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Is the development of resistance to biological control among plant pathogens possible?

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Abstract: Although many plant pathogens are known for their capacity to develop resistance to classical control methods, only few studies have explored their ability to overcome the effect of biocontrol agents. However, these studies highlight differences in the sensitivity of various isolates of plant pathogens to biocontrol agents or to compounds that are produced or synthesized as the result of their interaction with the host-plant. This observed diversity may contribute to the inconsistent efficacy of biocontrol agents sometimes observed in the field. Moreover the selection pressure exerted by an increase in the use of biocontrol agents may cause the emergence of new resistant phenotypes from these less sensitive isolates. This review highlights current knowledge concerning erosion of biocontrol against plant pathogens and its possible consequences for field efficacy.

Key words: biological control, durability, resistance, efficacy

Introduction

Much research effort has been dedicated in the last 40 years to the development of biocontrol agents against plant pathogens, resulting in the registration of an increasing number of commercial products. However, a recurring problem encountered in the field with biocontrol agents is their sometimes inconsistent efficacy (Nicot *et al.*, 2011). This variability of efficacy is generally attributed to climatic variations encountered in field conditions, a lack of ecological competence of the biocontrol agents, and/or an unstable quality of the products. However, reduction of efficacy in the field may also result from the diversity of sensitivity of plant pathogens to biocontrol agents. Possible loss of efficacy of a biocontrol agent could result from the pre-existence of isolates with low susceptibility in natural populations of plant pathogens. It could also arise if plant pathogens have the ability to produce natural mutants with reduced susceptibility under the selection pressure of biocontrol agents used by farmers.

This review highlights current knowledge concerning erosion of biological control against plant pathogens and its possible consequences for field efficacy.

Variability of plant pathogens

The durability of a control method for plant protection is defined as the persistence of its efficacy in space and time. It depends on the selection pressure exerted by the control method itself on populations of plant pathogens and it also depends on the capacity of these pathogens to adapt to the control method. Erosion of effectiveness of conventional plant protection methods has been widely studied in the past. The durability of chemical control has for

instance been considered because of the frequent and recurrent apparition of resistance to fungicides in major plant pathogenic fungal populations (REX Consortium, 2013). The breakdown of varietal resistance, especially those linked to major resistance genes, has also been widely studied for plant pathogens (REX Consortium, 2016). Although many plant pathogens are known for their capacity to develop resistance to classical control methods, only few studies have explored their ability to potentially overcome the effect of biocontrol agents. Reports on the effect of biocontrol agents on plant pathogens often consider only a single strain and one specific stage in the life cycle of the pathogen.

Case of resistance to biocontrol against insect pests

Recent results concerning pest management in agricultural systems, for which the use of biological control is more frequent, showed that resistance of pests towards biocontrol agents can occur (Siegwart *et al.*, 2015). Resistance to one or several toxins of the most widely used microbial bio-insecticide in the word, *Bacillus thuringensis*, has been described several years after its market approval. Resistances of pests to other biocontrol agents have also been pointed out. For example resistance of the codling moth *Cydia pomonella* to the bioinsecticide *Cydia pomonella* granulovirus was detected in France and Germany in pome fruit orchards (Siegwart *et al.*, 2015).

Diversity of sensitivity of plant pathogens to biocontrol agents

Contrary to the situation with insect pests, the durability of efficacy of biological control against plant pathogens has only been marginally investigated and there is no publication proving loss of efficacy in practice due to resistance to a given biocontrol agent. However, several studies have addressed the variation in sensitivity of plant pathogens to the effect of biocontrol agents. Testing a sufficiently high number of samples from field populations of the target plant pathogens for their level of sensitivity to biocontrol agents (i.e. establishment of baseline sensitivity) is a first step in the evaluation of the distribution and the potential impact of resistance in the field. All available results from the scientific literature reveal differences in sensitivity of pathogens to various biocontrol agents and to compounds that are produced or synthesized as the result of their interaction with the host-plant (Bardin *et al.*, 2015). This observed diversity may contribute to the reduced efficacy of biocontrol agents in the field, by means of the existence of less susceptible phenotypes in natural plant pathogen populations and by means of the possible emergence of new resistant phenotypes from these less sensitive isolates due to the selection pressure exerted by the biocontrol agent used by farmers.

Adaptation of plant pathogens to the effect of biocontrol agents

Should the use of biocontrol agents become generalized in the field, resistance might emerge, due to the selection pressure exerted by the biocontrol agent, as it did in the case of fungicide use. To elucidate this potential risk, repeated exposure of successive generations of a pathogen to compounds produced by a biocontrol agent or to a biocontrol agent itself, have been realized in few studies. This procedure, commonly carried out to evaluate the durability of efficacy of antimicrobial agents in human pathology or to assess the capacity of plant pathogens to adapt to fungicides, has revealed in some cases the capacity of plant pathogens

to adapt to the effect of biocontrol agents, suggesting practical resistance risk (Bardin *et al.*, 2015). Moreover, mechanisms of resistance to toxic compounds produced by microorganisms or plants have been studied and reviewed by several authors (Duffy *et al.*, 2003; Raaijmakers *et al.*, 2009; Fillinger *et al.*, 2012).

Conclusion

Even if data are too sparse to elaborate a general theory on the use of biocontrol agents in practice, this review highlights the necessity of proper management of these new products to avoid repeating the mistakes made with the deployment of various chemical pesticides.

Knowledge concerning the possible erosion of efficacy of biocontrol agents is essential to ensure a durable efficacy of this control method on target plant pathogens. This knowledge will result in identifying traits of plant pathogens that can foster the selection of resistant strains to biocontrol agents and modes of action of biocontrol agents that can favor the selection of resistant isolates in natural populations of plant pathogens.

Significant research efforts are still needed to acquire sufficient knowledge on the mode of action of biocontrol agents to optimize their use, to anticipate the potential failure of biological control and finally to integrate durability concerns in the screening procedure of new biocontrol agents and the careful management of their use once they become commercially available.

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