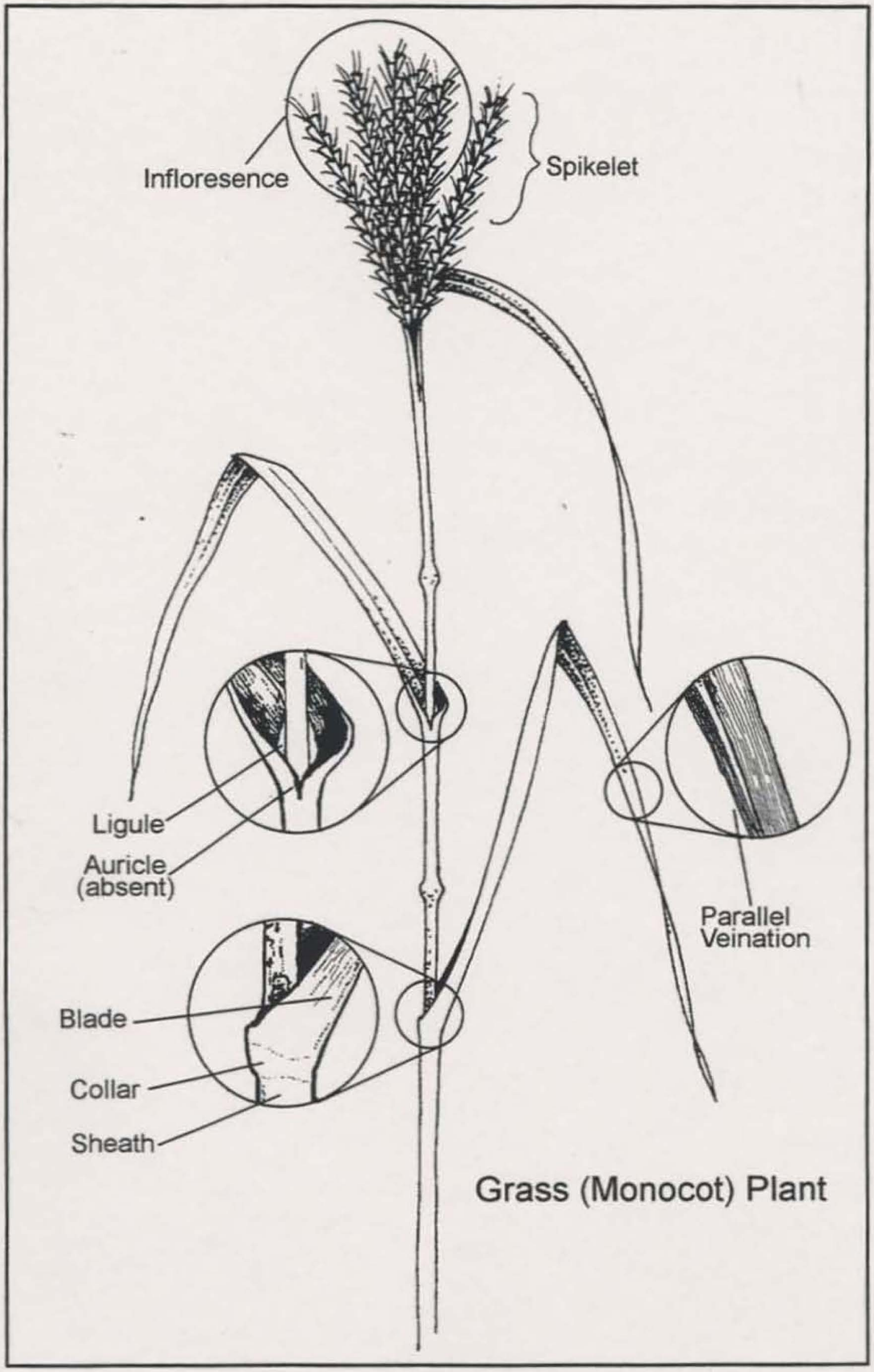
Chamaesyce hypericifolia

Costus speciosus



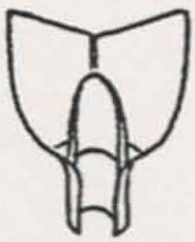
Oxalis barrelieri

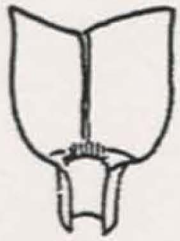
Polygala paniculata


Infloresence
Spikelet
Ligule
Auricle
(absent)
Parallel
Veination
Blade
Collar
Sheath
Grass (Monocot) Plant

Identifying Features of Grasses

LIGULES MAY BE:

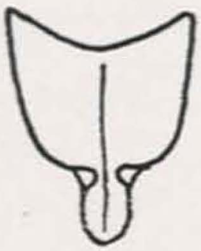

Membranous


Hairy


Absent

COLLARS MAY BE:

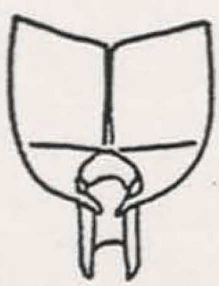

Continuous


Divided


Broad or narrow

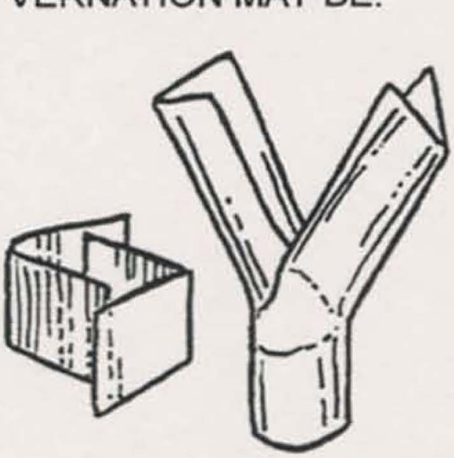
AURICLES MAY BE:

