Biological Control of Arthropod Pests and Weeds

Research Proposal to Succeed Regional Project S-267

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Statement of the Problem:

The growing emphasis on environmental and food safety has intensified interest in development of biological control as a means of controlling pests. The effective use of natural enemies in biological control programs is contingent on understanding their ecology and that of their targets, their interactions with production and management practices, and the most effective means for utilizing them. Further, exotic pests continue to pose threats to American agriculture and well being, making continued efforts in importation biological control relevant and necessary. At the same time, the target and non-target effects of these introductions must be documented to assure the continued value and safety of importation biological control. Resident populations of natural enemies do not always provide adequate levels of pest suppression. In such circumstances, it may be necessary to release native or introduced natural enemies. Success of this option, however, is dependent on effective production, distribution, and release technologies for the natural enemies so utilized (Ridgway et al. 1998). This proposal addresses each of the aspects of biological control noted above and places them in the overall context of the Southern Region.

Justification:

A component of the Southern Region Strategic Plan developed in 1996 is to "Discover and develop effective pathogens, parasites, predators, and other biologically based techniques such as host-plant resistance, naturally derived pesticides, and male sterility techniques to mitigate or manage pest populations" (SAAESD 2000, NAS 1996). Further, the Plan recognizes the need to "Create biocontrol techniques and integrate them with crop protection chemicals." The Experiment Station Directors ranked biologically based pest management technologies as the second most critical need for agriculture in the Southern Region, underscoring the importance of work in this discipline. The southern United States has a mild climate relative to the northern states, and as such supports a great diversity of pest arthropods and plants. Further, a moderate climate coupled with extensive international exchange in the Region creates ideal circumstances for the incursion and persistence of injurious invasive species.

The need for environmentally and economically sustainable production systems is growing as social pressure for safe food and fiber increases. In 1993, the Clinton Administration announced its goal of having integrated pest management (IPM) practiced on at least 75% of the production acreage in the U.S. by the year 2000. Biological control constitutes a cornerstone of IPM, and its use must be broadened and fine-tuned to effectively achieve widespread IPM implementation (Lynch et al. 1996). In addition, the passage of the Food Quality Protection Act in 1996 is requiring progressive detailed review of existing pesticides, and will certainly reduce the variety of pesticides available for use. Simultaneously, the more target-specific pesticides

now being developed are costlier than their broad-spectrum predecessors and will add economic burdens to growers, as they will have to use combinations of more expensive insecticides to achieve results comparable to those formerly attained with conventional broad-spectrum materials. Given the poor recent prices for commodities, growers may face grave economic situations if forced to rely strictly on the more expensive novel pesticides or transgenic crop technology to manage pests. The situation becomes even more complicated when considering pest management in natural and urban areas, where economic, environmental, or human risk concerns may entirely preclude the use of pesticides. The need for developing biological control programs for pests in a wide variety of situations is more acute than ever.

The Southern Region of the U.S. has a strong record of research and implementation in biological control. The three predecessors of this proposed Regional Research Projects (RRP) tackled a variety of problems, and successfully impacted various target pest populations in this region (see the attached Critical Review). The proposed project aims to build on this history, continue the work, and extend it to novel and expanding technology relative to crop and environmental protection (Aeschlimann, 1996).

Coordinated regional efforts will be fundamental for the success of this work, because many of the issues to be addressed span large areas, and the extent of biological control efficacy may likewise vary considerably across the region. Both formal and informal collaboration is inherent among the project participants, many of whom have worked together in previous regional projects for most of their careers. Examples of their collaboration include joint research projects and publications, grant and project reviews, information and equipment exchanges, extension and other kinds of training activities, and symposia at scientific societies. Collaboration across state and disciplinary lines is demonstrated by two biological control projects from the Southern Region that were recently funded by USDA-IFAFS. Additionally, a pre-proposal has been submitted to SARE for S-267 to deliver information and options for managing crop pests using biological control in IPM systems across the region. Many of the region's pest problems cut across state lines and are ripe for collaborative approaches that will be developed within this RRP. The past RRPs (S-192, S-238 and S-267) contained a rich documentation of collaboration and have been invaluable for building and supporting regional linkages.

Pest management research in the Southern Region has a strong historical emphasis on biological control, and this is reflected in the associated expertise and excellent facilities. This emphasis continues today, as reflected in the large number of active projects addressing biological control of arthropods and/or plants. A search of the CRIS database for the Southern Region (conducted in April 2000) yielded 12 NRI grants, 16 special grants, 12 State projects, and 94 Hatch projects which address biological control of weeds and/or arthropods to some extent. In addition, 4 of the 12 NRI grants involve participants in the current RRP, S-267. Further participation in the project will be encouraged and likely achieved through direct contact with the participants. Thus, there is currently considerable work on biological control proceeding in the Southern Region that underscores the continuing need for regional cooperation and coordination. The proposed project would provide an effective mechanism for continuing and expanding such integration of efforts as has previously been established. It also could provide a means of surveying and communicating the extensive range of ongoing research and extension activities (Williamson 1998). For example, the group in Florida recently established a State Major Program, "Delivery of Biological Control Information and Technology" that includes a website to increase communication and maintain linkages between the research and extension

communities. S-267 has a listserver that will be updated but no accessible repository of regional biological control information. We hope to establish a website with assistance from the Southern Association of Agricultural Experiment Station Directors (SAAESD).

Invasive species can be exceptionally disruptive in the Southern Region. Many high-profile invasions have occurred with severe economic and ecological impacts. Included in this lengthy list are the red imported fire ant, *Solenopsis invicta*, the silverleaf whitefly, *Bemisia argentifolii*, the tropical soda apple, *Solanum viarum*, hydrilla, *Hydrilla verticillata*, and the formosan termite, *Coptotermes formosanus*. In addition, the threat of new invasions in this region is persistent, as illustrated by the current situation with the pink hibiscus mealybug, an extremely polyphagous pest that may have extensive adverse effects (Francois 1996, Moffitt 1999). Such species are excellent candidates for importation biological control programs. However, importation projects have been greatly curtailed because of growing concerns over possible non-target effects of introduced natural enemies on native organisms (Follett and Duan 2000). Thus, it is critical to consider possible non-target impacts of introduced natural enemies and possible risks relative to the benefits, which could be obtained by suppressing the invasive pest. For this reason, key members of the environmental community will be encouraged to participate in S-267. A major inter-regional workshop was just completed to consider the potential impacts of the recent invader, *Cactoblastis cactorum*, on *Opuntia* spp. in North America. Environmentalists, botanists, horticulturists and others participated with entomologists in evaluating options for mitigating the problem (Mahr et al. 2000).

