Guide for clean seed replacement timing on-farm

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This guide provides information for developing decision support for farmers evaluating the best frequency of clean seed replacement in systems, in locations where farmers sometimes use informal seed and sometimes buy quality declared seed.

Seed health and seed degeneration. Pathogens and pests can accumulate when seed is saved on farm. This is the case for most crops, and especially for vegetatively-propagated crops like banana, cassava, potato, sweetpotato, yam, and cocoyam. Buying quality-declared seed benefits farmers by giving them healthier crops, at least at the beginning of the season. Pathogens and pests may still find the crop, but the crop gets a good start.

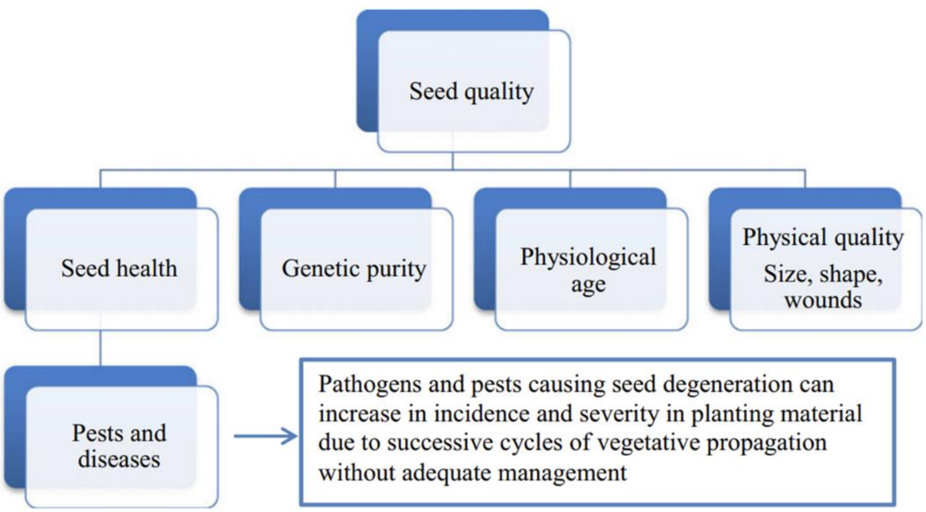

Figure A. Pests and diseases are an important component of seed quality. The buildup of pests and disease can occur when on-farm seed is saved across seasons (figure from Thomas-Sharma et al. 2016).

<u>Endemic versus invasive pathogens and pests</u>. A key distinction when considering how to manage a pathogen or pest is whether it is already established in the region and in a particular farm. Pathogen-free seed is critical for pathogens that are not yet in the region and very important when the pathogen is not yet in a farm. Once a pathogen is present in a region, use of quality declared seed still provides advantages by keeping disease levels lower for at least part of the season, even if the disease is not actually absent.

