Arms race at microbe level

Floricultura
ORCHIDACEAE & ARACEAE

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Each day, plants are exposed to a vast array of microbes seeking to consume their host - just like in the animal kingdom.

However, unlike most animals, plants can’t simply move away if their environment suddenly becomes hostile. If an insect starts eating a plant’s leaves, or a fungus begins to colonise a neighbour, a plant in nature must use all the means it has at its disposal to survive.

Luckily, plants possess a diverse system of defences. Although the plant immune system may seem less complex than its human counterpart at first glance, it is capable of continuously evolving to combat the clever tricks that disease-causing microbes devise to escape their host’s defences.

Humans have two immune systems – the basic, innate immune system that we are born with and our acquired immunity. Both systems use specialist immune cells. The acquired system is involved in the specific detection of foreign molecules. This system is primarily associated with the antibodies that help to detect specific pathogens and then trigger complex immune responses. Thanks to our incredibly advanced genetic system, we have an unprecedented arsenal of antibody variations at our disposal. But this system also builds a powerful immune memory, which enables us to fight off subsequent infections caused by a known pathogen faster and more effectively.

Plants, on the other hand, do not have specialist immune cells, which means that each individual plant cell needs to be equipped to defend itself against any and all pathogens it may encounter.

The cell wall: The first line of defence

The best way to fight off an enemy is not to let them in in the first place. All plant cells are surrounded by a cell wall, which acts as a first line of defence against intruders. Fusarium is a well-known fungal pathogen that affects many crops, including orchids, and it emits enzymes that break down cell walls. Fusarium – and many other microbes - intentionally or unintentionally shed specific molecules into their environment. Where possible, these molecules are detected by special detection proteins on the membrane of the plant cell.

When a cell recognises a pathogen in this way, the initial defence response is activated. This response leads to the creation of an arsenal of antimicrobial substances, including proteins that attack the fungal cells - which is not good news for a pathogen. However, over millions of years of co-evolution, pathogens and plants have both refined their defences in an effort to stay one step ahead of their enemy. Many pathogens are capable of slowing or even completely stopping the plant's initial defence response using 'effectors' [see diagram on page 5]. These special proteins are emitted into the host's cell by successful pathogens, where they actively interrupt the components of the initial defence response.

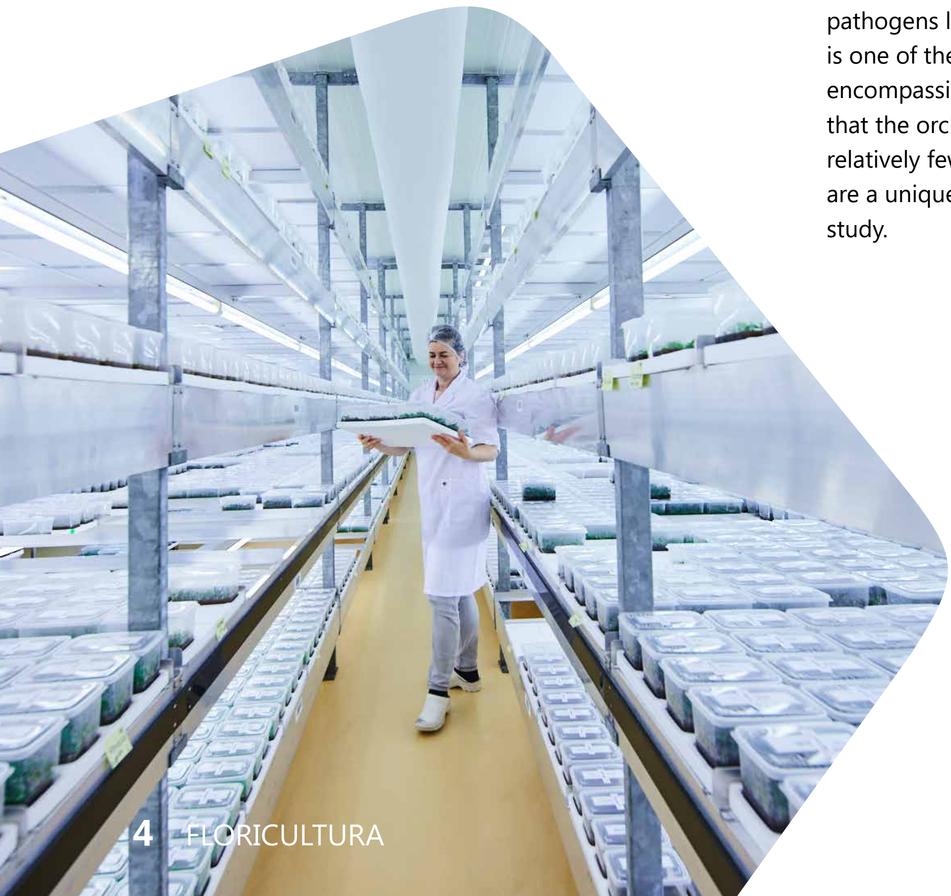
The resistance genes, or 'R-genes', form the second line of defence. To achieve resistance, R-genes code proteins that are often stored in the cell, creating a lock and key concept where the R-protein 'lock' searches for foreign component ‘keys’ in the cell that fit in the lock. If a match is identified, the alarm is sounded.

