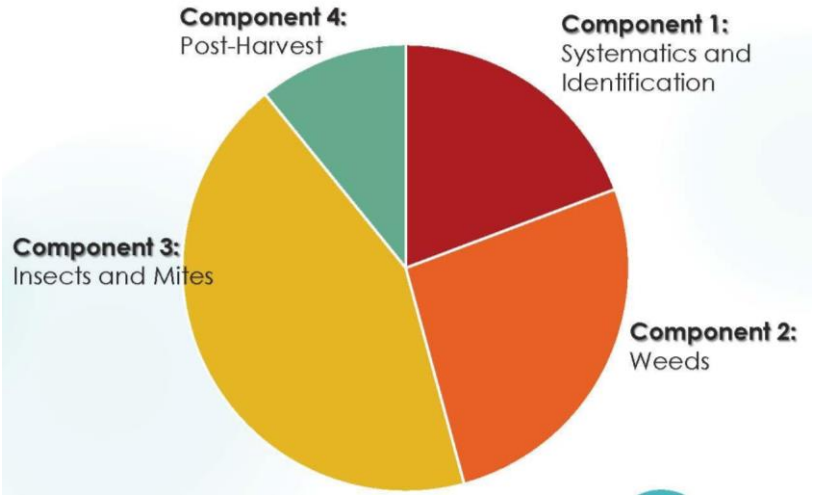
USDA AGRICULTURAL RESEARCH SERVICE
National Program 304
CROP PROTECTION AND QUARANTINE
Retrospective Review - October 2018

Introduction

ARS is a mission-directed, problem-solving agency with the capacity to integrate basic and applied research in response to stakeholder needs. The mission of ARS National Program 304 is to provide technology to manage pest populations below economic damage thresholds by the integration of environmentally compatible strategies that are based on increased understanding of the biology and ecology of insect, mite, and weed pests. The NP 304 Action Plan includes four Research Components:

1. Systematics and Identification
2. Weeds
3. Insects and Mites
4. Protection of Post-Harvest Commodities, Quarantine, and Methyl Bromide Alternatives

The goals of National Program (NP) 304 include to conduct fundamental research to create the knowledge base necessary to develop innovative control methods and IPM strategies, and to conduct applied research to produce informational and material products that improve pest and disease control in agriculture. Improvements include reduced costs, better controlled pests with fewer non-target, human, and environmental effects, and a reduction in the establishment and spread of invasive insects, mites, and weeds. These control strategies are applied in a variety of environments, from the production field to storage, shipping and packing facilities. The development, implementation, and improvements of pest and weed management and control strategies contribute significantly to maintaining the competitiveness and vitality of U.S. agriculture and improving the quality and security of our food and fiber supply. NP 304 is a large, comprehensive program with approximately 90 projects distributed across 4 research components as shown below.



The retrospective review panel (members are listed at the back of this summary) convened by webinar on October 16th and 18th. NP 304 leadership provided overviews of the progress in each of the 4 components as well as the USDA IR-4 program. The presentations highlighted representative project successes accomplishing the goals outlined in the 2015 to 2020 NP 304 Action plan.

Summary

The NP 304 Retrospective Panel appreciated the excellent presentations provided on the research conducted in each of the four program components. The NP 304 program leadership shared several examples of high impact research and outreach programs and if fully staffed and resourced are well positioned to fulfill the goals and objectives of the 2015 -2020 Action Plan. In support of the overall mission of NP304, the panel estimated that the NP 304 projects produced approximately 2,600 scientific publications. This represents an average of ca. 3 publications per scientist per year which is a very high productivity (against a baseline of 2 scientific publications per scientist per year) given that there are approximately 180 scientists funded by NP304. The NP304 program has highly qualified and talented scientists and researchers and since 2013 they have trained and mentored over 1,000 postdoctoral fellows and students (graduate and undergraduate students). Since 2013 they have also been awarded 228 peer-reviewed grants and funding awards with a wide range of US, international, industry and other government partners that have contributed to accomplishing the objects of the current NP 304 Action Plan. The international impact includes 1,200 collaborations with other nations. In the past 5 years, NP 304 has been involved in more than 50 cooperative research and development grants with private-sector collaborators to facilitate development and technology transfer of research innovations and they have received 10 new patents.

