Fungal disease management

Most of vegetables are grown from seeds

Significance of seed-borne diseases

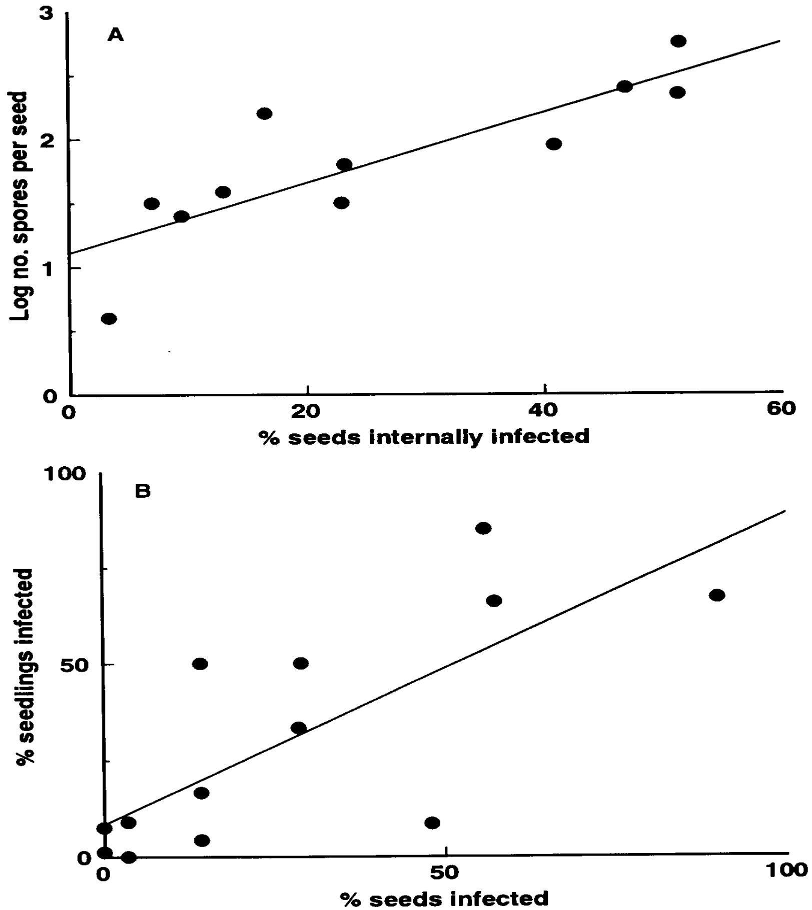
- Prolonged transmissibility
- Maximum infection
- Dissemination over long distance
- Introduction to new area
- Infected new soil
- Random infection foci in production field

Viability of seedborne fungal pathogens after storage at −20°C

Fungus	Host	No. of samples	Storage period (years)	Seeds infected (%)	
				Start	End
Ascochyta pisi	Pea	8	8–11	18	14
Ascochyta fabae	Vicia bean*	5	9–13	14	14
Pleospora betae	Sugarbeet	2	14	30	23
Leptosphaeria nodorum	Wheat	9	9–14	50	39
Micronectriella nivalis	Wheat, rye, barley	5	9–12	19	19
Cochliobolus sativus	Wheat, barley	9	8–12	43	33
Pyrenophora teres	Barley	5	8–12	24	16
Pyrenophora graminea	Barley	4	11–12	47	44
Colletotrichum lindemuthianum	Phaseolus bean†	1	12	99	93
Ascochyta boltshauseri	Phaseolus bean	1	12	52	41
Leptosphaeria maculans	Cabbage	1	11–13	13	12
Alternaria dauci	Carrot	4	9–14	22	21
Alternaria radicina	Carrot	3	14	37	28

* *Vicia faba.*

† *Phaseolus vulgaris.*



Seed infection relationships of *Alternaria brassicicola*. (A) Relationship between superficial conidia and internal infection of seeds. (B) Relationship between internally infected seeds and diseases seedlings.

Seed transmission relationships.

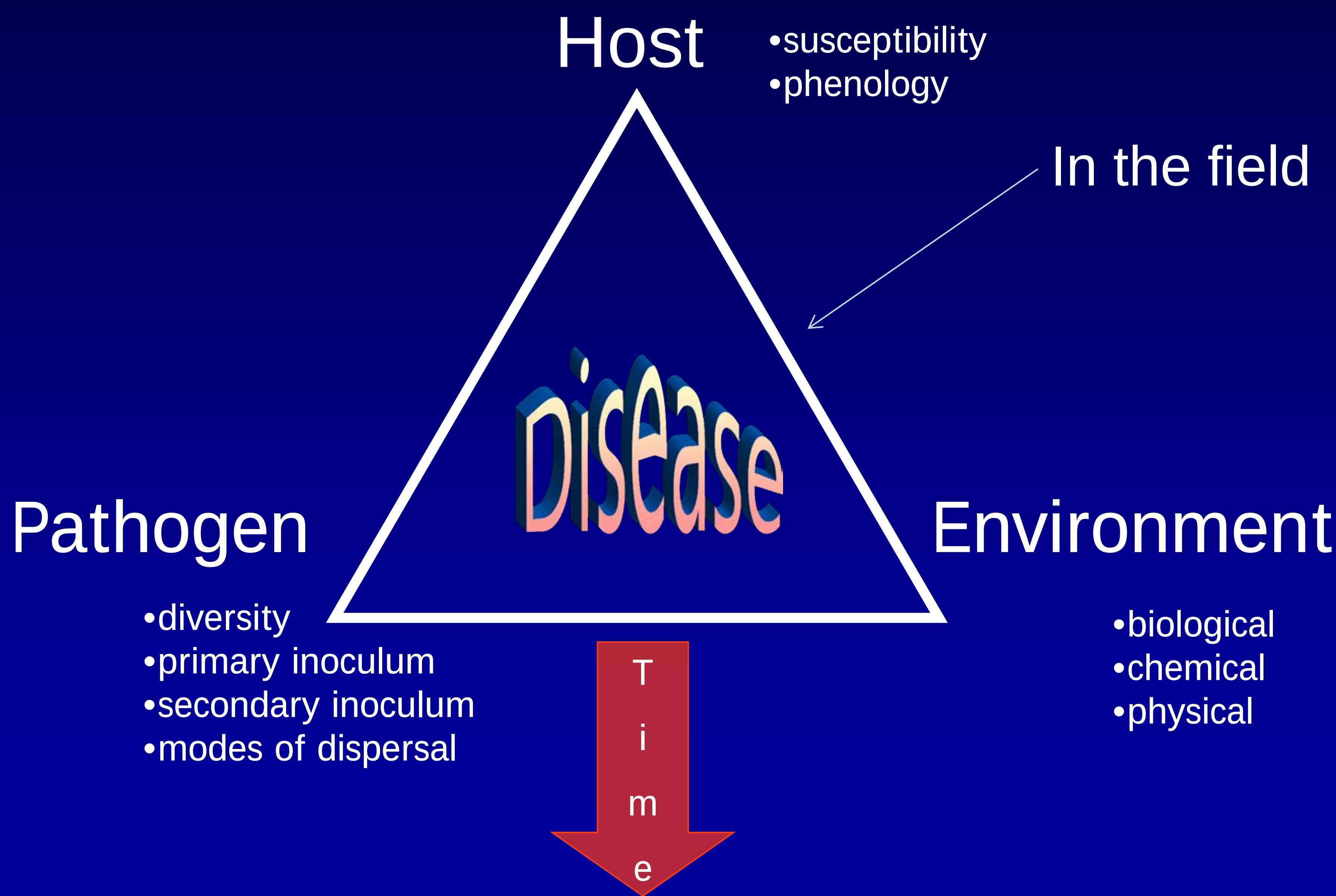
Pathogen	% infection in Lab/glhse	Field soil	Transmission ratio	Crop	Reference
Polyspora lini	15.0	1.7	9:1	Flax	Henry and Campbell, 1938
Colletotrichum lini	66.3	17.0	4:1	Flax	Henry and Campbell, 1938
Pyrenophora graminea and *P. teres*	50–75	5–10	10:1 to 7.5:1	Barley	Jorgensen, 1977
	50–65	0–11	0:0 to 6.0:1	Barley	Jorgensen, 1977
Ascochyta pisi	11.2	3.3	4:1	Peas	Maude and Kyle, 1970
	6.3	0.4	16:1	Peas	Maude and Kyle, 1970
	34.0	6.5	5:1	Peas	Maude and Kyle, 1970
Alternaria brassicicola	62.0	11.0	6:1	Cabbage	Maude and Humpherson-Jones, 1980b
	11.5	1.2	10:1	Kale	Maude and Humpherson-Jones, 1980b
	1.5	0.0	0:0	Kale	Maude and Humpherson-Jones, 1980b
Alternaria brassicae	28.0	9.3	3:1	Cabbage	R.B. Maude, pers. comm., 1991
	10.5	1.2	9:1	Oilseed rape	R.B. Maude, pers. comm., 1991
	14.0	1.2	12:1	Oilseed rape	R.B. Maude, pers. comm., 1991
Pseudomonas syringae pv. *phaseolicola*	9.2	0.84	11.0:1	Phaseolus bean	Taylor, 1970b
	3.5	0.37	9.5:1	Phaseolus bean	Taylor, 1970b
	1.4	0.15	9.3:1	Phaseolus bean	Taylor, 1970b
	0.1	0.0	0:0	Phaseolus bean	Taylor, 1970b
Pseudomonas syringae pv. *phaseolicola*	16.1	1.80	8.9:1	Phaseolus bean	Taylor *etal.*, 1979b
	1.1	0.13	8.5:1	Phaseolus bean	Taylor et al., 1979b
	2.4	0.22	10.9:1	Phaseolus bean	Taylor *et al.*, 1979b
	2.4	0.42	5.7:1	Phaseolus bean	Taylor *et al.*, 1979b
	5.4	0.57	9.5:1	Phaseolus bean	Taylor *et al.*, 1979b

Lab/glhse, laboratory/glasshouse tests

Inoculum thresholds and crop losses.

Crop	Pathogen	No. of affected seeds/ seedlings causing economic loss
Lettuce	Lettuce mosaic virus	1/30,000
Bean	*Pseudomonas syringae* pv. *phaseolicola*	1/10,000 to 1/16,000
Cabbage	*Leptosphaeria maculans*	1/10,000
Celery	*Septoria apiicola*	1/7000
Onion	*Botrytis allii*	1/100
Peas	*Ascochyta pisi*	> 5/100
Field bean	*Didymella fabae*	> 2/100

Disease Triangle



Disease will occur

- Susceptible plant
- Pathogen that can cause disease
- Environmental conditions favourable for disease development

Plant Disease Epidemiology

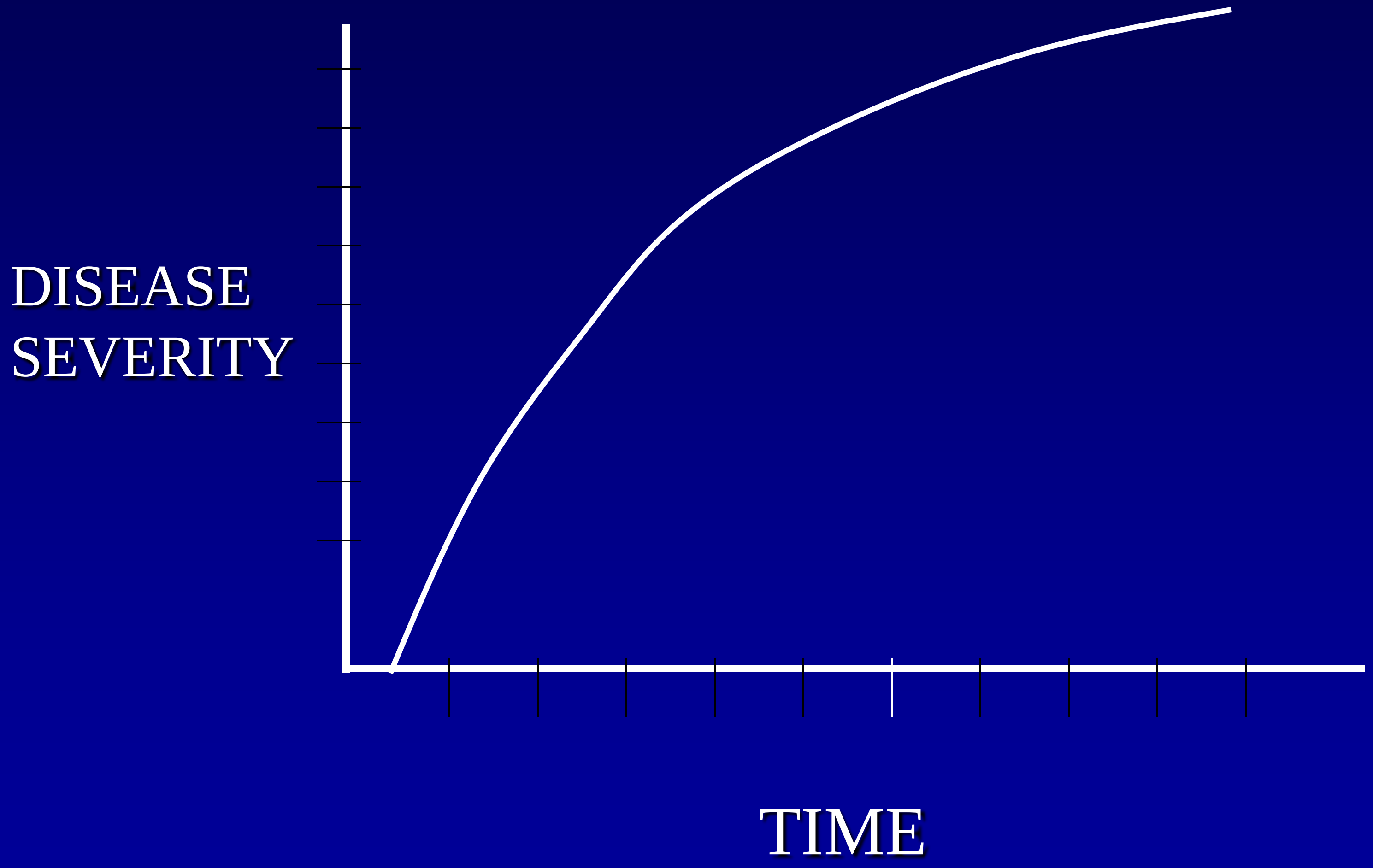
- Components of an Epidemic:
  - (1) Susceptible Host
  - (2) Virulent Pathogen
  - (3) Conducive Environment
  - (4) Favorable Time
  - (5) Extensive Space
  - (6) Favorable Human Activity

A monocyclic pathogen completes just one disease cycle per season. There are no secondary disease cycles

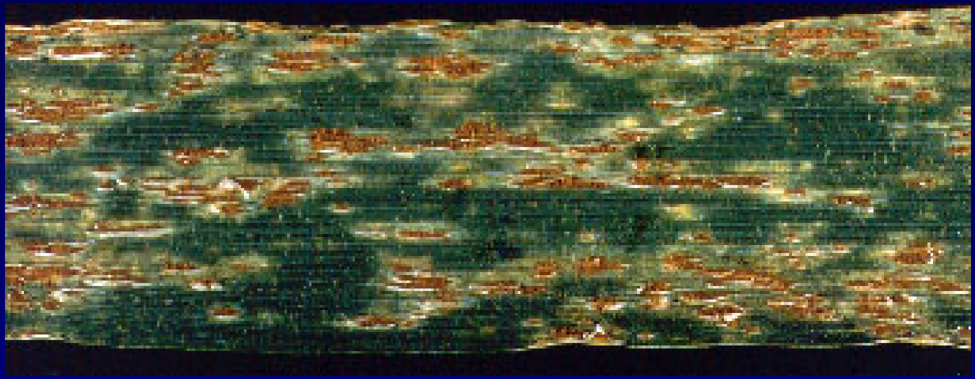
Soilborne pathogens are usually monocyclic due to physical constraints--inoculum is not dispersed within the growing season.

Verticillium wilt of strawberry

Disease progress curve for a typical monocyclic pathogen



Polycyclic pathogens have several secondary disease cycles each season.

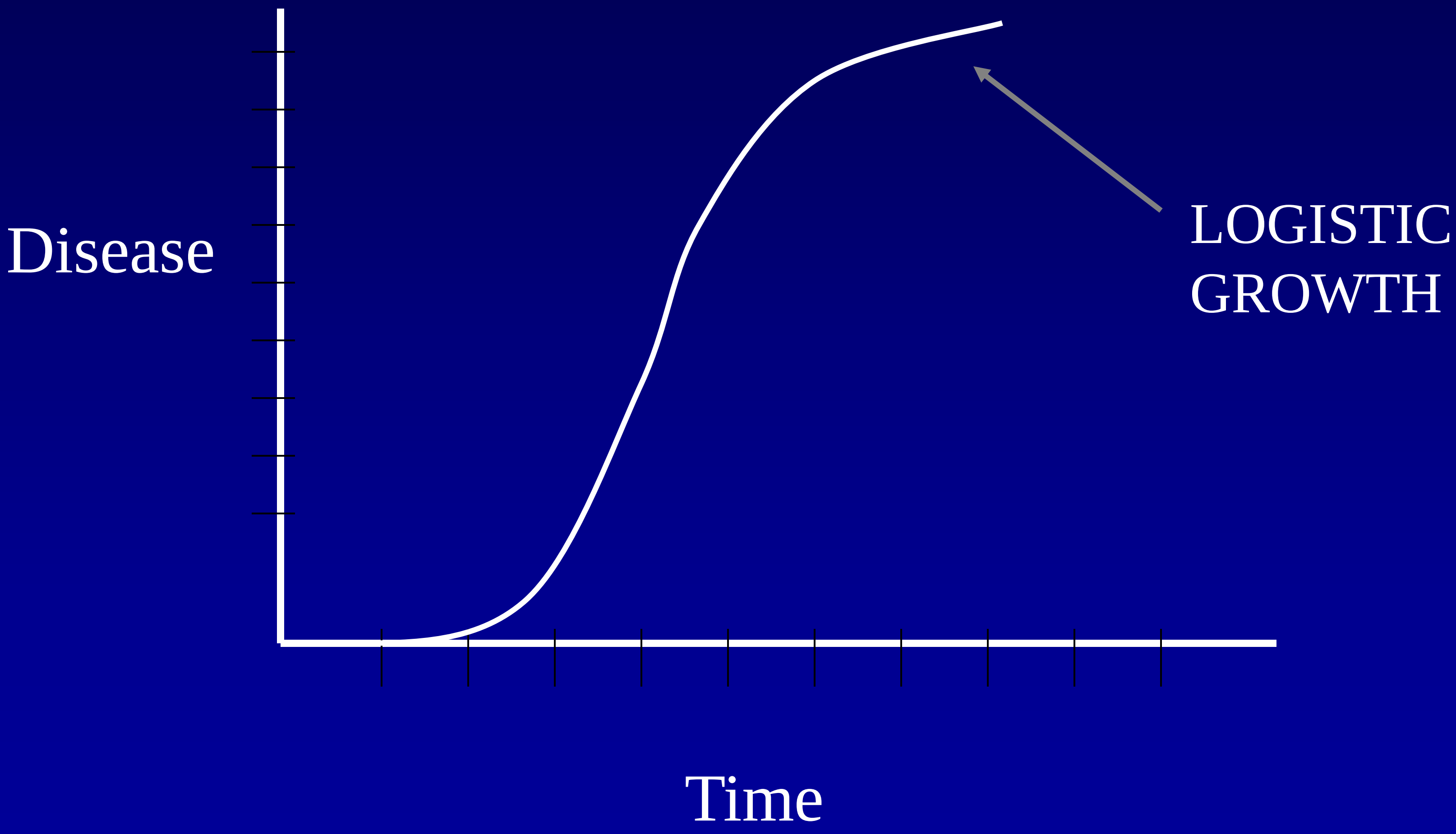


Oat stem rust

Halo blight

Soybean mosaic

Disease progress curve for a typical polycyclic pathogen is an S-shaped curve.