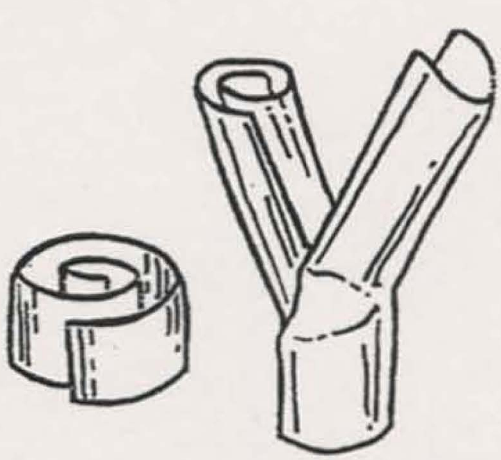

Long-clawlike

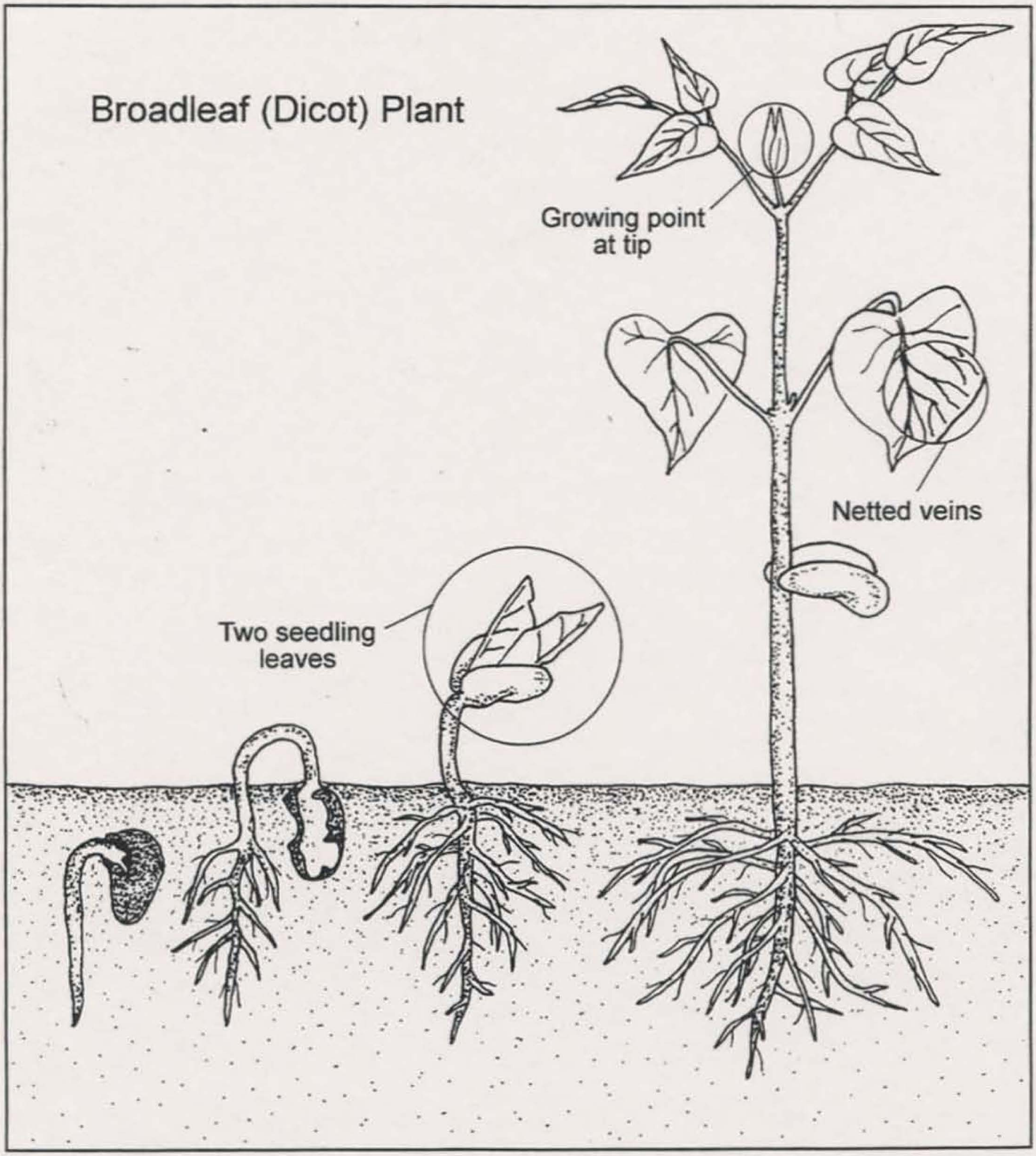

Short-stubby


Absent

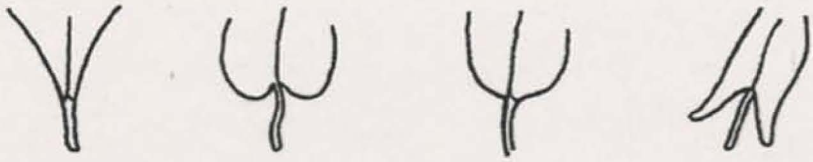
VERNATION MAY BE:


Folded in the bud


Rolled in the bud

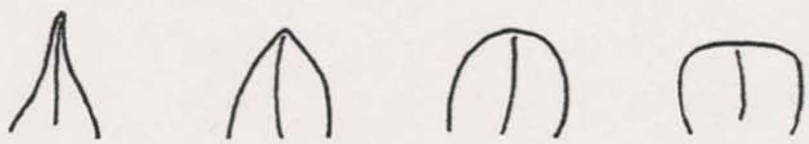

Broadleaf (Dicot) Plant
Growing point at tip
Netted veins
Two seedling leaves

LEAF BASES



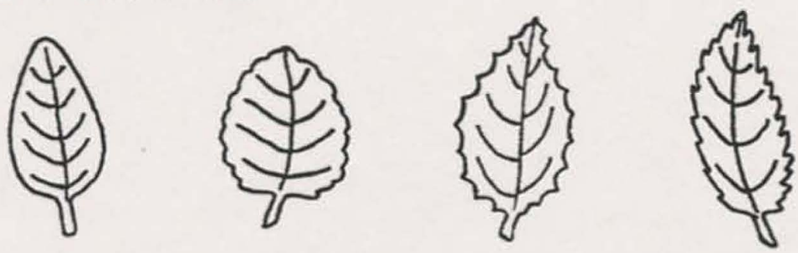
Attenuate | Cordate | Obtuse; Rounded | Sagittate

