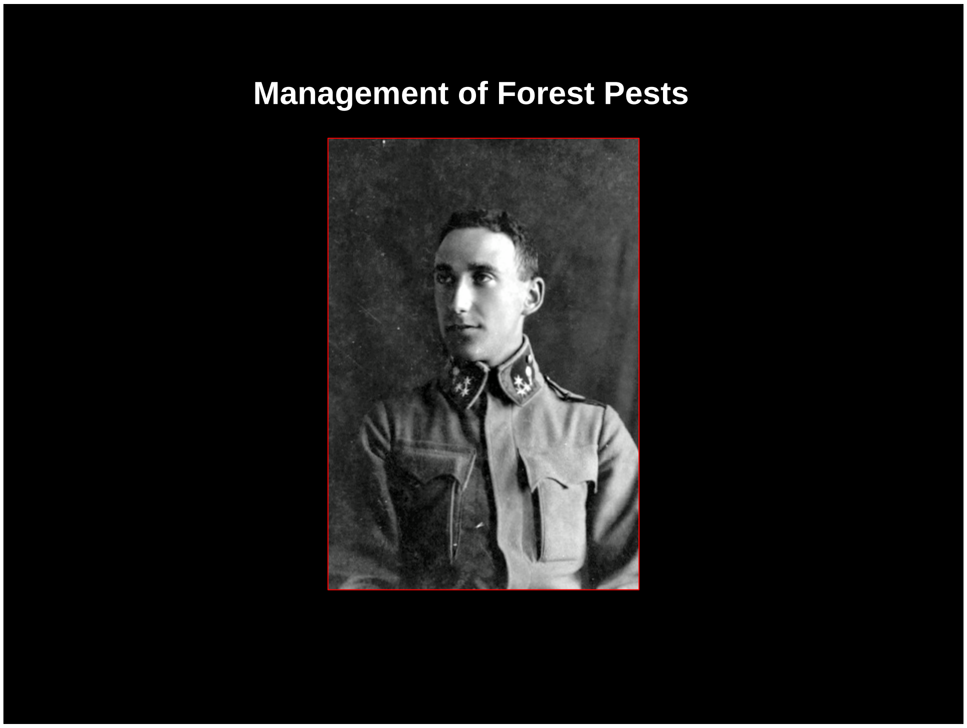
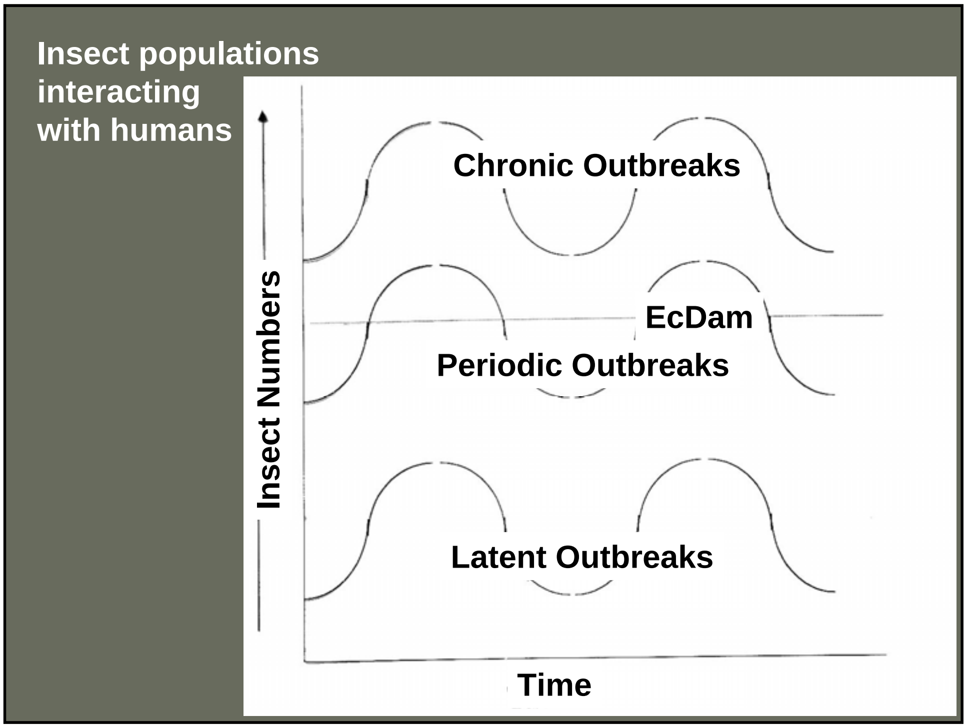
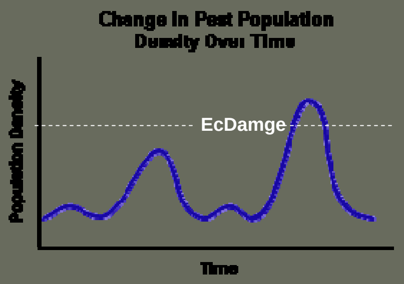


Management of Forest Pests



Insect populations interacting with humans

- The question is: What’s the economic damage level?
- 

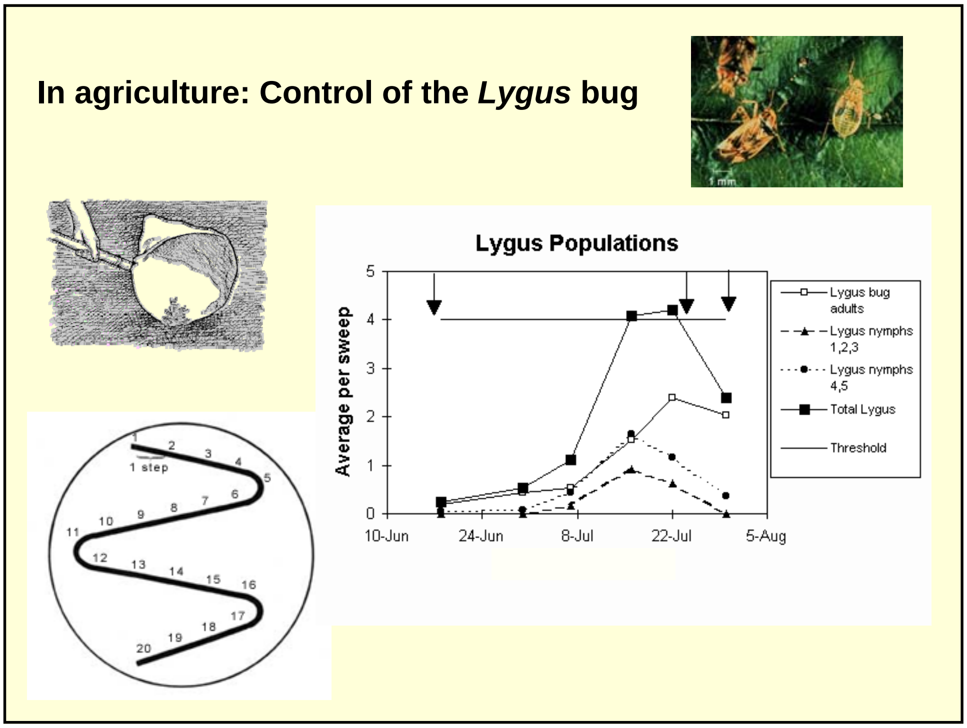
- As an insect population grows it reaches a point where it begins to cause enough damage to justify control measures.