NP304 also plays a key role in the facilitation of pesticide product registration approvals under USDA's IR-4 program (a federally funded program established in 1963 to conduct the research necessary for obtaining registrations of pest control agents needed to grow specialty (minor acreage) crops). IR 4 progress includes the development of 2,500 new uses for specialty crop protection applications over the past 30 months. An example of regulatory updates related to IR-4 included developing "data to support biopesticide registrations with emphasis on integration of biopesticides into conventional and organic cropping systems." The USDA IR4 program contributes $9.4 Billion to the annual US GDP and supports > 95,200 jobs".[1]

The retrospective review panel had several questions on research projects and work at various research facilities that are part of the NP 304 program but were not able to be included in the summary presentations due to time constraints. The panel recognized that annual science reviews, ongoing publications and reports outside of the retrospective review process would highlight progress of those areas. The alignment with stakeholder priorities is traditionally linked to five year cycles launched with stakeholder input. The panel feels there is a key opportunity for NP 304 to analyze ways to potentially improve broader and more frequent stakeholder input for inclusion in the research prioritization process.

Overall, NP 304 research has created new knowledge, methods, and technologies and was responsive to emerging issues. The research is relevant to the needs of agricultural industry, governmental action agencies, and the scientific community. The NP 304 program is highly effective and productive and is making excellent progress toward accomplishing the goals outlined in the 2015 to 2020 Action Plan.

[1] The Economic Impact of the IR-4 Project and Programs, 2017; S. Miller, J. Mann; Michigan State University

Research Areas for additional emphasis in the future include:

- Research on emerging pests and invasive species that impact global trade and regulations.
- Global risk characterization utilizing NP 304's international network to inform US predictions of new disease outbreaks and pest and invasive species introductions.
- Molecular biology research and genomics tools to understand weed biology, ecology and evolution of herbicide resistance in weed species and bud dormancy in perennial plants.
- Gene editing therapeutics.
- Research new mode of action sites for pest (weed, insect and disease) management.
- Develop new bioherbicides and biocontrol tools for emerging pests.
- Quantitative analytics in support of systems approaches.
- Systematics research and service identifications provided for insects, mites, microorganisms and weeds.
- Climate change/modeling impacts on insects, mites, weeds and emerging pests and ecosystems.
- Emerging pest management research and a closer link to understanding the management of newly established pests.
- Continued support of the IR4 program.
- Continued building of regional Integrated Weed Management teams
- Develop a national plan for invasive and emerging pest research that prioritizes species for clearly defined reasons, either because of their widespread ecological and/or economic and trade impacts , or because they function as effective model organisms for better understanding invasion processes.
- Increase research on remote sensing UAV (unmanned aerial vehicles) technologies, data analytics, automated image analyses, large scale multifactorial stepwise dynamic analyses, UAV swarm applications, and economic analyses of technologies.
- Development of precision technology packages including reliable and efficient real-time differentiation of weeds and crops under diverse field conditions, and precision application of chemical, mechanical and alternative weed control tools.
- Detection tools for below ground pests
- New fumigants or technologies to sterilize soils and decontaminate commodities/food produce
- New technologies for post-harvest crop protection and timber protection; including the development of innovative tools and strategies for the management of pests of durable and fresh commodities in trade through the application of research on genomics, biology and ecology.
- Herbicide and insecticide (eg. phosphine) resistance research related to trade barriers
- Breeding improved cover crops and crop breeding to develop improved competitive cultivars in crops with limited control options available
- Pest and weed management research to support organic crop production
- Identify cost effective alternatives for long-term weed management in conservation agricultural systems including preventative approaches to weed management

The panel suggests that the program review and update processes to obtain stakeholder input on priorities from the public and across government agencies within USDA and other government entities. Each research component should include metrics of impact including those related to economic analyses, climate change, emerging pest threats and trade as appropriate. The process should also include metrics on coordination with other USDA and other government agencies to increase leveraging opportunities and include types of scientific publications and communications/outreach options utilized to optimize technology transfer and impact of the research.

