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Robert Schuurink received his Masters's degree in Molecular Life Sciences from Wageningen University and his PhD from Leiden University in the Netherlands. He is now associate professor in the Plant Physiology group at the University of Amsterdam. His research group focusses on the regulation of specialized metabolism and plant-herbivore interactions with the aim to identify plant molecules, proteins and genes relevant to pest resistance. His research concerns not only the plant, but also the herbivores, for instance by identifying their effectors that modulate plant defenses.

Harro Bouwmeester

Harro Bouwmeester received his Master's degree and PhD in Plant Physiology from Wageningen University, the Netherlands

In the past decades, the field of plant biology has been dominated by studies on plant–biotic interactions. Indeed, most of the losses in the crops that provide our food are caused by pathogens, herbivores and parasitic plants. Concurrently, we have learned to appreciate beneficial partners, such as pollinators and natural enemies of herbivores, for integrated pest management. More recently, attention is focusing on the plant microbiome, not only on the more traditional Rhizobia and mycorrhizal fungi, but also on the myriad of other, potentially beneficial, microorganisms, belowground and aboveground. Despite these developments, agriculture still is sustained by pesticides and fertilizers. Although it has been known for a long time that these chemicals also hurt beneficial organisms, this has become more apparent with serious problems with bees and decreasing insect numbers. Some of these pesticides have therefore been banned, while whereas others will be phased out. There is therefore a large need for crops with natural resistance.

Traditionally, breeding for resistance against biotic constraints involved crossing and large-scale screening. However, due to the development of molecular markers associated with resistance or susceptibility, the concept of breeding by design has become mainstream. This entails quite often the generation of hybrid cultivars that contain the desired molecular markers providing the corresponding resistance. This demands a tremendous amount of knowledge of the interaction of the plant with the attacker and/or beneficial organisms. If this knowledge translates into markers that have a causal relationship with resistance or susceptibility, breeders can introgress them from relatives with the desired genomic trait or through genetic modification. Key challenges are thus the elucidation of the mechanisms that govern plant resistance, mostly via biotechnological approaches, and to determine the relevant molecular markers. This requires not only fundamental research but also problem-driven research. Finally, new technologies have emerged to protect plants against pathogens and pests by targeting vital genes of the latter using dsRNA or microRNAs, delivered by various methods.

In this special issue an overview is presented of recent advances in our understanding of the mechanisms that govern plant–biotic interactions, and ways to use that knowledge to protect plants from pest and pathogens. To achieve this overview we have created several subtopics, as detailed below.

Using biotechnology to elucidate the mechanisms underlying plant–biotic interactions

For this subtopic a number of papers focus on a particular biotic agent and the use of biotechnology to elucidate mechanisms underlying the interaction

(1985, 1990). After postdoctoral and research scientist appointments, he became Chair of Plant Physiology at Wageningen University (2008). Since 2016 he is Chair of Plant Hormone Biology at the Swammerdam Institute for Life Sciences (SILS) of the University of Amsterdam, the Netherlands. The work in his group is centered around signaling molecules and their role in the chemical communication of plants with other organisms.

of plants with that agent. One of the biggest problems for plants are viruses. Plants have developed several defense mechanism and Fontes et al. describe how viruses can suppress these antiviral mechanisms with relevance to antibacterial immunity as well. A number of papers subsequently focus on belowground interactions, not only with attackers but also with beneficial organisms. The interaction with nematodes is discussed by Eves-van den Akker et al., with emphasis on the biology on both sides of the interaction and on the development of genetic tools for functional analysis '*in nematoda*'. In the field of parasitic plants, the past decade or so, large progress was made in the understanding of mechanisms adopted by parasitic plants to allow parasitation of other plants. Yoshida and Kee review how genomics and transcriptomics have contributed to this and revealed how various parasitic plant species evolved similar processes to parasitize their host plant. Furthermore, it is becoming increasingly clear that beneficial microorganisms substantially contribute to the protection of plants against belowground attackers. Ratet and Gourion describe the mechanisms involved in the selection of beneficial microbes by plants whereas Abedini et al. focus on the plant metabolites important for microbiome recruitment. Knowledge of these small molecules and the interactions they mediate might ultimately lead to improvement of our crops.