Calculation of the Economic Damage Level

$$EcD = \frac{C*N}{V*I}$$

- C is the unit cost of controlling a pest, e.g. $20/acre.
- N is the number of pests injuring the commodity unit, e.g. 800 tip weevils/acre.
- V is the unit value of the commodity, e.g. $500/acre.
- I is the percentage of the commodity unit damaged, e.g. 10% loss.

$$EcD = \frac{20 * 800}{500 * 0.1} = 320/\text{pests per acre}$$



In agriculture: Control of the *Lygus* bug

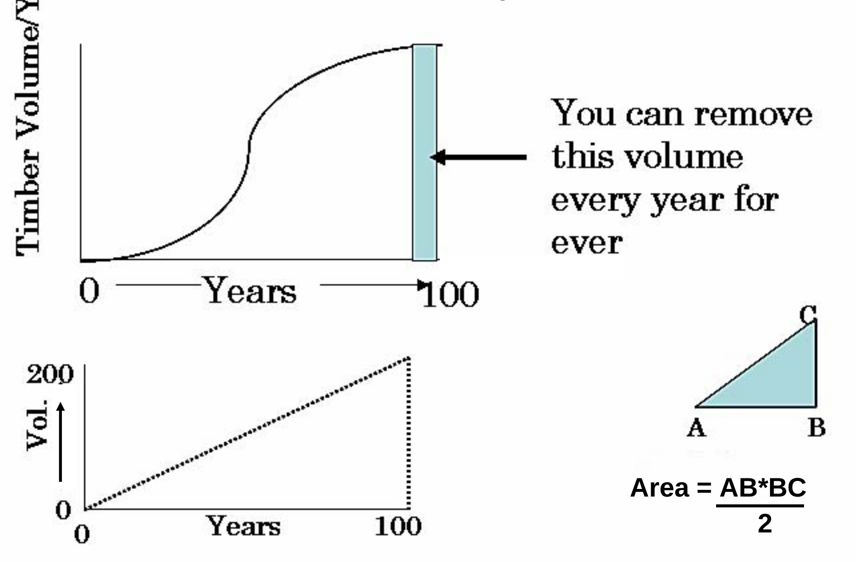
In farming you practice pest control via the 3-S approach.

Squat
Squint &
Spray

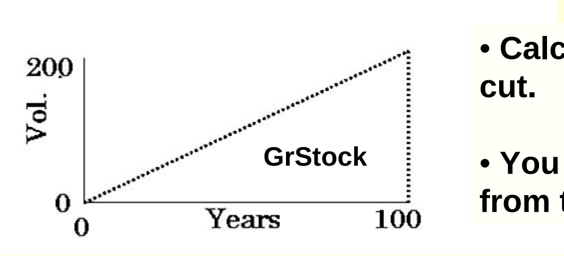
Other than intensive plantation forestry, we cannot practice the 3-S system because forestry deals with four dimensions:

1. Height
2. Width
3. Length
4. Time – 100yr rotations are still common.

In forestry if pests consume more than the allowable annual cut – they are at the EcD level.



Area = $\frac{AB*BC}{2}$



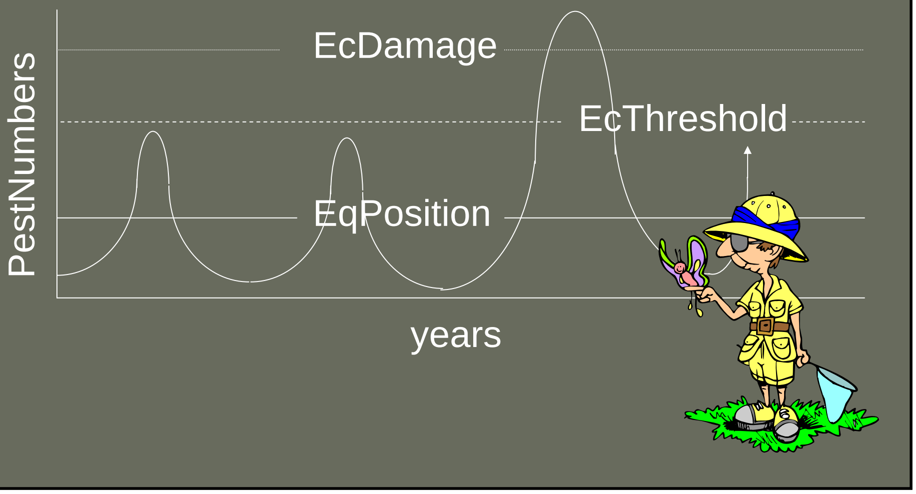
- Calculation of allowable cut.
- You can cut 200 cu.units from this forest for ever.

1. GrStock = $\frac{\text{Yrs*Vol.}}{2} \rightarrow \frac{(100)(200)}{2} \rightarrow$ 10,000 cu.units

2. Allowable cut = $\frac{\text{GrSt}}{\text{R/2}} \rightarrow$ 10,000 cu.units/50 → 200 cu.units

So, if a pest removes >200 cu.units per acre it's reached the level of causing economic damage!

In a general sense, then, insects can directly affect timber production



Going on:

- Insect control in agriculture is big business: a 10 billion dollar business.
- Periodically forest insect control involves millions of dollars: USFS, Yakama Indian Nat., and the DNR spent 1.3million dollars in controlling WSBW (1999, 2000, and 2001).
- In agriculture and intensive forestry (trees grow**n on** short rotation like crops) applied pest c**ontrol is** routine.

What Does “Control” Mean?

Simple: How many insects do you have to kill to stop an outbreak? Dah!

$$\mathbf{Mq} = \frac{\text{(Fecundity)(Sex Ratio) - 1}}{\text{(Fecundity)(Sex Ratio)}}$$

Fecund. = Avg. Nos. Eggs Laid/Female

$$\text{Sex Ratio} = \frac{\text{No. Females}}{\text{No. Females + No. Males}}$$

Example of the Mq

The western spruce budworm:

- Each ♀ lays about 170 eggs.
- You collect 1000 pupae and rear them to adults & 500 are females and 500 males

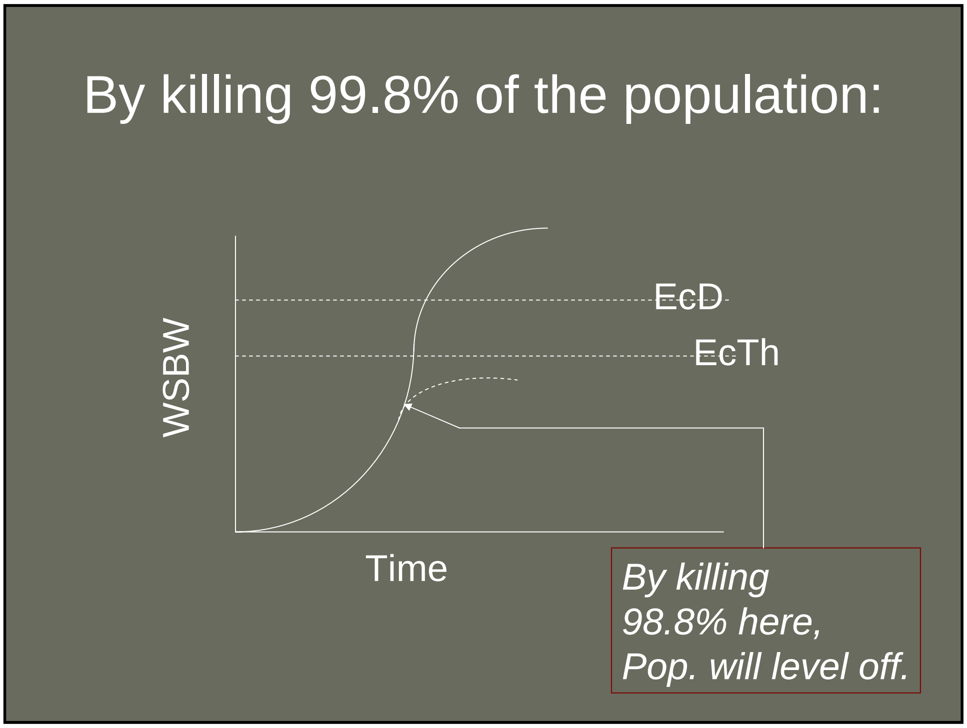
$$Mq = \frac{(170)(0.5)-1}{(170)(0.5)} = 0.988$$

Must die.

(170 eggs) * (.988) = 168

So! 170
-168
2

One is a male & the other
Is a female.



By killing 99.8% of the population:

By killing 98.8% here, Pop. will level off.

There is Direct Control

“Operations aimed directly at the pest in question for purposes of immediate suppression!”

Direct Control Tactics

1. Mechanical – chipping infested material, peeling of infested bark, sprinkler system on log decks;
2. Chemical methods – application of insecticides to reduce insect populations below the level of economic damage;
3. Physical methods – application of sterile males to reduce the reproducing population below the level of economic damage.

Mechanical control circa. 1920.

