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Integrated management of damping-off diseases. A review.

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Abstract: Damping-off is a disease that leads to the decay of germinating seeds and young seedlings, which represents for farmers one of the most important yield constraints both in nurseries and fields. As for other biotic stresses, conventional fungicides are widely used to manage this disease, with two major consequences. On the one hand, fungicide overuse threatens the human health and causes ecological concerns. On the other hand, this practice has led to the emergence of pesticide-resistant microorganisms in the environment. Thus, there are increasing concerns to develop sustainable and du-rable damping-off management strategies that are less reliant on conventional pesticides. Achieving such a goal requires a better knowledge of pathogen biology and disease epidemiol-ogy in order to facilitate the decision-making process. It also demands using all available non-chemical tools that can be adapted to regional and specific production situations.

Keywords: Correct identification of damping-off pathogens including non-secondary colonizers and anasto-mosis groups, Determination of potential interactions within and/ or between damping-off pathogens and other liv-ing organisms, predispose seeds and seedlings to damping-off diseases, Development of disease-suppressive seedbed soils with or without conservation agriculture

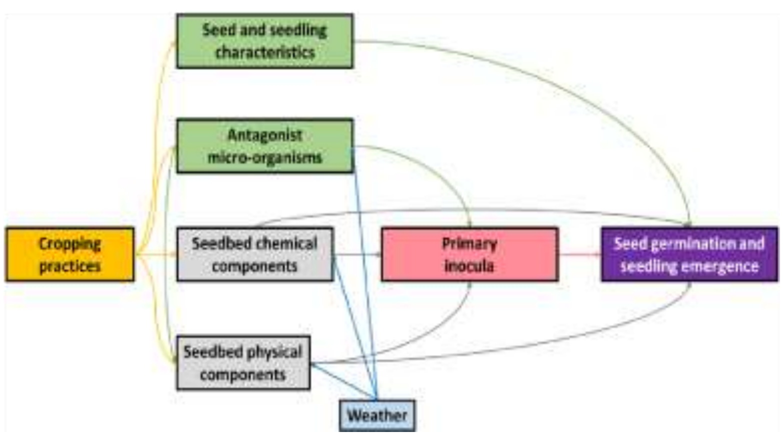
1.0 Introduction:

Damping-off is a historical term coined during the early nine-teenth century, and represents one of the oldest worldwide nursery problems as discussed in detail in the classic nursery manual (Hartley and Pierce 1917; Tillotson 1917; Hartley 1921). Damping-off was considered “the most serious prob-lem encountered in raising nursery seedlings,” and conse-quently was one of the most focused research subject since the beginning of its description (Hartley and Pierce 1917). The definition of damping-off is not straightforward in the litera-ture. Many authors refer to damping-off as a “disease” (McNew 1960; Horst 2013), while others refer to damping-off as a “symptomatic condition” (Agrios 2005; Kemerait and Vidhyasekaran 2006). In the former case, damping-off is usu-ally associated to soil-borne pathogens while in the latter both interpretations comprehend that damping-off involves non-germination, prevention of seedling emer-gence after germination, or the rotting and collapse of seed-lings at the soil level

2 Occurrence of damping-off symptoms

Most damping-off diseases present a single sort of symptom (pre- or post-emergence). However, both sorts of symptoms are also reported to some extent (Table 1) although the under-lying factors leading to the occurrence of each sort of symp-tom are poorly discussed in the literature. The complexity of damping-off symptoms result from interactions between cropping practices and the production situation (Aubertot and Robin 2013). This may explain the relevant lack of infor-mation. This complexity involves synergism among damping-off pathogens (Al-Hazmi and Al-Nadary 2015), variation of symptoms according to environmental conduciveness (Schwanck et al. 2015), direct effect of plant density (Burdon and Chilvers 1975), and many other factors, which are very specific for each damping-off symptom. For instance, the disease cycle components of damping-off are seldom discussed in a broader sense in the literature, by comparing different diseases. Some factors related to the time/moment of disease occurrence and timing of disease cycle components could determine whether pre- or post-emergence symptoms will occur. In this sense, it is possible that for both pre- and post-emergences damping-off, the infection occurs during seed germination but a longer or shorter incubation period may implicate in pre- or post-emergence damping-off. In addition, the effect of individual factors involved on the disease pro-cesses from the disease cycle and the host cycle (e.g., seed germination), for damping-off symptom development, is rare-ly discussed in the literature. Taken together, several studies virtually explore the effect of a given factor (e.g., temperature) on damping-off diseases intensity (Ben-Yephet and Nelson 1999), without specifying whether the factor plays a specific role on the pathogen (e.g., organism metabolism) or on the host (e.g., slow germination process increases time exposure underground). Further knowledge on disease cycle features and processes would help better understand damping-off symptom occurrence. Although it was out of the focus of this work, it is worth to mention that from the extensive literature review, we did not perceive any pattern on the sort of damping-off symptom (pre- or post-) according to the region, the pathogen genus, or crop species affected. Therefore, a meta-analytical approach to test hypotheses associated with damping-off diseases would be highly valuable to better ex-plain the factors involved in damping-off symptoms