The panel suggests that NP 304 program include in their prioritization process a decision analysis and rationale for when Agricultural research should be conducted by NP 304; and/or conducted in collaborations with land grant universities, NGOs and/or the private sector and when research is at the phase that it should be conducted/transferred outside of NP 304 to be progressed by other entities. The development of a skill gap analysis with a resource plan for the future of NP 304 research to identify expertise that will be needed for future technologies, projects, and training could be helpful to inform or be part of the next action plan. Training new researchers in species genomics (including insects, mites and weeds), taxonomy and systematics, post-harvest technologies and invasive and emerging species is critically important to meet the mission and goals of NP 304. The next action plan should also include the development of a long range maintenance and strategic plan for collections, databases and taxonomic research infrastructure for insects, mites, microorganisms and weeds.

NP 304 Review Panel Members

Chair:

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Dr. Leroy Whilby
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Florida Department Agricultural and Consumer Services

Reference Materials

Reference Item	Drop Box File Name
NP 304 Action Plan (2015-2020)	**Action Plan**
Current Project Listing (80 Appropriated Research Projects)	Appendix 1 - NP304 Project Listing_FINAL 10.01.18
NP 304 peer-reviewed publications by research project (2013-2018)	Appendix 2 - NP 304 Peer-reviewed publications_FINAL 10.01.18
Selected supporting information and documentation for accomplishments and impact of NP 304 research (2013-2018)	Appendix 3 - NP304 Selected Documentation 2013-2018
List of Cooperating Institutions as Co-Author on NP 304 Peer-Reviewed Publications (2013-2018)	Appendix 4 - List of Cooperating Institutions for NP 304Author304_20180921b
Component 1	
Action Plan Framework	Action Plan - Component 1
Slides	Component 1 Slides
Projects and Publications	Projects and Publications for Component 1
Component 2	
Action Plan Framework	Action Plan - Component 2
Slides	Component 2 Slides
Projects and Publications	Projects and Publications for Component 2
Component 3	
Action Plan Framework	Action Plan - Component 3
Slides	Component 3 Slides
Projects and Publications	Projects and Publications for Component 3
Component 4	
Action Plan Framework	Action Plan - Component 4
Slides	Component 4 Slides
Projects and Publications	Projects and Publications for Component 4
Assessment Criteria for NP 304	NP304 Assessment Criteria for 5-year Programmatic Review
Agricultural Research Service 2017 Annual Report on Science	2017 ARS Annual Report on Science
FY 2017 Annual Report	NP 304 FY 2017 Annual Report_FINAL
FY 2016 Annual Report	NP 304 FY 2016 Annual Report_FINAL
FY 2015 Annual Report	NP 304 FY 2015 Annual Report_FINAL
FY 2014 Annual Report	NP 304 FY 2014 Annual Report_FINAL
Capacity of United States Federal Government and its partners to rapidly and accurately report the identity (taxonomy) of non-native organisms intercepted in early detection programs	lyal_federal_capicity_taxonomy_draft_8march2018
Accomplishment Report 2007-2012	NP 304 Accomplishment Report 2007-2012

