



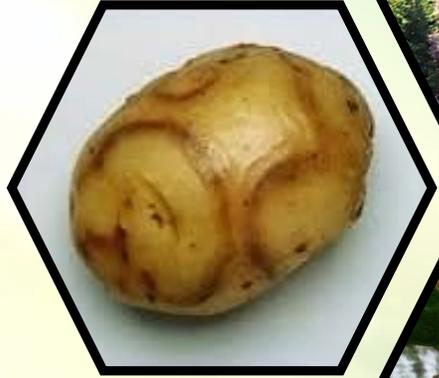
United States
Department of
Agriculture

Agricultural
Research
Service

National Program 303

Plant Diseases

Action Plan 2017-2021



AGRICULTURAL RESEARCH SERVICE
NATIONAL PROGRAM 303 – PLANT DISEASES

Action Plan 2017 – 2021

Goal: National Program (NP) 303, Plant Diseases, supports research to improve and expand our knowledge of existing and emerging plant diseases and to develop effective disease management strategies that are safe to humans and the environment and that are economically practical and sustainable.

Plant diseases are caused by many types of pathogens including fungi, oomycetes, bacteria, viruses, viroids, phytoplasmas, and nematodes. These diseases cause billions of dollars in economic losses each year to crops, landscapes, and forests in the United States. Plant diseases reduce yields, lower product quality or shelf-life, decrease aesthetic or nutritional value, and may contaminate food and feed with toxic compounds. Control of plant diseases is essential for providing an adequate supply of food, feed, fiber, and landscape crops, but effective control requires an understanding of the biology of these disease-causing agents.

To improve plant health, the outcomes and impact of NP 303 research and outreach activities include growing plentiful, high quality crops for all citizens; supporting productive agricultural and forest industries; and managing healthy landscapes in our country. Additionally, proactive research addressing climate change and the increased global movement of plant material is necessary to combat emerging domestic diseases and exotic diseases not yet found in this country, in order to protect our crops as well as maintaining and expanding export markets for U.S. plants and plant products.

The specific components of National Program 303, Plant Diseases are:

Component 1: Etiology, Identification, Genomics and Systematics. Rapid, reliable pathogen detection and identification procedures for accurate and timely disease diagnoses are of critical importance as international trade of plant products increases and as the United States and its trading partners seek to protect themselves from the introduction of exotic plant pathogens. This component includes research on: developing or improving diagnostics for existing, emerging, or exotic pathogens; developing or improving pathogen detection and/or quantification methods (e.g. remote sensing); systematics, evolution, comparative genomics, and population genomics of pathogens; and understanding the etiology of exotic, emerging, or poorly understood plant diseases.

Component 2: Biology, Ecology, and Genetics of Plant Pathogens and Plant-Associated Microbes. Critical to developing effective disease management methods is an understanding of the genetics, ecology and epidemiology of pathogens as well as an in-depth knowledge of the fundamental biology of pathogen-host-vector interactions and the phytobiome. This component includes research on: molecular, genomic, cellular, and organismal aspects of plant pathogens, plant-associated microbes, and their interactions with plant hosts; interactions of pathogens with vectors (including vector-plant interactions as they influence pathogen transmission and disease development); ecology, epidemiology, and spread of pathogens and vectors; and impact of climate change on pathogens, their vectors, and disease expression.

Component 3: Plant Health Management. Effective, safe, environmentally-sound, affordable, and sustainable strategies and tools are needed to manage plant diseases or pathogens associated with plants. Plant pathogens exhibit a remarkable ability to change and adapt, allowing them to overcome resistant crop varieties or evade control strategies and chemicals that were once effective. The principal goal of this component is to improve plant health through the genetic, cultural, chemical, or biological manipulation of the host, pathogen, vector, plant-associated microbial communities, or beneficial organisms. This component includes research on: development, characterization, and deployment of genetic resistance

(conventional or transgenic/intragenic) against pathogens or vectors; manipulation of cultural practices or plant-associated microbes to promote plant health or manage pathogen or vector populations; progress toward viable alternatives for methyl bromide as well as optimization of alternatives already in use; development, characterization, and deployment of biological agents that reduce pathogen or vector populations or otherwise enhance plant health; improvements to the efficacy of chemical agents to control pathogen and vector populations; and development of integrated disease management systems to improve plant health and crop production.

Research in NP 303 complements research in other Agricultural Research Service National Programs, particularly those in the Crop Production and Protection Section, such as NP 301 (Plant Genetic Resources, Genomics and Genetic Improvement) and NP 304 (Crop Protection and Quarantine).