'Many pathogens are capable of slowing or even completely stopping the plant's initial defence response'

Whether directly or indirectly, most R-genes seem to be involved in the process of detecting effectors in the plant cell. For a long time, scientists believed that there was a gene-for-gene relationship between pathogens and plants, with a specific R-gene tasked with detecting a specific pathogen. This concept is aligned with our antibody-based immune systems; each antibody detects a very specific component. Although there may be a large number of R-genes in the genome of a given plant, the numbers vary significantly between species and we now know that it is not possible to draw a direct correlation between the number of R-genes and the number of pathogens. For example, the rice genome contains around 500 genes with R-gene characteristics, while some orchid genomes contain just five! We have also discovered that it is possible for only one R-gene to be involved in resistance against a variety of pathogens, including bacteria, fungi and nematodes.

Limited R-genes not a barrier to defensive success

More recently, scientists discovered exactly how plants seem to be able to defend themselves against many different pathogens with a limited number of R-genes. Effectors, which are made by pathogens to attack the plant’s initial defence response, appear to do this via a limited number of the host’s defence components. Effectors from a diverse range of pathogens are therefore striving to deactivate the same plant protein.



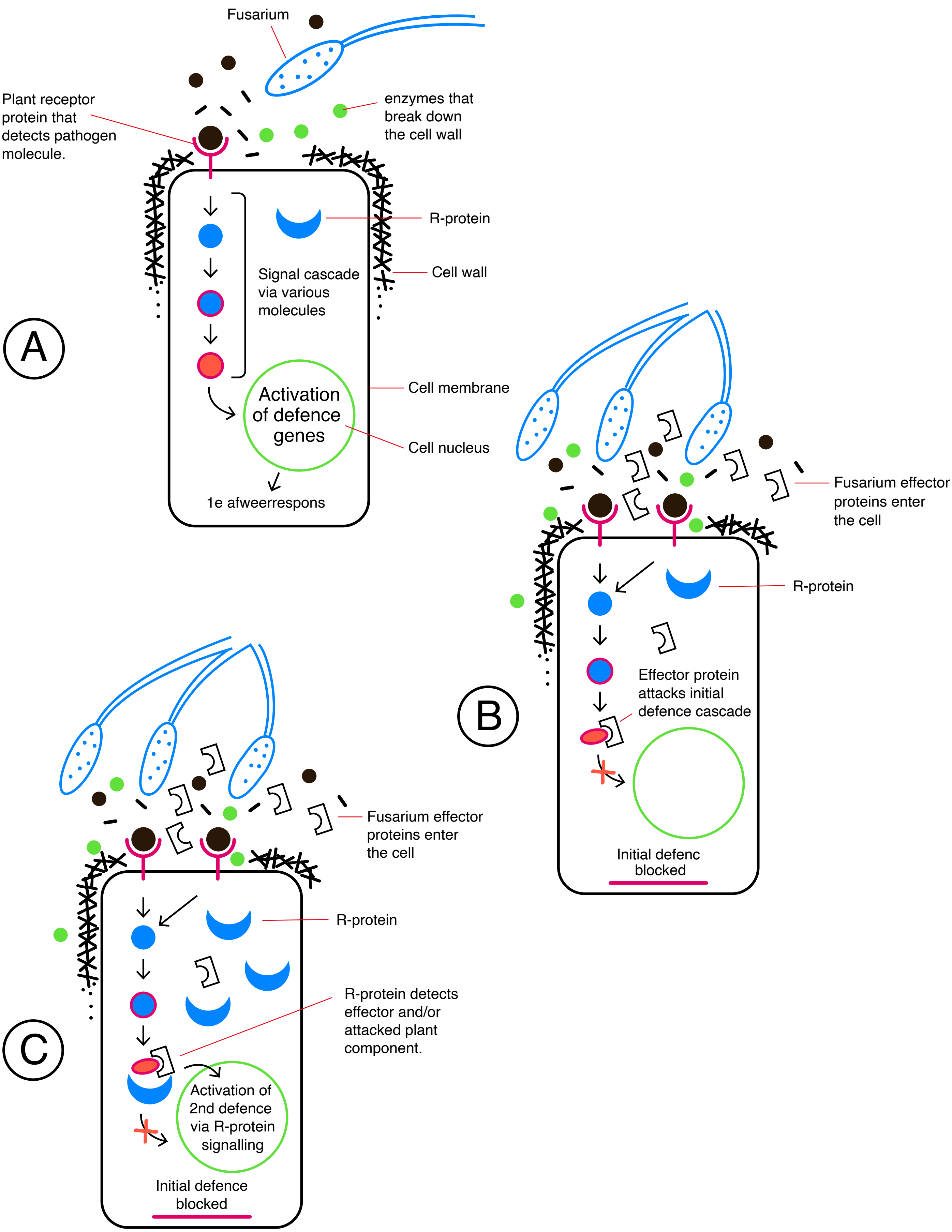
