Project 39-2022: Development of a predictive model to determine the influence of weather on the northern range expansion of redbanded stink bug

Annual Report, April 2021- March 2022

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Background and Objectives

The redbanded stink bug (RBSB), *Piezodorus guildinii* Westwood (Hemiptera: Pentatomidae), is a Neotropical species that was first detected in the US in the Florida Everglades in the late 1960s. This stink bug attacks several leguminous plants but did not become a major pest of soybeans (*Glycine max*) in the US until the early 2000s when high levels of damage were reported in multiple southeastern states. This insect uses piercing-sucking mouthparts to feed on several types of soybean tissue, but the most damage is caused by feeding on seedpods. The invaded range of RBSB has been characterized by pulsed expansions northwards into soybean growing regions of MS that eventually contract. Cold winter temperatures have been implicated in the southwards range contraction and in helping reduce RBSB abundance at higher latitudes. However, the specific environmental conditions that drive or limit northward expansion and the associated threats to soybean yield remain unknown.

Given that redbanded stink bug emerged as a pest in the US and Mississippi decades after its initial establishment and that we are currently living through a time of increasing climatic uncertainty, mechanistic understandings of how annual weather patterns influence population dynamics of RBSB are critical for estimating its potential impacts each year. Understanding how weather impacts RBSB abundance and distribution was achieved through (i) the continuation of monitoring to delimit the annual range of this pest and (ii) targeted investigations of the environmental conditions that lead to annual changes in pest abundance across the landscape. Ultimately, we hope to use this information to forecast annual potential impacts from redbanded stink bug.

A combination of fieldwork and geospatial modeling was used to pursue the following objectives:

1) Conduct ditch bank and cover crop surveys in legumes in the early spring to predict RBSB populations
2) Quantify the role of weather in RBSB range expansion and contraction in Mississippi

Report of Progress/Activity

Objective 1: Conduct ditch bank and early cover crop surveys in legumes in the early spring to predict RBSB populations

1st Quarter Progress: Completed: Spring ditch banks samples were conducted and reported in the Mississippi Crop Situation newsletter.
2nd Quarter Progress: Completed: Spring ditch banks samples were conducted and reported in the Mississippi Crop Situation newsletter.
3rd Quarter Progress: Completed: Spring ditch banks samples were conducted and reported in the Mississippi Crop Situation newsletter.
4th Quarter Progress: Preparations are currently being made to begin ditch bank surveys for 2022

Objective 2: Quantify the role of weather in RBSB range expansion and contraction in Mississippi

1st Quarter Progress: Our team of investigators hired Mr. Thomas Paul as a graduate research assistant to lead analyses investigating the effects of weather on RBSB populations. A global database of >800 occurrence points of redbanded stink bug was compiled from Global Biodiversity Information Facility (GBIF.org), reports from the primary literature, and surveys from university researchers in the southeastern US (hereafter southeast). Daily climate data from across the southeast were obtained from PRISM (https://prism.oregonstate.edu/) at a resolution of 4×4 km.

2nd Quarter Progress: Occurrence points for RBSB from across the southeast were selected for analyses (Figure 1), cleaned (e.g., duplicate occurrences removed), and then spatially joined with the climate data. Previous work on RBSB cold tolerance indicated that exposure to -5 °C for 10 hours kills ~90% of individuals. To determine if insect cold tolerance could help predict observed RBSB occurrences across the southeast, we extracted two climatic metrics: (i) minimum temperatures and (ii) number of days below -5 °C at each occurrence point in the previous winter (October-April). We found that several RBSB occurrences experienced winter temperatures below -5 °C (Figure 2) and were observed in areas with multiple days below 5 °C (Figure 3). We are currently working to disentangle the role of insect dispersal in survival, however, as insects found late in the growing season could have dispersed from several kilometers away, originating from warmer overwintering locations.

3rd Quarter Progress: We obtained an additional dataset documenting the (i) annual yield losses from stink bugs per state across the southeast (2010-2020) and (ii) percent of observed stink bugs that were redbanded stink bugs, which enables estimates of annual damage attributable to RBSB. These data are currently being used to investigate changes in RBSB damage in relation to minimum winter temperatures. Based on observations during Quarter 2 (i.e., that some insects appear to overwinter in locations where ambient temperatures are believed unsuitable), a second study was initiated to determine how RBSB chooses between different overwintering substrates (soybean biomass vs. pine needles vs. broadleaf leaf litter vs. bare soil) and how the microclimates provided by those substrates differ.