Abbreviated Notes – NP 304 Research Components 1 through 4

COMPONENT 1: SYSTEMATICS AND IDENTIFICATION

"ARS will continue to conduct research on the categorization and identification of organisms, including systematics, biodiversity, and taxonomy. Taxonomic efforts focus on the identification of insects and plants that are pests, or potential pests, of the Nation's crops and natural ecosystems, as well as insects and microbes that are possible natural enemies of invasive pests, especially those that show potential as biological control agents. Taxonomic revisions are conducted, including descriptions of new species. Confirmatory identifications are made for potentially invasive insects and weeds. Systematics tools, including phylogenetics, cladistics, and DNA bar-coding, are used to categorize insects and weeds based on genetic and evolutionary relationships, supporting not only identification, but also population genetics and ecological niches."[2]

As background, the fundamental systematics of many insect, mite, microorganisms and weeds are still not adequately understood, and modern research tools (DNA sequencing, pheromones and other chemical tools, and advanced microscopy and digital imaging systems) have the capabilities of tremendously improving our understanding. In addition, many of the key pests and weeds are species complexes that need to be understood in order to apply integrated pest management strategies.NP 304 plays a key role in advancing research in systematics and identification of key pests.

Needs in the area of research were emphasized in a recent report commissioned by the US National Invasive Species Council entitled "Capacity of the United States Federal Government and its partners to rapidly and accurately report the identity (taxonomy) of non-native organisms incepted in early detection programs" [link] and in the final report of the 17th meeting of the FAO Commission on Genetic Resources in Food and Agriculture (CGRFA) in February 2019 [link]. The CGRFA report "noted the special features of micro-organisms and invertebrates, including the need to strengthen taxonomic research and identification activities, and the collections that support them."

Many of the pests in the US that are considered widespread and common are actually complexes of cryptic species, and the effective control or management of these species requires understanding the species complex. Climate change makes it more important to understand these species complexes, because the "dominant" species within such complexes may change, thus changing impacts on crops, etc., and associations with hosts, parasites, and symbionts. Such knowledge must draw heavily on the accumulated data from collections such as those maintained by the USDA.

The NP 304 systematics research and service identifications provided for insects, mites, and microorganisms are unique nationally (and internationally), and provide a vital service to agriculture that only the federal government can provide. Nationally, many universities and natural history museums have individual researchers on particular insect, mite, or microorganisms, but none have the critical mass or research mandate to provide the broad functions provided by ARS. No industry or other stakeholder group fills this role.

[2] USDA ARS National Program 304 Crop Protection and Quarantine Action Plan [2015-2020], page 4

Internationally, USDA systematics services are also important to many developing countries. Several states have identification labs for plant pests, but they rely heavily on the USDA for technical support. USDA research and identification services for weeds are more selective, but still serve a unique role that universities and industry do not fill.

Progress on the major goals for systematics and identification within NP 304 and throughout ARS has been excellent. Some of this work will need to continue for many years to provide vital baselines, while other components are focused on solving specific problems in specific timeframes. Combinations of established methodologies and innovative, experimental methodologies are being used appropriately. Most of the scientists in this group are the best in their fields, and very productive, and also active in training the next generation of researchers.

The specific research goals are developed with input from a range of stakeholders (USDA, state, and county agricultural authorities; commercial interests; national and international academic community; and users), and also changes to meet emerging needs (such as new invasive pests). These scientists get direct input from users in the form of samples submitted for identification (supporting over 10,000 urgent pest identifications at ports annually, plus similar numbers from other stakeholders), so they have a unique connection to field applications.

The USDA maintains vital national collections of insects and mites (in collaboration with the Smithsonian Institution) and fungi and other microorganisms. In addition to supporting USDA research and service identifications, these collections provide infrastructure nationally and internationally for the understanding of these groups.

Overall, the existing research portfolio appears well balanced, albeit under-funded relative to the needs. The panel noted the importance of long-term maintenance of collections, databases, and research infrastructure to the ability to provide high quality research and service identification programs. One example is the microbial culture collection in Northern Regional Research Laboratory (NRRL) which is the largest publicly available collection of microorganisms in the world, and distributes thousands of microbial cultures to scientists in more than 40 countries in an average year. These cultures are critical to ARS research and have contributed to scientific advances described in more than 63,000 publications and 7,000 patents.[3]

The panel emphasized the importance of having scientists trained with taxonomic expertise for insects, mites, microorganisms, and weeds and to have the ability to allow rapid response to new invasive species or other emerging pests.

