

Como as plantas se defendem?

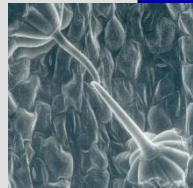
Mecanismos estruturais bioquímicos



Pré-formados

Estômatos, tricomas...

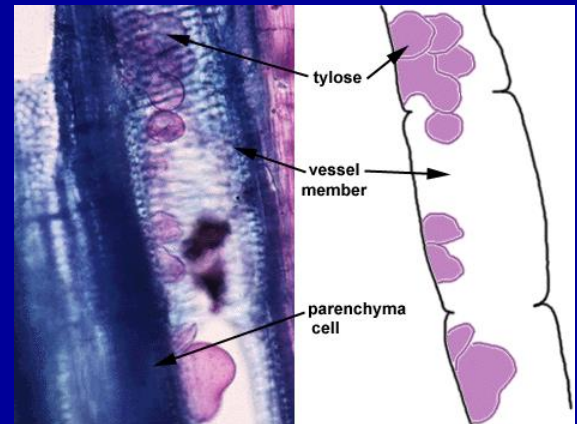
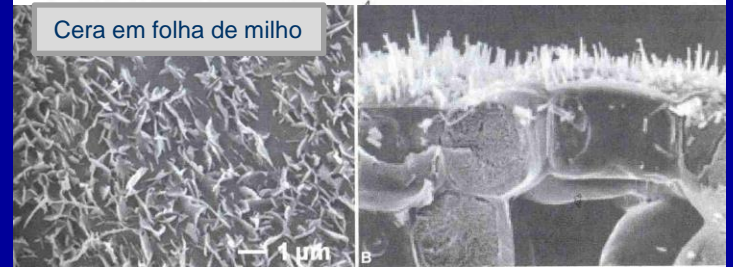
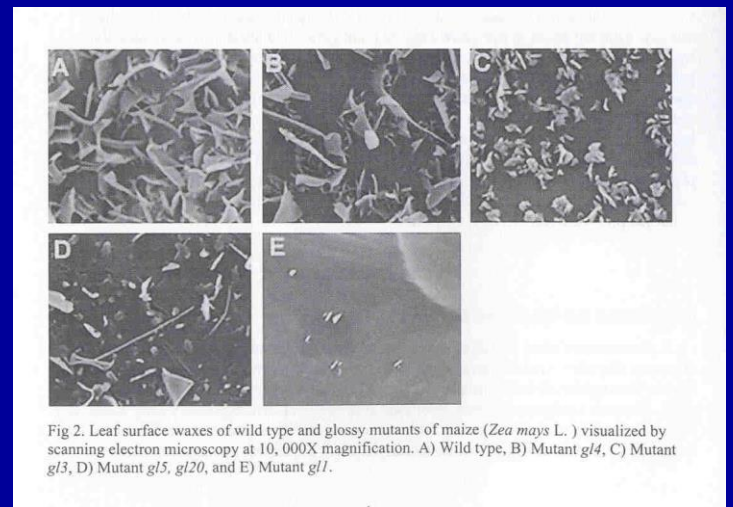
Fenóis, alcalóides...



Pós-formados

Tiloses, camadas de cortiça...

PR proteínas, fitoalexinas...



