USDA
AGRICULTURAL RESEARCH SERVICE

NATIONAL PROGRAM 303 – PLANT DISEASES ACTION PLAN 2006-2011



United States Department of Agriculture
Research, Education, and Economics
AGRICULTURAL RESEARCH SERVICE

NATIONAL PROGRAM 303 – PLANT DISEASES
ACTION PLAN
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Goal: Plant diseases – spread by viruses, viroids, bacteria, phytoplasmas, fungi, nematodes or other methods – cause billions of dollars in economic losses each year to agriculture, landscape, and forest settings in the United States. These diseases reduce yields, lower product quality or shelf-life, decrease aesthetic or nutritional value, and, sometimes, contaminate food and feed with toxic compounds. Control of plant diseases is essential for providing an adequate supply of food, feed, fiber and aesthetics. Yet, growers spend millions of dollars each year only to partially control the pathogens that attack their crops and other plants. Reducing these losses has long been a high priority for agriculture and for the Agricultural Research Service (ARS). Besides the obvious monetary benefits to producers and processors, successful plant health protection is important for maintaining and increasing food supplies with minimal increases in land under cultivation. Additionally, the knowledge and management of plant diseases of quarantine significance are vital, not only for protecting our domestic crops from foreign disease, but also for maintaining and expanding export markets for plants and plant products.

Strategies for controlling plant diseases include: Planting resistant crop varieties; Changing crop cultural practices or storage conditions to those less favorable for disease development; Employing biological controls; Applying chemical pesticides; and Using integrated disease management (combining two or more of the above approaches). The ability to develop any of these strategies depends first on identifying the pathogen causing the disease, then learning how to interrupt its disease cycle. The more that is known about the genetic, biochemical, and physiological processes operating in the host and the pathogen as infection and disease progress, the more likely a control method can be devised. Critical to developing effective control methods is an understanding of the ecology of pathogens (that is, how they survive, how they are dispersed, and how they interact with their environment), and the epidemiology or outbreak of disease and spread of pathogens.

As with all microorganisms, plant pathogens exhibit a remarkable ability to change and adapt. Newly discovered pathogens and more virulent strains of old pathogens continually arise and often overcome resistant crop varieties or can no longer be controlled by strategies and chemicals that were once effective. For this reason, continuous research is essential for developing new control methods to increase or even maintain current levels of crop production and commodity preservation. Further complicating the situation, public concern has grown in recent years over the use of chemicals to control diseases. This concern stems from fear that such chemicals may contaminate food or accumulate in the soil and ground water (and so be introduced into the food chain). As a result, pressure has increased to develop non-chemical approaches to plant disease control. Typically, non-chemical controls do not exist, or are less effective, or too costly. To develop or improve non-chemical control methods and procedures will require additional research.

Host-plant resistance to disease is probably the most desirable control strategy because it can be highly effective, environmentally benign, and usually entails little or no additional expense to producers. To be most effective, such resistance should be durable, i.e., not readily overcome by mutations in pathogens that increase their virulence. This requires detailed knowledge of the pathogens that are present, the pathogen's ability to change, and the nature of the resistance processes themselves.

When host plant resistance is unavailable for diseases, or only somewhat effective, strategies are needed to integrate cultural, biological, and chemical control procedures. For example, different crop rotations or improved cultural practices can sometimes suppress development of pathogenic organisms while maintaining a high level of productivity. Biological control shows great potential for disease control, but has often been unreliable or only marginally effective. Additional research is needed to understand the interactions of microorganisms in the soil, in plant parts, and on the mechanisms that biological control agents use to reduce or prevent the onset and development of disease. This is also true for the development of safer chemicals and increasing the efficiency of chemical applications. Appropriate use of chemicals will continue to be an important tool in the battle against plant diseases, especially where alternative controls are not effective.

Also required are rapid, reliable pathogen detection and identification procedures for accurate and timely disease diagnoses. Improved detection and identification procedures are becoming more important as international trade of plant products increases and as trading partners seek to protect themselves from the introduction of unwanted diseases.