LEAF TIPS



Acuminate | Acute | Obtuse | Truncate

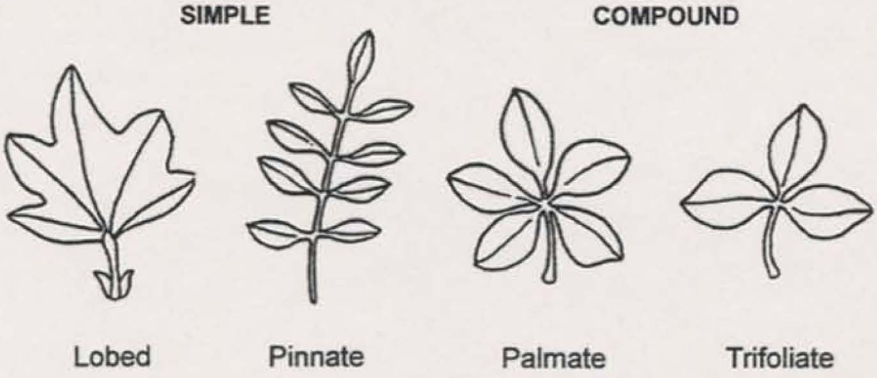
LEAF MARGINS



Entire | Crenate | Dentate | Serrate

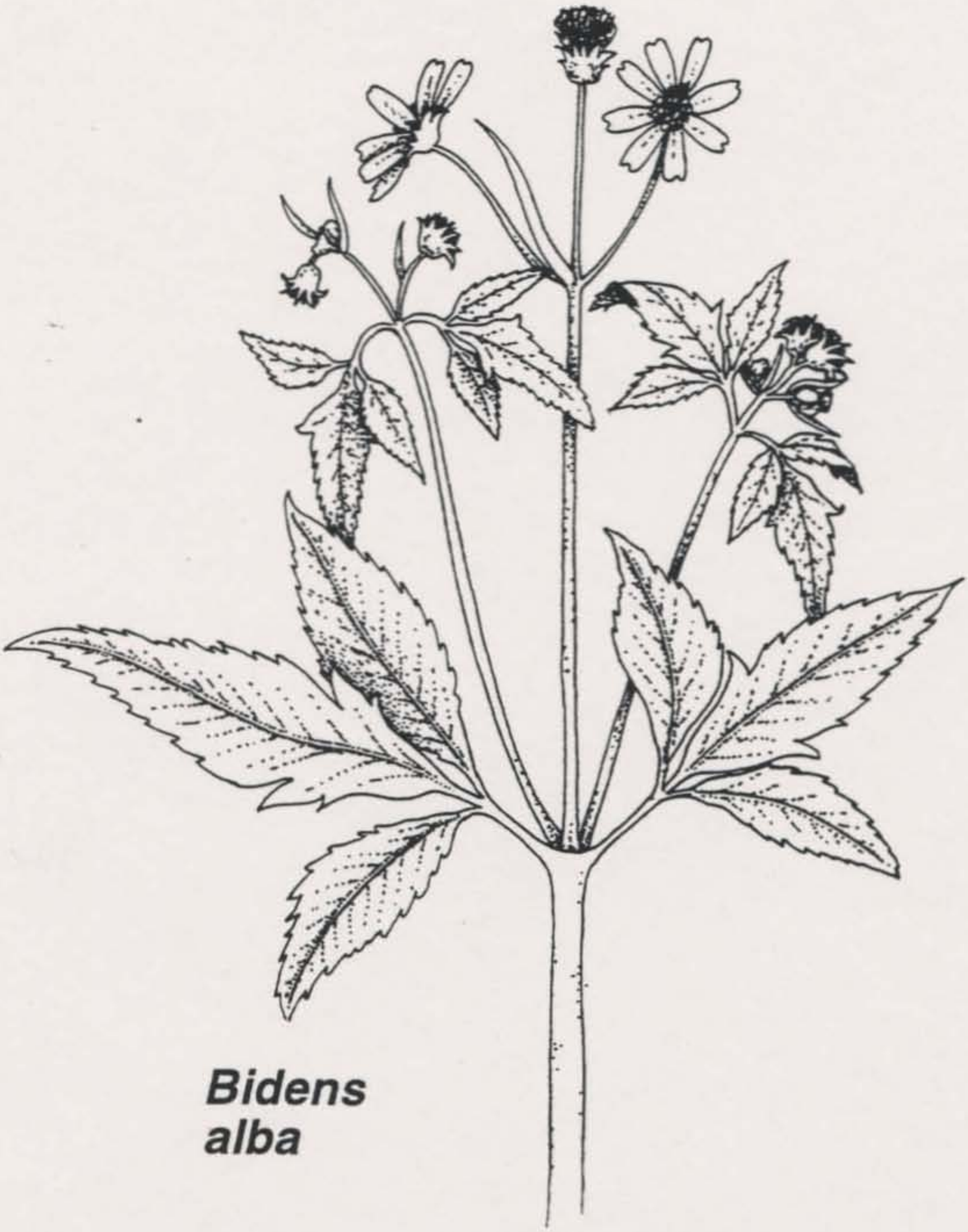
SIMPLE AND COMPOUND LEAVES

SIMPLE | **COMPOUND**



Lobed | Pinnate | Palmate | Trifoliate

Eleusine indica



Bidens alba

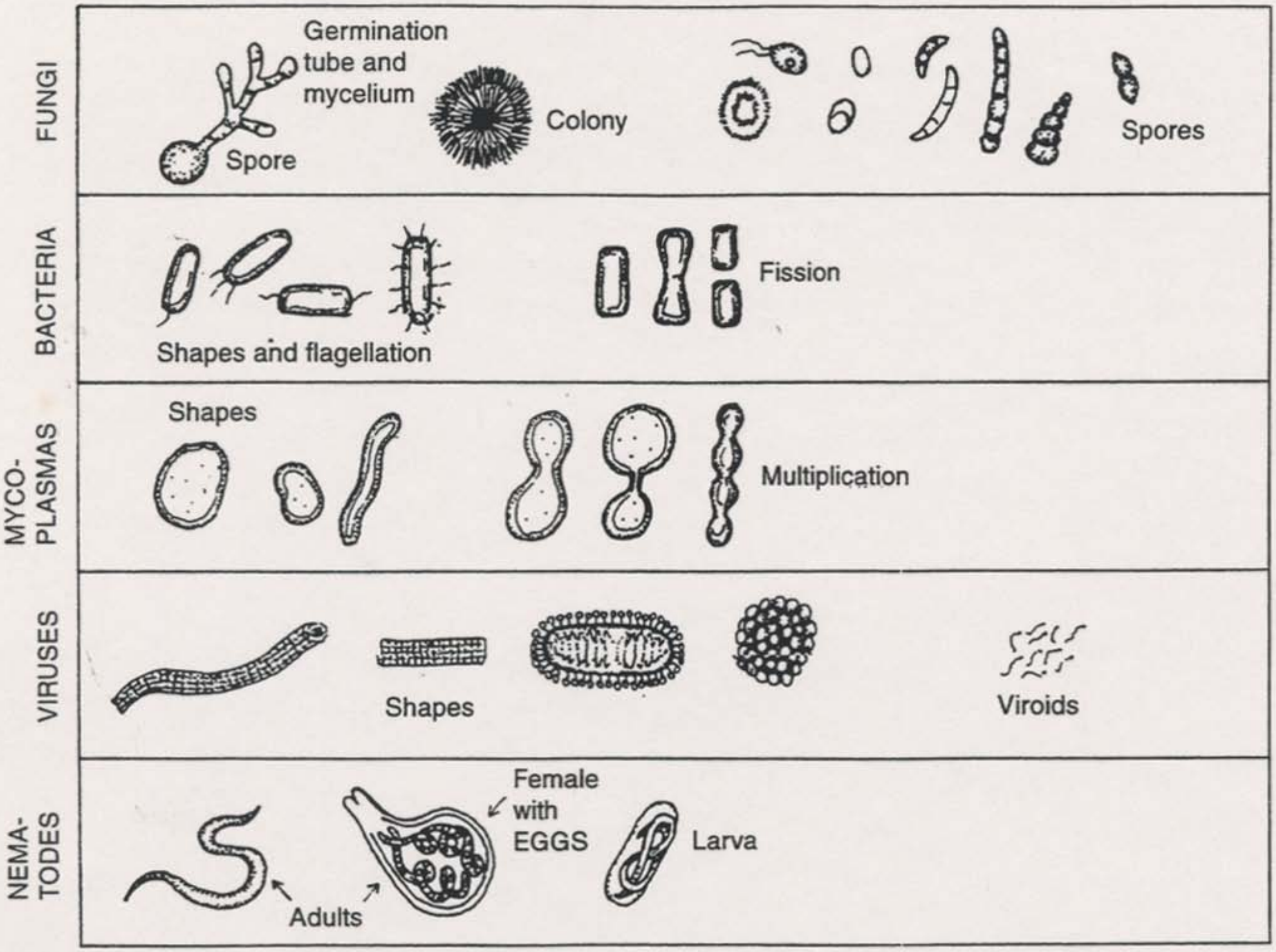
Stachytarpheta urticifolia

Emilia sonchifolia

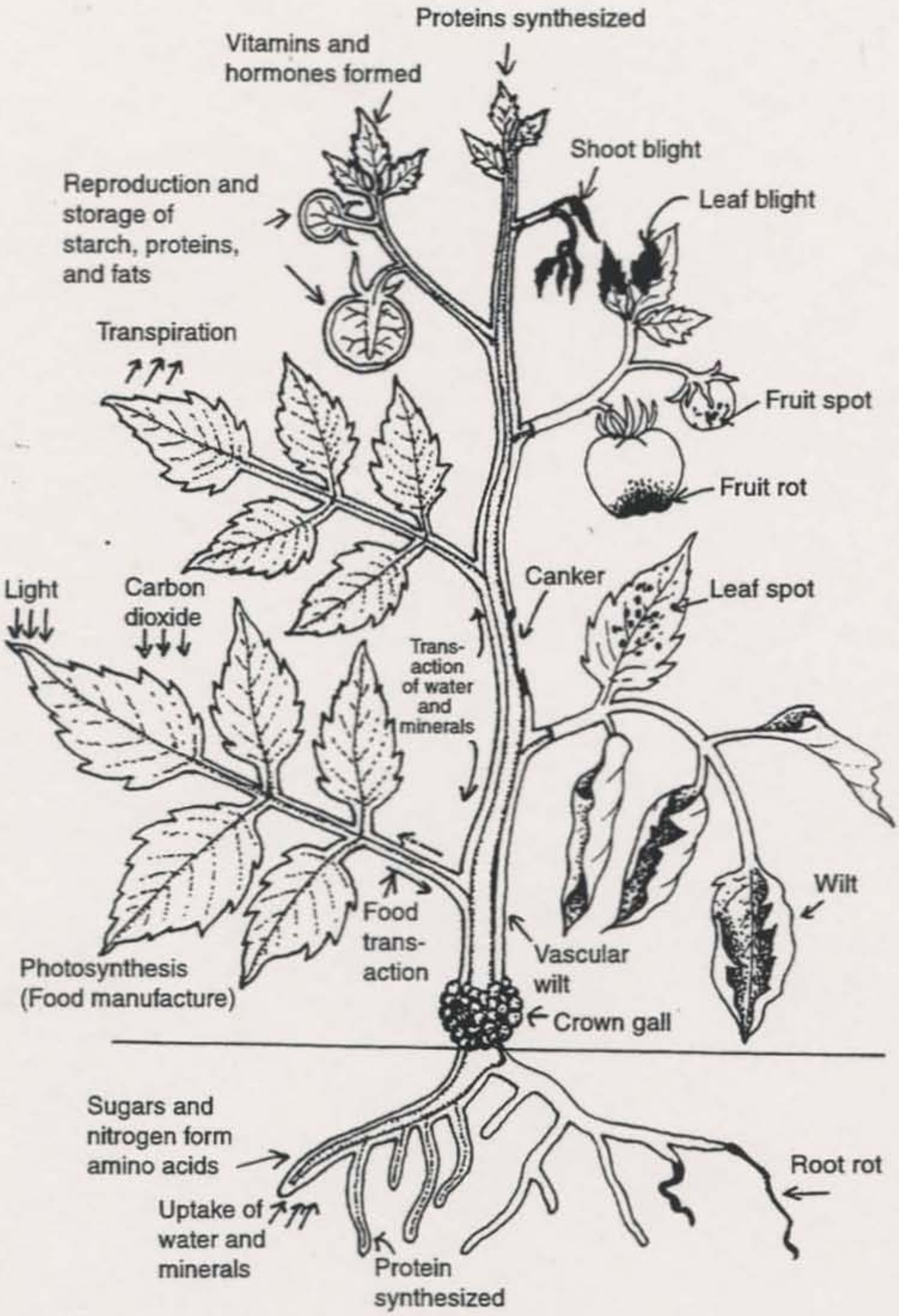
Paspalum conjugatum

Chlorocyperus rotundus

Kyllinga sp.

