PEST CONTROL: FUNGI, STREPTOMYCETES, AND YEASTS

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Keywords: pest control, fungi, streptomycetes, yeasts, crop losses, evolution of microorganisms, biological control

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Summary

Plant diseases continue to challenge our global agricultural production systems resulting in an average of 13% annual yield loss despite our best efforts to manage them with fungicides, resistant cultivars, and a variety of agronomic practices. About forty years ago the concepts of biological control were first developed. Interest in the development of "nature's own products" or biological control as an alternative management practice for fungal disease control resulted from the development of resistance to fungicides, the introduction of legislation restricting pesticide use, and global concerns for human health and environmental safety. Fungi, streptomycetes, and yeasts are the most abundant naturally-occurring, microscopic organisms found on plants and in soil. Strains of these microorganisms, such as AQ10, MycoStop, and Aspire have demonstrated an ability to protect some crops from plant diseases using an integrated approach combining a biological control product with traditional disease management practices. This chapter discusses the nature of crop losses experienced throughout the world due to fungal diseases, the traditional methods employed for disease control, the evolution of biological control concepts, and the emerging role of fungi, streptomycetes, and yeasts in crop protection.

1. Introduction

Soils are the most important resource available for enhancing agricultural production throughout the world. Healthy soils maintain a diverse population of biologically active microorganisms that perform a wide range of functions. Fungi, streptomycetes, and yeasts are the most abundant groups of microscopic organisms found on plants and in the soil. Each of these groups has species that may be beneficial or detrimental to mankind and agriculture. Fungi are responsible for the disintegration of organic matter, cycling of nutrients, and production of antibiotics (ie. penicillin), but also cause the majority of plant diseases found in agriculture throughout the world. Streptomycetes are instrumental in the breakdown of organic matter in the soil and produce 70% of the world's antibiotics that inhibit growth of fungi and bacteria (ie. *Streptomyces griseus* produces streptomycin), but they also cause plant disease (e.g. *S. scabies* causes potato scab). The primary role of yeasts has been the fermentation of carbohydrates which mankind has harnessed for the making of bread and production of alcohol.

New roles are being discovered for these groups of organisms, such as the remediation of contaminated soils, plant growth promotion, and crop protection. There is strong interest in the development of "nature's own products" or biological control as an alternative management practice for fungal disease control. This is a result of the development of resistance to fungicides and legislation which has gradually reduced the availability of other fungicides in the marketplace due to health and environmental concerns. Punja (1997) reviewed the use of fungi, bacteria, and yeasts as biological control agents for the reduction of fungal diseases on vegetable crops in Canada and believes that these organisms provide ample opportunities for commercial utility. However, the development and commercialization of biological control products has been met with varying degrees of success. This chapter will discuss the nature of crop losses experienced throughout the world due to fungal diseases and the traditional methods employed for disease control, the evolution of the biological control concept, and will examine the roles of fungi, streptomycetes, and yeasts in crop protection.

2. Crop losses due to fungal diseases

Since early times of plant cultivation, fungi have caused most of the plant disease epidemics around the world. Epidemics such as late blight famine of potato caused by *Phytophthora infestans* in 1845 and 1846 resulted in the starvation and death of hundreds of thousands of people in northern Europe and the immigration of half a million Irish to USA. Not all disease epidemics are so devastating, but many result in significant economic losses due to reduced yield and quality (see Table 1). The most important diseases based on crop losses and market potential are leaf spot diseases, late blight and downy mildews, rice diseases, fruit rots, seed-borne cereal diseases, powdery mildews, cereal stem diseases, rusts and smuts. Crop loss is defined as the difference between attainable yield under optimal conditions and the actual yield. During the period from 1965 to 1990, there has been an increase in crop losses from pathogens: up 6.1% in rice, 2.9% in wheat, 1.8% in barley, and 1.2% in maize. In other crops, losses have decreased over this period: down by 5.8% in potato, 2.1% in soybean, 1.5% in cotton, and 1.9% in coffee (Oerke et al. 1994). There are significant differences in the regional distribution of diseases and the losses incurred. Regions that utilize high input farming techniques, such as for cereal production in western and central Europe, often have higher losses associated with diseases, but intensive disease control practices reduce these losses by two-thirds to about 7% (Dehne and Oerke, 1998). In other regions of the world including North America, Oceania, Africa, and Asia, crop protection measures are less than 25% effective. So, despite increasing trends in the average yield in most regions of the world (see Table 1), pathogens are still causing crop losses averaging 13.3 % while current crop protection methods used globally (i.e. physical, biological, and chemical methods) are only providing 4.2% control (Oerke et al. 1994).