Recently developed biotechnology tools provide promising new approaches for controlling diseases. Genetically engineering plants for resistance to viral, bacterial, fungal, and nematode pathogens has shown some success, but more research is needed. Also, techniques have been developed that allow researchers to track specific resistance genes, facilitating breeding resistant varieties. Biotechnology offers the exciting possibility of developing disease resistance in plants that cannot be accomplished through conventional breeding procedures (for example, by introducing genes for resistance from unrelated species).

The overall goal of the Plant Diseases National Program is to develop and improve ways to reduce crop losses caused by plant diseases. The program focuses on developing effective disease control strategies that are not environmentally harmful, do not threaten the safety of consumers, and are compatible with sustainable and profitable crop production. The ARS program is conducted in cooperation with related research in other public and private institutions.

The Plant Diseases National Program (NP 303) is comprised of four components:

- Disease diagnosis: Detection, identification and characterization of plant pathogens;
- Biology, ecology, epidemiology, and spread of plant pathogens and their relationships with hosts and vectors;
- Plant disease resistance; and
- Biological and cultural strategies for sustainable disease management.

Relationship of this National Program to the ARS Strategic Plan: Outputs of NP 303 research support the "Actionable Strategies" associated with the performance measures shown below from the *ARS Strategic Plan for 2003-2007*, Objective 3.2: *Develop and Deliver Science-Based Information and Technologies To Reduce the Number and Severity of Agricultural Pest, Insect, Weed, and Disease Outbreaks.*

Performance Measure 3.2.4: Develop and release to potential users varieties and/or germplasm of agriculturally important plants that are new or provide significantly improved (either through traditional breeding or biotechnology) characteristics enhancing pest or disease resistance. **Target:** Make available reliable diagnostic molecular assays to detect and identify emerging diseases and pests. Primers and probes are developed and protocols established for validation by State action agencies and cooperators.

Performance Measure 3.2.5: Provide fundamental and applied scientific information and technology to protect agriculturally important plants from pests and diseases. **Target:** Specific information and technology will be available to producers to control disease and pest outbreaks as they occur. Strategies and approaches will be available to producers to control emerging crop diseases and pest outbreaks.

Performance Measure 3.2.6: Provide needed scientific information and technology to producers of agriculturally important plants in support of exclusion, detection and early eradication; control and monitoring of invasive insects, weeds and pathogens; and restoration of affected areas. Conduct biologically based integrated and areawide management of key invasive species. **Target:** Knowledge and understanding of the ecology, physiology, epidemiology, and molecular biology of emerging diseases and pests will be improved. This knowledge will be incorporated into pest-risk assessments and management strategies to minimize chemical inputs and increase production.

Component 1. Disease Diagnosis: Detection, Identification and Characterization of Plant Pathogens

The control of a plant disease depends upon the ability to identify the disease or the pathogen causing it. In addition to pathogens and diseases known to science, scientists frequently discover new emerging diseases caused by previously unknown pathogens or new strains of known re-emerging pathogens, some of which mutate rapidly. American agricultural producers face not only a vast assortment of indigenous pathogens, but also many exotic organisms that could devastate U.S. agriculture if accidentally or deliberately introduced. Consequently, the security of the U.S. food supply depends in part on the ability to detect and identify pathogens crossing American borders, 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. Because agricultural globalization has expanded, the need for taxonomic and other biological knowledge of foreign pathogens similarly has increased.

The scientific discipline that includes the identification of organisms — systematics — also encompasses the classification of organisms based on their evolutionary interrelationships. An accurate classification of pathogens often enables scientists to assess potential pathogenicity of a newly identified organism.

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 diagnosis, detection, and taxonomic research. Priority research targets will include pathogens: 1) with high impact on crop yield, quality, and producer income; 2) of regulatory/quarantine importance; 3) important to national biosecurity; and 4) suited for understanding basic mechanisms of virulence/avirulence, infection modes, etc. Specific targets will also be developed in collaboration with the Animal and Plant Health Inspection Service (APHIS), state departments of agriculture, industry, stakeholder groups, and land-grant universities so as to focus on the most important detection and identification needs and to develop standardized, validated, and optimal tools to meet those needs. Collaborations with foreign national agricultural research centers and international agricultural research centers will also optimalize progress. Research on disease diagnosis also is of great economic and scientific value, and will complement and draw from research conducted by National Program 301, Plant Microbial and Insect Genetic Resources; NP 303, Component 2: Biology, Epidemiology, and Ecology of Pathogens; and NP 303 Component 3, Plant Disease Resistance.

