Overview

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Inoculum threshold of seedborne pathogens is the amount of seed infection or infestation with plant pathogens that will cause a disease in the field under a conducive environment and lead to economic losses. It is important to establish the inoculum threshold level when clean seed is used as a disease control measure.

Use of clean seed is an important disease control measure because seed transmits plant pathogens and seed is exchanged worldwide. Each year, seeds are exchanged throughout the world by commercial seed trading activities, through germ plasm exchange activities of international organizations, and by public and private institutes concerned with crop improvement. Because many plant pathogens can survive in, on, or with seed, seed has been and continues to be an important vehicle for transmitting plant pathogens throughout the world. For example, in 1984 P. Hewett reported at the 18th International Seed Testing Association, Plant Disease Committee (ISTA-PDC), Workshop that seed of *Vicia faba* has carried three viruses and ascochyta leaf and pod spot from North Africa, Belgium, and Germany to England and then from England to France, Denmark, Canada, New Zealand, and Australia. Many plant viruses occur widely in plant germ plasm collections, and their viruses can be transmitted through exchange and use of germ plasm (10). For example, soybean mosaic virus has been distributed through the world via international exchange of soybean germ plasm. This virus in *Glycine max* germ plasm collections has reduced yield of affected germ plasm accessions (7). The outbreak of pea seedborne mosaic virus in the 1970s has been traced back to *Pisum sativum* germ plasm (9). Thus, use and exchange of clean seed is an important method to manage plant disease. Many public and private institutes (12) involved with seed exchange activities realize this importance and are using every possible means to produce and ship clean seed.

When a disease does not occur in a country or area, it is logical to protect the area by quarantine and insist that only "pathogen-free" or "disease-free" seeds be allowed to enter. However, when a disease is present in a country, clean seed may still be used for disease management. Finite levels of seed infection may be acceptable if this level does not result in economic loss from plant disease. In this case, the term "clean" seed is preferred over "pathogen-free" seed or "disease-free" seed in disease control programs. Clean seed is seed with a pathogen level that will not result in economic loss to its user. Seed plants are grown under field conditions that are neither sterile nor necessarily free of disease. "Pathogen-free" or "disease-free" or "zero-tolerance" becomes a practically unrealistic and impossible requirement under these conditions. Although increasingly sensitive seed testing techniques are being developed and used, seed health testing for seedborne pathogens can never certify that there is absolutely no contamination. In addition, these terms create a false sense of security when determination is based on a nil test result (11).

Inoculum threshold, thus, becomes a very important factor in seed pathology and plant disease control by the use of clean seed. It can validate seed testing and certification programs, it can be used to evaluate the efficacy of seed treatment programs, and it can provide realistic guidelines for the development and implementation of disease control programs in seed production fields. These programs are necessary to produce and ship clean seed.

In spite of its importance, inoculum threshold is difficult to establish. It is influenced by many factors, such as macro and micro environment, cultural practices, agricultural systems, locations, certification requirements, and generation of seed (breeder, foundation, or certified seed). For example, lettuce mosaic virus can be controlled by using seed certified to have 0 infected seed in 30,000 in California and 0 in 2,000 in the Netherlands (8). Different climate and cropping systems make the difference. The Netherlands has cooler weather, hence, a lower aphid population. There, farmers practice multiple cropping system (i.e., leek-lettuce-cabbage) to break the disease cycle. In contrast, California has warmer weather and high populations of aphids. Lettuce is grown during almost the whole year in California. Thus, there is no interruption of lettuce production to break the disease cycle.

Inoculum threshold varies with growing practices. In 1973, low levels of seedborne *Phoma lingam* inoculum spread in cabbage transplant fields and resulted in severe blackleg disease losses, whereas no disease was reported when this same seed lot was direct seeded (3). Seedborne disease problems can be even more serious when transplants are produced in semisterile media under high moisture levels (1). Thus, threshold levels must be established for the average conditions under which the crop is grown.

Different inoculum thresholds need to be established for seeds at different levels in a certification program. The threshold for breeder seed must be lower than that for foundation seed or certified seed. The inoculum thresholds allowed for quarantine purposes must be zero.

Inoculum threshold levels should be determined by correlation between seed infection level established by seed testing and field disease damage data established by well designed experiments. However, due to the complexity discussed above, inoculum thresholds for most seedborne pathogens have not been established by this manner. Most of them have been set either arbitrarily or with only field observation data. However, there are few seedborne pathogens for which inoculum thresholds have been established with supportive correlation data, such as *P. lingam* (4), *Xanthomonas campestris* pv. *campestris* (15), *Pseudomonas phaseolicola* (17), and *Diaporthe phaseolorum* var. *sojae* and *Phomopsis* sp. (5).

Although we are establishing inoculum thresholds, there are two additional points that need to be thoroughly considered. First, simple, understandable statistical procedures are needed to validate the seedborne pathogen tests (6). Second, how can we decide the seed inoculum thresholds when other inoculum sources, soil, crop residue, and weeds exist?