The full extent of damage by many of the invasive species is difficult to document (Pimentel et al. 2000). For example, the red imported fire ant invades many habitats, disturbing wildlife and native ants, damaging crops, disrupting extant biological control, and inflicting physical harm on humans and animals. The complete ecological and economic costs of this ant's damage have yet to be fully ascertained but it is widely acknowledged that they are substantial, with estimates in excess of US$1 billion dollars per annum (Pimentel et al. 2000). To address these kinds of problems, we intend to add at least one agricultural economist to the proposed RRP. Similarly, the tropical soda apple is currently found in Mississippi, Alabama, Georgia, South Carolina, North Carolina, Tennessee, and extensively in Florida (NAPIS 2000). This strongly spined plant is highly disruptive in grazing areas, and is spreading in the southeastern U.S. Although its spread has been slowed somewhat by herbicide-based eradication efforts, this work is dependent on the ability of individuals across the region and beyond to find and correctly identify the plants. Since tropical soda apple can also readily grow in uncultivated and isolated areas, there is good reason to suspect that the plant is more widespread than is presently acknowledged. Such a situation, dispersed targets with risk of being undetected, is well suited to the use of biological control agents that have the capacity to locate plants independent of human intervention.

Non-invasive native pests also cause extensive damage in crops and other habitats. Management of these pests by natural enemies can provide benefits ranging well beyond the locations of immediate human concern, as well as providing more proximate assistance for pest managers. This can be particularly important for highly mobile and polyphagous species, such as the tarnished plant bug, *Lygus lineolaris*, or the beet armyworm, *Spodoptera exigua*. Further, chemical or other treatment of infestations of natural areas by pests may not be economically or environmentally feasible. In these circumstances, biological control may be the only possible means of control.

The advent of new technology, most notably transgenic insect-resistant crops and increasingly selective insecticides, has created numerous opportunities to more adequately integrate biological control into crop production systems. It has also enhanced the need for biological control, as new pests or pest situations have emerged. For example, although widespread use of Bt-transgenic cotton varieties has contributed to reduced insecticide inputs, it has also increased the problems with heteropteran pests (stink bugs, plant bugs, leaf-footed bugs) in the southeastern U.S. as insecticide spraying for lepidopteran pests has declined (Williams 1998). Thus, cotton growers are by necessity increasing their spray regimens to handle this new and difficult suite of pests. In addition, currently available selective insecticides are more costly and growers can not always afford to target each individual or closely related species when the pest complex is diverse. Development of biological control in low or targeted spray environments would be an invaluable component of IPM in these systems and would strengthen the sustainability and adoption of environmentally sound tools. More detailed studies of interactions between biological control agents and these new technologies are critical for devising appropriate IPM strategies (Ehler and Bottrell 2000).

Related Current and Previous Work:

Various current RRPs address aspects of biological control, some of which overlap with the Southern Region. The two projects most closely related to the one proposed here are the midwestern NCR-125 (an unfunded Regional Project) and western W-185. The emphasis of NCR-125 is similar to that of this project, but with a stronger extension component. Likewise, W-185 covers very similar objectives to those presented here, and there is considerable overlap in orientation. However, the issues of concern, e.g., pests, cropping systems, climatic issues, natural enemy complexes, in W-185 and NCR-125 U.S. differ substantially from those encountered in the Southern Region. Thus, although the objectives may be similar, the targets will differ, as will the research approaches. There are considerable linkages between workers in the Southern Region and those participating in W-185 and NCR-125, that will enhance cooperative effort and minimize redundancy. Prior to the *Cactoblastis* workshop, there was an Experiment Station Committee on Policy – Biological Control Working Group (ESCOP-WGBC) sponsored workshop, "Alternative Paradigms for Commercializing Biological Control" held at Rutgers University (Gaugler and Benson 1998). The Action Plan represented a collaborative effort by workshop attendees from across the U.S. Additionally, S-267 members frequently attend W-185 and NCR-125 annual meetings, and the chairman of S-267 will participate in the upcoming national conference, "The Practice of Biological Control: Importation and Management of Natural Enemies and Agents."

Several other Regional Projects include a minor biological control component, with most of these focused on plant pathogens (NC-125, NC-227, NE-140, NE-171, S-269 and W-147). Three Southern Region projects also address biological control of arthropods or weeds: S-293, "*Improved Pecan Insect and Mite Pest Management Systems*," S-265, "*Development of Entomopathogens as Control Agents for Insect Pests*," and S-268, "*Evaluation and Development of Plant Pathogens for Biological Control of Weeds*." The first is focused exclusively on pecans, the second (currently in re-write) insect pathogens as biological control agents, and the third is on the use of plant pathogens for biological control of weeds. Thus, although there is a limited amount of overlap between the proposed project and the other three, particularly in targets, they are distinct enough to be separate. Having several related projects limits participation in S-267

but provides efficient linkages because some S-267 members traditionally attend more than one RRP. Several workers from the other three projects are also involved in the one proposed.

The objectives of the current proposal's predecessors are listed in Table 1. The initial projects (S-192 and S-238) were focused primarily on importation biological control. The objectives of S-267 were broadened to reflect the widening interests in conservation and augmentation biological control in the Southern Region. The objectives of the current proposal are further expanded to incorporate novel technologies (e.g., transgenic varieties, cultural practices, selective pesticides) and needs (e.g., suppression of invasive species, alternative pest management tools, cost-effective and environmentally sound pest management) in the Southern Region.

Table 1 . Objectives for the three consecutive Southern Regional Research Projects, S-192, S-238, S-267, and Current Proposal

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S-192

Obj. 1. Survey and import biotic agents.

Obj. 2. Release, establish and evaluate introduced natural enemies.

S-238

Obj. 1. To survey for and import natural enemies to control scale insects, whitefly, aphids, fruit and leaf-feeding Lepidoptera, stalk boring Lepidoptera, fruit flies, muscoid flies, mole crickets, aquatic weeds, thistles, and other target pest groups having regional scope.

Obj. 2. To conduct biosystematic research to determine the suitability of the natural enemies for consignment from quarantine.

Obj. 3. To colonize and biologically evaluate the selected introduced natural enemies of arthropod pests and weeds.