Natural vs "Cultivated" Systems

- "Natural" Systems
  - Genetically Diverse
  - Many plant species
  - Factors of genetics, spatial separation
  - Pathogens (usually) have evolved with their hosts

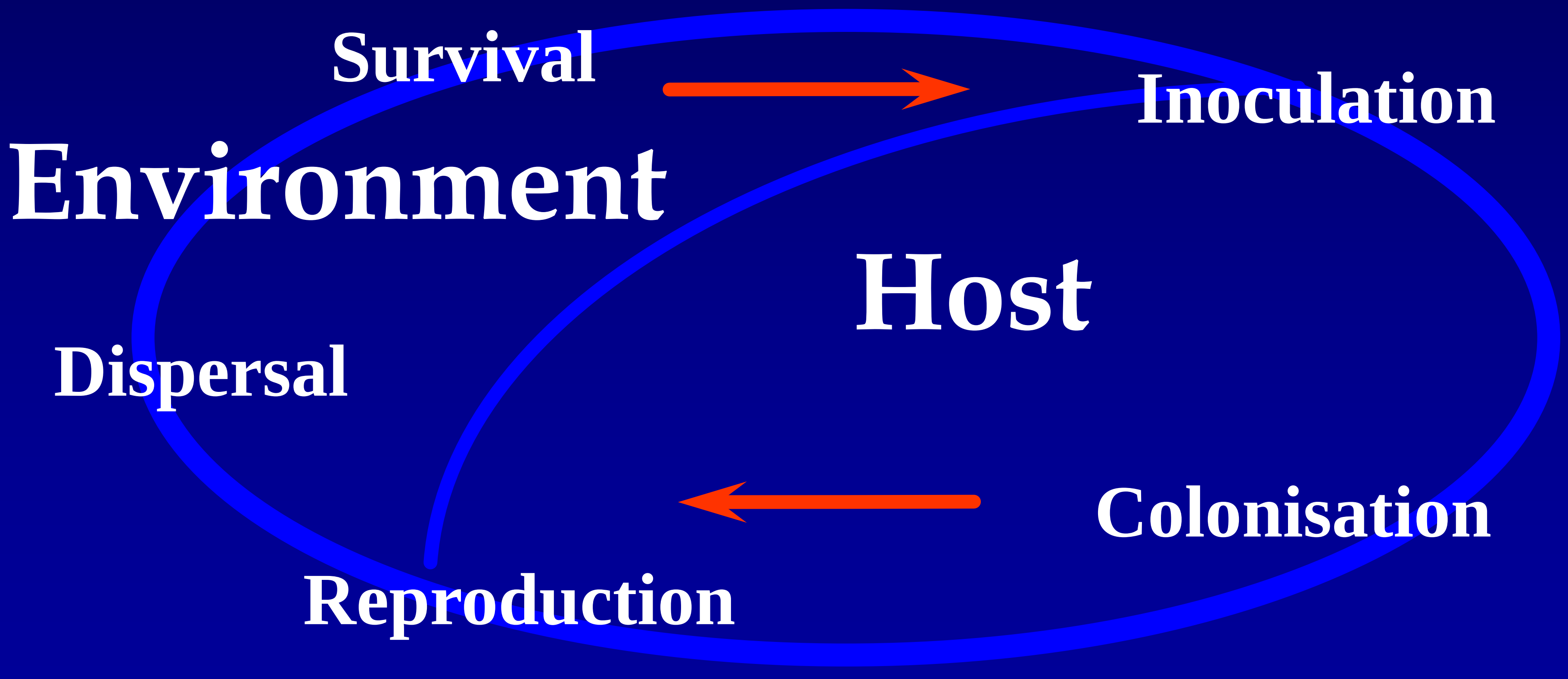
Cultivated Systems

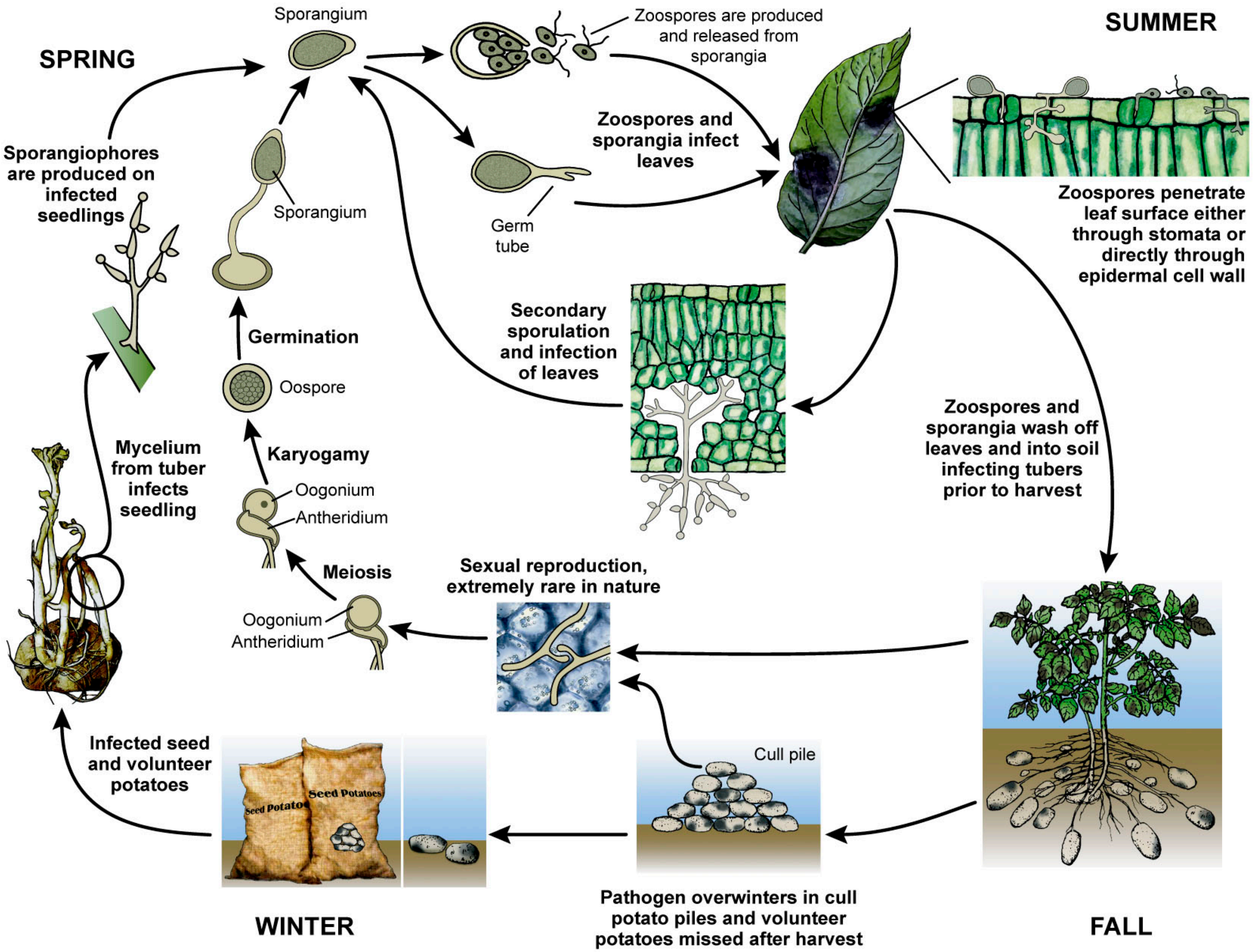
- Economics of production
- Productivity
- Quality control

All require genetically homogenous crops that are:

- Prime targets for epidemics

Chain of Events in Disease Cycles




SPRING
Sporangium
Zoospores are produced and released from sporangia
SUMMER
Zoospores and sporangia infect leaves
Sporangiophores are produced on infected seedlings
Sporangium
Germ tube
Zoospores penetrate leaf surface either through stomata or directly through epidermal cell wall
Germination
Secondary sporulation and infection of leaves
Oospore
Zoospores and sporangia wash off leaves and into soil infecting tubers prior to harvest
Mycelium from tuber infects seedling
Karyogamy
Oogonium
Antheridium
Meiosis
Sexual reproduction, extremely rare in nature
Oogonium
Antheridium
Infected seed and volunteer potatoes
Seed Potatoes
Seed Potatoes
Cull pile
Pathogen overwinters in cull potato piles and volunteer potatoes missed after harvest
WINTER
FALL

Epidemic

- Natural consequence of introducing a virulent pathogen into a relatively homogeneous susceptible host population

The Irish Potato Famine--*continued*

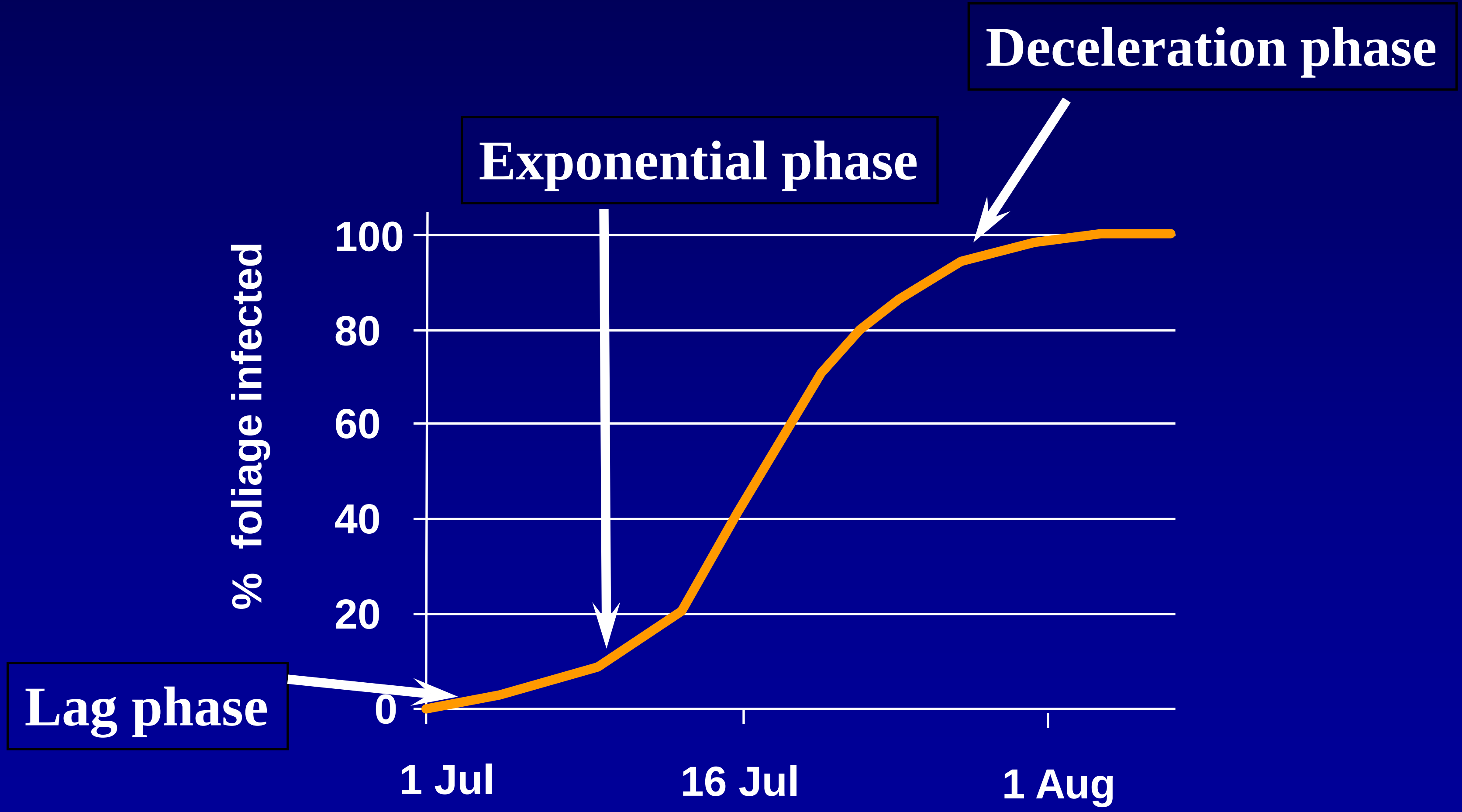
In order to feed its people, Ireland relied primarily upon two high-yielding potato varieties.

When the potato disease struck, it resulted in a massive crop failure that lasted five years, 1845-1850.

Sources: Encyclopedia Britannica, 2002; Illustrated London News, 1849

Disease Progress Curve

eg *Phytophthora infestans*



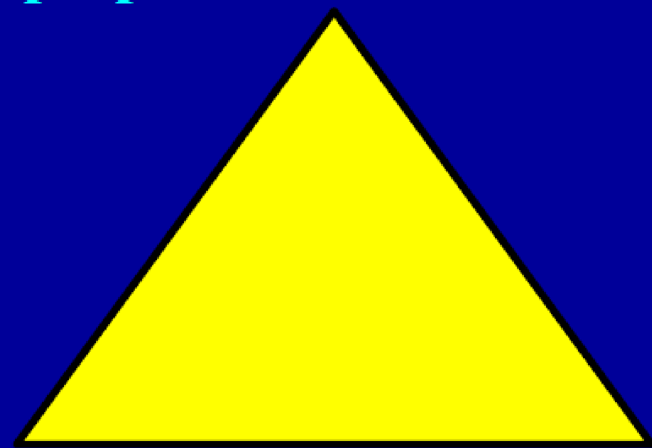
PLANT DISEASE MANAGEMENT

General Concepts

Disease Triangle

Host

Total of all properties that affect susceptibility



Pathogen

Total of all properties of pathogen (virulence, abundance, etc.)

Environment

Total of all conditions that affect disease

All three factors are necessary components of disease

If components could be quantified, Area of triangle would represent amount of disease.

Vanderplank's Equivalence Theorem

"Effects of host, pathogen and environment can be translated into terms of the rate parameter of an epidemic"

Change in any component has an equivalent effect on disease

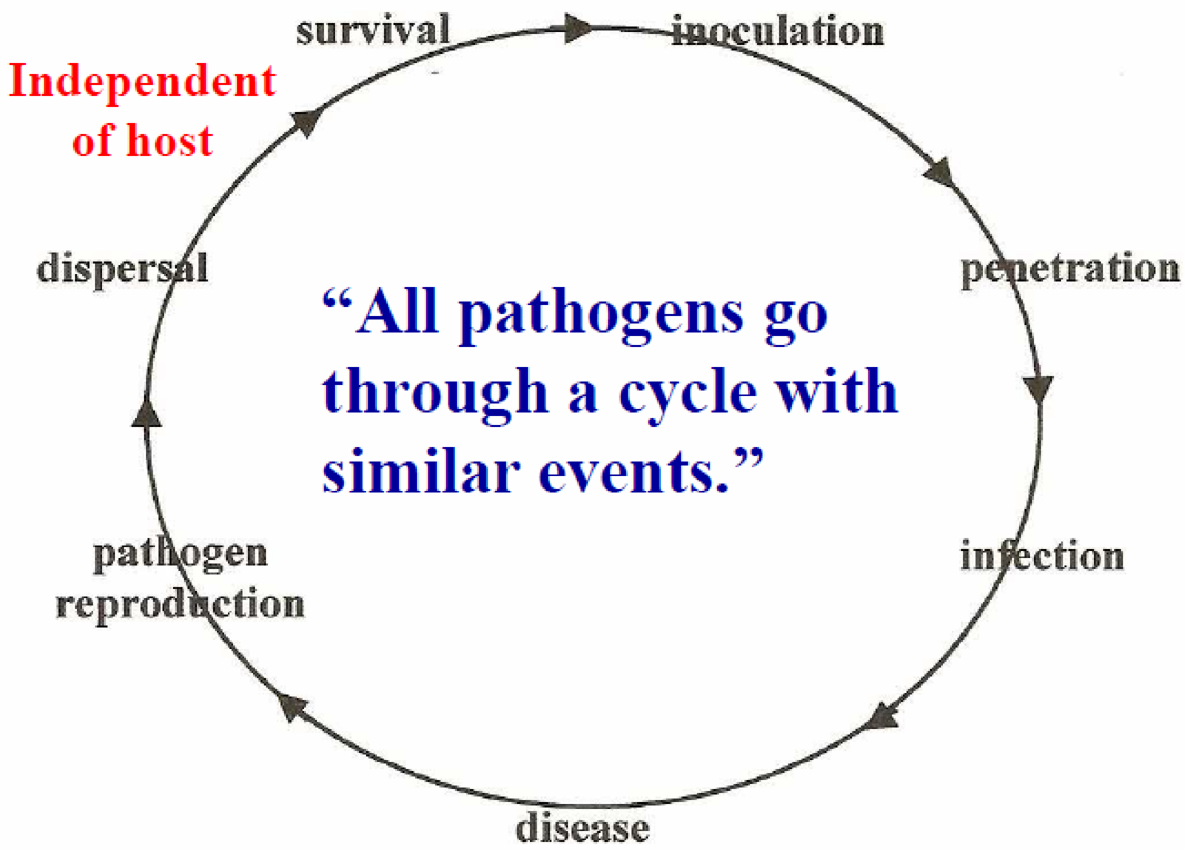
- More-less susceptible host
- More-less aggressive pathogen
- More-less favorable environment

} All affect amount of disease

Therefore, disease management principles and practices are often centered around the concept of the Disease Triangle.

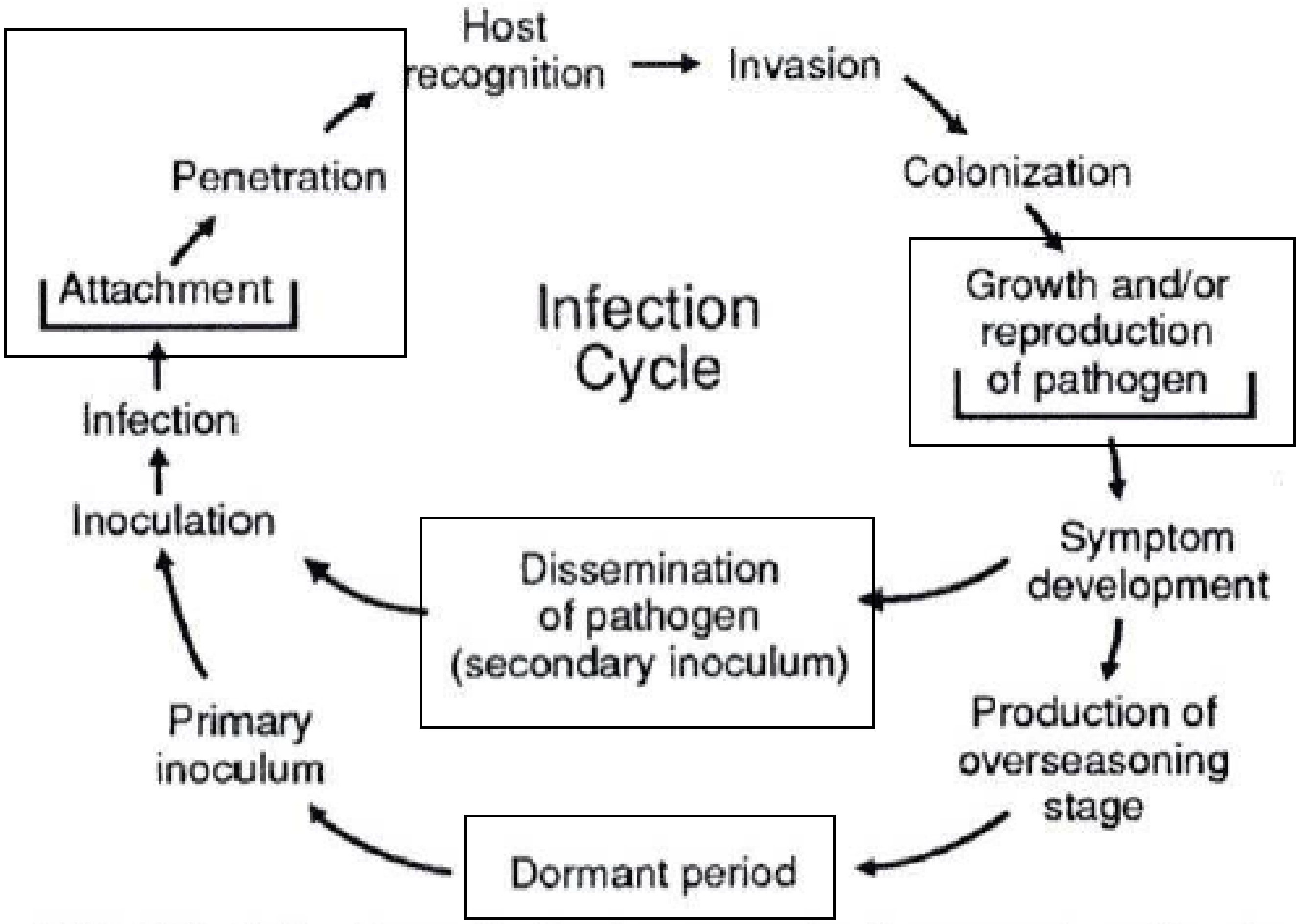
Management tactics often seek to manipulate one or more of the components of the disease triangle.

