AGRICULTURAL BIOSECURITY: PREVENTION, DIAGNOSIS, AND CONTROL STRATEGIES FOR PATHOGENS AND PESTS

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BACKGROUND

The primary goal of any successful agricultural biosecurity program is to prevent entry of a pathogen or pest into a susceptible population of plants or animals. When preventive measures fail, it is imperative to have early detection, rapid and accurate assessment, and immediate implementation of various interventions that prevent spread, control the infection, and then begin the recovery phase. The current scientific status of diagnostic methods for either plants or animals does not meet these criteria for many pathogens or pests.

Rapid, specific, and low-cost diagnostic methods are still a rarity in agriculture, compared with those available for human health problems. This is due in part to the lack of necessary information about the genomic makeup of the agents to permit use of time- and cost-effective modern techniques such as Rapid or Real Time Polymerase Chain Reaction (RTPCR). In other instances, some of the needed scientific information is available, but the methods have not been fully validated, laboratories lack the resources to purchase the equipment needed to perform these tests, or the funding for initial developmental work has not been available.

Building on existing work in genomics and the commonality of host-pathogen interactions among the phyla of animals, insects, and plants, we propose to expand our research and educational programs – both resident and outreach – to develop the knowledge and expertise required to ensure biosecurity of our agricultural and rural communities and a secure and safe food supply. Many pests or pathogens are potential weapons for use by terrorist groups, and we need to be prepared for emerging threats – either accidental or deliberate. The program will focus on agents that are easily spread, have high infectivity at low infective dose levels, or have high economic consequences. It is important to note that additional focus and funding in this area will also spin off technologies helpful in controlling domestic diseases or pests.

GENOMICS

Genomics is the study of an organism's entire nucleic acid (genetic) sequence, structure, and function. It is a blueprint for understanding how the organism functions and how it adapts to changes in diverse environments. Genomics – including genome sequencing, functional genomics, and bioinformatics – provides a basis for examining biological phenomena in ways that were previously not possible. The continued development of this technology holds great potential to provide innovative strategies for solving production problems in agriculture while at the same time increasing our ability to defend the nation's food supply from intentional introductions of diseases and pests.

The continued development of genomic research is essential to provide the foundation for future progress in dealing with these issues and to provide a foundation for the development of new products. Because of the broad implications and importance of this research area, it is vital that the public sector fund and support genomic research to ensure that the results are available in the public domain and are broadly accessible to those interested in improving agricultural production systems. Some genomic research will

be of little interest to the private sector but may be critical to certain agricultural and environmental areas. Further, educators and extension specialists need access to this information to enhance educational efforts directed at end users, producers, and consumers.

There is a fundamental need to sequence the genomes of animals and plants, as well as their pathogens and pests. This information is really only valuable if the initial research is followed by what is commonly referred to as functional genomics or proteomics. This latter area of research will provide information about the specific virulence factors of the pathogens, resistance, and susceptibility factors in the host and will enable the development of diagnostic techniques and preventative and control strategies, such as vaccines and biocontrol agents.

As we have presented previously, we believe there is significant advantage in considering the mechanisms of pathogenesis and virulence factors in both animal and plant pathogens in collaborative research programs. Similarly, we expect that we will achieve greater progress in understanding host defense systems if we consider plants, animals, and insects in a coordinated manner.

In animals, the information on zoonotic diseases such as anthrax, brucellosis, and tuberculosis can make significant contributions to solving both agricultural and public health problems. There are also plant pathogens that represent significant public health issues (see Vidaver and Tolin, in Fleming and Hunt, *Biological Safety Principles and Practices*, ASM Press, pp 27-33, 2000). For a summary of common features, see the outcome of the 1999 National Academy of Sciences colloquium entitled "Virulence and Defense in Host-Pathogen Interactions: Common Features Between Plants and Animals" (Keen et al., PNAS, 97:8854-8855, 2000) and "Common and Contrasting Themes of Plant and Animal Diseases" (Staskawicz et al., Science, 292:2285-2289, 2001).

DETECTION, RAPID ASSESSMENT, AND CONTROL

Should an organism slip through the prevention system, early detection is an absolutely essential component of a biosecurity system. An example of what can happen when detection is absent is the case of the Chinese soybean aphid. This insect was introduced into North America, became established, and spread throughout the Midwestern soybean production area before it was first detected. Had this insect been intentionally introduced, perhaps carrying a highly virulent viral pathogen, the consequences for American agriculture could have been dire. Foot-and-mouth disease offers another example. Infected animals shed large amounts of virus before they manifest visual symptoms. Therefore, the sooner the virus is detected, the greater the chance to prevent its spread to vast areas. By the time foot-and-mouth disease was detected in the United Kingdom during the 2001 outbreak, it had already spread across the entire country. Ultimately, more than 7% of their livestock was slaughtered. A similar outcome in the U.S. would be devastating.

Detection must operate on many levels. Intensive production systems, where the farmer or rancher has more direct contact with the production units, require different detection systems than are needed in extensive production systems, where a single individual may work with thousands of production units. Similarly, there are different detection needs for small land area operations vs. large land area operations.