Relationship of This National Program to the USDA Strategic Plan:

This action plan is relevant to two goals in the USDA Strategic Plan for 2014-2018 (<http://www.usda.gov/documents/usda-strategic-plan-fy-2014-2018.pdf>).

NP 303 supports USDA Strategic Plan Goal 3: Help America Promote Agricultural Production and Biotechnology Exports as America Works to Increase Food Security. A specific supported objective of Goal 3 is: Objective 3.1 Ensure U.S. Agricultural Resources Contribute to Enhanced Global Food Security.

NP 303 also supports USDA Strategic Goal 4: Ensure That All of America's Children Have Access to Safe, Nutritious, and Balanced Meals. A specific supported objective of Goal 4 is: Objective 4.4 Protect Agricultural Health by Minimizing Major Diseases and Pests to Ensure Access to Safe, Plentiful, and Nutritious Food.

Relationship of this National Program to the USDA REE Action Plan:

This Action Plan fits under the general guidance of the USDA REE Action Plan's (http://www.ree.usda.gov/ree/news/USDA_REE_Action_Plan_03-2014.pdf) Goal 1: Sustainable Intensification of Agricultural Production, Subgoal 1B: Crop and animal health, and Subgoal 1C: Crop and Animal Genetics, Genomics, Genetic Resources, and Biotechnology.

Relationship of this National Program to the USDA ARS Strategic Plan:

This Action Plan supports the 2012-2017 ARS Strategic Plan, Goal Area 3: Crop Production and Protection: Goal 3.2 (Protect our Nation's crops (Plant Diseases, Crop Protection and Quarantine, and Methyl Bromide Alternatives – NP 303, 304 & 308) (<http://www.ars.usda.gov/SP2UserFiles/Place/00000000/NPS/OAA/ARS%20Strat%20Plan%202012%20-%202017%20Final.pdf>). Specific emphasis is placed on delivering scientific information and tools to control and eradicate domestic and exotic diseases. Research and outreach activities address crop improvement; prevention and treatment of plant diseases; identification, detection and management of pests, including quarantine pests; improved crop management strategies; and development of methyl bromide alternatives. The following performance measure sets the targets for NP 303 research within the USDA ARS Strategic Plan:

Performance Measure 4.3.2:

Provide scientific information to increase our knowledge of plant genes, genomes and biological and molecular processes to protect crops and cropping systems from the negative effects of pests and infectious diseases. Develop sustainable control strategies for crop pests and pathogens based on

fundamental and applied research that are effective and affordable, while maintaining food safety and environmental quality.

Component 1: Etiology, Identification, Genomics and Systematics.

The management of a plant disease depends critically on our ability to understand the cause of the disease and to identify and classify the causal and/or associated pathogen(s). In addition to endemic pathogens and diseases, agricultural commodities are frequently challenged by emerging diseases caused by previously unknown pathogens, or new strains of endemic pathogens that arise by genetic mutation or recombination. Furthermore, the expanding globalization of agriculture inevitably introduces exotic organisms that could devastate U.S. agriculture if undetected and uncontrolled. Finally, plant-associated microbes also can produce toxins that may be harmful to humans or animals.

Consequently, the security of the U.S. food supply depends in part on the timely detection and identification of new pathogens emerging within, as well as those introduced to, the United States, regardless of whether the introduction is accidental, deliberate, or via natural forces. The history of crop protection in America is replete with occasions when the ability to detect or identify a plant pathogen or disease has resulted in enormous positive economic impact. Global agricultural expansion and consequent international trade have made timely detection of known pathogens of increasing concern and the identification of novel pathogens even more important. The detection of microbe associated toxins on plant agricultural products also has become recognized as an emerging problem.

Although a robust industry in the United States supplies commercial diagnostic services and reagents for plant pathogen identification, publicly-funded efforts are needed to conduct and transfer up-to-date basic research on pathogen identification, classification, and diagnosis to regulatory agencies, stakeholders, and other users. Consequently, there is a critical need for continuous research into the development of new, rapid, sensitive, accurate, and inexpensive detection and diagnostic methods for nearly all existing, changing, and emerging pathogens. Research within this component will complement and draw from research conducted by the other components of NP 303 and National Program 301, Plant Genetic Resources, Genomics and Genetic Improvement. Collaborative efforts with the USDA Animal and Plant Health Inspection Service (APHIS), State departments of agriculture, industry, stakeholder groups, regional diagnostic laboratories, as well as foreign national agricultural research centers and international agricultural research centers, will identify the most critical diagnostic needs and facilitate the development of standardized, validated, and optimized tools appropriate for the end user.

Problem Statement 1: Diagnostics, Etiology, Genomics and Systematics of Plant Disease and Associated Microbes.