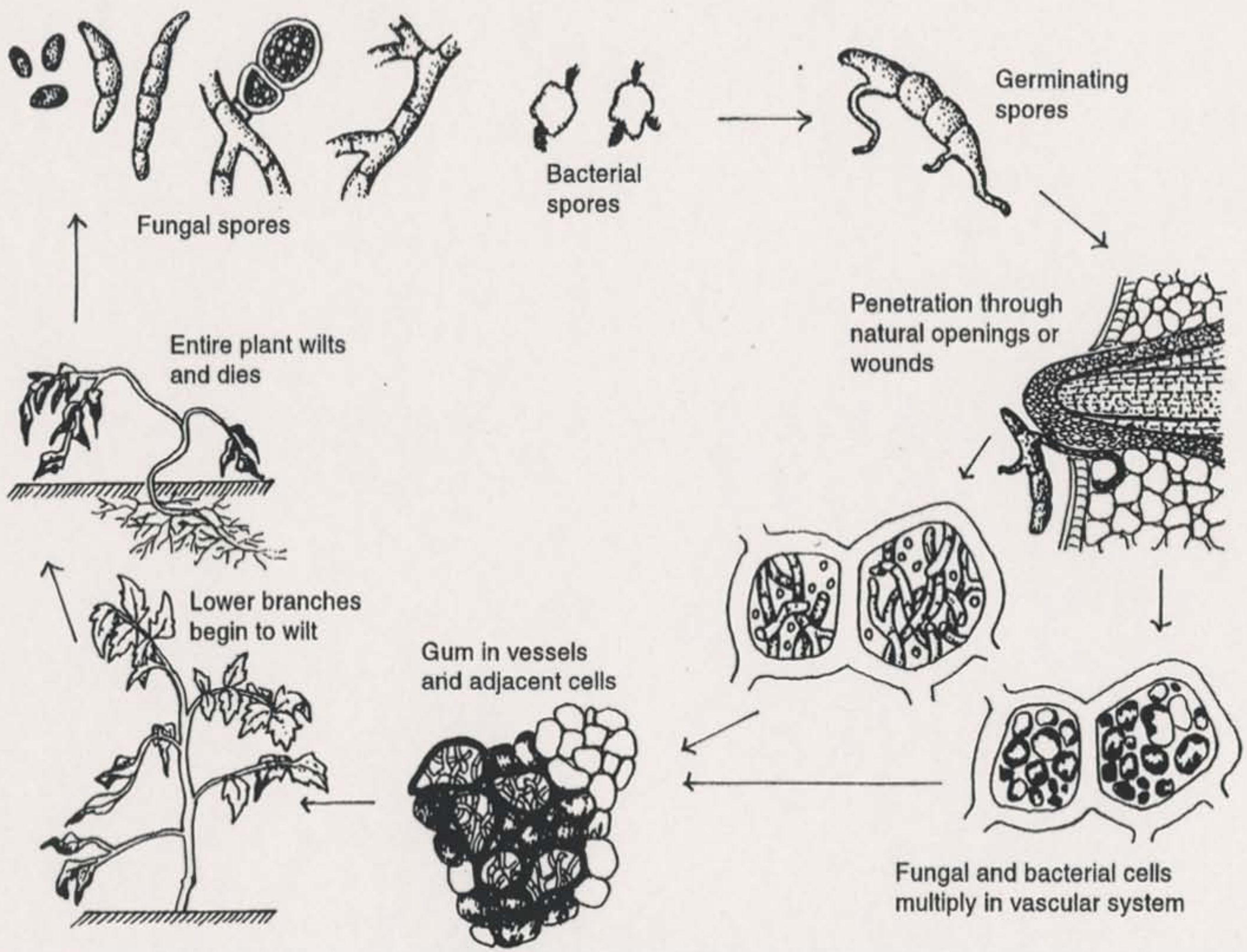


SHAPES AND REPRODUCTIVE STRUCTURES OF SOME OF THE GROUPS OF PLANT PATHOGENS

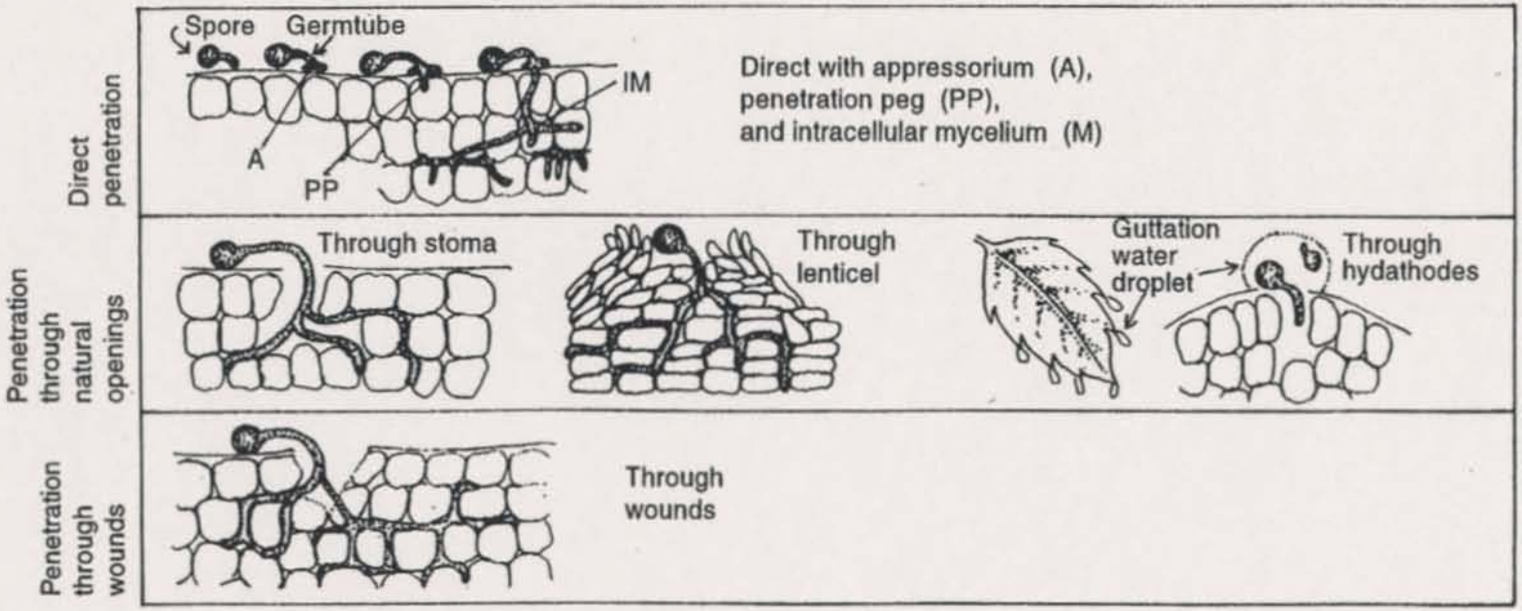


SCHEMATIC REPRESENTATION OF THE BASIC FUNCTIONS IN A PLANT (LEFT) AND OF THE INTERFERENCE WITH THESE FUNCTIONS (RIGHT) CAUSED BY SOME COMMON TYPES OF PLANT DISEASES