Disease Cycles

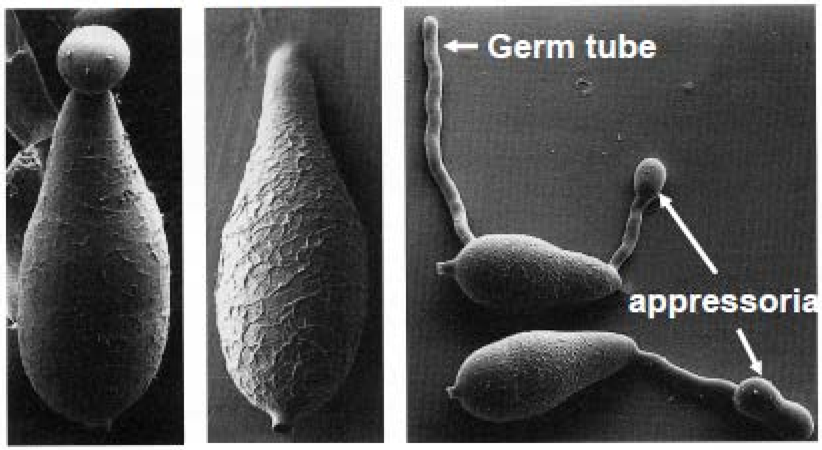


Knowing how particular pathogens go through their disease cycle is important in developing management strategies.

Fungal Infection

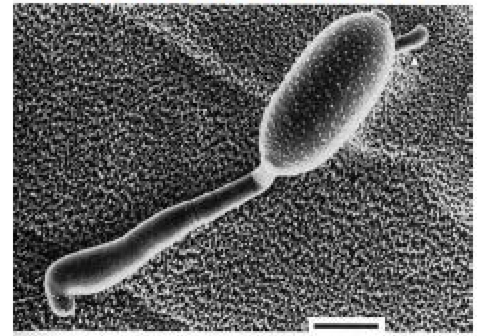


ATTACHMENT

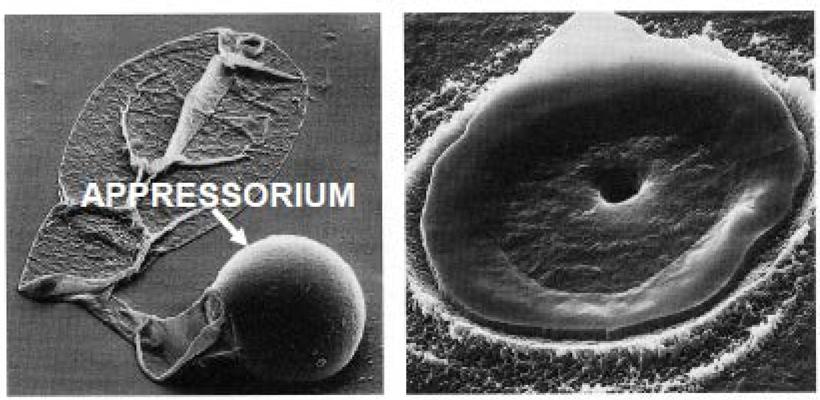


(a)

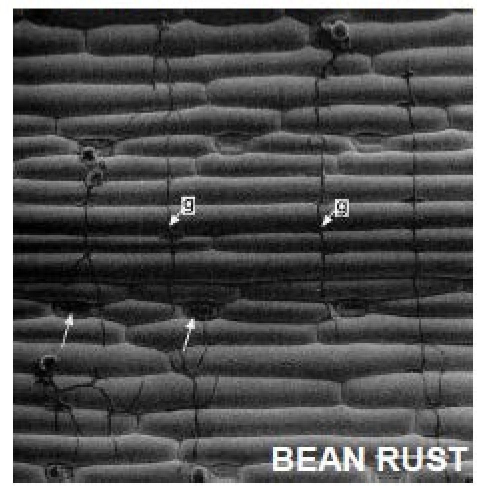
GERMINATION



DIRECT PENETRATION

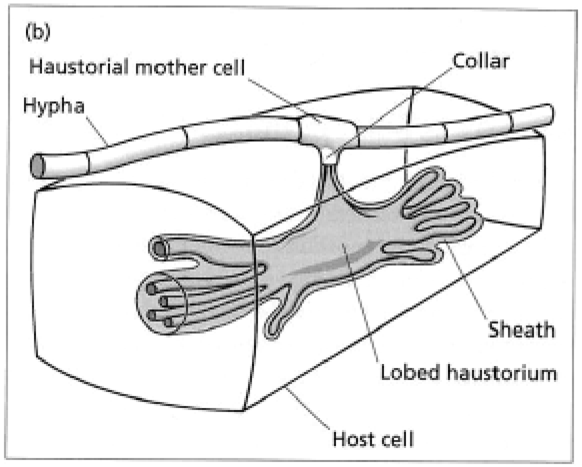


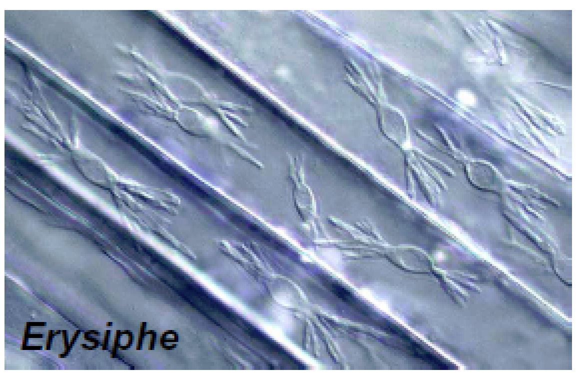
STOMATAL PENETRATION

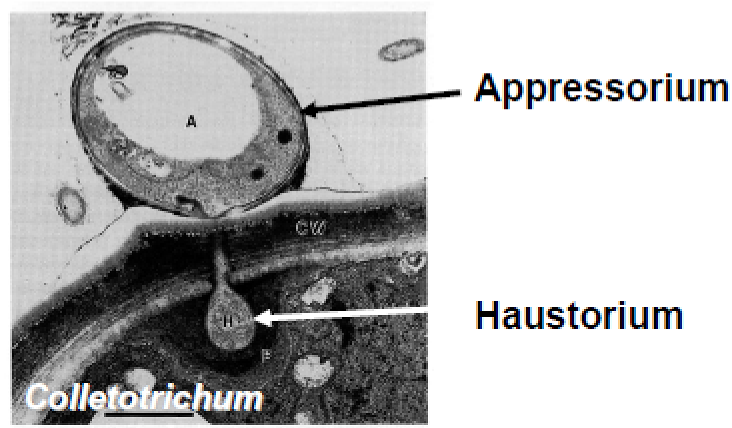


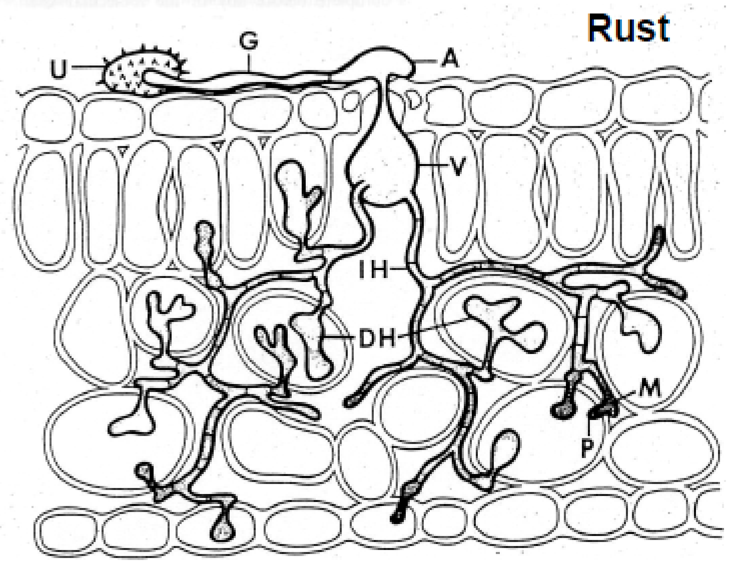
INFECTION

Powdery Mildew Haustoria



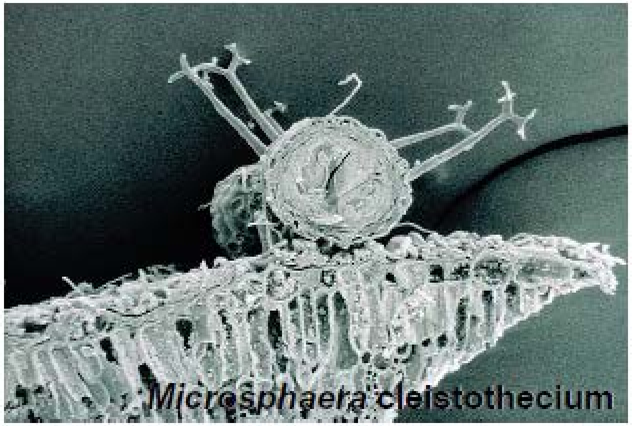


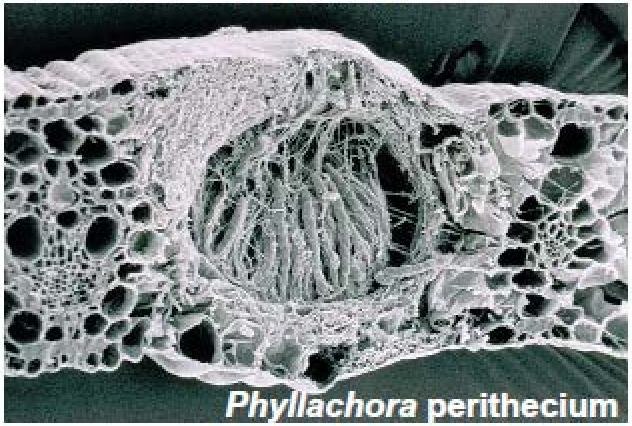




SPORULATION - REPRODUCTION

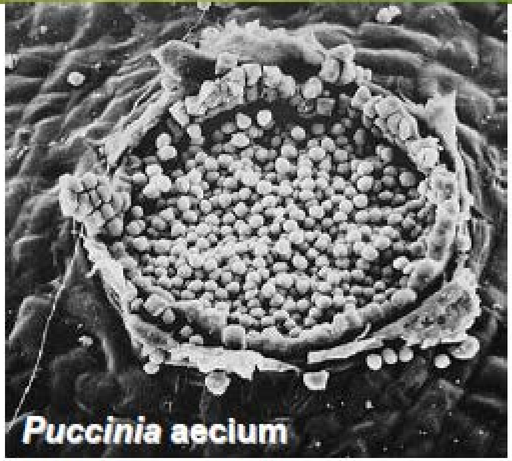
SEXUAL


Microsphaera cleistothecium


Phyllachora perithecium

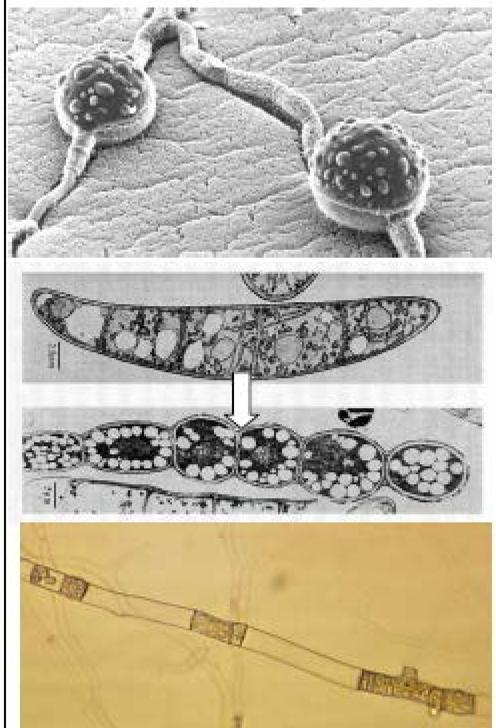
ASEXUAL


Cercospora conidia

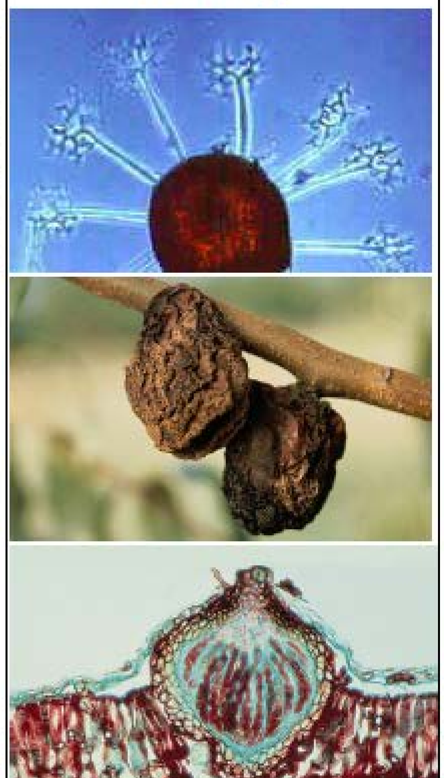

Puccinia aecium

RESTING STRUCTURES

Chlamydospores



Fruiting



Sclerotia

Host Tissues

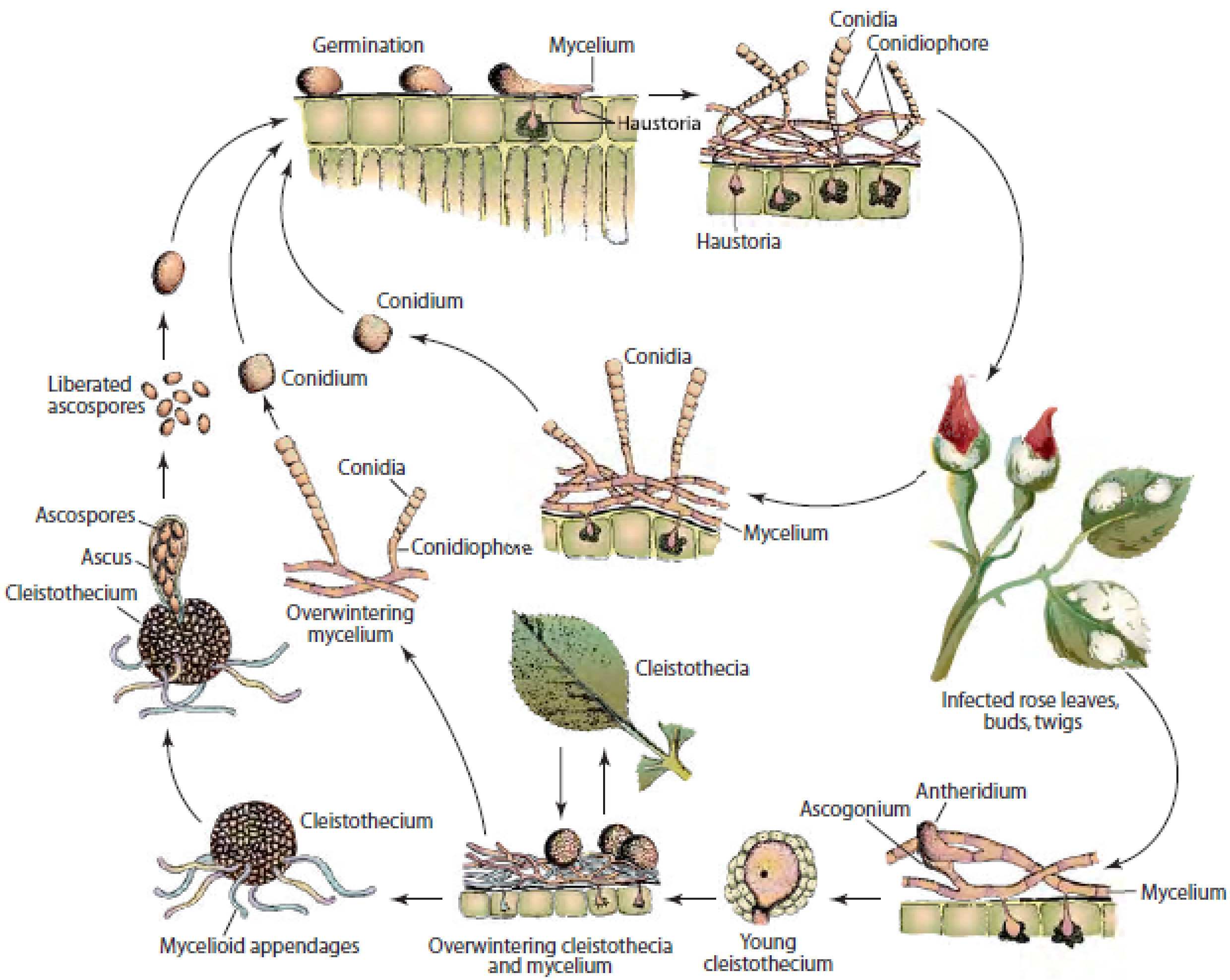


FIGURE 11-50 Disease cycle of powdery mildew of roses caused by *Sphaerotheca pannosa* f. sp. *rosae*.


25

A central concept to epidemiology is that different pathogen populations have different disease cycles..

