Management of Diseases in Seed Crops

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INTRODUCTION

The success of modern agriculture is dependent on a vital seed industry that enables the timely production and distribution of high-quality, pathogen-free seed of high-yielding cultivars adapted to specific geographic regions and methods of production. The value of the world seed market is estimated at $40–60 billion, and the demand for seed is expected to keep pace with the world's growing population.[1] The increasingly global nature of the seed industry brings an associated risk of widespread dissemination of seedborne pathogens. As a result, effective disease management in seed crops remains central to the seed industry.

SEED CROP DISEASES

Although management of plant diseases is important for most crops, it is particularly critical for production of high-quality seed. Plant pathogens can reduce the quantity and quality of seed harvested, and many can be seedborne (Fig. 1). A significant proportion of the seed market is associated with worldwide movement of seeds, and seeds are distributed internationally for breeding programs and research purposes. Seeds provide an efficient means of inadvertently disseminating plant pathogens. Numerous examples can be found of plant disease epidemics resulting from the introduction of seedborne pathogens, often culminating in significant economic losses.[2]

Strategies for Managing Seed Crop Diseases

General strategies for disease management in agriculture are pertinent to seed crops, i.e., exclusion of pathogens from regions of seed production, eradication of pathogens from seed crops, protection of seed crops, alleviation of disease pressure using cultural practices, and incorporation of disease resistance into cultivars. However, seed production is a complex process involving meticulous criteria followed rigorously by seed producers.[3] Consequently, disease management programs for seed crops can be more complex than for commercial crops, and require integration of the many tools available. The specific strategies selected are influenced primarily by economic factors, ultimately governing the value and amount of seed produced.

The extremely low tolerance for pathogens in seed crops has resulted in specialized areas of seed production in regions where pathogens are unable to establish or usually remain below threshold levels during seed development.[4,5] In the United States, seed production occurs primarily in the western states where pressure from fungal and bacterial pathogens is reduced by low rainfall and relative humidity. For example, bean seed production occurs in the semiarid regions of Washington and Idaho. Similarly, the mild winters and dry summers of western Washington make this maritime region ideal for production of biennial Brassica seed crops free of black rot (*Xanthomonas campestris* pv. *campestris*) and black leg (*Phoma lingam*). Crucifer seed crops in Denmark are located in coastal areas where winds ventilate the crops, reducing development of black spot (*Alternaria brassicicola*).[2] Furthermore, whenever possible seed crops are isolated from commercial crops for disease control. Lettuce seed produced in the San Joaquin valley of California is isolated from commercial crops in the Salinas valley to prevent infestations of aphids carrying lettuce mosaic virus.[5]

Production of seeds is an energy-intensive process.[3] Consequently, some plant species become increasingly susceptible to certain pathogens at flowering. Development of leaf spot of spinach caused by *Stemphylium botryosum* is greatly exacerbated in the presence of pollen, necessitating initiation of protective fungicide applications prior to pollen shed in spinach seed crops.[6] Although *Fusarium oxysporum* f. sp. *spinaciae* causes damping-off of spinach seedlings, symptoms of Fusarium wilt in the seed crop are not apparent until flowering. Yield losses in the seed crop can be extensive without $\geq$10-year crop rotations.[7]

The duration of the seed crop season may result in a long window of susceptibility to infection or provide opportunities for infection during periods of stress or injury (e.g., winter injury in biennial carrot seed crops). Overwintered biennial and perennial seed crops may harbor pathogens that can spread to neighboring first-year crops. This green bridge effect led to epidemics of the aphid-vectored beet western yellows luteovirus in the beet seed industry in western Oregon.[8]

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Fig. 1 Scape and umbel blight in an onion seed crop, caused by the fungus *Botrytis aclada*, reduces the quantity and quality of seed harvested. (*View this art in color at www.dekker.com.*)

Cultural practices can create less favorable conditions for disease development. Crop inspections and roguing of symptomatic plants or alternative hosts of plant pathogens can reduce disease in a seed crop. Crop rotation is essential for managing many plant diseases. The minimum duration of rotation depends on the longevity of specific pathogens, and may range from a few years to >10 years. Planting seed crops in suppressive soils can assist in production of pathogen-free seed, as demonstrated for pea seed crops free of *F. oxysporum* f. sp. *pisi* in California.[5] Furrow irrigation restricts splash-dispersal of many pathogens compared to overhead irrigation. Increased spacing of plants reduces disease pressure for fungal and bacterial pathogens as a result of increased air circulation. Incorporation of infested crop debris into the soil reduces survival of some pathogens. Fire is used to reduce inoculum levels of certain plant pathogens (e.g., burning of stubble/straw in grass and cereal seed crops).

