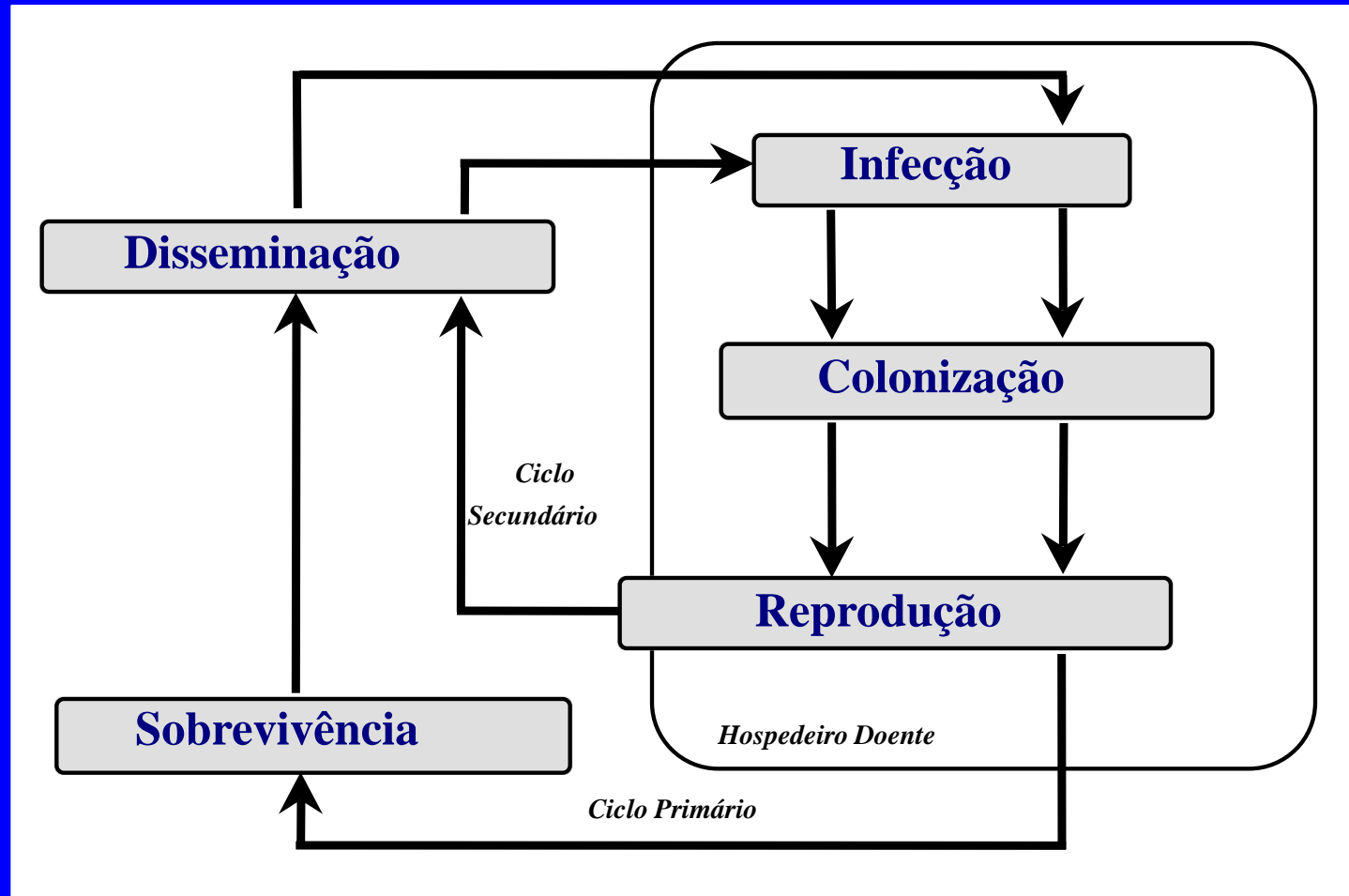
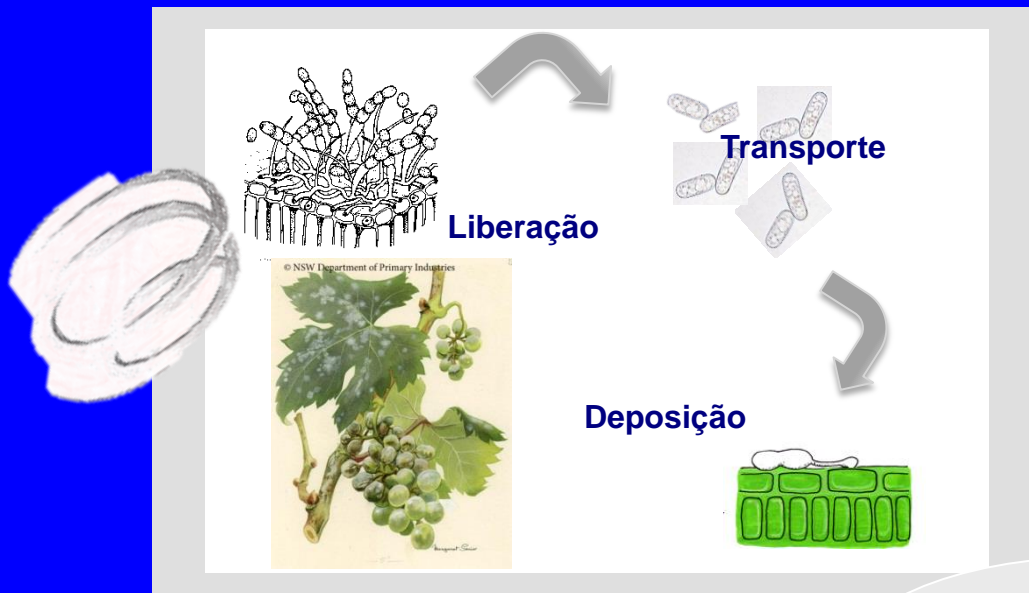


# Ciclo das relações patógeno-hospedeiro



# Disseminação



• **Liberação** → ativa/passiva

spore release  
take off  
removal

• **Dispersão** → ativa/passiva  
(ar/água/homem/insetos)

dispersal  
transport  
motion

• **Deposição** → sedimentação  
impacto  
turbulência

landing  
deposition

unidade de dispersão  
alterações bioquímicas e morfológicas  
↓  
unidade de infecção

# Liberação - remoção da fonte

até 10 km

Camada convectiva

até 1 km

Camada de transição

até 150 m

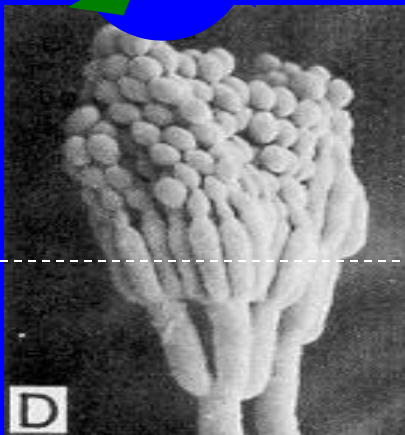
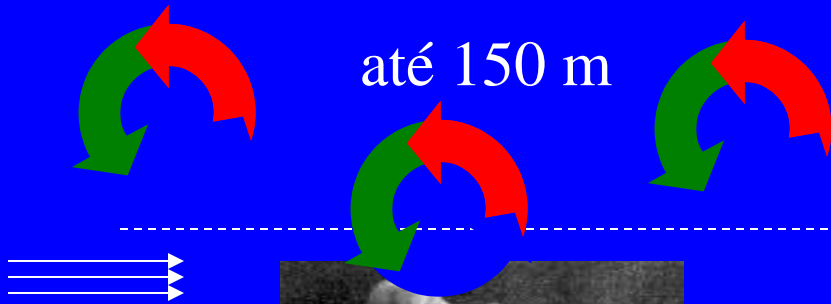
Camada de turbulência

Camada laminar  
milímetros

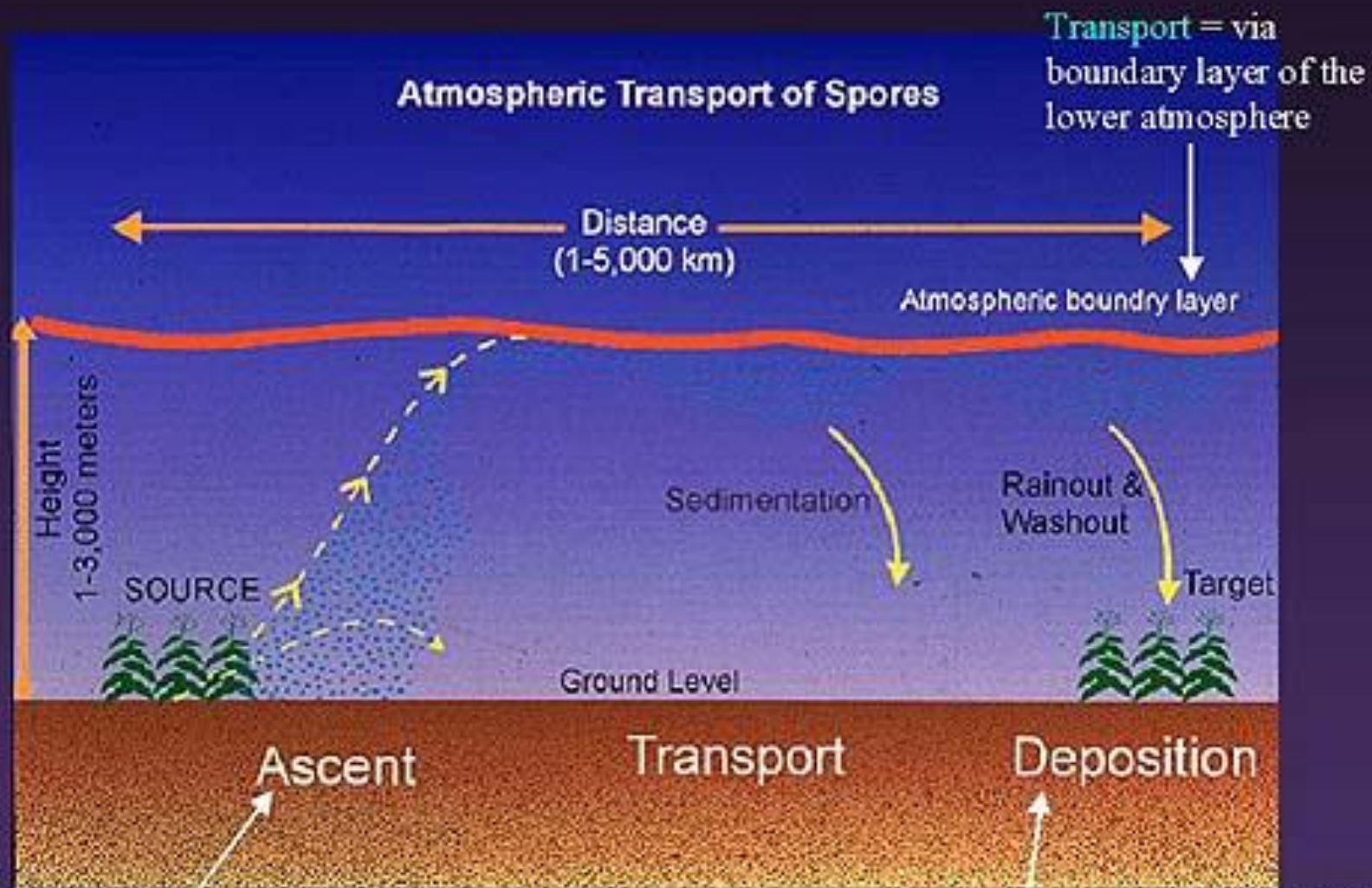
Camada estacionária  
micrômetros

Estratosfera

Troposfera



## Atmospheric Transport of Spores

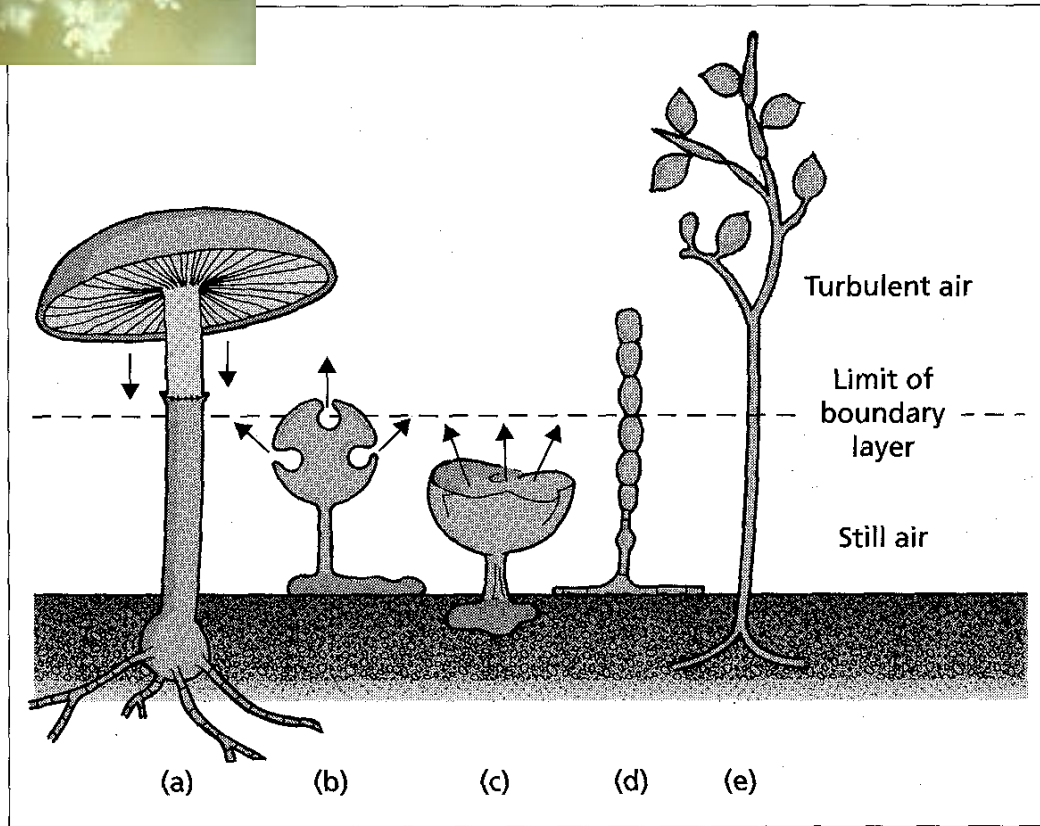
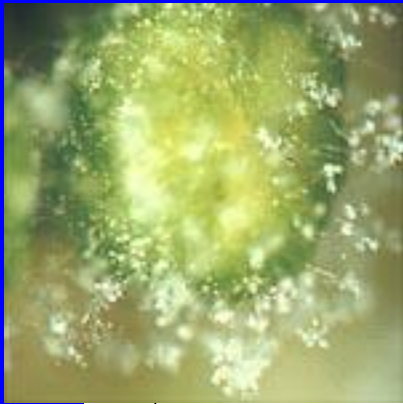


**Source** = infected field, plant bed or greenhouse

**Deposition** - via rain showers (rainout or washout)



# Liberação - remoção da fonte



a - *Armillaria*  
gravidade

b - *Claviceps*

c - *Sclerotinia*  
ejeção

d - *Oidium*

e - *Plasmopara*  
liberação pelo  
vento ou chuva  
cadeia de conídios e  
esporangióforo longos

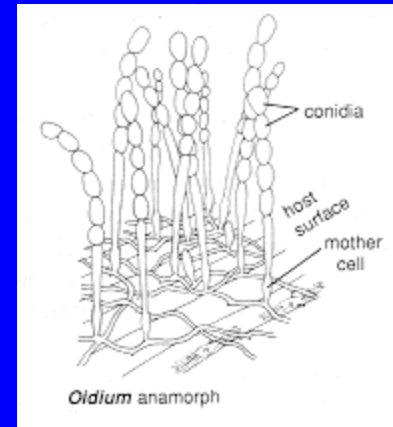
# Liberação Passiva

energia externa



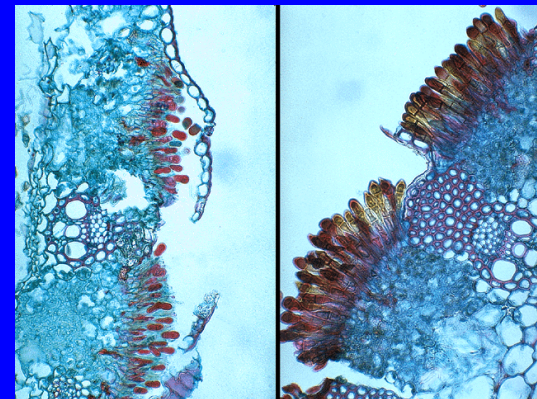
(Inglod, 1971)

## Oídios - *Oidium*



## Ferrugens

*Puccinia*, *Uromyces*, etc.



## Mildios

*Plasmopara*, *Peronospora*, etc.