COMPONENT 2: WEEDS

"ARS will develop innovative approaches to control weeds in cropping systems, aquatic and wetland ecosystems, and rangelands. Weed management represents the largest single pest management cost in agriculture. Synthetic herbicides account for approximately 75 percent of all pesticides used. As a result of our growing dependence on these compounds, the rising evolution of herbicide resistance has become one of the largest problems facing conventional agriculture, including populations of weeds with resistance to multiple herbicides. New methods are needed to reduce the development of herbicide-resistance in weeds, and for containing their spread when resistance does occur. One method to prevent resistance is rotational use of multiple herbicides

[3] From ars.usda.gov, link.

with different modes of action. However, this strategy is limited because current herbicides have limited number modes of action; herbicides with new mode of action sites are needed. Thus, ARS will evaluate phytotoxins as a source of new, ecologically sound herbicides with new modes of action. In addition, crop plants that are resistant to weeds have not yet been developed, although insect-resistant crop varieties are common. A better understanding of allelopathy and how weeds suppress the growth and productivity of crop plants, as well as the genetics behind these phenomena could enhance our ability to breed for better weed-resistance in crops. Invasive weeds also cause serious problems beyond the croplands, sometimes taking over whole landscapes, clogging waterways, and altering ecosystem services. Biological control has provided successful weed control in such situations, but new agents are continually needed to deal with new invasive plants. In addition, ecological studies are needed to develop effective strategies for re-establishing native ecosystems after a major weed invasion has been controlled, and for re-establishing sensitive landscapes that have been destroyed by wildfires, mining activities, overgrazing, or other actions that leave areas vulnerable to another weed invasion."[4]

Presentations of examples of several high impact projects in component 2 were provided to the panel by the ARS technical leadership and included the following: biological control examples of aquatic plants, modes of action of natural phytotoxins, citral, sorgoleone, bioherbicides, herbicide resistance management, and use of cover crops for weed control.

The development of new bioherbicides with novel MOAs show great promise Research on sorgoleone was one example representing an allelopathic broad-spectrum weed growth inhibitor/suppressor. Research identifying key steps in the sorgeolone biosynthesis pathway, and a root hair specific promoter in rice and Arabidopsis, are significant milestones to develop sorgoleone-producing crops.

Research identifying genes for crowding-related stress in sweet corn was another example that could lead to the development of new varieties more tolerant of dense planting as a weed management tool.

The establishment of integrated weed management teams is a successful initiative to meet key objectives in the 5 year action plan. The NP 304 program plays an important role bringing together regional stakeholders to advance research on integrated weed management. The inclusion of economists in the two regional teams so far established is excellent. Additional efforts to expand into the western US, especially California and the southwest is very important.

Important research is being conducted to increase the efficacy of targeted biocontrol tools. Examples include mapping of clonal genotypes in rush skeletonweed to help in the search for new biocontrol agents and mapping of hybrid knotweed which was found to comprise 71% of US invasion, spreading by seed as well as vegetative propagules. Results from another project showed that the use of certain biocontrol agents resulted in water hyacinth being more susceptible to lower rates of herbicides. These findings will enable improved targeting of biocontrol efforts.

The ARS projects on post-invasion land restoration are of high value to land managers and practitioners improving the understanding on factors that impact the germination of restoration species and the effects of invader genotypes on subsequent restoration success. This is another area where ARS has made and hopefully will continue to make unique contributions by

[4] USDA ARS National Program 304 Crop Protection and Quarantine Action Plan [2015-2020], pages 4-5

performing applied research for which it would otherwise be difficult to obtain support. Continued work on genetics of restoration plant materials and on tools and practices to monitor weed invasions such as the remote sensing project to monitor an aquatic weed (water hyacinth) invasion in California are important. The panel was interested in having the opportunity to learn more about the nationwide ARS efforts in invasive plants.