Definitive diagnostics are the linchpin for characterizing pathogen populations and ultimately for developing and implementing effective disease management strategies. Accurate and accelerated methods for identifying the cause(s) of a plant disease are critical for disease management and for the safe movement of horticultural and agricultural products. Although microscopic examination may identify many pathogens, accurate disease diagnoses may require more specific biochemical, molecular, or genomic tests. Different pathogens may induce the same symptoms or symptoms so similar that only a highly trained specialist can make a definitive identification. Serological or nucleic acid-based assays are readily available for many common pathogens of major crops but are lacking for a majority of pathogens, especially those of minor and specialty crops. Some pathogens may change rapidly, making it important that diagnostic tools are up-to-date. In other cases, the only reliable means of diagnosis and identification may be bioassays that require months to complete. Still other pathogens are fastidious and are not easily cultured or propagated and must be identified from the

original diseased tissue. Also, there may be no effective sampling methods available for detecting particular pathogens within some plant materials. Identification tools may not exist for newly emerging pathogens, and rapid development of these tools will be required.

Etiology is the identification of the cause or causes of disease which may be one pathogen, the interactions of multiple pathogens, or the interactions of pathogens with other biotic and/or abiotic factors. Systematics is the naming, description, preservation, and classification of organisms, and the study of their distribution, evolutionary history, and environmental adaptations. In the current era of high-throughput sequencing, new tools have become available whereby the whole genome of newly emerging pathogens can be sequenced allowing more rapid development of detection methods. Understanding and managing plant disease requires knowledge of the etiology of disease as well as the genome and systematics of the pathogen(s) responsible for the disease. The causal agents of many exotic and emerging diseases have not been identified. Similarly, certain diseases are thought to be caused by pathogen complexes or organisms that cannot be cultured, and their etiology remains unclear. Once known, an in-depth study of the systematics of the responsible pathogen often enables scientists to assess the potential impacts of a newly identified or introduced organism and may allow them to suggest management approaches. In many cases, morphologically identical variants of the same pathogen species differ in pathogenicity on host plant species or varieties and these differences can be due to relatively minor alterations in gene sequence, gene expression, or in modification of proteins and other metabolites. Genomic-, proteomic-, and metabolomic-based methods thus continue to inform studies on pathogen classification, but these approaches are not always available or applicable. Knowledge developed by this program, based on morphology, population genetics and genomics as well as evolutionary approaches, provides a biological framework for continued and in-depth investigations on pathogen biology necessary for disease management.

Research Needs

The ARS national plant pathology research capacity is strong, yet the demands by many emerging and re-emerging diseases require that flexible national priorities be established for pathogen detection and diagnosis and subsequent systematics research. Expanded and well-maintained databases and specimen/culture collections to support these activities are needed. The systematics of plant pathogens are critical for understanding disease etiology, transmission, and control, but there are large gaps in knowledge about specific groups of pathogens. Comprehensive knowledge of the etiology and systematics of domestic and exotic plant pathogens will be developed via structural, molecular, genomic and other approaches. Classification schemes for accurately predicting biological properties critical to disease diagnosis and control will be developed. Existing and new technologies will be applied to detect and identify plant pathogens in soils, plants, plant materials, agricultural products, disease vectors, and any other organism or material suspected of harboring a pathogen. Priority research targets will include pathogens that have: 1) a high impact on crop yield, quality, and producer income; 2) regulatory or quarantine importance; 3) importance to national biosecurity; or 4) application as model organisms for understanding host-pathogen interactions, infection modes, or other basic mechanisms.

Anticipated Products

- New, more rapid, reliable, economical methods for detecting and identifying plant pathogen species, strains, or pathotypes, often within hours or minutes of specimen examination, and often using limited amounts of plant or non-plant material.
- Pathogen genome sequences that provide a basis for rapid development of detection methods as well as reference genomes for population genomics and evolutionary studies.
- Diagnostic methods capable of concurrently detecting and identifying several pathogens and/or microbial-associated toxins.
- Inexpensive, user-friendly, pathogen detection methods that do not require highly trained personnel or state-of-the art laboratory equipment and facilities.

- More effective methods, such as nucleic acid, protein or metabolite biomarker systems, for distinguishing pathogen genotypes.
- New statistically-sound sampling methods that enable more efficient recovery/isolation of representative pathogen samples.
- Pathogen surveys that monitor pathogen diversity and genetic changes in critical pathogen populations.
- Characterization of the key genetic and biological features of exotic plant pathogens in advance of their introduction into the United States.
- Systematically valid, accurate, and comprehensive phylogenetic systems for classifying and understanding pathogen evolutionary relationships that are linked to, and integrated with, voucher specimen collections and databases.
- Diagnostic keys, compendia, and other guides for identifying pathogens and diseases.
- More accurate and comprehensive phylogenetic classifications that can predict agriculturally-relevant aspects of pathogen biology.
- Discovery of pathogens or pathogen complexes responsible for important plant diseases that currently have unknown etiology.
- Curated culture collections and genomic databases that serve as reference for re-emerging and newly emerging pathogens.
- Improved methods for selection of diagnostic reagents (PCR primers, antigenic targets) and systematic information from genomic data.