# Liberação passiva por impacto



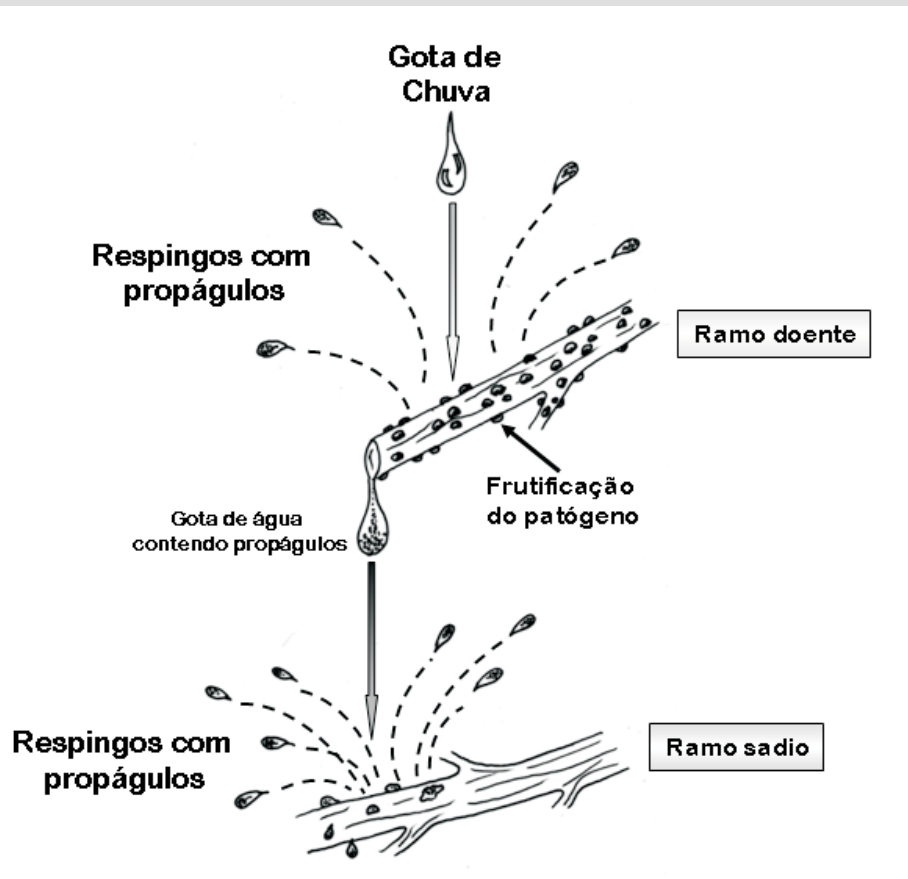
11. Teliospore cloud of *Tilletia controversa* released during harvest of plants affected by dwarf bunt. (Courtesy J. A. Hoffmann)



**carvão da cana-de-açúcar**

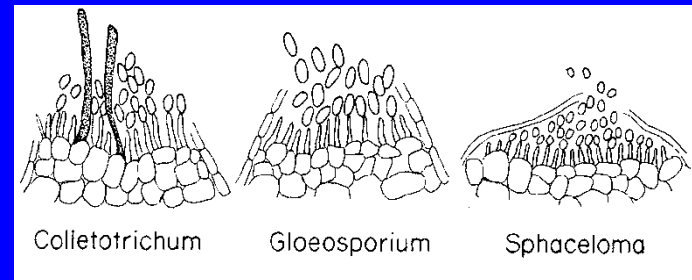
# Liberação passiva

Energia externa

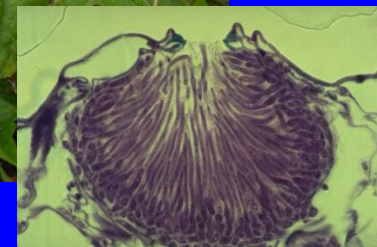


(Inglod, 1971)

## Antracnose *Colletotrichum* *Sphaceloma*



## Manchas - *Septoria*



## Manchas bacterianas *Xanthomonas*



# Liberação passiva

## Effects of Surface Topography and Rain Intensity on Splash Dispersal of *Colletotrichum acutatum*

X. Yang, L. V. Madden, L. L. Wilson, and M. A. Ellis

Postdoctoral research associate, associate professor, research assistant, and professor, respectively, Department of Plant Pathology, The Ohio State University and Ohio Agricultural Research and Development Center, Wooster, Ohio 44691. Research support and salaries provided by state and federal funds (especially USDA Competitive Grant 87-CRCR-1-2307) appropriated to Ohio Agricultural Research and Development Center, The Ohio State University. Journal Article 105-90. Use of trade names implies neither endorsement of products by the authors, nor criticism of similar ones not mentioned. Accepted for publication 31 May 1990 (submitted for electronic processing).

### ABSTRACT

Yang, X., Madden, L. V., Wilson, L. L., and Ellis, M. A. 1990. Effects of surface topography and rain intensity on splash dispersal of *Colletotrichum acutatum*. *Phytopathology* 80:1115-1120.

Effects of ground cover, plant canopy density, and rain intensity on the splash dispersal of *Colletotrichum acutatum* were studied using a rain simulator. In one experiment, three ground covers (soil, straw, and plastic) and two rain intensities (15 and 30 mm/hr) were evaluated by collecting splash droplets with conidia in sheltered gravity samplers consisting of petri plates with a selective medium for *C. acutatum*. Ground covers were characterized by random roughness, the standard deviation of surface elevation. Infected fruits with sporulating lesions were clustered on the ground to serve as the inoculum source. Sampling plates were positioned 20, 40, 60, 80, 100, and 120 cm from the source and were exposed to rain for 1-min periods (every 5 min) for a total duration of 46 min. Ground cover had a major effect on splash dispersal, as measured by colonies growing in selective medium. The estimated total number of colonies over time and space ( $N$ ) was inversely proportional to roughness; i.e., straw had the largest random roughness but the lowest  $N$ , and

plastic the opposite. Differences in  $N$  among ground covers were due to differences in steepness of the dispersal gradients (i.e., straw had the steepest gradient and plastic the shallowest), not to the release rate of spores at the source. Total number of colonies increased with rain intensity, but the effect was due to the release rate, as measured by the intercept parameter of a gradient model. Rain intensity did not influence gradient steepness. The effect of plant canopy density on splash dispersal of *C. acutatum* was evaluated in a second experiment using a soil ground cover. Leaf area index (LAI) was inversely related to  $N$ . Cross-row dispersal of spores was reduced by 90% or more for two rows of plants with LAI  $\geq 2.7$  compared to no plant rows. Results support the hypothesis that surface topography (including ground cover and plant canopy) is a major factor controlling splash dispersal due to its effect on splash droplet trajectories and loss of inoculum.

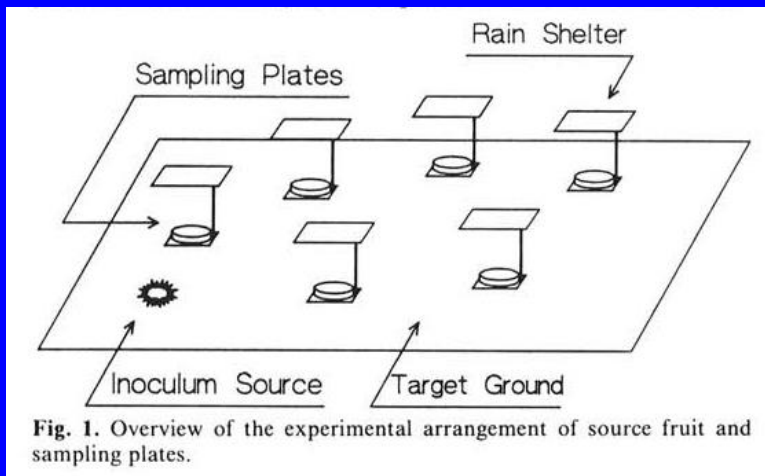


Fig. 1. Overview of the experimental arrangement of source fruit and sampling plates.

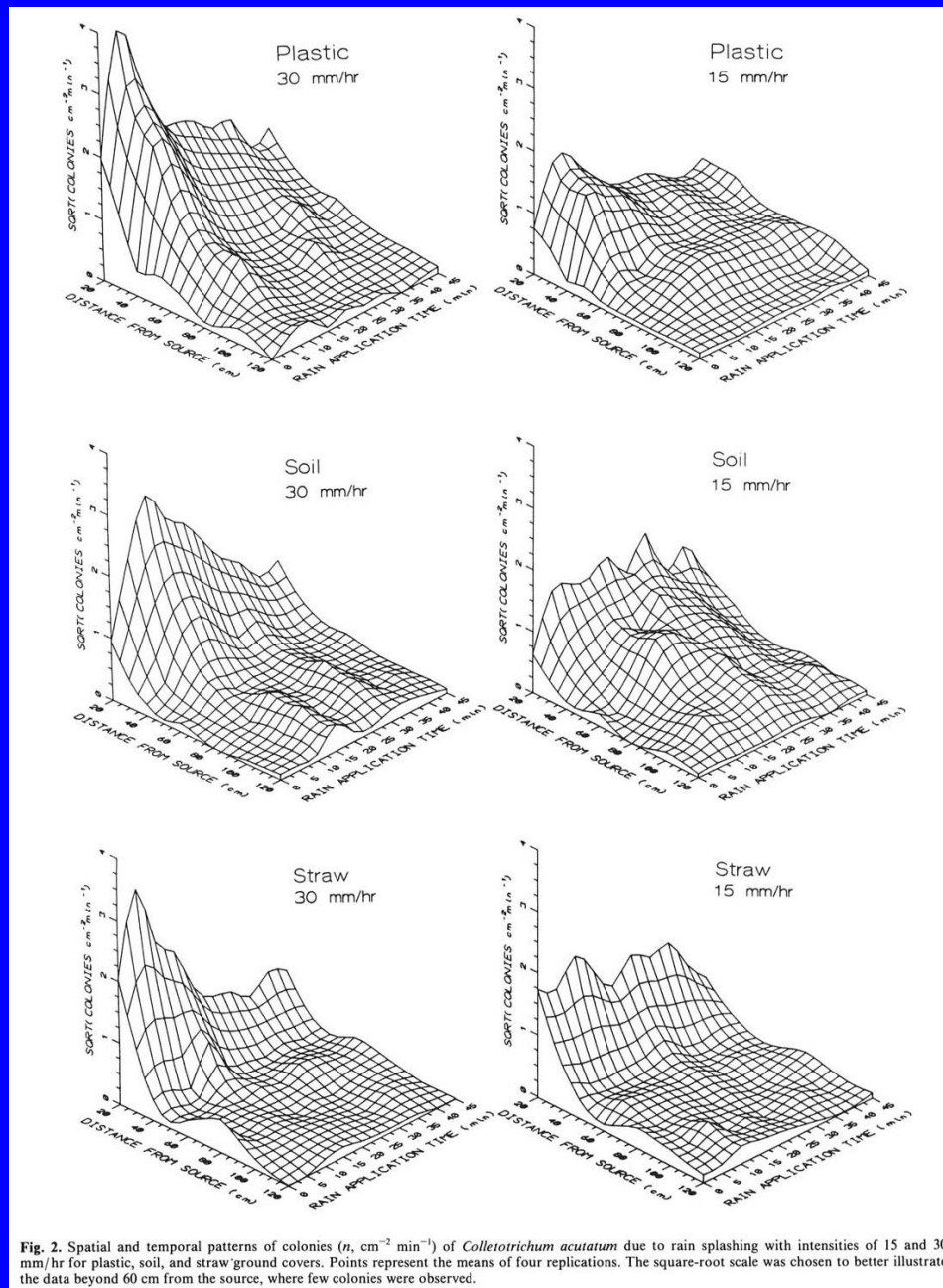
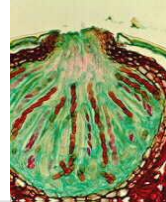


Fig. 2. Spatial and temporal patterns of colonies ( $n$ ,  $\text{cm}^{-2} \text{min}^{-1}$ ) of *Colletotrichum acutatum* due to rain splashing with intensities of 15 and 30 mm/hr for plastic, soil, and straw ground covers. Points represent the means of four replications. The square-root scale was chosen to better illustrate the data beyond 60 cm from the source, where few colonies were observed.

# Liberação ativa Energia do patógeno

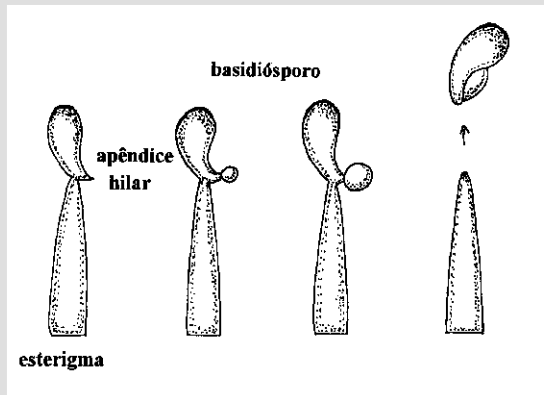
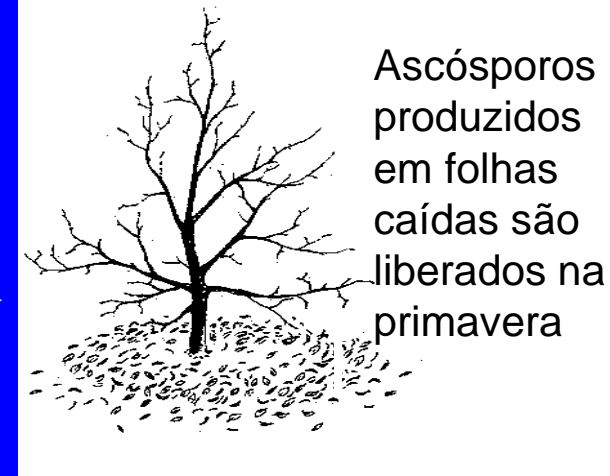
ascósporos  
maduros



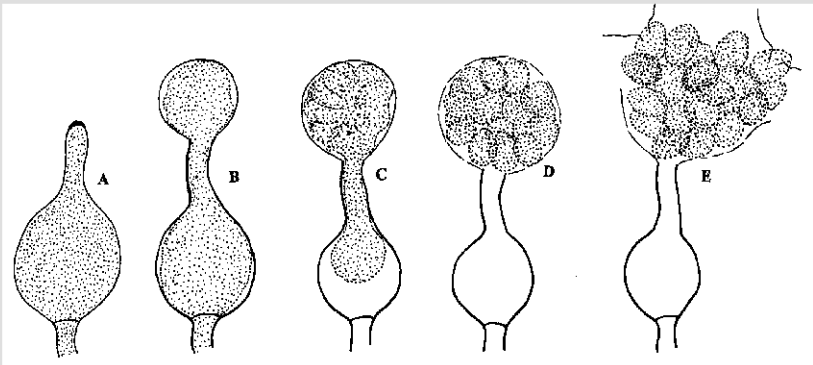
liberados



## Ascomicetos



Uredinales



Pythium sp.

# liberação ativa

## Ejeção de ascósporos



## *Monilia* em "blueberry"

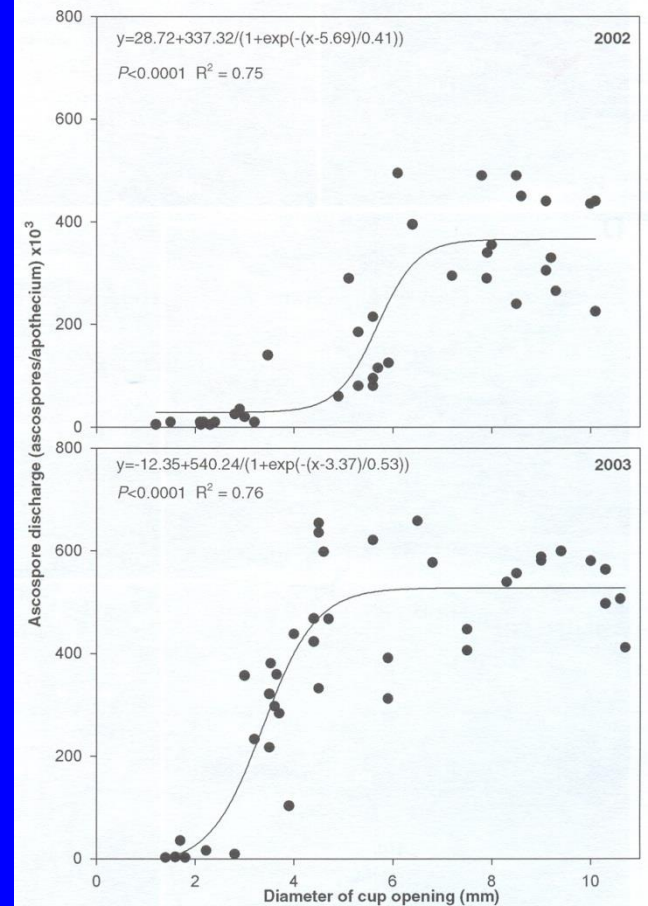


Fig. 2. Relationship between apothecium cup size and total number of ascospores discharged per day by apothecia of *Monilia vaccinii-corymbosi* in experiments carried out in 2002 and 2003.

