A Strategy for Prioritizing Research Goals and Outreach Plans to Reduce Soybean Production Losses Caused by Stink Bugs and Related Insect Pests

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4 May 2011

Soybean production throughout much of the US is threatened by a complex of pod-attacking stink bugs that reduce seed yield, compromise quality, diminish profit, and threaten the environment. For many of the common species such as southern green stink bug, green stink bug, and brown stink bug, research has provided some insight into their biology and the specific plant symptoms left behind. Effective management strategies have been used to reduce the impact of these pests; however, infestations are often too severe and control measures fail to prevent substantial economic losses.

Recently, a complex of stink bugs and associated species including brown marmorated stink bug (BMSB), redbanded stink bug, and kudzu bug (bean plataspid) have emerged as new yield-limiting pests in US soybean. In contrast to the established stink bug species, little information is currently available to provide a basis for effective management strategies for these three new pests. Unless novel management options are identified very quickly, entomologists predict that these three insects will cause significant injury to soybean and reduce crop value across many soybean production regions. In late March 2011, a group of soybean entomologists and breeders from eleven soybean producing states convened in Atlanta, GA, to prioritize stink-bug-related management issues that must be solved if US soybean production is to remain economically viable in these regions.

The group agreed that gathering biological, ecological, and pest management information on these emerging insect species is of critical importance in order to ameliorate their damage and crop losses. The extent of the distribution for these new species is currently unknown, but recent observations suggest that their range and numbers will continue to expand. Based upon recent history, these pests are highly likely to decrease significantly the crop value and increase management costs. The purpose of this **Strategic Plan** is to prioritize concerns and to provide a guide to stakeholders, commodity, public, and regulatory organizations to facilitate: (1) more precise assessments of the damage potential in soybean due to stink bugs and similar insects, (2) determination of the biology of stink bugs and similar pests, (3) better understanding of stink bug ecology across local and regional farmscapes, (4) improved management strategies, and (5) coordinated approach to deliver these findings to producers, county extension agents, crop consultants, and other vested entities. Individual projects and proposals across the affected portion of the US Soybean Belt will focus primarily on problems of specific pests, especially these recently-established species. Despite regional differences that exist in species composition, infestation levels, and economic impact, the workshop participants identified four critical needs for research.

(A) Determine and quantify the effects on soybean yield, seed quality, and crop value

(B) Determine basic stink bug biology and ecology across the soybean farmscape

(C) Develop integrated pest management (IPM) strategies

(D) Implement extension and information delivery and outreach programs

This **Strategic Plan** provides a focus for developing robust data sets that will ultimately guide effective management options for established stink bugs species, emerging stink bug species, and associated species (i.e., kudzu bug). The Plan describes in detail four research priorities and outlines specific strategies for research and extension scientists to develop projects that will provide sustainable and practical solutions for US soybean producers.

Section A: Determine and Quantify Effects on Yield, Seed Quality, and Crop Value

Background

Plants are most susceptible to stink bug injury during the soybean reproductive stages due to the stink bugs' search for nutrients found in pod and seed structures. However, one exception is the recently discovered invasive species, kudzu bug, that attacks stems and petioles. Stink bug damage is caused by the insertion of the stylets (piercing-sucking mouthparts) through the pod wall and into the developing seed (petioles and stems for the kudzu bug), enabling the extraction of plant fluids. Stink bug-injured soybean has been associated with a decrease in pod number, fewer seed per pod, lower seed weight (and volume), decreased oilseed content, and increased protein content. Symptomology includes necrotic areas and stains that surround the puncture and often visible on developing pods and seeds. This damage can remain evident on mature seed. Stink bug feeding can also cause the seed coat to shrink and/or wrinkle resulting in smaller, abnormally shaped (shriveled) seed. Damage to mature seed is characterized by white irregular spots and an internal chalky appearance. Stink bug feeding may also introduce pathogens that exacerbate the damage. As a consequence, seed injured by stink bug has exhibited lower germination rates than non-injured seed.

Delayed maturity of soybean plants (green bean or green stem syndrome) as a response to stink bug infestations has been reported for southern green stink bug and brown stink bug. Furthermore, stink-bug-associated pathogen infections may affect over-all plant health and subsequently lead to indirect losses in seed quality. Although injury symptomology is well understood for the established stink bug species, plant symptoms associated with the recently-established species across a range of US geographies are less known. It is critical that we acquire this information soon if we are to define actual economic losses and provide a basis for cost-effective and environmentally-acceptable IPM strategies.