Potential Benefits

- Quicker, more effective, and more broadly applicable (e.g., from plants, soil, air, etc.) pathogen detection and identification methods.
- Improved taxonomic descriptions and classifications of pathogen groups that utilize systematic, morphological, biological, molecular and genomic data.
- Enhanced knowledge of pathogen genetic diversity, especially with respect to pathogenicity and evolution, thereby enhancing the ability to predict disease outbreaks.
- Accurate identification of plant pathogens worldwide by diagnosticians.
- Control or eradication of invasive pathogens accelerated by early detection and by taxonomic and other knowledge obtained prior to their introduction into the United States.
- Agricultural losses minimized by the timely detection and identification of pathogens already present in the United States and by the subsequent application of control measures.
- Regulatory decisions based on rapid pathogen detection and scientific data will facilitate the export and import of agricultural products and other plant materials while minimizing the potential for introduction of exotic pathogens.
- More rapid and accurate pathogen assays that accelerate breeding of durable resistance that is not limited to current, local populations of pathogens.

Component 1 Resources:

Nine ARS projects in NP 303 address the research problems identified under Component 1, and the scientists assigned to these projects are located at:

- Beltsville, Maryland
- Corvallis, Oregon
- Ft. Pierce, Florida
- Salinas, California
- Wenatchee, Washington

Component 2: Ecology, Epidemiology, and Genetics of Plant Pathogens or Plant-Associated Microbes.

Unprecedented innovation in the life sciences in recent years has transformed our understanding of how pathogens cause disease at the molecular and cellular level. Discoveries in the molecular characterization of plant pathogens and the fundamental nature of their interactions with plant hosts, vectors, symbionts, antagonists, and other associated organisms have improved our basic understanding of plant susceptibility, resistance, disease development, pathogen transmission, and host defense responses. This information in turn has been used to develop practical applications for disease management. Similarly, advances in bioinformatics, predictive modeling, and remote sensing have forged new opportunities to understand the dynamics of pathogen populations and disease epidemiology, and to determine how pathogens and their vectors survive and disperse in a wide variety of environments. This knowledge identifies potential targets available to interrupt the life cycle of pathogens or vectors in order to prevent disease or reduce its economic impact.

Problem Statement 2A: Fundamental Pathogen Biology

Pathogens range from relatively simple viruses to very complex organisms, such as fungi and nematodes. The genomes of many agriculturally-relevant pathogens have been sequenced and re-sequenced in order to understand genetic diversity between and within pathogen species. Next generation sequencing (NGS) has allowed accelerated progress in sequencing of multiple pathogen genomes. Genomic sequencing of some pathogens has allowed for the identification of valuable virulence genes that have been used as powerful diagnostic tools and has offered leads for the development of eradication strategies and resistance in host plants. Genomic sequencing and select resequencing of more plant pathogens, including those with large and complex genomes, are needed to extend the power of genomics to other agriculturally-important plant pathogens.

While the availability of genomic sequence data increases our knowledge of the genetic potential of pathogens, functional analysis of pathogens is also needed to determine how this potential results in plant disease. Recent advances in cell biology and cellular imaging, as well as proteomic and metabolomic technology has greatly advanced our ability to understand the functional significance of pathogen genomic variation to plant disease. Nevertheless, functional analysis has become a significant bottleneck for understanding and utilizing currently available and emerging genomic information. The widespread adoption of NGS and the resulting explosion of genomic sequence data has only widened the gap between genomes and functional understanding. Meeting the challenge of increased NGS data will require developing advanced bioinformatics resources and interdisciplinary systems approaches involving computational biology coupled with laboratory methods for high-throughput functional genomics as well as fundamental studies in biochemistry, cell biology, and genetics.

ARS research will make significant contributions to understanding the fundamental biology of plant pathogens of economic and regulatory significance to U.S. agriculture, which in turn can be translated to novel disease management strategies that disrupt a pathogen's ability to cause disease or its ability to overcome plant defense responses.

Research Needs

ARS will sequence genomes of important and emerging pathogens of major and specialty crops. Bioinformatics will be used to define features of sequenced genomes and compare them to infer functional significance. Functional studies will test genomic features of pathogens for their impact on plant disease (e.g., infection, virulence, transmission) using genetic, biochemical, cytological, as well as proteomic and metabolomic approaches.