In intensive and small land area operations, the development of technology that the producer can use to assess the health of an animal or plant before the development of symptoms is essential. Equipment currently under development, such as hand-held or easily portable infrared sensing equipment, must be made available. Intensive and small land area operators need to be trained to recognize symptoms once they appear. They need to be informed about procedures to contact the diagnostic network currently being developed to verify their preliminary assessment. At present, other funds (from Homeland Security) are being used to establish the first animal and plant disease/pest diagnostic centers as

components of a national Rapid Detection and Response Network.

For extensive and large land area operations, the continued application of geo-spatial technology in the form of remote sensing must be a priority. The collaborations that comprise the AG 20/20 program, which currently involves CSREES, NASA, the National Corn Growers Association, the National Cotton Council, the United Soybean Board, and the National Association of Wheat Growers, should be expanded to include more producer groups. Ranchers as well as farmers should be involved. Additional research is needed to define how healthy animals and plants appear in satellite imagery and the different appearances that are induced by challenges from biotic (insects and pathogens) vs. abiotic stress factors (water, nutrients, etc.). APHIS has successfully used the concept of "sentinel plants" to detect early outbreaks of new infestation of citrus canker in Florida. Based on the information gained through genomics research, it may be possible to produce genetically engineered organisms that respond to low doses of animal or plant pathogens and react in ways that can be easily detected before symptom development.

In addition to the need to monitor managed systems, it is also important to determine the health of natural systems as well. Many diseases and pests of livestock and crops are also diseases and pests of native flora and fauna. A surveillance system that only monitors agricultural areas will be easily breached and is doomed to failure. This fact clearly demonstrates the enormity of the task and the need to engage a broad-based cadre of support.

Once a potential biotic challenge has been detected, rapid and accurate assessment is the next step in agricultural biosecurity. As mentioned previously, a rapid diagnostic network is being developed as part of a separate initiative. The genomics research proposed in this document will provide this network with new ways of assessing pathogens and pests rapidly and accurately. Many of these assessments will be made at the production site using new tools developed as a result of the genomics research. Early detection may enable easy management and control. However, despite early detection, control may still be difficult and could require several years of research to discover best control procedures, e.g., vaccines or resistant varieties.

EDUCATION AND OUTREACH

Detection and assessment systems must be operative at multiple levels to be effective. However, the number of skilled observers and diagnosticians is limited. The regional Rapid Detection and Response Centers for animal and plant diagnostics can assist in this effort as they begin to develop their programs. On-campus and outreach educational programs will be essential to expand the capacity of these few individuals.

The science of genomics and the downstream application of functional genomics are in their infancy. There is a need to train a future generation of scientists who will have the skills and capacity to move the science forward. Programs are needed to encourage colleges and universities to create multi-disciplinary programs with the goal of training such individuals to provide the fundamental knowledge needed to ensure agricultural biosecurity. Educational programs are also needed at colleges and universities to attract and train competent individuals in the skills of detection, epidemiology, and risk assessment.

There is also an urgent need to retrain and retool currently established researchers in genomics technology through training programs such as short courses and sabbaticals. It is critical to ensure that agricultural scientists have access to state-of-the-art equipment and other resources to rapidly translate genomic information into practical applications.

Outreach programs, such as train-the-trainer programs, are needed to provide an adequate number of individuals who can recognize changes from the normal appearance of plants and animals and are in

regular contact with production sites. These include farmers and ranchers, state and county extension specialists, crop consultants, pesticide applicators, veterinarians, and others.

In the face of a deliberate attack on the nation's food production systems, there are not enough people currently involved to meet the challenge of independent on-site verification and make preliminary assessments of purported detection events. A volunteer training program is needed to provide a workforce that can be rapidly mobilized and directed to specific sites to make initial determinations of potential bioterrorist acts. This volunteer force can also be utilized in routine surveillance and monitoring activities so that deliberate acts, as well as naturally occurring events, can be detected as rapidly as possible. The involvement of consumers in the security of the food and fiber production system will enhance their awareness of intentional or unintentional food adulteration and contribute to a safer food supply as well.

The program must be flexible and ensure cooperation between private and public sector personnel. Because of its historic role as the leader in educational programs through the Cooperative Extension System, CSREES should provide leadership to develop the needed educational programs in consultation with sister agencies, especially the Agricultural Research Service, the Animal and Plant Health Inspection Service, and the Food Safety Inspection Service. Once in place, education and extension efforts must be coordinated with state and local authorities, local educators, and other local service personnel, such as the police, by faculty from the Land Grant University System.

EXPECTED OUTCOMES

Successful implementation of this program will lead to the following outcomes:

- Rapid, on-site diagnostic tests to detect new diseases and pests
- Informed communities that assist in surveillance and detection of pests/diseases
- Reduced use of antibiotics and replacement with new treatment modalities
- Reduced pesticide chemical use and new biocontrol systems for plant diseases
- New and more effective vaccines for animals
- Enhanced safety and security of the food supply
- Prevention/control of outbreaks of devastating diseases in animals and plants
- Trace back potential to site(s) of origin of pest/disease

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