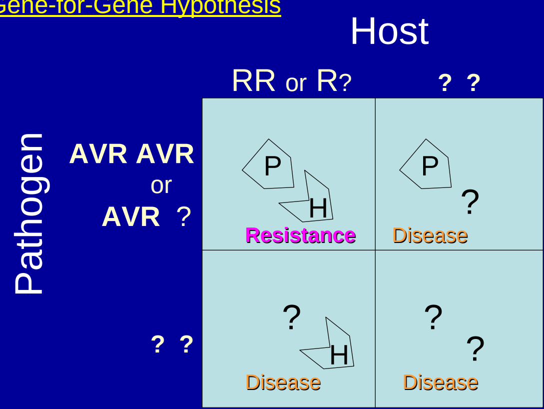
Gene-for-Gene Hypothesis



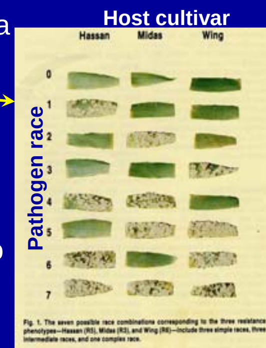
Specific recognition in upper left box only

How many races?

Three cultivars, each with a different R gene yields 8 races (2^3)

Ten cultivars, each with a different R gene could discern a possible 1024 races (2^{10}) !!

The set of cultivars used to characterize races is called a 'differential set'



A common test question:

For each of the boxes, indicate whether or not the races of a rust pathogen will succeed in infecting the host cultivars

Avirulence (A) or lack-of-avirulence (? or 'a') genes possessed

Resistance (R) or lack-of-resistance (? or 'r') genes in each cultivar

Race:	$A_1A_2A_3A_4$	$A_1a_2A_3A_4$	$a_1A_2A_3A_4$	$a_1a_2A_3A_4$	$a_1a_2a_3a_4$
$r_1r_2r_3r_4$					
$R_1r_2r_3r_4$					
$r_1R_2r_3r_4$					
$R_1R_2r_3r_4$					
$R_1R_2r_3R_4$					

'R', 'A' = active product present '?', 'a', 'r' = active product absent

A common test question:

For each of the boxes, indicate whether or not the races of a rust pathogen will succeed in infecting the host cultivars

Avirulence (A) or lack-of-avirulence (? or 'a') genes possessed

Resistance (R) or lack-of-resistance (? or 'r') genes in each cultivar

Race:	$A_1A_2A_3A_4$	$A_1a_2A_3A_4$	$a_1A_2A_3A_4$	$a_1a_2A_3A_4$	$a_1a_2a_3a_4$
$r_1r_2r_3r_4$	yes	yes	yes	yes	yes
$R_1r_2r_3r_4$	no	no	yes	yes	yes
$r_1R_2r_3r_4$	no	yes	no	yes	yes
$R_1R_2r_3r_4$	no	no	no	yes	yes
$R_1R_2r_3R_4$	no	no	no	no	yes

'R', 'A' = active product present '?', 'a', 'r' = active product absent

Where do we see R-gene resistance used?

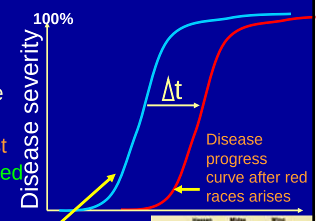
Obligate biothrophs
- rusts (cereals, pine, flax, coffee, corn)
- smuts (cereals, corn)
- eastern filbert blight (Oregon hazelnuts)
- downy mildews (sunflower, lettuce, crucifers)
- powdery mildews (cereals, cucurbits)
- viruses (many crops)
- nematodes: sedentary endoparasites (tomato, cereals)

Facultative saprophytes
- apple scab
- bacterial leaf spots (legumes, cotton, arabidopsis)
- ascomycete leaf spots (rice, tomato, bean)
- vascular wilts (crucifers, tomato, banana)
- oomycetes - root rot (soybean), late blight (potato)

Host resistance & **Disease dynamics**

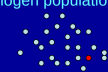
Qualitative,
race-specific resistance

Reduces initial inoculum because only a subset of pathogen genotypes (in the beginning, most if not all) are specifically recognized

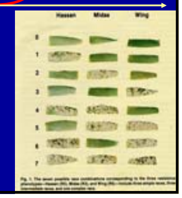


Disease progress curve prior to Introduction of blue race R-gene

Pathogen population



After introduction of the R-gene, the 'Blue' race is recognized but red race is not. Frequently, the red race arises later via mutation



