Protection

I. Insects

A. Introduction

Insects are one of the greatest destroyers of tree fruits and seeds. They reduce both quality and quantity of seeds and affect angiosperms and gymnosperms equally. Damage is done through all reproductive stages, from developing buds to cleaned seeds in storage. Losses to seed insects are huge, and much is yet to be learned about their complete role in the reproductive cycle of woody plants.

B. Objectives

1. Learn the orders of insects that cause the most damage to tree seeds and the species they attack.
2. Recognize the types of injury that insects cause.
3. Learn some methods of insect control and management.

C. Key Points

The following points are essential in protecting seeds from insects:

1. Insects of the orders Hymenoptera, Diptera, Lepidoptera, Hemiptera, Coleoptera, Homoptera, and Thysanoptera do the most damage to flowers, fruits, and seeds of woody plants.
2. Damage ranges from causing reproductive structures to abort to causing loss of seeds in storage.
3. General types of damage include:
   - a. Destroying the seeds only, Hymenoptera (wasps).
   - b. Forming galls and mine scales, Diptera (flies).
   - c. Free feeding, Lepidoptera (moths).
   - d. Consuming endosperm, Hemiptera (true bugs).
   - e. Mining cone axes, Coleoptera (beetles).
   - f. Causing cone abortion, Homoptera (aphids and others) and Thysanoptera (thrips and others).
4. Control methods depend on identifying the insect's life cycle and the host-plant relationship.
5. Some methods for reducing damage are preventive measures, insecticides, natural biological control agents, and proper management techniques.

D. Damage

1. **General concepts**
   - a. Insects reduce seed production by infesting buds, flowers, cones, and seeds. Bud damage causes wilting, abnormal growth, and abortion of flowers and immature fruit. Damaged fruits may be deformed, worm infested, riddled with galleries, and susceptible to secondary infection by pathogens.
   - b. The most damaging insects to flowers, fruits, and seeds of most trees are largely restricted to six orders: Lepidoptera (moths and butterflies), Diptera (flies), Coleoptera (beetles), Hymenoptera (wasps), Hemiptera (true bugs), and Thysanoptera (thrips).
2. **Specific concepts**
   - a. Coleoptera (beetles) are the most damaging group in arid and semiarid zones.
     - (1) Bruchidae (bruchid beetles) are the most important by far for Leguminosae.
       - *(a)* *Amblycorus, Bruchidius, Caryedon,* and others feed on *Prosopis, Tamarindus, Acacia, Parkinsonia, Gleditsia,* and *Cordia.*
       - (b) Eggs are deposited on developing fruits, and the larvae eat seed tissues. One group emerges at fruit maturity (trees and shrubs). A second group infests pods at later stages of development, emerges, and reinfests the same seeds in storage (e.g., peas and beans, Fabaceae).
       - (c) Bruchid beetles are serious seed predators of *Acacia* in arid zones.
     - (2) Curculionidae (weevils) lay their eggs on developing fruits.
       - *(a)* *Conotrachelus* are important cone worms in Mexican *Pinus* and other subtropical pines.
       - *(b)* *Curculio* and *Conotrachelus* are the common acorn weevils in *Quercus.*
       - *(c)* *Thysanocnemis* are important seed weevils in *Fraxinus.*
       - *(d)* *Nanophyes* can destroy 60 percent of the seed crop of *Terminalia ivorensis.*
       - (e) *Apion ghanaense* destroy many flowers and seeds of *Triplochiton.*
   - b. Lepidoptera (moths and butterflies) can damage stored seeds.
     - **(1)** Pyralidae attack many tropical legumes, primarily the developing pods and seeds. This family also contains the very damaging cone worms of *Pinus (Dioryctria).* Larvae destroy seeds, cone scales, and cone axes (60 percent loss).