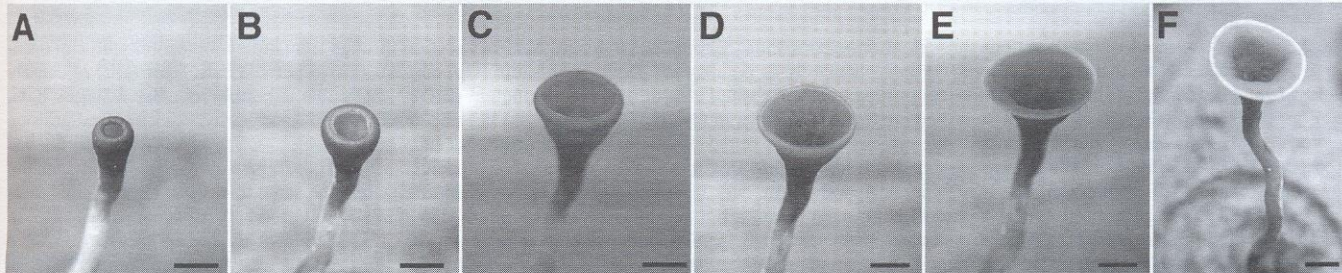
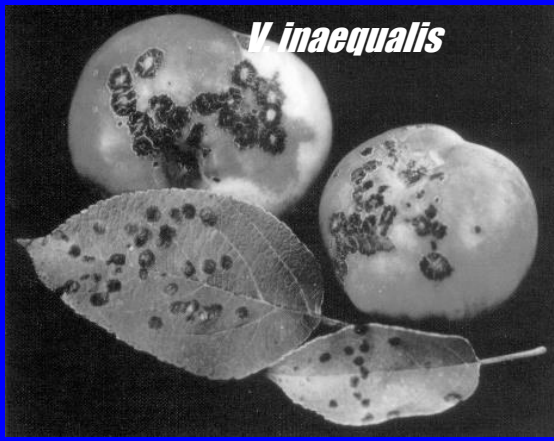
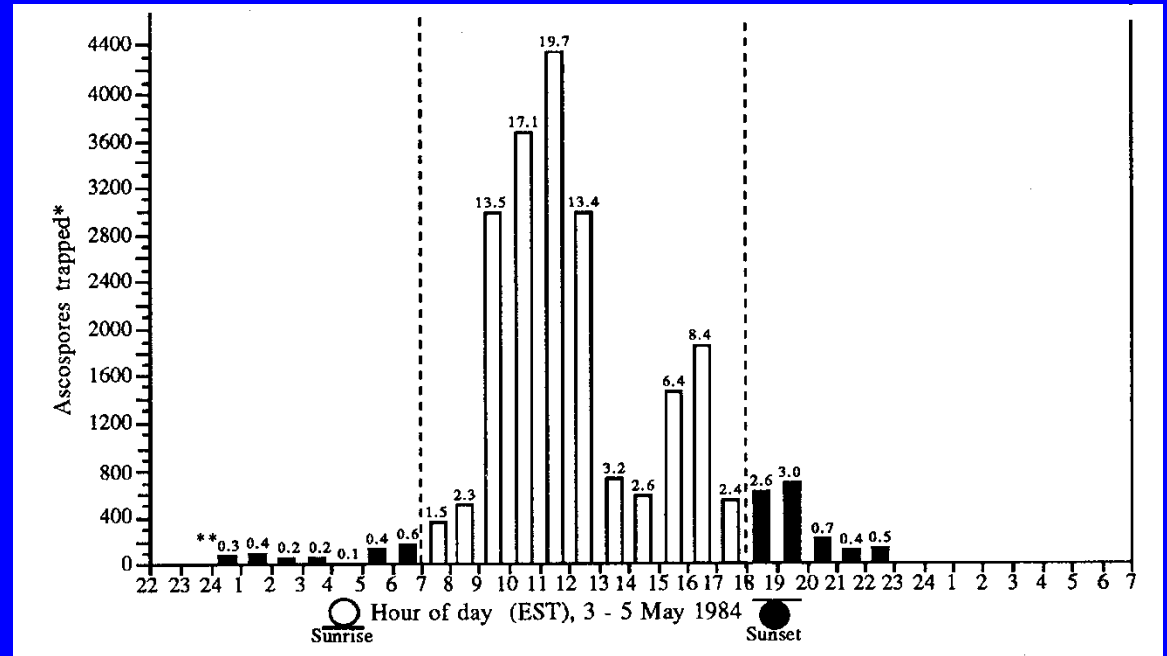
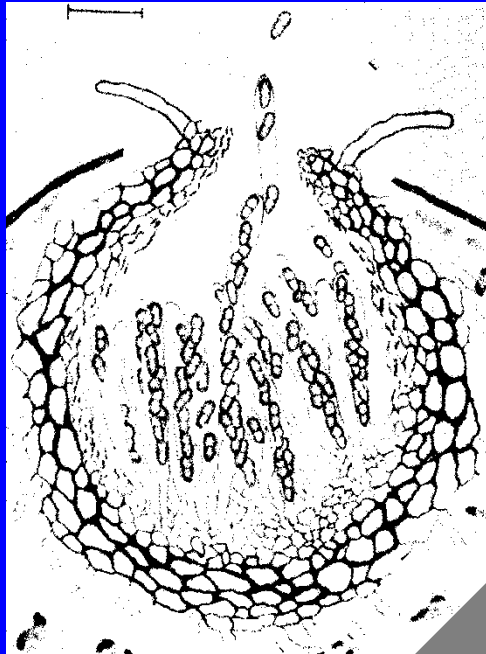


Fig. 1. Micrographs showing the development of an apothecium of *Monilia vaccinii-corymbosi* over a period of 6 days (A to F = day 1 to day 6). Bars = 5 mm.



# liberação ativa

## Ejeção de ascósporos

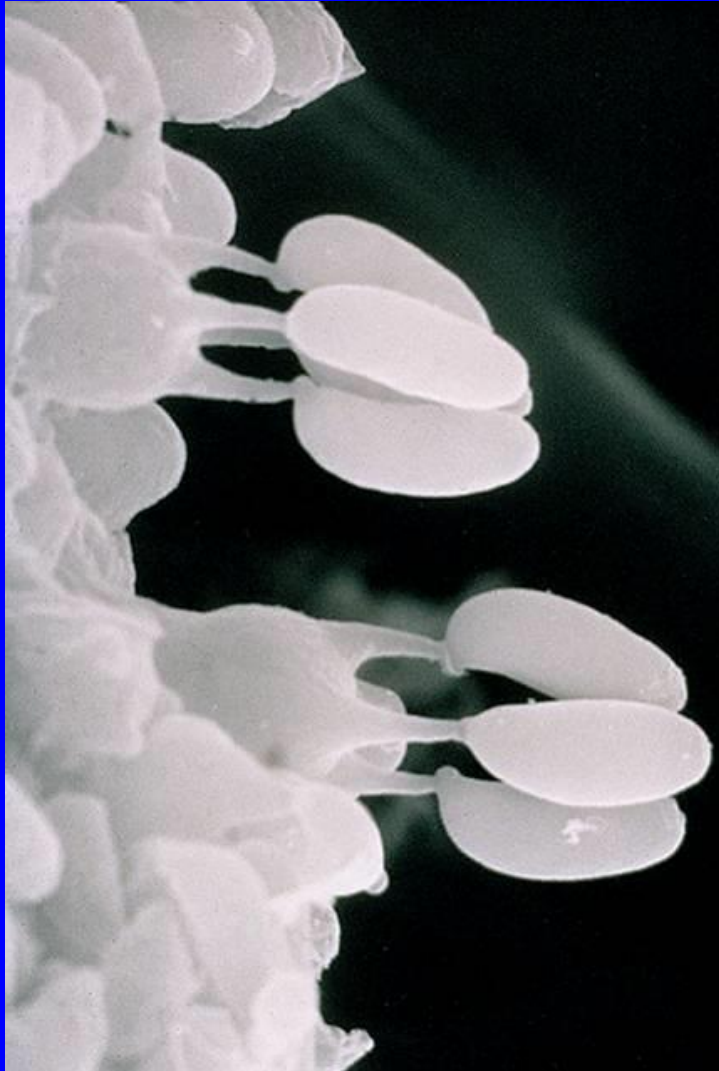


Liberação diária de *Venturia inaequalis*

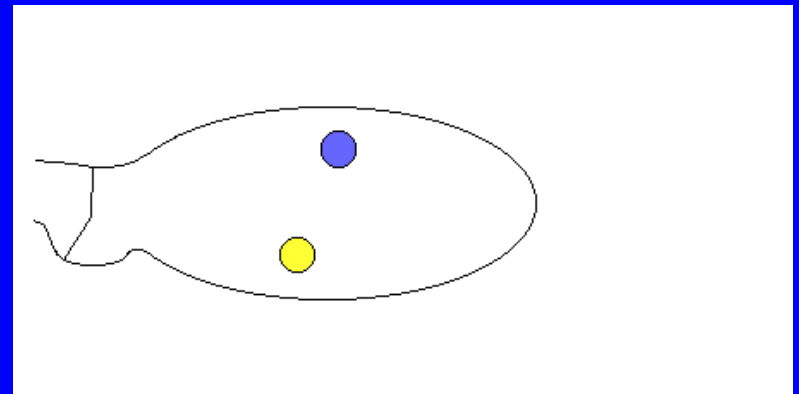
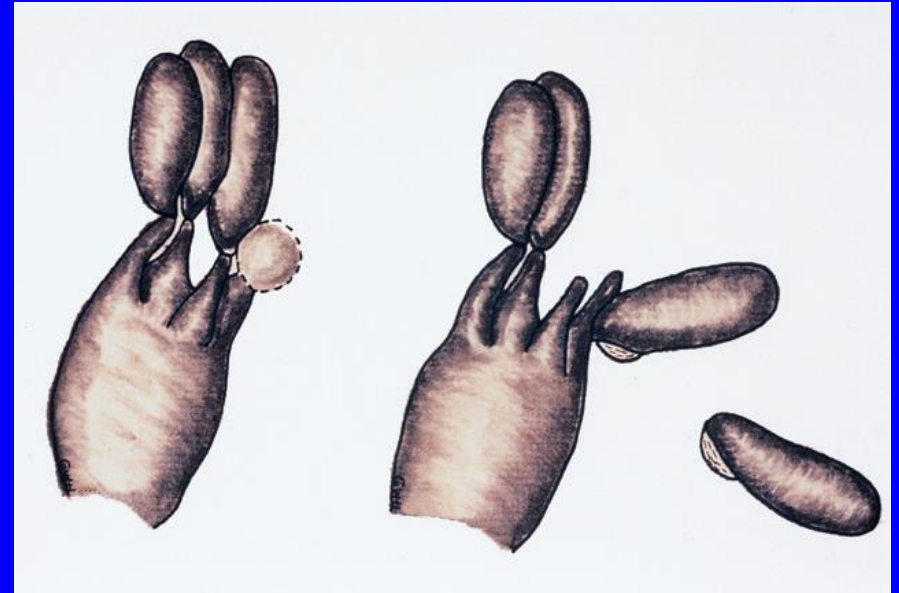
## Ciclo circadiano

Ciclo próprio de cada espécie, presente a partir de determinada fase evolutiva, observado sob condições ambientais constantes, manifestado por variações periódicas de acordo com o momento do dia

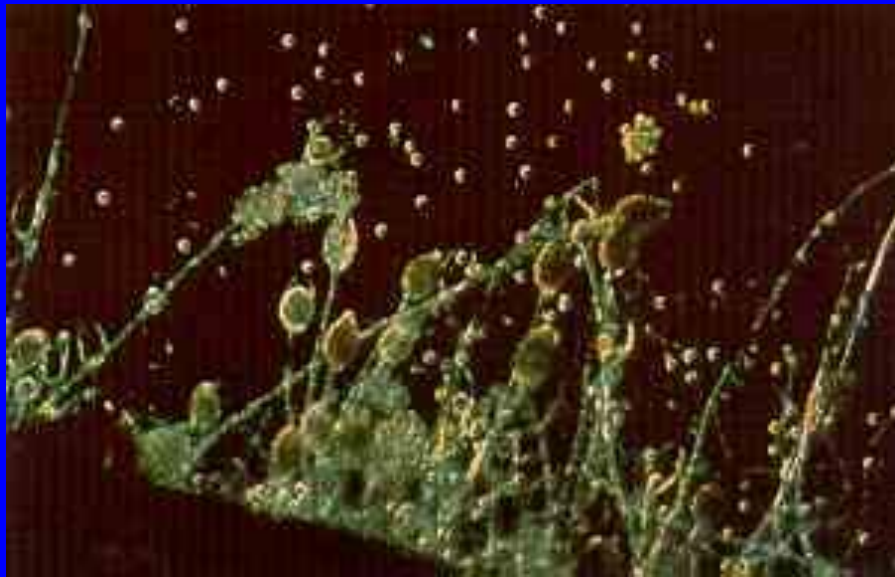
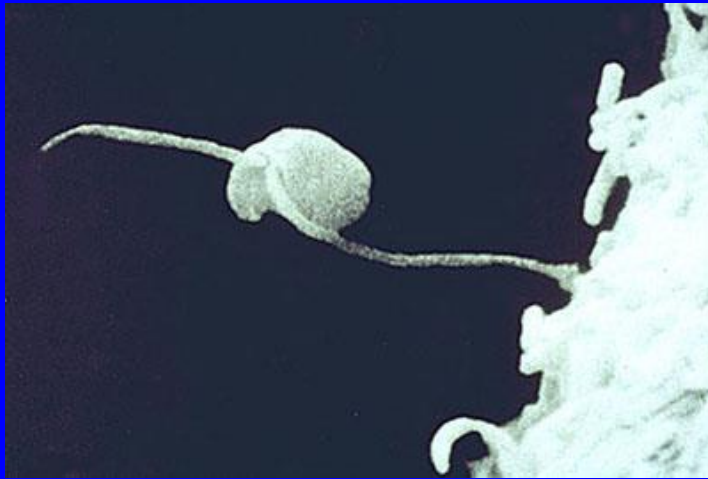
# liberação ativa