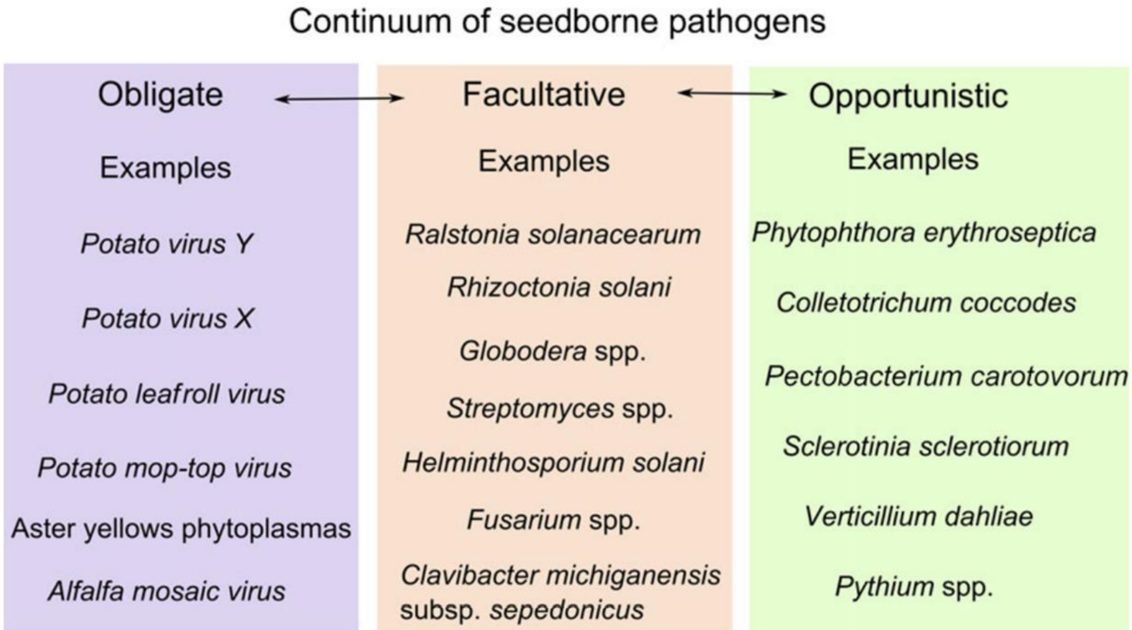

Figure B. An example of seedborne pathogens for potato. Some damaging species like viruses are inside planting materials while others like some insect pests can be associated with planting material (figure from Thomas-Sharma et al. 2016).

Use of informal seed. Informal seed saved on-farm, or obtained from friends and neighbors, may be sufficiently disease- and pest-free for use in the coming season. If disease and pest pressure was low, the seed may be fine. Farmers may also select for symptomless plants to be their sources of seed, to reduce risk. But over time, pathogens and pests tend to build up.

<u>On-farm management of seed health</u>. On-farm management strategies can reduce the frequency with which formal seed needs to be purchased. For example, positive selection is the practice of identifying symptomless and robust plants and using those as a seed source. Negative selection is the practice of identifying unhealthy plants and avoiding those as a seed source. These practices can substantially reduce the pathogen load in seed produced on-farm. To use these practices, farmers need to be trained in identifying symptoms and need to have the time available to monitor and mark plants prior to saving seed.

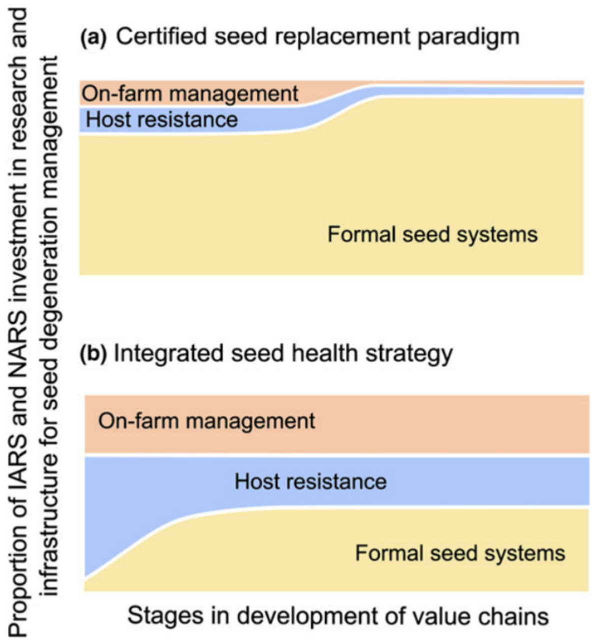

Figure C. The ‘certified seed replacement paradigm’ emphasizes focusing on farmers’ purchase of formal seed, while the ‘integrated seed health strategy’ emphasizes integrating formal seed, host resistance, and on-farm management, such as ‘positive selection’ of seed from symptomless plants to avoid disease (figure from Thomas-Sharma et al. 2016). Combined use of on-farm management (such as positive selection), disease resistant varieties, and well-timed purchase of quality-declared seed can boost farmer profits and productivity.

How frequently should external clean seed be obtained? If farmers can afford it, buying quality-declared seed every year is often a worthwhile investment. At the same time, farmers can invest in improved varieties. In cases where quality-declared seed is too expensive to buy every year or is not always available, farmers need to decide how frequently to buy seed.