S-267

Obj. 1. Assess biological control approaches using native and exotic natural enemies for implementation in pest management systems.

Obj. 2. Enhance augmentation of natural enemies and colonization of introduced natural enemies through improved rearing, distribution and release methods.

Obj. 3. Evaluate effects of exotic natural enemies on non-target organisms.

Obj. 4. Quantify the impact of natural enemies on the pest species.

Current Project Objectives:

OBJECTIVE 1: Cooperatively survey for, import, and assess natural enemies for invasive pests.

OBJECTIVE 2: Assess integration of exotic and indigenous natural enemies with current and novel pest management approaches, to improve environmental and economic sustainability.

OBJECTIVE 3: Evaluate effects of introduced natural enemies on target and non-target organisms.

OBJECTIVE 4: Characterize and quantify the role of indigenous natural enemies in suppressing pest and beneficial species.

OBJECTIVE 5: Improve colonization and efficacy of natural enemies through habitat manipulation for resident species and improvement of rearing, distribution, and establishment of released exotic or native natural enemies.

Procedures:

OBJECTIVE 1: *Cooperatively survey for, import, and assess natural enemies for invasive pests.*

Procedures: There is an ongoing need to discover new biological control agents for both new and established invasive pests. The long-established working hypothesis is that there are natural enemies in the country of origin that can be imported and used to control non-indigenous pest species. Examples of established pests requiring additional research are red imported fire ant, mole crickets, thrips, muscoid flies, water hyacinth, kudzu, Chinese privet, Chinese tallow, melaleuca, and Brazilian peppertree. Examples of newly invading pests are the bromeliad weevil, mealybugs, brown citrus aphid, citrus psylla, old world climbing fern, giant salvinia, and tropical soda apple.

To meet this need, foreign exploration and surveys will be conducted cooperatively to identify biological control agents in the home range of the pest species. The regional project will serve to coordinate surveys and share information regarding planned foreign explorations, and to make the most efficient use of existing quarantine facilities. This work also will be done in cooperation with overseas USDA laboratories in France, Argentina, and Australia. Modern molecular methods will be used to identify countries of origin and biological control agent biotypes to maximize the likelihood of successful discovery and establishment of new natural enemies. Systematists will be involved in all phases of the project.

Promising natural enemies will be imported into quarantine facilities in the region for pre-release risk assessment and evaluation of production and biological characteristics. Risk assessment for weed control projects will follow the guidelines established by the Technical Advisory Group (TAG) for Biological Control of Weeds. Risk assessment for projects with arthropod targets also will be conducted, and will include host range studies, screening for pathogens, and evaluation of potential interference between arthropod and weed pest biocontrol agents. Only those natural enemies that have undergone risk assessment will be released from quarantine. Teams of scientists working within the project will coordinate releases from quarantine and distribution of biological control agents.

Direct collaboration within this objective of the regional project includes research on biological control of thrips by *Geocoris spp*. and the entomopathogenic nematode, *Thripenema fuscum*. Cooperators are in the north Florida and South Georgia vegetable growing areas. Scientists in Florida, Georgia, South Carolina and North Carolina are also conducting collaborative research on red imported fire ant, *Solonopsis invicta*. A new 3-year study is beginning on fire ant control at Ft. Jackson, South Carolina to slow reinfestation after bait treatment by releasing parasitic phorid flies, *Pseudacteon tricuspis* and *P. curvatus*, and microsporidia, *Phelihania* spp. Ongoing, multistate classical biological control projects are being conducted on water hyacinth, alligator weed, salvinia and other aquatic weeds by the USDA, U.S. Army Corps of Engineers and university cooperators. A series of parasites of the

sweetpotato whitefly, *Bemesia argentifoli*, have been imported from USDA overseas laboratories to Texas for distribution across the region. Of particular importance has been *Eretmocerus eremicus* that is now available commercially. Additionally, natural enemies of the citrus leafminer, Asian citrus psylla and brown citrus aphid may have applications in citrus areas outside of Florida in the near future.

Expected outcomes: It is anticipated that natural enemies will be discovered and introduced for control of melaleuca, Brazilian peppertree, old world climbing fern, kudzu, tropical soda apple, water hyacinth (including pathogens), Chinese tallow, Chinese privet, tarnished plant bug, brown citrus aphid, cotton fleahopper, bromeliad weevil, red imported fire ant, muscoid flies, mole crickets, and weevils. The efficiency of foreign exploration will be enhanced by regional cooperation. Improvements in identifying home ranges of newly arrived invasive species will increase the likelihood of discovering biological control biotypes that are adapted to the target pest. For example, it is expected that proper biotyping will improve the prospects for control of giant salvinia, Russian wheat aphid, and silverleaf whitefly. Screening of candidate agents for pathogens before release from quarantine will prevent their accidental release. The conduct of rigorous risk assessment will improve the acceptance of classical biological control by the regulatory and environmental communities, as well as the public.

OBJECTIVE 2: *Assess integration of exotic and indigenous natural enemies with current and novel pest management approaches, to improve environmental and economic sustainability.*

Procedures: Integration of pesticides and natural enemies is becoming increasingly important, which necessitates the development of specific data on natural enemy-pesticide interactions. The hypothesis is that pest management will be most effective and economical if a variety of compatible technologies are developed and employed, rather than attempting to use a single option. Current and novel pesticides will be assayed in the laboratory, greenhouse and field. Laboratory studies will assess lethal and sublethal effects of pesticides, including commercially available pathogens, on economically important natural enemies, such as *Trichogramma* spp., coccinellids, and selected heteropteran predators. Greenhouse studies will permit examination of pesticides and natural enemies under more natural, yet controlled circumstances and provide insights into population level studies conducted in the field. Field evaluations will characterize impacts of pesticides on natural enemy populations and biological control efficacy in relevant production systems.

The interactions of natural enemies with transgenic crops are becoming increasingly important as these crops are being planted extensively in the Southern Region. It is, therefore, critical that these interactions be clarified and quantified in order to minimize secondary pest outbreaks. Spatial and temporal patterns of natural enemy abundance and diversity in relation to transgenic crops will be characterized through detailed surveys of natural enemies in transgenic and non-transgenic crops. The influence of transgenic plants on natural enemy dynamics at the regional level will be evaluated by manipulating spatial patterns and ratios of transgenic and non-transgenic plantings and examining the population dynamics of the natural enemies within the manipulated system. Movement of natural enemies between transgenic and non-transgenic plantings also will be studied. The effects of the transgenic crops on the fitness of natural enemies, directly and through the hosts or prey, will be examined by measuring relevant life-history traits, such as longevity, fecundity and host finding.