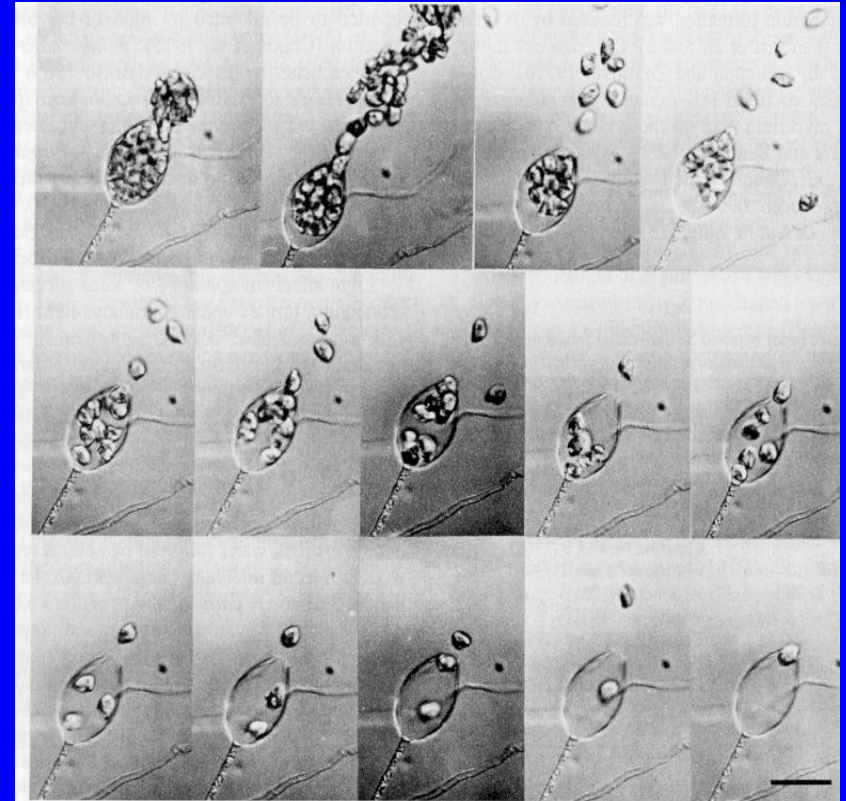
# Liberação de balistósporo



# liberação ativa

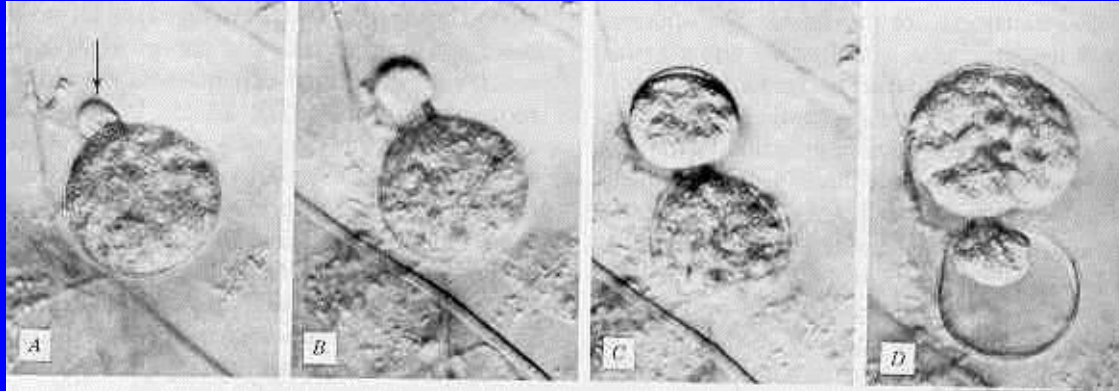


**esporângios e zoósporos de  
*Phytophthora cinamomi*  
em água**



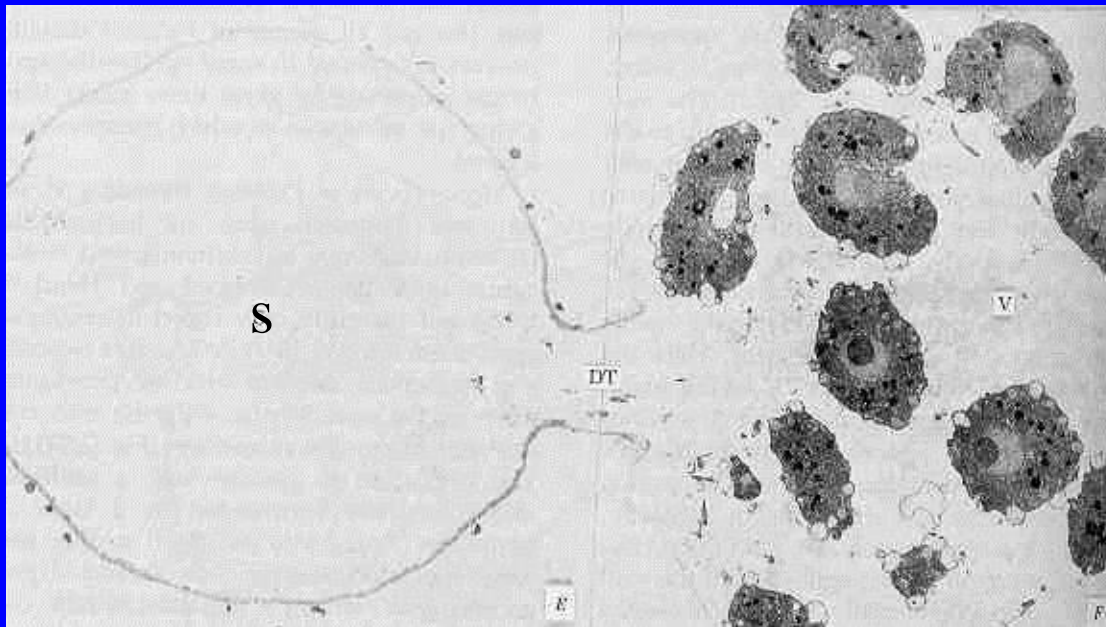
**liberação de zoósporos de  
*Phytophthora medicaginis***

# liberação ativa



**Descarga de zoósporos:**  
A - esporângio com papila apical  
B a D - passagem do citoplasma para a vesícula (<15 min)

## *Pythium proliferum*



**Esporângio vazio (S) e vesícula evanescente (V) com alguns zoósporos**

# Dispersão

Ar

Curtas distâncias (camada de turbulência)  
Longas distâncias (camada convectiva)

**Fungos**, Nematoides

Água

Respingos  
Enxurrada

**Bactérias**  
**Fungos**  
**Nematoides**

Insetos

**Vírus**  
**Fitoplasmas**  
Bactérias  
Fungos  
Nematoides  
Viroides (1)

Pólen

**Vírus**  
**Viroides**  
**Fungos**

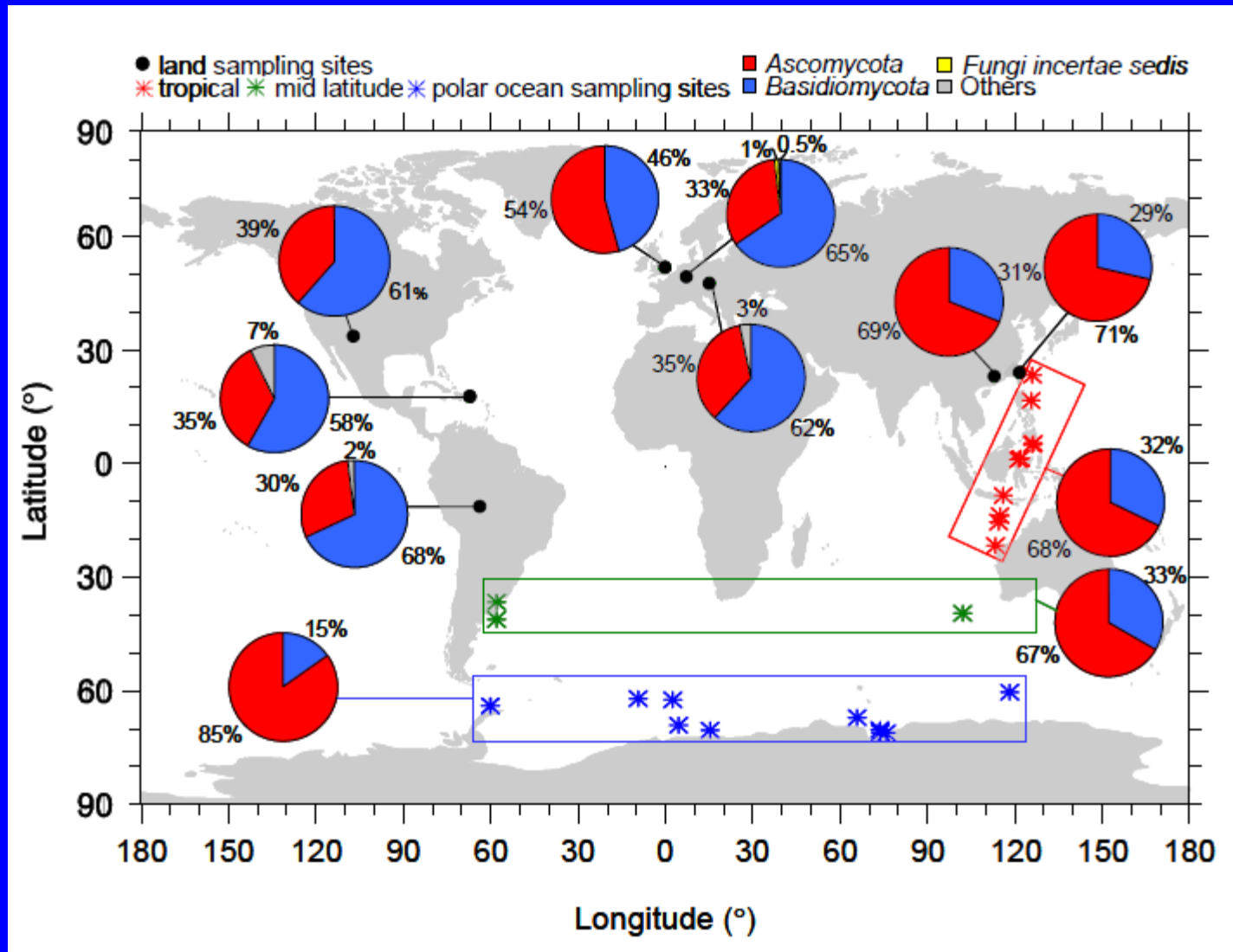
Homem

Transporte de material propagativo  
Tratos culturais (enxertia, colheita, desbrota)

**Vírus, Fungos, Bactérias, Viroides, Nematoides, Fitoplasmas, ...**



# Dispersão de fungos pelo ar



**Fig. 1.** Geographical location and relative proportions of different phyla in continental, coastal, and marine (ocean) sampling locations (10 to 42 samples of aerosols/site, 1.5 to 50 m height) (Frohlich-Nowoisky et al. 2012)

# Dispersão de fungos pelo ar

Fig. 2. Species richness of airborne fungi: mean relative proportions of different phyla (A), different classes of *Basidiomycota* (B), and different classes of *Ascomycota* (C) in continental (Austria, Arizona, Brazil, Germany), coastal (China, Taiwan, Puerto Rico, UK), and marine (Pacific, Indian, Atlantic, Southern Ocean) samples.

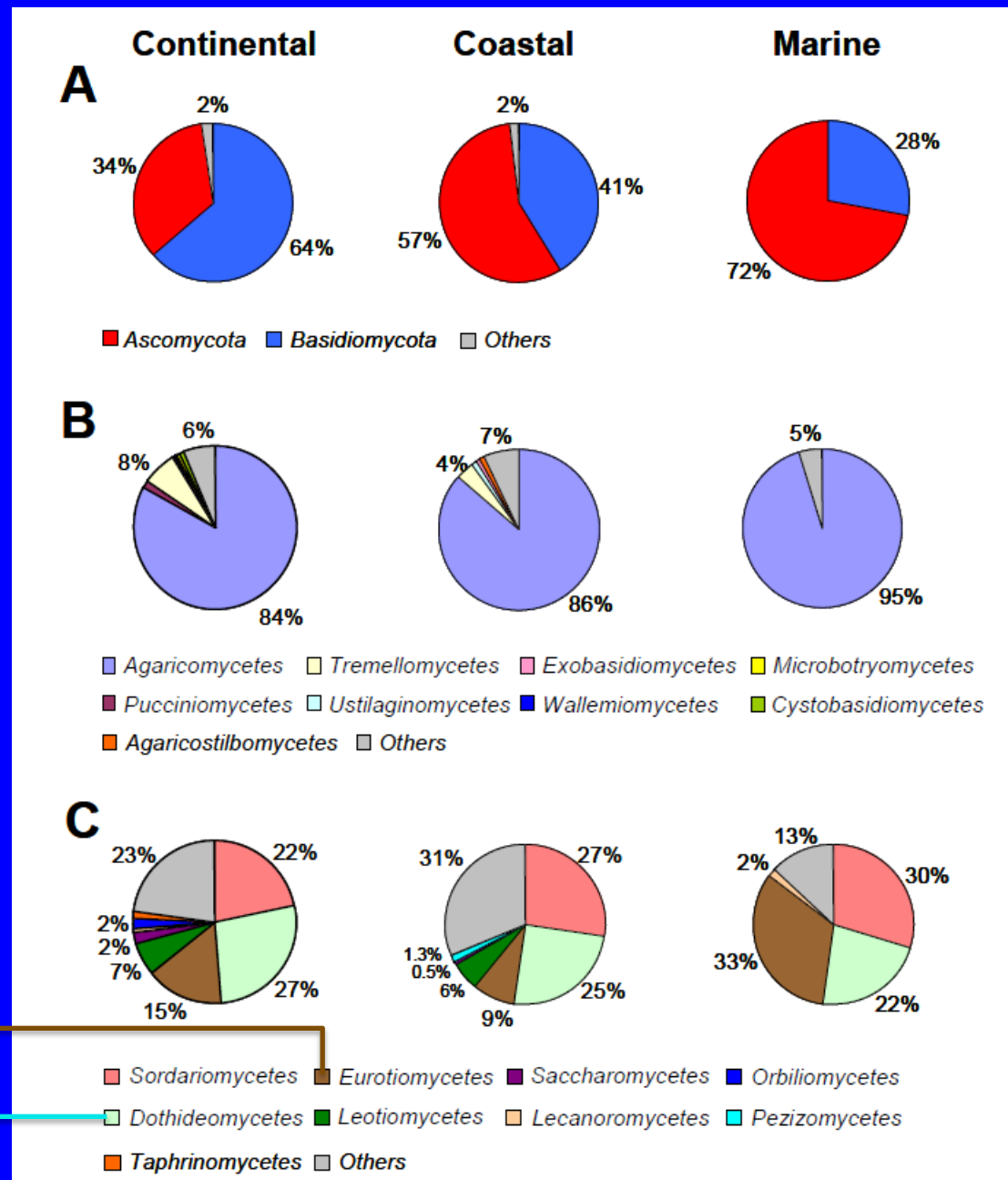
(Frohlich-Nowoisky et al. 2012)

## *Penicillium*

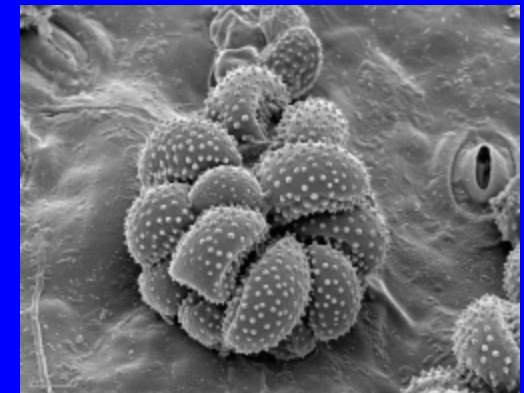
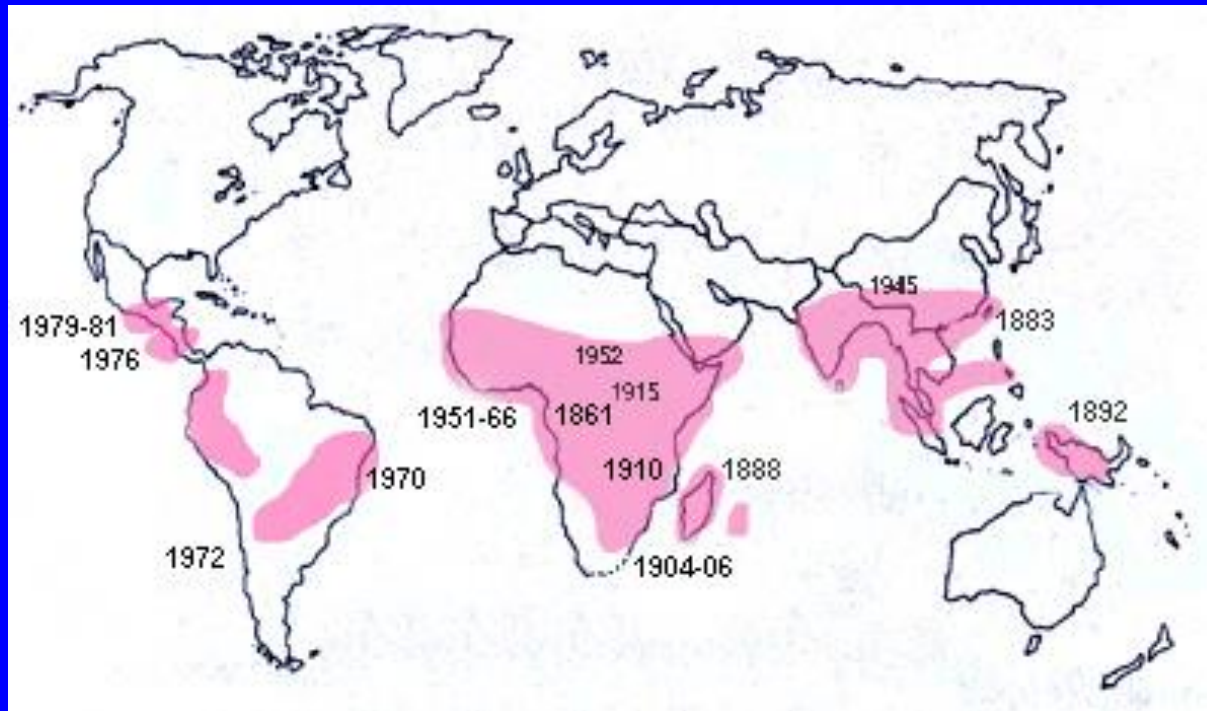
Presente em 60% das localidades de 36 a 59% das amostras