Anticipated Products

- Discovery of virulence proteins capable of triggering plant defense responses.
- Characterized pathogen genomes, pathogen libraries, and culture collections.
- Reliable bio-markers for important pathogen traits.
- Linking phenotype to genotype of pathogens and pathogen populations.
- Proteomic and metabolomic resources.
- Increased knowledge of pathogen biology and life cycles.
- New technologies for evaluating the role of pathogen genes and gene products in pathogenicity and transmission.
- Detailed understanding of mechanisms of adaptation in pathogen genomes to hosts, pesticides and other agronomic factors.

Potential Benefits

- Identification of pathogen vulnerabilities for disease control, aiding development of novel disease management strategies.
- Defining the role of particular pathogen traits in disease development, advancing efforts to breed plants for disease resistance.
- Ability to predict and potentially manipulate plant response to pathogens and pathogen-derived products.
- New technologies based upon the high replication capacity of plant viruses to express desirable proteins in plants for the prevention and treatment of plant and animal diseases, thereby impacting their health and benefitting producers and processors.

Problem Statement 2B: Systems Approaches to Pathogenesis

Disease development is a complex process that involves a network of interactions between the pathogen and host plant, and in many cases a specific vector. For a multitude of pathosystems, additional organisms may be involved in mitigating or exacerbating disease. Gene discovery focusing on single organisms has been a useful approach to understanding pathogenesis but these studies have not captured the entire complexity of the interaction of the pathogen, its plant host and environmental variables. Furthermore, gene regulation, expression, and many interrelated downstream processes are far more complex than initially thought. Understanding all facets of disease expression requires knowledge of communication and interactions between and among organisms. ARS will conduct coordinated and collaborative research that develops a systems approach to understanding all components of a disease and understanding all factors that contribute to the process and how they interact. The results from these studies will enable the development of new control methods that target specific mechanisms of pathogenesis.

Research Needs

A fundamental understanding will be developed for how pathogens cause disease, trigger and suppress host defenses, survive, reproduce, and disperse, and coexist with vectors to move between hosts.

Anticipated Products

- Novel disease control strategies that can be developed based on specific molecular targets identified in these studies.
- Compounds that can prevent the efficient transmission of pathogens by vectors.
- Discovery of the underlying pathogenic mechanisms essential for the initiation, establishment, and spread of plant disease.
- Use of pathogen avirulence genes to discover novel plant disease resistance genes.

- Plant disease resistance genes strategically pyramided in response to changes in pathogen populations.

Potential Benefits

- Improved knowledge of pathogen vectoring which can lead to new management tools and strategies.
- Identified genes or pathways that provide specific targets to interrupt pathogen-host or pathogen-vector interactions.
- Innovative disease management strategies that are deployed in the field based on new molecular targets identified.
- Deployment of new plant disease management strategies.

Problem Statement 2C: Ecology and Epidemiology of Plant Diseases

Plant disease epidemics result from timely combinations of susceptible host plants, virulent pathogens, and favorable environmental conditions. For some diseases, the interactions may also include efficient pathogen vectors. An understanding of these interactions is essential for disease forecasting and management. In addition, knowledge of factors that allow disease to increase over space and time, as well as the ecology of the pathogen and associated vectors, will aid in predicting their ability to cause an epidemic. Knowledge of the ecology and life cycle of a pathogen, including its survival and reproduction, is needed as a basis for epidemiological models and disease management strategies. Utilizing increasingly available NGS technology, population genomics of key pathogenic organisms also may provide clues to pathogen traits important for pathogen fitness and disease spread. Taken together, this knowledge will be used to design better methods for monitoring pathogen and vector populations to facilitate the development of expert systems for disease forecasting and provide the basis for alternative approaches to disease management and control.

Furthermore, it has become increasingly apparent that non-pathogenic microbes may have a profound influence on plant health and productivity. As such, ARS will contribute to phytobiome research using metagenomics approaches to characterize microbial communities associated with plants including viruses, prokaryotes and microbial eukaryotes in the rhizosphere, phyllosphere, and the endophytic space.

Research Needs

Methods for determining the genetic diversity and population dynamics of pathogens and associated microbes in the field will be developed by way of population genetic and population genomic approaches. Monitoring emerging and transitioning diseases is necessary to determine pathogen load and inoculum dispersal patterns (globally and locally). Development of robust statistical methods to quantify relationships between disease levels and economic loss will be addressed to provide better methods for yield loss assessments. Forecasts for plant disease and, when appropriate, pathogen vectors, will determine optimum periods to apply management options aimed to reduce crop inputs costs without increasing risk of crop loss. Phytobiome research will be used to understand the microbial community components of sustainable plant health.