(2) *Melissopus* and *Valentinia* are moths whose larvae destroy developing fruits of *Quercus.*
(3) *Agathiphaga* can destroy more than half the seeds in *Agathis* cones in the western Pacific area.
(4) Gelechiidae is a family of small moths that attack *Juniperus* cones; they are very destructive.

c. Hemiptera (true bugs) feed on seeds with specialized sucking mouth parts. Saliva is injected into seed tissue to digest it.
(1) Coreidae attack *Erythrina* seeds in India and some *Acacia* species in Africa. The bugs reportedly move to trees when crops are sprayed. This family also includes *Leptoglossus,* the very damaging pine seedbug on tropical and subtropical *Pinus,* and *Leptocentrus,* which damages flowers and fruits on teak.
(2) Pentatomidae, the stink bug family, feed on seeds of *Pinus.*

d. Hymenoptera (wasps) includes many beneficial insects, but also some that feed on tree seeds.
(1) Torymidae includes a major conifer seed pest, *Megastigmus* spp. Its larvae feed on *Pinus, Abies,* and *Pseudotsuga.*
(2) Eurytomidae includes the genus *Bruchophagus,* whose larvae feed on *Acacia* seeds; most feed on smaller legumes than *Acacia* because *Acacia* pods are so tough.

e. Homoptera includes aphids, cicadas, and scales. Scales damage some Mexican pines, but they are not a major predator. Some damage to cones and seeds of *Pinus pinaster* is caused by aphids in South Africa; in one instance, seed yield was reduced by 72 percent.

f. Thysanoptera (thrips) cause damage, but little is known about the important predators. However, *Gnophothrips* damage or kill female buds and flowers of *Pinus* (Mexican and other subtropical species).

E. Controlling Insects

Control measures must be guided by the species and ecology of the insect to be controlled. The first step is to identify the problem and its source insect. Seeds with insects feeding internally are collected and placed in plastic bags to allow the insects to mature. The resulting information on the life cycle and insect-host relationship determines control measures.

1. **Prevention** — The insect may be prevented from reaching the seeds. For example, in The Gambia, long sleeves are put over the flowering branches to exclude pests in *Acacia* seed orchards. Such measures are feasible only in very valuable seed orchards.
2. **Chemical control** must be applied when the insect is at a vulnerable point in its life cycle. For example, if the insect spends most of its life inside of, and protected by, seed tissues, chemical sprays will not be effective during that period.
   a. Foliar sprays: 1-percent azinphosmethyl spray for cone worms and seedbugs was once common in Southern United States pine seed orchards, but environmental concerns reduced this practice. Sprays of nuvacron and endosulfan have controlled insect damage in teak seed orchards.
   b. Systemic poisons: Carbofuran applied as granules in the soil (4.5 g per centimer of diameter at breast height kl.b.h.1) gives good control of cone worms, borers, and seedbugs, but it is not effective against seed chalcids.
   c. Light traps: Can be used in seed orchards to reduce the population of egg-laying adults.
   d. Chemical traps: Baited with sex attractants, chemical traps may reduce breeding populations.
   e. Carbon dioxide: Treatment with carbon dioxide is a promising new measure to kill larvae in seeds. Shipping seeds in a carbon dioxide-rich atmosphere is also promising.
3. **Natural enemies** — The target insect's life cycle and history should reveal its natural enemies.
   a. The bruchid beetles have natural parasitoids that attack the egg, larval, and pupal stages. The parasitoids are mostly from the insect order Hymenoptera. Mass-rearing the parasitoids to control the beetles may be possible if circumstances warrant.
   b. In Hawaii, seed beetles have been successfully controlled biologically by introducing wasps to attack eggs, larvae, and pupae. The seed beetles lay their eggs on the outer surface of the pods and are, therefore, easily controlled by wasp predators. Larvae and pupae, however, are more difficult to control. Adult seed beetles have such short lives they are not susceptible to parasitoids.

c. **A** species of mite *(Pymotes)* will also feed on seed beetles. However, laboratory results do not corroborate field data, so this control method is in question.

4. **Collection** — Good seed collection is the first step in minimizing losses incurred in storage. Removing infested seeds during cleaning is the second step. Water flotation and density separation methods can be extremely effective. If good seeds were collected, they must be stored properly to control insects. Both low temperature and low moisture content will subdue insect infestations; however, it is much better to avoid transporting the insects to storage initially. Two weeks at — 18 °C will kill most larvae. Drying seeds at 40 to 42 °C will kill insects. Heating seeds in warm water and fumigating with serafume, methyl bromide, or carbon bisulphide will also control insects. Chemical treatments should be avoided, however, because they can reduce viability if applied improperly. High moisture content makes recalcitrant seeds especially susceptible to damage.