I. Pathogens that complete one or even part of one disease cycle/year are called monocyclic.

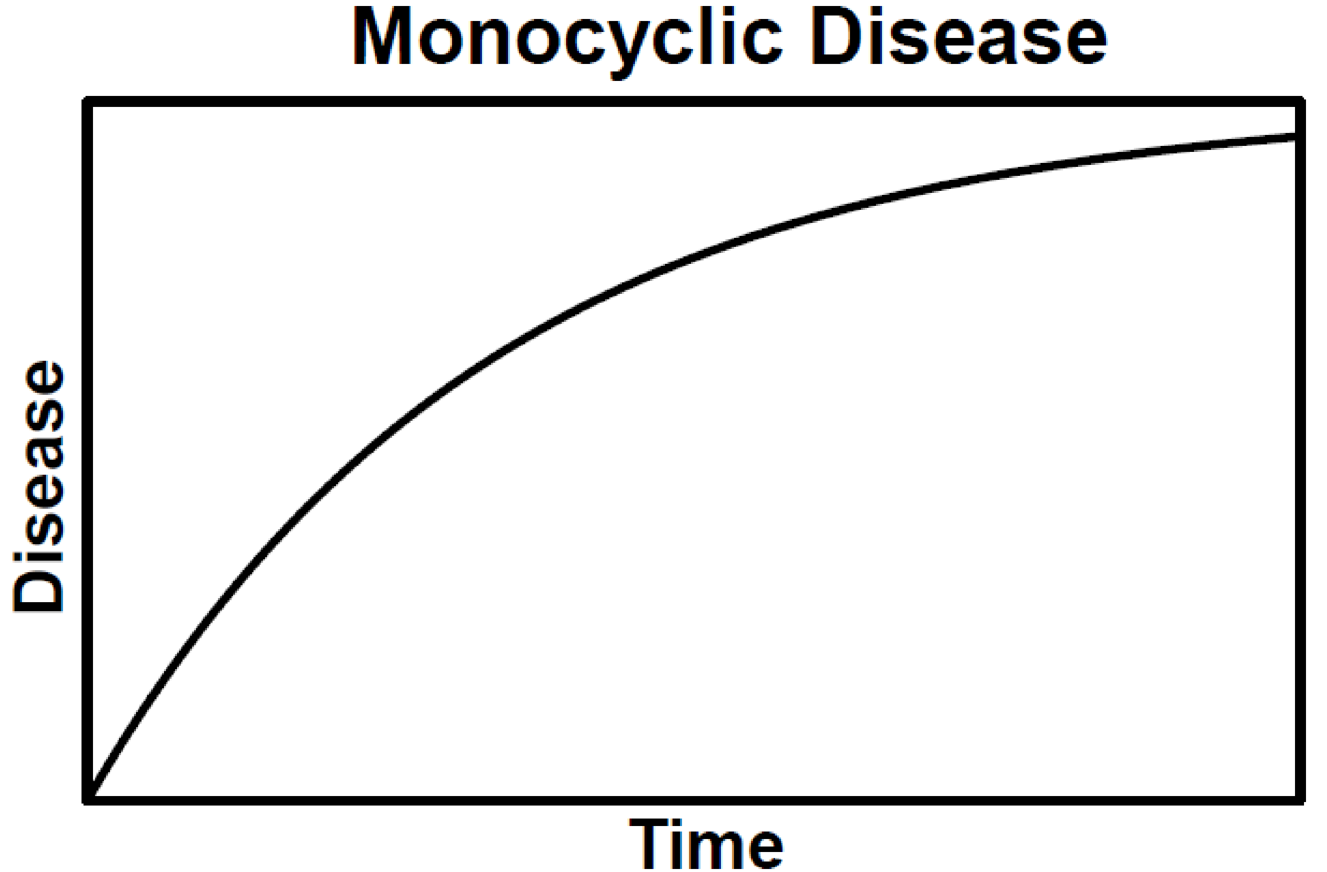
In monocyclic pathogens the primary inoculum is the only inoculum available for the entire season. There is no secondary inoculum and no secondary infection.

The amount of inoculum produced at the end of the season, however, is greater than at the start of the season so the amount of inoculum may increase steadily from year to year.

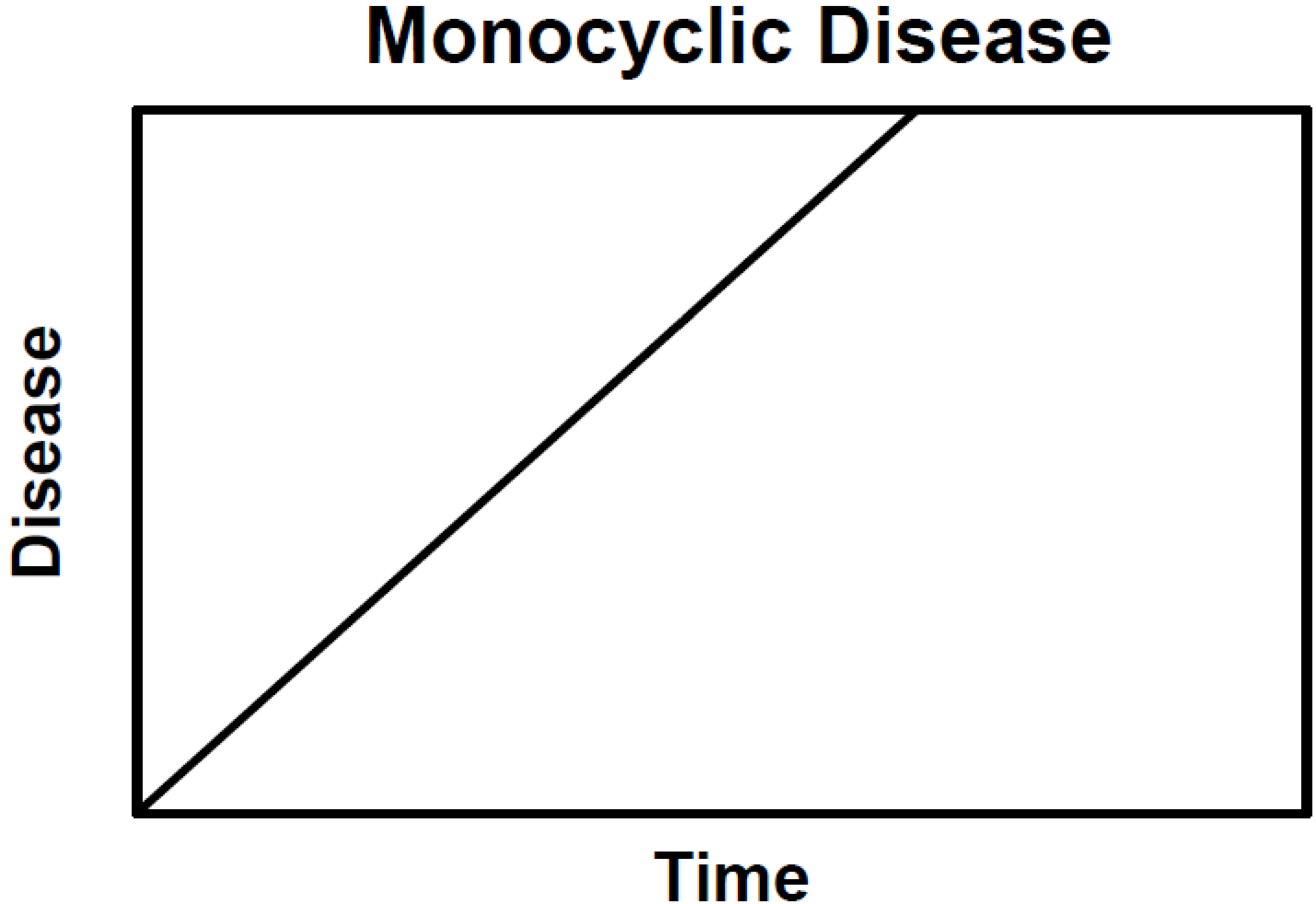
Verticillium wilt of strawberry

This representation of plant disease over time is referred to as a **"Disease Progress Curve"**

Graphically, disease caused by monocyclic pathogens looks like a saturation curve.



Rate of increase of disease over time can be represented by a simple interest function.



Examples of Monocyclic Diseases

Blackleg of potato (*Erwinia caratovora*)
Verticillium wilt
Cereal Cyst Nematode

II. Polycyclic = multiple cycles/year (compound interest)

Most pathogens go through more than one (2-30) disease cycles in a growing season and are referred to as polycyclic.

Only a small number of sexual spores or other hardy structures survive as primary inoculum that cause initial infections.

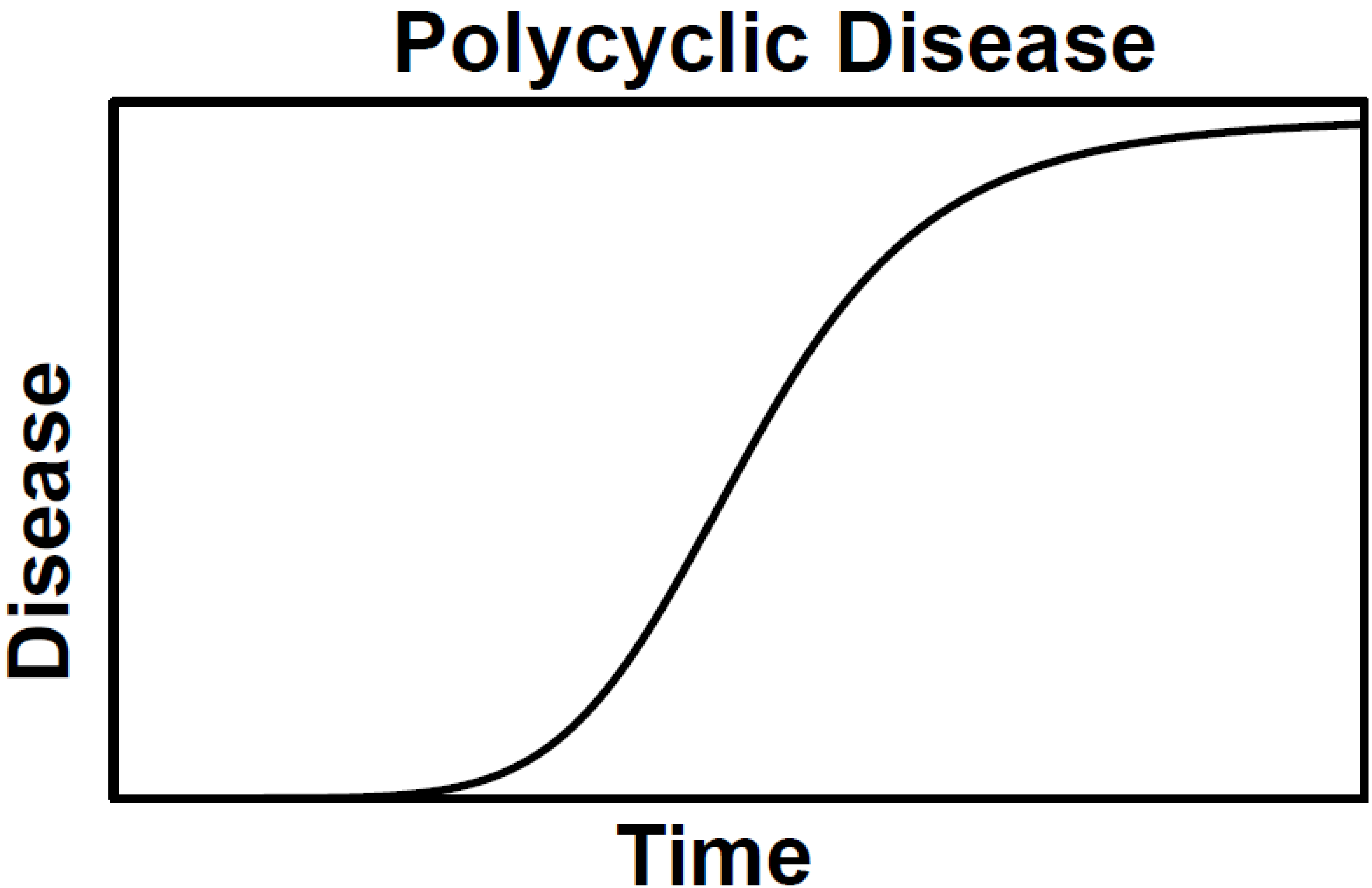
Once infection takes place, large numbers of asexual spores are produced as secondary inoculum at each infection site.

These spores can produce new (secondary) infections that produce more asexual spores and so on.

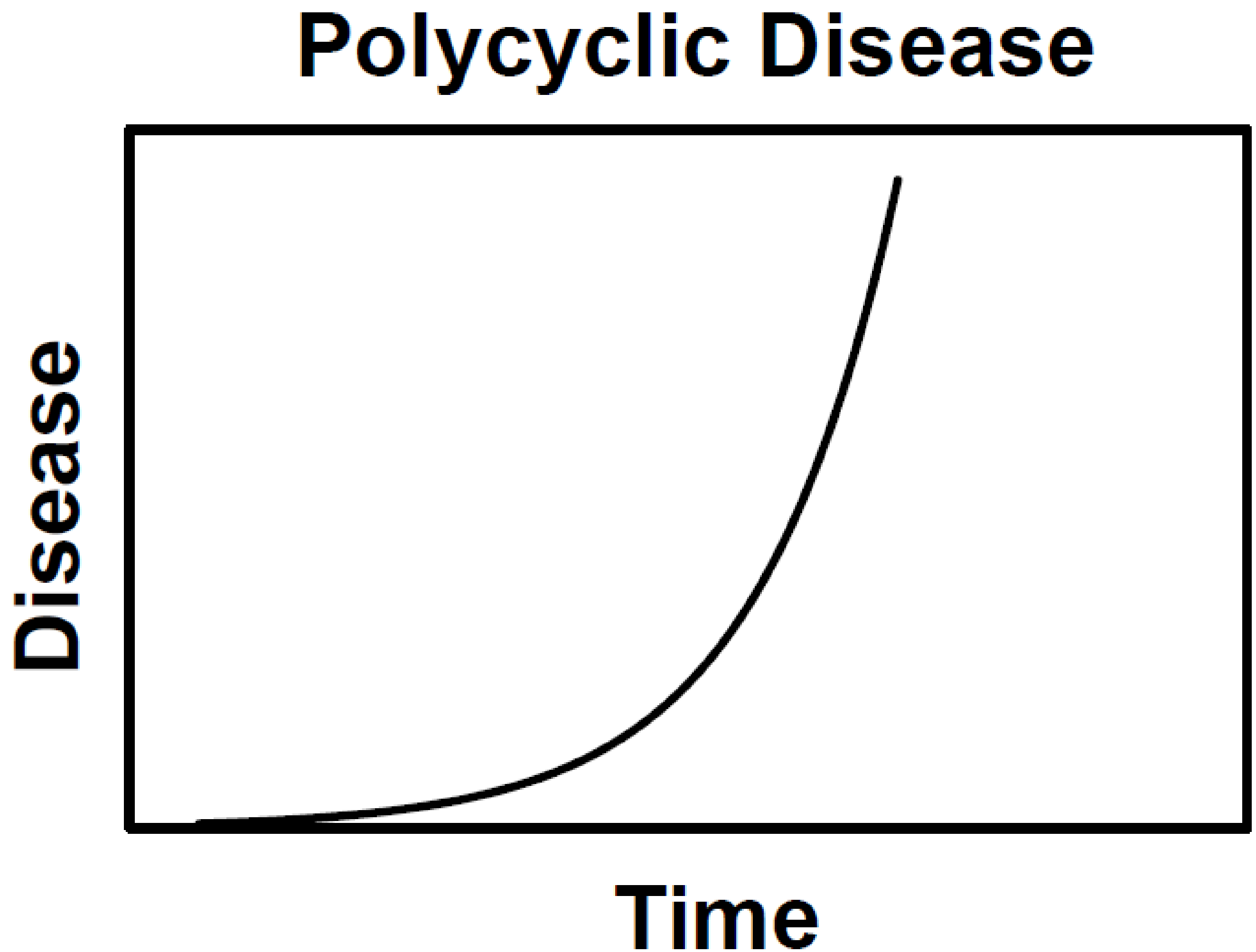
With each cycle the amount of inoculum is multiplied many fold.

Downy mildew of grape

Graphically this type of population growth is represented as a **sigmoid curve**



Rate of increase of disease over time can be represented by a compound interest function.



Many of these pathogens are disseminated primarily by air
Or air-borne vectors and are responsible for of the explosive epidemics in most crops

Examples of Polycyclic Diseases

Downy mildews
Powdery mildews
Late blight of potato
Leaf spots
Blights
Grain rusts
Aphid borne viruses
Root-knot nematodes

Implications for Disease Management Strategies

Monocyclic Diseases

Reduce the amount of primary inoculum, or affect the efficiency of invasion by the primary inoculum.

Polycyclic Diseases

Reducing the amount of primary inoculum has less impact.

Reducing the rate of increase of the pathogen more beneficial.

Stay tuned….

Other Concepts Related to Disease Cycles

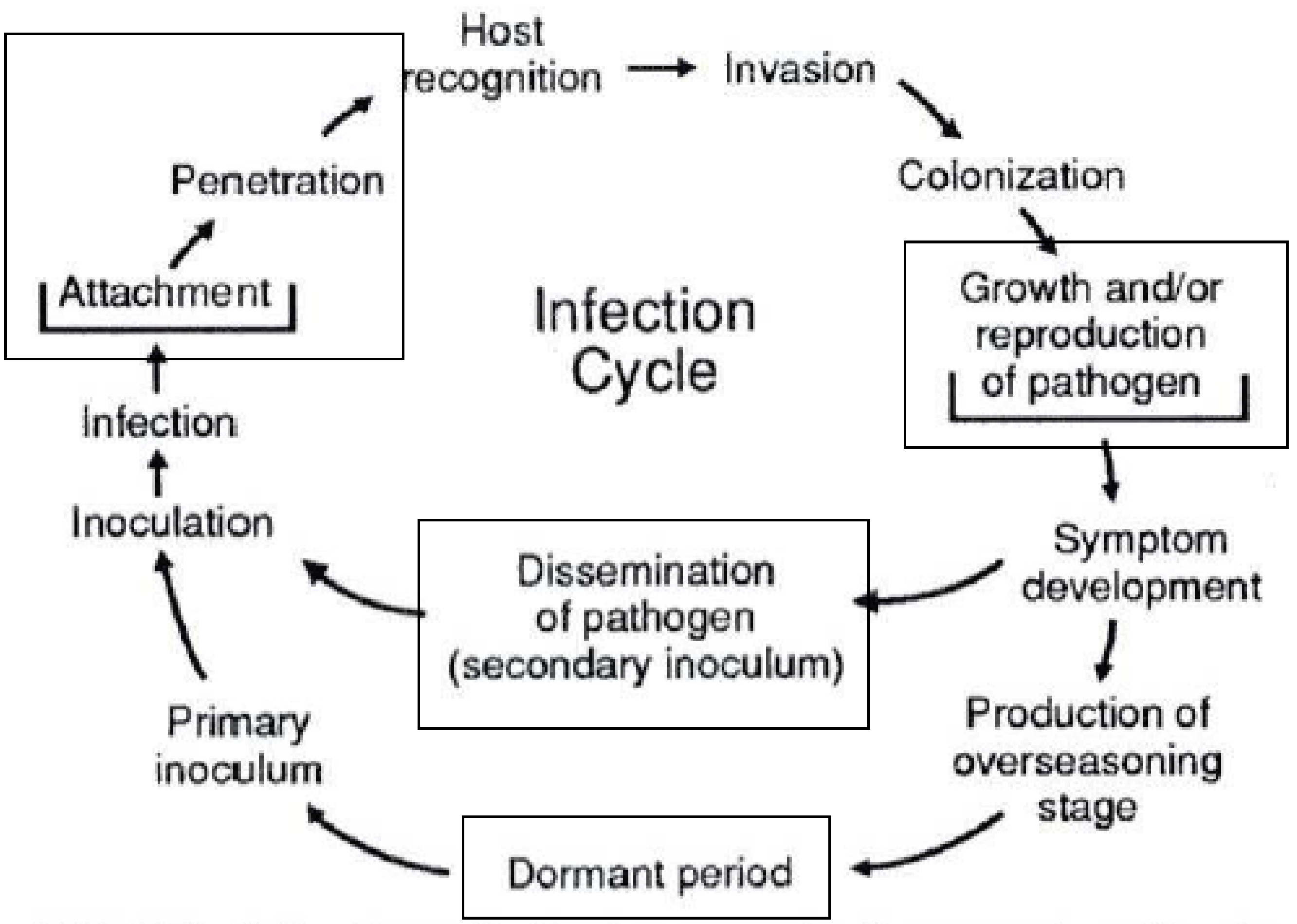
Successful Infections => symptoms
Before symptoms:
Incubation period = time between infection and appearance of the disease symptom.

The **length of the incubation period** of different pathogens/diseases varies with:

1. the **particular pathogen-host combination**
2. the **stage of development** of the host
3. the **temperature** in the environment.

Can make disease assessments misleading If infections are presymptomatic during scouting.