Anticipated Products

- Robust statistical models to quantify relationships between disease levels and economic loss, and analyzing impact of disease.
- Mathematical models for disease forecasting/epidemic development of diseases with a user interface for growers.
- Better sampling methods for disease prediction.

- Increased knowledge of pathogen life cycles, which can identify vulnerabilities to be targeted for disease management.
- Characterization of migration based on population genomic studies including identification of source and sink populations.
- Knowledge of microbial communities associated with healthy or disease-suppressive plant environments.
- Better understanding of environmental effects on pathogen and biology and dispersal.

Potential Benefits

- Predictive models for farmers to allocate resources for increased crop productivity, targeted application of chemical treatments, and informed deployment of pathogen-resistant plants.
- Reduction of farmer input costs, improved product quality and prevention of yield losses.
- Accelerated and informed breeding of crops for resistance.
- Reconstitution of microbial communities promoting stable plant health.

Component 2 Resources:

Twenty-three ARS projects in NP 303 address the research problems identified under Component 2, and the scientists assigned to these projects are located at:

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|--------------------------|---------------------------|
| • Beltsville, Maryland | • Lincoln, Nebraska |
| • Corvallis, Oregon | • Madison, Wisconsin |
| • Fargo, North Dakota | • Parlier, California |
| • Fort Detrick, Maryland | • St. Paul, Minnesota |
| • Fort Pierce, Florida | • West Lafayette, Indiana |
| • Ithaca, New York | • Wooster, Ohio |
| • Jackson, Tennessee | |

Component 3: Plant Health Management

Effective, safe, environmentally-sound, affordable, and sustainable strategies are needed to manage plant diseases threatening agricultural productivity as well as managed and natural landscapes in the United States and abroad. Many of these diseases are not managed adequately by methods available today, and others are controlled by chemicals that may be unavailable in the future due to environmental or safety concerns. To manage the full spectrum of plant diseases caused by endemic and exotic pathogens, new tactics must be developed, optimized, and integrated into disease management systems. These tactics will include durable plant host resistance, as well as effective and reliable biological and cultural controls. Integration of non-chemical management tactics can also be used to delay and manage pesticide resistance in pathogen populations and reduce the overall dependence on pesticides for the control of many plant diseases. Development and optimization of these disease management tactics requires a fundamental knowledge of host-pathogen-vector-environmental interactions. Deployment and integration of this knowledge into disease management systems will rely on cross-cutting, interdisciplinary programs.

Problem Statement 3A: Development and Deployment of Host Resistance

Host resistance is a direct and environmentally benign method to control plant diseases. Resistance is most often directed toward the pathogen, but resistance to pathogen vectors also can be effective in management of some plant diseases. Unfortunately, durable and effective host resistance may not be available, or has not been identified for most plant pathogens in most crops. Even in cases where resistance genes may be identified, developing disease-resistant cultivars that maintain desirable

agronomic and horticultural traits is a long-term project. In recent years, tremendous progress has been made in the identification and characterization of disease resistance genes and proteins, and new tools have been developed to integrate genomic and genetic data for the goal of crop improvement. Genomic selection, resistance gene marker-assisted selection and the use of quantitative resistance loci (QRLs) facilitate the identification of disease-resistant genotypes early in the breeding process. The application of NGS to crop genomes has greatly expanded our catalog of plant genes, but now new methods are needed to establish the function and potential utility of these genes for improving disease resistance. Pathogen effectors discovered using genome sequencing can be applied to discover novel disease resistance genes. Due to the pathogen genetic diversity and their ability to mutate quickly, attaining stable disease resistance in crops is a constantly moving target and requires knowledge of the pathogen populations as well as access to diverse plant germplasm and plant pathogen collections. Genetic modification of plants using transformation technologies has been effective for developing disease-resistant plants – e.g., virus-resistant plum, papaya, and squash – and this technology can circumvent or minimize the loss of important agronomic and horticultural traits. These examples rely on the introduction of foreign genes to achieve pathogen-derived resistance. Recent advances in plant transformation can eliminate foreign genes in favor of using gene regulatory sequences and resistance genes derived from the plant species being transformed. The use of these “intragenic” technologies may alleviate many of the concerns associated with transgenic plants expressing foreign genes. Research on pathogen-host interactions aided by bioinformatics will identify candidate genes from the host that are appropriate for the development of intragenic disease resistant plants.