## *Cladosporium*

Presente em todas as localidades de 27 a 98% das amostras

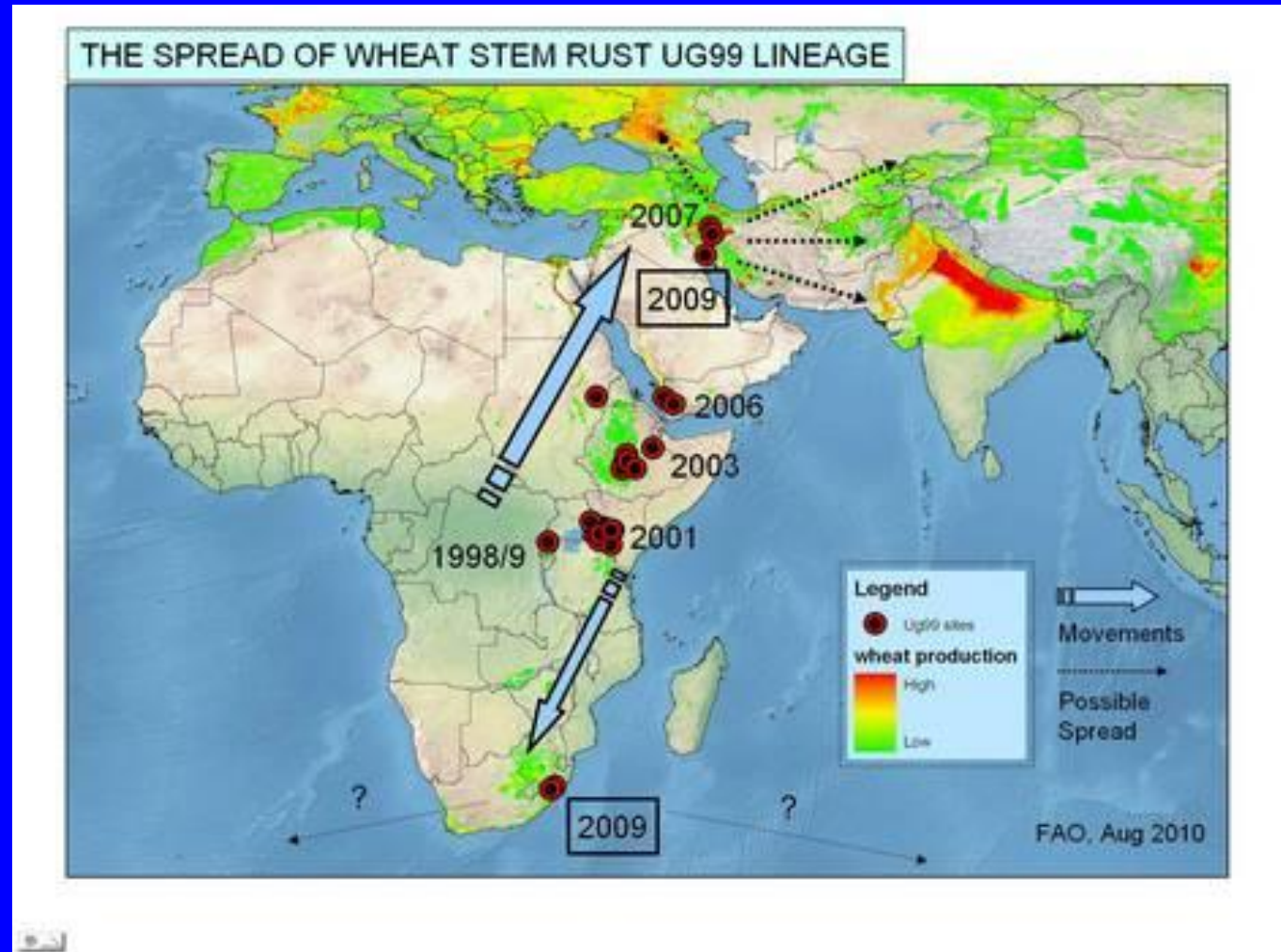


# Dispersão a longas distâncias pelo ar

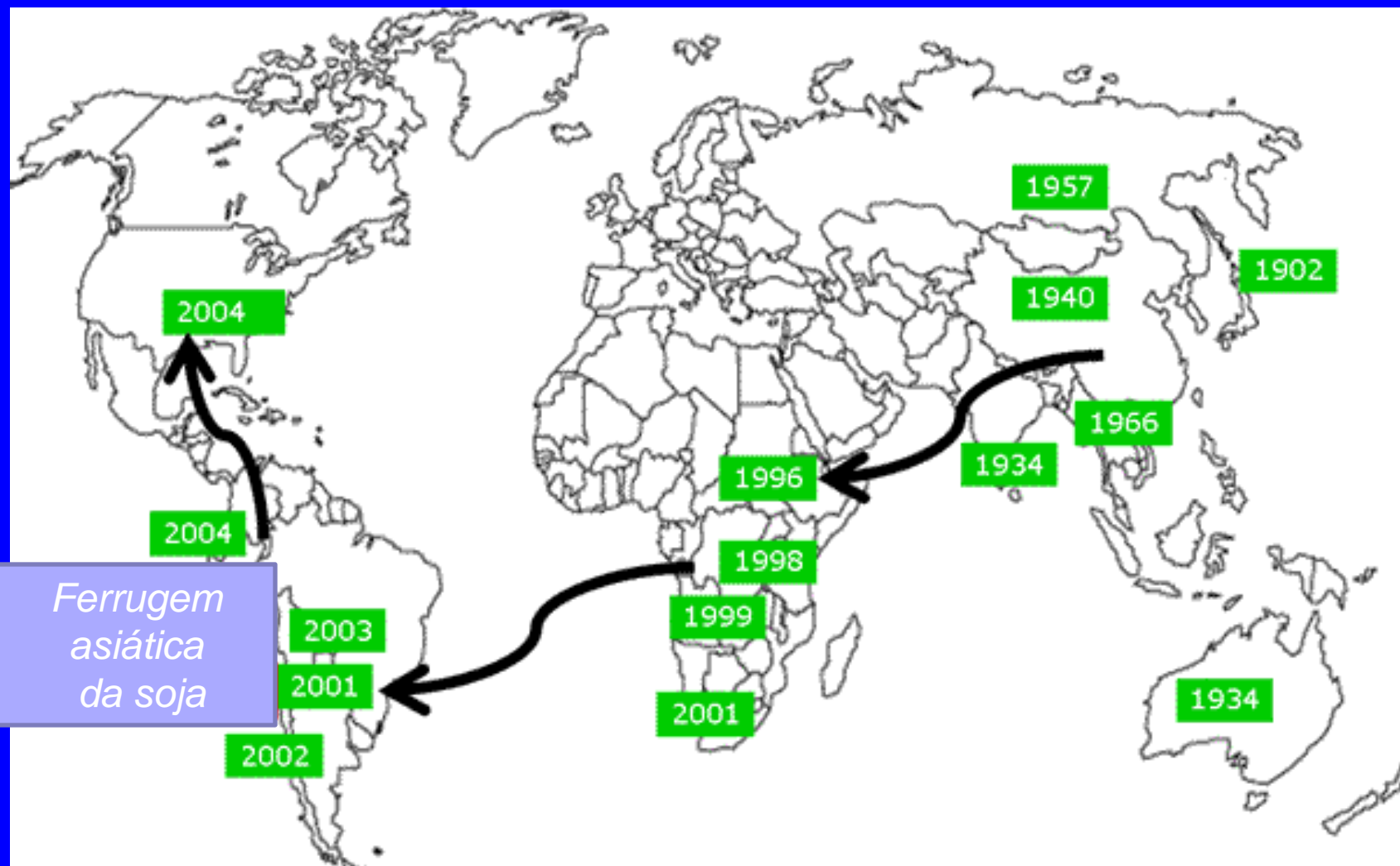


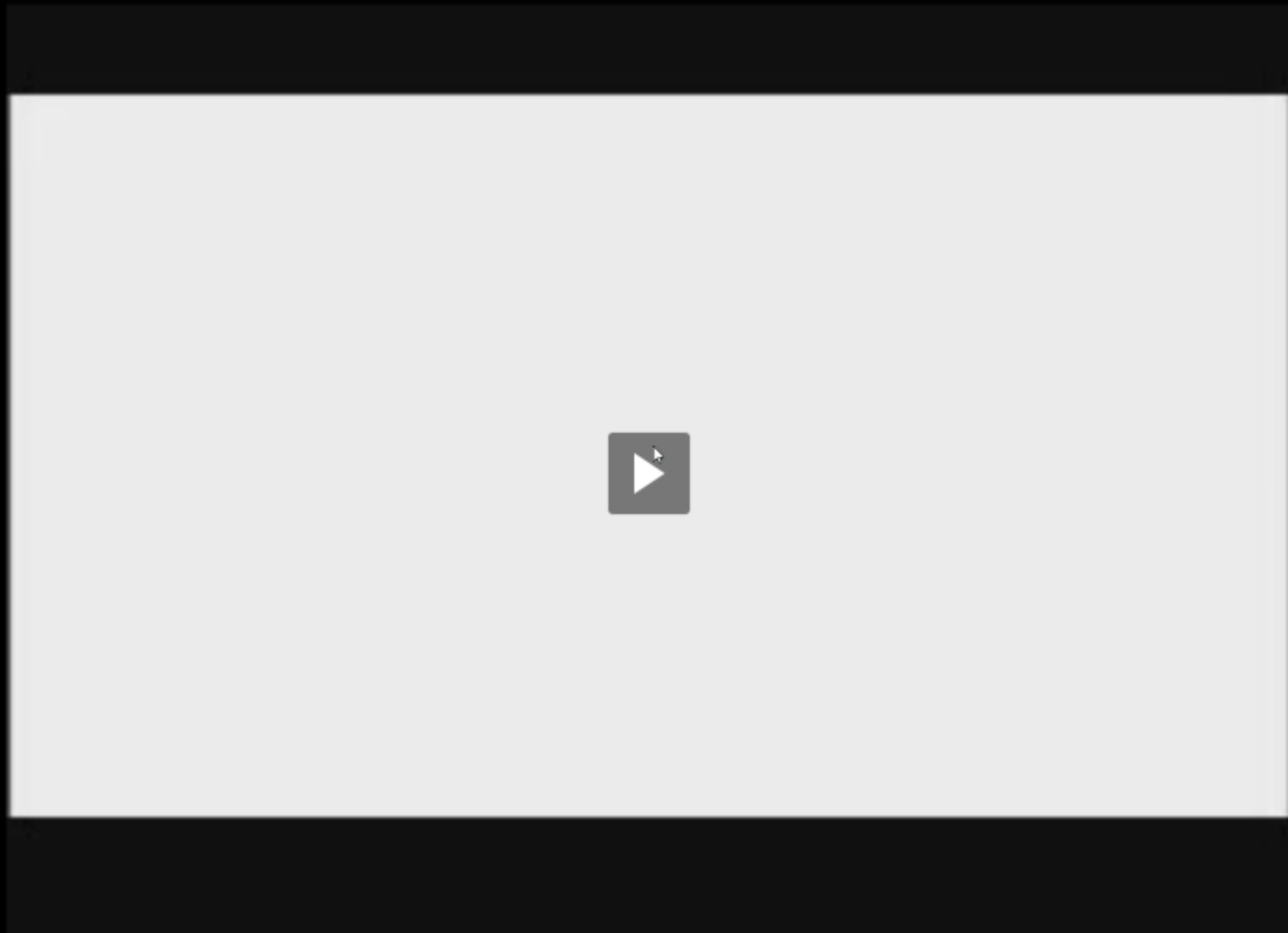
Distribuição de *Hemileia vastatrix* e datas da primeira constatação em cada país

# Dispersão a longas distâncias pelo ar



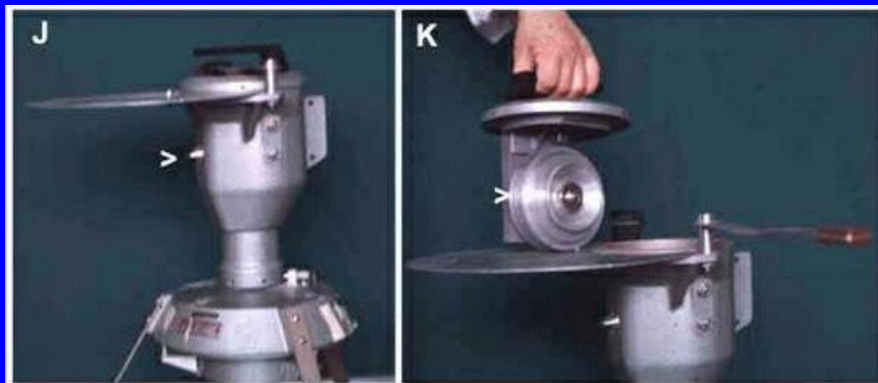
# Dispersão a longas distâncias pelo ar





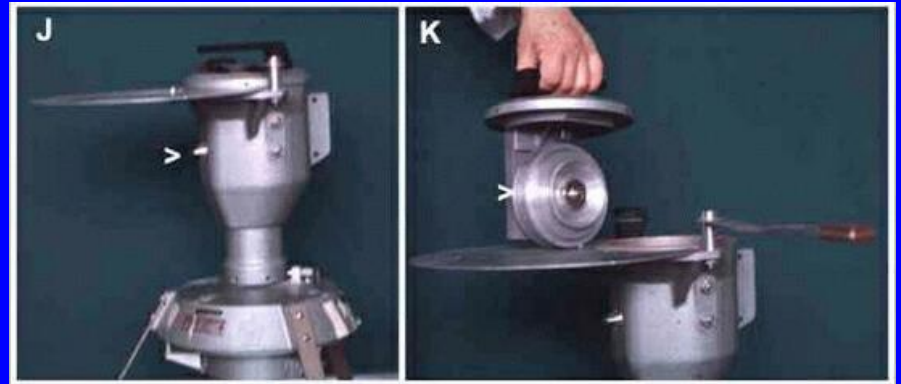
# Dispersão e deposição

Como medir o transporte de esporos?



# Dispersão e deposição

Como medir o transporte de esporos?





# Dispersão e deposição

Como medir o transporte de esporos?

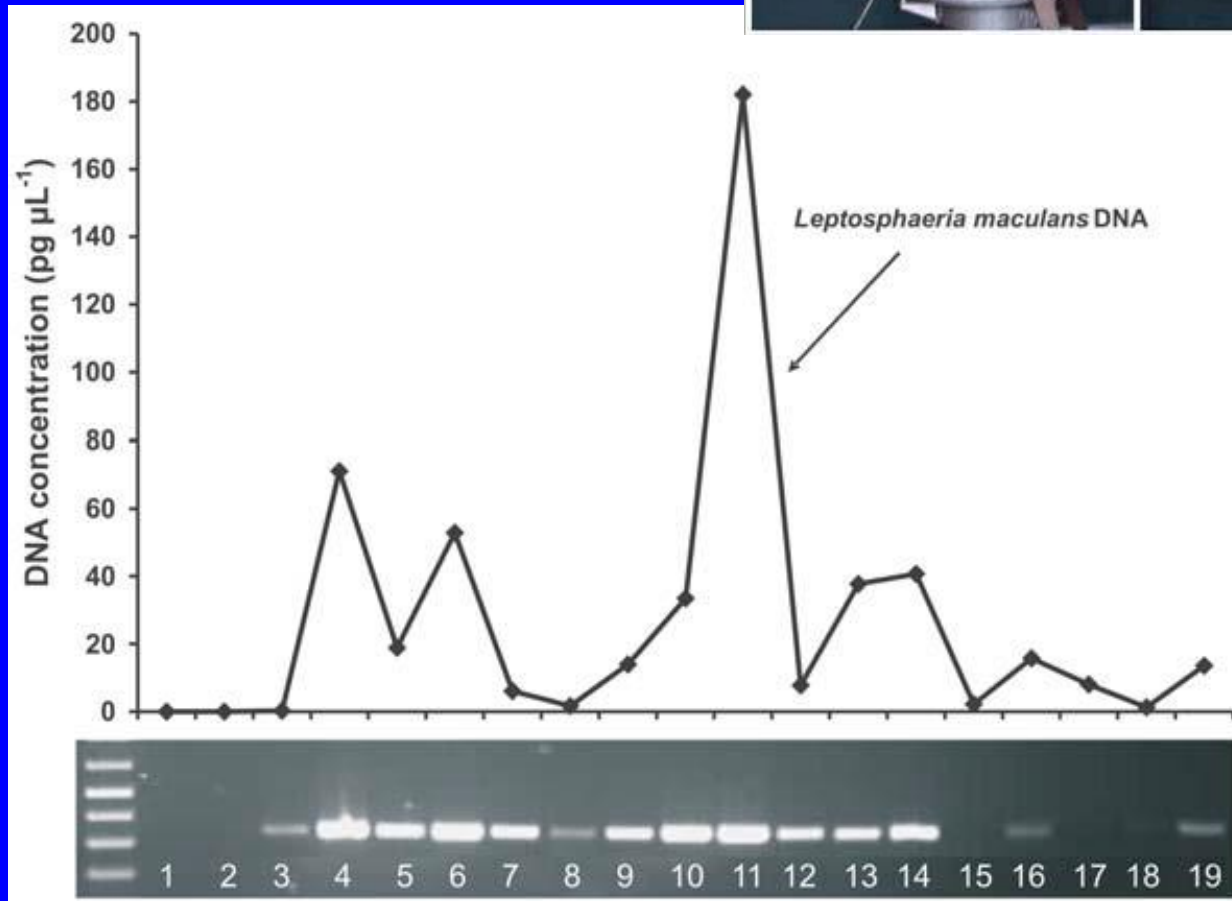
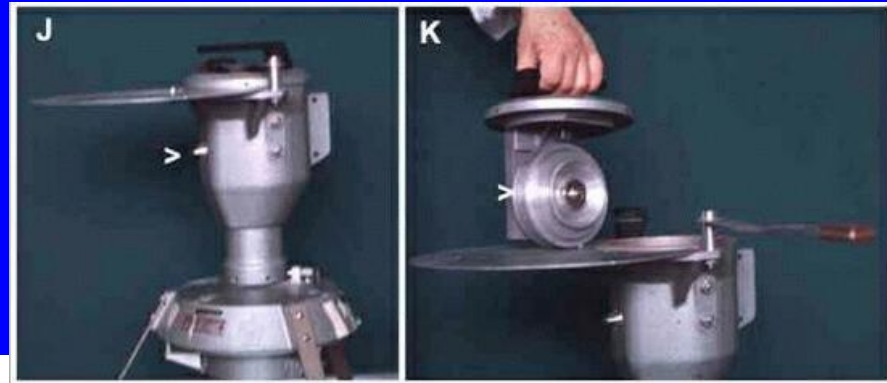


