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Biological control and plant diseases—a new paradigm

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Words are the symbols with which we think. Therefore, our thoughts are profoundly influenced by how we define our words. The definitions that we give words constitute 'mini-paradigms' which encapsulate ideas. These 'mini-paradigms' if precisely defined can facilitate concise thinking. If poorly defined, our understanding becomes muddled.

A variety of definitions have been presented for 'biological control' in plant pathology [1,3,4,9] Earlier definitions took their roots in entomology where the emphasis in biological control is on the use of predaceous or parasitic organisms. More recent definitions of biological control of plant diseases [3] have emphasized the use of biological processes and products, as well as organisms as biological control agents.

Initially, plant pathologists adopted the entomologist's classical definition of biological control [5] which involves, 'the actions of parasites, predators, and pathogens in maintaining another organism's density at a lower average that would occur in their absence.' This narrow 'one on one' (organism *vs* organism) definition of biological control limits us from thinking of 'biological control systems' which would include interactions of biocontrol agents with the pest, environment, and disease process. In an attempt to broaden the biological control concept for entomology, Barbosa and Braxton [2] have expanded the definition of biological control to include 'Parabiological Control' as a manipulation of the pest or the pest's resources to favor control of a pest.

A fundamental difference exists between the objects to be controlled by entomologists and plant pathologists. Entomologists are targeting primarily an *organism* (the insect), while plant pathologists are targeting a *process* (the disease), as well as the organism (pathogen). Strategies for controlling the disease process (therapy) can differ from those used to control the pathogen.

Gabriel and Cook [8] have proposed that the many methods of pest and disease control be divided simply into biological, physical, and chemical. They include the use of natural or modified organisms, genes, or gene products (delivered by organisms) in their definition. A distinction is made between chemicals 'delivered' by living organisms and chemicals 'extracted' from living organisms, the former being biological control and the latter being chemical control according to their view.

Definitions are both inclusive and exclusive. The clarity with which distinctions are made between that which is included and that which is excluded is the key to a good definition. Also, the inclusiveness and exclusivity of a definition affects relationships among the components of a definition and the subsequent evolution of scientific thought. For example, if genetic resistance is not considered biological control, scientists and concepts in biological control and genetic resistance will evolve independently.

As we gain deeper insight into biological control systems for plant diseases, it becomes apparent that a broader definition of biological control is required to encompass the complex interactions that occur. In our studies of yeast antagonists that control postharvest decay of fruits and vegetables, we have discovered that the mode of action is mediated both by the antagonist and the host. In the classical sense certain antagonistic yeasts attach to the pathogen and degrade their cell walls [11]. They also compete at the wound site with the pathogen for space and nutrients [6]. It has also been found that yeasts antagonistic to postharvest pathogens can 'turn on' host defense reactions to disease, such as defensive enzymes and anatomical barriers [7]. In order for a definition of biological control to include these phenomena, it would have to include the host response to disease, as well as the 'one on one' interaction of the antagonist and pathogen.

I would like to present a definition of biological control of plant diseases that is more inclusive than previous definitions. My purpose in doing this is to create a paradigm which does not exclude all the elements which are involved in naturally occurring biological control systems.

Therefore, I would like to define the biological control of plant diseases as: *The control of a plant disease with a natural biological process or the product of a natural biological process*. This definition would include 'biological' chemicals 'delivered' by living organisms and 'extracted' from living organisms. It would also include host resistance (constitutive and elicited). Biological control under this definition would be clearly distinguishable from physical and synthetic chemical control of plant diseases.

We have been using this concept of biological control of postharvest diseases in formulating biological control systems to control postharvest diseases of fruits and vegetables. Utilizing this broader definition of biological con-

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trol, we combine antagonistic microorganisms, natural fungicides, and elicitors of host defenses into multifaceted biological control strategies. We have selected antagonistic microorganisms for their ability to directly parasitize and compete with plant pathogens, as well as to induce resistance responses in the host to the disease. To enhance biocontrol activity, we have been formulating antagonistic yeasts with natural compounds such as chitosan which is fungicidal and has the capability of 'turning on' host defenses to disease. We speculate that such complex biocontrol systems will be more stable and less likely to be skirted by pathogen resistance.

An argument can be made that multifaceted biological control systems may have been selected for in nature. J Duke (University of Maryland, personal communication) has proposed that synergistic combinations of natural pesticidal compounds in plants have evolved. He suggests that we have been remiss in isolating single compounds in plants with biological activity and should be looking for these synergistic combinations. We have seen synergistic fungicidal activity when certain natural plant fungicidal compounds are combined (Wilson *et al*, unpublished data).

It is hoped that the proposed new paradigm for biological control of plant diseases will help in more clearly understanding existing biological control systems and in the formulation of more effective biological control strategies [10].

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