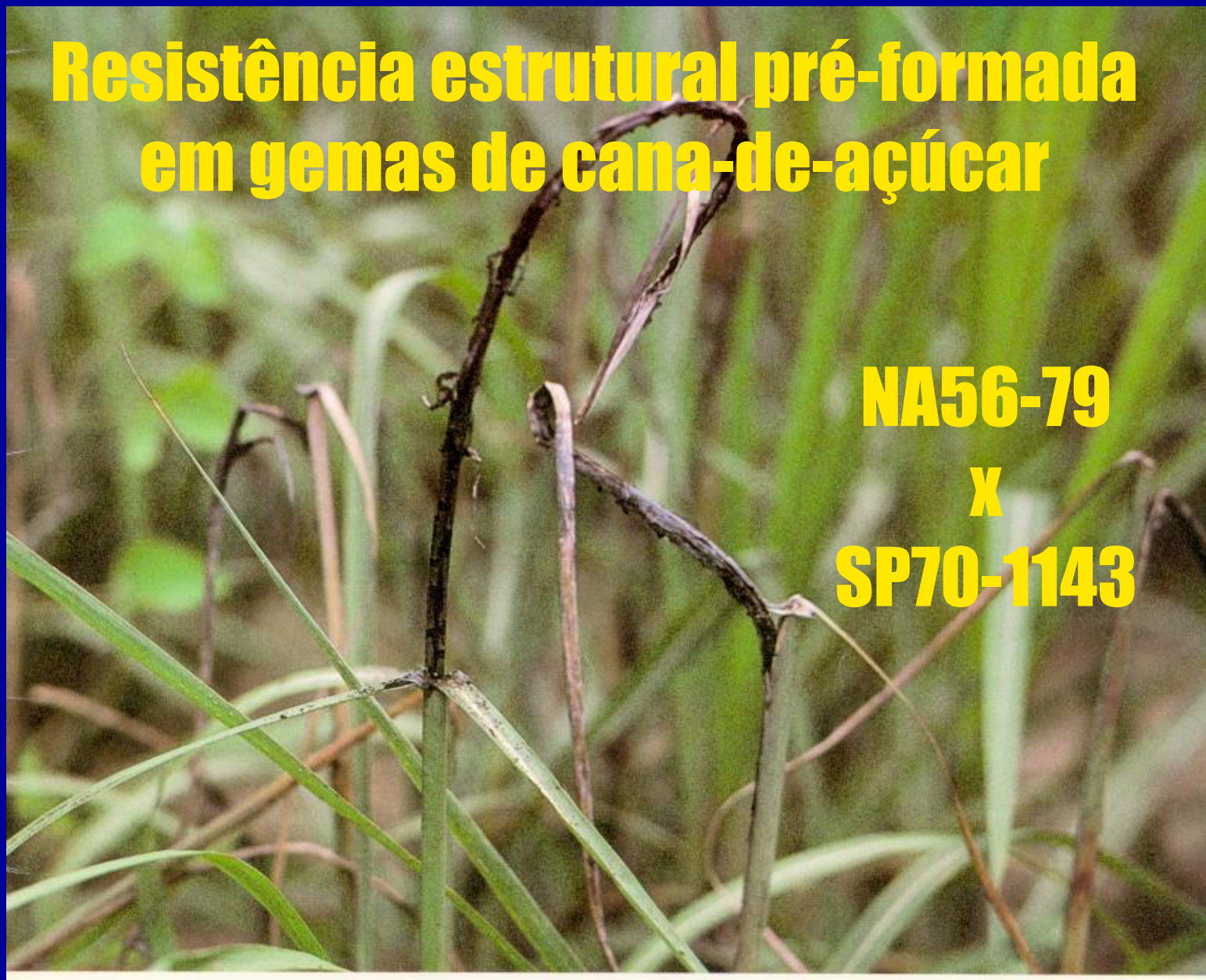
Tomate infectado com *Verticillium*

**Resistência estrutural pré-formada
em gemas de cana-de-açúcar**

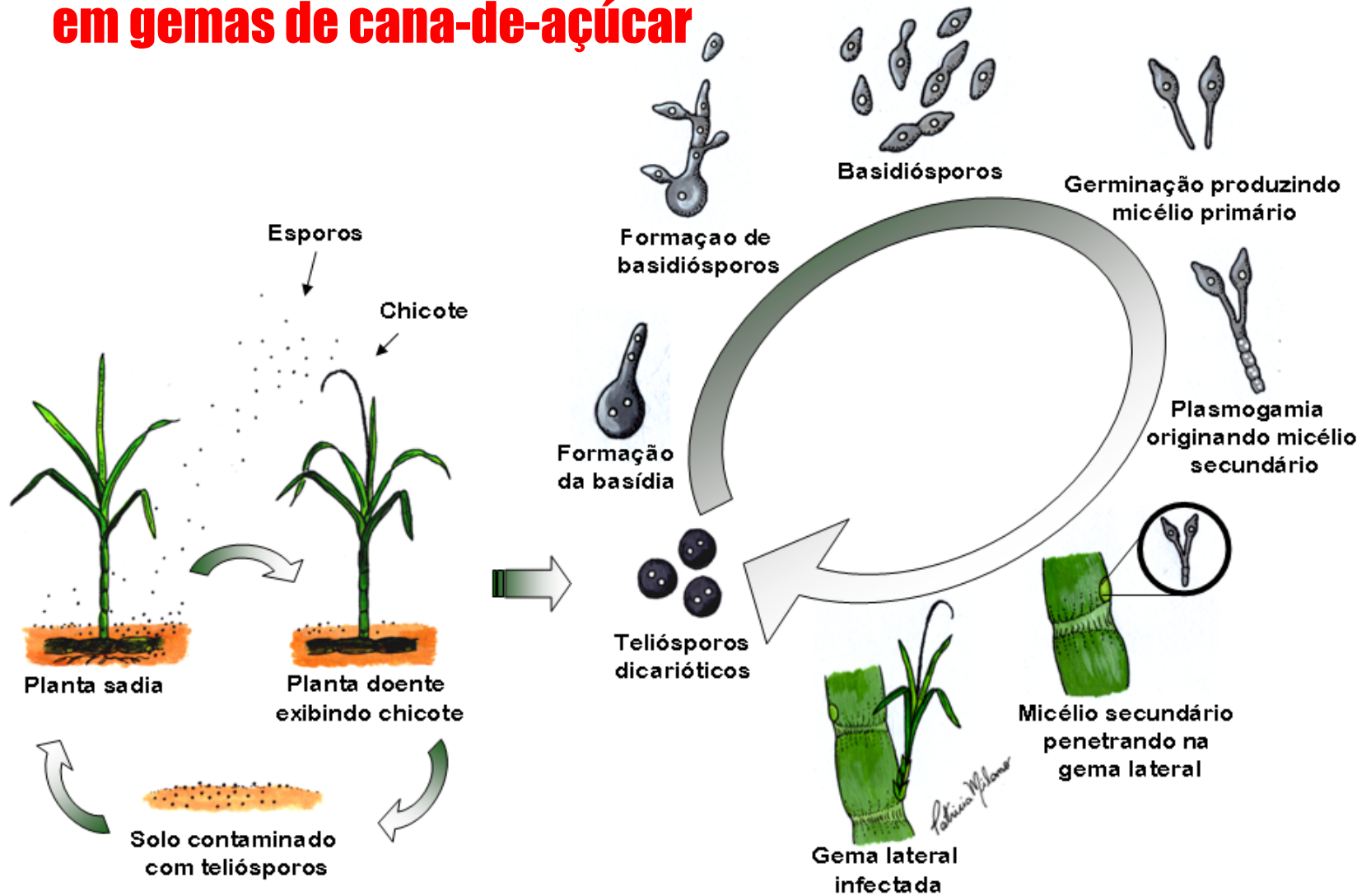
NA56-79

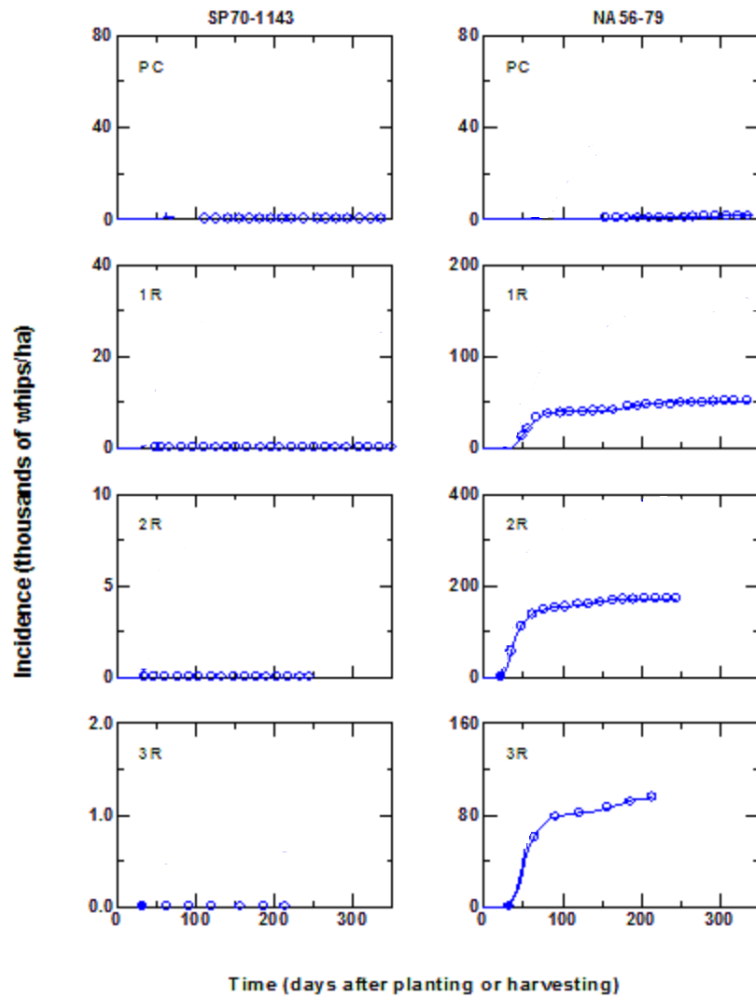
X

SP70-1143

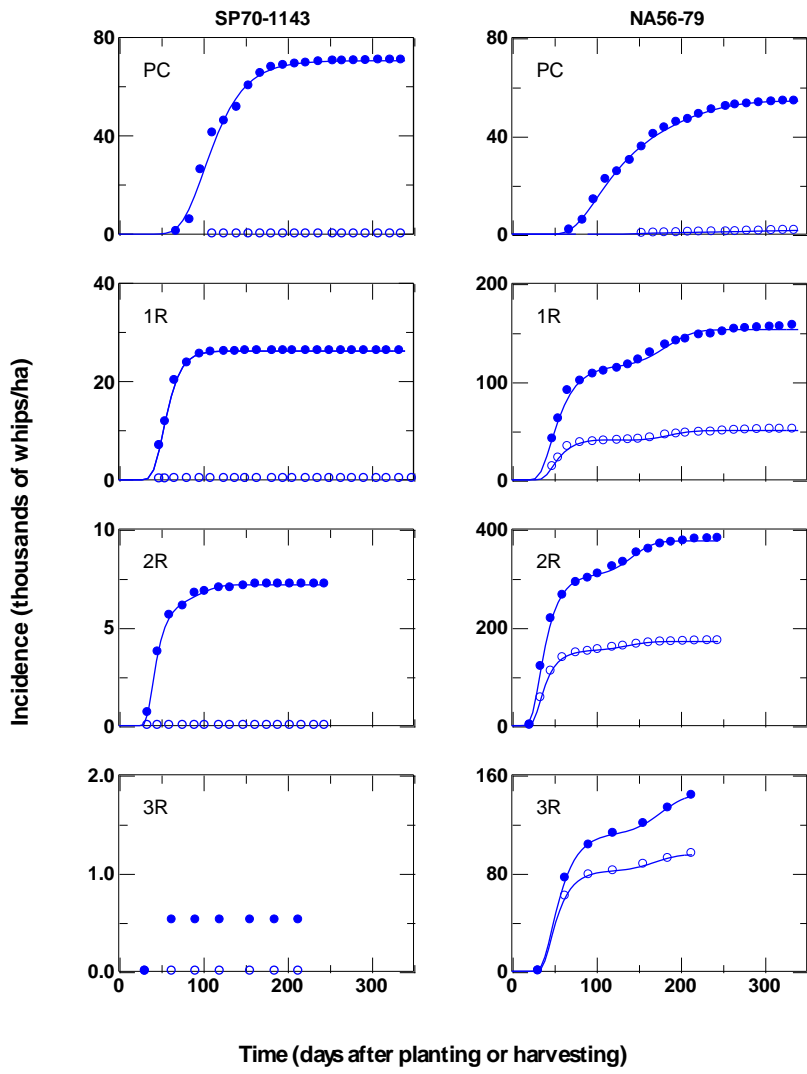


Resistência estrutural pré-formada em gemas de cana-de-açúcar

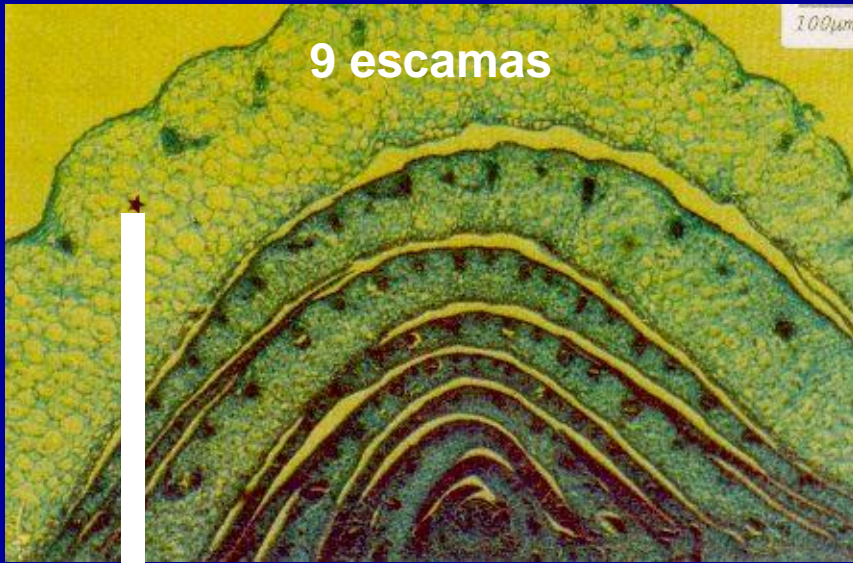




SP70-1143 e
NA56-79
inoculadas com
suspensão de
teliósporos sem
ferimentos nas
gemas



SP70-1143 e
NA56-79
inoculadas com
suspensão de
teliósporos sem
ferimentos nas
gemmas (círculos
vazios) ou após
(círculos cheios)
ferimentos nas
gemmas