Fungal Infection



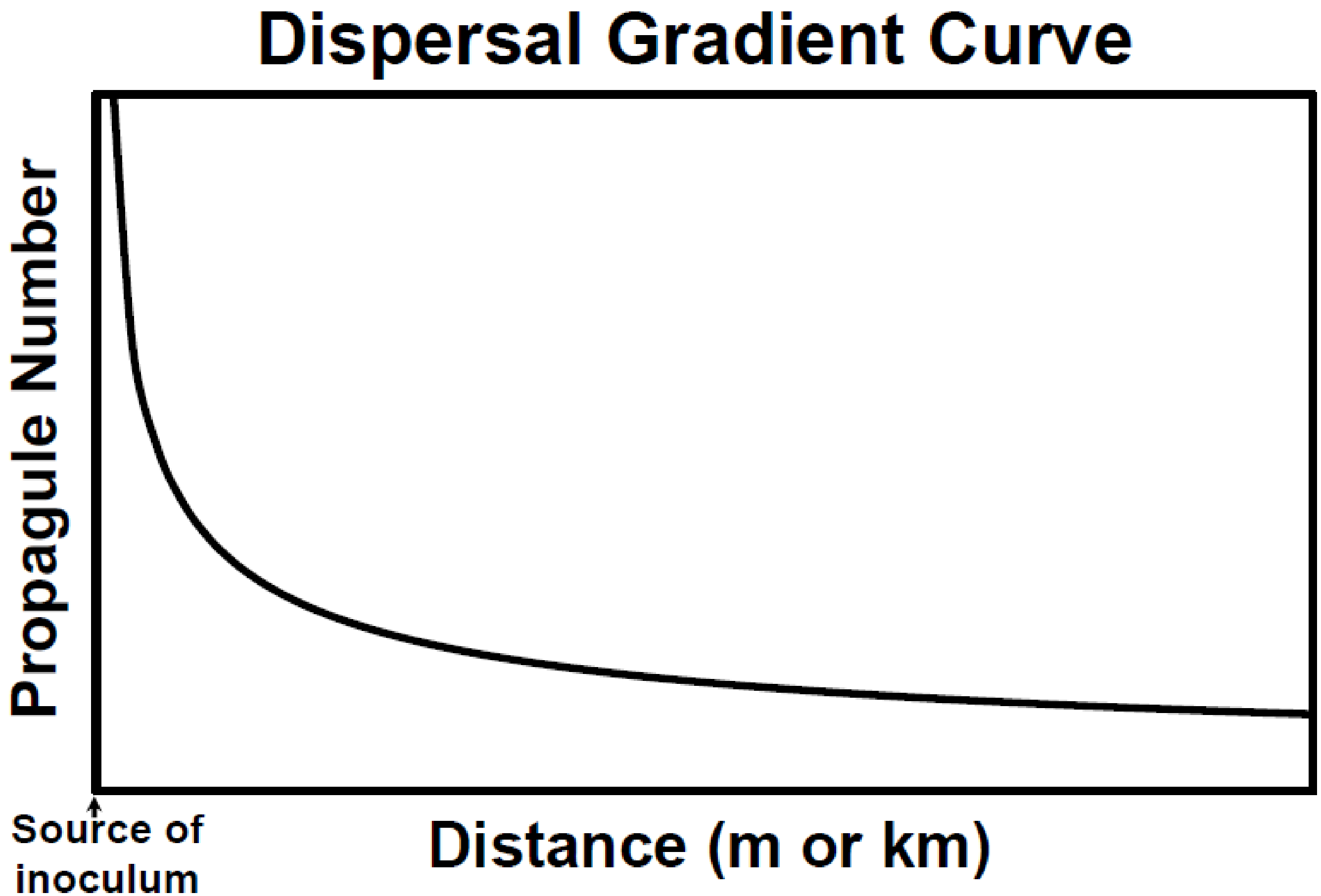
Latent period = time from infection until production of new inoculum (reproduction).

Duration can have a large effect on the rate of the epidemic.

Affected by characteristics of the **host** (stage of development, age of tissue, physiological condition), the **pathogen,** and the **environment** (temperature, moisture).

Gradients in pathogen densities and disease are frequently observed.

Factors that affect spatial variation in the amount of incoming inoculum lead to dispersal gradients.



The percentage of disease and the scale for distance vary with the type of pathogen or its method of dispersal, being small for soilborne pathogens or vectors and larger for airborne pathogens.

Disease gradients can also be caused by environmental gradients such as, variations in soil type, fertility, or gradual changes in microclimate.

Southern Corn Leaf Blight Epidemic -- *continued*

The pathogen introduced was

Cochliobolus heterostrophus race T

Progress of Southern Corn Leaf Blight Epidemic in North America (1970)

The generation time for new inoculum?

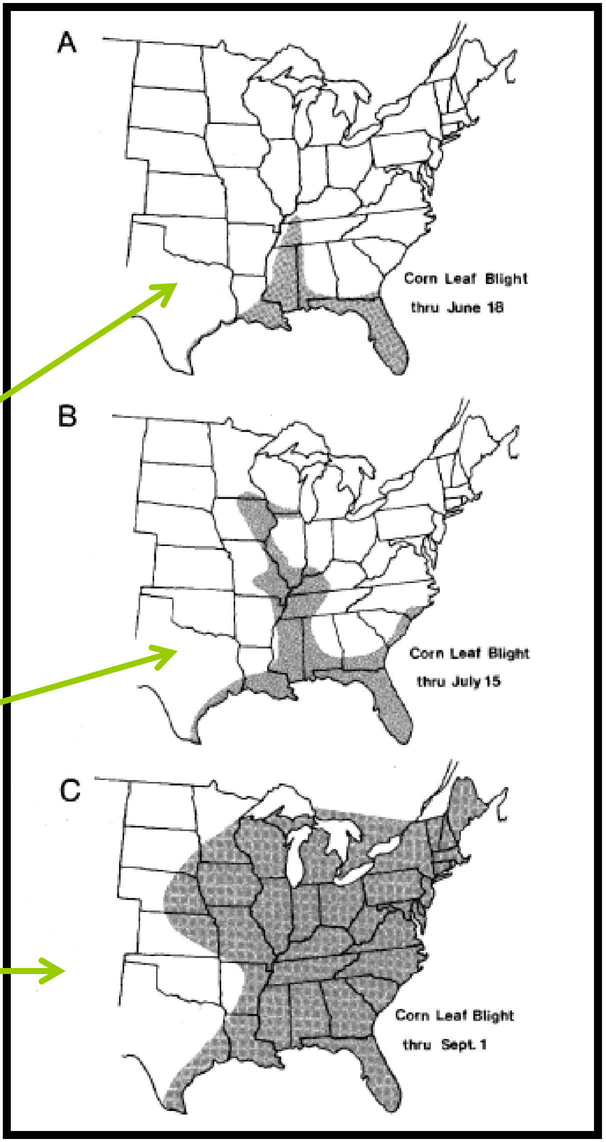
Only 51 hrs

The path:

A. June 18

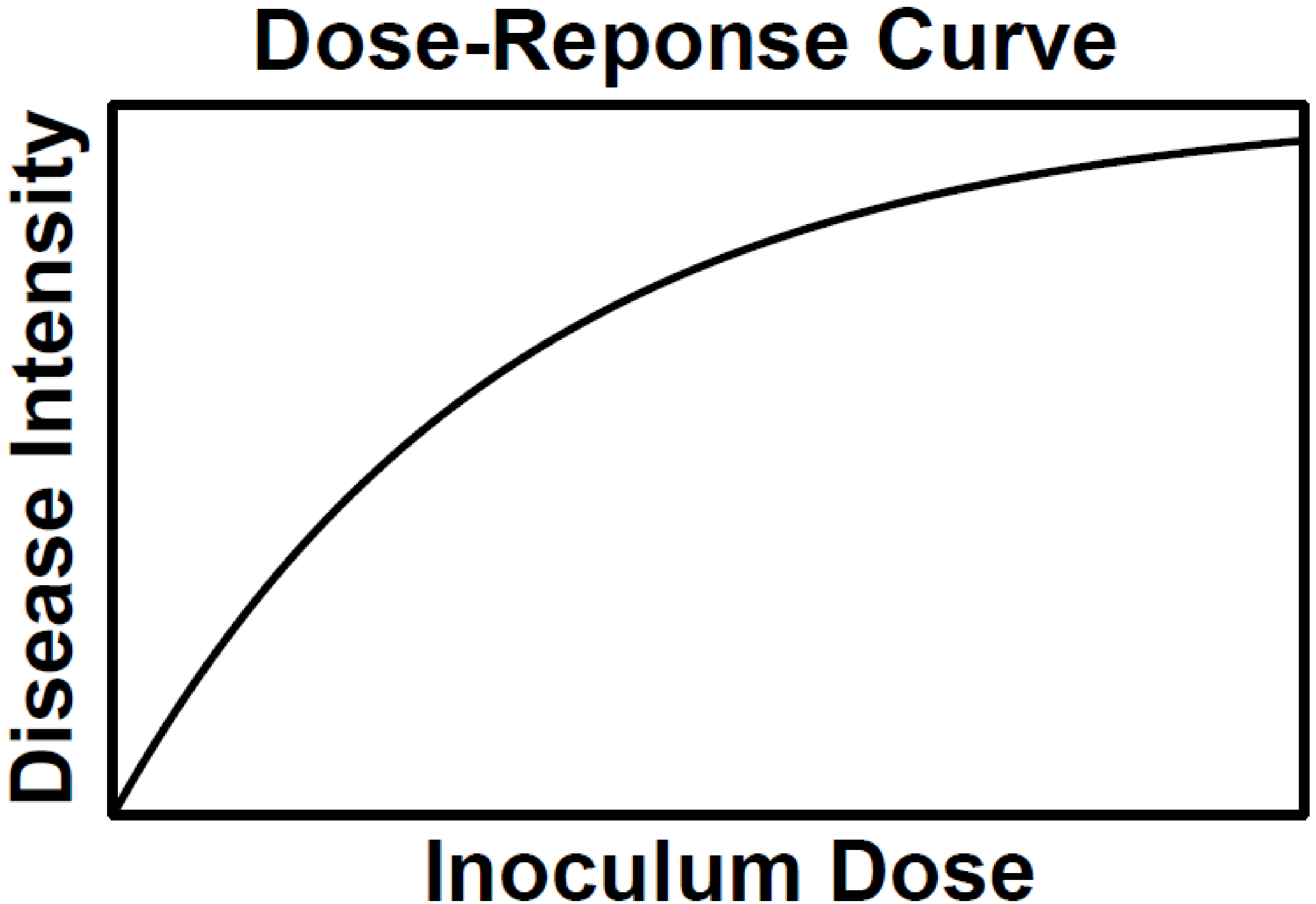
B. July 15

C. September 1

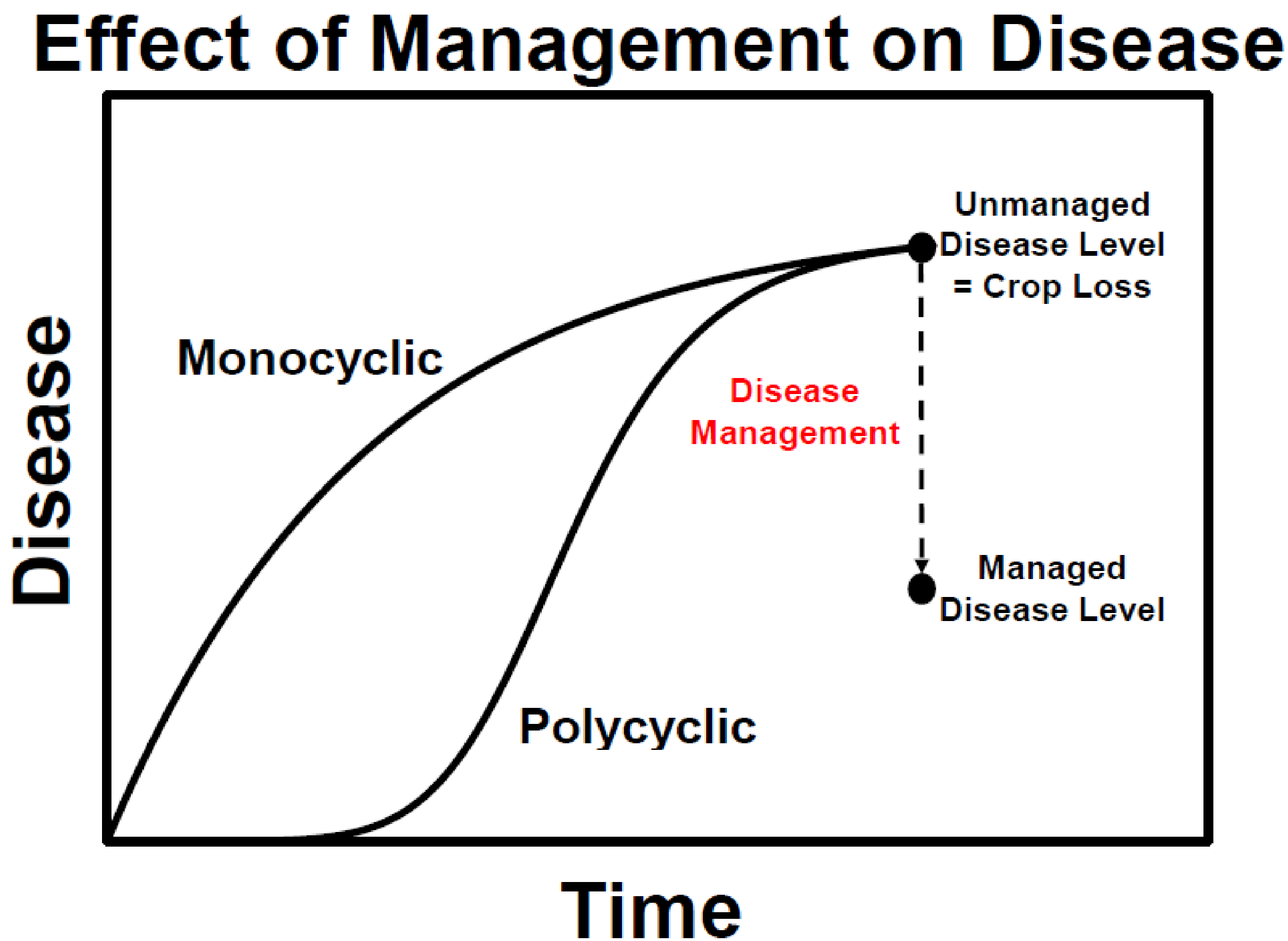


Source: Plant Diseases: Their Biology and Social Impact

Variations in pathogen density as the result of dispersal gradients or other causes are important relative to the impact of a Dose Response on disease.



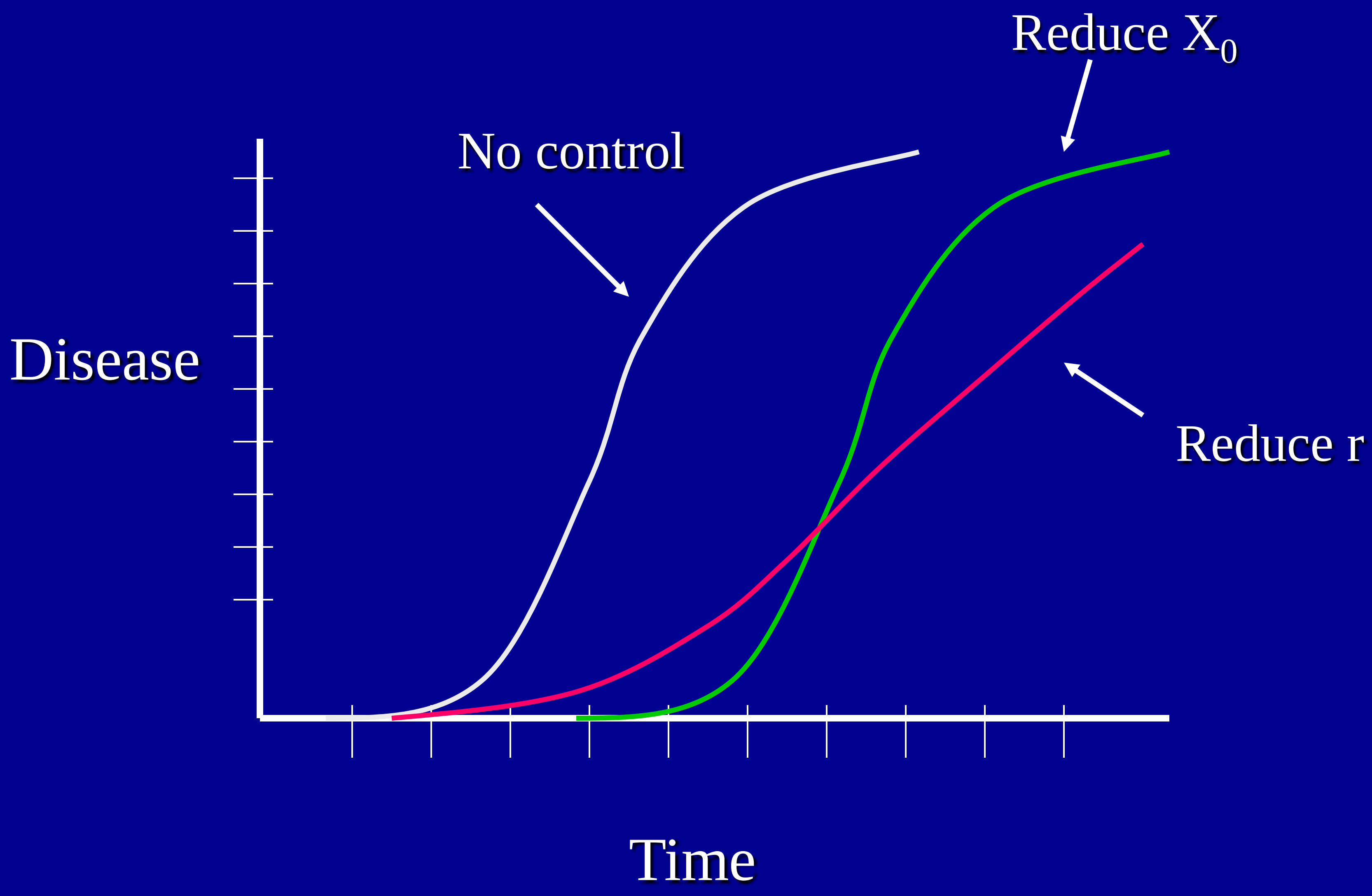
Purpose of disease management is to prevent disease from exceeding some level where profit or yield is significantly diminished.



Principles of epidemiology indicate that control measures can do this in only two ways:.

1. **They may reduce (or delay) disease at the beginning of the season (x_0) or**

2. **They may decrease the rate of disease development (r) during the growing period.**


Reduce X_0
No control
Disease
Reduce r
Time

Ways to reduce disease (inoculum) at beginning (x_0)

Affects monocyclic and polycylic diseases

Fumigation	Certified seed
Sanitation	Seed treatments
Quarantine	Host plant resistance

Ways to decrease the rate of disease development (infection rate) (*r*)

- Change the environment
- Fertilizer application
- Host plant resistance

Ways to change t (see "b" on figure)

- Harvest early before disease becomes severe
- Plant early (cereal cyst nematode)

Control of different diseases requires different strategies.

Some pathosystems, monocyclic and polyetic diseases can be affected by use of an x_0-reducing practice only.

However, for most diseases more than one control procedure is used and these are often chosen to reduce x_0 <u>and</u> *r*.