Various cultural practices are gaining grower acceptance in the Southern Region. Among the most prominent of these are conservation tillage, cover crops, multiple cropping and crop rotation. These practices affect microhabitat, seasonal distribution of resources within the field, field architecture and microclimate. All of these factors affect the efficacy of natural enemies, as well as the abundance, timing and distribution of pest species within the field. Understanding how cultural practices interact with biological control also may yield opportunities to manipulate habitats to increase suitability for natural enemies. Studies of natural enemies in relation to cultural practices in this project will focus primarily on conservation tillage and cover crops. The abundance and diversity of natural enemies in conservation tillage systems will be compared with those in conventional systems. Experimental manipulations, primarily selective exclusions, will be used to quantify and compare the impact of the natural enemy complex in conservation and conventionally tilled crops.

Interdependence among research projects in the region is particularly important for testing so called "new chemistries," including imidacloprid and other neonicotinoids, spinosads, avermectins, pymetrozine, tebufenozide, azadirachtin and formulations of *Bacillus thuringiensis.* Project participants in Texas, Arkansas, Louisiana, Georgia, Florida and North Carolina are evaluating the lethal and sublethal impacts of pesticides on important natural enemies. This is an ongoing effort, with new compounds constantly being added to the studies. Users will assemble the results of this work into an electronic database for ready access, and updates will be added periodically. This web-based system will be interfaced with others, particularly the one developed by Koppert (www.koppert.nl). Further, the influence of conservation tillage on the efficacy of natural enemies in row crops is being evaluated in Georgia, South Carolina, and Alabama.

Expected Outcomes: Understanding the interactions between pest management technology, conventional and novel, and natural enemies will lead to more effective integration of biological control in pest management systems. Assessing lethal and sublethal effects of pesticides at the individual and population levels will permit effective integrated use of pesticides and biological control. Characterizing impacts of transgenic plants on natural enemies will help clarify the effects of these plants on ecological and agricultural systems, and minimize secondary pest outbreaks. Determining effects of cultural practices on natural enemies will expose beneficial or detrimental consequences of adopting such practices, aiding growers in their production decisions. Information collected under this objective will be of immediate interest and use to producers. Thus, this information will be transferred to the user community through extension and other delivery mechanisms. Pesticide impacts will be compiled into a dynamic database and made publicly available in an electronic format.

OBJECTIVE 3: *Evaluate effects of introduced natural enemies on target and non-target organisms.*

Procedures: Biological control of exotic and invasive pests has long been viewed as an ideal, non-toxic approach for mitigating economic losses due to weed and insect pests that previously and routinely have been controlled by the use of toxic pesticides. It has been hypothesized that host-specific natural enemies are environmentally safe relative to those that attack a wide range of hosts and prey. Current trends indicate that the practice of biological control by the introduction of natural enemies, or classical biological control, will increase worldwide to address new pest problems created as a result of liberal free trade. However, the general

acceptance of biological control as a "safer" alternative to chemical pesticides has been challenged by recent concerns raised by stakeholders about the efficacy and safety of natural enemy introductions on target and non-target species. Clearly, it is the responsibility of the biological control community to objectively address these concerns. Stringent protocols for establishing the safety of plant-feeding organisms to control weeds have been in effect for many years. We propose to examine the effectiveness of those guidelines, and to determine the feasibility of extending those guidelines to other kinds of beneficial organisms.

Quantitative evaluation of introduced natural enemies on target species will be accomplished using manipulative experiments that incorporate accepted elements of experimental design, replication and statistical analyses. Effects of introduced biological control agents on target organisms will be separated from other sources of variation by comparing biological control treatments to experimental units, e.g., cages, plots, where biological control organisms have been excluded mechanically, chemically or biologically. For example, insecticidal check studies will be used to evaluate the effect of a naturalized weevil on two nonnative *Salvinia* spp., while the cage exclusion method will be used to determine the effect of the stem tip midge *Cricotopus lebetis* on the growth of hydrilla. Concurrent studies in the areas of origin and introduction will determine whether introduced natural enemies are likely to be effective. For example, the insecticidal check method will be used to assess the effect of herbivory on survival, growth and reproduction of melaleuca and Brazilian peppertree in their native ranges of Australia and South America, respectively. Simulated herbivory studies on melaleuca and Brazilian peppertree in Florida also will determine whether introduced natural enemies, such as the melaleuca weevil *Oxyops vitiosa*, are likely to play a major role in the suppression of invasive woody weeds.

The potential for long-term damage to non-target organisms sets classical biological control apart from chemical control. The ecological consequences of these non-target effects may run the gamut from temporary or sustained attack on individuals, suppression or extinction of populations and suppression or extinction of a species to community-level disruptions. Post-release monitoring programs will focus on state or federally listed threatened and endangered species, species that are critical to ecosystems and others. For example, studies to assess the impact of the musk thistle weevil, *Rhinocyllus conicus*, on non-target *Cirsium* spp. are being conducted in the Southern Region. Because few candidates for introduction are monophagous, host range testing will play a much greater role in evaluating the risks to non-target species, especially for insect biological control programs. Greater emphasis will be placed on host range in the area of origin using evidence from the literature, field surveys and field experiments. The rationale for this approach is that the host range in the area of origin is a realistic predictor of host range in the area of introduction. Finally, insect and weed biological control researchers will collaborate during the screening of natural enemies of insect pests to ensure they will not attack established or candidate weed biological control agents. The scope of these studies will demand considerable interaction with systematists to separate exotic from related native species that may attack related native or naturalized hosts. This collaboration will begin at the outset of a project and is an essential aspect of its initial evaluation. We also will describe possible natural enemy and host species interactions, e.g., competition with or displacement of native species.

Regional interactions for this objective include studies on the effects of *Rhinocyllus conicus* on musk thistle and non-target thistles that will be continued by project participants in Georgia, Tennessee, and North Carolina. Another developing collaborative project is biological control of the cactus moth, *Cactoblastis cactorum* a non-indigenous natural enemy of prickly

pear, *Opuntia* spp. C. *cactorum*, a native of South America, is now established in Florida and is moving into Georgia. It is expected to extend from Florida across the coastal South, through Texas and into Mexico. Cooperators have been assembled from these states. In another joint project, natural enemies are being assessed for controlling tropical soda apple. They are being imported from South America into quarantine at Gainesville, Florida and distributed to locations in Florida and Mississippi for testing. Mississippi will receive direct shipments when their quarantine facility becomes operational. Non-target effects of natural enemies is a major consideration in importing natural enemies for the hibiscus mealybug, *Maconellicoccus hirsutus*, in the event it becomes established in the U.S. It is a pest of beans, chrysanthemum, citrus, cotton, corn, peanuts and other crops that are grown across the region.