Research Needs for Seed Quality:

(1) Conduct tests that provide direct quantification of soybean seed yield loss in stink bug managed vs. non-managed control plots and in cage experiments

(2) Obtain yield loss estimates at the county level – acres infested/treated, cost of control, percent yield and quality reduction; utilize information to estimate state, regional, and national costs

(3) Quantify impact on seed quality

- (a) determine effects of infestations on seed shape, size, and composition (protein and oil); do these measurements correlate with those employed by the soybean processing industry?
- (b) identify pathogens found on and within seed damaged by stink bug
- (c) establish criteria for distinguishing seed quality problems associated with stink bugs and those associated with weather, especially drought and excess moisture
- (d) validate USDA grain quality standards for stink bug injury

(e) characterize the effects of stink bug damage on planting seed germination rates and seed/seedling vigor

(4) Assess the role of stink bug-type pests in delayed crop maturity (green bean syndrome)

(5) Determine relative seed damage and injury among species

(6) Identify interactions among growth stage, infestation level, and duration

Section B: Basic Biology

Background on BMSB:

The brown marmorated stink bug (BMSB), *Halyomorpha halys* (Stål), is an invasive stink bug native to Japan, Korea, Taiwan, and China. It is highly polyphagous, with more than 300 reported host plants, including soybean. Since its introduction in the US, the BMSB population has steadily increased and reached high densities in multiple Northeastern states representing a significant economic threat to diverse agricultural systems, including fruits, vegetables, ornamental, and field crops. In soybean, BMSB feeds preferably on developing seeds within pods but also feeds on plant stems, foliage, and blooms that create small brown or black puncture sites. Injury to young seeds is similar to that resulting from established stink bugs and causes deformation and even abortion of the entire pod, whereas older seeds become discolored and shriveled. In 2010, many field infestations of BMSB exhibited strong edge effects with feeding limited primarily to field margins causing a delay in plant maturity in those areas of the field. In addition to direct pod feeding damage, fields with delayed growth exhibited harvesting and grain storage problems.

The BMSB is likely to become an increasingly problematic pest in soybean on a national scale because: (1) BMSB has a very broad host range, including numerous specialty crops, field crops, and wild hosts that can support tremendous populations; (2) BMSB has unusual movement and dispersal behaviors, making detection and management more challenging, (3) the lack of an established detection method, treatment threshold or control strategy for BMSB in any cropping system; (4) BMSB is an excellent hitchhiker and has been officially detected in 28 states; (5) multiple generations per year could occur in more southerly latitudes in the U.S.; and (6) potential long-term solutions for BMSB management employing classical biological control are questionable and probably years away from being implemented.

Background on Redbanded Stink Bug:

The redbanded stink bug (*Piezodorus guildinii*, Neotropical green stinkbug, or small green stink bug) is a Neotropical species distributed from Argentina north to the southern United States (Panizzi and Slansky, 1985). The redbanded stink bug feeds on a wide range of cultivated and non-cultivated plant hosts, but has a preference for legumes. It causes severe economic damage in soybean, alfalfa, and other bean crops (Panizzi and Slansky, 1985). The redbanded stink bug has been a recognized and serious annual soybean pest in South America. Throughout much of the 1900s, the redbanded stink bug was known to exist in Florida and occasionally in other states but was not considered as a pest. Since the early 1970's, the redbanded stink bug replaced the southern green stink bug as the principle stink bug pest in portions of Brazil (Turnipseed and Kogan, 1976). Redbanded stink bugs reached levels of concern in south Louisiana in 2000, but was initially misidentified as the redshouldered stink bug, *Thyanta accerra* McAtee. In 2002, the redbanded stink bug presumably reached threshold levels and required insecticidal treatment in southern Louisiana. Subsequently, redbanded stink bug migration into southern Arkansas in 2006 and the Delta and Hill regions of Mississippi in 2007 was reported. By 2009, this species had expanded its range and importance such that it was the most serious soybean pest across most of the southern U.S. (including southeast Texas) bringing with it the associated symptoms, green bean syndrome and delayed maturity. It is not known what triggered the dramatic change in distribution and status of the redbanded stink bug.

A considerable amount of work has been conducted on this species in Brazil where it is particularly damaging to soybeans (McPherson and McPherson, 2000). Very little is known about this pest in the US soybean agro-ecosystem. Preliminary research has shown the redbanded stink bug to be less susceptible to labeled insecticides compared to other soybean-attacking stink bugs. This trait, coupled with its wide host range and the limited knowledge of its biology, has hindered satisfactory control of this pest.