Efforts to increase the work on bioherbicides and crop breeding to develop improved competitive cultivars is especially important in crops with limited control options available. USDA should continue to work with private collaborators to see these potential advancements reach the commercial market.

Weed biology and physiology; weed genomics; and herbicide resistance biology and mechanisms are areas that USDA should concentrate on and will generally apply across large geographical areas and disciplines. The impact of climate change on invasive plants, weed populations, and ecosystems will be an important area of future research. There is often limited work being done in these areas in the private or public sectors. There was a general consensus of the panel that weed research was underfunded.

The cover crop research examples presented were geographically limited and expansion should include the west and southwest. Research on organic weed control and best practices could help improve integrated weed management options across large areas. Research prioritization efforts should include collaborative efforts with private, public, NGOs and other government agencies to leverage resources, advance knowledge and ensure efforts are not duplicated. The research prioritization process could also include obtaining inputs during meetings of scientific societies such as the Weed Science Society of America and other national and regional societies.

COMPONENT 3: INSECTS AND MITES

"This component encompasses ARS' efforts to control insect and mite pests of agricultural crops and natural ecosystems. Multiple cropping systems will be investigated, with the arthropod pests of interest ranging from native organisms to established or recently introduced invasive species. Increased global trade and travel have led to acceleration in the rate of unintentional introductions of invasive species. Several of these invasive arthropod pests threaten food and fiber crops and others entire natural ecosystems. Major pests cost more than $1 billion in yield losses and control costs each year. Additionally, climate and land-use changes may alter the geographical distribution, timing, and abundance of some pests. These challenges are difficult and complex and will require multifaceted approaches from ARS scientists, who will emphasize sustainable approaches. Research efforts will include biological and cultural control methods and developing more environmentally friendly chemical pesticide approaches. Furthermore, ARS scientists will develop early detection and response methods for both invasive species and endemic pests expanding into new areas. Resistance management programs will be expanded and improved to protect genetically engineered crops from insect resistance. In addition, scientists will utilize technological advances in molecular genetics, proteomics, physiology, biochemistry, and genomics to explore novel ways to control pests. Collectively these efforts will improve U.S. food security and help protect the Nation's natural resources."[5]

[5] USDA ARS National Program 304 Crop Protection and Quarantine Action Plan [2015-2020], page 5

The research in component 3 is a core pillar of NP304's mission to "provide technology to manage pest populations below economic damage thresholds by the integration of environmentally compatible strategies that are based on increased understanding of the biology and ecology of insect, mite, and weed pests."

Component 3 research is broad in scope and with specific and high priority areas of focus. The work in terms of scientific quality has been found to be of high quality and appropriate by subject matter experts elsewhere; for example, in a separate evaluation completed in 2015 [link] and as evidenced through excellent publications and impact metrics.

A description of component 3 was provided to the review team by the ARS technical leadership and included the following examples: IPM for specialty crop insects like spotted wing Drosophila (SWD), coffee berry borer (CBB) and silverleaf whitefly (SLWF). In the case of SWD, improved lures were developed; biological controls were advanced; developed two different pesticides with significant advantages over conventional chemistries (OP, carbamates, pyrethroids); reduced active ingredient applied through refined spray patterns; and explored CRISPR-modifications to obtain sterility opening the door to future SIT applications.

In the case of SLWF, understanding of the physiology of feeding led to development of chemistries that blocked salivary sheath formation which is required for feeding; explored parasitoid refugia ("banker" plants); and determined biological control economic thresholds for several species.