VASCULAR WILTS CAUSED BY FUNGAL & BACTERIAL ORGANISMS

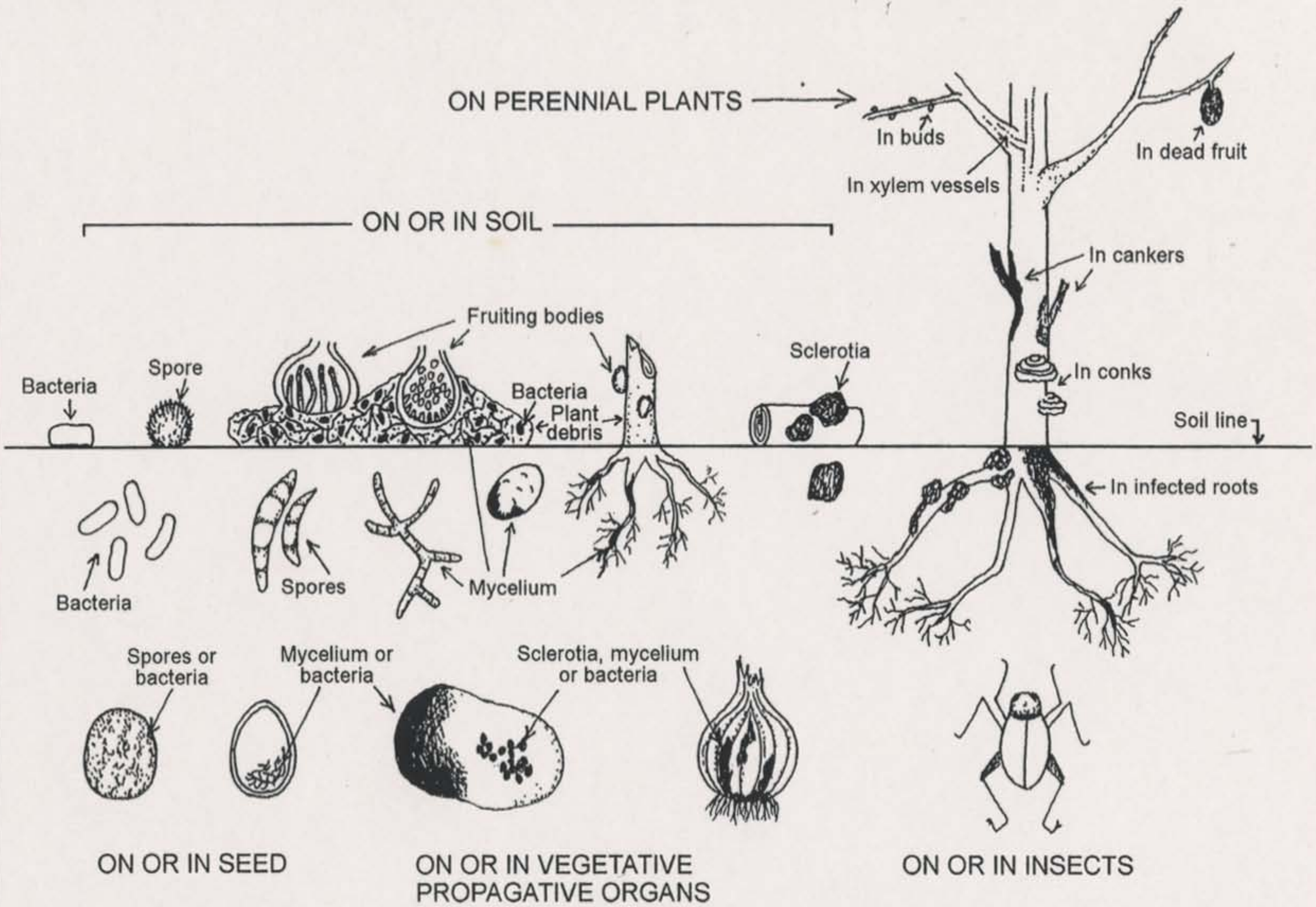


METHODS OF PENETRATION AND INVASION BY FUNGI AND BACTERIA



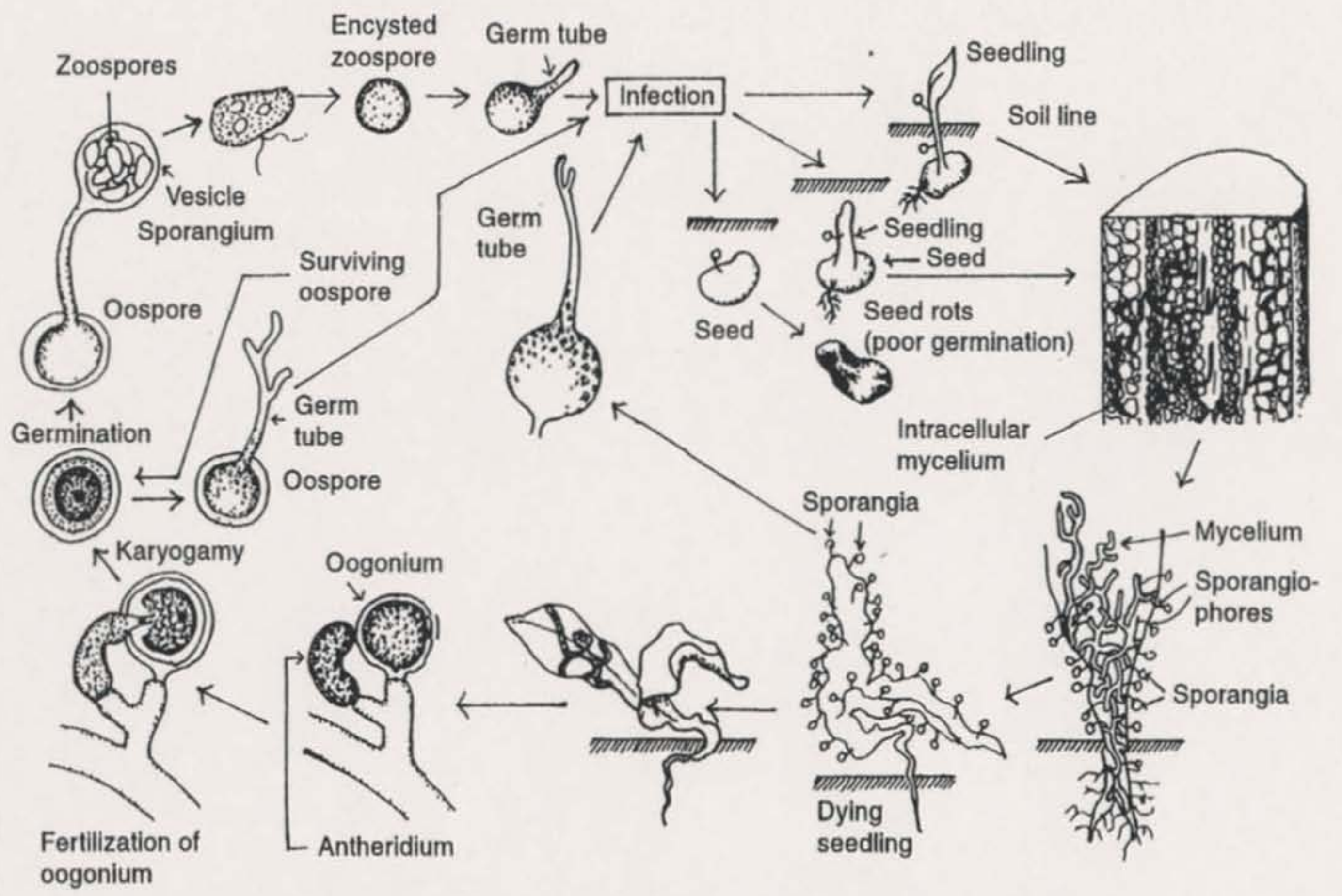
13.1

FORMS AND LOCATIONS OF SURVIVAL OF BACTERIA AND FUNGI BETWEEN CROPS

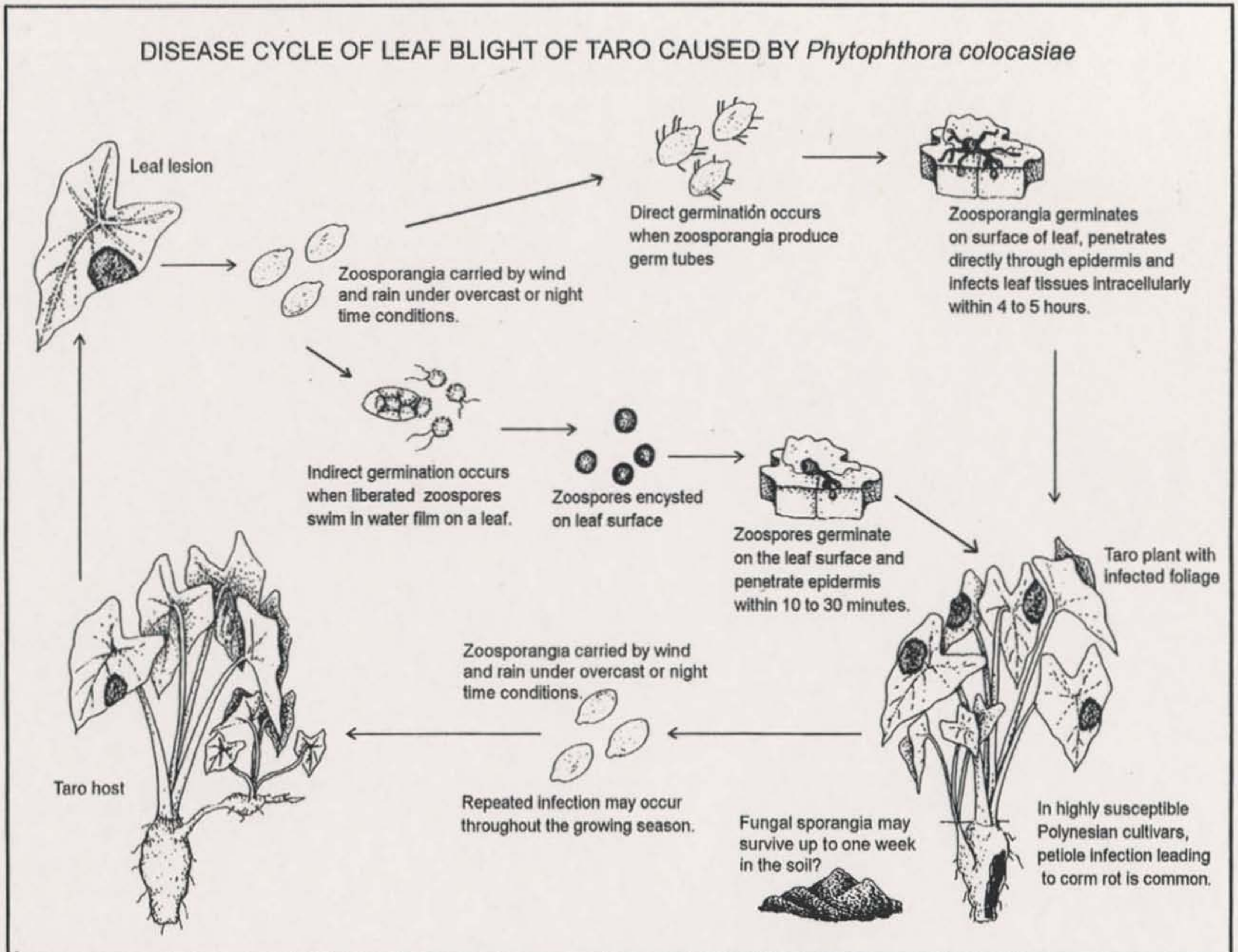


13.2

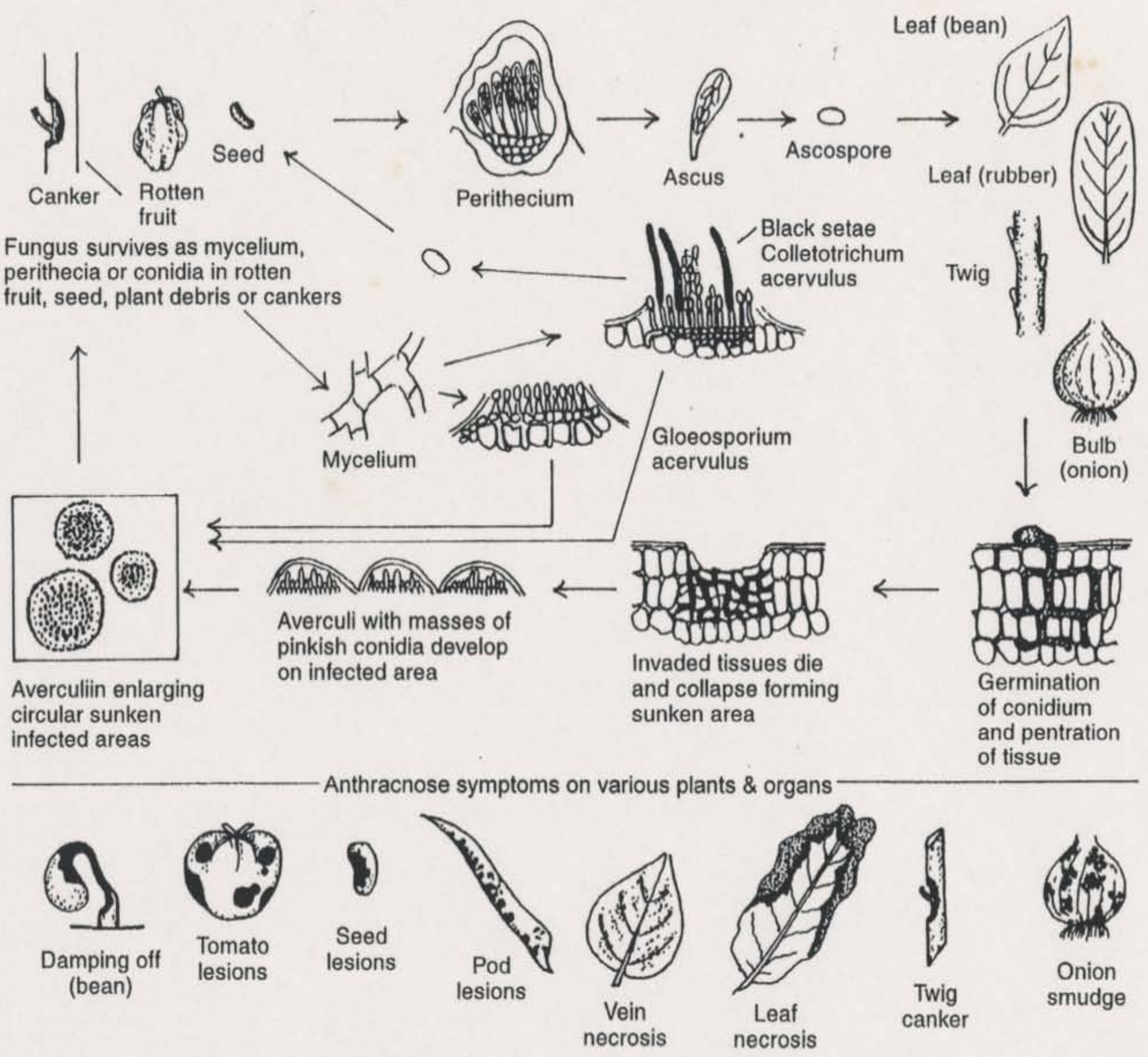
DISEASE CYCLE OF DAMPING OFF AND SEED DECAY CAUSED BY *Pythium spp.*



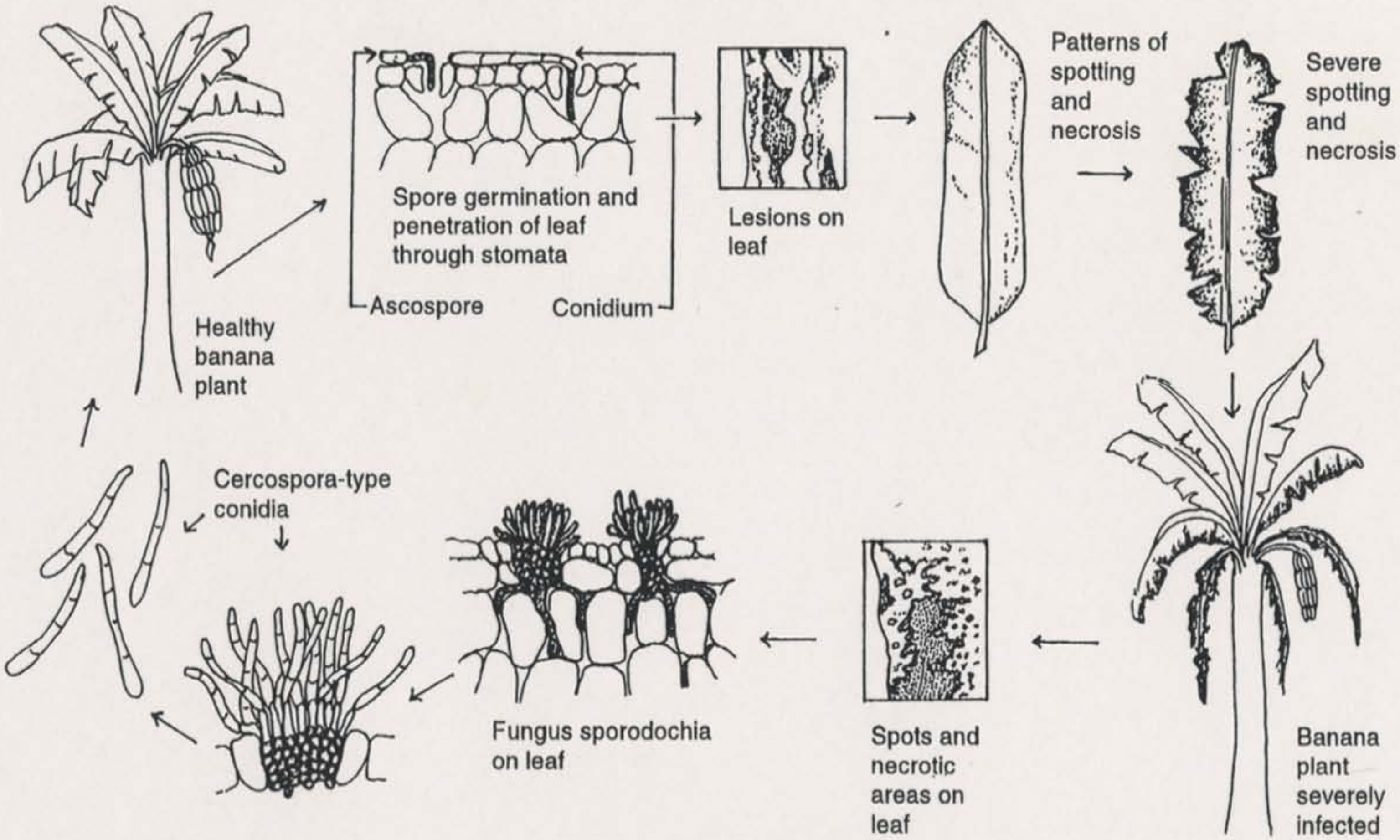
14.1


DISEASE CYCLE OF LEAF BLIGHT OF TARO CAUSED BY *Phytophthora colocasiae*
Leaf lesion
Zoosporangia carried by wind and rain under overcast or night time conditions.
Direct germinatión occurs when zoosporangia produce germ tubes
