Mitigation of climate change effect on crop plants' immunity by engineering thermostability of plant immune receptors

Extreme weather conditions associated with climate change affect many aspects of plant and animal life cycle, including pathogen infections. One of the consequences will be a reduction in the availability of natural resources and a deterioration in agricultural productivity due to the inability of crop plants to activate immune receptors at high temperatures. The most vulnerable to climate change include main food sources i.e. wheat, maize and potato.

Plant immune receptors mostly belong to the NB-LRR family. In their structure can be distinguished by a NB -nucleotide binding domain, a C-terminal leucine-rich domain (LRR) and an N-terminal CC or TIR domain. Conformational changes in immune receptors accompanying the recognition of pathogen proteins (the so-called avirulence factors -Avr) and the exchange of ADP for ATP activate intracellular signalling pathways that trigger a cascade of programmed cell death, referred to as the hypersensitivity reaction (HR). Activation of the HR reaction thus results in the inhibition of the multiplication of pathogens and further plants infection. At elevated temperature, however, the normal process of cell death activation is often blocked, and the mechanism of this inhibition remains unknown. Given the rapid increase in temperatures across the globe, it is critical to investigate the underlying mechanisms that regulate the activation of plant immune responses under such extreme conditions.

Our preliminary results of studies on several R proteins have shown that the conserved spatial arrangement of the NB-ARC domain of R receptors controls their thermal stability and retention of pathogen detection at elevated temperatures. Therefore, it is extremely important to investigate whether appropriate modifications of the temperature-sensitive R immune receptors would restore their functionality.
The main goal of the project is to understand the mechanisms by which elevated temperature affects the function of crop plant immune receptors, and to effectively design selected receptors so that they would be able to trigger an immune response at elevated temperatures.

In the proposed project, using the methods of structural biology, we will analyse the structures of over 30 immune receptors, important from the economic point of view. Based on the obtained model, we will design modified variants of selected proteins important for resistance breeding, i.e. Mi 1.1 and Mi 1.2 that provide resistance to root-knot nematodes, Sr-35, which gives resistance to wheat rust Rp1-D21, which gives resistance to common rust in maize and Rpi-amr1 and Rpi -amr3 two resistance receptors against number one potato pathogen – late blight. After introducing the designed modifications, we will perform a functional analysis of the tested receptors. In the transient expression system, at elevated temperatures, we will test the ability of the modified proteins to the Avr recognition and cell death induction. We will quantify this process using various HR physiological markers. Next, we will determine the stability of the proposed protein variants and their ability to bind Avr factors at elevated temperature using microscale thermophoresis (MST). Finally, we will obtain engineered plants expressing modified R proteins and test them to determine whether they confer systemic resistance to pathogen infection at high temperatures.

We believe that the obtained results will not only contribute to understanding the mechanism of the functionality of plant immunoreceptors, but will also be used to develop new programs for plant resistance breeding.