Cultivation Insights

# Plant Disease Resistance

- Plant disease resistance is one of the best ways to manage plant diseases.
- Both race specific and non-race specific forms of resistance are available for many diseases.
- Resistance can prevent infection or slow the development and spread of disease.

## What is plant disease resistance?

Plant disease resistance is one of the most effective, inexpensive, and environmentally sound means for managing plant diseases.[1] The term resistance is defined as "the ability of a plant variety to restrict the growth and/or development of a specified pest and/or the damage it causes when compared to susceptible plant varieties under similar environmental conditions and pest pressure."[2] Remember that all plants are resistant to most pathogens. That is to say that a tomato plant will not be infected by the fungal pathogen that causes common rust on corn or the bacterial pathogen that causes fruit blotch on watermelon. This is called non-host resistance.[3]

Plants can exhibit a range of reactions from fully susceptible to immune for the pathogens of which they are a host. Many vegetable seed companies use the terms High Resistance (HR) and Intermediate Resistance (IR) to designate the resistance reactions of their varieties based on guidelines from the International Seed Federation (ISF).[2] High Resistance describes plants that highly restrict the growth and/or development of a pathogen and/or the damage it causes under normal pest pressure compared to susceptible varieties (Figure 1). HR varieties can still show some symptoms or damage from the disease. Intermediate Resistance varieties restrict the growth and/or development of a pathogen and/or the damage it causes but may show more severe symptoms or damage than High Resistance varieties. Plants with Intermediate Resistance will usually show less severe symptoms or damage than susceptible plant varieties when grown under similar environmental conditions and disease pressure.[2]

*Figure 1. Tomato varieties with susceptible (left) and High Resistant (right) reactiions to powdery mildew infection.*

The ISF recommends the use of a standard system for indicating the specific races or strains of a pathogen to which a variety is resistant. For example, the designation Fol:1,2,3 indicates that a tomato variety is resistant to races 1, 2, and 3 of the Fusarium wilt pathogen *Fusarium oxysporum* f. sp. *lycopersici*. The resistance of a variety is usually compared to a standardized set of cultivars that define the range of known susceptible and resistant reactions to that disease. The lists of differential cultivars and the protocols for evaluating resistance are also provided by the ISF.[2]

## Types of Disease Resistance

Disease resistance traits can be categorized based on the number of host genes involved and the effectiveness against different races or strains of the pathogen. Race non-specific resistance, also called polygenic, partial, quantitative, and horizontal resistance, is effective against all races/strains of the pathogen at about the same level, and it is often controlled by several resistance genes. This type of resistance usually slows the rate of disease development and spread rather than preventing infection. Race non-specific resistance is often more durable than race-specific types of resistance, meaning that it is less likely that new strains of the pathogen will develop that can overcome the resistance.[3]

Race-specific resistance, also called R-gene resistance, monogenic, qualitative, and vertical resistance, is usually controlled by one or a few resistance genes and can be more effective against some races/strains of the pathogen and less effective (or not effective) against others.[3] The resistance genes (*R* genes) often work by allowing the plant to detect specific substances, called effectors, produced by the pathogen. When the effectors are detected, the plant cells' metabolic defense mechanisms are activated, helping the plant prevent or suppress infection by the pathogen.[1,4]

The pathogen effector molecules (usually proteins) are the product of avirulence (*avr*) genes in the pathogen, and they are detected by plants that contain the corresponding *R* genes for resistance. This form of disease resistance fits what is called the gene-for-gene model. If the plant has the correct *R* gene and the pathogen has the corresponding *avr* gene, the plant detects the pathogen, which triggers the defense mechanisms that stop disease development; a resistant reaction. If the pathogen lacks the corresponding *avr* gene or the plant lacks the correct *R* gene, then the pathogen is not detected by the plant, and disease occurs; a susceptible reaction.[1,4] The gene-for-gene model explains how new pathogen races can develop. If the *avr* gene in the pathogen changes (mutates) to the point where the R gene

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products no longer recognize the resulting effector molecule, then the presence of the pathogen will not trigger the defense system, and the resistance will no longer be effective.