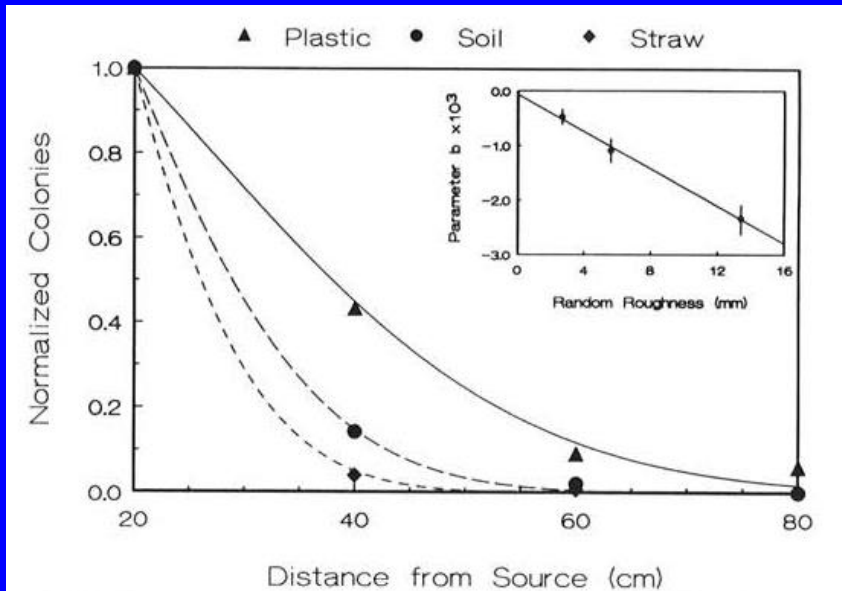
Figure 4. Concentrations of *Leptosphaeria maculans* DNA determined by real-time PCR (top), and bands of the 377-bp traditional PCR amplicon (bottom) from 19 selected samples (J. Kaczmarek et al., 2009)

# Dispersão e deposição

## Gradientes de dispersão

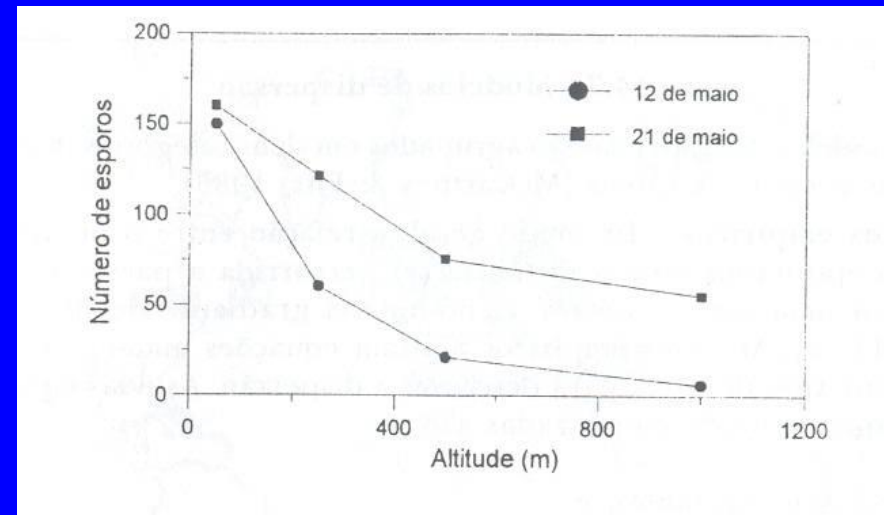
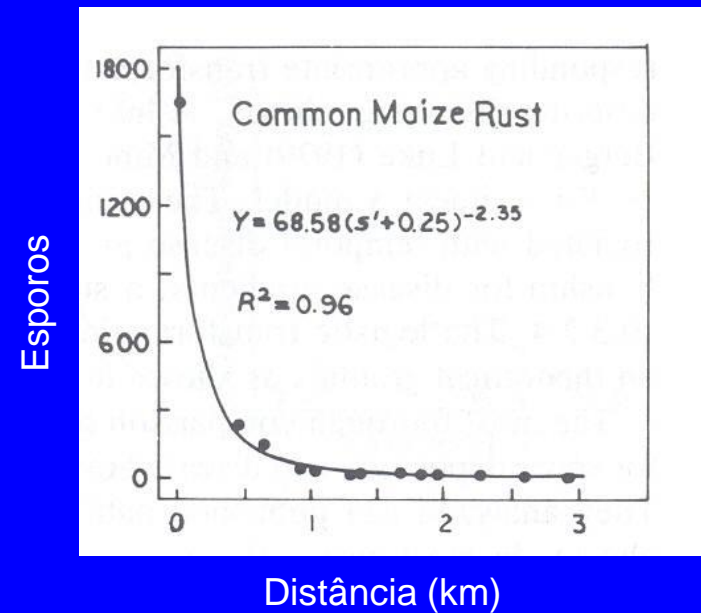
Previsão de epidemias

Planos de erradicação



**Fig. 4.** Effect of ground cover on gradient of colonies ( $n$ ,  $\text{cm}^{-2} \text{min}^{-1}$ ) over distance at 10 min into a 30-mm/hr rain. The vertical scale was normalized at 20 cm from the source so that the gradients can be compared. Data points are means of  $n$ , and smooth curves are the corresponding predicted values. The nested graph shows the relationship between the regression parameter  $b$  in equation 1 and surface random roughness, where vertical segments indicate standard deviations of data.

(Yang et al. 1990)

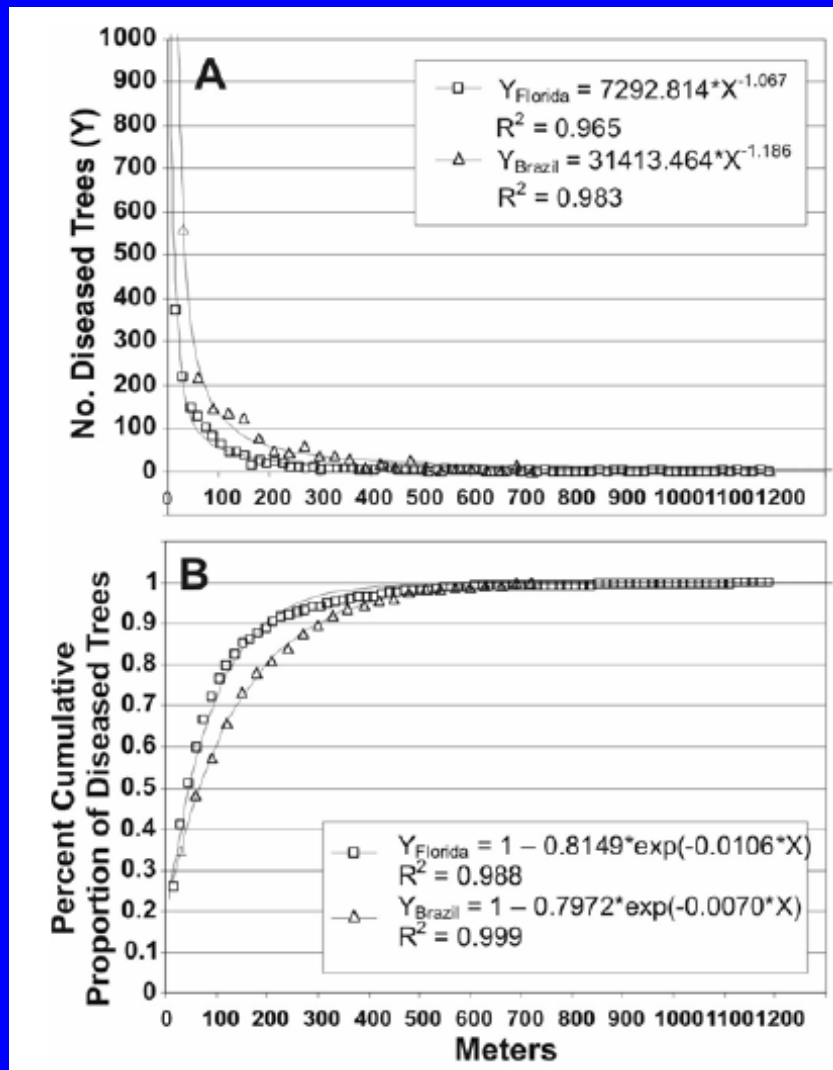


Coleta de esporos de *Hemileia vastatrix* em 2001  
Pedregulho, SP

# Dispersão e deposição

## Gradientes de doença

Previsão de epidemias  
Planos de erradicação

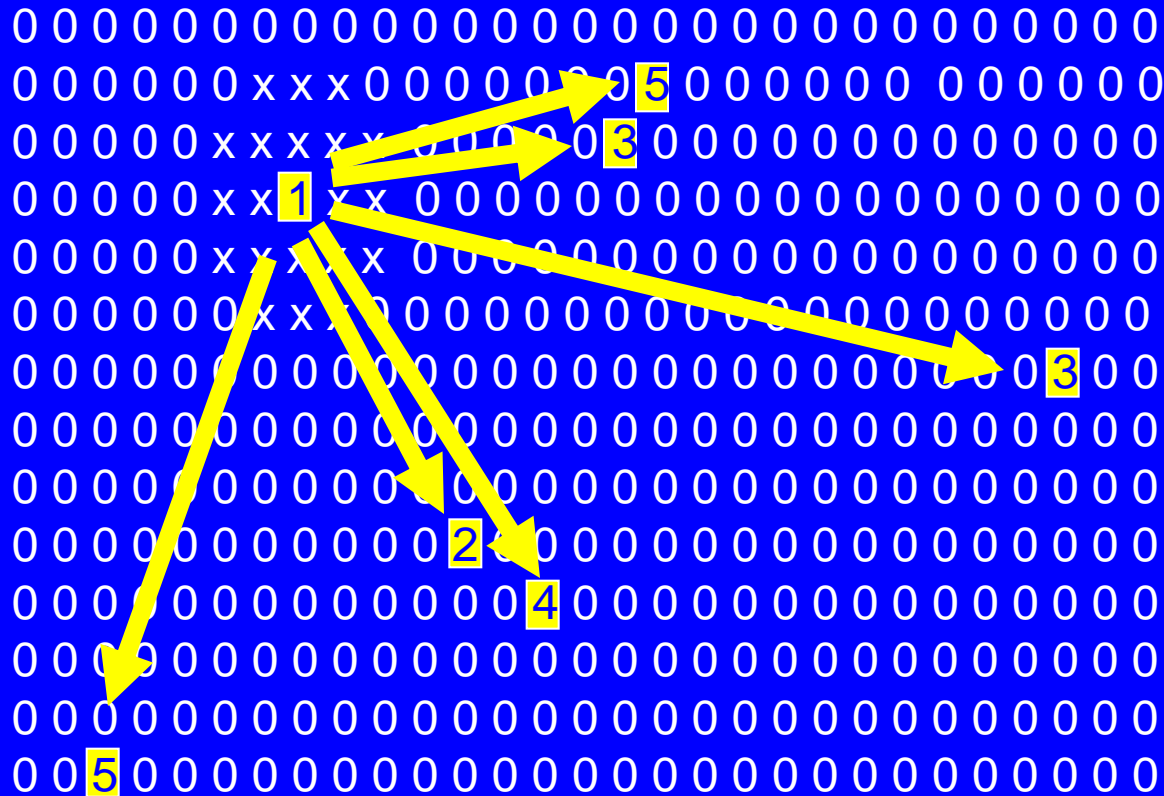


Gottwald et al. (2007)



# Dispersão e deposição

## Gradientes de doença



0 = planta sadia

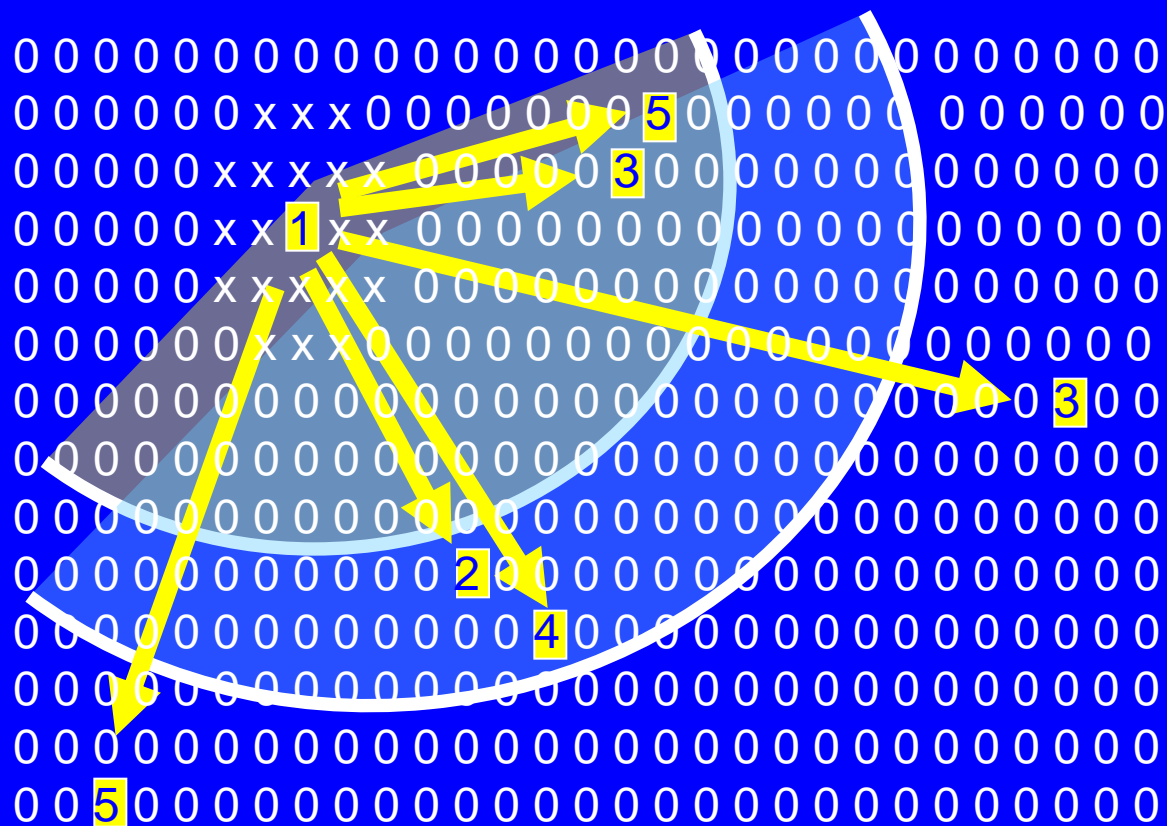
1 = planta doente na primeira inspeção (foco)