Expected outcomes: Host range limits of introduced natural enemies will be documented across appropriate geographical areas. Alternate, non-target hosts will be identified, both plant and animal (arthropod). Geographic spread of introduced biological control agents will be documented.

Evaluation of the effects of established natural enemies on non-target organisms will enable the development of a significant database to support meaningful risk assessment protocols for future biological control programs. The constantly changing databases list associations of exotic natural enemies and non-target hosts that will be used and updated over the life of the project and made available internationally through the internet.

OBJECTIVE 4: *Characterize and quantify the impact of indigenous natural enemies on pest and beneficial species*

Procedures: Evaluation of indigenous natural enemy efficacy is a key component of biological control programs. The hypothesis is that to be efficacious natural enemies must have significant individual or additive impacts in reducing pest populations. For natural enemies to be used effectively and efficiently in pest management systems, researchers must have a better understanding of how indigenous natural enemies affect the population dynamics of pest species. The role of existing natural enemy complexes in reducing pest populations must be explored thoroughly. Studies will measure host/prey suppression by natural enemies in selected commodities and assess the impact of existing natural enemies on the efficacy of introduced biological control agents.

Paired or triplicate mechanical exclusion methods such as cages, selective insecticide check techniques, and biological check procedures will be used to quantify the impacts of natural enemies on pest populations and biological control agents. Quantification also will include identification and evaluation of individual species and species complexes, and will allow for comparisons among different climates and cropping systems. Protocols will be modified and applied to selected pests/target species in a variety of plant/animal commodity systems through collaboration of members from participating states.

Multi-state research is being conducted in Georgia and Arkansas to assess the efficacy of natural enemies for controlling the cotton or melon aphid, *Aphis gossypii*. The existence and impact of natural enemies in selected of the region is the subject of a 2001 Southern Region SARE proposal, "Extension Guide to Crops, Pests and Natural Enemies." The proposed project will involve every state in the region. It is designed to significantly increase the capability of county extension agents across the Southern Region to deliver information and options for managing crop pests using biological control in IPM systems. It specifically will deliver the

following: a database will be updated periodically to cross-reference pests and associated natural enemies for primary crops in every state and county in the region, incorporation of a database containing important biological control information designed almost a decade ago for the region under the auspices of LISA (now SARE), biological control information and technology options for use by extension professionals, a direct linkage among extension specialists, researchers and county extension faculty, direct access to commercial natural enemies and identification of opportunities for biological control business in the states, and a website that contains the database and facilitates communication for S-267.

Expected outcomes: Knowledge of the impact of existing natural enemy complexes will enable an informed evaluation of the need for new natural enemies or other technologies to control pest species. Quantifying the effect of indigenous natural enemies on introduced ones also will document progress in implementing agents in new areas and will explain less-than-expected control by an introduced biological control agent. This information will help direct resources to further release and redistribute introduced agents. Finally, quantifying the impact of indigenous natural enemies will permit the development of biologically based IPM programs for crop/animal systems.

OBJECTIVE 5: *Improve colonization and efficacy of natural enemies through habitat manipulation for resident species and improvement of rearing, distribution, and establishment of released exotic or native natural enemies*.

Procedures: Habitats will be altered experimentally to provide resources needed by beneficial arthropods, to enhance their numbers and survival. These manipulations will include, but not be limited to, provision of nectar and pollen sources, larval habitat, lekking sites, and alternative prey or hosts. Target pests include muscoid flies, mole crickets, the cabbage looper and diamondback moth. The working hypothesis is that colonization, rearing, establishment and survival of natural enemies must be improved significantly for augmentation biological control to be widely adopted.

Procedures will be developed for rearing for the first time natural enemies of arthropod and weed pests, including indigenous natural enemies such as *Eretmocerus* spp. or specialized predators, such as the mirid, *Deraeocoris nebulosus*, *Delphastus pusillus*, and O*rius* spp. Existing methods of rearing will be improved with emphasis on artificial diets for natural enemies, larval rearing and adult holding containers, equipment and mechanization, controlled environments, and low cost materials. Diet presentation will be facilitated by new methods of encapsulation and key predators will be shifted from living hosts to artificial diets, e.g., *Chrysoperla* spp., *Geocoris* spp., *Orius* spp., coccinellids and predatory bugs. Feeding and holding systems currently being developed will significantly increase survival during shipment and increase shelf life.

Research will be conducted on the needs of the biological control industry, including development of new and improved production, distribution, application and impact evaluation technology for natural enemies. Commercial predatory mites are most important, followed in order of priority by: parasitoids for the silverleaf whitefly, *Chrysoperla* spp., filth fly parasitoids (Pteromalidae), *Hypoaspis* spp., *Trichogramma* spp, and entomophagous nematodes. Practical quality control standards for the most important commercially-produced natural enemies, improved rearing and automated insect counting techniques, and new storage, packaging and shipping methods will be developed. Procedures and materials are needed to optimize survival

and effectiveness of natural enemies shipped over long distances. Efforts will be made to maintain high quality natural enemies, and quality will be evaluated before they are used in the field. Research will focus on mechanical release methods for predatory mites, *Trichogramma* spp., and whitefly parasitoids, and on release rates (numbers and timing) and coverage required for controlling pests. Assuring that pest control methods are compatible with biological control will require determination of the immediate impact and residual toxicity of pesticides (cf. Objective 2 above).

Improvements will be made in the distribution and establishment of natural enemies by developing an inventory of quarantine and rearing facilities for the region. The capabilities of these facilities will be evaluated to develop rearing, holding and shipping methods that increase the survival and establishment of released natural enemies. Quarantine and post-quarantine colonies of beneficial arthropods will be assessed to provide information and enhance collaboration. The distribution and release of beneficial arthropods from these colonies into areas unoccupied by them will be subject to experimental design and collection of data on environmental variables.