	Crop loss %	**Economic loss $ billion**	**Production million tonnes**	**Yield increase per year %**	**Fungicide sales $ million**	**Fungicide use as % of total pesticides [z]**
Rice	15.1	33.0	509	2.1	900	25.4
Wheat	12.4	14.0	548	2.8	1440 [y]	31.6
Barley	10.1	1.9	172	1.8	1440 [y]	31.6
Maize	10.8	7.8	449	1.9	100	2.9
Potato	16.3	9.8	273	0.2	255	31.1
Soybeans	9.0	3.2	103	1.9	60	2.0
Fruit and vegetables	18.6	29.4	747	2.4	2385	34.3
Mean	13.3	14.2	400	1.9	857	21.2

(Adapted from Oerke et al. 1994; Dehne and Oerke, 1999; Schwinn 1992)
[z] Total pesticides based on sales of fungicides, insecticides, and herbicides for a crop;
[y] total sales all cereal crops

Table 1. Estimated average annual losses from plant diseases in the production of food crops and the amount of fungicides used in crop protection between 1987-1990

3. Traditional disease control practices

Although diseases should be controlled with integrated disease management, fungicides are the only method available that actively control disease within a growing crop. Globally, foliar spray and dust applications account for about 90% of the fungicide market, seed treatments for 10%, and the use of fumigants is relatively minor (Dehne and Oerke, 1998).The use of fungicides has increased from 1965 to 1995 with sales climbing from $340 million to $5900 million worldwide. Approximately 75% of the fungicides sold are used in western Europe and East Asia, 18% in North America and Latin America, and 7% in the rest of the world (Schwinn 1992). Cereals, rice, potato, and fruits and vegetables are among the principal food crops that receive the largest quantities of fungicides (see Table 1). During the 1990s, systemic fungicides with greater persistence were developed and took over 66% of the market share. There was also the adoption of different fungicide application technology, such as reduced rates of application, synergy with adjuvants, accurate timing of applications, and more efficient nozzle designs, which have reduced costs of application and improved the level of control. Frequent intensive use of fungicides with single modes of action has resulted in the development of resistance in some pathogens. For example, 60% of *Phytophthora infestans* isolates (late blight of potato) in the UK and the Netherlands are resistant to phenylamide fungicides (Dehne and Oerke 1998). Yet, these compounds remain an important tool for disease management provided they are used in rotation with other fungicide classes using other modes of action and other disease management practices.

Other components of an integrated disease management program include cultivar resistance and cultural practices such as crop rotation, tillage, sanitation, seeding date, row spacing, seeding depth, and fertility (Bailey, 1997). Genetic resistance derived from either traditional plant breeding methods or genetically engineered technology is the most economical way to reduce losses from plant diseases. A study in wheat compared the cost of production using leaf spot tolerant crop cultivars that were grown either with or without intensive fungicide management (Paxton et al., 1992). This study found that although the yields were higher with fungicides (by 13%), the cost of production was 36% more, resulting in an economic loss. The next most commonly used practice is crop rotation which manipulates soil-borne and residue-borne pathogens by decreasing the pathogen inoculum levels. The rate of pathogen decline parallels the rate of crop stubble decomposition. Cook and Veseth (1991) showed the influence of cropping history on the yield of irrigated spring wheat in a field naturally infested with take-all (*Gaeumannomyces graminis* var. *tritici*):

- wheat grown consecutively for 16 years yielded 4.1 tonnes per hectare,
- wheat grown after 12 years of wheat and 3 years of barley yielded 3.9 tonnes per hectare, and
- wheat grown after 12 years of wheat and 3 years of potato yielded 5.8 tonnes per hectare.

Barley was a host for take-all and so pathogen inoculum did not decline, whereas potatoes were not a host and the pathogen could not survive in the absence of a susceptible host or residue. Implementation of the remaining integrated disease management practices may contribute 5-10% greater yield, but the results are widely varied among pathogens, crops, and regions.

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Biographical Sketch

Karen Bailey is a research scientist with Agriculture and Agri-Food Canada in Saskatoon, Saskatchewan, Canada. Working as a plant pathologist, she has developed integrated pest management strategies for diseases of cereal, oilseed, and pulse crops, which have been utilized by farmers and researchers throughout North America, the Middle East, and Australia. These strategies included the development of new crop cultivars with disease resistance, and reducing disease problems with other management tools, such as agronomic practices and fungicides. Dr. Bailey's research is currently focused on the processes of biological control and the development of naturally-occurring microorganisms as the pest control tools of the future.