Synergism, Antagonism, and Additive Action of Fungicides in Mixtures

Presented at the 86th Annual Meeting of The American Phytopathological Society
August 9, 1994, Albuquerque, NM

Introduction

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This symposium is sponsored by the APS Chemical Control Committee, with cosponsorship by the IPM and Environmental Quality and Plant Health committees. Financial support for the symposium has been provided by APS; Sandoz Agro, Inc., Des Plaines, IL; ISK Biosciences Corporation, Mentor, OH; Griffin Corporation, Valdosta, GA; Ciba Crop Protection, Greensboro, NC; and Rhone-Poulenc Ag Company, Research Triangle Park, NC.
Accepted for publication 20 June 1996.

Since the advent of single-site inhibitory fungicides, there has been increased interest in the use of fungicide combinations for controlling plant-pathogenic fungi. At present, there are many reports in the literature of successes with two-way mixtures for controlling specific plant pathogens (2,3,6–9). In some instances, a combination is effective because it delays or overcomes resistance in the population of the pathogen to one of the components in the mixture (3,8,10). One example is the combination of a single-site fungicide such as metalaxyl with a multisite fungicide such as mancozeb (7). In recent years, combinations have been reported as synergistic when dosage rates of one or both of the components can be reduced without loss of effective control of the target pathogen. Most modern fungicides are single-site inhibitors. When utilized in two-way mixtures, such fungicides may maintain or enhance the level of control of a pathogen at reduced rates for both components compared to the control achieved by either of the components utilized in combination or alone at normal rates. Such combinations also may simultaneously reduce the potential for development of resistance by the target pathogen to either component. Synergistic interactions between fungicides, including the role of synergism in resistance management, have received increasing attention, in recent years, in in-depth experiments conducted under both laboratory and field conditions. Much of this work has been conducted in Israel, Switzerland, and the Netherlands.

My personal interest in the subject of fungicide synergism originated during the late 1960s and early 1970s, when the multisite fungicides maneb, mancozeb, and tank-mixed zineb (nabam plus zinc sulfate) rapidly failed in their control of Botrytis leaf blight of onion caused by *Botrytis squamosa* in New York (4,5). That failure has continued to the present day. At about the same time the failures began to occur, the annual experiments I conduct for control of Botrytis leaf blight indicated that benomyl was ineffective in control of *B. squamosa*, although it was very effective in controlling *B. cinerea*. However, when the two fungicides, mancozeb and benomyl, were combined in a mixture with a normal rate of mancozeb and a low rate of benomyl, excellent control of Botrytis leaf blight was achieved. Unfortunately, registration for commercial use of benomyl on onion has never been obtained in New York. Currently, fungicide mixtures of mancozeb at normal dosage rates and a dicarboximide fungicide, iprodione or vinclozolin, at a low rate, apparently acting in a synergistic manner, are effective in commercial control of Botrytis leaf blight at normal levels of natural disease severity (6). Dicarboximide fungicides are not effective when used alone to control moderate to severe levels of Botrytis leaf blight under field conditions. Most onion growers in New York are now using either double or triple combinations of mancozeb, iprodione, and chlorothalonil to control the disease (4).

In my research trials over the years in commercial onion fields in New York for the control of Botrytis leaf blight, I have studied many double and triple combinations involving single-site and multisite fungicides. In these investigations, a number of interactions that appear to involve fungicide synergism in control of the disease have been noted. With increasing pressure from environmentalists and regulatory agencies to reduce pesticide use, the search for synergism in fungicide mixtures in which the rates of all toxicants are reduced but still effective is an attractive goal.

It is the hope of the APS Chemical Control Committee that this symposium will result in an expanded focus, particularly in the United States, on the use of synergistic fungicide interactions to control plant diseases. It also is hoped that the symposium will lead to the global establishment of rigorous standardized methodologies for detecting fungicide synergy in fungicide mixtures and that researchers in the United States will utilize these methodologies in analyzing synergistic reactions. The use of the term synergy should be used with caution and only after the data from experiments have been analyzed following an accepted protocol and synergism has been detected. If additive action is the mechanism of control, it should be measured by standard rigorous procedures and, thereby, reported. Because antagonism can occur in mixtures (1), standards for its measurement and reporting also should be rigorously applied.

The speakers for the symposium have studied various aspects of synergism, antagonism, and additive action of fungicides in mixtures for many years, and each has published a series of outstanding research papers on their investigations. The speakers are Yigal Cohen from Israel, Ulrich Gisi from Switzerland, and Maarten de Waard from the Netherlands. I am very pleased they have agreed to participate in this symposium. The first paper will

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Publication no. P-1996-0924-02O

be given by Dr. Cohen, the second by Dr. Gisi, and the third by Dr. de Waard.

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