Cooperative research on objective five will increase commercial biological control and improve the establishment and impact of natural enemies. An advancing project is commercial production of the entomopathogenic nematode, *Steinernema scapterisci*, for controlling non-indigenous, *Scapteriscus* spp. mole crickets. These very damaging pests of pasture and turf grasses, and some newly planted field crops, occur across the southern region. They are temporarily controlled by using expensive chemical insecticides that can have undesirable non-target effects. Research is currently conducted in Florida, Georgia and Texas. Predators, such as *Geocoris punctipes* and *Orius insidiosus*, are being reared in Florida and distributed across the southern region for new pest management applications. There will be increases in the use of *Chrysoperla carnea* in the near future because their shelf life is being extended with artificial diets. Fly control using parasitoids is being researched in Florida, Georgia North Carolina. Koppert, the largest biological control company in the world, has placed full-time pest management consultants in Florida and Texas. They will expand their markets to adjacent states and develop cooperative research projects. Current projects generally focus on the use of predaceous mites for controlling spidermites in vegetable and ornamental crops.

Expected outcomes: Success will be determined in terms of enhanced numbers of beneficial arthropods and reduced populations. It is expected that favorable habitat manipulations will be developed during the project that will be implemented by growers to foster biological control. The use of commercially produced natural enemies will increase when they are more available, affordable and effective. Determination of the immediate impact and residual toxicity of pesticides will assure that pest control methods are compatible with biological control. Often natural enemies cannot be used because other pests in the environment must be controlled with synthetic pesticides. Credible research, such as that conducted at federal and state experiment stations, will support the marketing of natural enemies. The outcome will be measured in terms of successful establishment and control of the target species.

Organization:

The organization will be as prescribed in the USDA Regional Research Manual (http://aster.uvm.edu/rr/rrman.htm#I). Research under this project will be planned and directed by the regional technical committee. The membership of the regional technical committee will

include the regional administrative advisor (non-voting); one technical representative for each participating SAES, appointed by the directors; technical representatives from 1890 Universities, each participating USDA laboratory, and other research agencies appointed by an appropriate administrator; and a non-voting CSREES representative. Each participating SAES, 1890 University, and USDA, Agricultural Research Service laboratory and other cooperating research agencies are limited to one vote on matters of major importance regardless of the number of representatives that each agency has on the technical committee. All representatives are allowed to vote on matters that the voting members feel should be decided by all. The administrative advisor may invite non-voting consultants, as appropriate.

All members of the technical committee are eligible for office, regardless of sponsoring agency affiliation. The chair, in consultation with the administrative advisor, will notify the technical committee members of the time and place of meetings (according to the suggestions of the technical committee members), prepare the agenda, and preside at meetings of the technical committee and executive members. The chair will be responsible for preparing or supervising the preparation of an annual report of the regional project. The secretary will assist the chair and preside in the chair's absence, record and distribute the minutes, and perform other duties as requested by the technical committee or the administrative advisor. The secretary will be elected by the voting members of the technical committee and will succeed the chair.

Technical coordination among states and agencies will be accomplished by having subcommittees as needed for appropriate research areas, e.g., field crop pests, whiteflies and scales, interiorscapes and glasshouses, livestock pests, weed pests, etc. The proposed administrative structure of the technical committee will be:

1. Experiment Station Administrative Advisor,
2. CSREES Representative,
3. Executive Committee: The Executive Committee will be composed of the past chair, chair, secretary, and administrative advisor.

The current committee members involved in preparing the proposal are: J. Bernal, Texas Agricultural Experiment Station S. K. Braman, Georgia Agricultural Experiment Station; G. Buckingham, USDA-AWRL; G. D. Buntin, Georgia Agricultural Experiment Station; J. P. Cuda, Florida Agricultural Experiment Station; H. A. Frank, Florida Agricultural Experiment Station; W. A. Jones, USDA-BIRU; N. C. Leppla, Florida Agricultural Experiment Station; L. S. Osborne, Florida Agricultural Experiment Station; and J. R. Ruberson, Georgia Agricultural Experiment Station.

The technical committee will meet at least once each year and summaries of the past year's research will be exchanged, research plans outlined, the next meeting location (and time) discussed, and a secretary elected. When possible and of benefit, annual meetings will be held jointly with related regional technical committees. The executive committee has authority to conduct business between annual meetings and perform other duties as assigned by the technical committee.

SIGNATURES:

Regional Project Title: Biological Control of Arthropod Pests and Weeds

Administrative Adviser	**Date**
Chair, Regional Association of Directors	**Date**
Chair, Committee of Nine	**Date**
Administrator **Cooperative State Research, Education,** **Economic and Extension Service**	**Date**

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TABLE 2. PROJECT LEADERS **SPECIALTY:**

Alabama Agricultural Experiment Station (AlaAES)		
	M. Eubanks*	Insects
	A. Appel	Insects
Arkansas Agricultural Experiment Station (ArkAES)		
	D. T. Johnson	Insects
	T. J. Kring*	Insects
	D. C. Steinkraus	Insect Path.
Florida Agricultural Experiment Station (FAES)		
Apopka	L. S. Osborne	Insects
Gainesville	J. L. Capinera	Insects
	R. Charudattan	Plant Path.
	N.C. Leppla	Insects
	J. H. Frank	Insects
	M.A. Hoy	Insects/Mites
	J P. Cuda	Weeds
Homestead	R. M. Baranowski	Insects
Lake Alfred	H. W. Browning	Insects
	C. C. Childers	Mites
Monticello	R. F. Mizell	Insects
Georgia Agricultural Experiment Station (GAES)		
Griffin	S. K. Braman	Insects
	G. D. Buntin	Insects
	R. D. Oetting	Insects
Tifton	J. R. Ruberson*	Insects
	D. C. Shepard	Insects
Kentucky Agricultural Experiment Station (KyAES)		
	B. C. Pass	Insects
	K. V. Yeargan*	Insects
Louisiana Agricultural Experiment Station (LaAES)		
	D. J. Boethel	Insects
	S. J. Johnson	Insects
North Carolina Agricultural Experiment Station (NCAES)		
	D. B. Orr*	Insects
	J. Meyer	Insects
Oklahoma Agricultural Experiment Station (OAES)		
Stillwater	K. Giles	Insects

South Carolina Agricultural Experiment Station (SCAES)

Blackville	S. G. Turnipseed	Insects
Charleston	B. M. Shepard	Insects
	G. S. McCutcheon	Insects
Clemson	G. R. Carner	Insect Path.
	H. W. Fescemeyer	Insects