Problem Statement 1A: New Diagnostic Methods and Tools

Historically, most pathogens have been detected and identified through in-vitro screens, painstaking microscopic examination, or a series of biochemically based tests. Although many pathogens can be identified by microscopic examination, others require a highly trained and experienced specialist to make an accurate determination. Access to expensive electron microscopes may also be required. In other cases, the only reliable means of pathogen detection may be bioassays that require months to complete. Other pathogens are fastidious and cannot easily be cultured or propagated. Also, there may be no effective sampling methods available for detecting some pathogens within some plant materials. Consequently, new, rapid, sensitive, accurate, and inexpensive methods are needed urgently. At present, DNA-based identification tests exist for only a minority of plant pathogens. Nevertheless, the number of new molecular technologies available to plant pathologists for developing new tests will continue to expand rapidly. Because new molecular approaches may yield accurate tests only when developed within a sound systematic framework, such method development will also require complementary morphological research.

Research Needs

Plant pathogen genomes will be characterized in detail to develop rapid and accurate methods for detecting and identifying pathogen species and pathotypes. Other new pathogen identification methods will involve identification of new structural or biochemical means for discriminating taxa and applying new microscopic or biochemical methodologies. New molecular and structural traits will be analyzed under Problem Statement 1A to formulate systematically valid phylogenetic classifications for pathogens.

Outputs

- New, rapid, reliable, "field-friendly" methods with acute discriminating power for detecting and identifying plant pathogen species, strains, or pathotypes, often within

hours or minutes of specimen examination, and often using tiny amounts of plant or non-plant material.
- Diagnostic methods capable of detecting and identifying several pathogens concurrently.
- Inexpensive on-site or pre-plant pathogen detection methods that do not require highly trained personnel.
- More effective methods, such as genetic marker systems and in vitro screens, for distinguishing pathogen genotypes.
- New statistically-sound sampling methods that enable more efficient recovery/isolation of representative pathogen samples.

Anticipated Impact
- Quicker, more effective, and more broadly applicable (e.g., from plants, soil, air, etc.) pathogen detection and identification methods that enable the outputs and impacts listed under Problem Statement 1B.

Problem Statement 1B: Detection, Identification, Characterization, and Classification of Pathogens

Detection, identification, characterization, and classification of plant pathogens are multi-stage, extremely complex processes. Mere detection of some pathogens is complicated because they do not induce symptoms until relatively late in disease development. Symptom-free plant materials used for propagation are notorious vectors for pathogen transmission. Accurate disease diagnoses may also be difficult because different pathogens may induce the same symptoms, may be physically indistinguishable, or may be so similar that only a highly trained specialist can make a definitive identification. In many cases, morphologically identical variants of the same pathogen species differ in pathogenicity on host plant species or cultivars. Although DNA-based methods of identification are now being enlisted for pathogen identification, these methods are not always available or applicable. For minute pathogens, such as bacteria, mollicutes, viruses, phytoplasmas, or viroids, identifications often necessitate elaborate procedures such as electron microscopy, graft transmission, serology, or other biochemical methods. Although accurately classifying pathogens is important for understanding disease etiology, transmission, and control, the systematics of plant pathogens is plagued by large gaps in knowledge about specific groups of pathogens.

Research Needs

Comprehensive knowledge of the taxonomy and biology of domestic and exotic plant pathogens will be developed via structural, molecular, and other approaches. This newly-generated knowledge base 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. Classification schemes for accurately predicting biological properties critical to disease diagnosis and control will be addressed.

Outputs
- Discovery of plant diseases and pathogen species and strains new to science or new to the United States, together with assignment of formal scientific names for the new species or variants.

- Detection and identification of pathogens known to cause or potentially cause U.S. agricultural losses.
- 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.
- Enhanced knowledge of pathogen genetic diversity, especially with respect to pathogenicity and evolution.