Research Needs

A more in-depth understanding of crop resistance mechanisms and defense responses is necessary to identify plant genes best suited for the development of resistant crops either through conventional breeding or transgenic/intragenic approaches. To develop more durable disease resistant crops and more rapidly react to newly evolving pathogens, new tools are needed. Determining the function of resistance genes in crop plants, will help to exploit the greatly expanded knowledge of pathogen effectors. General disease resistance mechanisms will be better understood, as well as the mechanisms of resistance to specific plant diseases. Knowledge of genetic diversity and shifts in the virulence profiles of pathogen populations will help scientists anticipate emerging vulnerabilities for U.S. crops to initiate breeding for crops resistant to emerging pathogens. Collections of pathogens will be developed and maintained especially with regard to pathogen race-, pathovar-, or species-differentiating host plants.

Anticipated Products

- Expanded genetic and genomic resources for crops, their pathogens, and other microbes needed to develop new strategies for crop protection from disease.
- New tools to identify plant genes with critical roles in disease resistance.
- Expanded disease-resistance mechanisms that are deployed to benefit crop production.
- Tools for the rapid expression of pathogen effectors in crops to enable discovery of new resistance genes and to enable effector-assisted breeding.
- Characterized plant and pathogen germplasm collections to identify new genes for disease resistance.
- Molecular markers that facilitate plant breeding for disease resistance.
- Efficient methods for incorporating disease resistance genes into crop plants.

Potential benefits

- Enhanced availability of new genetic and genomic information for crops and crop pathogens accelerates plant breeding, resulting in disease-resistant crops that lower input costs while reducing economic losses due to plant diseases.

- More effective disease resistance protection for crops based on knowledge of pathogen attributes required for pathogen virulence and disease development.
- Better understanding of the genetic control and physiological basis for plant defense mechanisms to pathogens that will enhance breeding for disease-resistant crops.
- More accurate and timely assessment of rapidly changing genetic profiles of pathogen populations and emerging vulnerabilities in U.S. crops.
- More effective strategies for deploying host-plant resistance genes to combat emerging diseases.

Problem statement 3B: Biologically-Based and Integrated Disease Management

Multiple disease control tactics are necessary to manage the diverse array of pathogens that can simultaneously or sequentially diminish crop productivity or the health of plants in managed or natural landscapes. These tactics include cultural control methods, such as sanitation, crop rotation, and other agronomic practices that have been mainstays for the management of plant disease. Some cultural control methods function by promoting natural processes of biological control, such as populations of plant- or soil-inhabiting microorganisms that suppress plant disease. Individual strains of microorganisms that suppress plant disease have been developed as biological control agents, which are used today in commercial agriculture for the management of a limited number of plant diseases. New cultural practices and biological control agents are needed to combat diseases caused by emerging and exotic pathogens. Used alone, many biologically-based control tactics suppress disease to a degree, but their efficacy and reliability can be enhanced when combined with other tactics. There is a critical need for research integrating host-plant resistance, biological, cultural, and chemical control tactics into pest management systems that optimize plant health in commercial agriculture and the landscape and minimize the impact on the environment. Enhanced methods for pathogen detection and monitoring and knowledge of pathogen biology, ecology, and epidemiology are key elements of integrated disease management systems, enabling the tactics to be employed most effectively and efficiently toward a sustainable system.

Research Needs

Field research is needed to validate the integration of multiple control tactics into overall plant disease management strategies based on the interactions between the environment, host plant and pathogen. Available control tactics include host resistance, biological control agents, suppressive soils, management and cropping practices, natural products, organic amendments, altered levels of pesticides, as well as physical and chemical treatments. New biocontrol agents and cultural practices, such as novel cropping practices or organic amendments, must be discovered, characterized, and tested in the field to identify those providing the greatest level of disease suppression. Forecasting or disease management systems can incorporate environmental aspects with plant and pathogen factors to reduce disease. Methods for large-scale production, formulation, and application of biocontrol agents and natural products must be developed to optimize the efficacy and reliability of these products in the field. Because the widespread use of biological control in agriculture is impeded by unexplained variations in biocontrol efficacy, research is needed to understand the biological, chemical, and physical factors that influence the establishment of these agents and expression of their essential biological control traits on plant protection. Biological control is based on a complex network of interactions among the pathogen, plant, antagonist, and environment, and the nature of these multi-trophic interactions must be elucidated so that more reliable and efficacious biologically-based disease management tactics can be developed. Finally, knowledge of how the environment affects disease development needs to be integrated with knowledge of pathogen and host biology to develop integrated, systems-based disease management strategies.

Anticipated Products

- Selection criteria for biological control agents based upon knowledge of key biological control traits and genes.
- Tools and methods for analyzing system-specific plant-microbe-environment interactions and evaluating the success of biological and cultural control tactics.
- Knowledge of the microbial communities in disease-suppressive soils obtained through altered cropping practices, the use of organic amendments, or other approaches will be used to develop farming recommendations.
- Production, formulation, and application technologies that enhance the efficacy of biological control agents and natural products.
- Integration of knowledge on how the environment modulates disease development will result in disease management systems.
- Integration of control measures including plant resistance and cultural, biological, and/or chemical control, into effective, economical, and sustainable disease management systems.