x = plantas erradicadas pelo raio

2, 3, 4, 5 = plantas doentes nas reinspeções

# Dispersão e deposição

Gradientes de doença

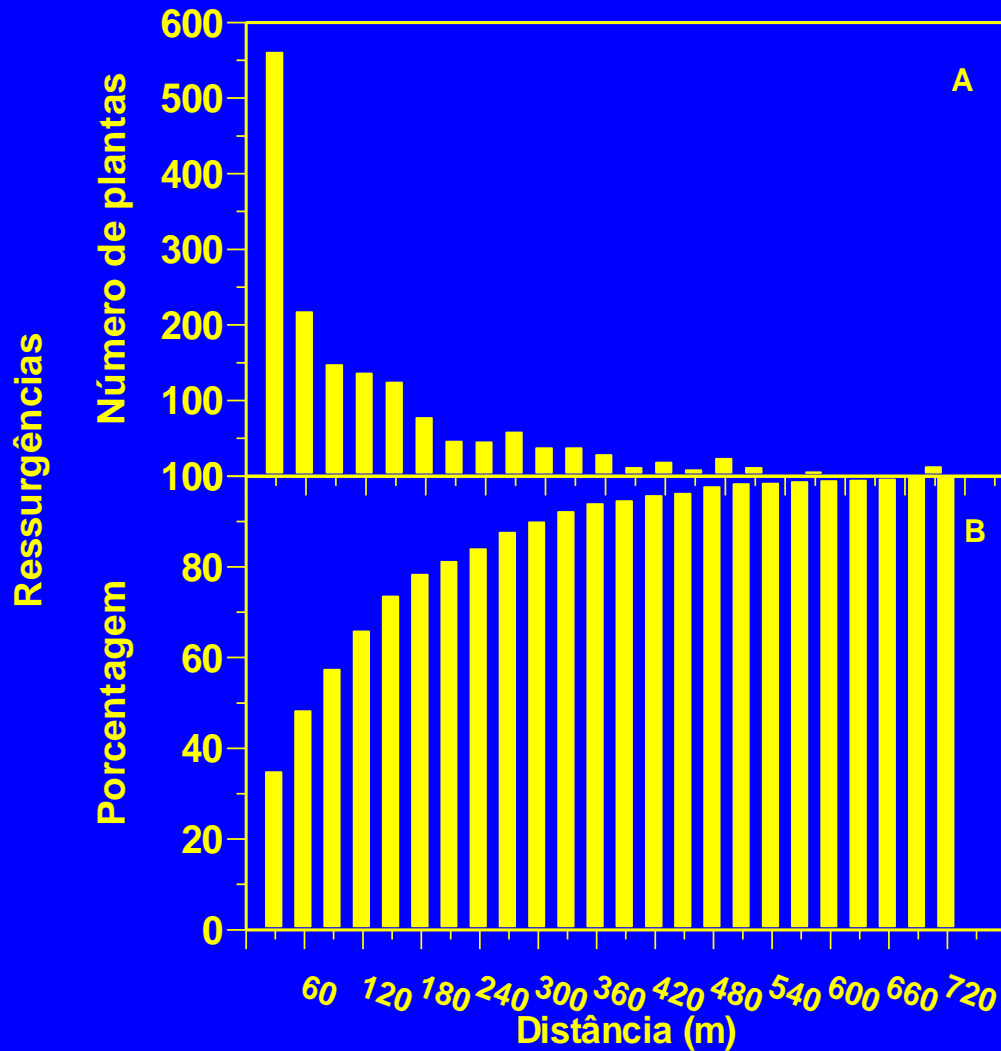


Plantas	Distância
2	30
2	30-60
2	60-90

Plantas (%)	Distância
33	Até 30
66	Até 60
100	Até 90

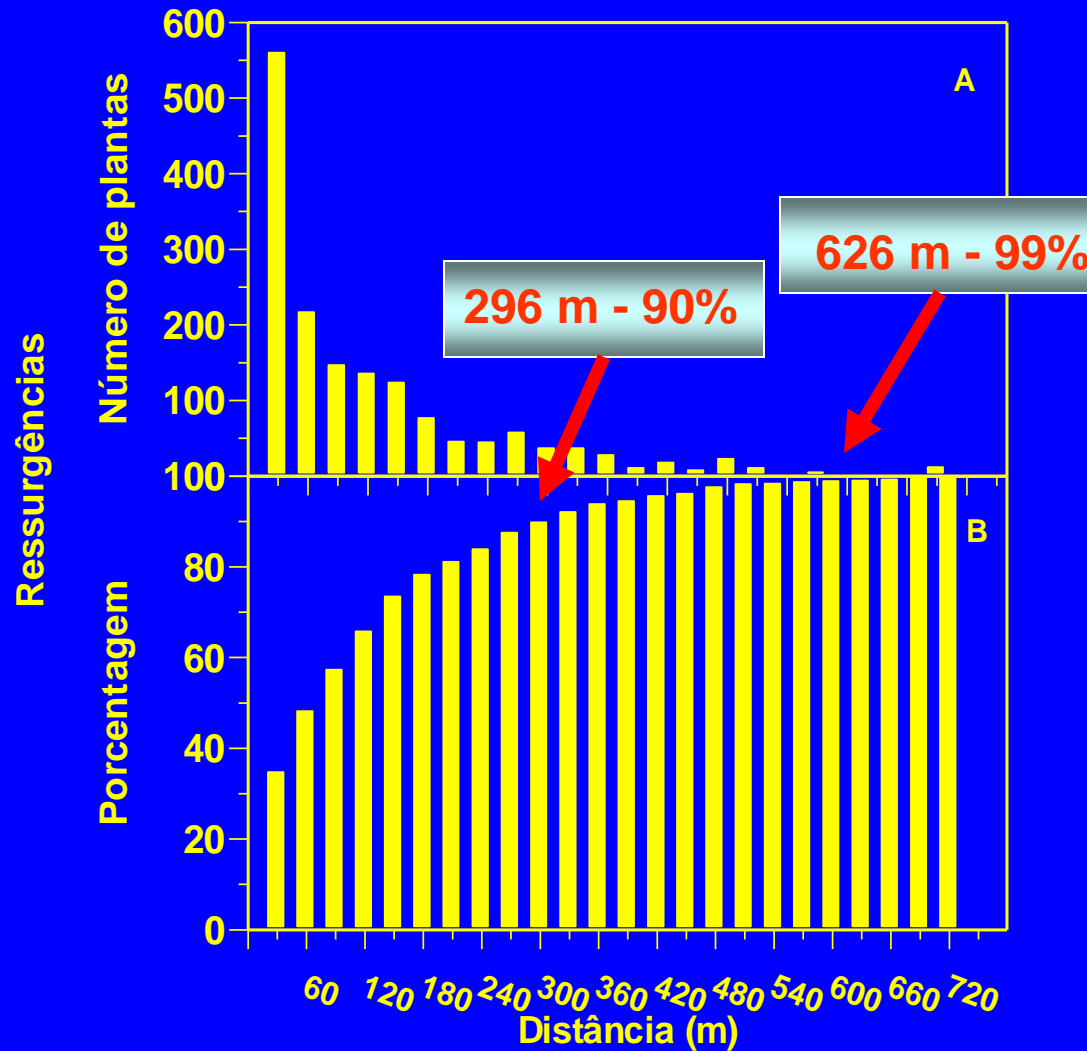
# Dispersão e deposição

Gradientes de doença



# Dispersão e deposição

Gradientes de doença





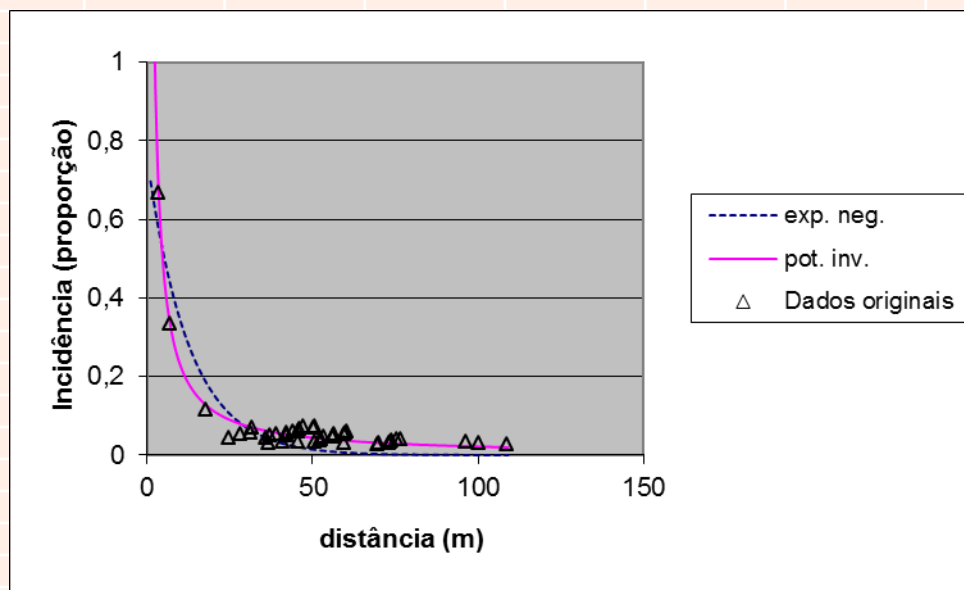
# Dispersão e deposição

Como ajustar modelos a gradientes de doença

distância	incidência(%)
3,50	0,66666667
17,50	0,115384615
31,30	0,056338028
31,50	0,068493151
39,13	0,054545455
42,00	0,05785124
43,85	0,059259259
45,50	0,06122449
46,04	0,067114094
46,96	0,071895425
50,11	0,068965517
50,48	0,073033708
60,22	0,059322034
96,30	0,032967033
7,00	0,333333333
28,00	0,054545455
35,69	0,042553191
37,21	0,051020408
42,00	0,049586777
52,03	0,037234043
52,50	0,041666667
53,31	0,045454545
56,00	0,047393365
56,44	0,049773756
56,54	0,053811659
59,50	0,053719008
59,81	0,056910569
100,22	0,030800821
24,50	0,044444444
36,54	0,03125
40,82	0,034482759
45,50	0,034013605
50,48	0,033707865
59,50	0,030567686
69,74	0,027586207
70,00	0,030508475
73,08	0,03125
73,50	0,034267913
73,83	0,037037037
75,39	0,039039039
76,44	0,041543027
108,73	0,02851711

exponencial negativo  
 $y=a*\exp(-bx)$   
 $a=0,754; b=0,079; R2=0,84$

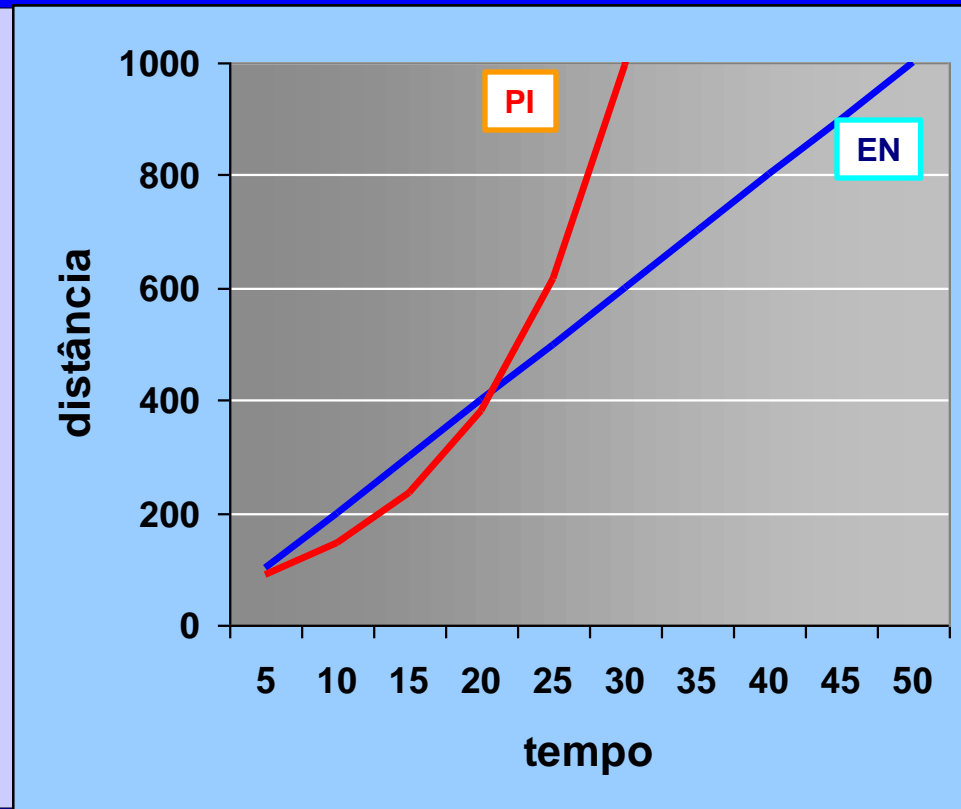
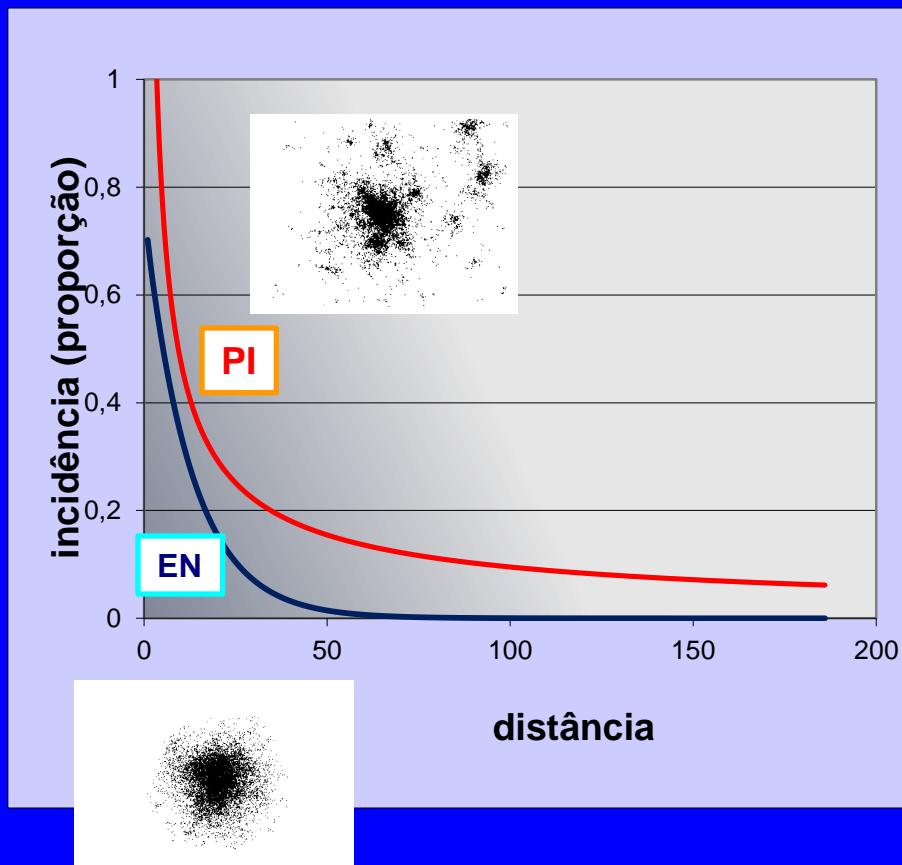
potência inversa  
 $y=a*x^b$   
 $a=2,392; b=-1,02; R2=0,98$



# Dispersão e deposição

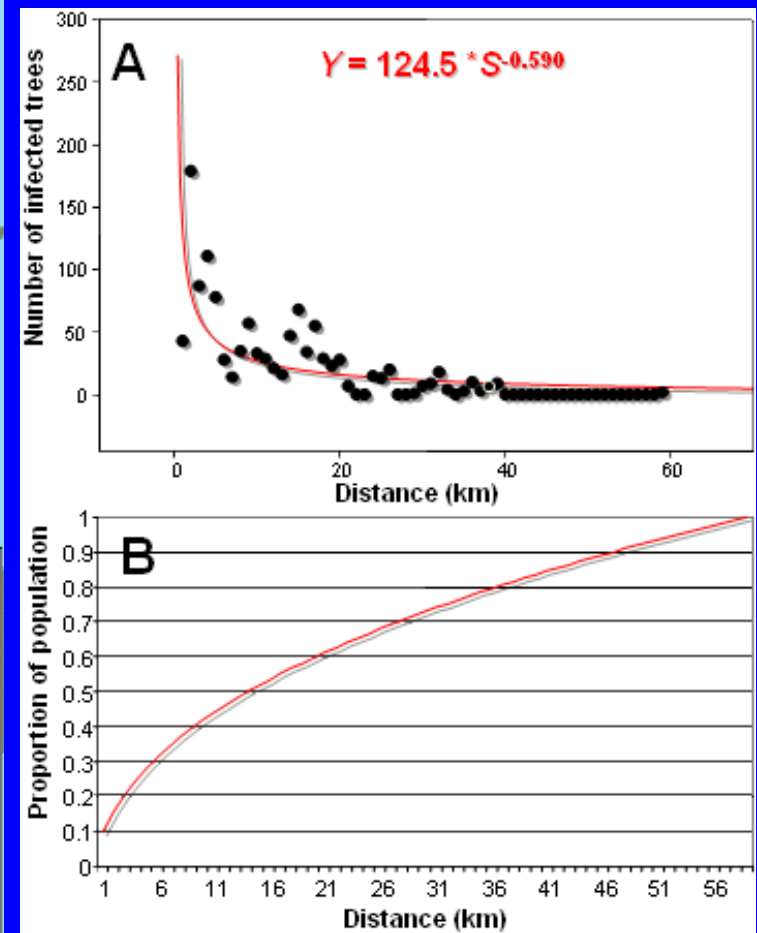
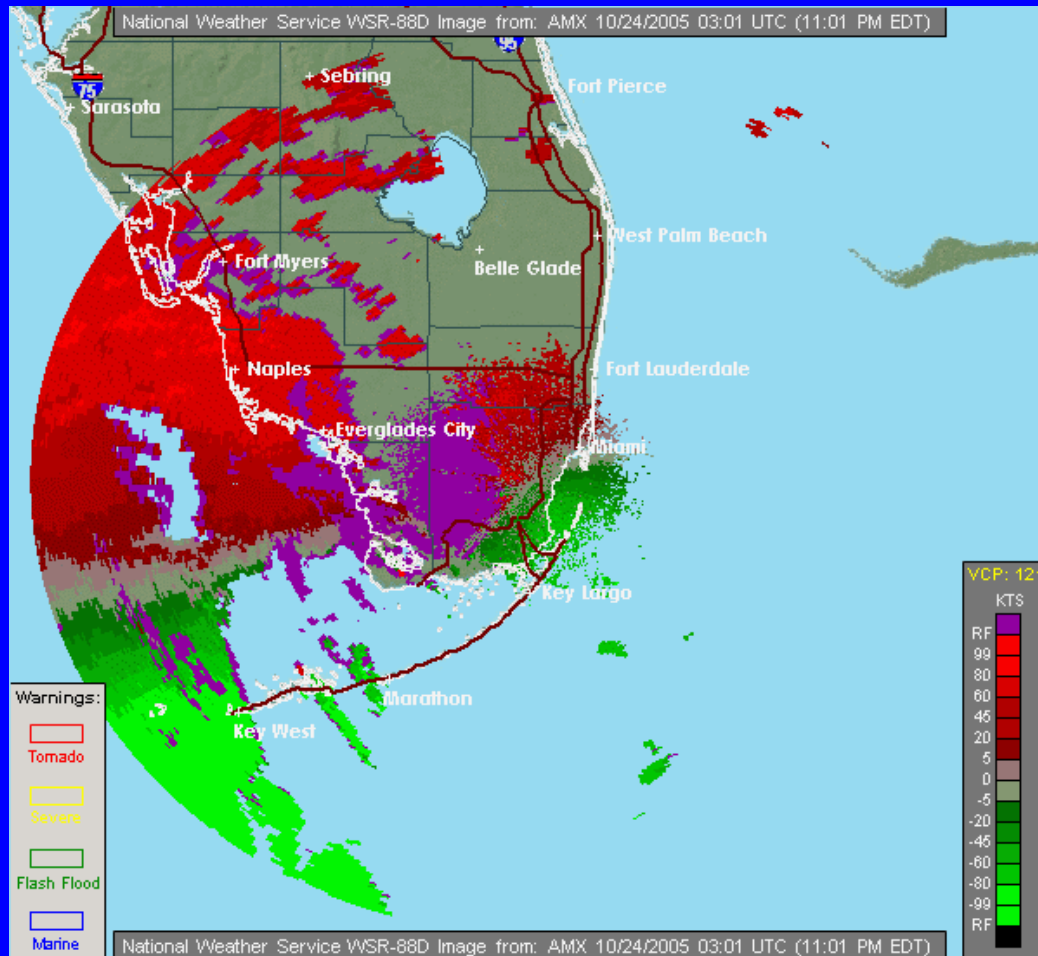
Modelo potência inversa (PI) – longas distâncias atingidas por pequena quantidade de inóculo (Fat tail)

Modelo exponencial negativo (EN) – o inóculo não atinge longas distâncias



# Modelos de dispersão e deposição

Cancro cítrico na Flórida - efeito de furacões



# Transmissão - Liberação, dispersão e deposição

Fungos e nematóides

*Phyllotreta cruciferae*



conídios de *Alternaria brassicicola*  
de repolho

Dillard et al. (1998)  
Plant Disease



*Bursaphelenchus xylophilus* em  
traquéias de *Monochamus* spp.