Anticipated Impact

- Accurate identification of plant pathogens worldwide by diagnosticians employing ARS-developed knowledge.
- Control and eradication of invasive pathogens accelerated by early detection and by taxonomic and other knowledge obtained before 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.
- Science-based regulatory decisions facilitating the transport of agricultural products and other plant materials across political borders while minimizing the potential for introduction of exotic pathogens.
- More rapid and accurate pathogen assays (especially pre-plant) that accelerate breeding of pathogen-resistant cultivars.
- U.S. agricultural exports and imports are facilitated by more rapid pathogen detection and identification at ports of entry.

Component 1 Resources:

Thirteen (13) ARS CRIS projects that are coded to National Program 303 address the research problems identified under Component 1. ARS scientists who are assigned to these projects include:

Location:	Scientists:
Beltsville, Maryland	Kinard, Gary R.; Davis, Robert E.; Castlebury, Lisa A.; Jordan, Ramon; Samuels, Gary J.; Carta, Lynn K.; Hartung, John S.
Fort Detrick, Maryland	Damsteegt, Vernon D.; Schaad, Norman W.; Frederick, Reid.
Parlier, California	Yokomi, Raymond K.
Wenatchee, Washington	Roberts, Rodney G.
Corvallis, Oregon	Martin, Robert R.

Component 2. Biology, Ecology, Epidemiology, and Spread of Plant Pathogens and Their Relationships with Hosts and Vectors.

Great emphasis has been placed on the molecular characterization of plant pathogens and the molecular nature of interactions of pathogens with their host. These molecular studies have contributed basic knowledge of pathogen biology and genetics, which has been applied to practical applications for disease control of some pathogens. However, knowledge of the molecular characteristics of many agriculturally important plant pathogens is lacking, as is an understanding of the cellular and molecular interactions that result in susceptibility, resistance, and/or disease development. In addition, the dynamics of pathogen populations and disease epidemiology, critical in disease development, are poorly understood. Understanding how pathogens move from plant to plant, including vectoring within plantings and in harvested commodities, and how pathogens interact with their environment can suggest points where they may be susceptible to control. Understanding these processes can lead to the development of methods that interrupt the life cycle of pathogens and prevent disease or reduce its economic threat. Increased knowledge of pathogen survival on plant parts and seeds is also needed to develop methods for reducing the spread of disease, both domestically and internationally, and to develop integrated management practices for post-harvest diseases. Research conducted in this component will complement and draw from research conducted in NP 303 Component 1, Disease Diagnosis and Component 3, Plant Disease Resistance.

Problem Statement 2A: Pathogen Biology, Virulence Determinants, and Genetics of the Pathogen.

Disease development is a complex process that involves a network of interactions between the pathogen and host plant. Fundamental discoveries of pathogen genome organization and function are used to study pathogen evolution, niche adaptation, and emergence of new pathogens. In addition, genetic maps for bacterial, viral, and fungal pathogens are critical for pathogen diversity studies and to identify loci for pathogenicity and aggressiveness of isolates. Knowledge of the mechanisms of host plant resistance/susceptibility and pathogen adaptation is also critical to an understanding of disease development. As pathogenicity may be based on effector proteins produced by the pathogen, their identification provides a tool for identifying new resistance genes in the host. The life cycle of a pathogen, including survival and reproduction, has great epidemiological consequences as it affects the amount of disease caused by a specific pathogen within a given period of time. Novel disease control strategies can be developed based on specific molecular targets identified in these studies. ARS research will develop the knowledge of the biology of plant pathogens and fundamental principles involved in plant/pathogen interactions and identify opportunities for improved methods of disease control.

Research Needs

Knowledge of pathogen biology, structural genomics, gene function, and virulence determinants will be advanced to understand pathogen/host interactions and disease development.

Outputs

- Description of pathogen genomes, development of pathogen libraries, and maintained pathogen collections.

- Improved knowledge of the molecular basis of pathogenicity and evolution of major agricultural pathogens.
- Increased knowledge of pathogen biology and life cycles in association with their plant host.
- Novel disease control strategies that can be developed based on specific molecular targets identified in these studies.
- New technologies for evaluating the role of pathogen and host genes in pathogenicity and for functional genomics of pathogens will be developed

Anticipated Impact

- Innovative research strategies will yield information on the role of plant and host genes in disease development and will aid development of improved resistant varieties of crop plants and better control measures for plant diseases.
- Understanding pathogen diversity will ensure that resistant cultivars have non-specific resistance that is not limited to current, local populations of pathogens.
- Identification of gene flow between pathogen species that may cause the appearance of new pathogens.
- Measurements of pathogen load would be applied to assessing the likelihood of a serious disease problem developing with resultant economic losses in specific field locations and years.