Zoosporangia germinates on surface of leaf, penetrates directly through epidermis and infects leaf tissues intracellularly within 4 to 5 hours.
Indirect germination occurs when liberated zoospores swim in water film on a leaf.
Zoospores encysted on leaf surface
Zoospores germinate on the leaf surface and penetrate epidermis within 10 to 30 minutes.
Taro plant with infected foliage
Zoosporangia carried by wind and rain under overcast or night time conditions.
Repeated infection may occur throughout the growing season.
Fungal sporangia may survive up to one week in the soil?
In highly susceptible Polynesian cultivars, petiole infection leading to corm rot is common.
Taro host

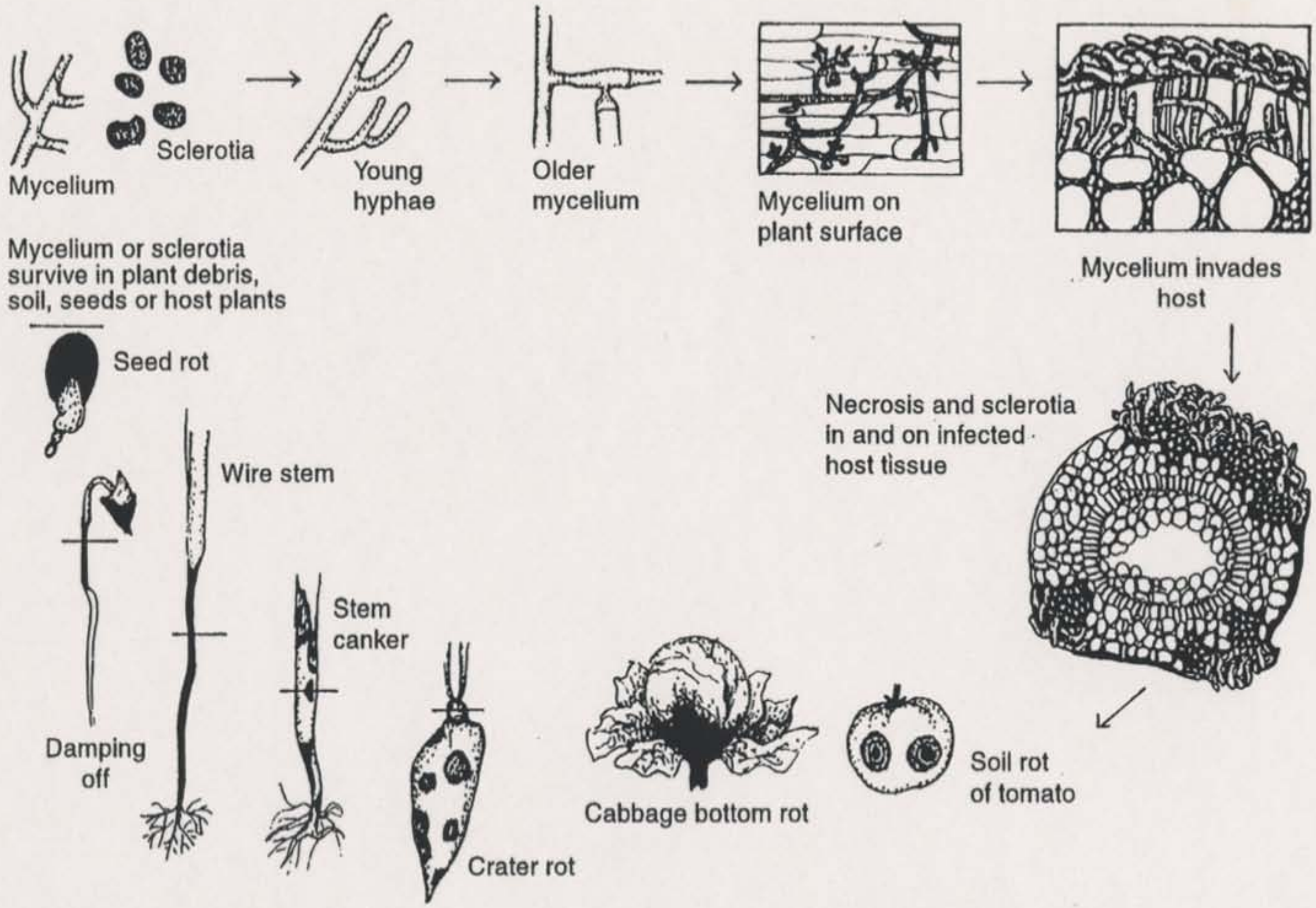
DISEASE CYCLE OF THE ANTHRACNOSE DISEASES CAUSED BY *Glomerella cingulata* and *Colletotrichum* or *Gloeosporium spp.*