Background on the Bean Plataspid (a.k.a., kudzu bug)

Information on bean plataspid (*Megacopta cribraria*) in the US is limited because it was first reported here in 2010. Originally from Asia, the bean plataspid is found in kudzu and soybean. The bean plataspid is brown or olive-green, pea-sized (or 5 mm long), and barrel-shaped (or bulbous). It may have other names such as lablab bug and globular stink bug. Entomologists in South Carolina, Georgia, and Alabama have been documenting its distribution and it has been found in Tennessee and North Carolina as well.   These bugs appear to reproduce efficiently and fly well; entomologists expect the pest to be widespread soon. The bean plataspid feeds on stems and leaves and can be controlled with pyrethroids but reinfestation resumes quickly when populations are high. Effects on yield are unknown and data associating infestation levels with yield loss will be invaluable as thresholds are established. This pest often overwinters within residential structures.

Research Needs for Biology:

(1) Conduct studies to gain a better understanding of reproductive biology, phenology, and life cycle of the emerging stink bug species (BMSB, redbanded stink bug, and kudzu bug).

(a) investigate voltinism (number of generations per year)

(b) determine life table parameters (fecundity, longevity, and survivorship)

(c) identify and quantify mortality factors (parasitism, predation, and diseases)

(2) Determine temperature and photoperiod requirements to develop degree-day models to predict spring emergence and generation phenology.

(3) Identify pheromones associated with BMSB, redbanded stink bug, and kudzu bug.

(4) Characterize phenology and utilization of other host plants serving as sources of infestations in soybeans.

(5) Conduct adult and nymphal feeding studies to ascertain the effects of feeding injury and potential pathogen transmission relative to life stage.

(6) Determine the key factors associated with overwintering biology, identify induction and emergence triggers, and gather information on overwintering sites

(7) Conduct spatiotemporal distribution studies that provide information on the dynamics of infestations relative to: (a) adjacent habitats, (b) within-field environment, and (c) within-plant morphology.

Section C: Management

Background

The nature of the symptoms described in Section A (Seed Quality) and the behavior patterns described Section B (Biology) will provide a foundation for management practices that agencies and the soybean industry can use to solve stink-bug-related problems confronting producers. Clearly, producers need cultural practices and synthetic pesticides options that are based upon timely field observations and events from nearby farmscapes. Accurate determination of stink bug numbers and species composition are critical for formulating a management strategy. Synthesizing all of the factors and variables associated with a soybean crop threatened by stink bug into a specific management protocol requires a strong understanding of how these factors interact. The primary goal for the research outlined below is to provide IPM options for hemipteran soybean pests. These management strategies and tactics include five categories: cultural, biological, decision rules, sampling, and chemical control.

Pragmatic cultural management strategies for stink bugs are lacking. Some preliminary host plant resistance has been identified, but resistance screening and incorporation into commercial lines is limited. There is also strong evidence that field edges harbor greater populations of these stink bug species, which could be compatible with tactics involving trap crops or different maturity groups of soybean.

The biological control tactic with the most promise is the classical approach, where natural enemies in the insect's country of origin are identified, imported, and colonized. Natural enemies have been identified and released using the classical approach for many hemipteran pest species and some natural enemies have been identified and imported and are currently under quarantine evaluation for possible future release against the three emerging species (BMSB, redbanded stink bug, and the kudzu bug). Documentation describing the potential host range, establishment, dispersal, and effectiveness of these agents is sparse for the established stink bug species and virtually non-existent for the three emerging species.

Thresholds are critical to IPM and a revisiting of decision rules is needed, not only for the three emerging species, but also for other hemipteran pest species. Most thresholds in use for stink bugs need revision because they are not species-specific, are not specific to the wide range of soybean cropping systems in use, and are static (i.e., they do not change as a function of time and with the phenology of the crop). Seed quality is an issue that is important to soybean marketing but is a trait that has been largely overlooked in the creation and implementation of these thresholds.

Sampling methods to document hemipteran pest abundance are not consistent across the soybean production system, but are needed if new thresholds are to be effective. The most popular methods include the sweep net and drop cloth. Although a method favored by many, the drop cloth can only be used in wide row soybeans (viz., rows 30 inches or wider) and cannot be used when the soil is wet. Other methods used largely for research purposes include pheromone traps and the rigid beat sheet (essentially a box with a screen attached to the bottom), which can be used in soybean with narrower row widths. Pheromones are not available for all hemipteran pest species and data linking pheromone catches with other sampling methods are non-existent or preliminary.