Host resistance & **Disease dynamics**

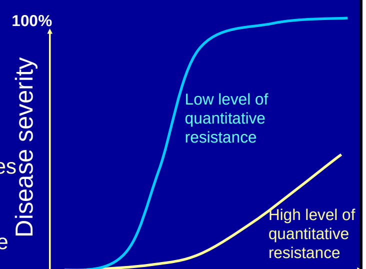
Quantitative, non-race specific resistance

Reduces the infection rate

Slows how rapidly disease develops

Is effective against all isolates of the pathogen

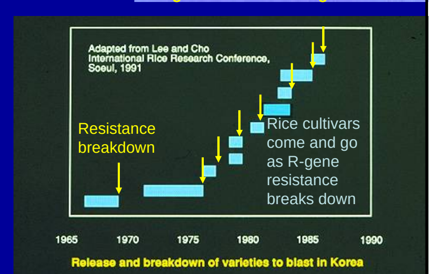
Generally, it lasts a long time



Major gene (R-gene) resistance:

Upside: simply inherited and extremely effective 🙂

Downside: 🙁
it breaks down when pathogen loses its *elicitor* (i.e., stops making the AVR gene product)



= period of time R-gene resistance was effective

Smart deployment of Race specific resistance:

R-Gene pyramids

(I.e., use of multiple, effective R genes simultaneously)

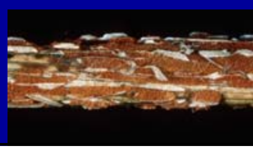
R6

R4 R5

R1 R2 R3

Theory: If a mutation from AVR1 (recognized) to avr1 (i.e., no ***elicitor***) occurs once every 10^8 to 10^{10} asexual spores, then a simultaneous mutation from $AVR_1, AVR_2, \ldots, AVR_6$ to $avr_1, avr_2, \ldots, avr_6$ will be a very, very rare event.

R-Gene pyramids have been highly effective for control of cereal rusts

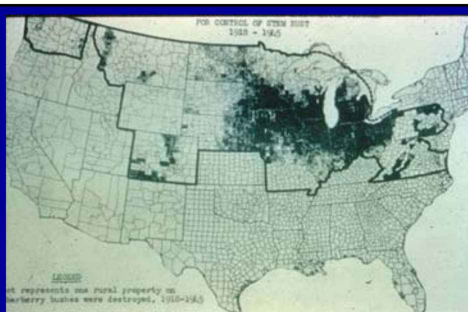


Smart deployment of race specific resistance:

What is this man doing?

Hints:

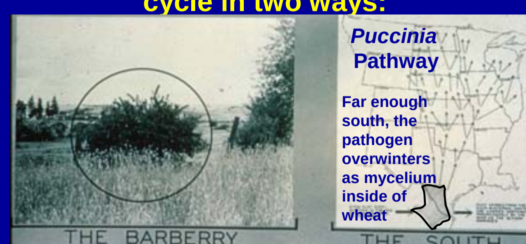
- He works for the government
- The white stuff is NaCl
- The bush is *Berberis vulgaris*



Between 1918 and 1975, under the direction of the federal government, more than 100 million bushes of *Berberis*, *Mahonia* and *Mahoberis* spp. were killed in 16 Northern wheat-growing states. The program was stopped in 1975.

Recently (2003), common barberry has begun a resurgence.

Stem rust of wheat can turn its primary cycle in two ways:



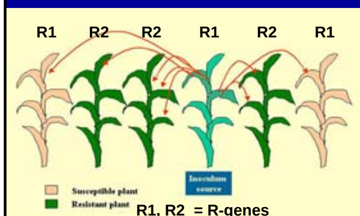
Why was/is eradication of barberry so important?