Factors supporting more frequent quality-declared seed purchase
Seed is available and accessible (affordable)
New varieties have improved traits
Disease is spreading in the area
Labor is not available to practice on-farm management such as positive selection
Current on-farm varieties are disease susceptible

Table 1. Some factors that favor more frequent purchase of quality-declared seed.

Developing decision support for frequency of clean seed replacement. To support farmer decision-making about how frequently to purchase seed, it is helpful to have a general guideline about the costs and benefits of purchase. This might be adapted to particular environments in a region. An example of a recommendation might be the following. ‘For farms above X m, it is best to buy seed every 5 years. For farms below X m, it is best to buy seed every 3 years.’ There is also the potential to adjust decision making for varieties that are resistant versus susceptible to the most important diseases and pests.

Thomas-Sharma *et al.* (2017) developed a model to evaluate likely outcomes for seedborne disease and yield loss based on a set of parameters describing the cropping scenario: weather conduciveness to disease, level of disease resistance in the variety grown, frequency of seed purchase, etc. These give a general perspective on seed health over time. To support decisions in a particular crop in a particular region, this type of model can be parameterized based on experiments in the region, and the resulting model can be tested and adjusted for the region.

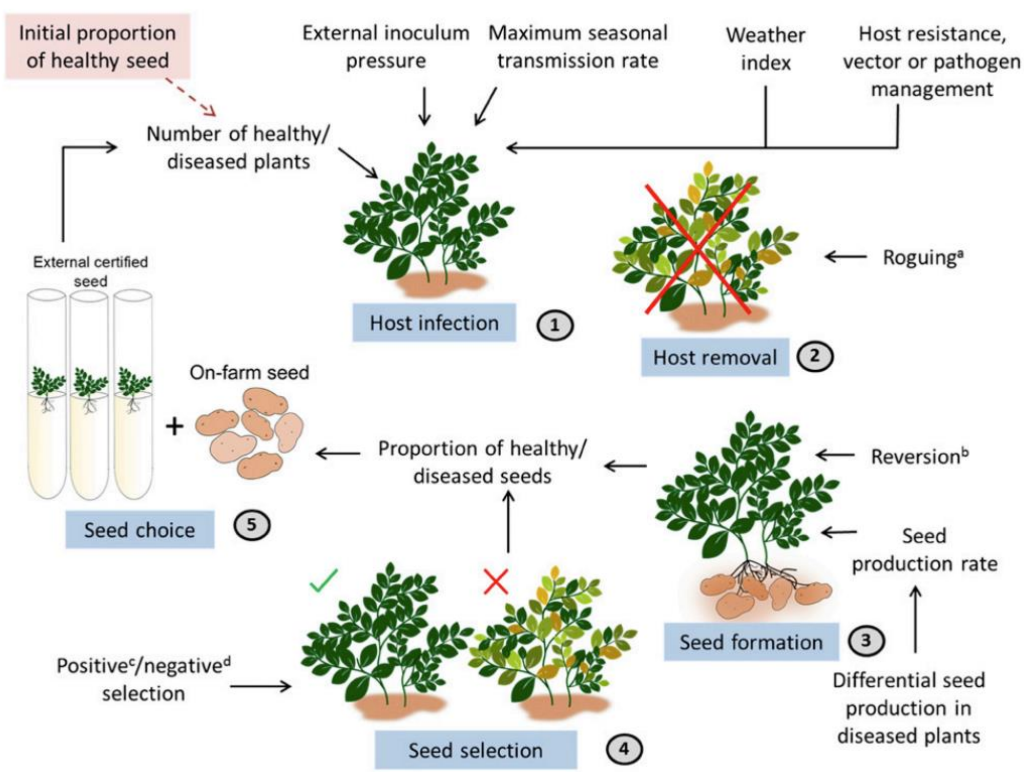

Figure D. Components of farm management that help to determine how frequently it is cost-effective to purchase seed. These parameters are included in the model developed by Thomas-Sharma et al. (2017), and the figure is taken from that publication.