Chemical Control

Bark Beetle Spray

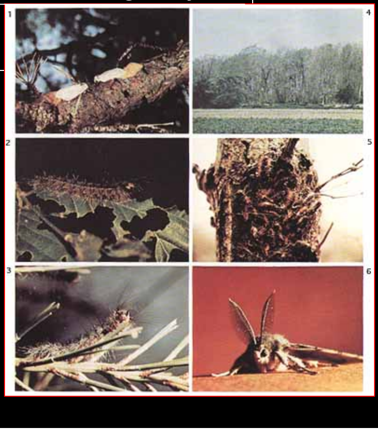
Spruce Budworm Spray

Chemical Control

Seed Orchard, Texas

Recently-planted
pine seedlings

It was hoped that the weightlessness of Skylab might induce some intracellular redistribution of material within the embryo or alter the permeability of cell membranes to cause an early end to diapause. Research performed in biological experiments on the Biosat 2 satellite in 1967 had demonstrated the feasibility of such approaches. Thus, the purpose of the experiment was to prematurely terminate the diapause of gypsy moth eggs by exposure to zero gravity.



“Taking the gypsy moth to outer space and….”

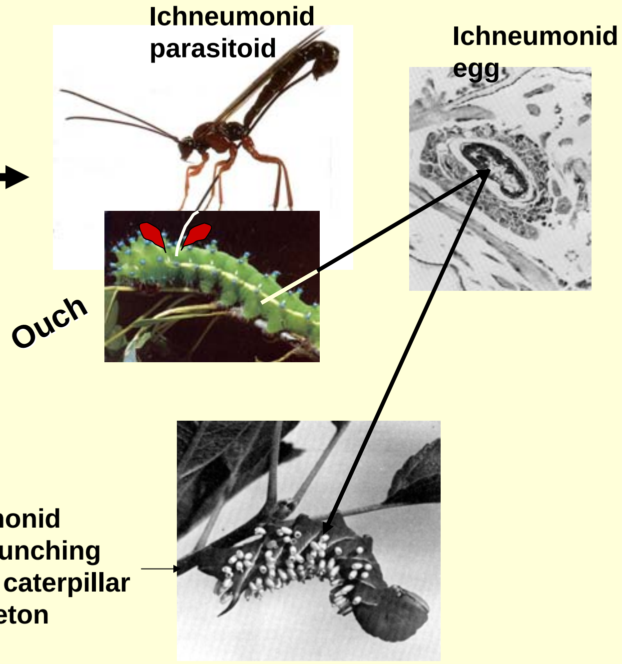
There is Indirect Control

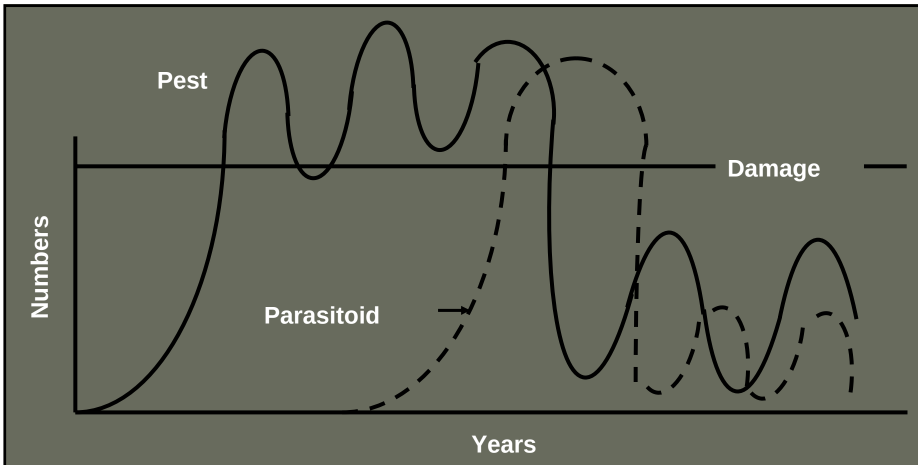
“Operations designed to modify environmental factors to secure the ultimate limitation of insect numbers.”

Three common methods:

1. **Biological control**
2. **Silvicultural control**
3. **Legal control**

Permanent Biological Control: Typically Applied To an Introduced Pest!





Permanent Biocontrol: (1) pest introduced from Europe, (2) principal parasitoid introduced a few yrs. later, & (3) typical host-parasitoid curve occurs which is about 90 ^{0} out of phase -- density dependent relationship!

Permanent Biological Control

Benefits:
- Self perpetuating
- Selective in action
- Doesn’t create more problems than it solves

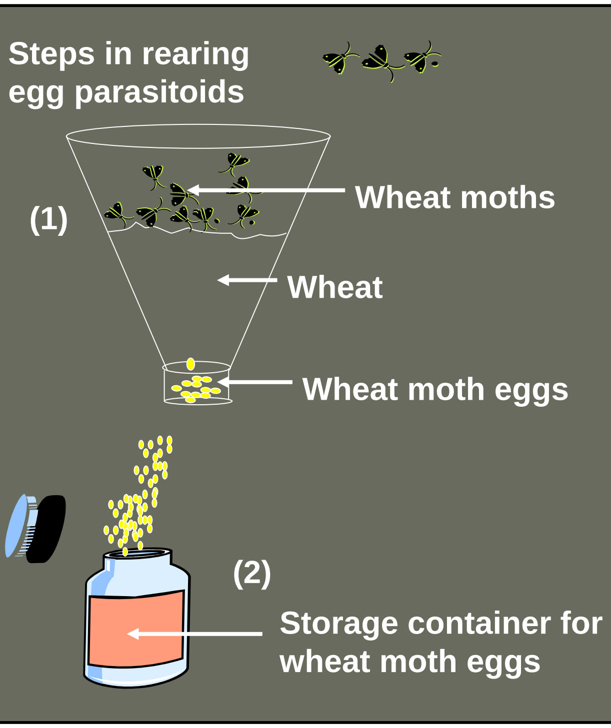
Problems:
- Not so useful against direct pests
- Takes several yrs. to establish
- Must be used over large area
- Some degree of damage must be tolerated

Temporary Biological Control

Has the same objectives as direct control -- “get them now, all of them!”

Examples of temporary biological control would be: (1) the rearing and release of parasitoids or
(2) pathological biological control (use of viruses, bacteria, or nematodes).

Steps in rearing egg parasitoids



(1)

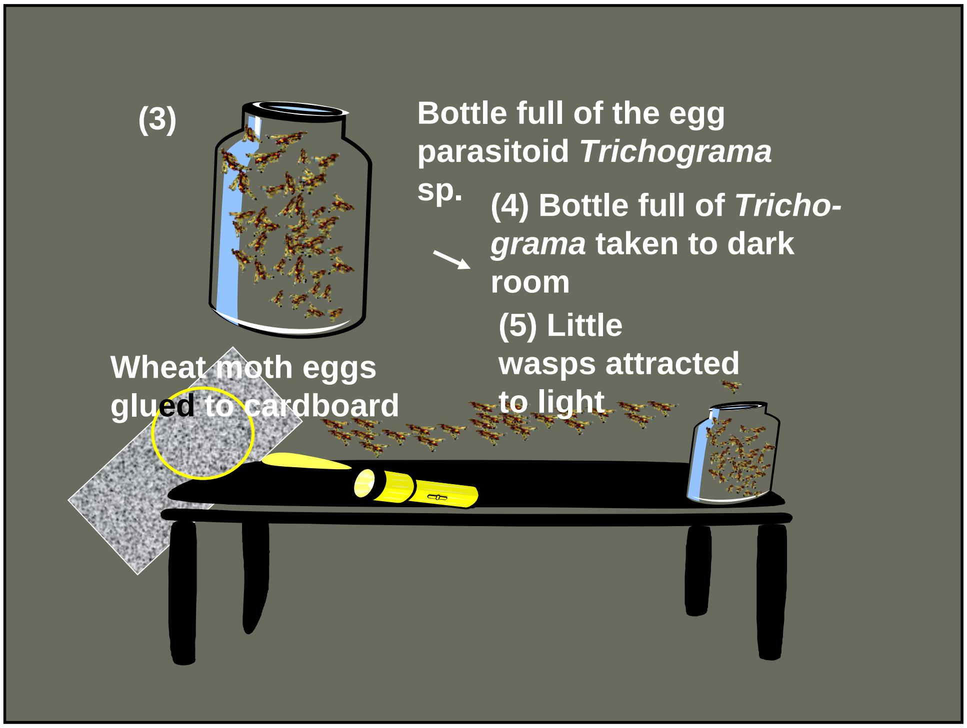
Wheat moths

Wheat

Wheat moth eggs

(2)