These integrated control measures use a combination

- **cultural methods,**
- **resistance breeding**
- **regulatory actions,**
- **chemical control measures**

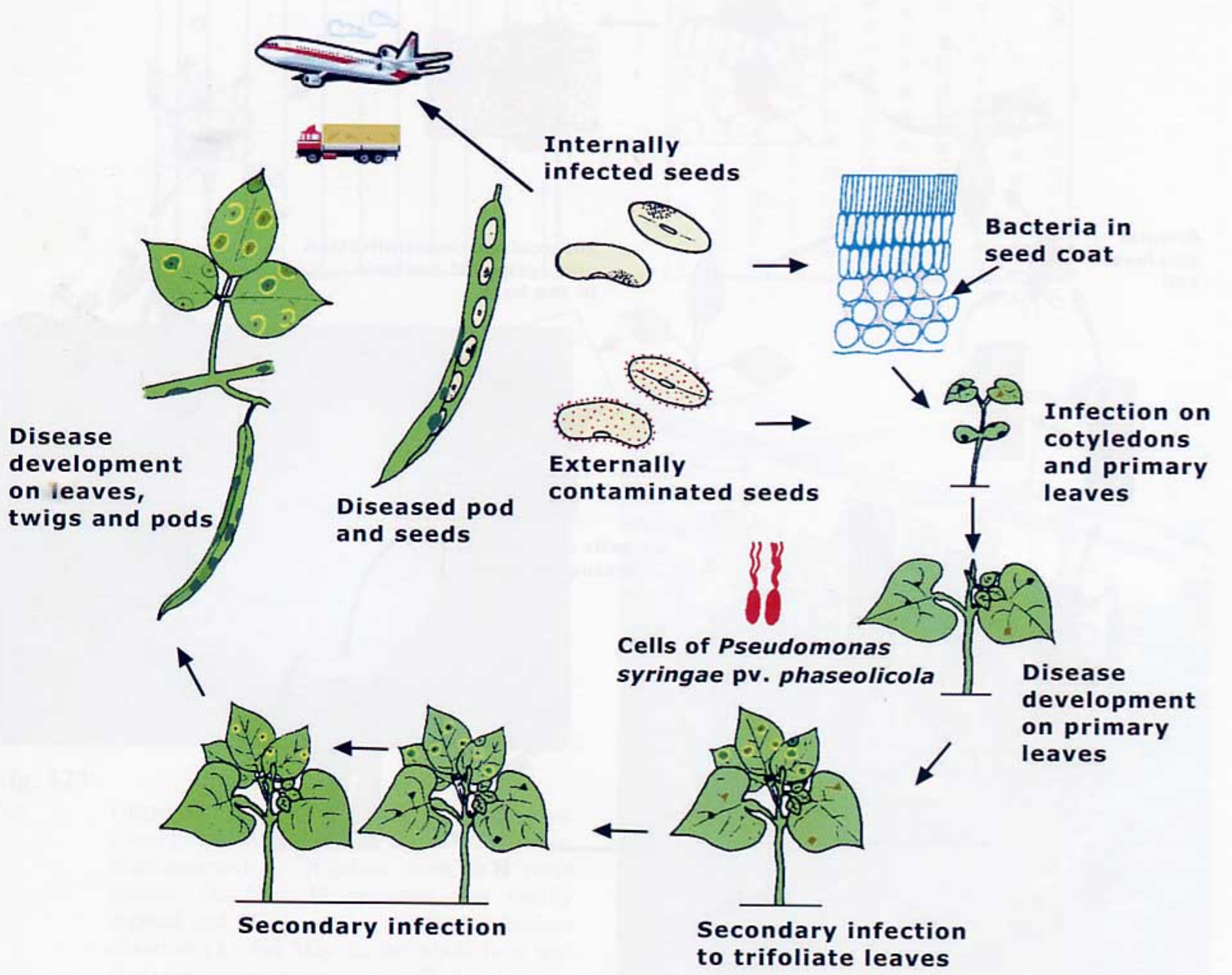
Disease Control Measures

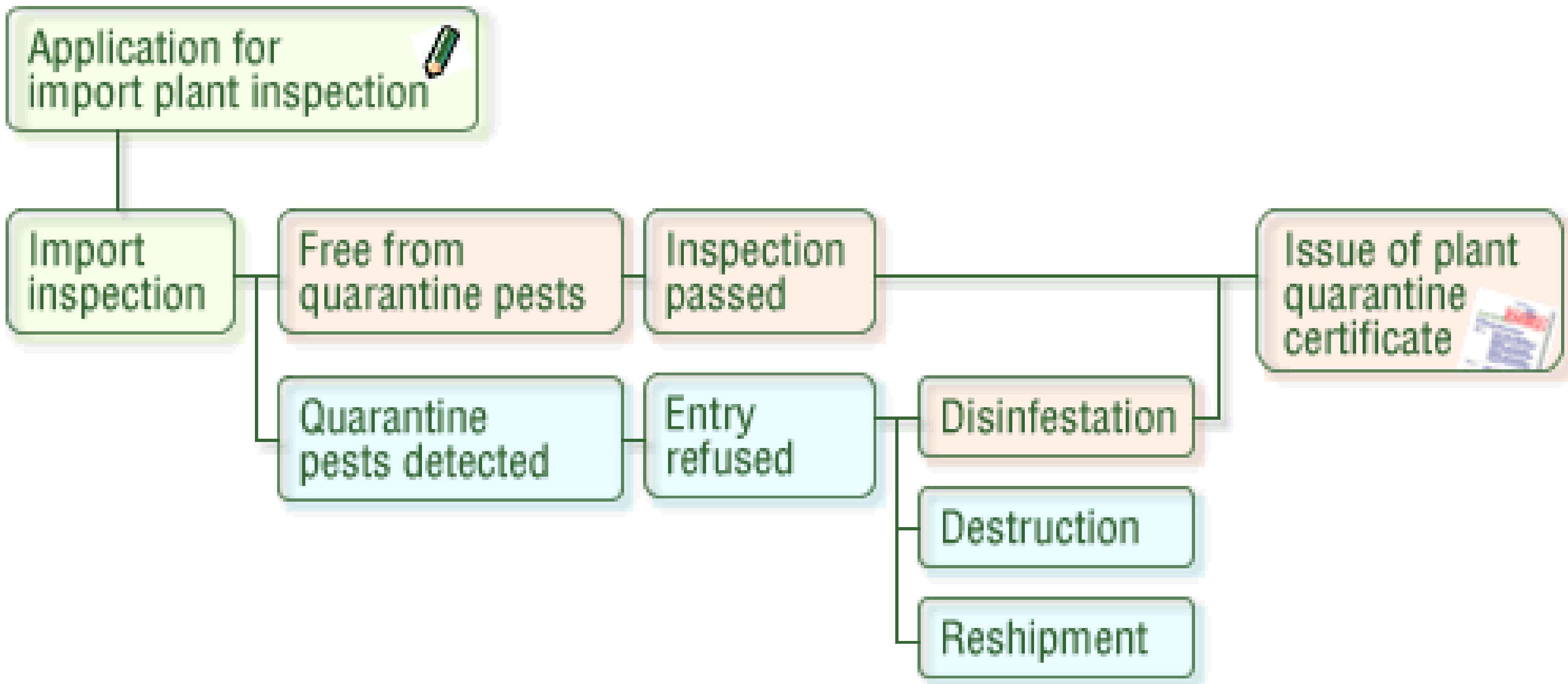
- Quarantine and other exclusion mechanisms
- Cultural practices
- Crop protection chemicals
  - fumigants, fungicides
- Resistant cultivars
- Biological control

Pathogen exclusion -Quarantine & Sanitation

- Sanitation - a matter of common sense
  - –machinery, boots etc should be cleaned between fields (soil-borne diseases)
  - –recycle run-off irrigation water within same field (*Phytophthora, Pythium, Fusarium*)
    - in nurseries, use chlorinated water

DISEASE CYCLE OF HALO BLIGHT (*PSEUDOMONAS SYRINGAE* PV. *PHASEOLICOLA*) OF BEAN (*PHASEOLUS* SPP.)



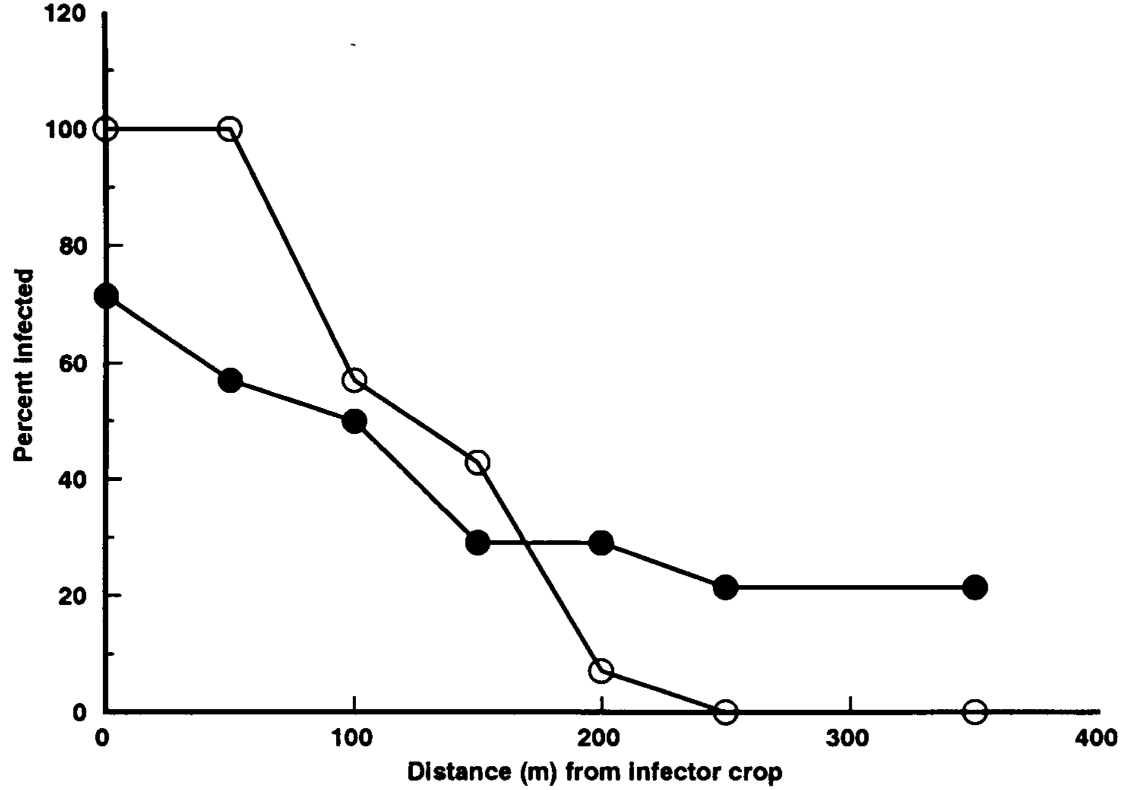

Application for
import plant inspection
Import
inspection
Free from
quarantine pests
Inspection
passed
Issue of plant
quarantine
certificate
Quarantine
pests detected
Entry
refused
Disinfestation
Destruction
Reshipment

Strategies:

- Prohibition
  - Quarantine & Embargo
- Intercept
  - Inspection
- Elimination
  - Treatment

Sanitation

- Avoid growing crops in fields near (downwind of) inoculum sources
- Avoid sequential cropping
- Destroy stubble. (Foliar diseases)
- Disease-free, or “pathogen tested” planting materials
- Eliminate alternate and reservoir hosts



Cross infection study of *Altemaria brassicicola*. ○, incidence of infected plants in a vegetative brassica crop, August 1978; ●, incidence of infected seeds from the same crop in July 1979. (Redrawn from Humpherson-Jones and Maude, 1982.)

Cultural Practices

- Removal or destruction of inoculum
  - direct removal
  - stubble destruction
  - weed control
- Cultivation
- Heat
- Crop rotation
- Mulching

Soilborne pathogens, inoculum is not dispersed within the growing season but possible dispersed by irrigation, worker

Verticillium wilt of strawberry

Table 3. Effect of soil solarization on subsequent development of Fusarium wilt on lettuce in 2004 to 2007 field trials

Year, solarization period (days)	Soil temperature (°C)[y]	Beds shaped	Disease incidence (%)[z]
2004			
0	37	No	50 a
41	41	No	29 b
2005			
0	41	Yes	92 a
28	47	Yes	9 b
56	46	Yes	8 b
2006			
0	38	No	100 a
0	38	Yes	100 a
30	45	No	84 ab
27	49	Yes	52 b
69	44	No	79 ab
66	48	Yes	44 b
2007			
0	41	Yes	67 a
33	44	Yes	25 b

[y] Mean soil temperature at a depth of 5 cm during solarization period.

[z] Percentage of plants that were dead or diseased and displayed typical symptoms of Fusarium wilt at crop maturity. Values for each year followed by a different letter are significantly different according to the *t* test ($P = 0.13$ in 2004 and $P < 0.001$ in 2007) or the Tukey Test ($P < 0.05$ in 2005 and 2006).

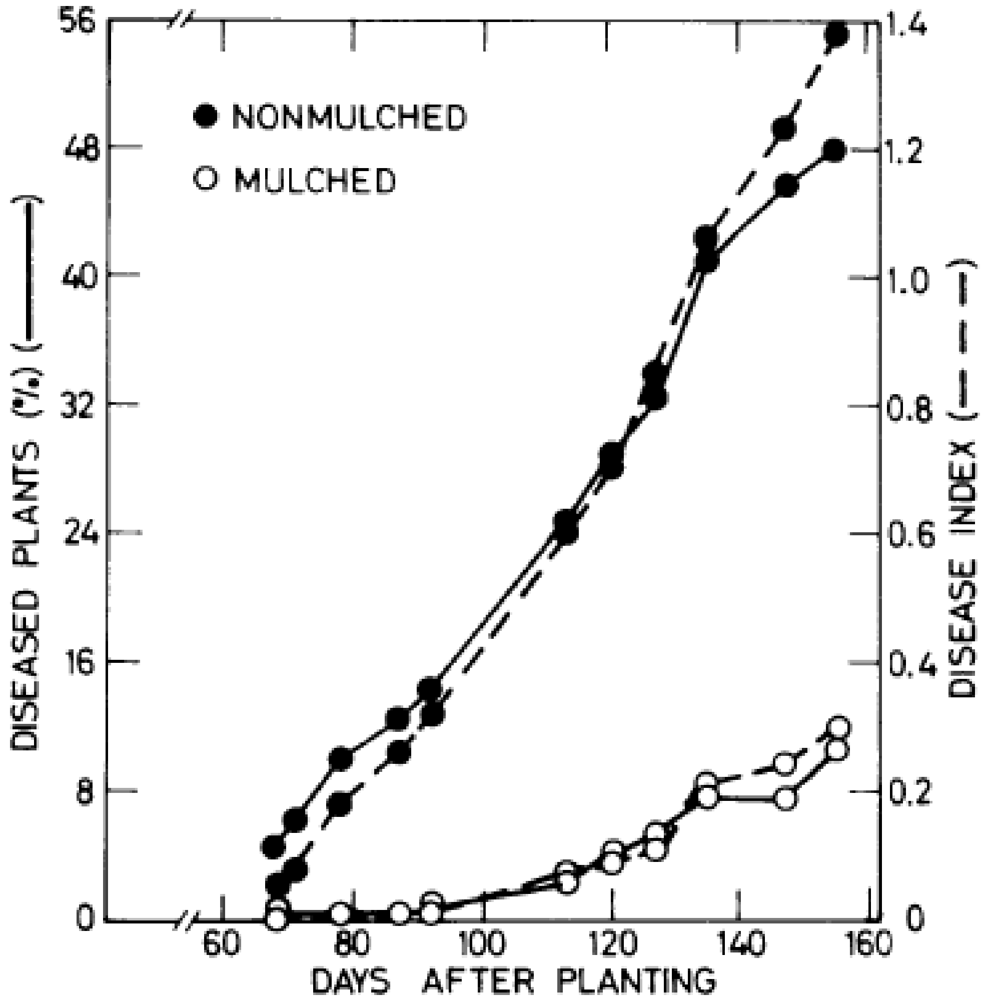


Fig. 2. Effect of solar heating of soil on Verticillium wilt of eggplant. Disease index: scale of 0–4, with 0 = healthy.

TABLE 2. Effect of the type of polyethylene mulch on the relative area under the late blight progress curve (RAUDPC) in three tomato experiments conducted in walk-in tunnels[y]

	RAUDPC (%)		
Polyethylene[z]	Autumn 2004–05	Autumn 2005–06	Spring 2006
Nonmulched	50.6 a	14.5 a	45.8 a
Bicolor aluminized	3.8 b	0.6 b	14.8 b
Black	6.1 b	0.7 b	18.3 b
Clear	6.5 b	1.2 b	17.1 b

[y] Disease progress curves are presented in Figure 4. In each column, numbers with different letters differ significantly as determined according to the highly significant difference test at $P = 0.05$.

[z] Polyethylene type used for soil mulching; mulch applied before planting.

TABLE 1. Effects of mulching and chemical control on the relative area under the late blight progress curve (RAUDPC) in two tomato experiments conducted in greenhouses[y]

Mulch, treatment[z]	RAUDPC (%)	
	Autumn 2003–04	Autumn 2004–05
Nonmulched		
Untreated	68.5 a	43.9 a
Kocide	60.2 a	42.9 a
Mulched		
Untreated	2.8 b	14.7 b
Kocide	0.6 b	11.3 b

[y] Disease progress curves are presented in Figure 2. In each column, numbers with different letters differ significantly as determined from the highly significant difference test at $P = 0.05$.

[z] Soil mulching and fungicide treatment. Mulched = bicolor aluminized polyethylene mulch before planting and Kocide = plants sprayed weekly with a mixture of Kocide 2000 (0.5%) plus Neemguard (2%).

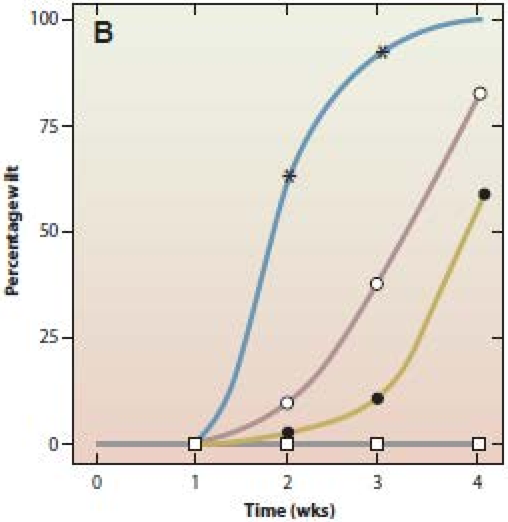


FIGURE 9-16 (A) Soil solarization in Cote d' Ivoire in Africa. Soil removed from holes to solarize before being replaced. (B) Effect of soil solarization on *Fusarium* wilt of watermelon. ⋆, infested, nonsolarized soils; ○, infested soil solarized for 30 days; ●, infested soil solarized for 60 days; □, noninfested, nonsolarized soil. [From Martyn and Hartz (1986). *Plant Dis.* 70, 762–766.]

