

Immunity in plants to diseases

Author(s): проф. д-р Иван Киряков, Добруджански земеделски институт – гр. Генерал Тошево, ССА

Date: 02.05.2025 *Issue:* 5/2025



The use of resistant varieties and hybrids is considered the most effective and environmentally sound method for controlling diseases in agricultural crops. Unfortunately, we often witness a reduction in the resistance of individual genotypes when they are grown for a prolonged period in specific areas. The duration of maintaining the level of resistance in individual genotypes (varieties, hybrids) is closely related to the mechanisms that build their immunity, as well as to the virulence potential in the populations of the respective pathogens. Knowledge of the mechanisms that build immunity in plants is of essential importance both for the development of an adequate breeding strategy and for the implementation of measures to prevent the loss of already achieved resistance.

The term “immunity” originates from the Latin word “*imunitas*”, meaning free or inviolable. Depending on its specificity, plant immunity is divided into non-specific and specific. Non-specific immunity is associated with the absolute, complete resistance of a particular plant species to phytopathogens, within whose host range it does not fall. As an example, the causal agent of bean rust *Uromyces appendiculatus*, can be mentioned, to which the varieties of *Triticum aestivum* (common winter wheat) are completely resistant. Specific immunity is that in which individual genotypes of a given plant species exhibit resistance to phytopathogens that are capable of infecting the respective species. The causal agent of brown rust in wheat *Puccinia triticina* infects *Triticum aestivum*, but the individual varieties possess different levels of resistance.

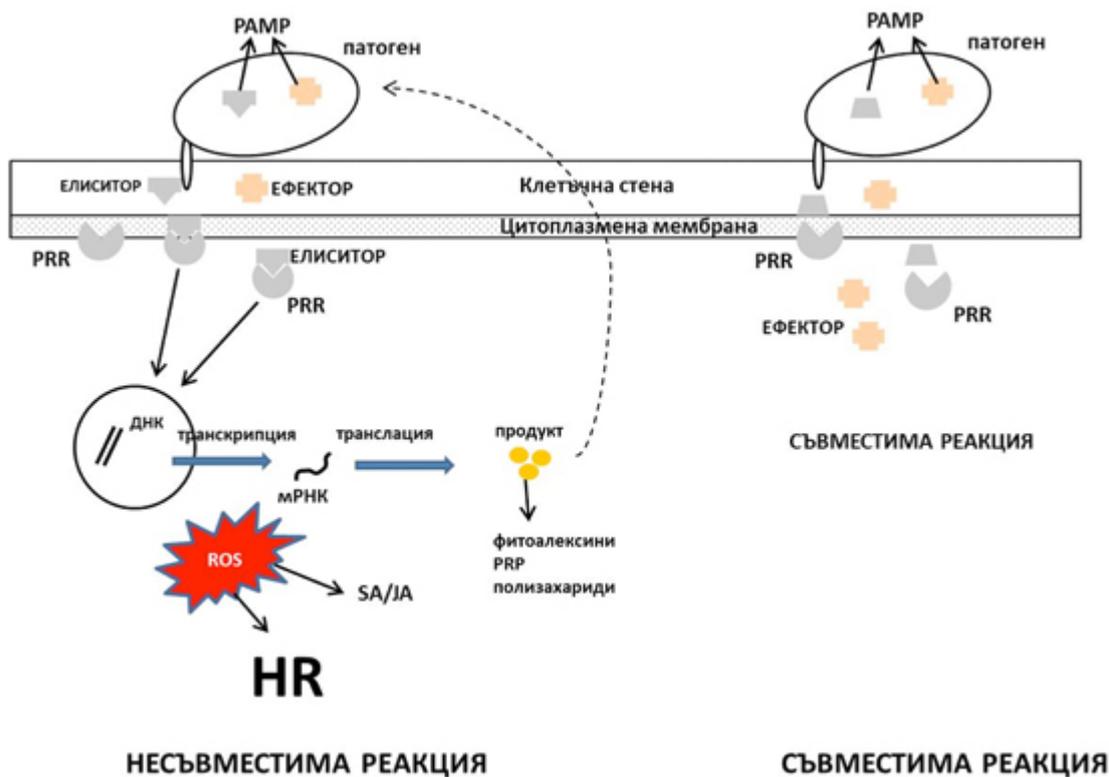
According to their origin, immunity can be divided into innate or hereditary and acquired. Innate immunity is associated with factors that are inherited in the generations of the respective variety. Acquired immunity appears or arises in plants during their ontogenetic (individual) development under the influence of a given pathogen or external conditions and is not inherited by the progeny. Most often it arises after infection or disease in plants, after which they increase their resistance to this and other pathogens.

According to the mechanisms of formation, plant immunity is divided into passive and active. Passive immunity is associated with morphological or anatomical characteristics of the individual varieties – presence of a waxy coating, thickness of the cuticle and epidermis, number per unit area and structure of the stomata, plant architecture, etc. These varietal characteristics are constant regardless of the presence or absence of conditions for the course of pathogenesis (the infection process and disease development). Overall, the mechanisms of passive immunity prevent or delay the infection process, which in the second case leads to fewer developmental cycles of the pathogens. The reduction in the number of cycles during the growing season is of essential importance for polycyclic pathogens (rusts, powdery mildews, septorioses, etc.), in which the development of epiphytotics (epidemics) is closely related to their repeated multiplication. For example, passive immunity can be illustrated by the influence of the plant habit of common bean on the incidence of sclerotinia rot caused by *Sclerotinia sclerotiorum*. Varieties with an upright and loose plant habit are less severely attacked by the pathogen, since they create a microclimate that does not allow prolonged moisture retention during flowering, i.e. they prevent infection of the plants.