Data needs for developing decision support. To develop useful decision support, data are needed to understand at least three types of relationships. First is the relationship between time and the level of disease in seed that is saved on-farm. Second is the relationship between disease level and economic loss. Third is the effect of environment (and/or variety or other management factor) on these relationships. Combining models of these relationships, we can look at likely yield loss over time in the set of environments (and/or varieties or other management factors) being considered and see at which time point yield loss is more expensive than the cost of purchasing quality-declared seed, i.e., when yield loss is likely to exceed an economic threshold.

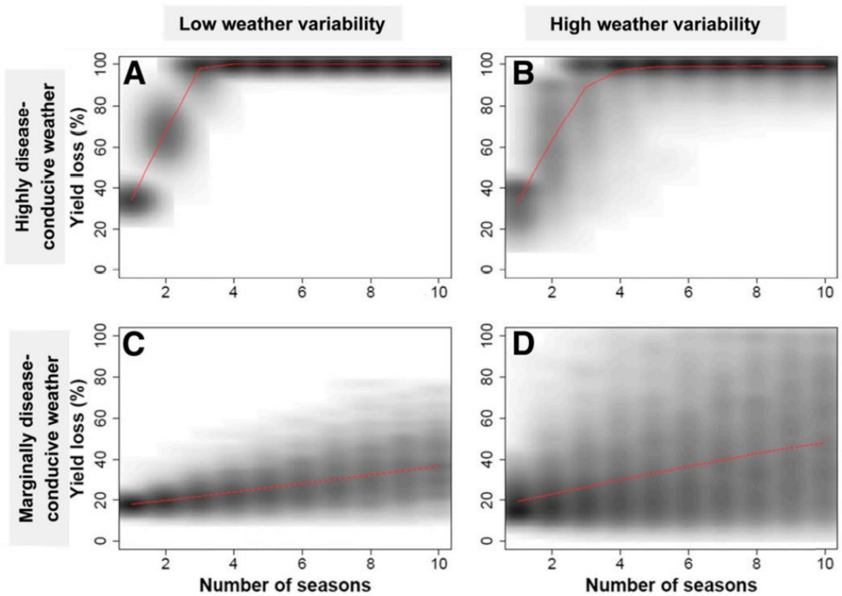

Fig. 2. Long-term (10 season) yield loss under no-management scenarios, with low starting levels of infection, under **A and B,** highly disease-conducive weather and **C and D,** marginally disease-conducive weather scenarios with high (0.3) and low (0.1) season-to-season variability in weather, in the absence of external inoculum (based on 2,000 simulations). Other parameters are set to default values in Table 2. Red lines indicate the mean value.

Figure E. Fig. 2 from Thomas-Sharma et al. (2017). The climate (mean weather conditions) at a location is an important component of seed degeneration, since disease-conducive climates will tend to have more rapid seed degeneration. Variation in weather between years is also important, as illustrated here. General decision support may be based on climate, and decisions about seed purchase may also draw on information about unusually conducive or non-conducive current years.

<u>Time and level of disease</u>. First, a general understanding of the relationship between disease levels and the number of seasons is needed to begin to understand how frequently seed should be purchased. This data might be collected in designed experiments or in observational studies in farmers' fields. Ideally there would be many replicates and many years of data to represent the level of variability in the study region.

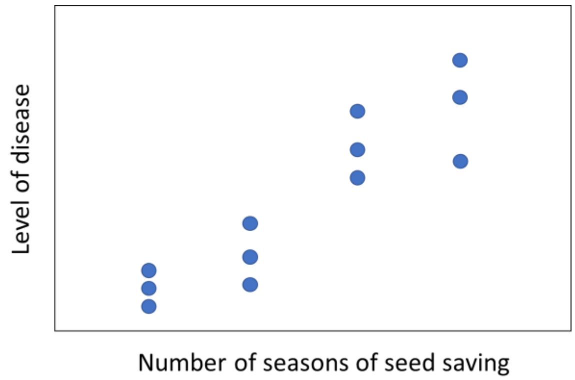

Figure F. A first step is to understand the general relationship between the level of disease and the number of seasons of on-farm seed saving, or use of informal seed.