Storage container for wheat moth eggs



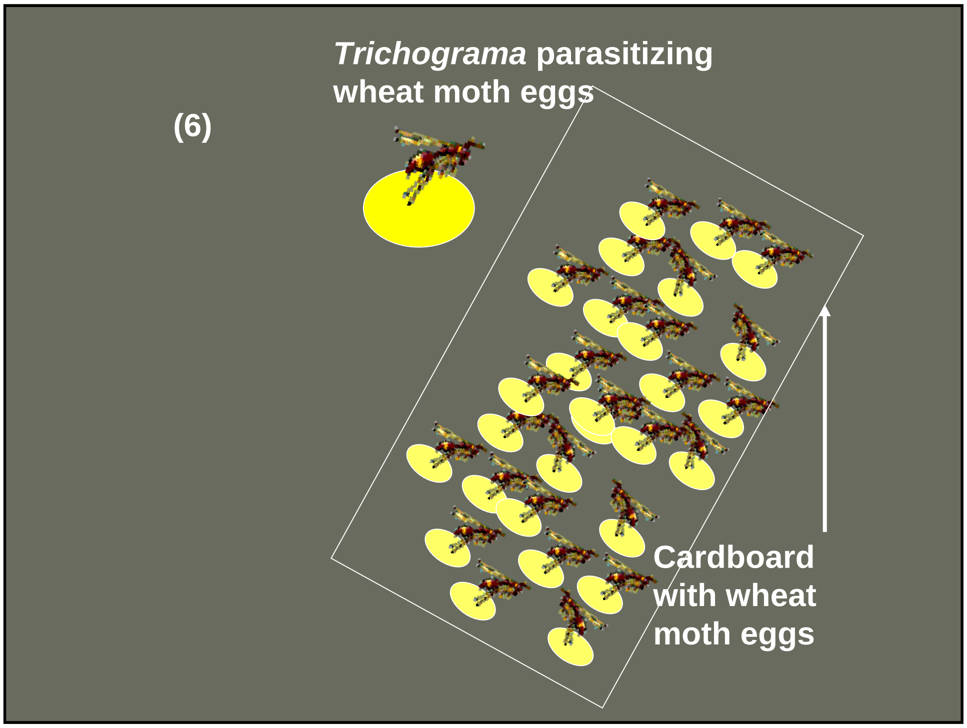
(3)

Bottle full of the egg parasitoid *Trichograma* sp.

(4) Bottle full of *Tricho-grama* taken to dark room

(5) Little wasps attracted to light

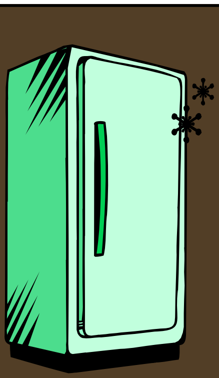
Wheat moth eggs glued to cardboard



(6)

Trichograma parasitizing wheat moth eggs

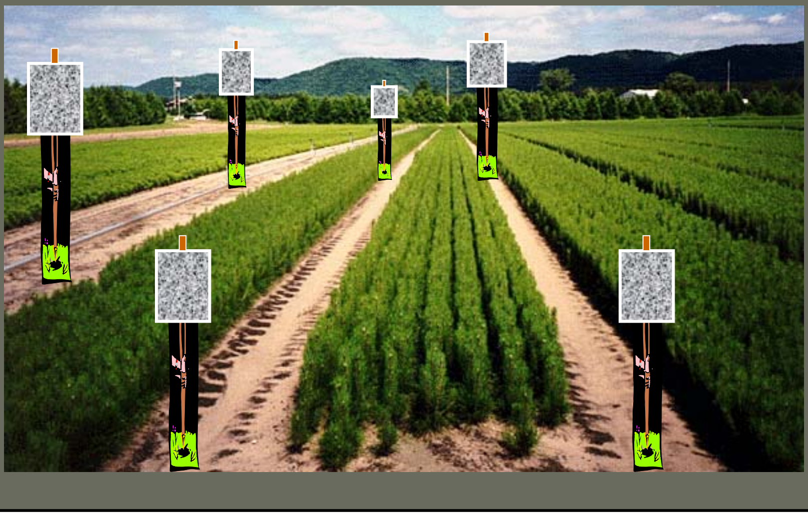
Cardboard with wheat moth eggs



(7) Cardboards with parasitized eggs are cut into small rectangles and placed in refrigerator

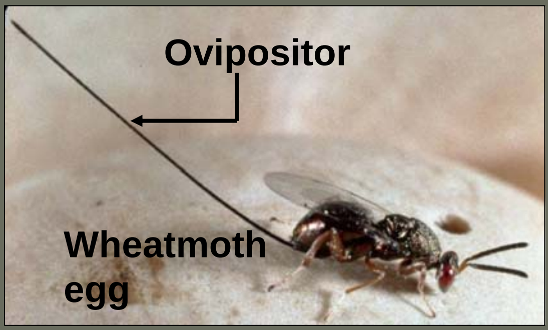
(8) Temperature of refrigerator and time parasitized eggs are kept in frig controls the emergence time of adult wasps -- the egg parasitoids.

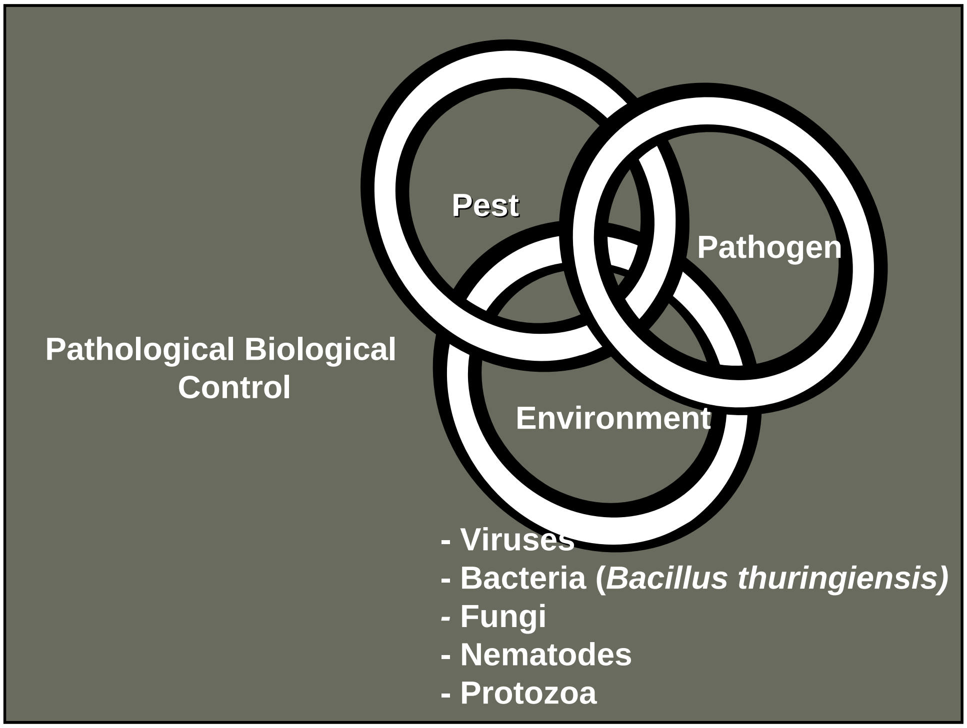
Cardboards with thousands of wheat moth eggs parasitized by *Trichograma*



Rearing the *Trichograma* sp.