Active immunity is associated with defence mechanisms that are manifested during infection or at different stages of pathogenesis, and the factors determining immunity are inherited by the progeny. Varieties whose resistance is based on active immunity possess specific genes whose activation is associated with receptors (PRR) located in the cell plasma membrane and/or cytoplasm (figure). For their expression, it is necessary that the pathogen against which they provide protection produces molecular substances (PAMP), known as elicitors

(molecules recognized by the receptors). In cases where the receptors of the specific genes recognize the elicitors in the attacked cell, signalling molecules accumulate, which activate the expression of the specific genes. As a result, phytoalexins and pathogen-related proteins (PRP) are synthesized, which have a toxic effect on the pathogen. Recognition of the pathogen leads to the accumulation in the cell of reactive oxygen species (ROS) such as superoxide anions (O_2^-) and hydrogen peroxide (H_2O_2), resulting in its programmed death, known as the hypersensitive reaction (HR). At the same time, plant hormones such as jasmonic acid (JA) and salicylic acid (SA) are synthesized in the cell, which are transported to neighbouring cells and transmit an alarm signal. As a result, the neighbouring cells die, thereby blocking further development of the pathogen. Concurrently, the plant hormones produced by the dying cells, and above all SA, are transported throughout the plant and stimulate the activation of general defence mechanisms, leading to the emergence of so-called systemic acquired immunity, which provides protection of the entire plant against the pathogen. If the molecular substances produced by the pathogen (also known as effectors) are not recognized by the receptors, the infection is irreversible, i.e. a compatible reaction is observed. The theory of [Harold Henry Flor](#) (1942), also known as the “gene-for-gene” theory, is related to active immunity. According to this theory, for every resistance gene in the population of a given plant species there exists a corresponding virulence gene in the respective pathogenic species.

Depending on the mechanisms determining immunity, plant resistance is divided into three categories – tolerance, vertical resistance and horizontal resistance. Tolerance is associated with the ability of individual genotypes to withstand a high degree of infection (similar to that of susceptible varieties) without this affecting yield or product quality.



Mechanisms of active immunity. PAMP – pathogen-associated molecular substances; PRR – pathogen-associated receptors; PRP – pathogen-related proteins; ROS – reactive oxygen species; SA/JA – plant hormones; HR – hypersensitive reaction

Vertical resistance is associated with active immunity. It is controlled by specific genes known as “race-specific” genes and is therefore also referred to as “race-specific” resistance. Since this resistance is controlled by one or several major genes, it is often referred to as “monogenic” or “oligogenic”. The advantage of varieties with vertical resistance is that they exhibit complete resistance to the pathogen against which it is directed. The main disadvantage, however, is that this resistance is expressed only to certain parts of the populations of the respective pathogen, known as “physiological races”. Another essential disadvantage of vertical resistance is the selection pressure it exerts on pathogen populations. An example is the increasingly frequent incidence of brown rust in widely grown foreign wheat varieties in our country. When they were first introduced, their resistance to this disease was at a high level. Their widespread cultivation in recent years has led to significant changes in the pathogen populations, which is why we are now witnessing severe infections. The reasons for this phenomenon are related to a change in the virulence potential of the pathogen as a result of the reduction in the areas planted with varieties that maintained the then existing populations of brown rust in the country at the time the new varieties were introduced.

The replacement of the varietal structure in our country exerted selection pressure on the pathogen populations, which in turn led to the spread of new pathotypes (individuals with different virulence belonging to the same

race), uncharacteristic for our territory, which overcome the resistance of the new varieties. The presence of new pathotypes in the country is also confirmed by the fact that in recent years Bulgarian varieties have shown higher resistance to brown rust. The main breeding strategy aimed at preventing the emergence of new races is related to the so-called “pyramiding” of genes in a single genotype, or more simply, the development of varieties with two or more race-specific genes. This strategy reduces the likelihood that mutant or recombinant forms capable of overcoming them simultaneously will arise in the pathogen populations.

The mechanisms of horizontal resistance are associated primarily with passive immunity, although numerous studies confirm the participation of partially non-functional specific genes. Since this resistance is directed against the entire pathogen population, it is also known as “race-non-specific” resistance. Horizontal resistance has a polygenic nature and is therefore also referred to as “polygenic”. The main advantage of horizontal resistance is that it does not exert selection pressure on pathogen populations, and therefore its effectiveness is maintained for a prolonged period of time, i.e. it is difficult for pathogens to overcome it. Unfortunately, from a breeding point of view, the development of varieties with horizontal resistance is a lengthy and complex process due to its polygenic nature.

Undoubtedly, the development and use of varieties/hybrids combining the mechanisms of vertical and horizontal resistance is the most appropriate measure for the control of diseases in cultivated plants, as it prolongs the period of effectiveness of resistance. Unfortunately, in most cases the resistance of varieties introduced into practice is based on the mechanisms of vertical resistance. The main measure to prevent changes in the virulence potential of pathogenic populations is related to the use of a set of varieties whose resistance is based on different race-specific genes. The widespread cultivation of varieties with the same genetic basis in terms of resistance inevitably leads to rapid changes in pathogen populations and hence to the epiphytotic development of diseases.