Tennessee Agricultural Experiment Station (TnAES)

	J. F. Grant*	Insects/Weeds
	P. L. Lambdin	Insects

Texas Agricultural Experiment Station (TxAES)

Amarillo	G. J. Michels	Insects
College Station	F. E. Gilstrap	Insects
	K.M. Heinz	Insects
	J. Bernal*	Insects
	J. W. Smith	Insects
	R.A. Wharton	Insects
	J. B. Wooley	Insects
Dallas	A. E. Knutson	Insects
Weslaco	J. C. Legaspi	Insects

Virginia Agricultural Experiment Station (VaAES)

Blacksburg	L. T. Kok*	Weeds
Suffolk	D. A. Herbert	Insects

Other Cooperators:

Agricultural Research Service, USDA

Aquatic Weed Research Laboratory (USDA-AWRL)

Ft. Lauderdale, Florida

	T. D. Center	Weeds
	R. E. Pemberton	Weeds

Gainesville, Florida

	G. R. Buckingham	Weeds

Biological Control Mass Rearing Research Unit (USDA-BCMRRU), Starkville, MS

	D. A. Nordlund	Insects
	A. C. Cohen	Insects

Center for Medical, Agricultural, and Veterinary Entomology (USDA-CMAVE), Gainesville, FL

	S. M. Ferkovitch	Insects
	E. R. Mitchell	Insects

J. M. Sivinski	Insects
D. Barnard	Insects
C. Geden	Insects
R. S. Patterson	Insects

Grassland, Soil and Water Research Laboratory
(USDA-GSWRL), Temple, Texas

P. E. Boldt	Weeds
C. J. DeLoach*	Weeds

Insect Biology and Population Management
Research Laboratory (USDA-IBPMRL), Tifton, Georgia

J. E. Carpenter	Insects
W. J. Lewis	Insects
P. G. Tillman	Insects

Plant Science and Water Conservation Research
Laboratory (USDA-PSWCRL), Stillwater, Oklahoma

J. D. Burd	Insects
N. C. Elliott*	Insects
M. H. Greenstone	Insects

Southern Insect Management Research Laboratory
(USDA-SIMRL), Stoneville, Mississippi

D. D. Hardee	Insects
L. Williams	Insects

Southeastern Fruit and Tree Nut Research Laboratory
(USDA-SFTNRL), Byron, Georgia

T. Cottrell	Insects

Subtropical Agricultural Research Laboratory,
Beneficial Insects Research Unit
(USDA-BIRU), Weslaco, Texas

W. A. Jones	Insects
R. J. Coleman	Insects
R. S. Pfannenstiel	Insects

U.S. Horticultural Research Laboratory
(USDA-USHRL), Fort Pierce, FL

U. S. Vegetable Laboratory (USDA-USVL),
Charleston, South Carolina

	A. Simmons	Insects

Others

Florida A&M University (1890)(FAMU),
Tallahassee, Florida

	C. W. O'Brien	Insect Taxon./ Weeds
	S. Reitz	Insects
	K. Bloem	Insects

Florida Department of Agriculture (FDA)

Florida Division of Plant Industry (FDPI),
Gainesville, Florida

	R. Nguyen	Insects

North Carolina Department of Agriculture (NCDA),
Raleigh, North Carolina

	K. Kidd	Insects/Weeds

U. S. Army Corps of Engineers, Waterways
Experiment Station (ACE-WES) Vicksburg, Mississippi

	A. F. Cofrancesco	Weeds
	M. J. Grodowitz	Weeds

National Biological Control Institute, USDA-APHIS (NBCI)
Hyattsville, Maryland

	E. Rudyi	

Administrative Adviser

	F. E. Gilstrap	Insects

CSREES Representative	J. S. Yaninek	

TABLE 7. RESOURCES:

	% Commitment			Objectives				
	SY	PY	TY	1	2	3	4	5
Agricultural Experiment Stations								
Alabama Agricultural Experiment Station (AlaAES)	0.2	0	0				X	X
Arkansas Agricultural Experiment Station (ArkAES)	0.4	0	0.3		X	X	X	X
Florida Agricultural Experiment Station (FAES)	2.55	1.8	5.2	X	X	X	X	X
Georgia Agricultural Experiment Station (GAES)	1.0	1.0	1.0	X	X	X	X	X
Kentucky Agricultural Experiment Station (KyAES)	0.2	0	0				X	X
Louisiana Agricultural Experiment Station (LaAES)	0.3	0	0				X	X
North Carolina Agricultural Experiment Station (NCAES)	2.3	2.0	1.25	X	X	X	X	X
Okalahoma Agricultural Experiment Station (OAES)	0.1	0	0				X	
South Carolina Agricultural Experiment Station (SCAES)	0.45	0.6	0.5		X	X	X	X
Tennessee Agricultural Experiment Station (TnAES)	0.6	1.5	0.4				X	X
Texas Agricultural Experiment Station (TxAES)	1.0	0.4	1.0	X	X	X	X	X
Virginia Agricultural Experiment Station (VaAES)	0.2	0	0			X		X
AES Totals	9.3	7.3	9.15					
Agricultural Research Service, USDA								
Aquatic Weed Research Laboratory (USDA-AWRL), Ft. Lauderdale and Gainesville, Florida	1.5	0	3.5	X		X		X
Beneficial Insects Research Unit (USDA-BIRU), Weslaco, Texas	3.0	0	3.0	X	X	X	X	X
Biological Control Mass Rearing Research Unit (USDA-BCMRRU), Starkville, Mississippi	0.4	0	0.4					X
ARS Resources (cont.)								
	% Commitment			Objectives				