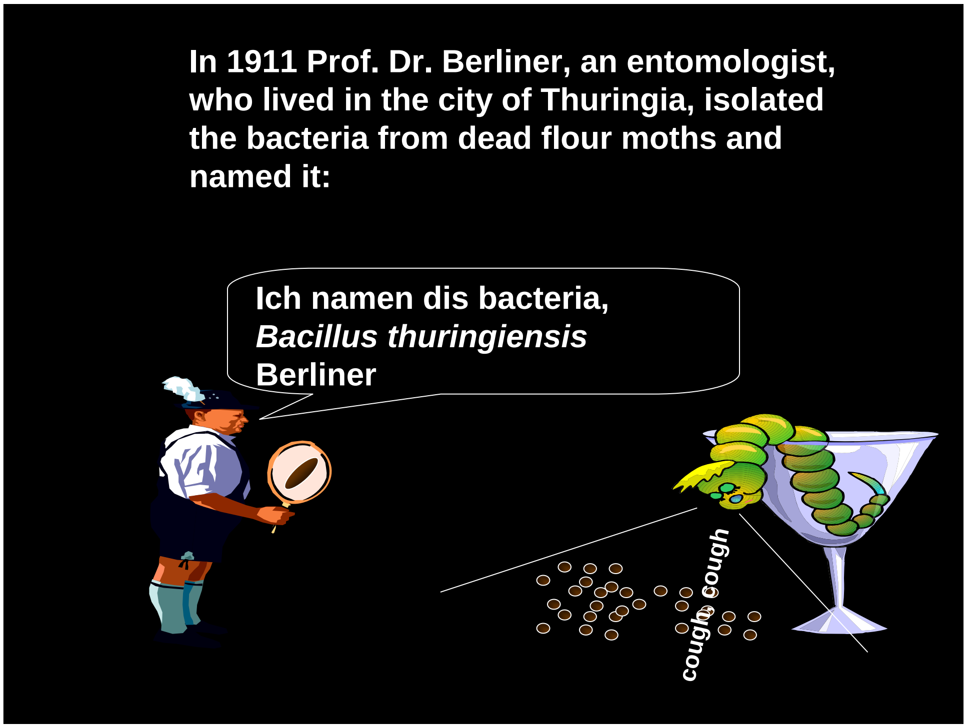
The egg parasite, *Trichograma sp.*





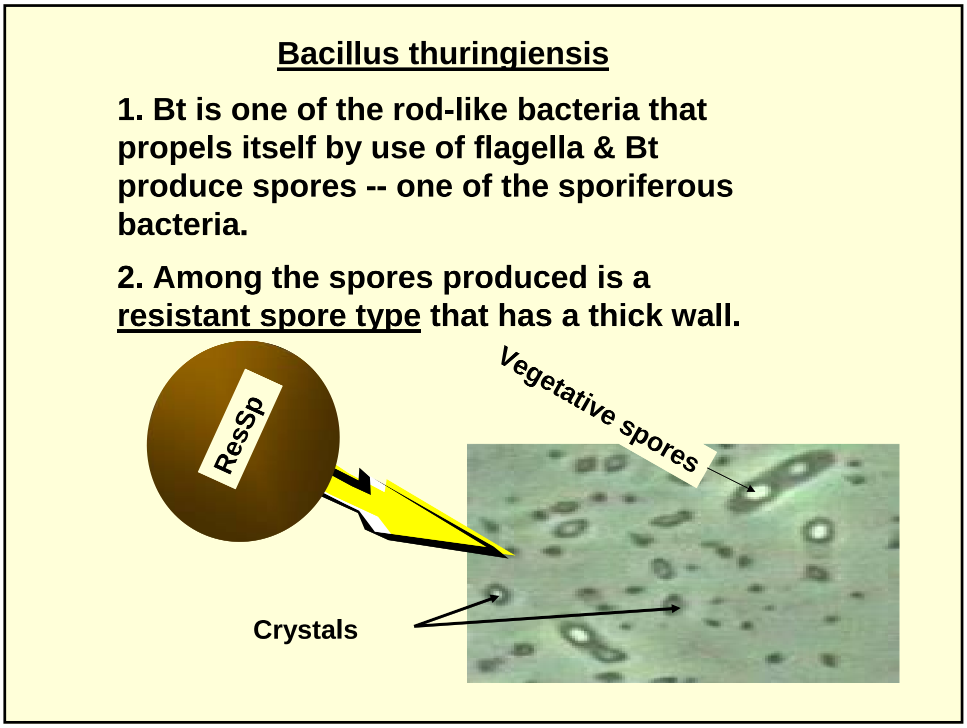
Pathological Biological Control

- Viruses
- Bacteria (*Bacillus thuringiensis)*
- Fungi
- Nematodes
- Protozoa



In 1911 Prof. Dr. Berliner, an entomologist, who lived in the city of Thuringia, isolated the bacteria from dead flour moths and named it:

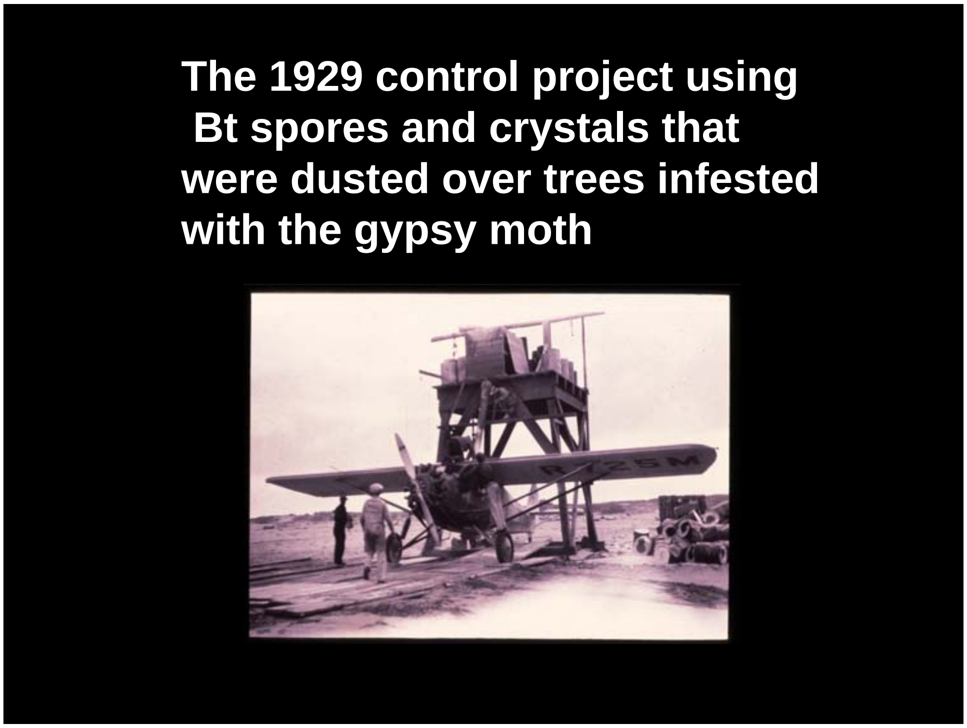
Ich namen dis bacteria,
Bacillus thuringiensis
Berliner



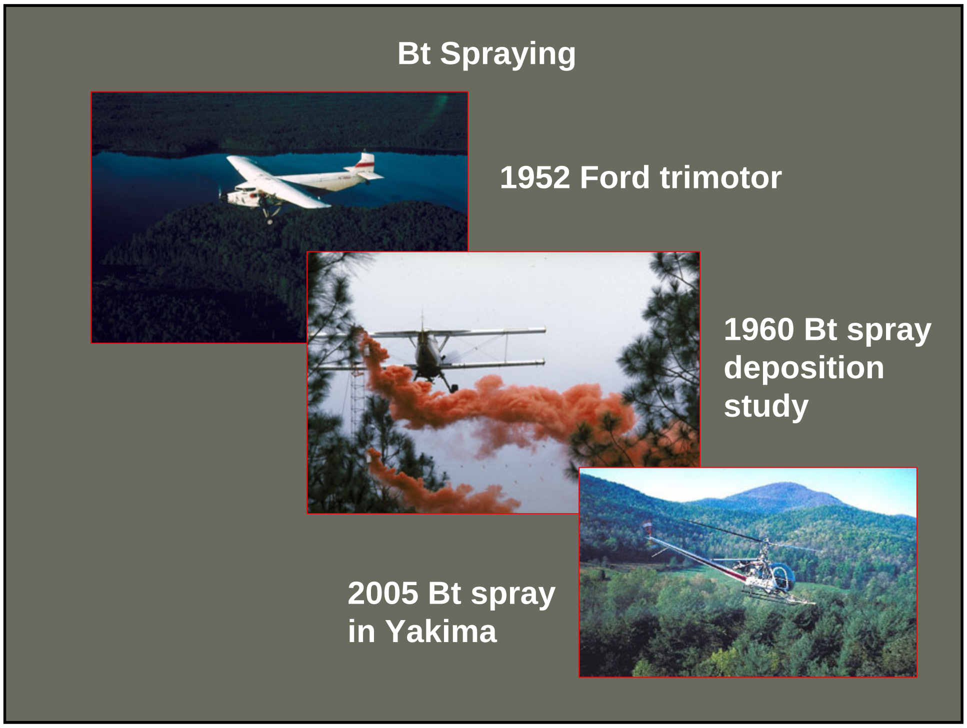
Bacillus thuringiensis

1. Bt is one of the rod-like bacteria that propels itself by use of flagella & Bt produce spores -- one of the sporiferous bacteria.