9 escamas

100µm

SP70-1143



7 escamas

100µm

NA56-79



20µm

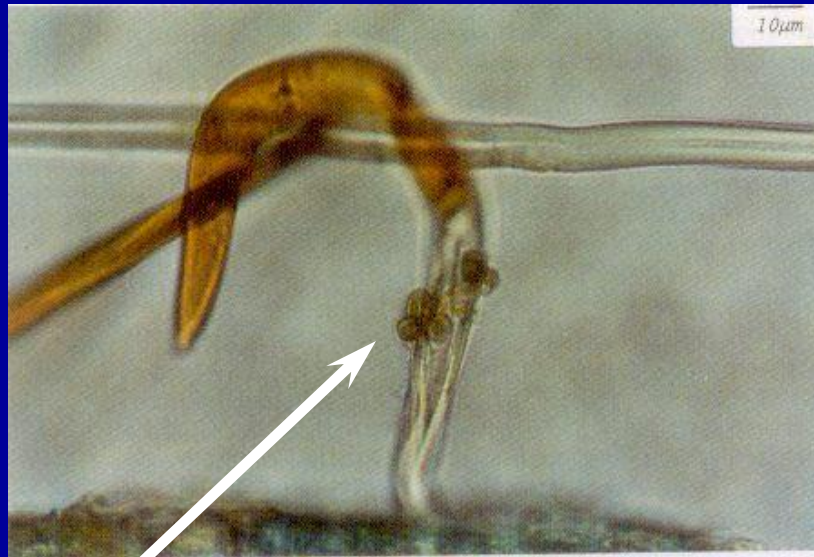
LIGNIFICAÇÃO DE PAREDES



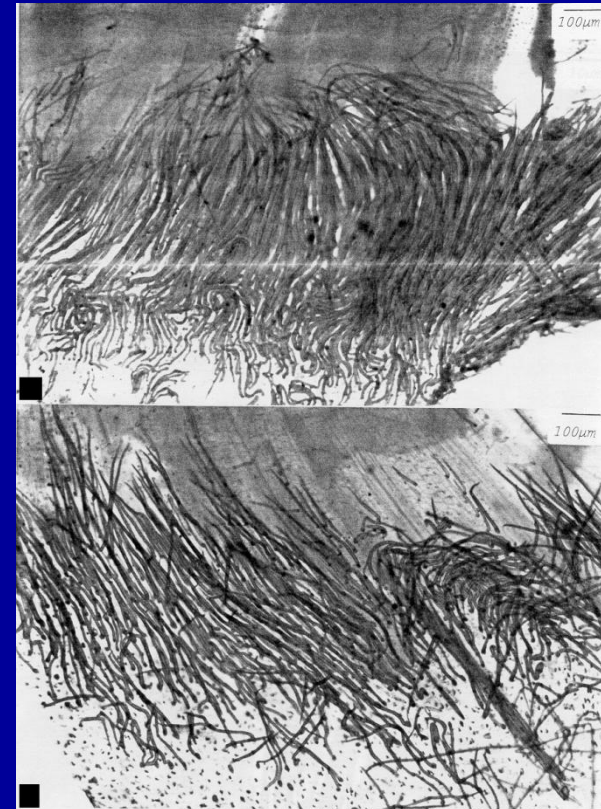
20µm

tricomas

SP70-1143
resistente ao carvão
316,6 tricomas/cm



teliósporos de *Sporisorium scitamineum*
(*Ustilago scitaminea*)



NA56-79
suscetível ao carvão
250,0 tricomas/cm

Epicuticular Wax and White Pine Blister Rust Resistance in Resistant and Susceptible Selections of Eastern White Pine (*Pinus strobus*)

Jason A. Smith, Robert A. Blanchette, Todd A. Burnes, Jeffrey H. Gillman, and Andrew J. David



Comparação de seleções de *Pinus* suscetíveis (H111 - A) e resistentes (P327 - B) à ferrugem branca (Smith et al., 2006)

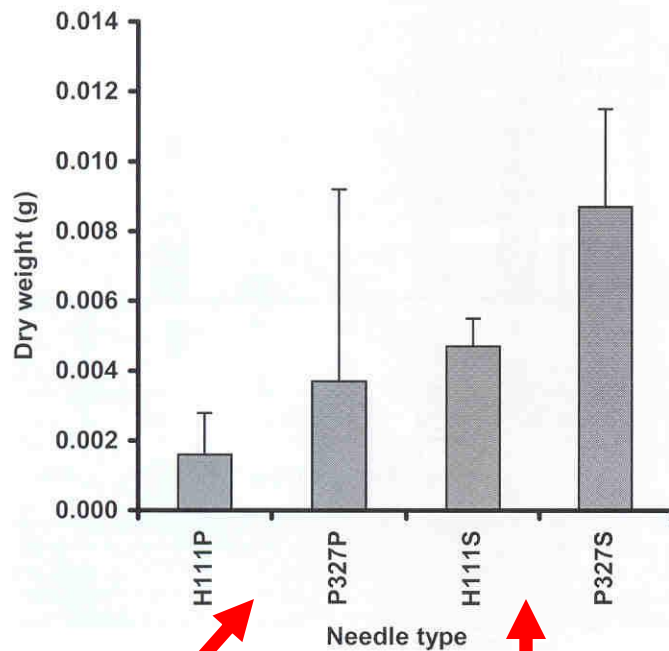


Fig. 1. Mean dry weight measurements (g) of needle wax removed from 1 g of primary (P) and secondary (S) needles from seedlings of selfed crosses of white pine blister rust-susceptible and -resistant *Pinus strobus* selections H111 and P327, respectively. Error bars represent standard deviation for each group.

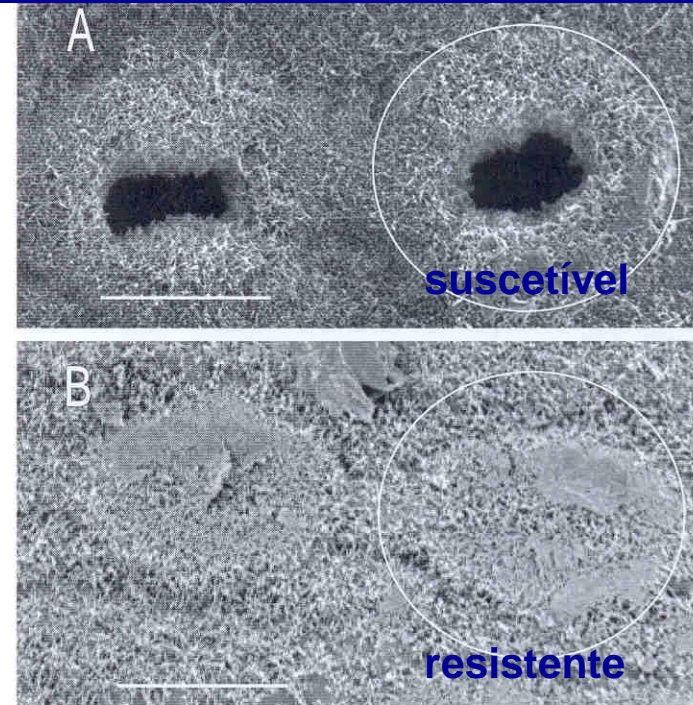
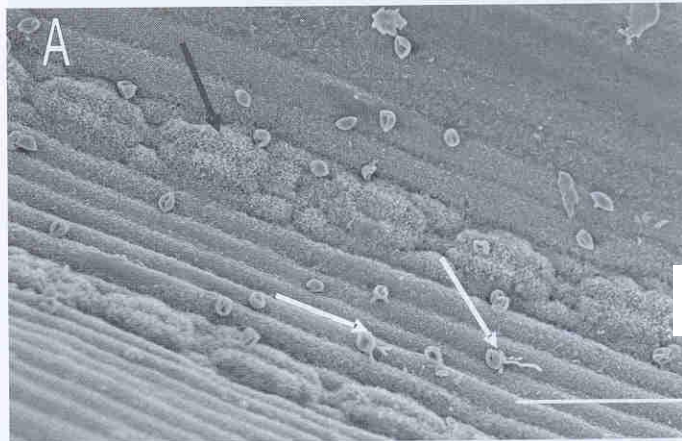


Fig. 2. Environmental scanning electron microscopy image of stomata of secondary needles of **A**, susceptible clone H111 (bar = 60 μ m) and **B**, resistant clone P327 (bar = 60 μ m). Notice the large opening to stomatal chamber and lack of wax occlusion in **A** and the complete wax occlusion of stomata in **B**. White circles provide outline of a stoma.

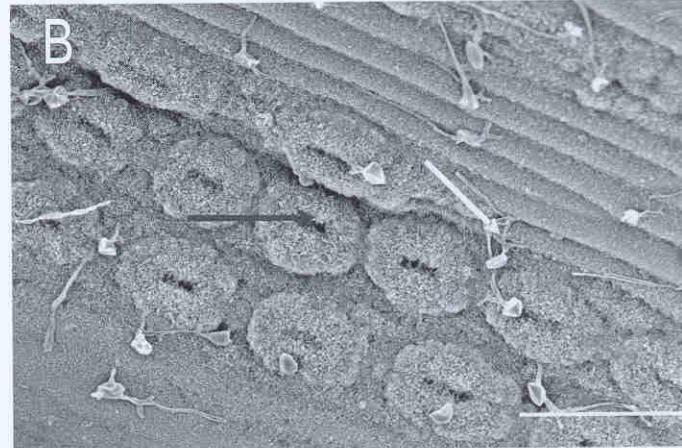
Acículas velhas

Acículas jovens

Comparação de seleções de *Pinus* suscetíveis (H111 - B) e resistentes (P327 - A) à ferrugem branca



resistente



suscetível

Fig. 6. Environmental scanning electron microscopy image of germinating basidiospores of *Cronartium ribicola* on primary needles from seedlings of **A**, resistant P327 x P327 (bar = 100 μ m) and **B**, susceptible H111 x H111 (bar = 100 μ m). Notice the few germinating spores with short germ tubes (white arrow) and the wax-occluded stomata (black arrow) in **A** and the numerous germinating spores with longer germ tubes (white arrow) and lack of wax occlusion of stomata (black arrow).