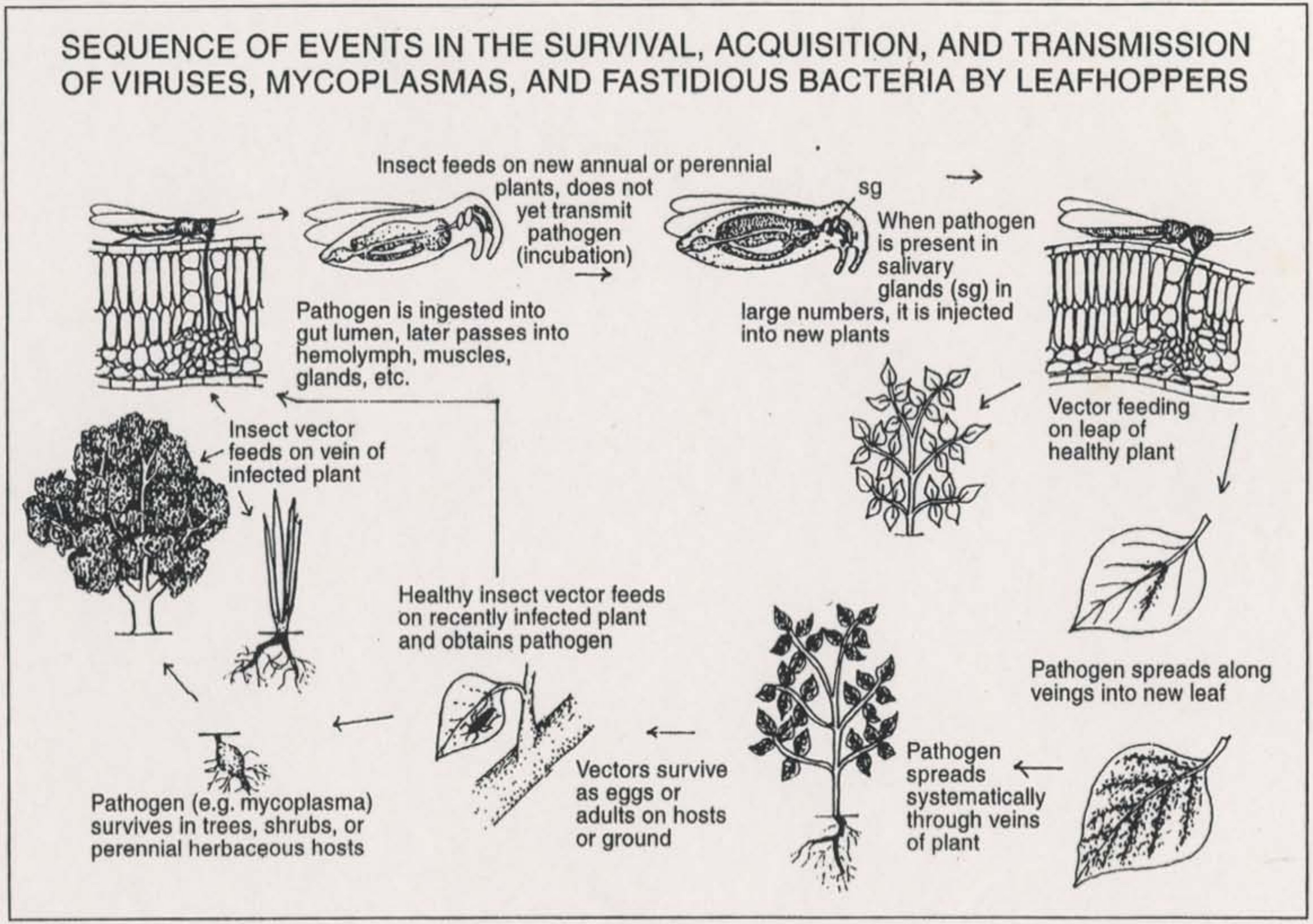
DEVELOPMENT OF SIGATOKA DISEASE CAUSED BY *Mycosphaerella Musicola*



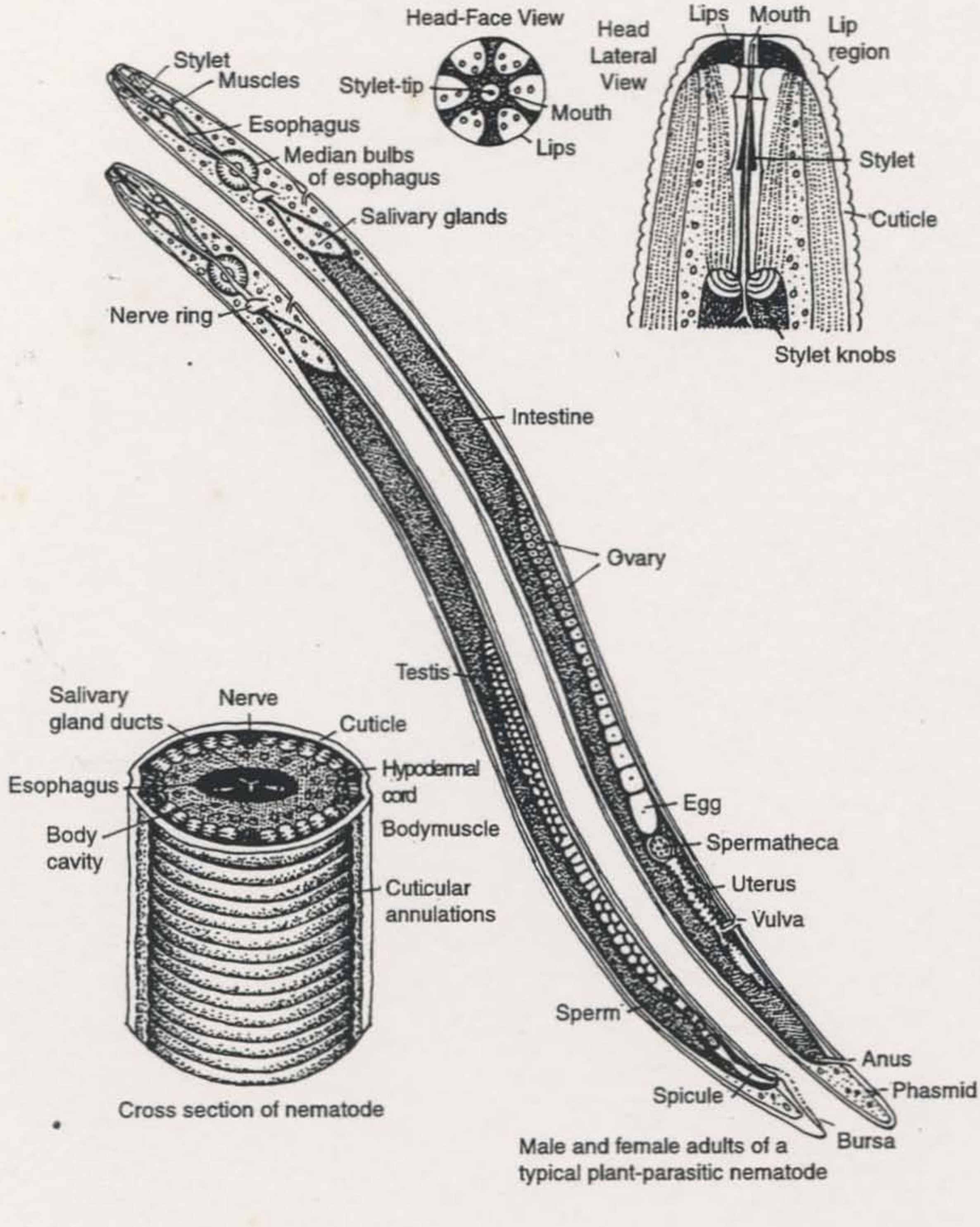
DISEASE CYCLE OF *Rhizoctonia solani (Thanatephorus cucumeris)*