	SY	PY	TY	1	2	3	4	5
Center for Medical, Agricultural, and Veterinary Entomology (USDA-CMAVE), Gainesville, Florida	2.0	0	2.5	X		X	X	X
Food Animal Protection Research Laboratory (USDA-FAPRL), College Station, Texas						X		X
Grassland, Soil and Water Research Laboratory (USDA-GSWRL),Temple, Texas	0.1	0	0	X		X		
Insect Biology and Population Management Research Laboratory (USDA-IBPMRL), Tifton, Georgia	0.4	0	0		X		X	X
Plant Science and Water Conservation Research Laboratory (USDA-PSWCRL), Stillwater, Oklahoma	2.3	1.0	4.0				X	X
Southeastern Fruit & Tree Nut Research Laboratory (USDA-SFTNRL), Byron, Georgia	0.1	0	0			X		
Southern Insect Management Research Laboratory (USDA-SIMRL), Stoneville, Mississippi	1.0	0	0.5	X		X		X
U.S. Horticultural Research Laboratory (USDA-USHRL), Ft. Pierce, Florida				X				X
U.S. Vegetable Laboratory (USDA-USVL), Charleston, South Carolina	0.1	0	0					X
Other Cooperating Agencies								
Florida A&M University (1890)(FAMU), Tallahassee, Florida	1.0	0	0.5	X				
Florida Division of Plant Industry (FDPI), Gainesville, Florida								X
Florida Department of Agriculture, Tallahassee, Florida						X		X
North Carolina Department of Agriculture (NCDA), Raleigh, North Carolina				X		X	X	X
National Biological Control Institute, USDA-APHIS (NBCI) Hyattsville, Maryland								
U.S. Army Corps of Engineers (ACE-WES), Vicksburg, Mississippi								X
Cooperator totals	11.9	1.0	12.4					

Appendix: Research foci and the research linkages within the project, by Objective (Note: Objective 5 participants also are listed with that objective in the proposal body to clarify specific contributions in subobjectives)

Objective 1: *Cooperatively survey for, import, and assess natural enemies for invasive pests.*

Target	Linkages
Weeds:	USDA-AWRL, FAES, FAMU, USDA-SIMRL, NCDA, USDA-GSWRL, GAES, USDA-BIRU, NCAES
Muscoid flies:	USDA-CMAVE, GAES, NCAES
Thrips:	FAES, TxAES, GAES, USDA-CMAVE, FAMU
Mole crickets:	FAES, GAES
Pink hibiscus mealybug:	FAES, GAES, USDA-USHRL
Weevils:	FAES, USDA-USHRL
Homoptera:	FAES, FDACS, USDA-BIRU, TxAES
Plant bugs:	USDA-BIRU, USDA-SIMRL, GAES, TxAES
Diamondback moth:	USDA-BIRU
Glassy-winged sharpshooter:	USDA-BIRU
Various:	USDA-ARS laboratories in France, Australia, and Argentina

Objective 2: *Assess integration of exotic and indigenous natural enemies with current and novel pest management approaches, to improve environmental and economic sustainability.*

Emphasis	Linkages
Transgenic crops:	TxAES, FAES, GAES, USDA-BIRU
Pesticide impacts:	ArkAES, GAES, USDA-IBPMRL, FAES, SCAES, NCAES, TxAES, USDA-BIRU
Cultural impacts:	SCAES, ArkAES, GAES, FAES, TxAES
Predatory mites:	FAES

Objective 3: *Evaluate effects of introduced natural enemies on target and non-target organisms*

Target	Linkages
Coccinellids	GAES, USDA-SFTNRL, ArkAES
Brown citrus aphid	FAES, FDA, GAES, USDA-FAPRL
Lepidoptera	
Armyworms	ArkAES, GAES, NCAES, SCAES, USDA-SIMRL SCAES, USDA-BIRU, TxAES, USDA-SIMRL
Others	ArkAES, GAES, NCAES, SCAES, USDA-SIMRL, USDA-BIRU
Mole crickets	FAES, GAES, TxAES
Muscoid flies	ArkAES, FAES, USDA-CMAVE, USDA-FAPRL
Plant bugs/Lygus	Tx-AES, USDA-BIRU
Scales/mealybugs	FAES, TxAES
Weeds	FAES, TnAES, TxAES, VAES, NCDA, UDSA-AWRL, VaAES, USDA-BIRU, USDA-GSWRL

Objective 4: *Characterize and quantify the impact of indigenous natural enemies on pest and beneficial species*

Target/ Focus	Linkages
Lepidoptera:	ArkAES, KyAES, NCAES, GAES, SCAES, USDA-IBPMRL, USDA-BIRU
Ants:	TxAES, AlaAES, GAES, FAES
Spider mites:	FAES, GAES
Lace bugs:	GAES, FAES, NCDA
Muscoid flies:	USDA-CMAVE, NCAES, GAES
Hydrilla:	FAES, FAMU, NCAES, USDA-BIRU
Thistles:	GAES, TnAES, NCDA
Homoptera:	ArkAES, GAES, FAES, LaAES, SCAES, NCDA, USDA-BIRU, OAES, USDA-PSWCRL
Plant bugs:	USDA-BIRU, GAES
Natural enemy surveys:	FAES, GAES, KyAES, TnAES, USDA-BIRU

Objective 5: *Improve colonization and efficacy of natural enemies through habitat manipulation for resident species and improvement of rearing, distribution, and establishment of released exotic or native natural enemies.*

Target/Focus	Linkages
Aphids	ArkAES, FAES, TxAES, FDPI, USDA-USHRL USDA-PSWCRL
Lepidoptera	
Armyworms	ArkAES, GAES, NCAES, SCAES USDA-IBPMRL
Heliothines	ArkAES, GAES, KyAES, MsAES, NCAES, SCAES, USDA-IBPMRL, USDA-SIMRL
Others	ArkAES, FAES, GAES, NCAES, SCAES, USDA- IBPMRL, USDA-SIMRL
Mole crickets	AlaAES, FAES, GAES, SCAES, NCDA, TxAES, LaAES, NCAES
Muscoid flies	ArkAES, FAES, GAES, NCAES, USDA-CMAVE, USDA-FAPRL
Scales, Mealybugs	FAES, GAES, USDA-CMAVE, USDA-FAPRL
Weevils/Beetles	FAES, FAMU, GAES, TnAES, NCDA
Whiteflies	
Bemisia	FAES, GAES, TxAES, USDA-SARL
Ash whitefly	GAES, SCAES, TxAES, FDPI
Weeds	FAES, USDA-Various, others
Eurasian watermilfoil	TnAES, USDA-AWRL, ACE-WES
Hydrilla	FAES, FAMU, USDA-AWRL, ACE-WES, USDA-BIRU
Thistles	GAES, TnAES, VaAES, NCDA
Cabbage looper/ Diamondback moth	USDA-CMAVE, USDA-USVL, SCAES, USDA-BIRU
Relay crops	USDA-IBPMRL, GAES
Predators	FAES, KyAES, USDA-BCMRRU, USDA-BIRU
Parasitoids	FAES, USDA-BCMRRU, USDA-CMAVE, USDA-BIRU
Nematodes	FAES
Citrus pests	FAES, FDA