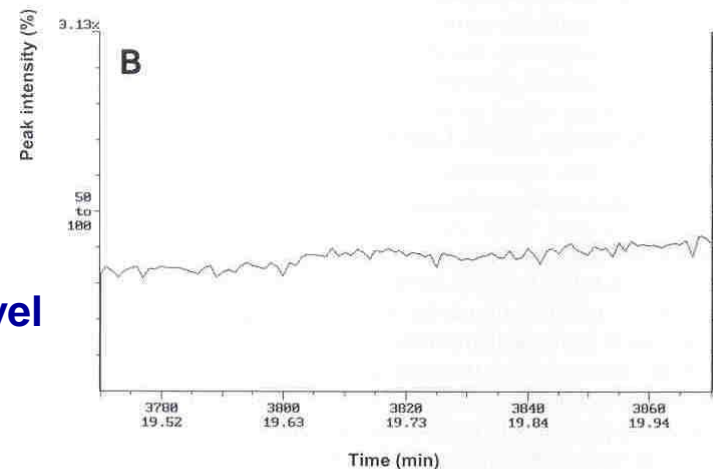
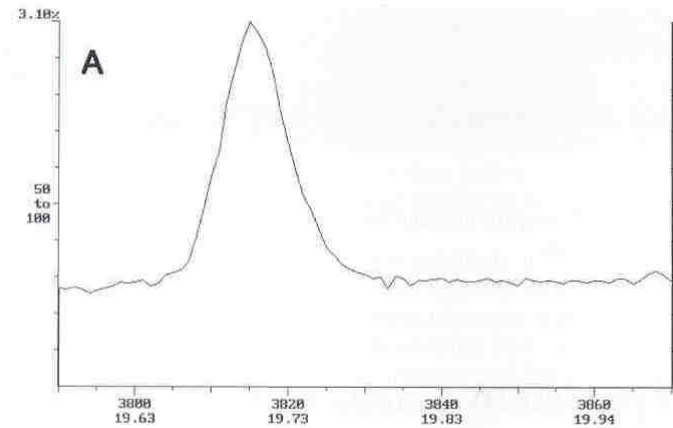


Fig. 9. Gas chromatography/mass spectrometry (GC/MS) chromatograms showing peak of a compound found in epidermal wax extracted from primary needles of **A**, resistant family P327, but not found in extracted wax from primary needles from **B**, susceptible family H111. GC/MS chromatograms using secondary needles provided similar results. x axis = time (minutes) and y axis = peak intensity.

Mecanismos de defesa pré-formados

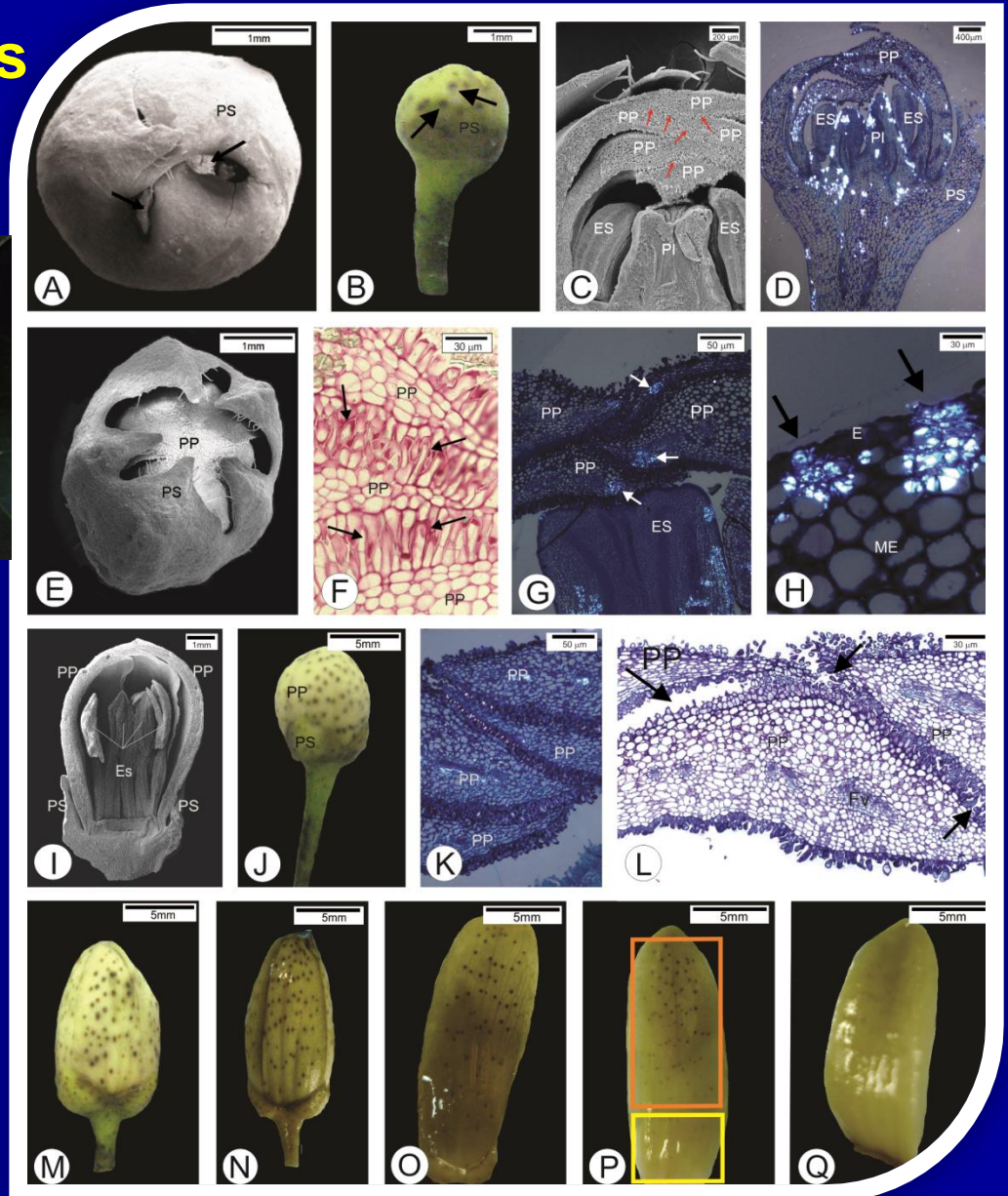
Podridão floral dos citros



Botões florais de *Citrus sinensis*

Resistência a *Colletotrichum acutatum* até 8 mm

Controle químico a partir de 8 mm



Mecanismos de defesa bioquímicos pré-formados

Compostos fenólicos

Taninos

Saponinas

Exsudatos fungitóxicos

Proteínas / peptídeos

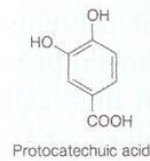
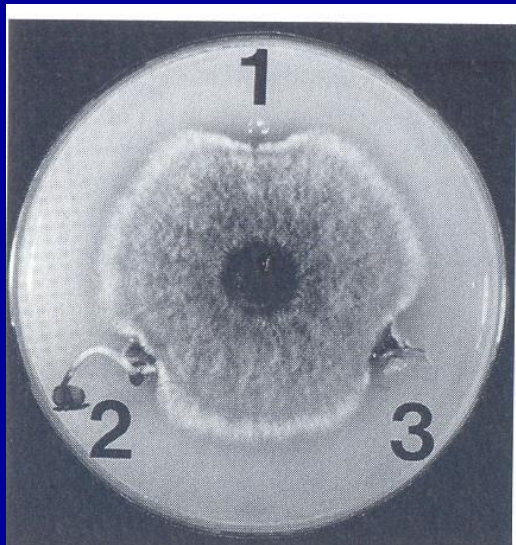


FIGURE 6-2 Onion smudge, caused by the fungus *Colletotrichum circinans*, develops on white onions but not on colored ones, which, in addition to the red or yellow pigment, also contain the phenolics protocatechuic acid and catechol, both of which are toxic to the fungus. (Photograph courtesy of G. W. Simone.)