Disease level and economic loss. Second, an understanding of the relationship between disease level and yield loss is needed. Previous studies may be a source of information about this relationship, but the relationship may also be different for newer varieties. Varieties with greater tolerance will have less loss for the same level of disease. The yield loss can then be calibrated to current market values for crop products to evaluate the monetary loss associated with a disease level.

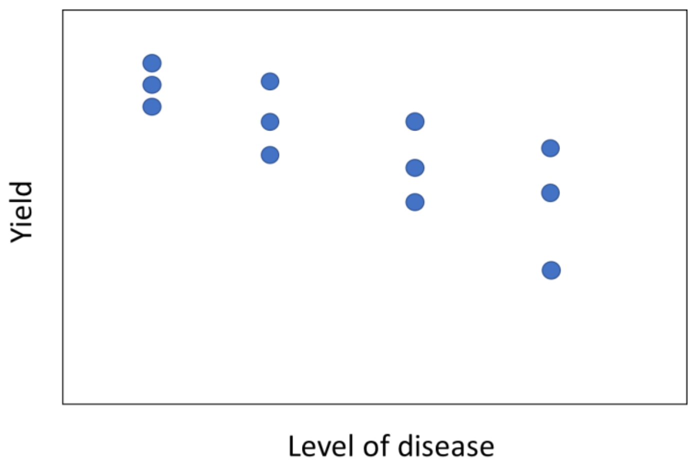

Figure G. A second step is to understand the relationship between the level of disease and resulting yield, calibrated for the current value of crop yield.

Effect of environment, variety, and/or other management factors. A decision support system can be more useful if it can be set up to be more specific. As mentioned above, one possibility would be a rule such as the following. ‘For farms above X m, it is best to buy seed every 5 years. For farms below X m, it is best to buy seed every 3 years.’ Similarly, decision support specific to particular varieties, based on their disease resistance and tolerance, can be more useful. The information about disease increase over time can be combined with information about economic thresholds, specific to a climate subregion and a variety type.

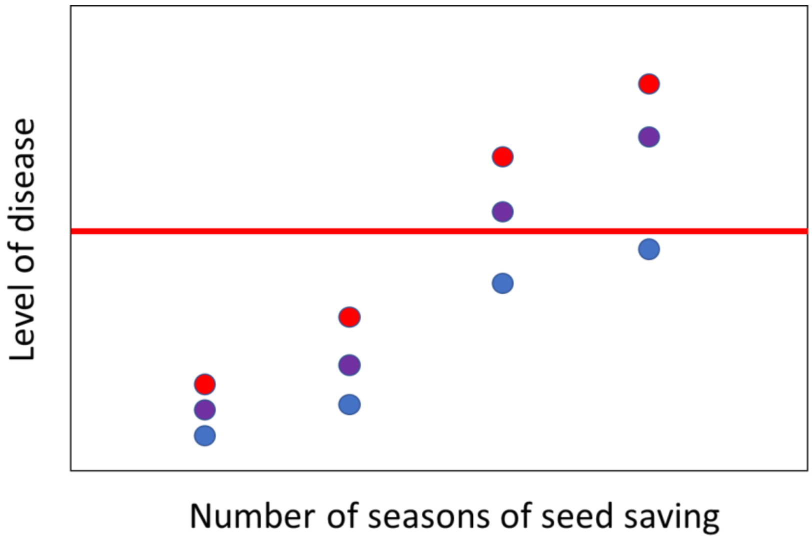

Figure H. The level of disease across time. Here the different color observations represent different scenarios, for example blue might be high elevation, purple medium elevation, and red lower elevation, where there might be more abundant vectors at lower elevations so that pathogens spread more quickly. Sufficient replicates from each specific climate-variety-management category will provide more confidence. The red line indicates an economic threshold above which purchase of seed is economically justified. This economic threshold would be evaluated based on the additional information about yield loss and economic value.