Foliar applications of fungicides, bactericides, and resistance-inducing chemicals can provide effective management of many plant pathogens in seed crops. The extended season of seed crops, combined with the low tolerance for seedborne pathogens, often necessitates a greater number of pesticide applications than in commercial crops and requires precise timing of applications with periods of increased susceptibility and disease pressure. However, the minor acreage of individual seed crop species impedes attainment of pesticide registrations for seed crops because of the limited returns to pesticide manufacturers. As a result, some states have implemented programs that qualify certain seed crops for non-food, non-feed status to facilitate pesticide registrations.

Fumigation, and biofumigation using cover crops, can eradicate persistent inoculum of some pathogens, but the former may be cost-prohibitive.[2,4,5] Seed treatments provide effective means of eradicating or reducing some pathogens, and can be applied to both the stock and harvested seed. Fungicide seed treatments eradicate seedborne inoculum, inhibit seed-to-seedling transmission of pathogens, or protect emerging seedlings from soilborne or airborne pathogens. Systemic fungicides are valuable for eradication of internal seed infection and protection of subsequent new growth of seedlings. Physical seed treatments (e.g., hot water, steam, or chlorine) can eradicate or reduce inoculum on seeds. The efficacy of seed treatments depends on the degree of internal infection of the seed, the amount of inoculum in a seed lot, specificity of the treatment, and potential phytotoxicity of the treatments.[1,3,4]

Plant breeding has successfully introduced disease resistance into many commercial seed crop cultivars. However, resistance may not be available for some pathogens. In hybrid seed crops, resistance may only be present in one of the parent lines, necessitating disease management practices for the susceptible parent. Furthermore, some pathogens have the ability to overcome single-gene resistance, complicating efforts to manage diseases in seed crops using resistance.

Quality control is fundamental to the seed industry.[2] Seed certification programs encompass field inspections and lab assays so that the history of seed lots can be traced.[4] Emphasis is placed on assays for seedborne pathogens, as many can go undetected during field inspections. To be of value, seed health assays must be specific, sensitive, reliable, cost-effective, and rapid.[5] In 1958, the International Seed Testing Association initiated development of standardized seed health assays.[1] Despite this, most seed testing protocols published in the literature have not been standardized, resulting in a range of methods utilized by different laboratories. This can lead to different results, sometimes with significant ramifications regarding international seed shipments. Techniques for detecting seedborne pathogens include visual inspection, incubation on agar or blotters, staining, pathogenicity tests, serological assays (e.g., enzyme-linked-immunosorbent assays), and nucleic acid assays (e.g., polymerase chain reaction assays).[5,9] Approval of seed lots for shipment may be based on results of seed assays, so rapid turnaround is critical in seed testing facilities. Advances in rapid nucleic acid assays have overcome problems with inhibitory seed-derived compounds, resulting in increasing application of this technology for seed health assays.[9]

CONCLUSION

The new U.S. National Organics Program for certified organic produce states that the ‘‘producer must use organically grown seeds,’’ ‘‘may use untreated nonorganic seeds . . . when equivalent organic varieties are not commercially available,’’ and seeds ‘‘treated with prohibited substances may be used to produce an organic crop when the application of the substance is a requirement of Federal or State phytosanitary regulations.’’[10] These standards have increased the demand for organically-produced seed, but have also raised concerns about associated increases in losses from seedborne pathogens because of the limited number of organic options for seed treatment and disease management. Research is needed to investigate alternatives for successful production of pathogen-free organic seed.

The rapid acceleration in worldwide movement of seed can be justification for plant quarantines. However, there is a significant lack of epidemiological research on the economic impacts of specific seedborne pathogens, on which the regulations and quarantines regarding seedborne pathogens need to be based.[1] Consequently, many of a large number of new phytosanitary regulations cannot be justified scientifically and have been interpreted as phytosanitary barriers used only to protect domestic agricultural industries.[1] Epidemiological research is needed to provide a scientific basis on which to implement regulations affecting the global seed industry.

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ARTICLES OF FURTHER INTEREST

Bacterial Survival and Dissemination in Seeds and Planting Material, p. 111
Integrated Pest Management, p. 612
Seed Borne Pathogens, p. 1126
Seed Production, p. 1134
Seeds: Pathogen Transmission Through, p. 1142

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