Apsnet.org

# Transmissão - Liberação, dispersão e deposição

Fonte de inóculo  
cv.Valencia



Simulação diária de orvalho



Controle do ambiente dentro  
e for a das gaiolas

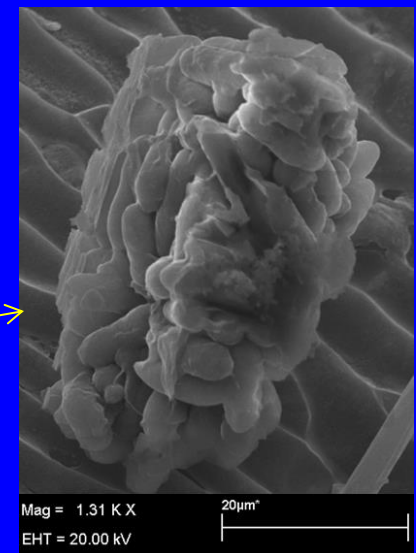
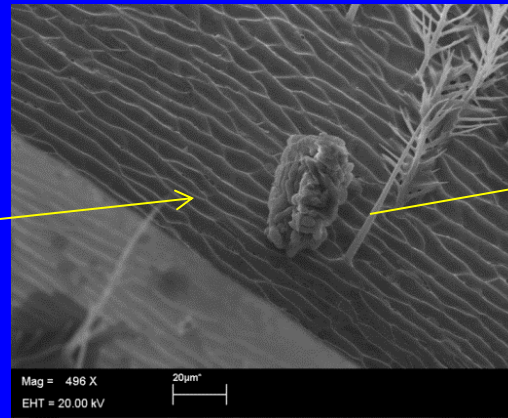
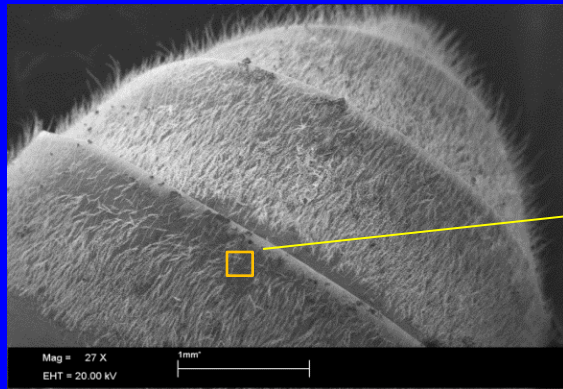


# Abelhas podem dispersar *C. acutatum* de plantas inoculadas para sadias

Experimento 1



Experimento 2



# Transmissão - Liberação, dispersão e deposição

## Vírus, fitoplasmas e bactérias

**Pulgão preto (*Toxoptera citricida*)**  
**Vírus da tristeza dos citros**



**Parathona**

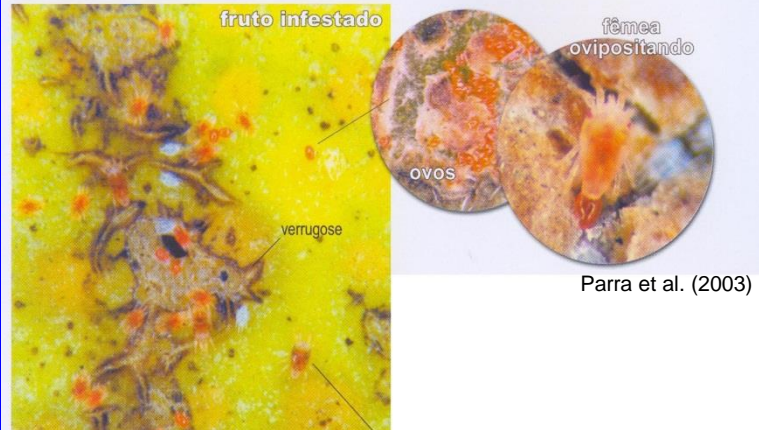


**Cigarrinhas**  
***Xylella fastidiosa***



# Transmissão - Liberação, dispersão e deposição

Ácaro-da-leprose, *Brevipalpus phoenicis*



*Brevipalpus phoenicis*

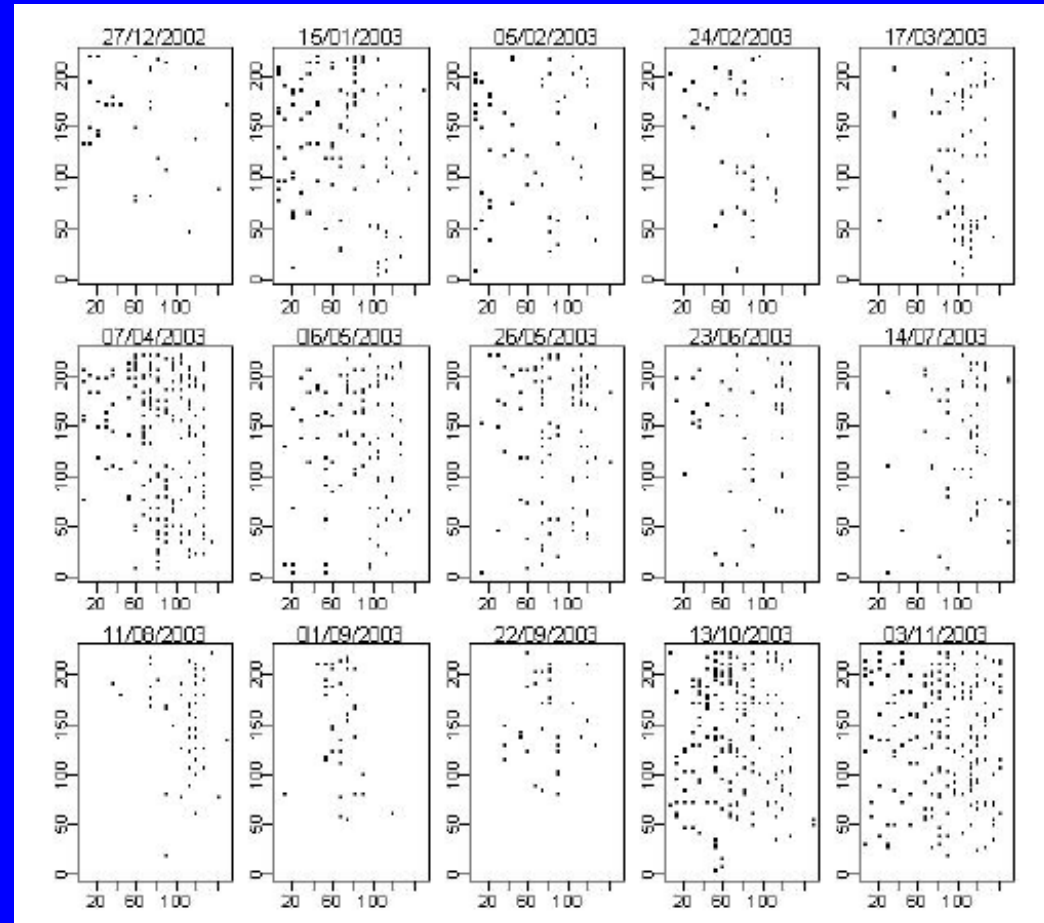
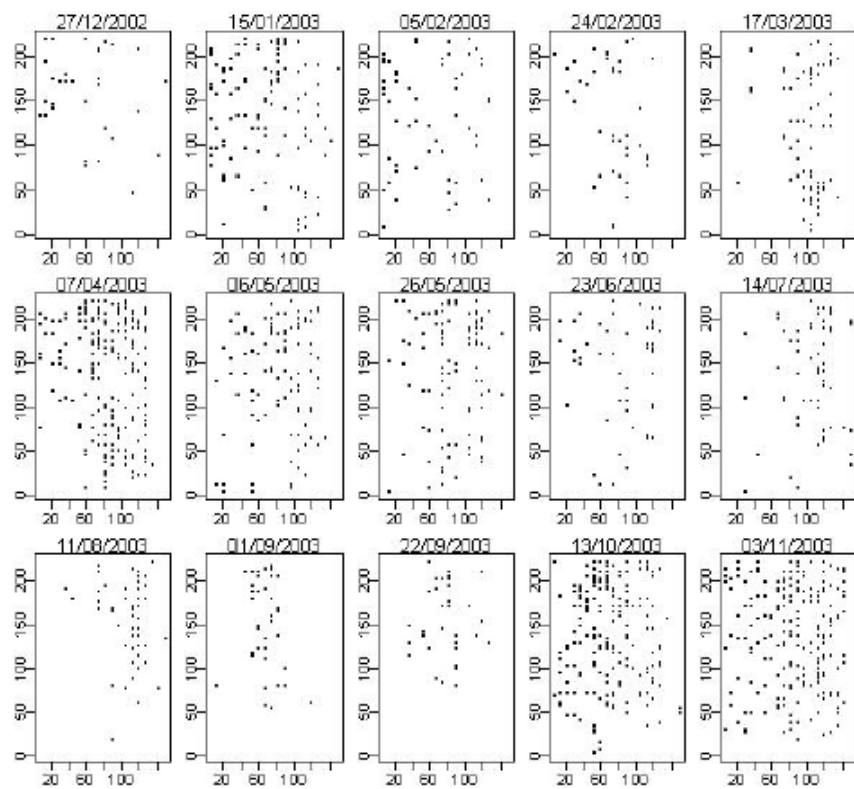


Fig. 4. Typical local lesion symptoms of leprosis (cytoplasmic type) in (A) leaves and fruits of sweet orange (*Citrus ssp.*) (B).

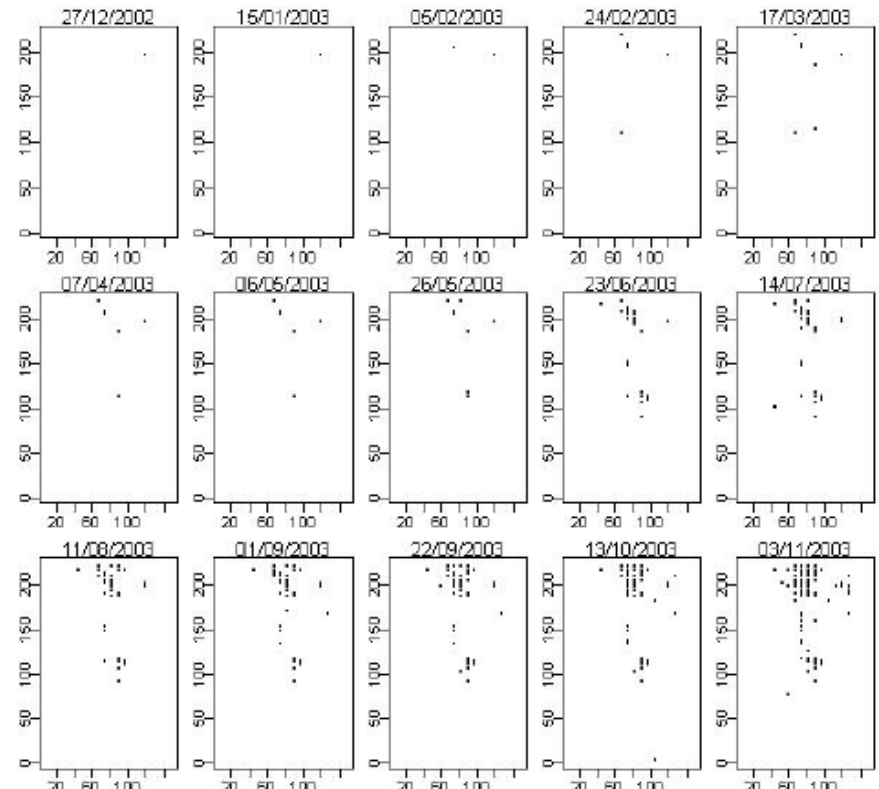


# Transmissão - Liberação, dispersão e deposição

*Brevipalpus phoenicis*

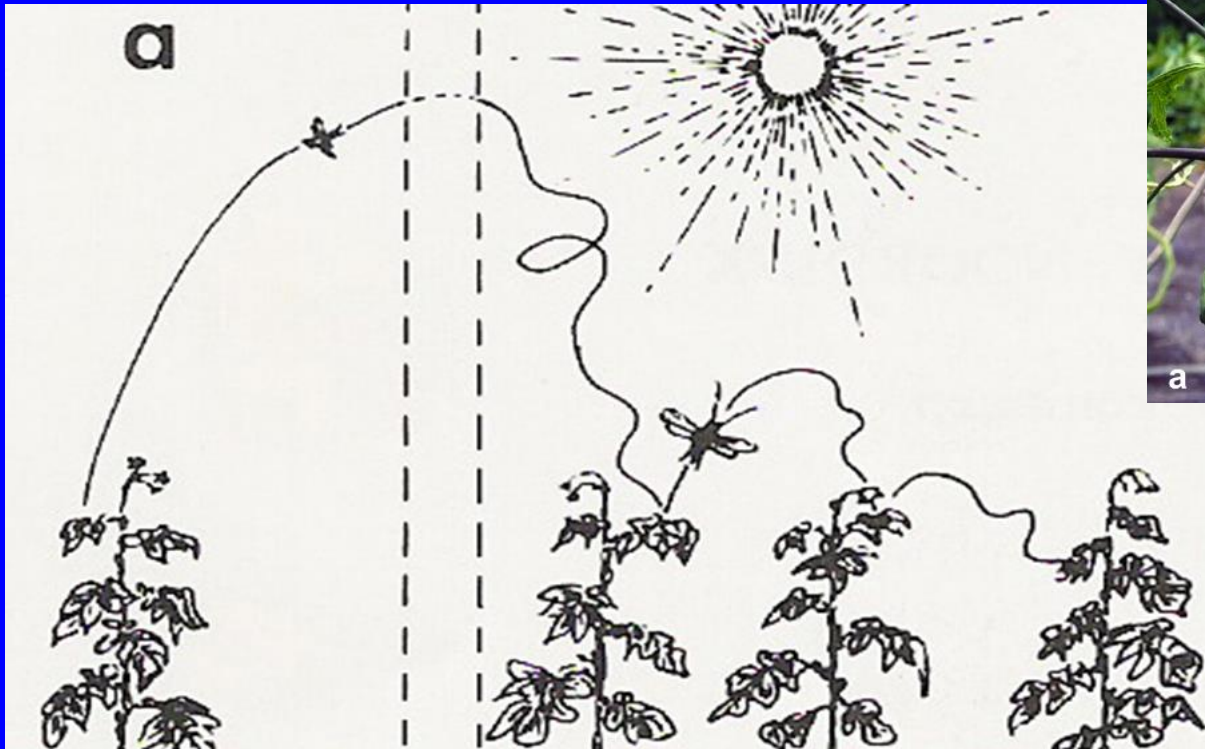


Leprose



# Transmissão - Liberação, dispersão e deposição

Transmissão de vírus de forma não persistente



Papaya ringspot virus (PRSV) on squash leaf and fruit