Inibição do crescimento micelial por exsudatos de sementes e de raízes de rabanete

Mecanismos de defesa bioquímicos pré-formados

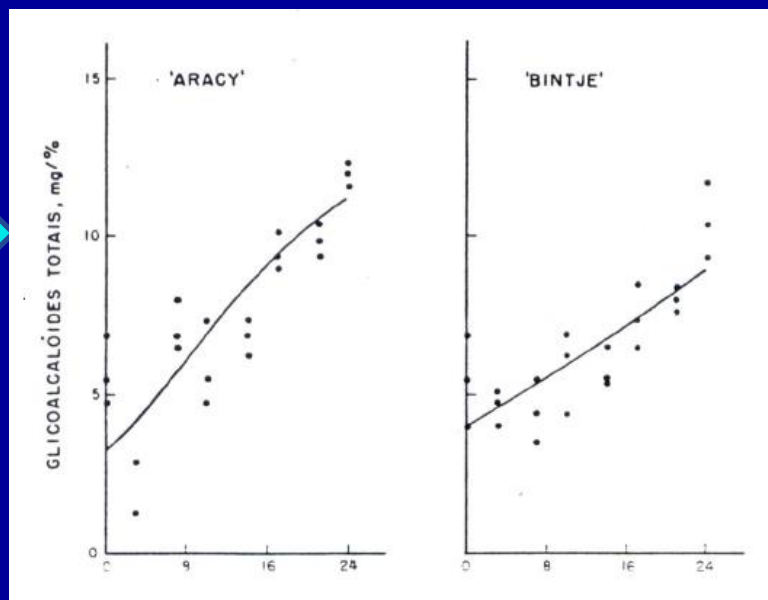
Tabela 35.1 - Exemplos de substâncias antimicrobianas pré-formadas envolvidas na resistência das plantas contra patógenos (modificado e adaptado de Mansfield, 1983).

Espécie vegetal	Substância	Forma ativa	Grupo químico*
<i>Acer platanoides</i> ("Norway maple")	Ácido gálico	-	Fenol
<i>Allium cepa</i> (cebola)	Ácido protocatecólico e catecol	-	Fenol
<i>Avena sativa</i> (aveia)	Avenacinas	-	Saponina triterpenóide
<i>Hordeum vulgare</i> (cevada)	Hordatinas	-	Derivados de cumaroilagmatina
<i>Triticum aestivum</i> (trigo)	Glicosídeo de dihidroximetoxibenzoxazinona (DIMBOA)	DIMBOA	Hidroxamato cíclico
<i>Lotus corniculatus</i> (cornichão)	Linamarina	Cianeto de hidrogênio	-
<i>Tulipa gesneriana</i> (tulipa)	Tuliposídeos A e B	Tulipalinas A/B	Lactona
<i>Malus sylvestris</i> (maçã)	Floridizina e floretina	<i>o</i> -Quinonas	-
<i>Pyrus communis</i> (pêra)	Arbutina	Hidroquinona	-
<i>Solanum lycopersicum</i> (tomate)	Tomatina	-	Saponina alcalóide
<i>Solanum tuberosum</i> (batata)	α -Solanina α -chaconina Ácidos clorogênico e caféico	-	Saponina alcalóide Fenol

Tabela 35.2 - Exemplos de proteínas e peptídeos anti-microbianos envolvidos na resistência das plantas contra patógenos.

Tipo	Atividade biológica
Quitinase; β -1,3-glucanase	Ação sobre componentes da parede celular do patógeno
Proteínas ligantes de quitina	Interferência na síntese da parede celular do patógeno
Tioninas / Defensinas	Desestabilização da membrana fúngica
Proteínas de transferência de lipídeos	Possivelmente desestabilização da membrana fúngica
Proteínas inativadoras de ribossomos	Inibição da elongação de peptídeos
Lisozima	Digestão dos polímeros da parede celular bacteriana
Inibidores de proteases	Inibição de enzimas digestivas de pragas e patógenos
Inibidores de poligalacturonase	Inibição da ação de poligalacturonases

Teores de alcalóides em tubérculos de batata mantidos sob luz durante 24 dias



Mecanismos de defesa pós-formados

CELULAR

- Papilas (lignina, fenóis, silício, celulose..)
- Lignificação (polímero tridimensional)
- Glicoproteínas ricas em hidroxiprolina (GPRHP)

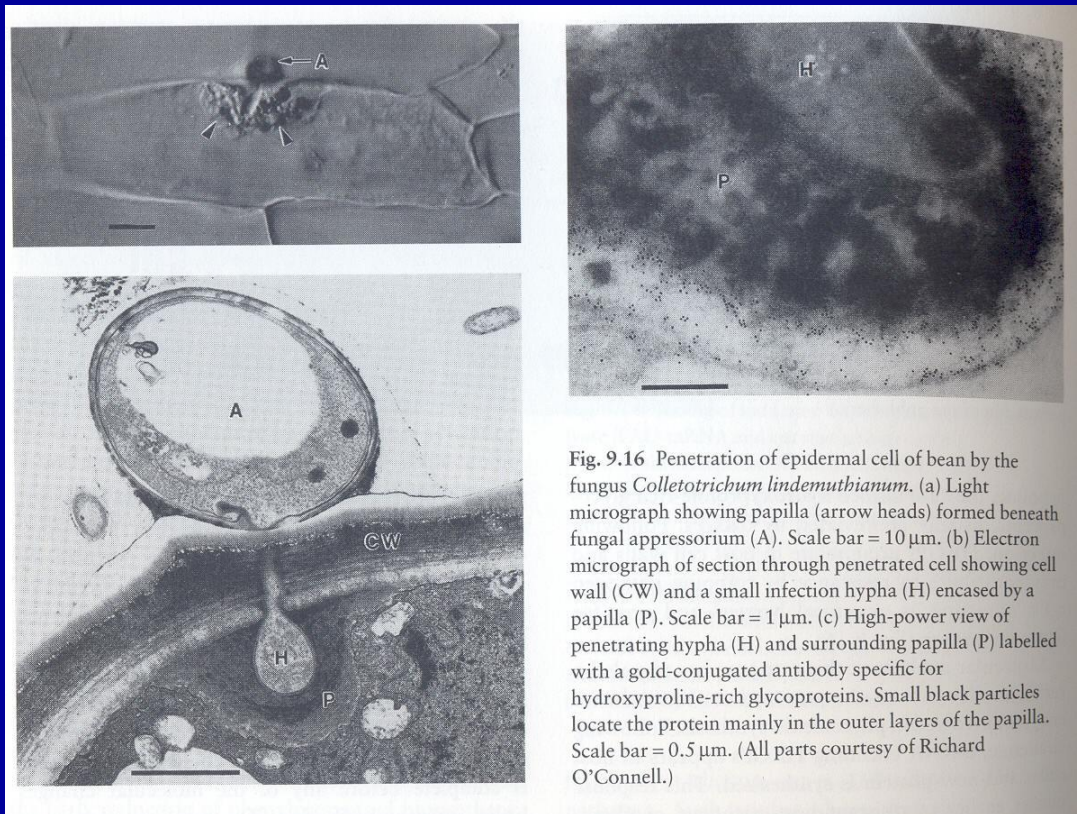
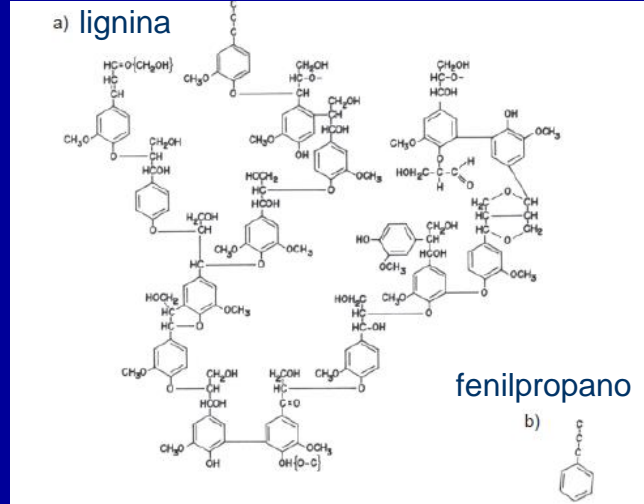


Fig. 9.16 Penetration of epidermal cell of bean by the fungus *Colletotrichum lindemuthianum*. (a) Light micrograph showing papilla (arrow heads) formed beneath fungal appressorium (A). Scale bar = 10 µm. (b) Electron micrograph of section through penetrated cell showing cell wall (CW) and a small infection hypha (H) encased by a papilla (P). Scale bar = 1 µm. (c) High-power view of penetrating hypha (H) and surrounding papilla (P) labelled with a gold-conjugated antibody specific for hydroxyproline-rich glycoproteins. Small black particles locate the protein mainly in the outer layers of the papilla. Scale bar = 0.5 µm. (All parts courtesy of Richard O'Connell.)