4th Quarter Progress: We used maximum entropy (Maxent) models, a machine learning tool that links presence only data with environmental variables, to forecast habitat suitability for RBSB across the southeastern US. The models were using occurrence points in the southeast (Figure 1) and historical climate normals (i.e., recent changes in climate were not incorporated), and projected that, as expected, the most suitable climates for RBSB are concentrated in warmer, coastal areas (Figure 4). However, soybean growing regions in the MS delta were moderately suitable, with a 10-20% probability of persistence. Future efforts will be aimed at refining model predictions to determine (i) areas suitable for overwintering and (ii) the effects of changing climate on model predictions.

Impacts and Benefits to Mississippi Soybean Producers

Redbanded stink bug is one of the most devastating insect pests Mississippi soybean producers encounter. Proposed surveys completed through Objective 1 were used in weekly newsletters to alert growers to potential threats from RBSB for the 2021 growing season. RBSB is one of the few insect pests we encounter where fairly predictable outbreak populations can be predicted through sampling of wild hosts prior to planting soybeans. These estimates aid the MS soybean grower in budget planning. Activities in objective 2 resulted in substantial progress towards developing a predictive model of RBSB occurrence that integrates (i) RBSB survival through winter (ii) thermal buffering provided by overwintering substrates. Additionally, our species distribution model will be refined to generate forecasts over longer timescales, such as expected changes in overwintering survival in the coming decades. Taken together, we hope these efforts provide growers with early season information on potential yield losses from this pest and insights into longer term threats from RBSB, which can be used for budgeting expenses and determining potential profitability of late planted soybean.

End Products–Completed or Forthcoming

The graduate student working on this project, Thomas Paul, has presented at four regional meetings and one national meeting. This work comprises the majority of Mr. Paul's MS thesis and, following an additional year of analyses and writing, is expected to result in one to two peer reviewed publications.

Presentations

Paul, T.G., F.R. Musser, P. Chakrabarti, A.L. Catchot, and S.F. Ward. 2022. Development of an overwintering suitability model for redbanded stink bug, a pest of soybean. Mississippi State University Graduate Research Symposium, Feb 26. Mississippi State, MS.

Paul, T.G., F.R. Musser, P. Chakrabarti, A.L. Catchot, and S.F. Ward. 2022. Quantifying overwintering site selection and survival of redbanded stink bug, a pest of soybean. Beltwide Cotton Conferences, Jan 4 – 6. San Antonio, TX.

Paul, T.G., A. Catchot, and S.F. Ward. 2021. Climate prediction models for redbanded stink bug. Mississippi Entomological Association, Nov 8-9. Mississippi State, MS.

Paul, T.G., F.R. Musser, P. Chakrabarti, A.L. Catchot, and S.F. Ward. 2021. Assessing overwintering survival and range dynamics of redbanded stink bug. Entomological Society of America, Oct 31 – Nov 3. Denver, CO.

RBSB Ditchbank Survey: https://www.mississippi-crops.com/2021/04/22/rbsb-ditchbank-survey-week-of-4-19-21/

RBSB Ditchbank Survey: https://www.mississippi-crops.com/2021/04/30/rbsb-ditchbank-survey-week-of-4-26-21/

RBSB Ditchbank Survey: https://www.mississippi-crops.com/2021/05/07/rbsb-ditchbank-survey-week-of-5-3-21/