Erb et al. review how plant specialized metabolites determine multitrophic interactions with an emphasis on their role in the interactions of plants with natural enemies of herbivores. These natural enemies can also adapt to the plant chemistry to enhance biologic control but field experiments will be necessary to establish this firmly. Along similar lines, Kant and Schuurink discuss the role of ontogeny in plant-herbivore interactions, both for the plant and herbivore as defense responses alter during their life-stages. The recognition of herbivory-associated cues that originate from oral secretions, eggs or damaged plant cells is discussed by Reymond. Finally, Frachon et al. discuss the mechanistic and evolutionary aspects of plant-pollinator interactions and how this can help us understand its dynamics in a changing environment.

Omics approaches to elucidate mechanisms underlying microbiome recruitment

Relatively new are the multiomics-driven approaches combined with sophisticated statistical analyses that allow for the discovery of genes or signaling pathways relevant to biotic interactions. Zancarini et al. review not only the use of genome wide association studies (GWAS) to identify plant genes underlying microbiome recruitment but also the role of root exudates in shaping the microbiome. In particular, they discuss new integration methods to unravel new relationships especially in multi-omics integration using structural equation models (SEMs). Bergelson et al. argue that many plant genetic loci are involved in influencing plant microbial communities and that a lot more work is needed to translate these findings to achieve crop improvement.

Biotechnology to engineer biotic interactions: reducing pathogenic interactions and improving beneficial interactions

Great potential is envisioned for RNA-mediated plant protection. Not only cross-kingdom RNAi but also environmental RNAi where dsRNAs and sRNAs are sprayed on plants. Jin et al. describe how host-induced gene silencing can be used to combat pathogens and how direct application of RNAs, that target genes of pathogens, on crops can affect pathogenic fungi. Šečic' and Kogel review the knowledge of the mechanisms allowing the uptake of dsRNA by fungi and the subsequent gene silencing. Crucial is the design of the dsRNA and the presence of the RNAi machinery in the fungus. Related to this topic, Zhang and al describe the potential of microRNAS in pest control.

As potato is one of the main staple crops in the world it also suffers from several diseases, such as those caused by the late blight pathogen *Phytophthora infestans* and nematodes. Several potential approaches to protect potato against root-knot nematodes are reviewed by Bali *et al.* among which also plant-mediated RNAi of nematode effectors. Resistance in citrus against *Candidatus Liberibacter* (*Clas*), a microorganism transferred by psyllids (*Diaphorina citri*) is much desired as it wipes out complete citrus orchards in Florida, USA and parts of Brazil. Promising approaches are reviewed by Alquezar et al., such as the use of genetic resistance against *Clas* or *D. citri*. Also the role of volatile organic compounds in attracting or repelling the vector is discussed as are the potential of RNAi and peptides. Finally, Yergeau and Agoussar discuss how to engineer the microbiome of plants to improve resilience arguing that speciation and selection are more promising than dispersal or the introduction of microorganisms.

Prospect papers: how to further exploit our knowledge to harness plant–biotic interactions

This issue ends with several papers giving a glimpse into the future. Two papers describe how plant-specialized metabolites can be used to improve resistance in crops. Ding et al. focus on the below-ground metabolites and how multi-omics approaches have given us insight in metabolic pathways and in natural variation and how this knowledge can be used to improve complex interaction-based traits. Zhou and Jander argue that we still need to know much more about metabolic pathways to be able to engineer them properly as metabolic pathways are often interconnected. Two papers focus on engineering of pathogen resistance in plants, using different angles. Fralie and Innes review the recent breakthrough in determining the structure of cell surface and intracellular immune receptors and how this knowledge can be used to engineer-specific recognition to convey resistance. Ruiz et al. argue that susceptibility genes are a promising alternative for engineering resistance also for potato against *P. infestans*. These susceptibility genes are used by pathogens to establish virulence and the inactivation of this particular function, while maintaining their essential other function for the plant, could lead to durable resistance. Both approaches are very exciting and promising.

We hope that you will enjoy reading this issue and become as excited as we are about the possibilities to harness our knowledge about biotic interactions to protect our crops.

Robert and Harro.