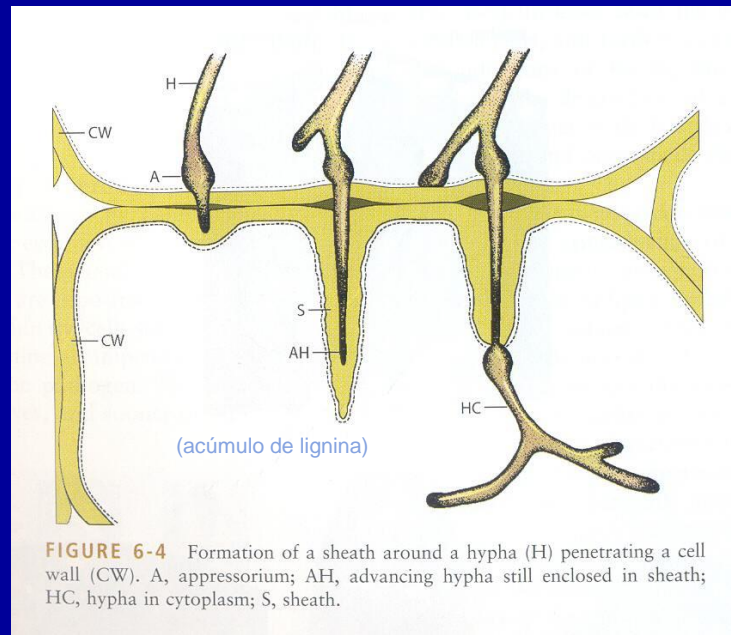
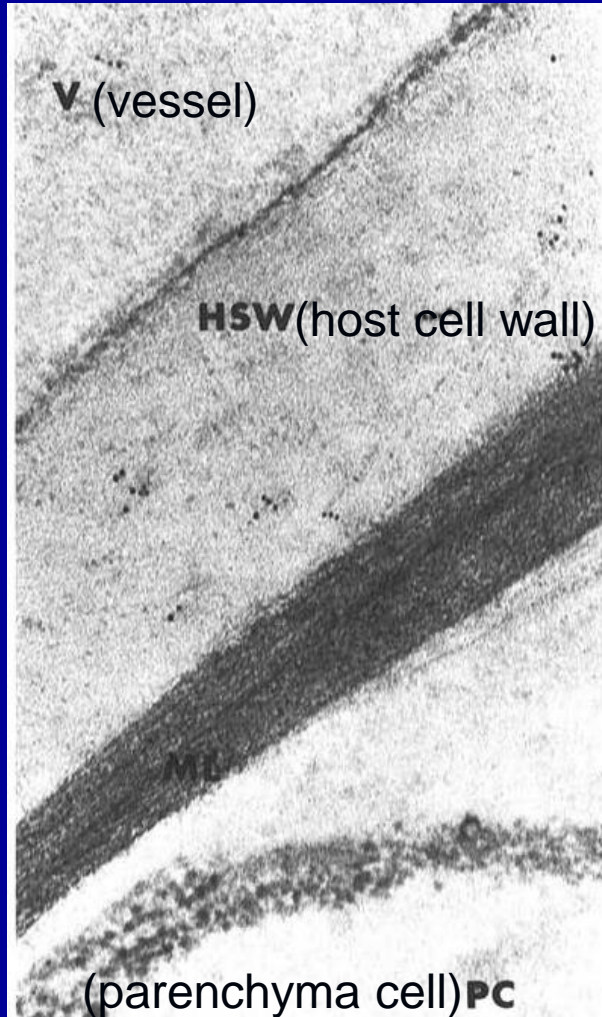


FIGURE 6-4 Formation of a sheath around a hypha (H) penetrating a cell wall (CW). A, appressorium; AH, advancing hypha still enclosed in sheath; HC, hypha in cytoplasm; S, sheath.

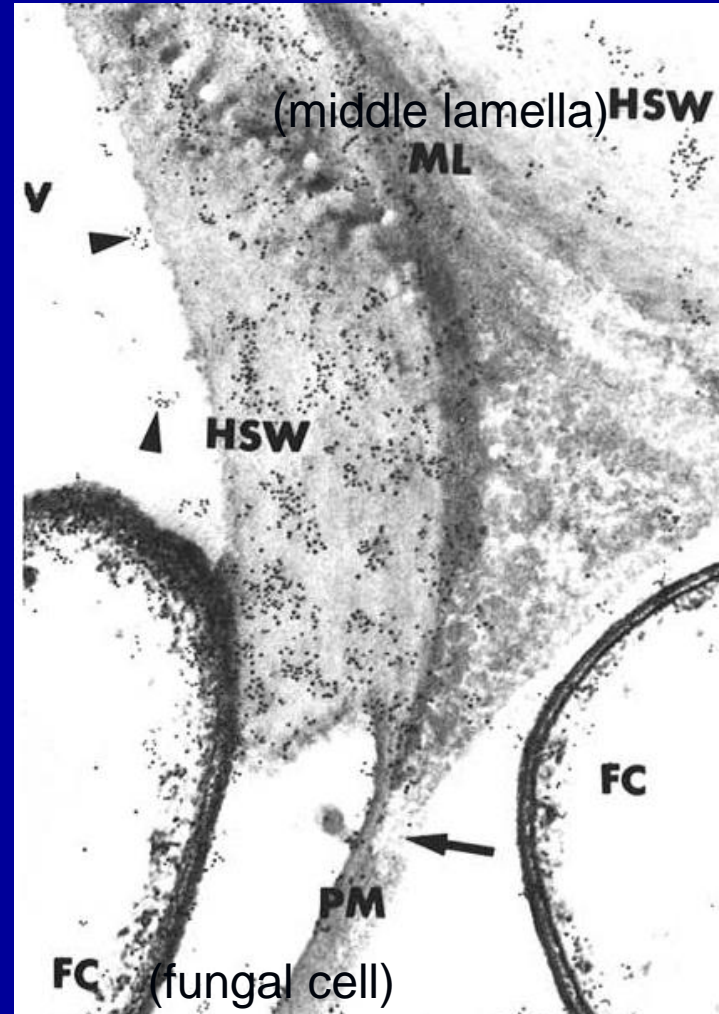
Mecanismos de defesa pós-formados

Glicoproteínas ricas em hidroxilprolinas: marcação com ouro em anticorpo raízes de tomate infectadas com *F. oxysporum*

Não inoculadas



120 h após inoculação



Mecanismos de defesa pós-formados

HISTOLÓGICO { Cortiça
Abcisão
Tilose

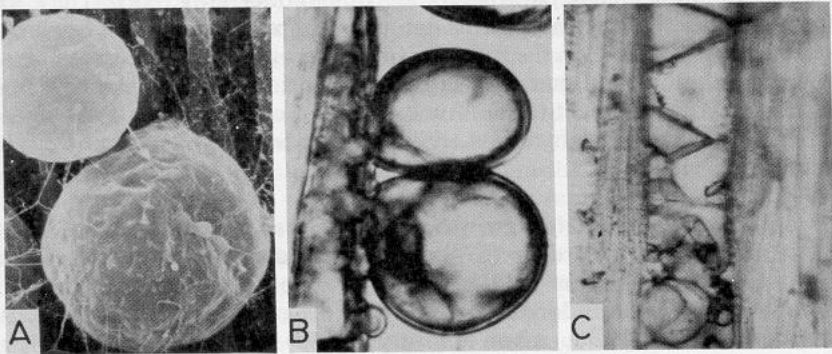


Fig. 16. The development of tyloses. **A**, Scanning electron micrograph of small tyloses emerging from pits in the scalariform wall of a *Fusarium*-infected vessel in the root of a resistant banana plant. **B**, Light micrograph of tyloses arising from a contact cell and protruding through pits into the lumen of a *Verticillium*-infected vessel in a hop plant. **C**, Tyloses immediately above an inoculum-trapping site in a vessel of the hypocotyl of a *Fusarium*-resistant tomato plant (cultivar Improved Pearson VF-11), 48 hr after inoculation with *F. oxysporum* f. sp. *lycopersici* race 1. The developing tyloses are globose; the angular shapes are tyloses that have completed their growth and have fused to form a tissue that walls off the vessel above the infection. A courtesy of G. E. VanderMolen; B reprinted, by permission, from Talboys (542), Fig. 4; C reprinted, by permission, from Beckman et al (50), Fig. 1C.

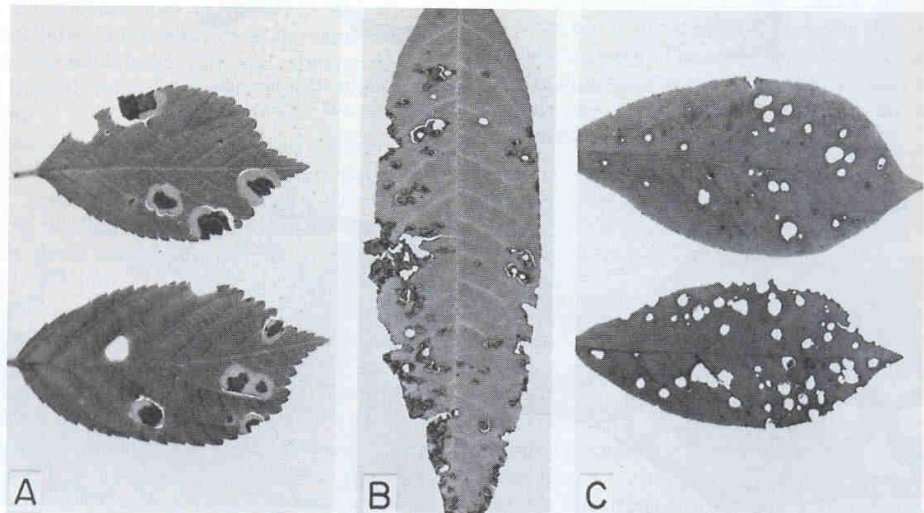
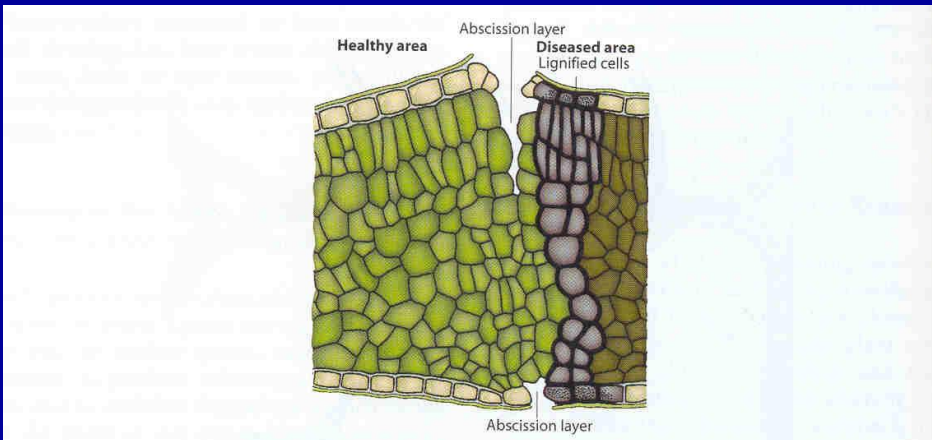