Problem Statement 2B: Plant-Microbe-Vector Interactions

The majority of plant viruses, mollicutes, and fastidious bacteria are disseminated by insect vectors, but they are also vectored by parasitic plants, mites, fungi, or nematodes. The molecular and cellular mechanisms of transmission are poorly understood and include complex interactions between the pathogen, vector, and host plant. Studies to determine the critical factors that influence developmental and circulative processes of vector transmission will provide strategies to influence the vectorial capacity of vector populations. There are many avenues of invasion and rates of colonization of the host plant by a plant pathogen, and under optimal nutritional and environmental conditions dramatic buildup of pathogen populations can occur. Development of improved methods to limit spread of vectored pathogens requires specific knowledge of interorganismal communication and interactions. ARS needs to conduct research that develops a better understanding of factors which influence vectoring of pathogens to be able to provide guidance on development of new control methods.

Research Needs

Critical pathogen/vector relationships that impact transmission and disease development will be established. An understanding of colonization/infection processes of plants by microorganisms will be developed.

Outputs

- New technologies for pathogen and vector management and control.

Anticipated Impact

- Improved knowledge of pathogen vectoring which can lead to reduced pesticide use and increased crop value.

Problem Statement 2C: Population Dynamics, Spread, and Epidemiology of Pathogens
Plant disease epidemics result from timely combinations of susceptible host plants, virulent pathogens, and favorable environmental conditions. An understanding of these interactions is essential for disease forecasting and control. In addition, determining the modes of spatiotemporal spread and community ecology of the pathogen will aid in determining their ability to cause an epidemic. ARS research will explore pathogen, host, and environmental factors that result in pathogen dispersal and development of epidemics. This knowledge will be used to design better methods for monitoring pathogens and development of expert systems for disease forecasting and alternative approaches to disease management and control.

Research Needs
Methods for determining genetic diversity and population dynamics of pathogens will be developed. Monitoring emerging and transitioning diseases is necessary for sampling to determine pathogen load and inoculum dispersal patterns (global and local). 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. Plant disease forecasts will allow optimum use of control measures with less input without increasing risk of crop loss.

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

Anticipated Impact
The research will provide a scientific basis for allocating resources for increased productivity, controlled application of chemical treatments, and targeted deployment of race-resistant germplasm, resulting in a reduction of input costs and prevention of yield losses.

Component 2 Resources:
Twenty four (24) ARS CRIS projects that are coded to National Program 303 address the research problems identified under Component 2. ARS scientists who are assigned to these projects include:

Location:	Scientists:
Beltsville, Maryland	Conway, William S.; Jones, Richard W.; Ueng, Peter P.; Baker, Con J.; Masler, Edward J.; Hammond, Rosemarie; Bauchan, Gary.
Fort Detrick, Maryland	Tooley, Paul W.
Ithaca, New York	Cartinhour, Samuel W.
West Layfayette, Indiana	Abney, Thomas Scott; Dunkle, Larry D.
Wooster, Ohio	Mian, Rouf
Madison, Wisconsin	Willis, David K.
Parlier, California	Stenger, Drake C.
Salinas, California	Wintermantel, William M.
Davis, California	Kluepfel, Daniel A.

Corvallis, Oregon	Alderman, Stephen C.; Mahaffee, Walter F.
Lincoln, Nebraska	French, Roy C.
College Station, Texas	Prom, Louis K.; Stipanovic, Robert D.
Lane, Oklahoma	Bruton, Benny D.
Fort Pierce, Florida	Gottwald, Timothy R.

Component 3: Plant Disease Resistance.