Chemical management is the most widely used tactic to manage stink bugs. The crop protection industry continues to provide alternative insecticide formulations for stink bug control and an abundance of data is available on this topic. Researchers and industry are keenly aware that insecticide screening studies targeting hemipteran soybean pests must continue across all regions in order to identify the most effective products. When following an IPM program, a producer's final option is chemical management. Insecticides are used in harmony with alternative strategies in order to optimize survival of beneficial insects.

Research Needs (for Section C):

(1) Cultural

(a) For short-term actions to improve host plant resistance, we need to develop standardized screening methods that will accommodate a large number of genotypes (e.g., thousands). For logistical reasons, these screenings will probably require phenotyping during the vegetative growth stages. Once would-be elite, resistance lines are developed, they need to be evaluated in replicated field trials for seed quality with reference to "known" germplasm that consistently scores as susceptible or resistant. Procedures for screening the variants will be modified based on the specific insect pest inflicting the damage.

(b) Long-term actions that focus on resistance breeding as well as gene and QTL mapping will be launched.

(c) Trap crops combined with chemical treatment to field edges need to be explored. Identifying combinations of trap crop and soybean maturity group compatible with enhanced management efforts is critical.

(2) Biological Control

(a) Classical biological control, especially for the three emerging pest species needs investigating. Natural enemy release should be coupled with collaborative efforts to document dispersal, establishment, and effectiveness.

(3) Thresholds

(a) Threshold revisions are needed, not only for the three emerging species, but for other hemipteran pest species. Observations need to include cumulative effects (e.g., duration as indicated by stink bug days), as well as single points in time. Thresholds must accommodate specific factors for each situation. Soybean maturity group, phenology, row spacing, cost of control, price of soybean, etc., all affect stink bug management. These studies will include field manipulation of natural stink bug populations via chemical exclusion techniques and more precise manipulation via artificial infestations and cages.

(b) As thresholds are refined, additional factors such as beneficial and native species abundance, changes in production systems, invasive species, yield, and seed quality must be considered.

(4) Sampling Methods

(a) Sampling methods need to be standardized if new thresholds are to be effective. The method needs to account for species, life stages, and production systems (e.g., row width, double vs. single crop, and maturity group). Determination of correlations among the sweep net, drop cloth, and rigid beat sheet need to be established. Seasonality, crop phenology, and time of day are factors affecting threshold.

(b) More aggressive pheromone trapping needs to be undertaken. Pheromones need to be identified by species and quickly developed for invasive species.

(5) Chemical Management

(a) Chemical management tactics need to be integrated with alternative management tactics to develop an effective and practical IPM program.

Section D. Extension

Background

Information exchange is a vital component to the successful implementation of new management tools. The Extension Services in the South are uniquely positioned to deliver and evaluate educational programs related to mitigating the impact of stink bug pests in soybean. Regional, state, and county based programs are designed to transfer knowledge to stakeholders that will be accomplished through existing and new program initiatives. Traditional classroom-style trainings, field days, presentations at various workshops and conferences, newsletters, magazines, and various web-based resources will be used to help educate growers, consultants and other agricultural professionals. These projects will complement projects conducted by scientists within Regional Project S-1039 (soybean IPM) that have tackled aphid and other soybean pests. Personnel from multiple disciplines in addition to entomology will strengthen already strong cooperative efforts to achieve these **Strategic Plan** objectives.

Extension Needs and Priorities

(1) Extension will document the distribution and spread of invasive species across the South including the BMSB, bean plataspid, and redbanded stink bug. The intent is to establish a web-accessible map showing the distribution of these invasive species similar to that of the IPM PIPE for soybean aphid and soybean rust (http://www.ipmpipe.org/). This web site will be accessible by the public but secured so that only a designated representative from each state confirms the presence of the pest on a county-by-county basis.

(2) Documented state-by-state insect loss estimates have not been routinely collected in the South. These types of data have proven valuable for other crops (e.g., cotton). The loss estimates document both regional and historical changes in pest pressure and control costs, and thus, identify critical IPM needs for soybean in the South. In 2007, it was estimated from an electronic survey that soybean producers spent $73 million annually to control stink bugs (Heitholt et al., unpublished). More recently, several states in the Mid South have published insect loss estimates in the Midsouth Entomologist (http://midsouthentomologist.org.msstate.edu/). Musser and Catchot (2008) reported methodology for tabulating loss methods in soybean that will serve as a template. Dr. Fred Musser, Mississippi State University, has agreed to help coordinate the tabulation and dissemination of insect loss estimates for southern states. An internet-based survey tool will be designed (e.g., SurveyMonkey – electronic survey software) with targeted questions to solicit insect loss and control cost estimates from key pest management advisors within each state including crop consultants and local Extension Agents. A designated entomology Extension Specialist in each state will use these data to help

generate loss estimates by state. The intent will be to publish these data annually on the internet.