List of Figures

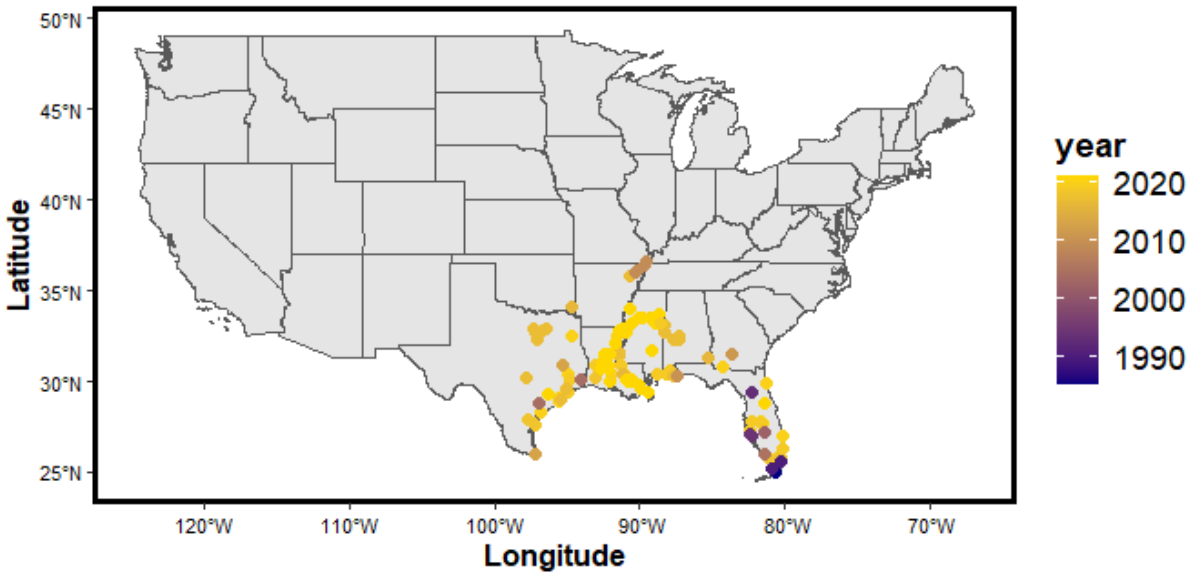

Figure 1 Redbanded stink bug occurrences across the southeastern US (1981-2021). Occurrences were compiled from Global Biodiversity Information Facility (GBIF.org), reports from the primary literature, and surveys from university researchers in the southeast.

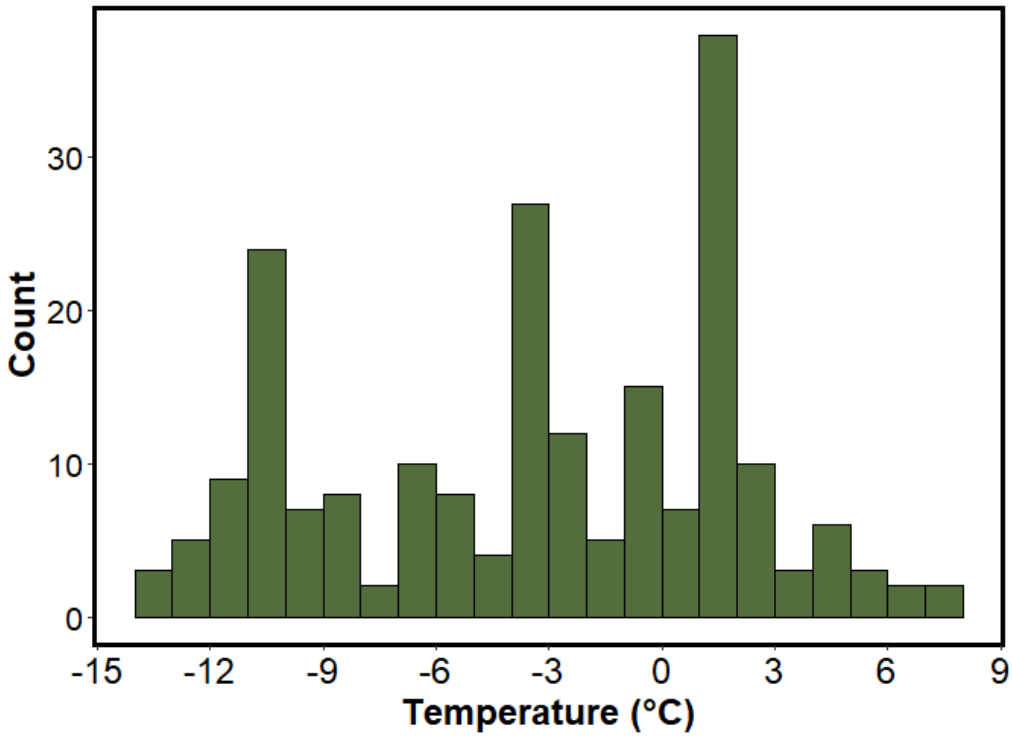

Figure 2 Histogram of minimum temperatures during the RBSB overwintering period at each occurrence point in Figure 1.