FIGURE 6-7 Schematic formation of an abscission layer around a diseased spot of a *Prunus* leaf. [After Samuel (1927).] (A–C) Leaf spots and shot holes caused by *Xanthomonas arboricola* pv. *pruni* bacteria on (A) ornamental cherry leaves; characteristic broad, light green halos form around the infected area before all affected tissue falls off, (B) on peach, and (C) on plum. The shot hole effect is particularly obvious on the plum leaves.

Mecanismos histológico de defesa pós-formados

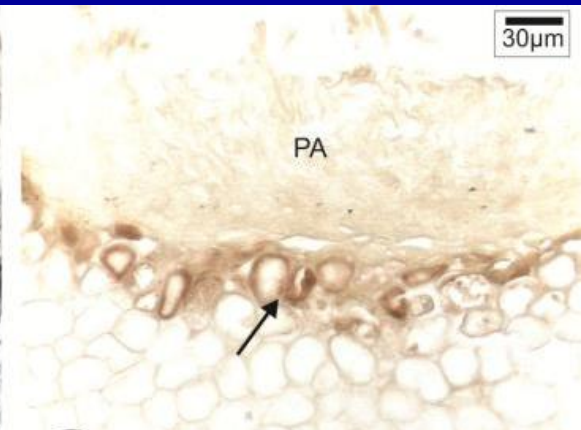
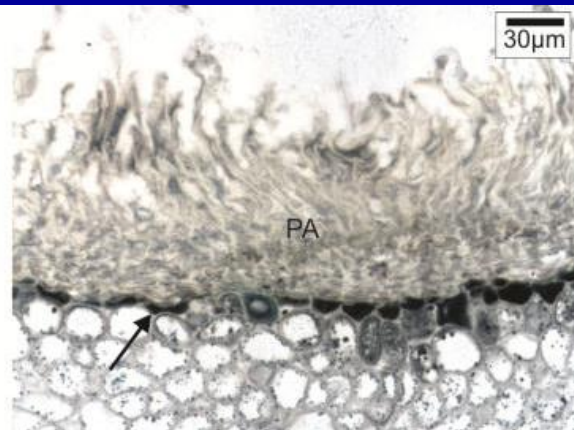
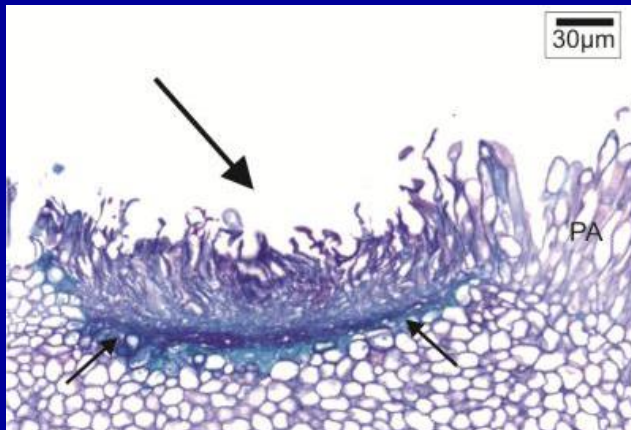
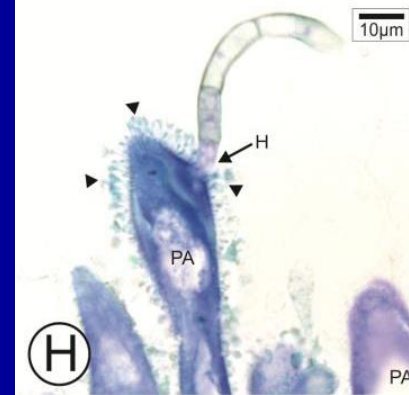
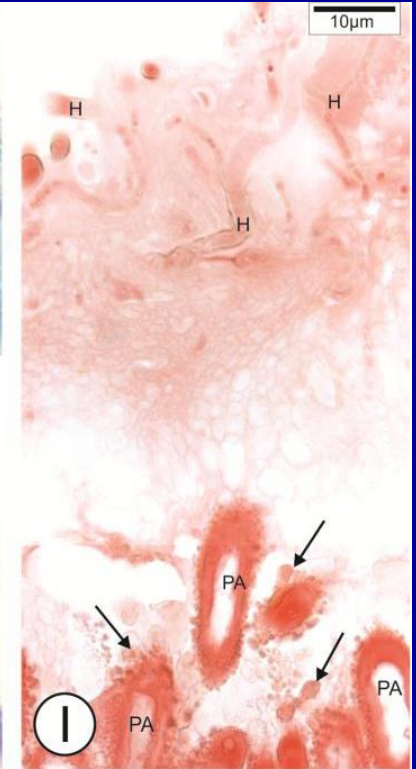
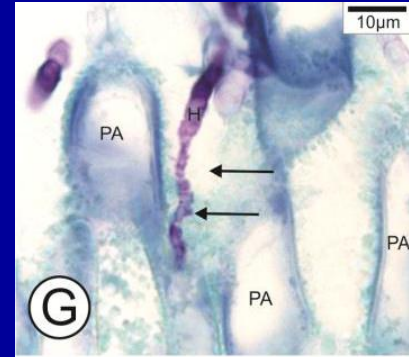
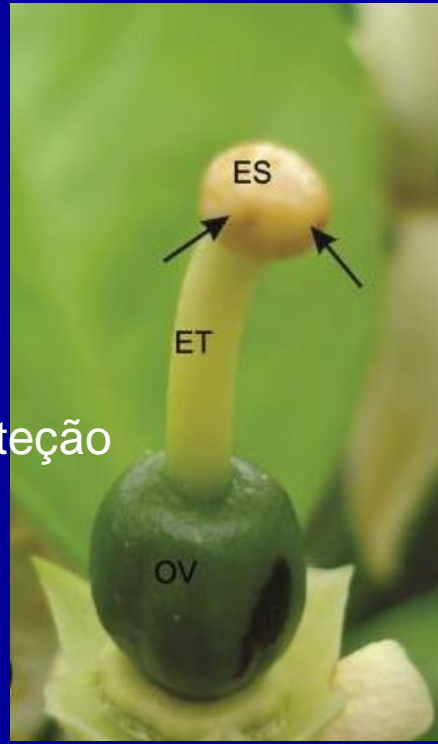
Colletotrichum acutatum

Estigma de citros

Secreções das papilas
(G, H, I)

Camada celular de proteção

Acúmulo de fenóis



Mecanismos bioquímicos de defesa pós-formados

- PR PROTEÍNAS – Proteínas relacionadas à patogênese
- Presentes na parede celular (baixa concentração)
- Produzidas após estímulo
- Quitinase, beta 1-3 glucanase, proteinase, etc.

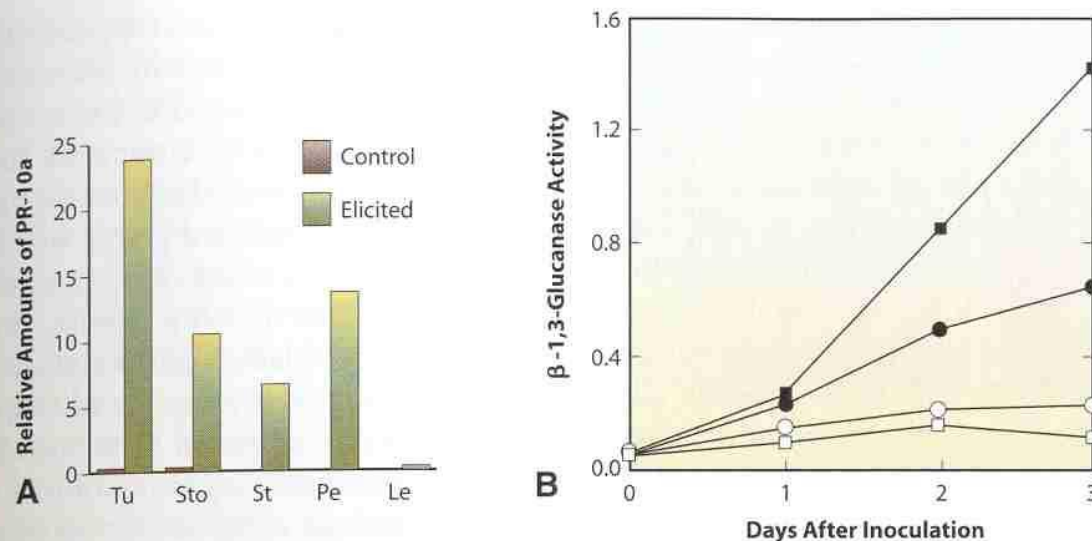


FIGURE 6-18 (A) Production and accumulation of a pathogenesis-related protein (PR10a) in potato tissues either untreated (control) or elicited by treating cut surfaces with a homogenate of the late blight fungus *Phytophthora infestans* and incubating for 4 days. Tu, tuber; Sto, stolon; St, stem; Pe, petiole; Le, leaf. [From Constabel and Brisson (1995). *Mol. Plant-Microbe Interact.* 8, 104–113.] (B) Levels of activity of the antifungal protein β -1,3-glucanase in the intercellular fluid of barley leaves, either left uninoculated (\square , \circ) or inoculated with the powdery mildew fungus *Erysiphe graminis* f. sp. *hordei* (\blacksquare , \bullet). The two barley varieties are nearly isogenic, except that one (\square , \blacksquare) carries an additional resistance gene that makes it resistant, whereas the other (\circ , \bullet) is susceptible. [From Jutidamrongphan *et al.* (1991). *Mol. Plant-Microbe Interact.* 4, 234–238.]

