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Editorial

Special Issue "Integrated Defense Responses in Crops against Soil-Borne Pathogens"

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Soil-borne pathogenic organisms can have severe detrimental effects on crop growth and yield production and represent a serious threat to food security. Conventional control measures are often not effective enough in constraining the spread of pathogens, due to their ubiquitous presence in the environment, their propagation inside the plant host, their persistence in plant debris and in soil over years due to the formation of resting organs or because of non-specific symptom development. A recent assessment on the five major crops worldwide revealed a 20 to 30% yield loss caused by pathogens and pests, with soil-borne fungi (true fungi and oomycetes) and nematodes reducing the yield by up to 9% [1]. It is further projected that the disease pressure caused by soil-borne pathogens will rise in the future due to the ongoing climate change [2]. Therefore, improved strategies are needed for controlling soil-borne diseases that integrate the application of beneficial microorganisms, agricultural practice, plant health stimulation, and soil treatments.

Plants are not rendered helpless to cope with these diseases and do respond with a set of integrated signal transduction pathways and defense responses that can lead to an enhanced plant protection or even resistance. A better understanding of these stress responses at the molecular, physiological, and phenotypic level will lead to new avenues in crop-breeding activities. It is also essential that the research is conducted under conditions close to the production systems. Although demanding with respect to labor, time, and money, experiments on glasshouse and/or field-grown crops will deliver more relevant results as compared to growth chamber or *in vitro* assays.

Twelve articles have been published in the Special Issue of *Agronomy* entitled "Integrated Defense Responses in Crops Against Soil-Borne Pathogens" that provide insights into the current activities to improve plant performance under disease pressure, promising solutions for disease management as well as elaborate summaries of research topics.

For the latter, the background and current status of managing *Fusarium* wilt disease in legume crops was reviewed by Sampaio et al. [3]. The review of Hanschen and Winkelmann [4] compiled the latest information on containing the complex replant disease by soil biofumigation measures. In a meta-study, Mesa-Valle et al. [5] investigated the most urgent directions of future research on plant nematodes by considering global publication efforts.

Two articles investigated the effect of beneficial microorganisms to alleviate disease responses. Beneficial *Bacillus subtilis*, combined with salicylic acid, improved plant performance of wheat when challenged with *Fusarium* and drought treatment [6]. Some rather uncharacterized beneficial *Serendipita* fungi were tested for their protective activity against *Fusarium* in two tomato genotypes with or without resistance toward the pathogen [7]. Ren et al. [8] reported on a novel seed coating agent that was efficient against *Rhizoctonia cerealis* infection of wheat.

Adapted agricultural practice is a promising strategy to decrease yield losses by soil-borne pathogens. Winter cover crops reduced the disease severity in red maple nursery production when

inoculated with different soil pathogenic fungi [9]. The possibility of crop rotation between sugar beet and oilseed rape was addressed with respect to limiting the occurrence of beet cyst nematode [10]. Two articles investigated the use of plants or plant extracts as biocontrol agents. Cruz-Rodriguez et al. [11] showed that the supplementation of branch extracts of *Crotalaria longirostrata* reduced the disease severity in maize upon *Fusarium* infection. The supplementation of dried spearmint and oregano increased tomato growth with respect to *Fusarium* and *Verticillium* infection [12].

Two articles report on plant stress responses. The time-dependency in the pathogen–pathogen interaction of potato with both root-lesion nematodes and the pathogenic fungus *Rhizoctonia solani*, was demonstrated by Edin and co-workers [13]. A second paper shows a dual challenge with a root knot nematode and the pathogenic fungus *Fusarium oxysporum*, in which two tomato genotypes with different levels of resistance against those pathogens exhibit specific photosynthetic responses and oxidative stress signatures [14].

Severe losses of crop quality and quantity by soil-borne diseases are a perpetual threat. Particularly the relevance of pathogenic fungi and nematodes is reflected in the articles published in this special issue. Especially the role of antagonists and amendments in fighting soil-borne pests was affirmed as well as the reasonable use of trap and cover crops. The authors point out that strategies beyond conventional measures controlling the diseases are promising and recommendable to consider for implementation in agricultural production systems.

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