Most of the gene-for-gene type resistance systems result in what is called a hypersensitive response in the plant. With a hypersensitive system, the plant cells near the point of infection undergo programmed cell death to disrupt the disease process. The plant cells may release substances that inactivate toxins produced by the pathogen or have antimicrobial effects on the pathogen. Some of these same defense systems are activated in susceptible varieties of plants, but the activation is delayed or takes place more slowly, allowing infection by the pathogen.[1] Race specific resistance can convey immunity or near immunity to a disease, or it can reduce the level of disease incidence and/or severity. However, as with race non-specific resistance, some symptoms may develop with an *R* gene resistance reaction (Figure 2). Race specific and non-race specific forms of resistance can be combined in the same variety to provide the benefits of both types of resistance.

## *Developing Resistant Varieties*

Both race specific and non-race specific resistance genes can be found in a number of sources, including native or foreign commercial varieties, older varieties, abandoned or discarded breeder's stock, and wild plant relatives. Resistance may also develop through the mutation of genes in existing varieties. Once resistance genes have been identified, they have to be transferred into commercially acceptable varieties that have the other characteristics desired by growers and consumers. This can be done using classical plant breeding, molecular genetic techniques, or both.[3]


*Figure 2. Lines of peppers that are resistant (A) and susceptible (B) to cucumber mosic virus (CMV).*

With classical plant breeding, a resistant plant is mated with a susceptible breeding line, and the resulting offspring of that cross are screened for the resistance trait following inoculation with a virulent pathogen under conditions favorable for disease development (Figure 2). The resistant offspring are then backcrossed to the susceptible breeding line several times to develop a line that has the desirable characteristics of the breeding line as well as the disease-resistant trait. This process is easier to accomplish with monogenic forms of resistance, but it is also used to transfer polygenic forms of resistance. The process can be speeded up by the use of marker-assisted selection. If the resistance trait is associated with a known genetic marker, then looking for the genetic marker in tissue taken from seeds or seedlings can eliminate the need for disease screening through inoculation during the backcrossing stages. The final product still needs to be evaluated following inoculation to ensure that the resistance trait has been transferred.[3]

Using molecular genetic techniques (genetic engineering) eliminates the need to cross resistant and susceptible plants. Laboratory techniques are used to extract the resistance gene(s) from a source and then transfer those genes into the genome of a desired plant variety. The transformed plant then needs to be evaluated for resistance following inoculation to ensure that the resistance trait is acting as anticipated. There are several advantages to using molecular techniques. One advantage is that the resistance genes can come from any source of DNA, not just plants that can be crossed with the recipient plant species. A resistance gene for a tomato disease may come from a potato plant, or a broccoli plant, or even non-plant sources. Some resistance genes for plant viruses have come from the viruses themselves. Another advantage of using molecular techniques is that only the desired resistance genes are transferred, eliminating the need for repeated backcrossing to get rid of undesirable traits.[3]

Because pathogens can adapt and form new races in response to the use of disease resistance, the process of developing disease-resistant varieties is an on-going one. Plant breeders and plant pathologists are continually trying to stay a step or two ahead of the pathogens by identifying and transferring new resistance genes into commercial varieties.

Sources:

[1] Bent, A. 1996. Plant disease resistance genes: Function meets structure. The Plant Cell 8:1757-1771.
[2] Plant disease resistance. 2020. International Seed Federation. https://www.worldseed.org/our-work/plant-health/overview/.
[3] Agrios, G. 2005. Plant pathology, 5th edition. Elsevier - Academic Press.
[4] Schumann, G. and D'Arcy, C. 2010. Essential plant pathology. American Phytopathological Society. St. Paul.

Websites verified 12/1/2020.

**For additional agronomic information, please contact your local seed representative.**



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