Mecanismos bioquímicos de defesa pós-formados

Fitoalexinas - compostos antimicrobianos de baixa massa molecular, sintetizados e acumulados nas células vegetais em resposta à infecção microbiana.

- 350 já identificadas
- Composição química diversa
- Produzida por 31 famílias botânicas
- Induzida por eliciadores ou indutores bióticos ou abióticos
- Produzidas por diferentes vias metabólicas
- Ação na membrana plasmática e metabolismo respiratório amplo espectro

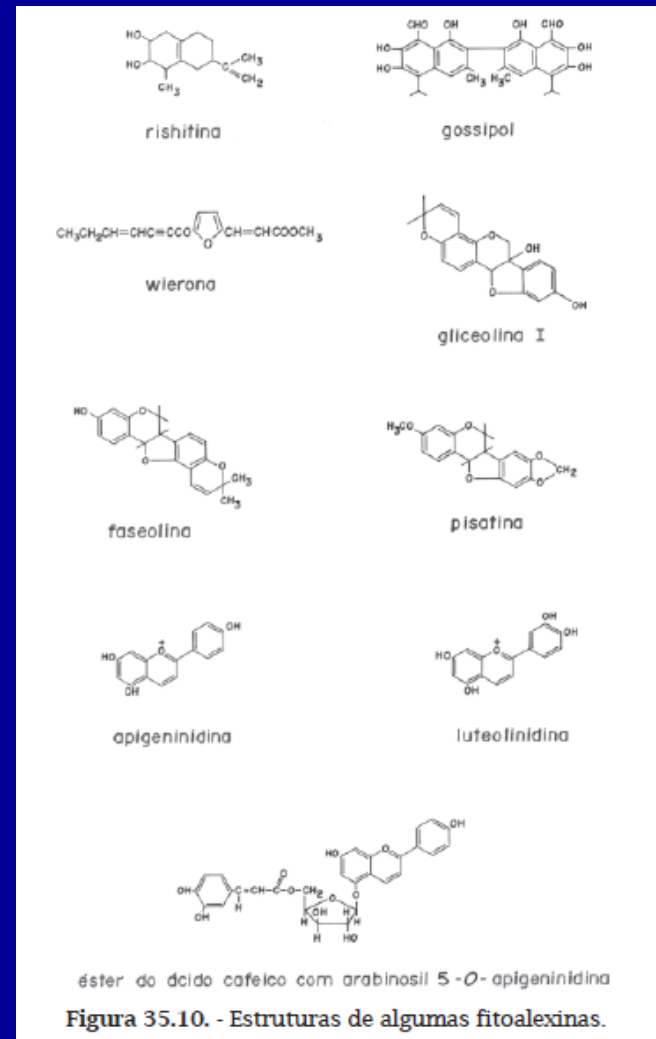
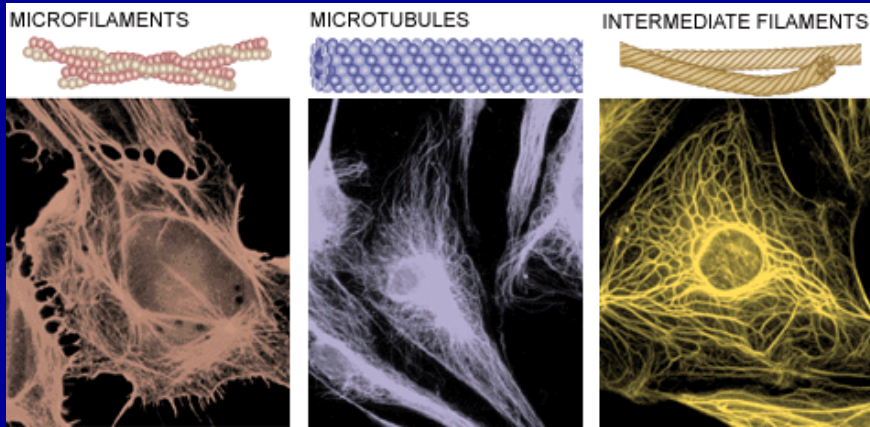


Figura 35.10. - Estruturas de algumas fitoalexinas.



Resposta de hipersensibilidade

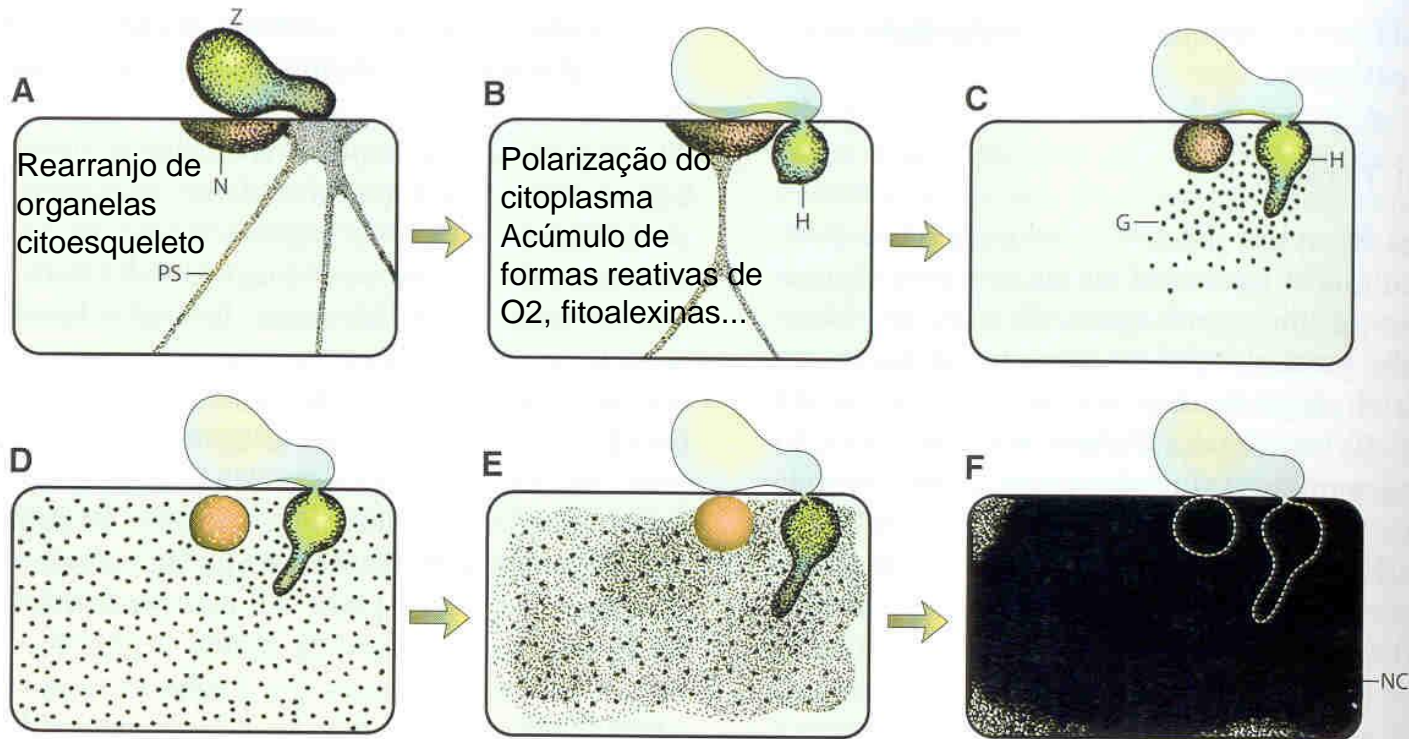


FIGURE 6-9 Stages in the development of the necrotic defense reaction in a cell of a very resistant potato variety infected by *Phytophthora infestans*. N, nucleus; PS, protoplasmic strands; Z, zoospore; H, hypha; G, granular material; NC, necrotic cell. [After Tomiyama (1956). *Ann. Phytopathol. Soc. Jpn.* 21, 54-62.]