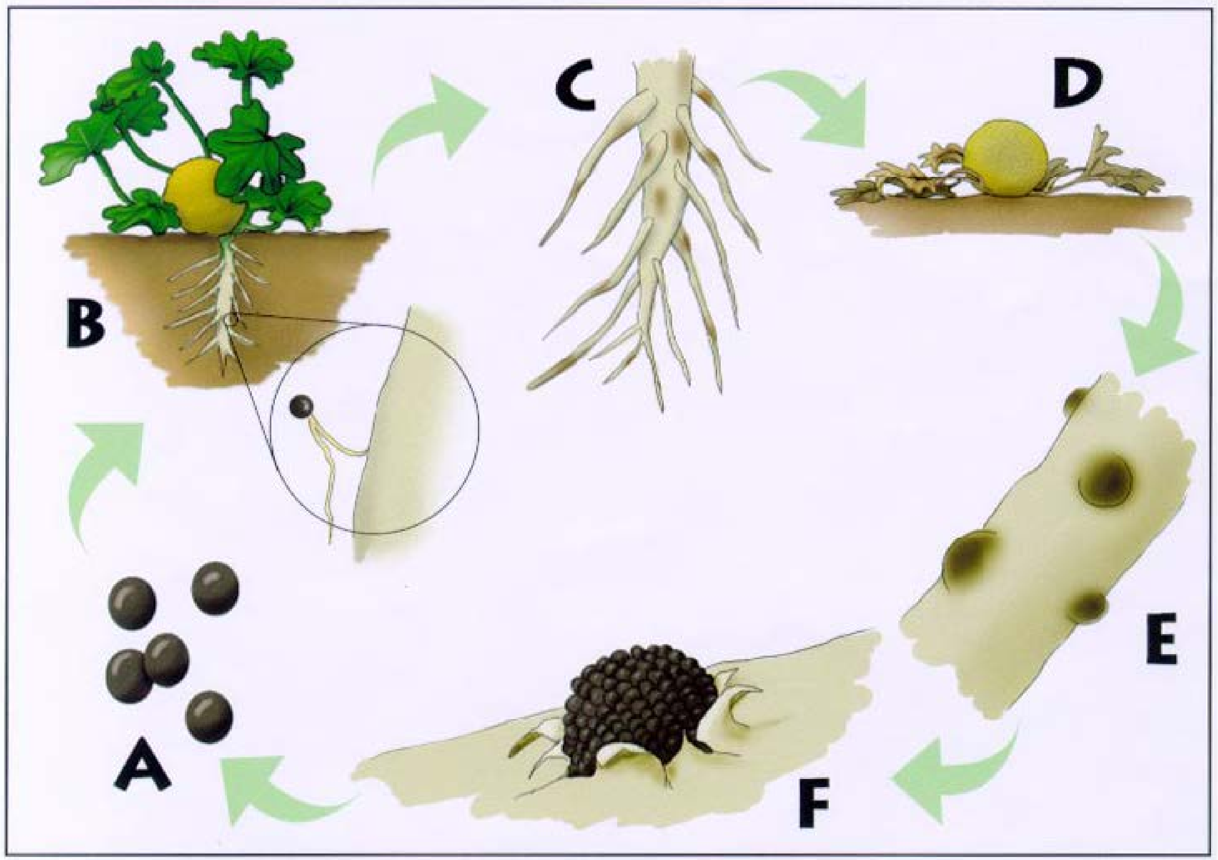


Fig. 3. Illustrated disease cycle of *Monosporascus cannonballus* in melons. (A) *M. cannonballus* ascospores without the ascus. (B) Germinating ascospore attached to melon root. (C) Lesions on melon root. (D) Wilting plant. (E) Swelling caused by perithecia formation in wilted plant root. (F) Ascospores released from perithecium. Based on references 22, 30, and 35.

Fig. 1. Late stage of wilt of melons caused by *Monosporascus cannonballus*.

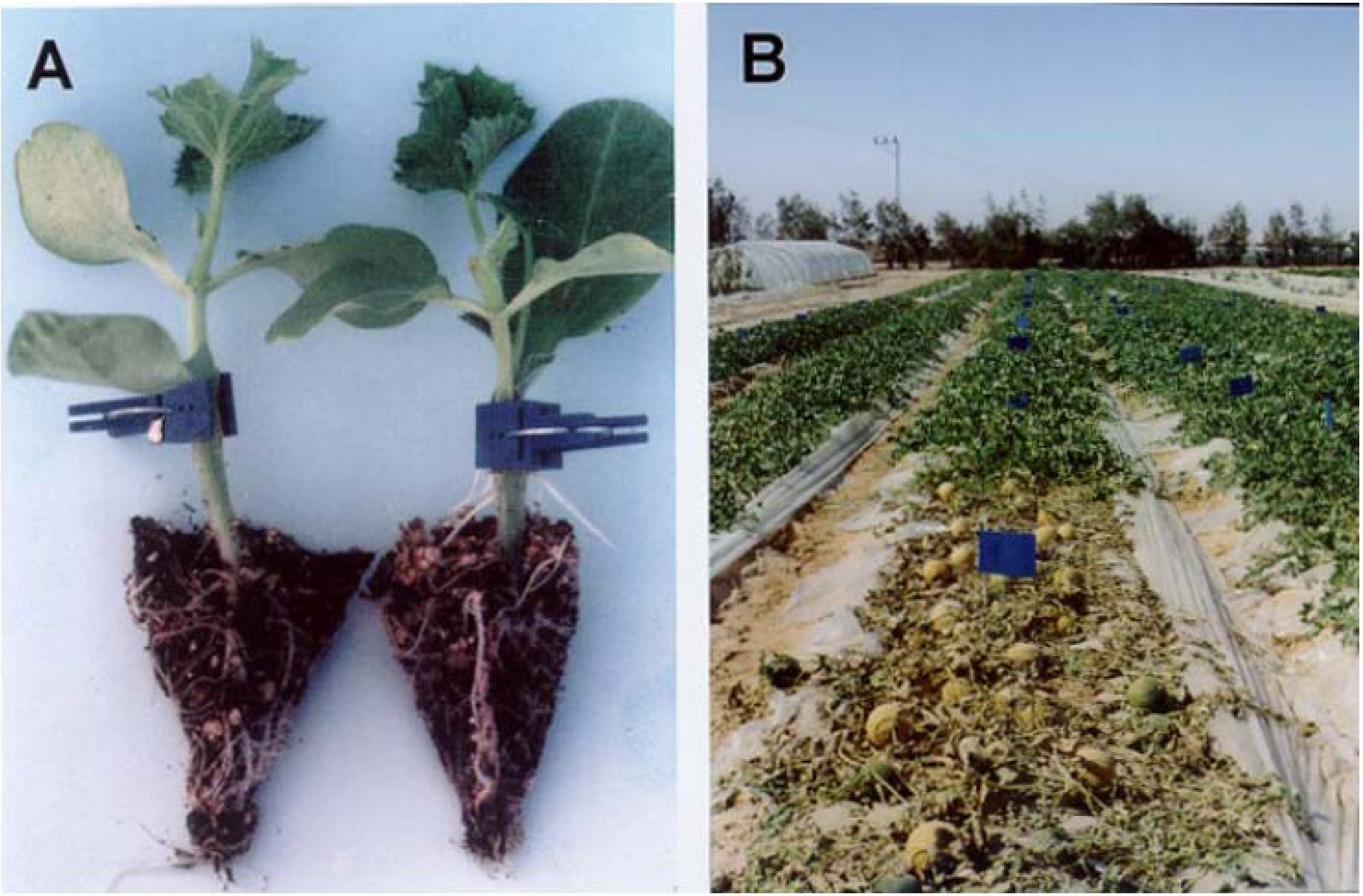


Fig. 5. (A) Melon scions grafted onto squash rootstocks. Left, good rootstock–scion compatibility, as exhibited by absence of adventitious root formation; right, poor rootstock–scion compatibility as exhibited by formation of adventitious roots. (B) Monosporascus wilt of nongrafted plants in the center foreground, compared with healthy melon plants grafted on various squash and melon rootstocks in the rest of the bed.

Table 3. Effects of methyl bromide (M.Br.) and grafting on Monosporascus wilt and melon yield, in an experiment conducted at 'En Tamar in autumn 1997[z] (6)

Treatment		Wilt incidence (%)	Yield (kg/m^2)	Marketable fruits ($no./m^2$)
Soil	Grafting			
Untreated	–	94	1.35	1.40
	+	12	2.23	1.79
M.Br. 15 g/m^2	–	8	2.66	2.47
	+	0	2.74	2.29
M.Br. 50 g/m^2	–	7	2.56	2.39
	+	0	2.63	2.44
LSD		10.3	0.76	0.18

[z] Melon (cv. 'Arava) transplants were grown in soil naturally infested with *Monosporascus cannonballus* at 'En Tamar.

Table 4. Effect of fumigants combined with soil solarization on incidence of Monosporascus wilt and yield of melons[w]

Fumigant[x]	Rate (g/m^2)	Solarization	Wilt incidence[y] (%)	Yield (kg/m^2)
Methyl bromide	50	–	3.3 c[z]	3.50 a
Methyl bromide	15	+	2.5 c	3.25 ab
1,3-dichloropropene (65%) + chloropicrin (35%)	40	+	16 c	2.85 b
1,3-dichloropropene (83%) + chloropicrin (17%)	40	+	70 b	2.75 b
Dazomet	45	+	4.5 c	2.95 b
Metham-sodium	30	+	6.8 c	3.56 a
Formalin	50	+	85.5 a	1.95 c
Nontreated	–	+	90.5 a	2.45 bc
Nontreated	–	–	94.5 a	2.02 c

[w] Experiment was conducted in autumn in a field naturally infested with the pathogen.

[x] Methyl bromide was applied using the hot gas method; 1,3-dichloropropene, metham-sodium, and formalin were applied via drip-irrigation system, Dazomet was spread on the soil and rototilled. Fumigants (except for methyl bromide) were tested only in combination with solarization, since they were not effective alone in previous experiments.

[y] Percentage of diseased plants was assessed at the end of harvest.

[z] Each treatment was performed five times in a randomized block design. Values in each column not followed by same letter are significantly different according to Fisher's protected least significant difference ($P = 0.05$).

FIGURE 9-31 Equipment for application of soil pesticides and fumigants. (A) Tractor applying a fumigant and laying plastic over it to keep the chemical from early escape. (B) Field beds treated with a volatile chemical and covered with plastic. (C) Multidisk tractor used to incorporate nonvolatile granular chemicals in soil. (D) Broadcast chisel application of low-volatility liquid fumigants into soil. [Photographs courtesy of (A) R. T. McMillan and (B–D) D. W. Dickson, University of Florida.]

Crop Rotation

- The most important cultural measure for disease control
- Breaks disease-cycle of pathogens
- Works best on pathogens with:
  - limited host range
  - low competitive saprophytic ability
  - no survival structures produced during the “non-host” phase
  - short period of viability of survival structures (1-2 years).

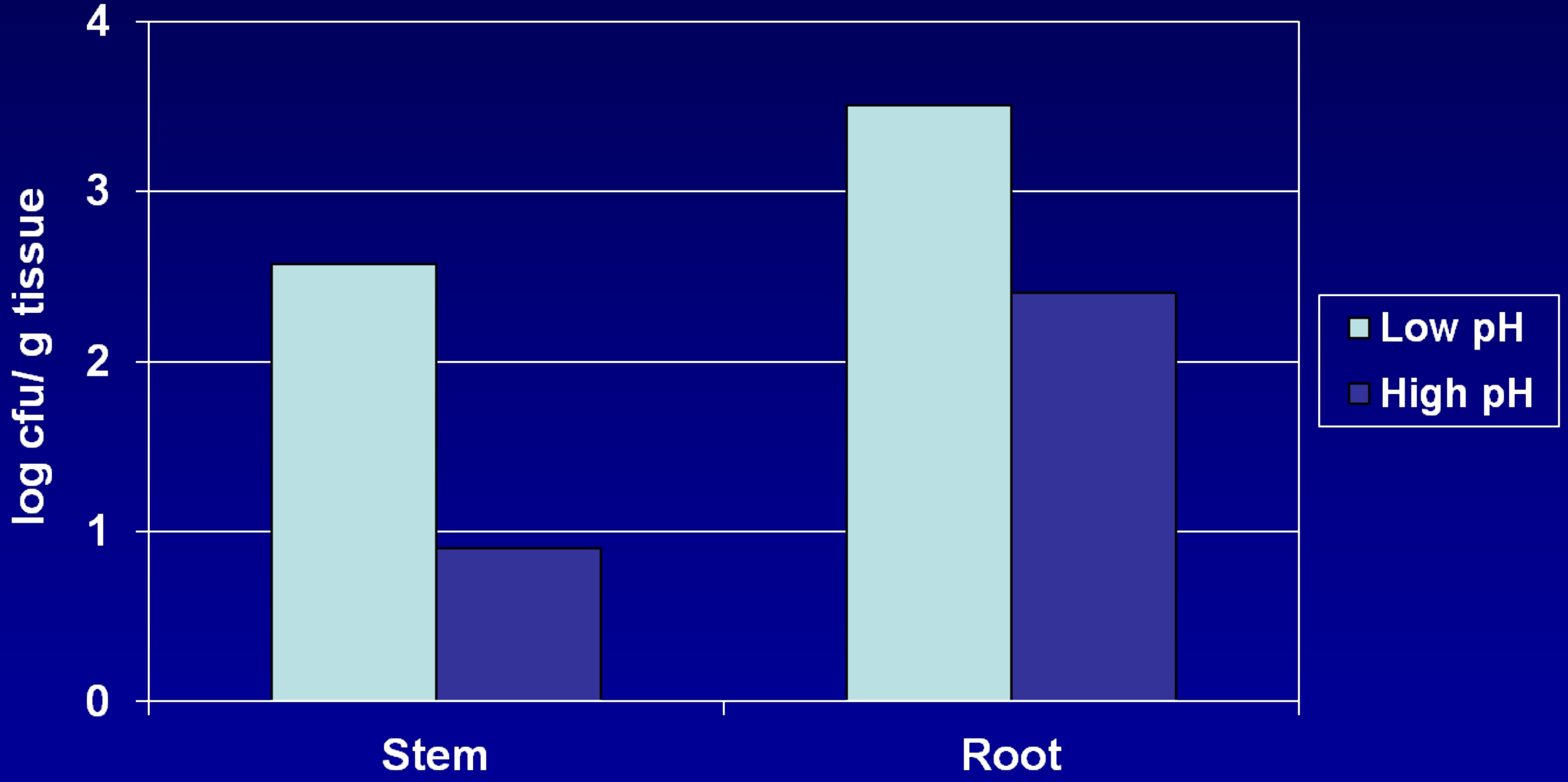
Management of Soil Environment

- Lime, nitrate - increase soil pH
- Sulphur, ammonium - decrease pH
- Sometimes act through direct toxicity
  - eg ammonia vs *Sclerotium, Fusarium, Phytophthora,* nematodes
- Ca in lime can increase Ca pectate formation in roots, which are then less susceptible to attack by *Rhizoctonia solani*

Manipulation of Environment to Modify Inoculum Potential

- Potato scab
- *Streptomyces scabies*
- Modify soil pH (<6.0) to reduce incidence of scabby potato tubers
- General concept that bacteria favor a “basic” environment and fungi an “acidic”” environment

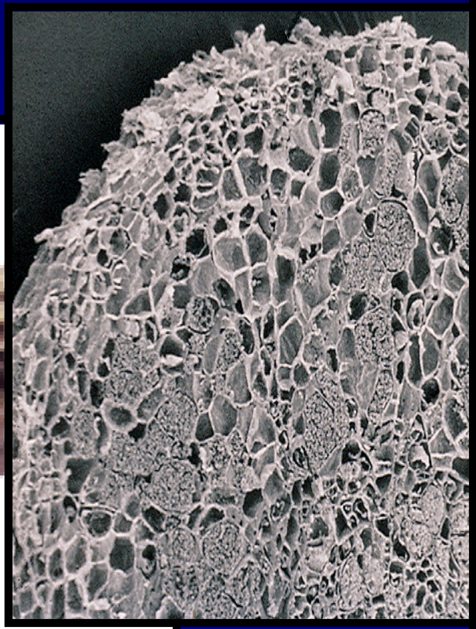
P. gregata detection decreases as soil pH increases in 2000

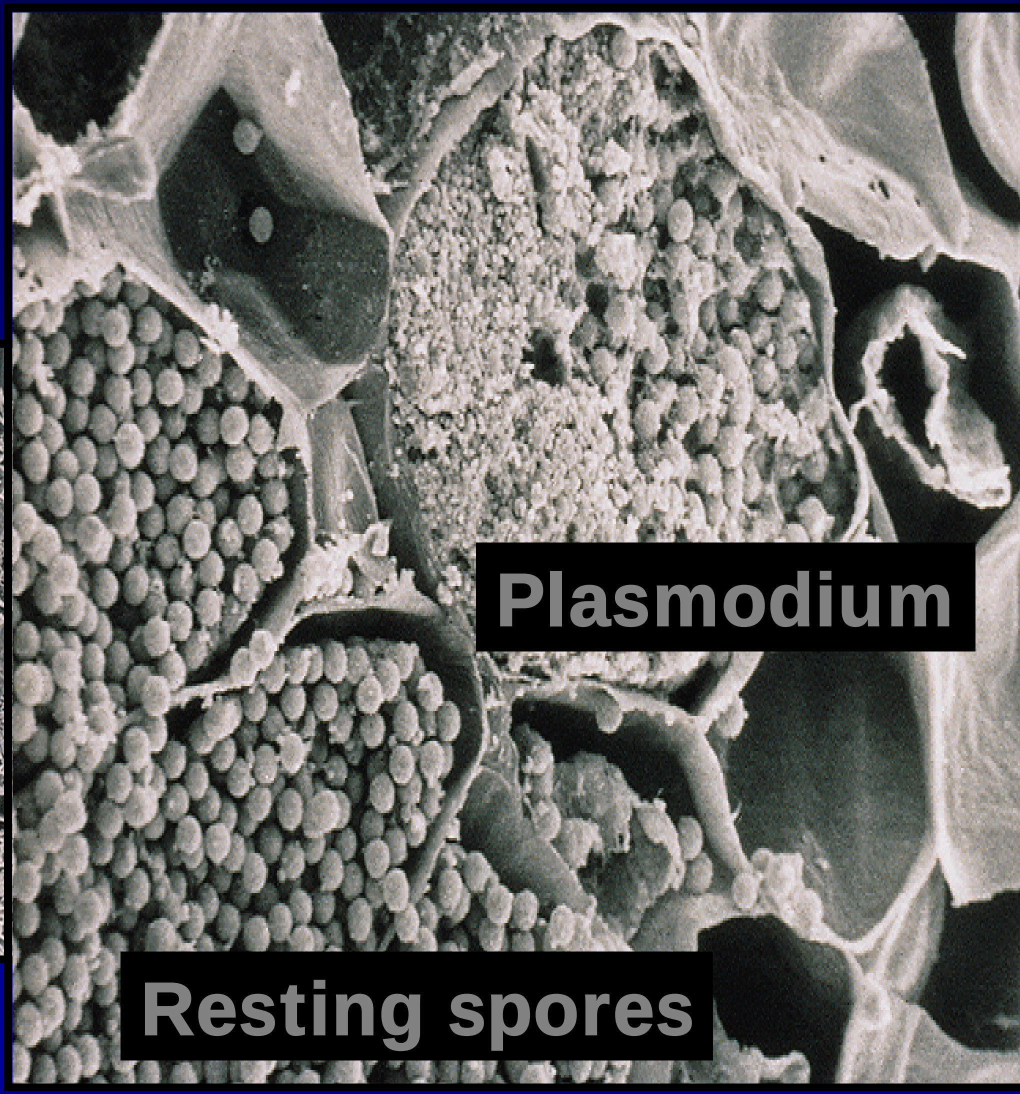


Clubroot of Crucifers

Clubroot of Crucifers
Plasmodiophora brassicae

Clubroot of Crucifers
Plasmodiophora brassicae





Organic Amendments

- Straw, Lucerne hay, chitinous by-products
- Green manure crops
- Change in nutritional status of soil for micro-organisms
- Complex actions
  - stimulation of antagonists
  - toxic action of breakdown products eg ammonia, saponins

Organic Amendments: Generally incorporated into soil

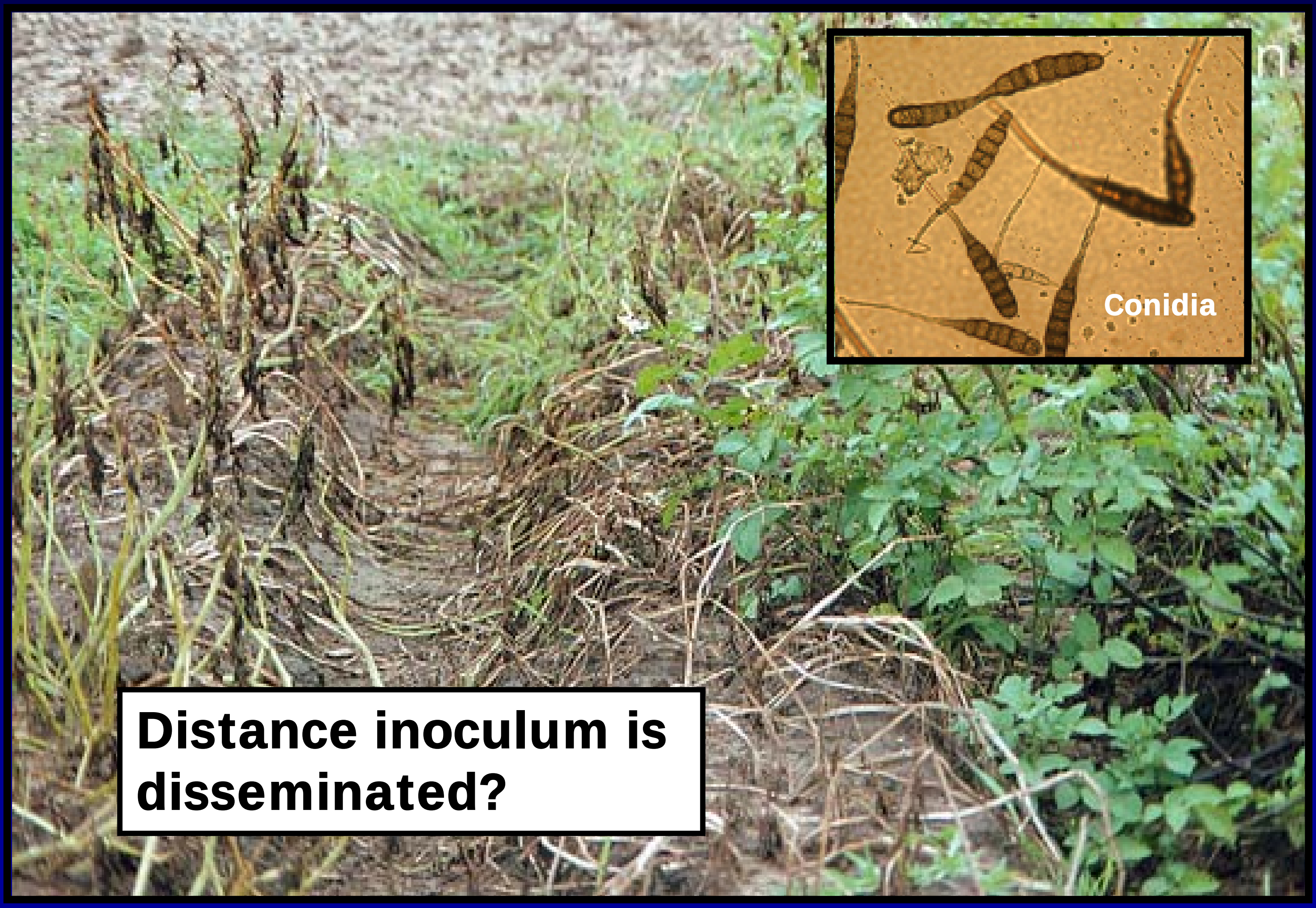
- ♦Green manure – Grow green manure crop and incorporate living plant material into soil immediately prior to planting.