F. Sources

For additional information, see Cibrian-Tovar and others 1986, Johnson 1983, Schopmeyer 1974, Southgate 1983.

II. Pathogens

A. Introduction

Pathogenic organisms (fungi, bacteria, and viruses) cause great economic losses. Not only are seeds the victim of pathogens, but they also are passive carriers (vectors) of pathogens that may not directly affect the seeds but may endanger other organisms. This fact is the basis of plant quarantine regulations that include seeds in the import and export restrictions on plant material.

B. Objectives

1. Learn the major types of seed pathogens and the typical damage that they cause.
2. Identify steps to decrease losses to seed pathogens.
3. Review documented occurrence of micro-organisms associated with tree seeds.

C. Key Points

The following points are essential to preventing seed pathogens:

1. The major disease-causing organisms are fungi, bacteria, and viruses.
2. All tree seeds carry micro-organisms, primarily on the surface of their seedcoats.
3. All seed micro-organisms are not pathogenic; some may even be beneficial.
4. Pathology of tree seeds has not been studied extensively; much work remains to be done.

D. Types of Pathogens

1. **Viruses**

a. Viruses are known to cause seven kinds of seed damage:

(1) abortion
(2) flower sterility
(3) seedcoat wrinkling
(4) shriveling
(5) chalky endosperm
(6) staining
(7) necrosis

b. In legumes, embryo-borne viruses reduce seed viability. Seedcoats shrivel and crack, shrinking the seeds. The seeds usually survive, but they remain small and, most significantly, transmit the virus to other seeds. In addition, the weakened state of the seeds allows secondary infection from other pathogens to reduce viability.

c. In agricultural legumes, a higher incidence of triploidy is associated with seed-borne viral infections. These triploid seeds germinate slower with less overall vigor than diploid seeds, and their seedlings usually do not survive.

d. There are economic complications in viral infections of agricultural seeds not important to tree seeds. For example, many virus infections discolor the seedcoat. Discoloration does not always mean poor seed viability, but it can influence the market price of seeds.

e. Although viruses live in seeds for very long periods (up to 30 years in bean seeds), it is not known how long viral-infected seeds will retain viability. The virus will usually outlive the seed.

2. **Bacteria —** Bacterial infections account for four kinds of seed damage:

a. Seed abortion includes problems ranging from shriveled seeds to size reduction to seed formation interruption; in each case, it will significantly reduce seed yields. The primary cause is *Xanthomonas.*

b. Seed rot usually begins in water-soaked lesions on the seedcoat. In young seeds, there is a general, overall rotting of tissue that then decomposes into bacterial slime. In mature seeds, the infection is usually localized in the seedcoat.

Latent symptoms are rapidly rotting seedlings. Infested seeds have discolored bacterial pendants attached. Seeds are sometimes so infested that cotyledons of surviving seedlings are covered by black lesions. *Xanthomonas is* also responsible for seed rot and is sometimes accompanied by rot fungi, such as *Colletotrichum.*

c. Seed discoloration is caused by pathogenic bacteria invading seedcoat lesions. The lesions usually begin as slight depressions caused by *Xanthomonas* or *Pseudomonas.* Common colors are usually reddish brown or yellow. In extreme cases, the seed eventually rots.

d. Slime disease (known also as tundu disease or tannau disease in Asia) is widespread (from Denmark to New Zealand) and of prime significance in agricultural seeds. It causes initial rotting, then a massive slime coat when wet, which dries to cover the seed with a varnishlike substance. Some symptoms also begin as slime and result in seed abortion. All causative agents are not clearly identified, but include several *Corynebacterium* species.