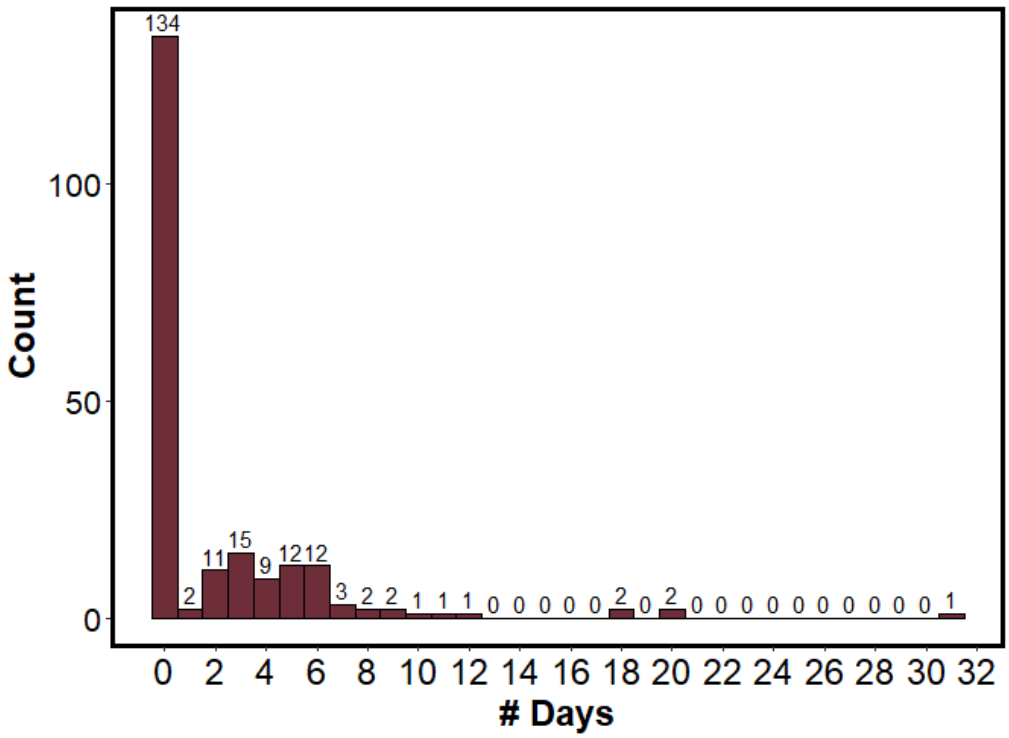

Figure 3 Histogram of number of days below -5 °C during the RBSB overwintering period at each occurrence point in Figure 1. Numbers above bars indicate counts for each bin.

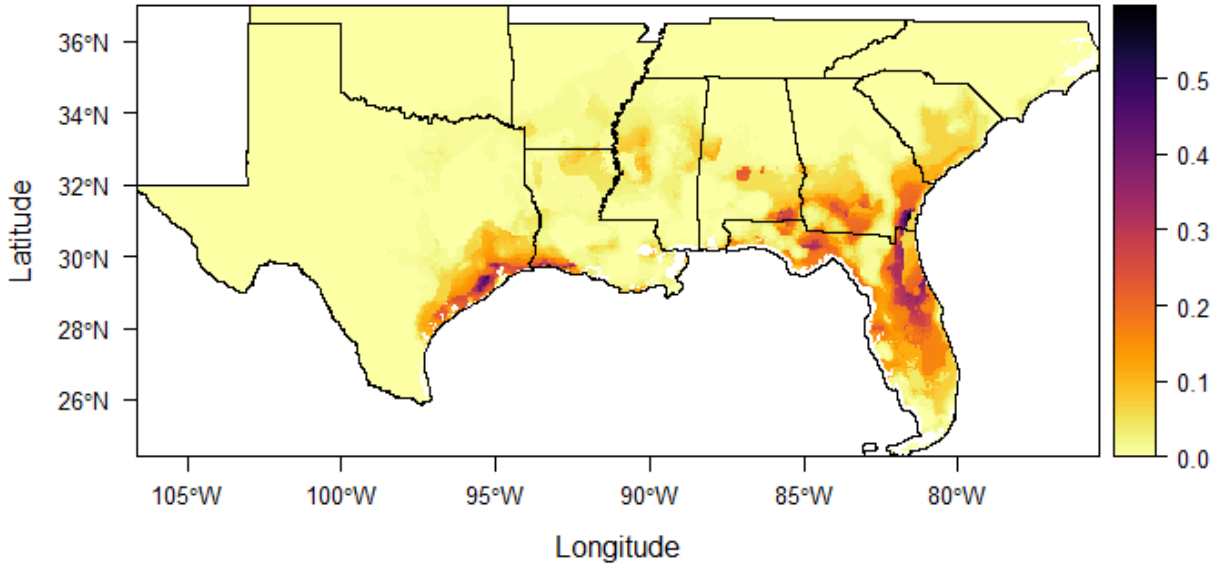

Figure 4 Species distribution model for redbanded stink bug. Scale bar indicates predictions of the probability of occurrence. Note that this model indicates suitability for persistence of RBSB over climate normals (e.g., mean temperatures over the previous 30 years), but interannual fluctuations can drastically alter climatic suitability across the southeastern US from year to year.