Crop production in the United States is continuously threatened by the introduction of exotic plant diseases and emerging strains of domestic pathogens. To respond to this changing threat, plant breeders have incorporated genes for disease resistance into vulnerable crops. This process requires anticipating and recognizing plant disease threats, maintaining adequate germplasm stocks from which to draw disease resistance genes, and rapidly moving resistance genes from unimproved germplasm into agronomically desirable cultivars. Increasingly, this process involves molecular genetic and genomic technology. In the long term, new principles and measures for disease management will be developed from a better understanding of host-pathogen interactions. Research conducted in this component will complement and draw from research conducted in National Program 301, Plant Microbial and Insect Genetic Resources; NP 303 Component 1, Disease Diagnosis; and NP 303 Component 2, Biology, Ecology, Epidemiology, and Spread of Plant Pathogens and Their Relationships with Hosts and Vectors.

Problem Statement 3A. Mechanisms of Plant Disease Resistance.

Recent research advances have created large and rapidly increasing genomic DNA sequence and gene expression databases for plants and plant-associated microbes. While progress for model plants and microbes has been rapid, advances in understanding host-pathogen interactions in crops have lagged. Much basic information on disease resistance and susceptible responses in crops is still lacking and genomes of many crops and crop pathogens are yet to be thoroughly characterized.

Research Needs

Our understanding of crop resistance mechanisms and defense responses in greater depth and detail will be assessed for crops. General disease mechanisms will be better understood, as well as details of specific plant disease mechanisms. Analyzing crop diseases will occasionally require exploiting model plants to identify the roles of specific processes and pathways. Understanding adaptive features essential for pathogenesis requires characterization and annotation of genome sequence data and functional analysis of microbial genomes.

Outputs

- Expanded genetic and genomic resources for crops, their pathogens, and other microbes needed to develop new strategies to protect crops from disease.
- Discovery of the underlying pathogenic mechanisms essential for the initiation, establishment, and spread of plant disease.
- Increased knowledge of disease-resistance mechanisms in crop plants.

Anticipated Impact

- Enhanced availability of new genetic and genomic information for crops and crop pathogens accelerates breeding disease-resistant crops.
- More effective disease resistance protection for crops based on knowledge of pathogen attributes essential for maximum disease virulence.
- Better understanding of the genetic control and physiological basis for plant defense mechanisms to pathogens speeds up breeding disease-resistant crops.

Problem Statement 3B. Disease resistance in new germplasm and varieties.
Attaining stable disease resistance in crops requires continued research and deployment of a changing array of resistance genes. Pathogen populations are ever changing, requiring constant monitoring of genetic variability and virulence. Developing disease resistance to this changing profile of pathogens requires ready access to germplasm resources from which to draw new sources of resistance. Genes for resistance must then be identified, characterized for their effectiveness, and rapidly moved into advanced lines of crops. Currently each step in this process requires years of work, often leaving crops highly vulnerable to disease loss until disease-resistant varieties can be developed and deployed. The research conducted under this Problem Area will be closely coordinated with and complement research conducted by National Program 301, Plant Genetic Resources, Genomics, and Genetic Improvement.

Research Needs

Knowledge of shifts in the genetic profiles and degree of virulence pathogen population to anticipate emerging vulnerabilities for U.S. crops will be advanced to initiate breeding for crops resistant to emerging pathogen biotypes. Breeding for resistance requires that collections of crops and their pathogens be developed and maintained especially with regard to pathogen race-, pathovar- or species-differentiating host plants. New technologies, such as marker-assisted selection and quick pathogen detection methods (see NP 303, Component 1), will accelerate crop breeding and crop genetic transformation.

Outputs

- Monitor genetic changes in critical pathogen populations by pathogen surveys.
- Characterize germplasm collections to identify new genes for disease resistance (in conjunction with National Program 301).
- Develop molecular markers that facilitate plant breeding for disease resistance (in conjunction with National Program 301).
- Discover and apply more efficient methods for incorporating disease resistance genes into crop plants (in conjunction with National Programs 301 and 302).

Anticipated Impact

- More accurate assessment of 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.
- More rapid development of disease-resistant crops that lower input costs and reduce economic losses.