Potential benefits

- Mechanisms of biological control gained from characterization of the plant-pathogen-antagonist-environment interactions will facilitate screening and deployment of new biocontrol agents and increase effectiveness of existing ones for plant disease management.
- Effective cultural control methods, including the use of cover crops, soil amendments, and recommended cropping practices.
- Newly developed tools for studying system-specific interactions will advance understanding and application of disease management in previously understudied systems, thus enhancing the use of this technology and safeguarding U.S. agriculture.
- Effective integrated disease management strategies and systems that are benign to human health and the environment as well as economically viable.

Problem statement 3C: Alternatives to Pre-plant Methyl Bromide Soil Fumigation

For more than half a century, the primary means of controlling most soilborne pests was the application of soil fumigants, particularly methyl bromide, prior to planting. With the identification of methyl bromide as an ozone-depleting substance, the international phase-out of methyl bromide began along with the search for alternatives to methyl bromide and other soil fumigants. Currently available chemical fumigants have varying degrees of risk for deleterious human and environmental impacts. In addition, chemicals adopted as alternatives to methyl bromide are limited in the spectrum of pests that they control. Approaches are needed to increase the efficacy and reduce emissions of the currently-registered products, as well as to provide alternative, non-fumigant soilborne pest management systems for the future. Combinations of biologically-based management tactics with reduced rates of fumigants need to be identified in order to minimize fumigant use while increasing the spectrum of pest control provided by environmentally-benign approaches. A greater understanding of soil microbial communities and soil ecology, along with the mechanisms of activity and the genetic basis of control will enhance the usefulness of biologically-based management tactics. A better understanding of interactions between pests that were previously controlled by methyl bromide, as well as pests emerging as a result of the use of alternatives is needed to develop effective fumigant replacement systems

Research Needs

Data regarding efficacy, spectrum of activity, and feasibility of use are needed for new chemicals to replace methyl bromide. Identification of resistant vegetable rootstocks for grafting and development of new biological control agents is needed to improve management of specific

soilborne pests. Culturally and biologically-based management tools, such as cover crops, soil amendments, crop rotations, alternative mulches, and biological control agents should be evaluated for their potential contributions to multi-component production systems. A more thorough understanding of healthy and suppressive soils is needed in order to create and maintain soils that are inherently disease and pest resistant. Crop production practices, such as fertilization and irrigation programs and changes in plant culture must be examined in order to optimize the use of organic amendments for disease control, while reducing inputs and costs in other areas. In addition, non-chemical management strategies need to be developed and evaluated within the framework of existing commercial production systems.

Anticipated Products

- Improved fumigant application methods to reduce emissions and enhance efficacy with less potential for negative environmental impacts.
- New chemicals or more efficacious use of current chemicals in controlling targeted pests.
- Additional commercially viable biological control agents.
- Disease-resistant rootstocks and grafted plants.
- Commercially acceptable (effective, feasible, affordable) pest and pathogen management systems.
- Characterization of healthy soils and use of this knowledge to develop methods to create and maintain healthy soils.
- Quantification of pest impacts on crop production.

Potential Benefits

- Growers remain competitive in the global market.
- Reduced use of soil fumigants with reduced deleterious environmental impacts.
- Integration of new chemicals, increased efficacy of biocontrol agents, and appropriate cultural management tools allowing for continued profitable production of high-value crops currently dependent on soil fumigation.
- Avoidance of future dependence on any single chemical pesticide.
- A more thorough understanding of pest and pathogen interactions required for more effective control.

Component 3 Resources:

Thirty-three ARS projects in NP 303 address the research problems identified under Component 3, and the scientists assigned to these projects are located at:

- | | |
|------------------------------|--------------------------------|
| • Beltsville, Maryland | • Kearneysville, West Virginia |
| • Byron, Georgia | • Peoria, Illinois |
| • Canal Point, Florida | • Pullman, Washington |
| • Charleston, South Carolina | • Salinas, California |
| • College Station, Texas | • Stoneville, Mississippi |
| • Corvallis, Oregon | • Tifton, Georgia |
| • Davis, California | • Urbana, Illinois |
| • Dawson, Georgia | • Washington, DC |
| • Fort Pierce, Florida | • Wenatchee, Washington |
| • Houma, Louisiana | • West Lafayette, Indiana |
| • Jackson, Tennessee | • Wooster, Ohio |
| • Parlier, California | |