(3) Web-based publications and blogs will be a primary method for delivering educational materials and news updates about stink bug management. Publications about stink bugs and their management are already available including several photographic guides. Other web resources are also available. However, there is a need to develop a centralized internet "warehouse" for new research results and other resources developed though the activities described previously. Extension scientists will cooperate with researchers to coordinate the development and delivery of these resources. Potential content will likely include stink bug distribution maps, insect loss estimates, identification guides and photographic libraries, sampling and threshold guidelines, and research outputs.

(4) Besides information delivery, Extension Specialists are heavily involved in the evaluation and demonstration of IPM recommendations, and thus, will support the proposed research initiatives. These will include the evaluation of sampling methodology, action thresholds, and insecticides efficacy. Extension Specialists in each state will also assess seed quality and relative stink bug damage levels by collecting grain samples from representative growers.

How the Research Objectives and Outreach Goals Complement Each Other

Quantifying *Seed Quality* will complement Biology and Management via:

(1) Decision rules (sampling and action thresholds)

(2) Identifying and characterizing host plant resistance traits and plant resistance (value associated with selected vegetative vs. reproductive traits)

(3) Timing of stink bug management strategies relative to plant development

(4) Stakeholder education for informed decisions on management strategies

(5) Supporting data for chemical control recommendations

(6) Improving diagnosis of stink bug-induced problems (eliminate confusion among other biotic and abiotic agents)

(7) Demonstrating a basis for relationship to production practices and soybean farmscape (e.g., cultivar and planting date)

Research on *Biology* will primarily impact progress made in Yield and Quality and Management. Specifically, results will improve the ability of entomologists and crop consultants to monitor stink bug populations, identify high-risk fields, develop decision-making tools, and apply control tactics at the most optimal times.

Management objectives complement the yield loss and seed quality objectives identified in Seed Quality with attention to the production system. Emphasis on sampling using pheromones and attention to spatiotemporal dynamics is complementary with Biology. Finally, efforts in *Extension* are the logical outputs of the completed objectives identified in Management/Sampling/Thresholds.

Overall Summary

Based on information gleaned from research on established stink bug species and emerging species, the workshop participants established three broad research goals and formulated an outreach plan. The research will clarify uncertainties associated with the nature of damage to plants, behavior of the emerging pests, and management options. Clearly, addressing future problems with these pests will require an integration of information from single-point-in-time scouting as well as from data reflecting nearby crops and ecosystems, soybean growth stage, economic factors, and species type. Without a focused integration of effort, these insects will have a severe impact on soybean yield, quality, and economic value. The participants identified specific, coordinated approaches necessary to better understand seed yield-quality, insect biology, sampling/thresholds, and extension goals. The **Strategic Plan** outlines a combination of basic and applied projects to ultimately help soybean producers effectively manage stink bugs. Much of the research and extension efforts in the next few years will have to be directed toward three emerging species (BMSB, redbanded stink bug, and kudzu bug) since the knowledge gap for these species is greater than for established species. The participants discussed options to optimize the dissemination of information acquired from the future projects. Because management strategies are needed within a short time frame, delivery of reliable and timely information will be as critical as the discovery process. Due to the distribution and spread of these emerging pests, projects will necessarily have a regional focus but findings will have great value for all soybean regions affected. The participants established and strengthened collaborations and will have specific project plans developed by the beginning of May 2011.

References:

McPherson, J.E, and R.M. McPherson. 2000. Stink bugs of economic importance in America North of Mexico. CRC Press, Boca Raton, FL 253 pp.

Musser, F. R. and A. L. Catchot. 2008. Mississippi Soybean Insect Losses. Midsouth Entomologist, 1(1): 29-36, http://midsouthentomologist.org.msstate.edu/Volume1/Vol1_1_html_files/vol1-1_005.html.

Panizzi, A.R., and F. Slansky. 1985. Legume host impact of performance of adult *Piezodorus guildinii* (Westwood) (Hemiptera: Pentatomidae). Environ. Entomol. 14:237-242.

Turnipseed, S.G., and M. Kogan. 1976. Soybean entomology. Annu. Rev. Entomol. 21:247-282.

Acknowledgments: The workshop participants thank the United Soybean Board for sponsoring the workshop.