2. Among the spores produced is a resistant spore type that has a thick wall.



The 1929 control project using Bt spores and crystals that were dusted over trees infested with the gypsy moth

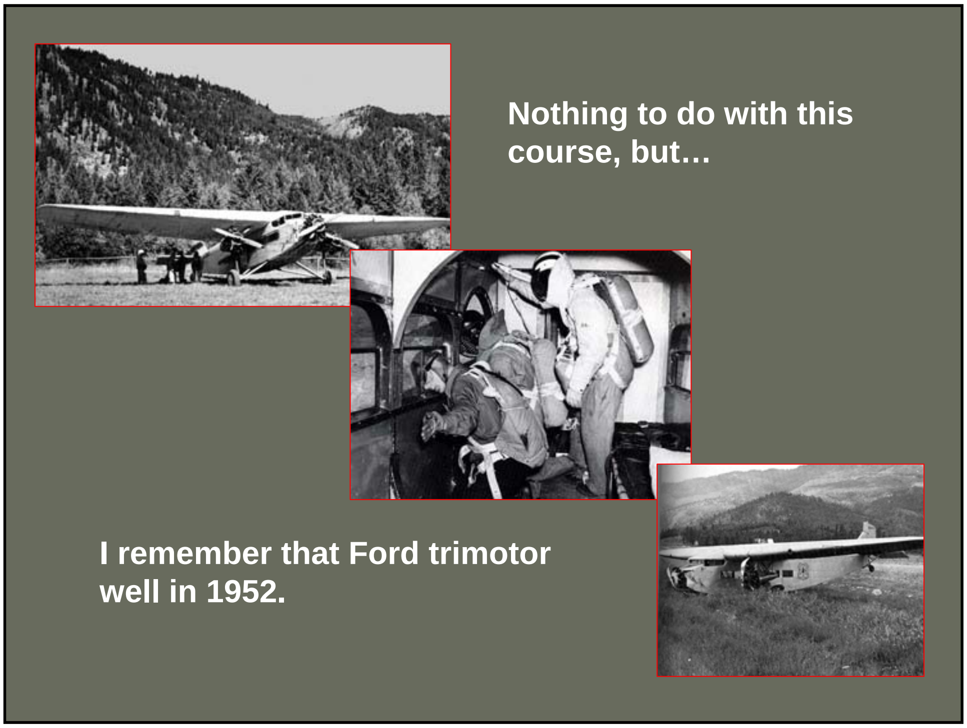


Bt Spraying

1952 Ford trimotor

1960 Bt spray deposition study

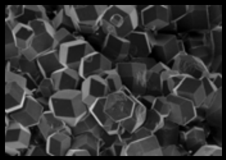
2005 Bt spray in Yakima



Nothing to do with this course, but…

I remember that Ford trimotor well in 1952.

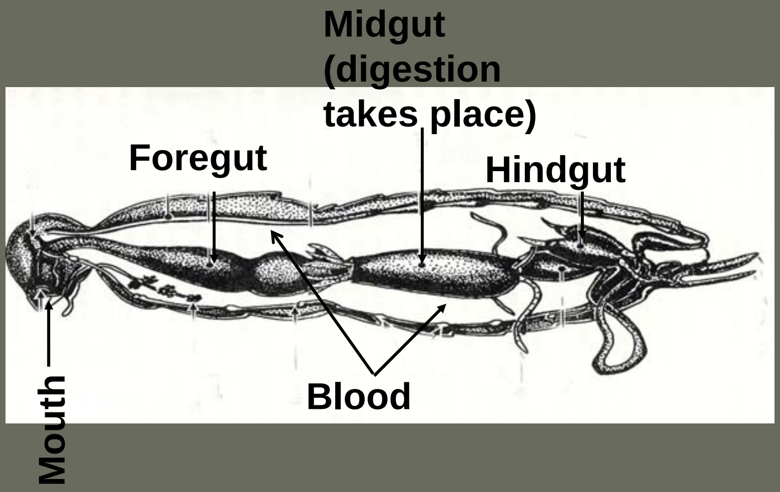
Bt has several toxins: chemicals deadly to the Lepidoptera

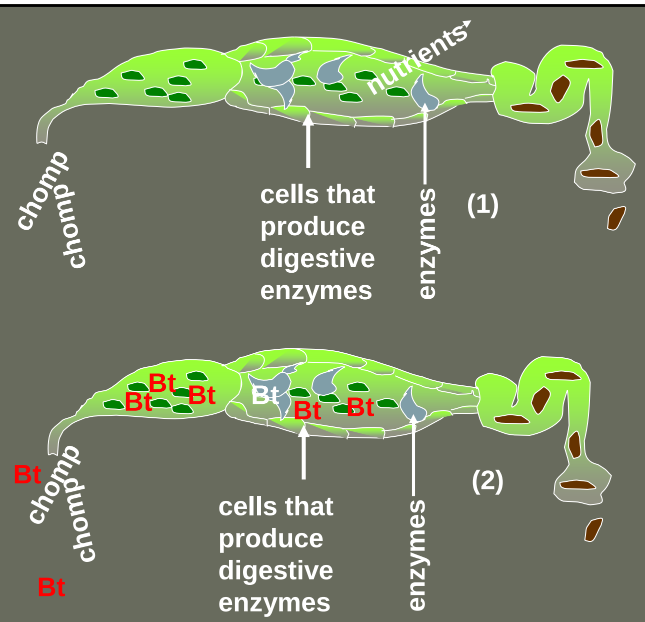


The crystals found in the resistant spore contain a toxin called endotoxin delta.

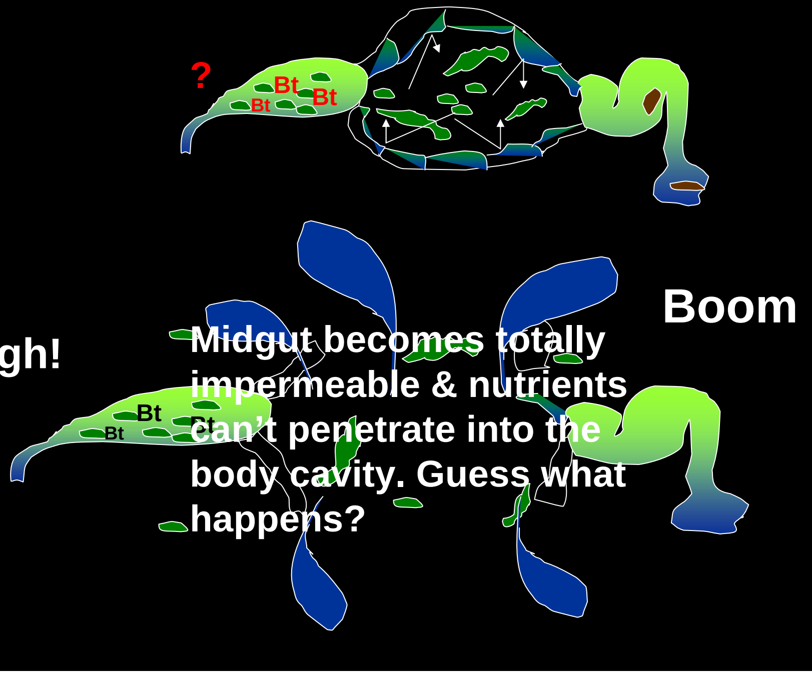
This endotoxin delta, by itself, kills caterpillars and larvae of mosquitoes, blackflies, and midges and its absolutely, positively, non-toxic to any vertebrate.

To understand the mode of action of Bt let’s review insect digestion





The Bt crystals dissolve under high pH: pH has to be high!



Midgut becomes totally impermeable & nutrients can't penetrate into the body cavity. Guess what happens?

