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Proposed Definitions Related to Induced Disease Resistance

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A clear definition of induced disease resistance is lacking, even though the area has been extensively researched and described. The lack of a precise definition leads to potential confusion on whether an underlying mechanism for biological control is induced resistance. We propose definitions, which were developed at a NATO Advanced Research Workshop on biological control, for induced disease resistance and related terms. These definitions are intended to invoke debate and increase effective communication among investigators of induced resistance.

Keywords: *induced resistance, induced systemic resistance, disease defense, mechanisms, biological control*

Induced disease resistance has been the subject of considerable research over the past two decades with the discovery that many pathogens or chemical compounds may be used to enhance host defense mechanisms leading to reduced damage by subsequent pathogen attack. Research interest in this area has recently broadened to include induced resistance as a potential mode of action of microbial biological control agents. Hence, researchers whose primary research interest is biological control are now faced with reviewing the history and current status of induced resistance research and terminology.

The lack of a simple definition of *induced resistance* makes it difficult for biological control researchers to know if they have shown that induced resistance is operable in a particular system. In contrast, published definitions of *biological control, antagonism, antibiosis, competition* and *parasitism* are frequently cited to help identify mechanisms.

In May 1991, 75 scientists from 21 countries participated in a NATO Advanced Research Workshop, held in Cape Sounion, Greece on the subject of biological disease control. In response to the growing interest in induced resistance, a discussion session was held to develop definitions of terms related to induced resistance. The following are proposed by us. Their purpose is to delineate concepts and focus debate so that colleagues can refer to common ground when discussing research related to induced disease resistance.

1. *Induced disease resistance* is the process of active resistance dependent on the host plant's physical or chemical barriers, activated by biotic or abiotic agents (inducing agents).

Three conceptual elements are included in this definition. Induced resistance involves turning on the plant's defense mechanisms. Activation of defense systems may be by physical or chemical changes in the plant. Inducing agents may include living agents and chemical agents.

2. *Local induced resistance* occurs when the protection from disease is limited to the plant region treated with the inducing agent. *Systemic induced resistance* occurs when the plant is protected systemically upon application of an inducing agent to a single part of the plant.

There are intermediate stages between local and systemic induced resistance, so we do not propose precise spatial limits to the term local induced resistance. Researchers can delineate the boundaries of protection and ascribe the appropriate term.

3. The *signal* is a translocatable host factor which conditions the host to respond in a resistant manner. The *trigger* is an event or process leading to production of the signal.

The terms 'signal' and 'trigger' are particularly confusing, as they are sometimes used as synonyms. According to the definition proposed here, the trigger occurs first and leads to production of the signal. Presumably the trigger is a part of the inducing agent or is produced by combined action of the inducing agent and the host plant. The signal moves in the plant—at least sometimes in the phloem (Tuzun & Kuc, 1985)—and starts the biochemical reactions in plant parts distant from the trigger, leading to expression of induced disease resistance. The signal is probably produced during local induced resistance, but might be different from the translocated signal that causes systemic induced resistance. We suggest that, for the present

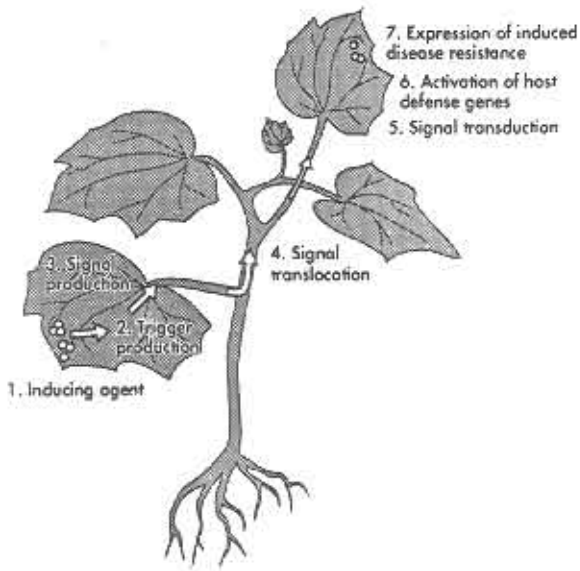

FIGURE 1. Schematic representation of steps in systemic induced disease resistance. (1) An abiotic or biotic inducing agent is applied to the plant; (2) the trigger is produced by the inducing agent or by combined action with the plant; (3) the trigger leads to production of the signal which is translocated (4); signal transduction (5) leads to activation of host defense genes (6) as evidenced by physical and/or biochemical changes in the plant; (7) induced disease resistance is expressed by reduction in disease following challenge with a pathogen.

induced resistance be separated from the hypersensitive response caused by incompatible pathogens, the elicitors of which lead to accumulation of phytoalexins in host tissues upon recognition by a receptor on the host cell membrane. The precise mechanisms of induced resistance remain largely unknown.

Putting these definitions together, one can envision induced systemic disease resistance as a multi-step process (Figure 1).

Cook & Baker (1983) define biological control as 'the reduction of the amount of inoculum or disease-producing activity of a pathogen accomplished by or through one or more organisms other than man'. They further state that the organisms may include 'the host plant manipulated with microorganisms toward greater or more effective resistance to the pathogen'. Hence induced disease resistance accomplished by biotic inducing agents is clearly an example of biological control *sensu stricto*.

Somewhat less clear is the case of induced disease resistance which results from an abiotic inducing agent. We propose that such cases be considered as biological control. In a discussion of biological control related to other controls, Cook & Baker (1983) suggest that 'biological control may come into play following the application of a chemical; for example the displacement of *Armillaria mellea* in citrus wood by *Trichoderma viride* following application of carbon disulfide (Bliss, 1951)'. Induced disease resistance by chemical agents seems to fall into the same category, at least insofar as the chemical agent acts by more than just direct toxicity to the pathogen. Indeed, one of the more exciting prospects in biological control concerns the identification of microbial components or metabolites that might activate host defences when applied instead of conventional fungicides. For this reason, a broad definition of biocontrol should be welcomed, and defined terms for induced resistance phenomena should prove helpful.

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