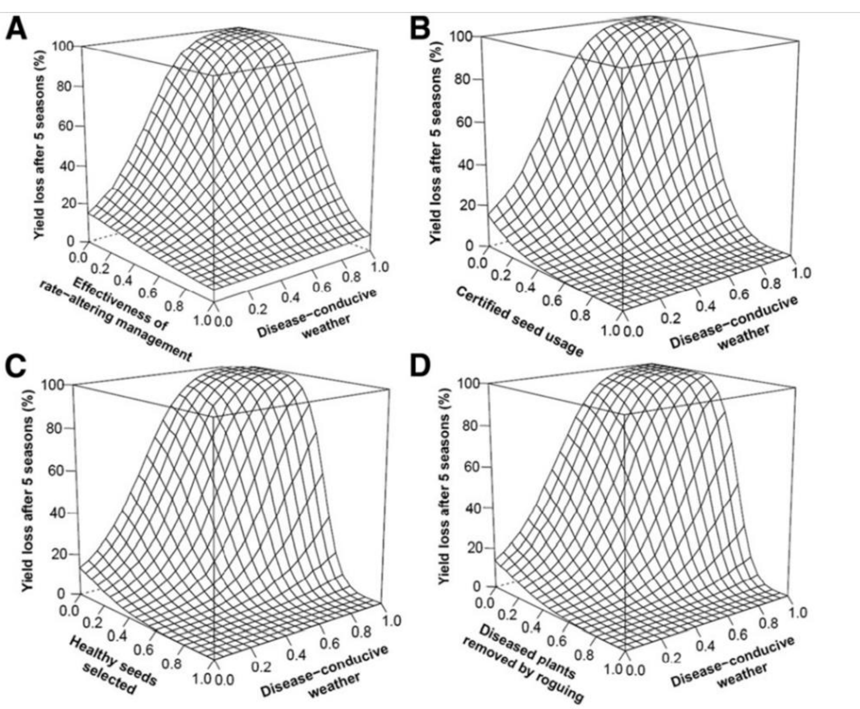

Fig. 3. Effect of rate-altering management components (such as vector or pathogen management and host resistance) (**A**) and incidence-altering management components: certified seed usage (**B**), seed selection (**C**), and roguing (**D**) on percent yield loss after 5 seasons under varying disease-conducive weather conditions,

Figure I. Figure 3 from Thomas-Sharma et al. (2017) illustrating how different components of systems may combine to produce different levels of disease loss over time. For example, (D) on-farm roguing (removal) of diseased plants can help to counterbalance the higher risk from having more disease-conducive weather.

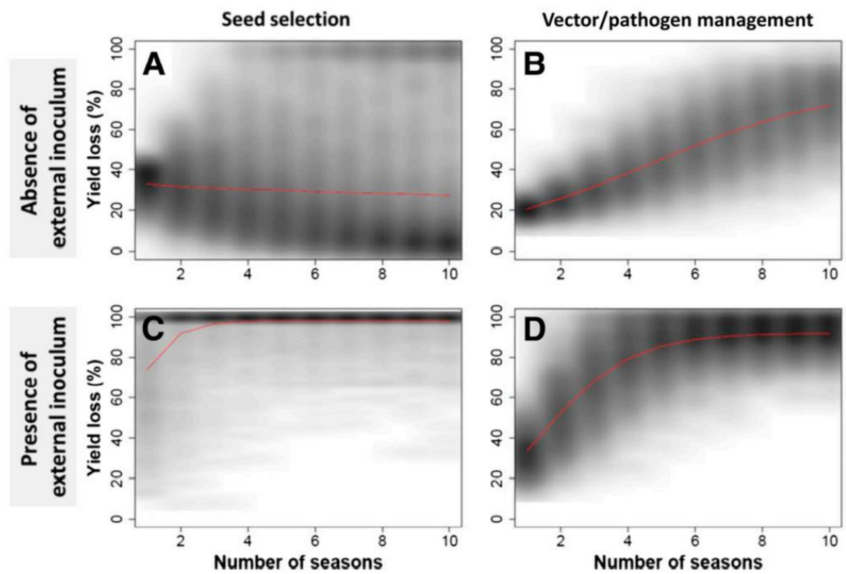

Fig. 4. Long-term (10 season) yield loss under **A and C,** seed selection and **B and D,** vector or pathogen management, in the presence and absence of external inoculum (based on 2,000 simulations). Vector management and seed selection, expressed in terms of the proportional effectiveness of management implementation (1 indicating complete effectiveness, and 0 indicating no management), had low variability (0.1) and were each set to 0.6 effectiveness of implementation. Other parameters were set to the default values in Table 2. Red lines indicate the mean values.