- Sudan grass – dhurrin (cyanoglucoside) => Hydrogen cyanide
- Species within mustard family – glucosinolates => isothiocynates

Organic matter – many sources

- Soybean meal
- Meat and bone meal
- Sphagnum peat moss
- Black peat
- Compost-Amended Potting Mixes – Successful in control of root rot pathogens in container systems. (Hoitink et al. 1991. Plant Disease 75:869-873)

Early Blight of Potato
Pathogen survival in host residue



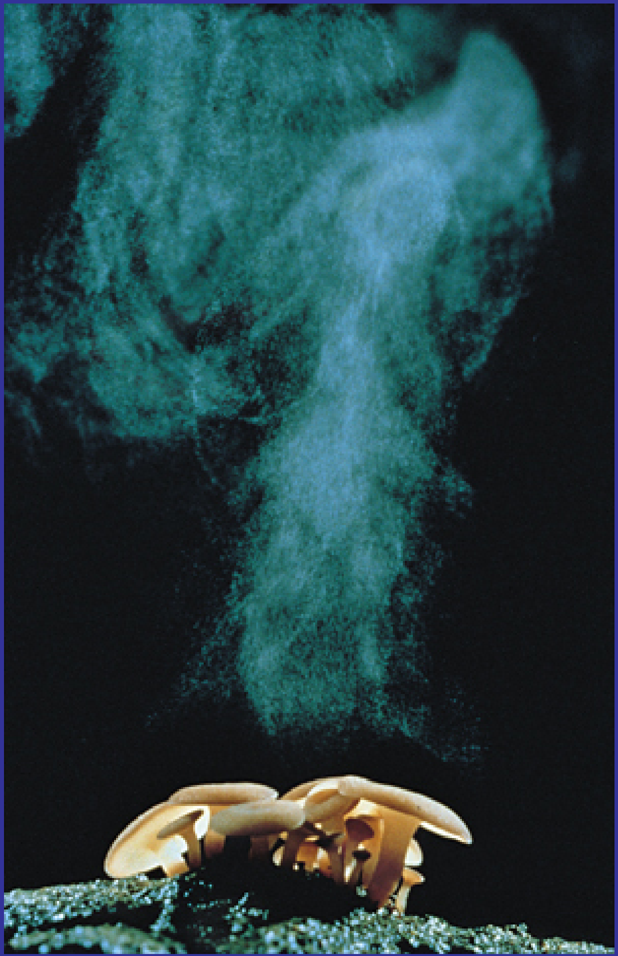
Asparagus plant debris left in the field

Manipulation of Environment to Modify Inoculum Potential

- Application of urea (nitrogen) to orchard litter to enhance microbial decomposition of apple leaves
- Goal to reduce survival of *Venturia inaequalis* in apple leaves
- Reduce primary inoculum

Ascospore discharge to the air *Sclerotinia sclerotiorum*

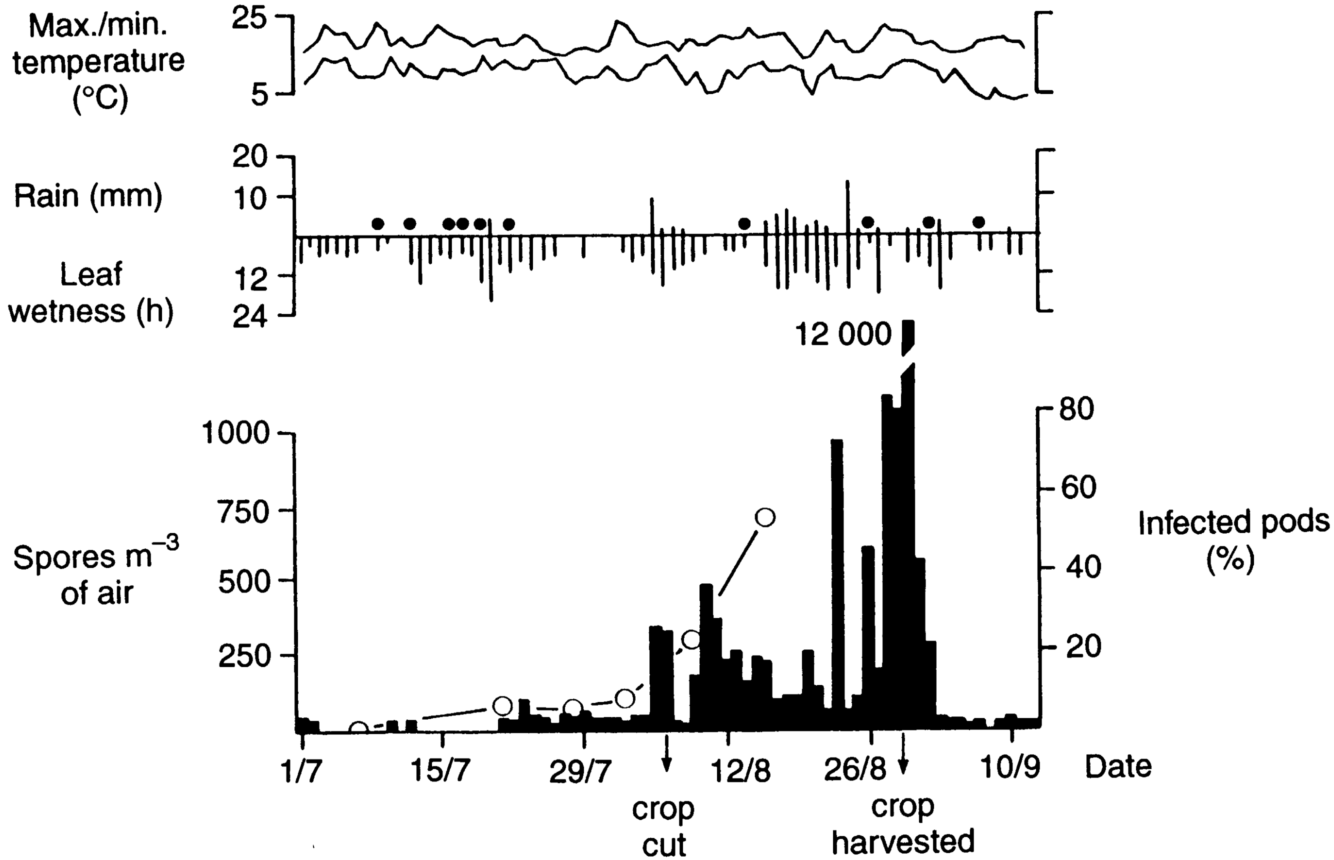
- **Rapid changes in pressure within asci**
- **Ascospores are ejected from ascus**
- **Wind currents carry ascospores to host**



Dense Crop Canopy on Orchard Floor – prevent ascospores from reaching apple buds

Management of Atmospheric Environment/Climate

- Effect of temperatures on disease
- Management of Microclimate -
  - Irrigation
  - Canopy Management
  - Avoid Water stress
- Avoid Heat stress
- Develop forecasting system



Effects of climatic factors and harvesting practices on the mean daily concentration of *Alternaria brassicicola* conidia in the air of a cabbage seed production crop. ●, > 0.2 mm to < 1 mm of rain; ○—○, infected pods.

Protected greenhouse

FUNGICIDES

- Sterilants and Fumigants
- Protectants
- Therapeutics (“systemics”, “eradicants”)

Protectants

- remain on plant surface
- have no effect on established infections
- vary in properties of persistence, redistribution
- broad spectrum
- relatively inexpensive

Therapeutants (systemic)

- compound or a metabolite penetrates host tissue
- may inhibit development of established infections
- often highly specific to certain fungal groups
- vary in “systemicity”, translocation, persistence
- often relatively expensive

Fungicide Application

- Seed treatment
- Soil treatment / “in-furrow”
- Foliar sprays

List of chemicals and commercial products registered

Kinds	Active ingredient
Fungicides	Benomyl,bitertanol, captan,carbendazim, carboxin, difenoconazole, Diniconazole, fenpiconil, iprodione, mancozeb, metalaxyl, metconazole, oxine-copper, pencycuron, quintozene, tebuconazole, thiabendazole, thiram, triadmenol, triazoxide
Bacteriocides	Bronopol, copper hydroxide, kasugamycin, oxolinic acid, streptomyces
Nematicides	Fenitrothion, fenthion, cartap, benomyl
Microorganisms	*Trichoderma, Bacillus subtilis, Pseudomonas cepacia, Rhizobium, Streptomyces griseoviridis*

Major benefits of seed treatment methods

Treatment	Major catagory	Major purpose or application	Horticultural crops
Physical	Irradiation	Sterilization seed-borne diseases	Some crops, if need
	Heat Treatment	Sterilization seed-borne diseases	Many vegetables
	Dry heat treatment	Sterilization seed-borne diseases including tobamovirus and others	Solanaceous & cucurbitaneous vegetables
Chemical	Pesticide treatment	Control of seed-borne diseases and insects in seeds and seedling	Selected vegetables
Biological	Useful microorganism	Trichoderma,Bacillus, Rhizobia, Pseudomonas, and others	Legume and most crops

Seed borne vegetable diseases that can be activatede by heat treatment dry heat treatment, hot water, or other heat-related treatment

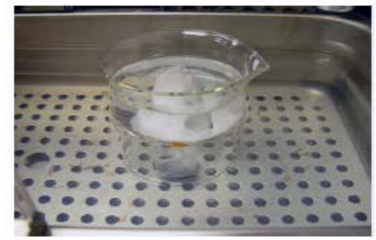
Crop	**Disease**	**Seed treatment**
Radish	*Alternaria brassicae*	**50 C HWT for 10-40 min after 6 hr cold water soaking; 75 C DHT for 72 hr.**
Brassica	**Black spot (*Alternaria*)**	**50 C HWT for 30 min after 6 hr cold water soaking; 75 C DHT for 72 hr**
	Rhizoctonia root rot	**50 C HWT for 30 min after 6 hr cold water soaking**
	Xanthomonas campestris	**50 C HWT for 15-25 min after 6 hr cold water soaking**
	Bacterial leaf spot	**50 C HWT for 30 min after 6 hr cold water soaking**
Tomato	**Stem canker**	**45-50 C HWT for 30 min**
	Bacterial canker	**50 C HWT for 1-2 min followed by 55 C for 25 min and washing**
	Tobacco Mosaic Virus	**70 C DHT for 48 hr.**
Cucurbits	**Anthracnose**	**50 C HWT for 15 min.**
	Cucumber Green Mottle Mosaic Virus	**70 C DHT for 48 hr or a long term storage**
	Fusarium root rot	**55 C HWT for 15 min.**
	Scab (*Cladosporium* sp.)	**70 C DHT for 48 hr.**

Hot Water and Chlorine Treatment of Vegetable Seeds to Eradicate Bacterial Plant Pathogens

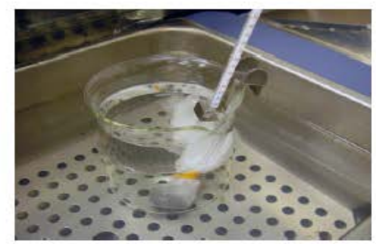
B. How to Hot Water Treat Seed.

Step 1: Wrap seeds loosely in a woven cotton bag (such as cheesecloth) or nylon bag.

Step 2: Pre-warm seed for 10 minutes in 100°F (37°C) water.



Step 3: Place pre-warmed seed in a water bath that will constantly hold the water at the recommended temperature (see table that follows). **Length of treatment and temperature of water must be exactly as prescribed.**



Step 4: After treatment, place bags in cold tap water for 5 minutes to stop heating action.

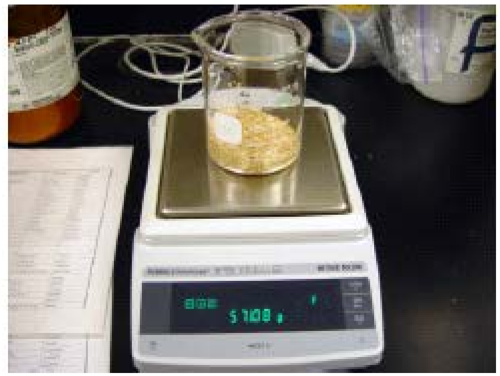
Step 5: Spread seed in a single, uniform layer on screen to dry. Do not dry seed in area where fungicides, pesticides, or other chemicals are located.

Step 6: Dust seed with Thiram 75WP (1 tsp/1 lb seed) once the seed is completely dry.

Seed	Water temperature		Minutes
	°F	°C	
Brussels sprouts, eggplant, spinach, cabbage, tomato	122	50	25
Broccoli, cauliflower, carrot, collard, kale, kohlrabi, rutabaga, turnip	122	50	20
Mustard, cress, radish	122	50	15
Pepper	125	51	30
Lettuce, celery, celeriac	118	47	30

B. How to Chlorine Treat Seed.

Step 1: Agitate seed in a solution of 25 oz Clorox plus 100 oz water with one teaspoon surfactant for 1 minute. Use 1 gallon of disinfectant solution per pound of seed (conversions provided below) and prepare a fresh solution for each batch.



Step 2: Rinse seed thoroughly in cold running tap water for 5 minutes.

Step 3: Spread seed in a single, uniform layer on screen to dry. Do not dry seed in area where fungicides, pesticides, or other chemicals are located.

Step 4: Dust seed with Thiram 75WP (1 tsp/1 lb seed) once the seed is completely dry.

TIMING of Control Measures

GOVERNED BY:-

- STAGE OF CROP GROWTH
  - *bud -swell, flowering, ripening*
- SPEED OF CROP GROWTH
  - *emergence of leaves, flowers etc after spraying*
- WEATHER CONDITIONS
  - *rainfall and temperatures following disease*

BIOLOGICAL CONTROL

- Biological Control = applied ecology
  - management of a microbial community to favour the biocontrol agent and disfavour the pathogen
- Biocontrol of soil-borne pathogens
- Biocontrol of foliar pathogens.

Classical Biological control

- "Classical biological control" of insect pests or diseases is the one-time introduction of exotic natural enemies into a region for long-term suppression and regulation of populations of naturalized pests
- Biocontrol agent usually found near centre of origin of pest/disease

Biological Control

- Inundative - “swamping” the system with large numbers of propagules of biocontrol agent
- Augmentative - Repeated introduction of biocontrol agent at critical times

Apply Trichoderma in the field


Clase Insecta
TRAMPAS ADHESIVAS
TECIA-TRAP
NEOELEGAN
COSMO-TRAP
Biofertilizantes Microbianos
Ley de Salud Agrícola Integral
LA FIJACIÓN BIOLÓGICA
DEL NITRÓGENO ATMOSFÉRICO
EN CONDICIONES TROPICALES
Tricho nia
PRODUCTO BIOLÓGICO
USO AGRICOLA
Ligeramente Tóxico


A
+ T
-T
B
-T
+ T
C
-T
D
+ T

Table 1. Production and delivery of biocontrol systems in commercial agriculture

System	Steps required	Approximate costs/step	Time to significant market penetration
Full-scale registration and production—the chemical pesticide model	1. Identification of good agent 2. Development of production and formulation system 3. Patenting of strain and/or process 4. Toxicology and other testing 5. Registration 6. Building large-scale production system 7. Nationwide or international marketing	1,2. $100,000 3. Up to $200,000 for international coverage, at least $30,000 for one country 4. At least $500,000 5. $100,000 6. Up to $3-4 million 7. $2-3 million Total: up to $8 million	3 to 6 years
Biofertilizer, inoculant, or plant strengthening agent	1. Discovery of a good agent 2. Development of production and formulation system 3. Patenting of strain and/or process 4. Building large-scale production system 5. Nationwide or international marketing	1,2. $100,000 3. Up to $200,000 for international coverage, at least $30,000 for one country 4. Up to $1 million 5. $0.5 million Total: $1.8 million	1 to 2 years
Local production	Discovery of a good strain	$100,000 Total: $100,000 or less	Less than 1 year
Government sponsored or produced agents	Depends upon governmental direction and philosophy	Unknown	Unknown

Recommendation for controlling of Phytophthora blight in USA

1. Select fields with no history of Phytophthora blight.
2. Select fields that did not have cucurbit, eggplant, pepper, or tomato for at least 3 years. No rotation period has been established for effective management of Phytophthora blight of cucurbits.
3. Select fields that are well isolated from fields infested with *P. capsici*.
4. Select well-drained fields, or do not plant the crop in the areas of the field which do not drain well.
5. Clean farm equipment of soil between fields.
6. Plant non-vining crops (i.e., summer squash) on dome-shaped raised beds (approximately 25 cm high).
7. Plant resistant varieties, if available.
8. Avoid excessive irrigation.

9. Do not irrigate from a pond that contains water drained from an infested field.
10. Do not work in wet fields.
11. Scout the field for the Phytophthora symptoms, especially after major rainfall, and particularly in low areas.
12. When symptoms are localized in a small area of the field, disk the area.
13. Discard infected fruit, but not in the field.
14. Do not save seed from a field where Phytophthora blight occurred.
15. Remove healthy fruit from the infested area as soon as possible and check them routinely.

Postharvest handling

– Harvesting
– Transportation
– Precooling and Packing
– Hygiene
– Storage