In the case of CBB, researchers tested a farnesene (a sesquiterpene) as a repellent, evaluated *Beauveria bassiana* as a microbial broadcast application, and noted the benefits of sanitation. Based on these research results, there has been excellent progress on the development of area-wide approaches to CBB management.

The management of zebra chip disease was also highlighted. According to the published literature, the causal agent was described in 2008 and the genome of the putative causal agent Ca.*Liberibacter solanacearum* was described in 2011, e.g., [link]. The importance of areawide monitoring and mapping of disease spread was described as a key management approach as part of new contributions during the present cycle. The role of matrimony vine as a reservoir for the psyllid vector was elucidated through molecular analyses of gut content and field surveys; matrimony vine could be used both as a sentinel and a trap plant. The new epidemiological findings –especially the role of matrimony vine- translated in reduced pesticide applications and a very significant drop in disease incidence.

Several excellent management approaches to citrus greening disease were highlighted and are still under research and development prior to potential commercial application.

Research in support of Roseau cane, emerald ash borer (EAB) management, Asian long-horn (ALB) beetle eradication and brown marmorated stink bug (BMSB) were presented. The BMSB program included a high impact, integrated program with strong outreach. Elements of survey, behavioral biology, rapid response, conventional chemistries, biological control, landscape multi-host dynamics were all integrated into a highly effective program that has minimized losses due to BMSB. Work led by ARS over the past decade has culminated in an elegant, balanced approach to areawide management that has greatly improved the management of this serious pest and effectively reduced its spread and impact through the use of biological control, attractant

lures, limited and targeted highly effective pesticides, knowledge of preferred hosts, advanced surveys and other practices.

The NP 304 research program met the key goals of the mission involving component 3. There were many examples of efforts to improve surveys, explore resistance (with limited field-ready advances to protect genetically engineered crops from resistance), establish new insecticidal chemistries, improve field-level management. ARS engaged in a variety of molecular genetics, physiology, proteomics, genomics, etc. often without clear links to deployable applications. The panel felt that additional information would have been helpful in the areas of global trade, climate change, and economic analyses and could be included in future prioritization processes.

Overall, the NP 304 program continued certain projects initiated under the previous research cycles, as well as initiated new research taking into account new areas of science, technology, and tools. There has been a noticeable increase in the use of molecular and DNA-based methods to use genomics in a variety of applications. This is consistent with the same trend in most areas of biological research and is driven by the availability of rapid sequencing tools, bioinformatics software, and gene editing technologies. Examples of gene-editing efforts have showed strong potential and applications are under development.

Examples of innovation included research associated with quorum sensing, use of UAVs (unmanned aerial vehicles) and the use of Rhizobacteria to suppress a root rot causal agent as well as several other examples. Many more examples are provided in the more detailed reviews of the categories identified by ARS.

Approximately 2600 scientific publications were produced and represent strong evidence that the NP 304 program advanced science and knowledge in key priority areas of focus. The research programs are coordinated with other national programs and include excellent collaborations and partnerships with many non-ARS cooperators and other stakeholders.

NP 304 research created new knowledge, methods, and technologies and the research is relevant to the needs of agricultural industry, governmental action agencies, and the scientific community.

The alignment with stakeholder priorities is traditionally linked to five year cycles launched with stakeholder input. The panel feels there is a key opportunity for NP 304 to analyze ways to potentially improve broader input for inclusion in the research prioritization process.

National Program 304 was responsive to emerging issues and the excellent examples provided in the presentation by ARS technical leadership showed high impacts from research important to stakeholders. Importantly, critical issues remain associated with a great variety of the challenges making the research in NP 304 critically important to continue to improve technologies that can be utilized by farmers, beekeepers, food-processors and land-managers.

Many high impact efforts, notably the eradication of pink bollworm and the impending eradication of the boll weevil are indeed of very high impact and also are the focus of several articles in this latest documentation of NP304 component 3 work.