In turn, R-proteins don’t always recognise the pathogen effectors; they seem to target their own defence components, which are also the components being attacked by the pathogens. This sophisticated solution enables a plant to detect a vast array of pathogens with a limited number of R-genes. The structure of the plant’s defence components changes when they are attacked by an effector, which enables them to be recognised by an R-protein. Successful identification triggers the activation of complex signal chains, which the plant uses to activate the required defence mechanisms both locally and systemically.

Genetic diversity for characteristics such as resistance, colour and leaf shape - the result of the ever-changing environment in which plants have evolved - has laid the foundations for many of the crop characteristics we strive to achieve today. In a number of areas, human selection in agriculture and horticulture has reduced this natural genetic diversity; by selecting breeding specimens with specific characteristics, you lose some of the plants' inherent genetic diversity. This trend, combined with the dwindling amount of land on our planet that is left to nature and remains unaffected by human intervention, means that the source of variation we have been able to draw on to date is becoming increasingly limited.

Model crops still lead the way

Although we are slowly learning more and more about how the defence systems of plants function, most of our knowledge still comes from research conducted on model crops. Unfortunately, orchids are not a scientific model crop, so there is no published data on orchid resistance genes to pathogens like Fusarium fungus. Although the orchid family is one of the largest and most diverse plant families, encompassing more than 27,000 varieties, it is worth noting that the orchid genomes studied to date appear to contain relatively few R-genes – a discovery that proves that orchids are a unique, complex and incredibly interesting plant to study.

Attack and defence



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