The need for establishing inoculum thresholds is now greater than ever because of the increasing seed movement and the need for reasonable phytosanitary requirements. This need was the major subject of various formal and informal discussions of the 18th ISTA-PDC Workshop. Dr. S. Young, who chaired the Pathological Advisory Committee of the Association of Official Seed Certifying Agencies, also requested help from plant pathologists in establishing inoculum thresholds for them to conduct reasonable seed certification programs. In addition, all seed testing stations, certification agencies, and the seed industry need to have established inoculum thresholds as guidelines for using clean seed to control plant disease.

Realizing this increasing need for inoculum thresholds and the complexity and difficulty in establishing inoculum thresholds for seedborne pathogens, the Seedborne Disease Committee of The American Phytopathological Society sponsored this symposium to further address these issues for seedborne fungi, bacteria, and viruses and the proper use of statistical procedures.

Inoculum thresholds have been established for many seedborne

fungi. Gabrielson documents effects of different conditions on inoculum thresholds by discussing these effects on seed transmission and disease spread in fields (2). He stresses that inoculum thresholds must be established for the average conditions of the area in which the crop will be grown. Schaad reports that inoculum thresholds for seedborne bacteria are usually low, because bacteria spread rapidly in conducive environments (14). He discusses inoculum thresholds of a few seedborne bacteria. Stace-Smith and Hamilton discuss factors contributing to economic damage caused by seedborne viruses and relate these factors to recognized plant virus groups (16). There are very few seedborne viruses for which inoculum thresholds have been established. Russell discusses sampling and statistics involved in accurate seed testing (13). Accurate estimates of pathogen levels in a seed lot are essential for establishing usable inoculum thresholds of seedborne pathogens.

LITERATURE CITED

1. Bassey, E. O., and Gabrielson, R. L. 1983. The effects of humidity, seed infection level, temperature and nutrient stress on cabbage seedling disease caused by *Alternaria brassicicola*. Seed Sci. Technol. 11:403-410.
2. Gabrielson, R. L. 1988. Fungi. Part of Inoculum Thresholds of Seedborne Pathogens Symposium. Phytopathology 78:868-872.
3. Gabrielson, R. L. 1983. Black leg diseases of Crucifers caused by *Leptosphaeria maculans (Phoma lingam)* and its control. Seed Sci. Technol. 11:749-780.
4. Gabrielson, R. L., Mulanax, M. W., Matsuoka, K., Williams, P. H., Whiteaker, G. P., and Maguire, J. D. 1977. Fungicidal eradication of seedborne *Phoma lingam* of Crucifers. Plant Dis. Rep. 61:118-121.
5. Garzonio, D. M. & McGee, D. C. 1983. Comparison of seeds and crop residue as sources of inoculum for pod and stem blight of soybean. Plant Dis. 67:1374-1376.
6. Geng, R., Campbell, R. N., Carter, M., and Hills, F. J. 1983. Quality control programs for seedborne pathogens. Plant Dis. 67:236-242.
7. Goodman, R. M., and Oard, J. H. 1980. Seed transmission and yield losses in tropic soybeans infected by soybean mosaic virus. Plant Dis. 64:913-914.
8. Grogan, R. G. 1980. Control of lettuce mosaic with virus-free seed. Plant Dis. 64:446-449.
9. Hampton, R. O., and Braverman, S. W. 1979. Occurrence of pea seed borne mosaic virus and new virus-immune germ plasm in the Plant Introduction collection of *Pisum sativum*. Plant Dis. 63:95-99.
10. Hampton, R., Waterworth, J., Goodman, R. M., and Lee, R. 1982. Importance of seedborne viruses in crop germ plasm. Plant Dis. 66:977-978.
11. Hewett, P. D. 1981. Seed standards for disease in certification. J. Nat. Agric. Botan. 15:373-384.
12. Kuan, T. L. 1983. The role of private industry in the production of high quality seed. Seed Sci. Technol. 11:1019-1026.
13. Russell, T. S. 1988. Some aspects of sampling and statistics in seed health testing and the establishment of threshold levels. Part of Inoculum Thresholds of Seedborne Pathogens Symposium. Phytopathology 78:880-881.
14. Schaad, N. W. 1988. Bacteria. Part of Inoculum Thresholds of Seedborne Pathogens Symposium. Phytopathology 78:872-875.
15. Schaad, H. W., Sitterly, W. R., and Humaydan, H. 1980. Relationship of incidence of seedborne *Xanthomonas campestris* to black rot of Crucifers. Plant Dis. 64:91-92.
16. Stace-Smith, R., and Hamilton, R. I. Viruses. Part of Inoculum Thresholds of Seedborne Pathogens Symposium. Phytopathology 78:875-880.
17. Taylor, J. D., Phelps, K., and Dudly, C. L. 1979. Epidemiology and strategy for the control of halo-blight of beans. Ann. Appl. Biol. 93:167-172.