Elimination of meiosis greatly(!) slows genesis of new races

Take home message:

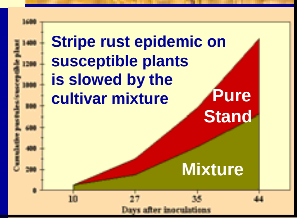
Everything else being equal, asexual pathogens are better candidates for suppression by R-genes than those frequently recombining their genomes

R-Gene Deployment - Cultivar Mixtures



Mechanisms of suppression:
Dilution of inoculum
Resistant plants are dispersal barriers
Avirulent spores induce SAR

Works best with polycyclic, foliar diseases of 'skinny' plants (rusts or powdery mildew of cereals)



Lecture: Considerations in breeding for and managing host resistance

Avoiding loss of R-gene resistance

- pathogen's life cycle
  polycyclic ☹ vs monocyclic ☺
- pathogen's genetics
  meiosis ☹, high mutation rates ☹
- Longevity of host plant
  ↓ ☺ ↑ ☹
- Ease of deploying multiple R-genes
  gene pyramids ☺
  cultivar mixtures

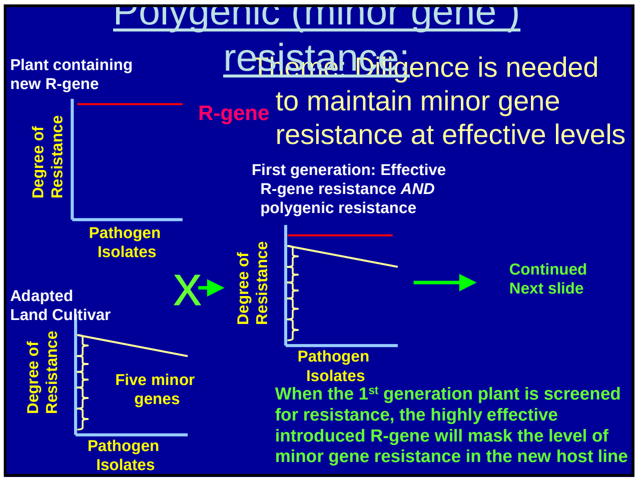
Maintaining effective minor gene resistance

- host exposed to maximum pathogen diversity? ☺
- yield/quality evaluated and maintained under conditions most favorable for disease? ☺
- continued diligent, field-based screening and marker-assisted selection during breeding efforts ☺

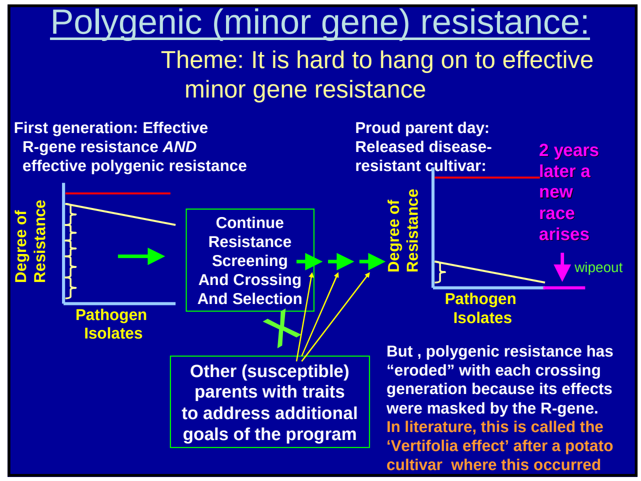
Breeding for Minor gene (polygenic) resistance

It is important to expose the potential cultivar to
the extremes of pathogen diversity for a significant period of time

Oat lines are grown in a 'pathogen brothel'.
Those **completely** resistant or extremely susceptible are thrown away.
Those that yield well with a bit of disease stay with the program. ☺



Polygenic (minor gene) resistance:
Theme: Diligence is needed to maintain minor gene resistance at effective levels
Plant containing new R-gene
R-gene
Degree of Resistance
Pathogen Isolates
Adapted Land Cultivar
X
Five minor genes
Degree of Resistance
Pathogen Isolates
First generation: Effective R-gene resistance AND polygenic resistance
Degree of Resistance
Pathogen Isolates
Continued Next slide
When the 1st generation plant is screened for resistance, the highly effective introduced R-gene will mask the level of minor gene resistance in the new host line



Polygenic (minor gene) resistance:
Theme: It is hard to hang on to effective minor gene resistance
First generation: Effective R-gene resistance AND effective polygenic resistance
Degree of Resistance
Pathogen Isolates
Continue Resistance Screening And Crossing And Selection
X
Other (susceptible) parents with traits to address additional goals of the program
Proud parent day: Released disease-resistant cultivar:
2 years later a new race arises
wipeout
Degree of Resistance
Pathogen Isolates
But , polygenic resistance has "eroded" with each crossing generation because its effects were masked by the R-gene.
In literature, this is called the 'Vertifolia effect' after a potato cultivar where this occurred