THE POTENTIAL ROLE OF INDUCED RESISTANCE, CROP NUTRITION, AND PHOSPHITES IN THE MANAGEMENT OF BLACK SIGATOKA.

EL PAPEL POTENCIAL DE RESISTENCIA INDUCIDA, NUTRCIÓN Y FOSFITOS EN EL MANEJO DE SIGATOKA NEGRA

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The need for another disease control strategy / contribution. The ability of currently registered fungicides to manage black Sigatoka has severely declined in recent years, especially in Central America. The topic of black Sigatoka management has been the inspiration of many scientific and professional meetings during the last decade, convening banana producers, disease managers, research professionals, and agrichemical companies. Despite significant resources dedicated to discovering and generating new technology, chemistry, and methods to manage the disease more effectively, major improvement has been scarce and short-lived. Strobilurin fungicides were the last effective class of chemistry registered for black Sigatoka control, and resistance by *Mycosphaerella fijiensis* has to these fungicides already has become widespread in Costa Rica and is likely to show a similar trend in other parts of the world where intensive banana production and black Sigatoka coexist. In the absence of new, effective fungicide chemistry to combat the disease, the importance of defining effective components of crop nutrition and induced resistance is more urgent.

History of induced resistance or systemic acquired resistance (SAR). The concept of induced resistance against disease in plants is not new. The pioneering studies [1,2,3] were published as far back as 1961. The concept is based on the observation that treatment of plants with a weak pathogen or exogenous substance can create a plant physiological defense response that reduces the pathogen's ability to attack the normally susceptible host. Further characterization of the concept was made by such researchers as Kuc [4]. It is now well accepted among plant scientists and plant pathologists that plants respond to pathogen attack by activation of a large number of defense mechanisms. These include the production of antimicrobial metabolites (phytoalexins) and proteins as well as physical reinforcement of cell walls through production of callose and lignin. Phytoalexins in *Musa* spp. have been described [5].

Chemical inducers. In the literature, exogenously applied chemicals which induce plant resistance against disease have been reported. One of these, acibenzolar-S-methyl [5] (Boost®, Bion®, Syngenta Crop Protection) was marketed in several crops including banana with claims of increasing the plants resistance to disease. In the case of banana, Boost has been intensively researched and field tested by large banana producers but has been used only sporadically on a commercial scale. The product does appear to induce a significant defense response in banana plants against black Sigatoka, but the level of this response has generally been perceived to be weak and/or inconsistent. Additionally, the use of Boost appears be associated with plant growth regulating (PGR) effects in banana.

Salicylic acid and its analogues also are widely reported in the scientific literature to induce plant defense responses [2,6,7]. Indeed, the phenomenon of SAR has been linked closely to salicylic acid, and many research articles point to salicylic acid as a biochemical messenger in plants triggering enhanced resistance to infections. The biochemical pathway encompassing this plant response has been termed the salicylic acid pathway. Acibenzolar-S-methyl has a salicylic acid component in its molecular structure. Research in banana has shown that salicylic acid can be applied without causing overt phytotoxicity. Its potential to induce a useful level of resistance against black Sigatoka is under field investigation.

Other compounds that have been reported to induce SAR in plants via the salicylic acid pathway include ß-aminobutyric acid (BABA), gamma aminobutyric acid (GABA), probenazole, ribloflavin, chitosan, and phosphorous acid or its salts (phosphites). With the exception of phosphites, there are no known reports of these compound's effects on banana and black Sigatoka.

Jasmonic Acid Pathway. Another important biochemical pathway, the jasmonic acid pathway [9], has been described to be involved in SAR as well as in induced systemic resistance (ISR). ISR refers to disease resistance induced by biochemical pathways associated with the colonization of roots by microorganisms. The interactions between the salicylic acid pathway and the jasmonic acid pathway, which can be antagonistic, are reviewed by Glazebrook [10].

Phosphorous acid. Since the discovery of fosfetyl-al, and the subsequent research by Fenn and Coffey [11, 12], the interest in phosphites as fungicides as grown significantly. It is now generally accepted that phosphites have both a direct effect (toxicity of phosphonate ion) and indirect effect (phytoalexin induction) on plant pathogens, and that all phosphites behave similarly as they decompose to the phosphonate ion (HPO_3^{-2}) in the plant [13,14]. Despite some reports to the contrary, several controlled studies have indicated strongly that phosphites are not nutritional sources for plants, to the contrary thay can worsen the effects of phosphorous (PO_4) deficiencies [15]. There have been several reports of positive interaction or synergism of phosphites with other compounds, such as acibenzolar-S-methyl [16], BABA [17], and salicylic acid. Phosphites have been characterized to some extent for control of black Sigatoka. It is likely that phosphites will play an important role in an integrated program for disease control in banana, but further work is needed to determine the optimum use patterns and tank mixtures.

Nutritional components. SAR and/or ISR involve energy-intense biochemical responses in plants, associated with the rapid increase in the synthesis of phytoalexins, defense proteins, and physical barriers in plant cell walls. These physiological responses increase the demand for plant nutritional components such as phosphates (PO_4), potassium, calcium, zinc, sulfur, and others. If the plant is starved of essential nutrients, the plant defense response may induce stress with associated negative consequences on plant development and crop production. Therefore. it seems essential to consider plant nutritional components in SAR and ISR research and application. Additionally, some elements and nutrients have been reported to have a direct effect on plant disease resistance, such as silicon, copper, and sulfur. The topic of nutritional components and their optimization in banana cultivation for increased resistance to black Sigatoka should be thoroughly explored.

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