Figure J. Figure 4 from Thomas-Sharma et al. (2017) illustrating the importance of the level of external inoculum. This is another important factor which can be expensive to measure. A farmer's decisions will also need to take into account how readily fields will be infected from neighboring fields or other parts of the region. Even if farmers manage carefully, outside inoculum can counterbalance the farmers' efforts.

Thomas-Sharma et al. (2017) discuss the broad range of data types that may be useful for constructing a decision support tool. The first stages of tool development might treat all scenarios in a region as similar, and then with further development the tool may take into account environment, variety, and management applied.

Testing decision support. Decision support rules can be tested on experiment stations or in farmers' fields. New data collected in these tests can also be used to improve the decision support recommendations.

The potential for decision support to benefit farmers. Good decision support can help farmers maximize their yield. If farmers use informal seed, they will save the cost of purchase but have higher risk of loss to disease and pests. Decision support can help farmers anticipate when the risk of loss is high enough to motivate seed purchase.

Examples of relevant studies.

Summary of the integrated seed health strategy, with an example for potato seed health (Thomas-Sharma *et al.*, 2016)

General model of seed degeneration as a function of the factors discussed in this guide (Thomas-Sharma et al., 2017) and a user guide for the corresponding code (Garrett & Xing, 2021)

Example of application of seed degeneration modeling, with observed seed degeneration and hypothetical yield loss evaluations (Ogero *et al.*, 2019)

An analysis of how best to balance considerations in establishing quality declared seed thresholds (Choudhury *et al.*, 2017)

Analysis of systems in which farmers may replace only part of their seed with formal seed in any given year (Navarrete *et al.*, 2022)

A management performance mapping framework to evaluate where a particular management approach, such as positive selection for on-farm management of seed health, is most effective (Buddenhagen *et al.*, 2022)

References

Buddenhagen, C. E., Xing, Y., Andrade Piedra, J., Forbes, G. A., Kromann, P., Navarrete, I.*, et al.* (2022) Where to invest project efforts for greater benefit: A framework for management performance mapping with examples for potato seed health. *Phytopathology,* **112,** 1431-1443.

Choudhury, R. A., Garrett, K. A., Klosterman, S. J., Subbarao, K. V. and McRoberts, N. (2017) A framework for optimizing phytosanitary thresholds in seed systems. *Phytopathology,* **107,** 1219-1228.

Garrett, K. A. and Xing, Y. (2021) *User guide to the seedHealth model as part of the integrated seed health approach*. Lima, Peru: CGIAR Research Program on Roots, Tubers and Bananas (RTB)

Navarrete, I., López, V., Borja, R., Oyarzún, P., Garrett, K. A., Almekinders, C. J.*, et al.* (2022) Variety and on-farm seed management practices affect potato seed degeneration in the tropical highlands of Ecuador. *Agric. Syst.,* **198,** 103387.

Ogero, K., Kreuze, J., McEwan, M., Luambano, N., Bachwenkizi, H., Garrett, K.*, et al.* (2019) Efficiency of insect-proof net tunnels in reducing virus-related seed degeneration in sweet potato. *Plant Pathology,* **68,** 1472-1480.

Thomas-Sharma, S., Abdurahman, A., Ali, S., Andrade-Piedra, J., Bao, S., Charkowski, A.*, et al.* (2016) Seed degeneration in potato: the need for an integrated seed health strategy to mitigate the problem in developing countries. *Plant Pathology,* **65,** 3-16.

Thomas-Sharma, S., Andrade-Piedra, J., Carvajal Yepes, M., Hernandez Nopsa, J., Jeger, M., Jones, R.*, et al.* (2017) A risk assessment framework for seed degeneration: Informing an integrated seed health strategy for vegetatively-propagated crops. *Phytopathology,* **107,** 1123-1135.