Component 3 Resources:
Fourteen (14) ARS CRIS projects that are coded to National Program 303 address the research problems identified under Component 3. ARS scientists who are assigned to these projects include:

Location:	Scientists:
Ithaca, New York	Gray, Stewart M.
West Lafayette, Indiana	Anderson, Joseph M.
St. Paul, Minnesota	Kolmer, James A.; Kistler, Corby.
Madison, Wisconsin	Leong, Sally A.
Albany, California	Baker, Barbara J.
Pullman, Washington	Chen, Xianming.
Fargo, North Dakota	Suttle, Jeffrey; Edwards, Michael C.
Stoneville, Mississippi	Stetina, Salliana R.
New Orleans, Louisiana	Grisham, Micheal P.
Jackson, Tennessee	Arelli, Prakash R.
Canal Point, Florida	Comstock, Jack C.
Charleston, South Carolina	Thies, Judy A.

Component 4: Biological and Cultural Strategies for Sustainable Disease Management

Considerable progress has been made to discover, understand, and apply biological and cultural practices for the control of foliar, fruit, soilborne, and post-harvest pathogens. These efforts have yielded a vast array of new biocontrol agents, suppressive soils, management and cropping practices, natural products, organic amendments, and novel physical and chemical treatments. Many of these treatments have been put into practice to control important plant diseases, but they continue to be inadequately exploited in modern agriculture. Considerable strides have been made to elucidate the fundamental biological, chemical, and physical mechanisms underpinning these treatments, but a huge knowledge gap still exists in this area. To speed the understanding and timely adoption of ecologically based, sustainable disease control practices throughout U.S. agriculture, research and development efforts require greater coordinated integration of classical phytopathological approaches with the development of implementation protocols, contemporary molecular biology and bioanalytical techniques, and emerging technologies of precision farming and genetic engineering. Research conducted in this component will complement and draw from research conducted in National Program 308, Methyl Bromide Alternatives; NP 303 Component 1, Disease Diagnosis; and Component 2, Biology, Ecology, Epidemiology, and Spread of Plant Pathogens and Their Relationships with Hosts and Vectors.

Problem Statement 4A: Biological and Cultural Control Technologies
There is a critical need for ecologically based strategies for managing invasive species, plant pathogens representing a biosecurity threat to U.S. agriculture, established diseases that have proven intractable to traditional disease control measures, previously controlled diseases that have re-emerged as new threats, and disease of minor crops not served by previous research. ARS research will find and characterize novel and more effective ecologically based strategies that can be used alone or in combination with other practices to control diseases and improve plant health. Since disease suppression by these strategies relies on a complex network of

interactions between the pathogen, plant, antagonist, and the environment, the interactions will be analyzed to determine the most practical applications for disease control.

Research Needs

Novel biocontrol agents, soil suppressiveness, management and cropping practices, natural products, organic amendments, and novel physical and chemical treatments will be characterized. Various biological, chemical, and physical treatments will be tested to identify those providing the greatest level of disease suppression. The genetic diversity within species of biocontrol agents will be characterized and the basis of the disease suppression of certain amendments, natural products, cropping practices, and soils will be identified. Ecologically based disease control practices that influence pathogen, plant, and/or microbial interactions will be found. Diverse approaches will be employed to understand the mechanisms of disease suppression observed in selected pathosystems after application of ecologically based control treatments. Naturally occurring antagonists or targeted application of sustainable treatments will be stimulated to promote disease suppressive environments.

Outputs

- Discovery and description of ecologically based methods of disease control.
- Characterization of the genomes and basic biology of selected biocontrol agents.
- Initial development and testing of new sustainable cropping and management systems that promote plant disease control.
- Novel physical and chemical treatments for reducing plant disease.

Anticipated Impact

- Innovative research strategies yielding more comprehensive information about ecologically based methods of disease control, in particular the fundamental biological, chemical, and physical basis of the control, and approaches to improve the effectiveness and consistency of the treatments.
- More comprehensive information about ecologically based methods of disease control and increased understanding of the interactions between plants, microbes, and their environment will advance more effective ecologically based disease control practices.

Problem Statement 4B: Pathogen, Plant, and Antagonist Interactions

The deployment and acceptance of ecologically based disease control practices has been slowed by a perception that these practices may not be as effective or consistent as more traditional and less sustainable approaches. Disease suppression by these practices relies on a complex network of interactions between the pathogen, plant, and antagonist that are modulated by the physical and chemical environment in which they occur. ARS will analyze and describe the chemical, physical, and biological nature of these interactions and ascertain the practical implications regarding disease control from the knowledge obtained from both fundamental and applied studies.