15.1


SEQUENCE OF EVENTS IN THE SURVIVAL, ACQUISITION, AND TRANSMISSION OF VIRUSES, MYCOPLASMAS, AND FASTIDIOUS BACTERIA BY LEAFHOPPERS
Insect feeds on new annual or perennial plants, does not yet transmit pathogen (incubation)
sg
When pathogen is present in salivary glands (sg) in large numbers, it is injected into new plants
Pathogen is ingested into gut lumen, later passes into hemolymph, muscles, glands, etc.
Insect vector feeds on vein of infected plant
Vector feeding on leap of healthy plant
Healthy insect vector feeds on recently infected plant and obtains pathogen
Pathogen spreads along veings into new leaf
Pathogen spreads systematically through veins of plant
Vectors survive as eggs or adults on hosts or ground
Pathogen (e.g. mycoplasma) survives in trees, shrubs, or perennial herbaceous hosts

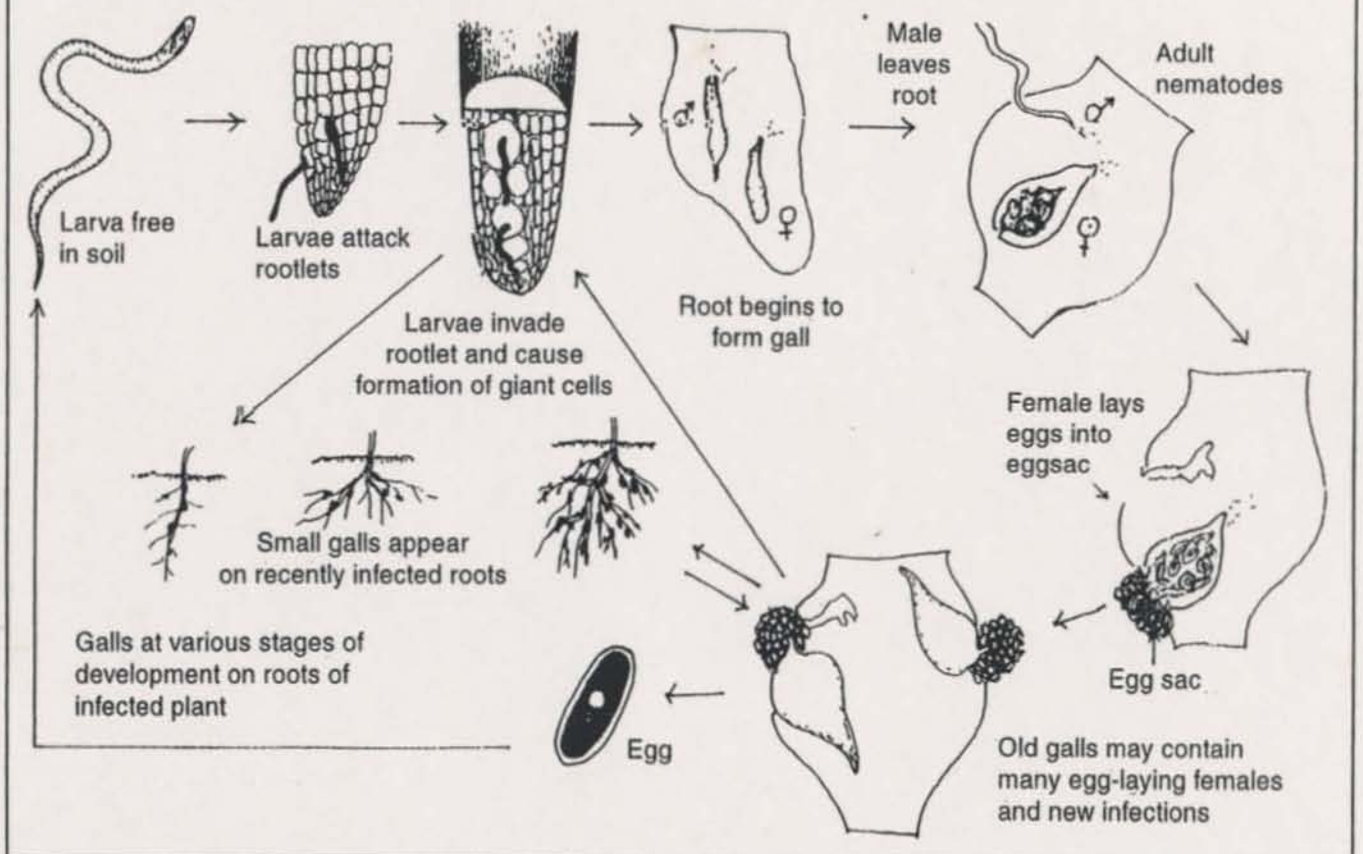
MORPHOLOGY AND MAIN CHARACTERISTICS OF TYPICAL MALE AND FEMALE PLANT PARASITIC NEMATODES

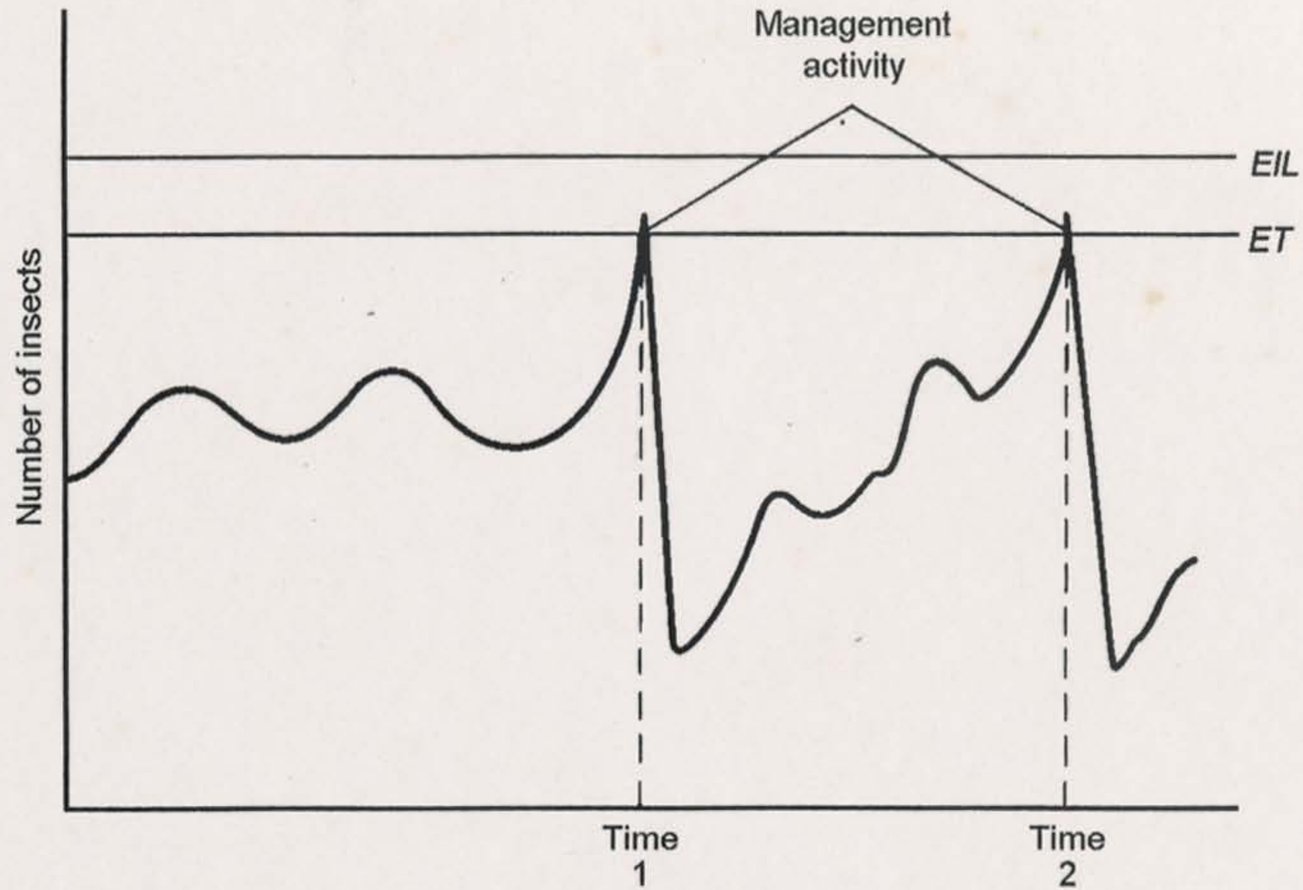


Cross section of nematode

Male and female adults of a typical plant-parasitic nematode

DISEASE CYCLE OF ROOT KNOT CAUSED BY NEMATODES OF THE GENUS *Meloidogyne*





Economic Injury Level (EIL) and Economic Threshold (ET)

19.1