Bt Toxins Continued,
mode of action

(1) The endotoxin delta (found in the proteinaceous crystal) hinders the permeability of the midgut. The insect stops feeding and the blood is contaminated and insect dies from septicemia.

(2) Many lepidopterans can’t dissolve the crystal (pH too acidic). In many of these caterpillars, toxic proteins enter blood when vegetatative spores are digested. Septicemia also occurs and the insects die within 24 - 36 hrs.

Conclusions:

The efficiency of Bacillus thuringiensis depends on:

- Quality of proteins that make up the crystals

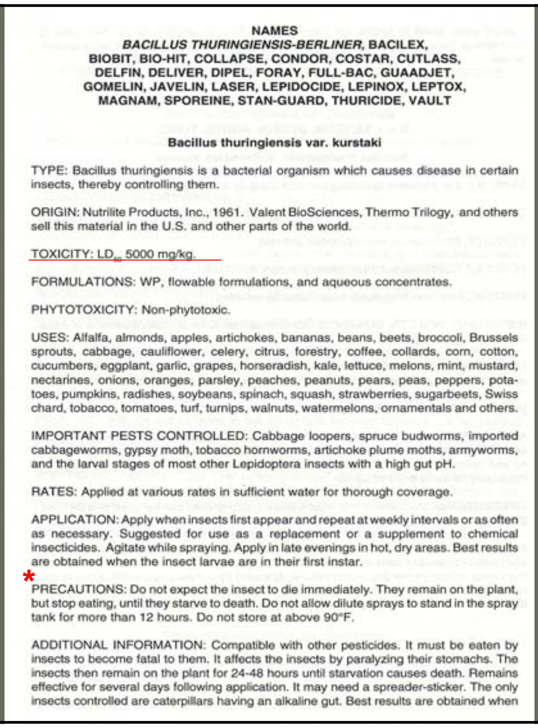
- Ability of caterpillars to dissolve the crystals, i.e. those with high pH in the midgut

- The ability of toxic products from vegetatative spores to cause septicemia

LD$_{50}$ = 5000ml/kg

(84kg)(5000) = 420,000mg

You’d have to eat over 1.25 lbs. of pure B$_t$



NAMES
***BACILLUS THURINGIENSIS-BERLINER*, BACILEX, BIOBIT, BIO-HIT, COLLAPSE, CONDOR, COSTAR, CUTLASS, DELFIN, DELIVER, DIPEL, FORAY, FULL-BAC, GUAADJET, GOMELIN, JAVELIN, LASER, LEPIDOCIDE, LEPINOX, LEPTOX, MAGNAM, SPOREINE, STAN-GUARD, THURICIDE, VAULT**

Bacillus thuringiensis var. kurstaki

TYPE: Bacillus thuringiensis is a bacterial organism which causes disease in certain insects, thereby controlling them.

ORIGIN: Nutrilite Products, Inc., 1961. Valent BioSciences, Thermo Trilogy, and others sell this material in the U.S. and other parts of the world.

TOXICITY: LD$_{50}$ 5000 mg/kg.

FORMULATIONS: WP, flowable formulations, and aqueous concentrates.

PHYTOTOXICITY: Non-phytotoxic.

USES: Alfalfa, almonds, apples, artichokes, bananas, beans, beets, broccoli, Brussels sprouts, cabbage, cauliflower, celery, citrus, forestry, coffee, collards, corn, cotton, cucumbers, eggplant, garlic, grapes, horseradish, kale, lettuce, melons, mint, mustard, nectarines, onions, oranges, parsley, peaches, peanuts, pears, peas, peppers, potatoes, pumpkins, radishes, soybeans, spinach, squash, strawberries, sugarbeets, Swiss chard, tobacco, tomatoes, turf, turnips, walnuts, watermelons, ornamentals and others.

IMPORTANT PESTS CONTROLLED: Cabbage loopers, spruce budworms, imported cabbageworms, gypsy moth, tobacco hornworms, artichoke plume moths, armyworms, and the larval stages of most other Lepidoptera insects with a high gut pH.

RATES: Applied at various rates in sufficient water for thorough coverage.

APPLICATION: Apply when insects first appear and repeat at weekly intervals or as often as necessary. Suggested for use as a replacement or a supplement to chemical insecticides. Agitate while spraying. Apply in late evenings in hot, dry areas. Best results are obtained when the insect larvae are in their first instar.

* PRECAUTIONS: Do not expect the insect to die immediately. They remain on the plant, but stop eating, until they starve to death. Do not allow dilute sprays to stand in the spray tank for more than 12 hours. Do not store at above 90°F.

ADDITIONAL INFORMATION: Compatible with other pesticides. It must be eaten by insects to become fatal to them. It affects the insects by paralyzing their stomachs. The insects then remain on the plant for 24-48 hours until starvation causes death. Remains effective for several days following application. It may need a spreader-sticker. The only insects controlled are caterpillars having an alkaline gut. Best results are obtained when

Spores of several fungi are used to control pests, e.g. *Beauvaria bassiana.*

❖ Fungal spores are disseminated

❖ Land on insect cuticle and exude a corrosive compound that allows the exploratory hyphae to penetrate

❖ The point is: the spores do not geminate in gut of the insect

<u>Problems:</u>

- **RH of atmos. around 90%**
- **The insects die slowly**

Use of *B. bassiana* in Viet Nam.

Another example of temporary biological control would be the use of entomophagous viruses

(1) Viral diseases are caused by the nucleic acid contained in virus particles called virions.

(2) Virions can be rod shaped, filamentous, spheres or complex in shape.

(3) The virions in insect viruses are encased in proteinaceous coats that are polyhedron in shape or granular or more complex.

Three common types of insect viruses:

1. NPV (nuclear polyhedral viruses)

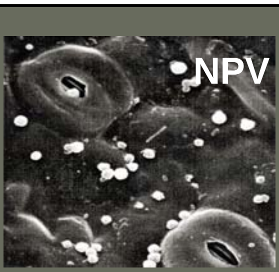
2. CPV (cytoplasmic polyhedral viruses)

3. Granulosis viruses

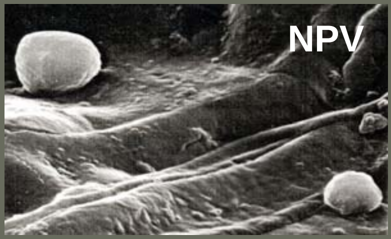
- NPV replicate in nuclei of cells

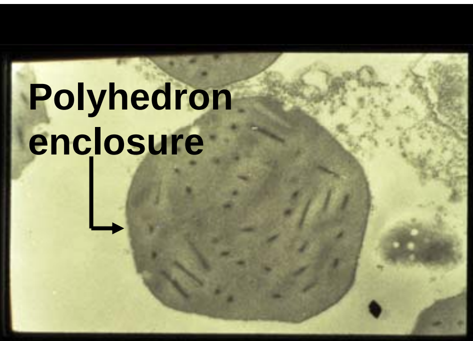
- CPV replicate in cytoplasm of midgut cells

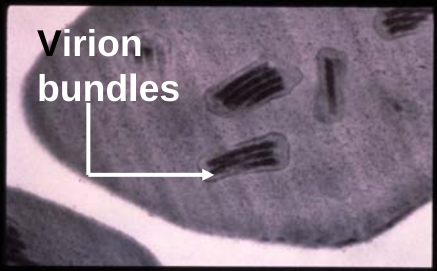
- Granulosis viruses have a single virion within their proteinaceous capsule



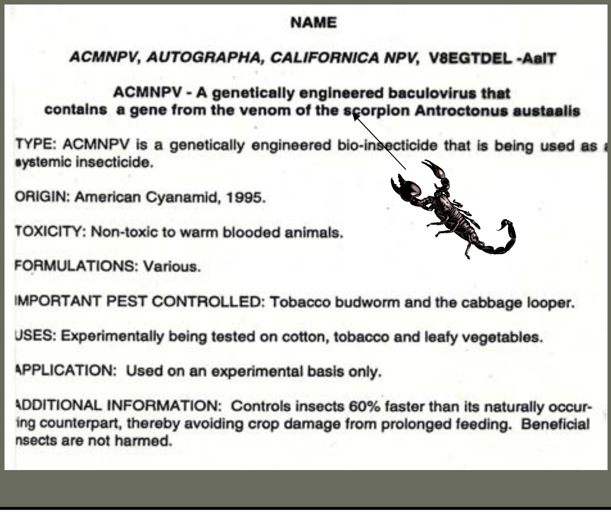
Virus polyhedrons on leaves
& when insect ingests them the
insects becomes infected







How about a bioengineered virus?