Research Needs
Unique insights into how ecologically-based disease control practices influence pathogen, plant, and/or microbial interactions will be explored for pathosystems functioning on subsurface, aerial, and post-harvest tissues of plants. Functional genomics; novel microbial tracking and digital imaging techniques; classical and contemporary bioanalytical technologies; and microbiological, molecular, biochemical approaches will be employed to understand the mechanisms of disease reduction observed in selected pathosystems after application of ecologically-based disease control treatments. Research will be conducted to understand how to purposefully foster disease suppressive environments via stimulation of naturally occurring antagonists or targeted application of sustainable biological, chemical, or physical treatments, including genetically modified organisms.

Outputs
- Improved knowledge of the mechanisms by which biological, chemical, and physical treatments suppress disease and the interactions between the plant, microbe, and environment.
- Enhanced levels of disease control for selected pathosystems via application of the knowledge of system-specific interactions occurring between pathogen, plant, and antagonist.
- Tools and methods for evaluating and describing system-specific interactions and the success of ecologically based disease control practices.

Anticipated Impacts
- Ability to understand interactions between plants, microbes, and their environment will facilitate greater effectiveness and more successful applications of ecologically based disease control practices, thus enhancing the use of this technology in U.S. agriculture.
- Newly developed tools for studying system-specific interactions will advance understanding and application of biological and cultural control methodologies in previously understudied systems.

Problem Statement 4C: Application of Sustainable Disease Management Tools
Application of novel biological, cultural, and physical disease control strategies can be hindered by inadequate knowledge of protocols for scaling discoveries from experimental to field applications, methodologies for integrating disease control measures into existing agricultural practices, and techniques for successfully applying control practices and products on a large scale. A paucity of basic information on producing and formulating efficacious biomass of biocontrol agents restricts the development of many promising antagonists. ARS research will develop methods for pilot-scale production of stabilized and formulated biomass of biocontrol agents, natural products, and organic amendments, and discover methodologies for enhancing the efficacy and consistency of disease control through the integration of diverse ecologically based disease management tools.

Research Needs

Protocols for the production and increase of biocontrol agent biomass and natural products will be optimized to generate treatments with enhanced efficacy and amenability to stabilization and formulation. The feasibility of integrating two or more disease management tools will be determined, and will include biological control agents, suppressive soils, management and cropping practices, natural products, organic amendments, reduced levels of pesticides, and physical and chemical treatments. The ecological basis of successful integrations will then be characterized. Formulations that foster the maintenance of long-term stability and efficacy of biocontrol agent biomass will be developed and the genetic and physiological basis of biomass stability will be characterized.

Outputs

- New production and formulation technologies that enhance the efficacy of biocontrol agents and natural products.
- Basic and applied information on integrating biological, cultural, and chemical control strategies to reduce plant disease.
- Biological control and natural products for protecting agriculturally important plants and/or minor crops from diseases.

Anticipated Impact

Advancement of new technologies, biological control products, and methodologies of integrated control that will reduce reliance on non-sustainable disease controls, provide more sustainable disease control systems, and improve plant health while preserving the environment.

Component 4 Resources:

Thirteen (13) ARS CRIS projects that are coded to National Program 303 address the research problems identified under Component 4. ARS scientists who are assigned to these projects include:

<u>Location:</u>	<u>Scientists:</u>
Beltsville, Maryland	Bailey, Bryan A.; Meyer, Susan L.
Kearneysville, W.Virginia	Wisniewski, Michael E.
Peoria, Illinois	Schisler, David A.
Urbana, Illinois	Noel, Gregory R.
Davis, California	Baumgartner, Kendra.
Pullman, Washington	Weller, David M.
Wentachee, Washington	Pusey, Paul L.
Corvallis, Oregon	Loper, Joyce E.
Fargo, North Dakota	Kemp, William P.
Tifton, Georgia	Timper, Patricia
Byron, Georgia	Nyczepir, Andrew P.
Charleston, South Carolina	Ling, Kai Shu.