Fig. 1. Generic conceptual model that represents the impact of cropping practices and weather on biotic and abiotic stresses affecting seed germination and seedling emergence



Overall, there is a paucity of information in the literature concerning how conservation agriculture may affect damping-off diseases although prediction can be made from traditional epidemiological knowledge. Because the major damping-off pathogens discussed in this paper have a broad host range, the retention of crop residues on soil surface maybe a nutrient (food) source for the pathogens after harvest as well the pres-ence of cover crops may act as a potential reservoir of these pathogens (intermediate hosts; (Bockus and Shroyer 1998; Cook 2001).

3. Integrated management of damping-off

An effective management of damping-off requires the deploy-ment of a number of strategies, which can be classified into the following four major groups: (i) seed treatment to enhance germination and seedling vigor, (ii) deployment of resistant or tolerant cultivars to damping-off diseases, (iii) adoption of best cropping practices, and (iv) timely treatment interven-tions of seedlings with effective products (conventional pesti-cides as well as biopesticides and/or biocontrol agents). None of these strategies is effective in managing damping-off dis-ease when applied individually and thus it requires that all of them are combined within the frame of IPM.

3.1 Seed treatment to enhance germination and seedling vigor

While the use of completely healthy seeds is the most effective means to prevent and/or contain damping-off diseases, seeds might not be always free from pathogens and thus would benefit from treatments. Even when there is no risk of con-taminated seeds from seed-borne pathogens, seed treatments can be an effective means to increase seedling emergence, particularly when done on seeds of low vigor and when the seed coat has been damaged (Mancini and Romanazzi 2014).

4.0 Key challenges and future priorities for damping-off management

In order to tackle the complex and multifaceted nature of damping-off diseases and a range of factors that affect their occurrence and development, we propose five research prior-ities, which are essential towards a better understanding and management of damping-off diseases.

4.1 Correct identification of damping-off pathogens including non-secondary colonizers and anastomosis groups

An accurate identification of the causal agent(s) associated with damping-off is imperative for understanding the etiology of damping-off outbreaks and thus represents a cornerstone for the decision-making process to IPM. This involves confirming the pest, learning how it spreads, and then identi-fying critical points for its management, including develop-ment of preventive measures based on adapted cropping prac-tices. Most often, the specific pathogen causing damping-off cannot be determined based on the visual inspections of symp-toms. Therefore, their correct identification is essential. It is generally performed using both culture-based and culture-independent methods. However, both of these techniques have their advantages and drawbacks and hence are comple-mentary to each other. For example, culture-based techniques allow for the characterization of important traits such as viru-lence or fungicide resistance. Not only are they time consum-ing, but they also underestimate the true diversity of species present within a sample (Zinger et al. 2012; James 2012b; Bik et al. 2016). Culture-independent methods, such as next gen-eration sequencing, on the other hand, allow to identify the overall species diversity present in a given sample but their limit is that they do not allow to determine the virulence and fungicide resistance of the microbes associated with the dis-ease (Lamichhane and Venturi 2015.

5.0 CONCLUSION:

The great economic importance of damping-off diseases and increasing concerns in finding sustainable solutions to this problem imply that opportunities exist to develop IPM strategies. Achieving this outcome will require a greater under-standing of the ecology, genetics, and pathogenicity of the microbes associated with the disease. Research should focus on critical niches of complexity, such as seed, seedbed, asso-ciated microbes, and their interfaces, for which innovative and robust experimental and modeling approaches are needed. In particular, development and validation of new simulation models or improvement of those already existing ones may result useful.

Legislative pressure, fueled by public concern over the use of conventional pesticides in agriculture, requires that alterna-tive to conventional pesticides be developed and applied for a durable and sustainable disease management. Nevertheless, management of damping-off appears to be less straightfor-ward than one might expect. Given that several pathogenic organisms interact and cause damping-off, it is fundamental to have prior knowledge of the interaction concerned, as even a very low population density of soil-borne pathogens can lead to severe epidemic development. Consequently, the prevention or containment of one pathogen may not resolve the problem of the interaction. Therefore, there is a remarkable need for a better understanding of the interactions between plants, the environment and natural resident microbial agents/communities, under the influence of cropping prac-tices. The information reported in this paper underlines the necessity of understanding such a complex relationship, which is essential for an effective decision-making process on damping-off disease management.

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