Products of NP 304 research are shared with the scientific community in the form of publications, scientific conferences, technical workshops and grower, commodity group, community and stakeholder meetings throughout the life cycle of a program. There is also use of social media in certain research and outreach areas and information exchanges with policy/regulation makers, The very fast nature of scientific developments, as seen in the area of gene-editing show that the 5

year action plans benefit from interim refinements and the ability to rapidly respond to new research challenges.

Overall, new technologies were adopted in many of the example projects highlighted and NP 304 research improved production practices and helped solve significant problems in agriculture

COMPONENT 4: PROTECTION OF POST-HARVEST COMMODITIES, QUARANTINE, AND METHYL BROMIDE ALTERNATIVES

"The importance of post-harvest pest management is two-fold. First, export of some commodities is dependent on the ability to eliminate their associated pests, weeds, and/or pathogens. Second, food that has been harvested and processed represents the maximum economic input for the commodity, so that any losses from pests are particularly expensive. However, chemical treatments for these products has become greatly constrained due to both the loss of important fumigant compounds, such as methyl bromide, and the development of pest-resistance to the fumigants that remain available. ARS will conduct research that covers the full spectrum of needs in this area, beginning with reducing pest infestation during harvest and storage, to improving detection of stored product pests, and then in developing innovative treatment methods based on sound biological principles. ARS has developed and applied cutting edge methods that have led to the preservation of U.S. exports valued at billions of dollars. These improvements benefit other nations as well, contributing significantly to world food security by assuring the stability of food during storage and distribution."[6]

The Research component of NP 304 for protection of post-harvest commodities, quarantine and methyl bromide alternatives is the smallest of the 4 NP 304 components and currently includes only 8 projects. The panel suggests that more resources be allocated to this area of research which is a critical component to remove barriers in our rapidly increasing global trade environment and important for food and environmental security. The researchers working on projects in component 4 are some of the most talented and highly respected throughout the world and they are highly capable of efficiently focusing on key markets in need of research. Research funding for post-harvest protection is not adequate and challenges are increasing. Phosphine resistance threats are increasing and appear to be showing up in the Pacific Northwest and Kansas and new alternatives are needed. There is also a critical need for further development of new tools, use training and best practices for residual grain products and post-harvest fruit and vegetable products.

More research is also needed in the area of new fumigants. Almost 25 years after the Montreal Protocol, Methyl bromide (MBr) is still being used and alternatives are still under development. USDA-ARS plays an important role to help facilitate research and market access to these alternatives. Three fumigants have been in the global pipeline for several years (EDN, Ethyl Formate, HCN) and these technologies would benefit greatly from additional ARS research as well as research on additional new technologies for fumigation.

Research coordination with projects outside of NP 304 on post-harvest timber and log technologies also need to be emphasized in the future as the log export trade is increasing and represents $2 billion/year in trade. (In 2019, MBr is expected to increase on logs by an estimated 1.0 million pounds.) Alternatives to methyl bromide on export logs do exist and are being used in

[6] USDA ARS National Program 304 Crop Protection and Quarantine Action Plan [2015-2020], page 5

other countries (Sulfuryl Fluoride – EU, Germany, Belgium; Phosphine – New Zealand and Ethylene Dinitrile (EDN) –soon to be used in New Zealand) but currently MBr is the only allowed use in the US for export logs.

Overall, the NP 304 research program advanced science/knowledge and created new knowledge, methods and technologies. USDA-ARS is a vital protector of food security and food preservation and additional research emphasis and resources are needed in the post-harvest, fumigant and plant quarantine areas. The panel suggests that an updated priority process with a focus on future markets in need of research be developed and continue to include collaborators across private, public, grower, commodity and trade associations and government groups. The prioritization process should include rapid response technologies and predictive modeling as well as metrics on climate change, economic and trade impacts. The next action plan should include plans for training the next generation of scientists in the area of post-harvest technologies. Research is underfunded in Component IV and if increased would highly benefit US agriculture and trade.