NAME

***ACMNPV, AUTOGRAPHA, CALIFORNICA NPV,* V8EGTDEL -AaIT**

ACMNPV - A genetically engineered baculovirus that contains a gene from the venom of the scorpion Antroctonus austaalis

TYPE: ACMNPV is a genetically engineered bio-insecticide that is being used as systemic insecticide.

ORIGIN: American Cyanamid, 1995.

TOXICITY: Non-toxic to warm blooded animals.

FORMULATIONS: Various.

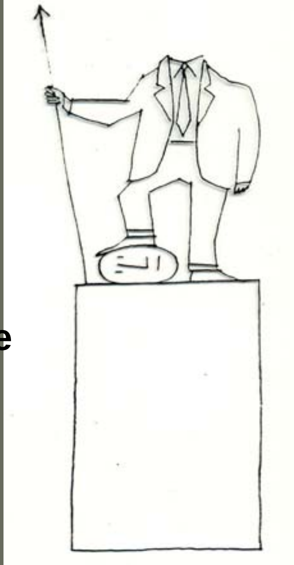
IMPORTANT PEST CONTROLLED: Tobacco budworm and the cabbage looper.

USES: Experimentally being tested on cotton, tobacco and leafy vegetables.

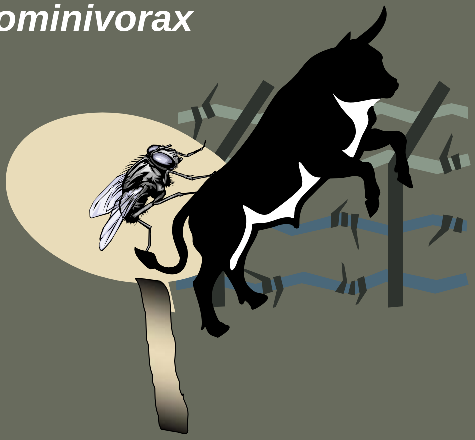
PPLICATION: Used on an experimental basis only.

DDITIONAL INFORMATION: Controls insects 60% faster than its naturally occur-ing counterpart, thereby avoiding crop damage from prolonged feeding. Beneficial nsects are not harmed.

Autocidal Insect Control: Sterile Male Technique



A Great Success in Control of the screw worm, *Cochliomyia hominivorax*



Screw worm maggot that feeds in wounds of cattle and other domestic animals in SW USA

The screw-worm.
(U.S.D.A.)

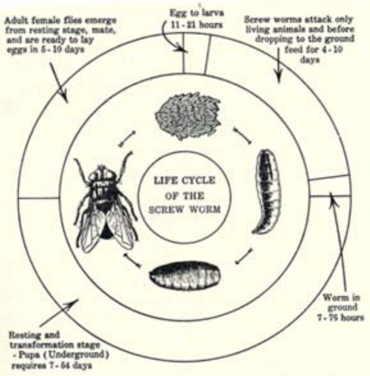
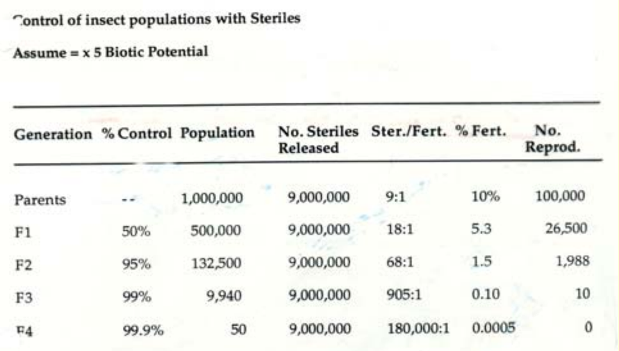


Fig. 543. Life cycle of the screw-worm fly.
(U.S.D.A.)

This is how the sterile technique works



Control of insect populations with Steriles

Assume = x 5 Biotic Potential

Generation	% Control	Population	No. Steriles Released	Ster./Fert.	% Fert.	No. Reprod.
Parents	--	1,000,000	9,000,000	9:1	10%	100,000
F1	50%	500,000	9,000,000	18:1	5.3	26,500
F2	95%	132,500	9,000,000	68:1	1.5	1,988
F3	99%	9,940	9,000,000	905:1	0.10	10
F4	99.9%	50	9,000,000	180,000:1	0.0005	0

Autocidal Insect Control
(Criteria for Success)

(1) Females should mate once

(2) It must be possible to separate sexes in pupal stage

(3) It must be possible to rear and sterilize large numbers of insects in a short time so as to be able to release millions & millions of males

(4) Reared males must compete successfully with wild males.

(5) there must be a practical release system

Autocidal insect control successes

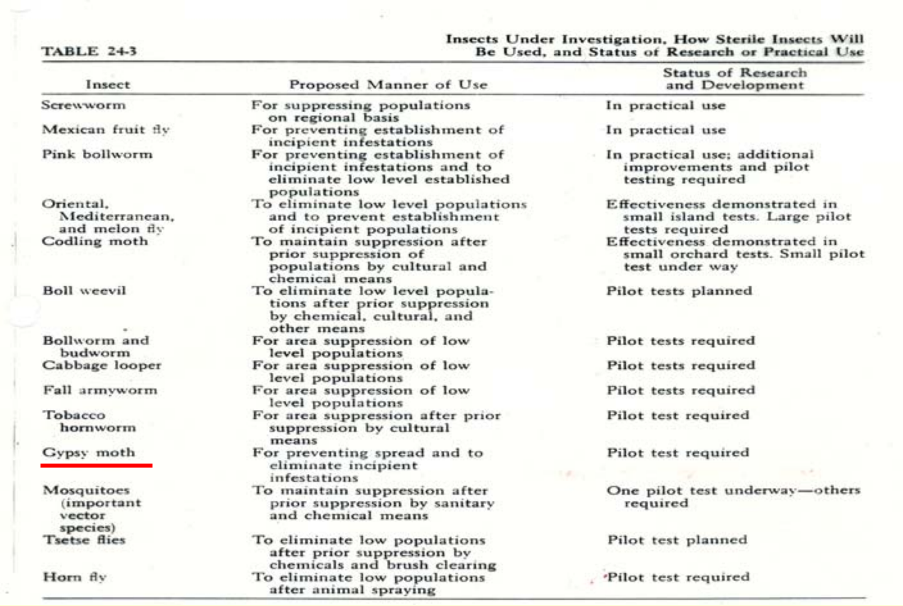


TABLE 24-3 **Insects Under Investigation, How Sterile Insects Will Be Used, and Status of Research or Practical Use**

Insect	Proposed Manner of Use	Status of Research and Development
Screwworm	For suppressing populations on regional basis	In practical use
Mexican fruit fly	For preventing establishment of incipient infestations	In practical use
Pink bollworm	For preventing establishment of incipient infestations and to eliminate low level established populations	In practical use; additional improvements and pilot testing required
Oriental, Mediterranean, and melon fly	To eliminate low level populations and to prevent establishment of incipient populations	Effectiveness demonstrated in small island tests. Large pilot tests required
Codling moth	To maintain suppression after prior suppression of populations by cultural and chemical means	Effectiveness demonstrated in small orchard tests. Small pilot test under way
Boll weevil	To eliminate low level populations after prior suppression by chemical, cultural, and other means	Pilot tests planned
Bollworm and budworm	For area suppression of low level populations	Pilot tests required
Cabbage looper	For area suppression of low level populations	Pilot tests required
Fall armyworm	For area suppression of low level populations	Pilot tests required
Tobacco hornworm	For area suppression after prior suppression by cultural means	Pilot test required
Gypsy moth	For preventing spread and to eliminate incipient infestations	Pilot test required
Mosquitoes (important vector species)	To maintain suppression after prior suppression by sanitary and chemical means	One pilot test underway—others required
Tsetse flies	To eliminate low populations after prior suppression by chemicals and brush clearing	Pilot test planned
Horn fly	To eliminate low populations after animal spraying	Pilot test required