3. **Fungi** are a serious threat to seed health simply because of the great numbers of species known as seed pathogens. In addition to being lethal infections, some fungi drastically reduce the quality of seeds even though they do not kill them. There are eight kinds of fungal diseases, and two or more commonly combine to attack seeds.

a. Seed abortion is the result of infection by smut fungi that infest host flower parts and replace them with fungal fruiting parts. Flowers and young seed structures are particularly susceptible to Fungi Imperfecti, but as the host matures, it can often withstand the pathogen. Other species infect but do not damage the seeds.

b. Shrunken seeds typically have shriveled seedcoats. Fungal infections of stems and leaves may cause seed shrinkage, thus reducing seed yield. Rust fungi are an example of this problem. Certain other fungi reduce the oil content in sunflowers.

c. Seed rot during germination is commonly caused by *Fusarium,* which produces dry rot. A large genus causing severe problems for many tree hosts is *Botrytis.* Also of significance are *Ciboria, Sclerotinia, Phomopsis, Valsa,* and *Gloeosporium.* Cones of many conifers are particulary susceptible to *Schizophyllum.* It is also important to control rot in seed storage. *Mucor* usually comes from the soil and then penetrates seedcoat cracks.

d. Sclerotization and stromatization are defined as the transforming of host flowers and seeds into sclerotia or stromata of invading fungi. *Ciboria* and *Phomopsis* cause a commonly known "popcorn" disease in many forest tree seeds.

e. Seed necrosis refers to dead tissue accumulation, usually attributed to seed-rot fungi. However, the penetration of the fungi is usually superficial, extending only into the epidermal tissue. In legumes, however, necrosis will extend into lesions of the cotyledons.

f. Seed discoloration is not the problem for forest tree seeds that it is for agricultural seeds. Tree seeds are usually not subject to standards of form and color that many edible seeds must meet. Still, tree seeds are discolored by lesions, fungal coatings, and pigmentation. Not all fungi identified as seed-discoloring fungi will produce pigmentation on seeds, even though the fungi have infected the seeds.

g. Lowered germination capacity is a broad category, and perhaps any pathogen could be placed here. However, some species seem to affect germination specifically. *Ustilago* may be present in the embryo but remains dormant until the seed itself germinates. Some reports attribute the cause to fungal-produced toxins.

h. The metabolites of some infecting fungi have adverse physiological effects in the seed. These metabolites are sometimes not harmful to the seeds but are harmful to the animals that eat the seeds.

E. Control Mechanisms

Seed pathogens can be controlled by reducing infection and treating seeds in laboratories, storage, and nurseries.

1. **Infection reduction—** Infections in orchards can be reduced by:

a. Locating seed orchards in areas of low infection risk.

b. Removing alternate host plants from seed production areas or orchards.

c. Practicing good sanitation in orchards and destroying infected trees, old fruits and cones, etc.

d. Applying fungicides (cone rust in *Pinus).*

e. Using good cone- and fruit-handling procedures; e.g.; reducing cone storage time and removing old cones. (Enormous amounts of infection can occur during extraction.)

2. **Seed treatment in laboratories**

a. Surface sterilization with hydrogen peroxide (H_2O_2) (30 percent for 20 minutes), sodium hypochlorite (Na0C1) (10-percent solution of commerical bleach), or ethanol (C_2H_5OH) (75 percent is somewhat effective).

b. Fungicides come in numerous types and concentrations; length of treatment and concentration must be tested before large lots are treated.

c. A hot water soak such as 50 °C for 15 minutes is used on rice to kill both external and some internal pathogens. This method has not been tested for tree seeds, but longer and hotter treatments might be effective on hard-seeded species.

3. **Seed treatment in storage** is common for some agricultural seeds but not for forestry seeds. Many fumigants or liquid organic fungicides are likely to decrease seed viability in storage. Dry treatments with fungicidal dusts are recommended for tree seeds if a fungicide is needed.

4. **Seed treatment in nurseries**

a. Damping-off requires treatment.

(1) Soil is fumigated before planting.

(2) Seeds are treated with fungicide Thiram is used in pines of the Southern United States.

(3) Soil is drenched with fungicide in container operations.

b. Seedling diseases can be controlled b37 treating seeds with the systemic fungicide Bayleton (800 mg/liter).

F. Micro-organisms Found on Tree Seeds

See Anderson (1986a) to identify those orga nisms that have been documented on the spe cies of interest.

G. Sources

For additional information, see Anderson 1986a, International Seed Testing Association 1966, Neergard 1977, Sutherland and other;3 1987.

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