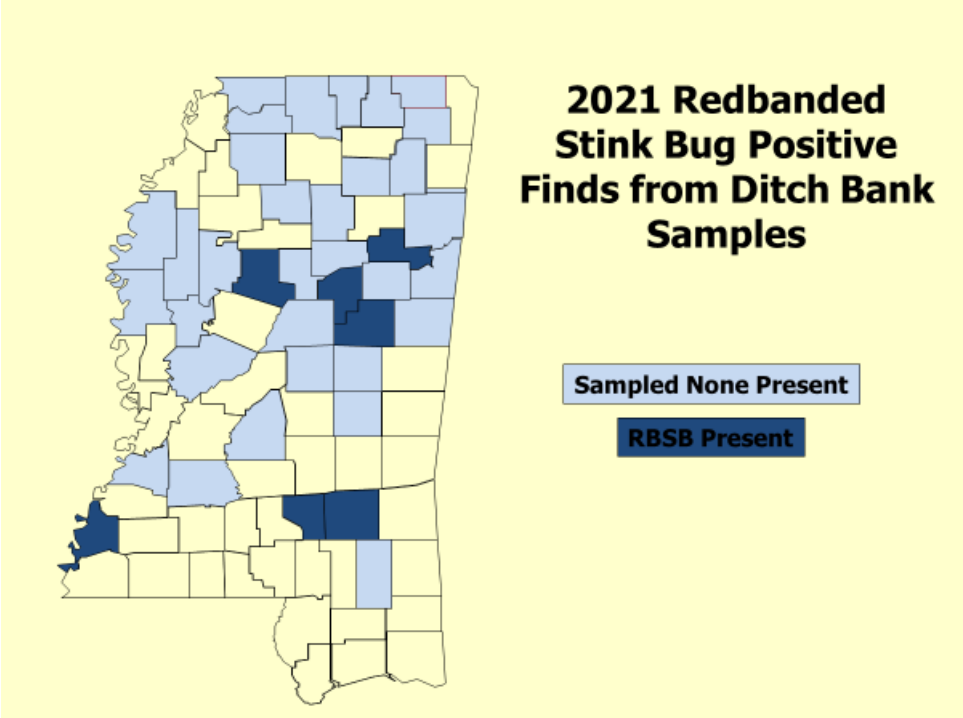

Figure 5. 2021 Redbanded Stink Bug distribution map of finds based on ditch bank sampling in the months of April and May.

Appendix A.

RBSB ditch bank survey results from the week of May 3, 2021:

- **Carroll County 1: 9/100 Sweeps**
- **Carroll County 2: 6/100 Sweeps**
- Montgomery County 1: 0/100 Sweeps
- Montgomery County 2: 0/100 Sweeps
- **Clay County 1: 12/100 Sweeps**
- Clay County 2: 0/100 Sweeps
- Monroe County 1: 0/100 Sweeps
- Monroe County 2: 0/100 Sweeps
- Lee County 1: 0/100 Sweeps
- Lee County 2: 0/100 Sweeps
- Prentiss County 1: 0/100 Sweeps
- Prentiss County 2: 0/100 Sweeps
- Alcorn County: 0/100 Sweeps
- Tippah County: 0/100 Sweeps
- Benton County: 0/100 Sweeps
- Pontotoc County 1: 0/100 Sweeps
- Pontotoc County 2: 0/100 Sweeps
- Calhoun County: 0/100 Sweeps
- Webster County: 0/100 Sweeps
- Yalobusha County 1: 0/100 Sweeps
- Yalobusha County 2: 0/100 Sweeps
- Panola County 1: 0/100 Sweeps
- Panola County 2: 0/100 Sweeps
- Noxubee County: 0/100 Sweeps

- Perry County: 0/100 Sweeps
- Neshoba County 1: 0/100 Sweeps
- Neshoba County 2: 0/100 Sweeps
- **Jones County: 1/100 Sweeps***
- Newton County: 0/100 Sweeps
- Marshall County 1: 0/100 Sweeps
- Marshall County 2: 0/100 Sweeps
- Desoto County 1: 0/100 Sweeps
- Desoto County 2: 0/100 Sweeps
- Tate County: 0/100 Sweeps
- Sunflower County 1: 0/100 Sweeps
- Sunflower County 2: 0/100 Sweeps
- Humphrey 1: 0/100 Sweeps
- Humphrey 2: 0/100 Sweeps
- **Yazoo County: 4/2420 Sweeps**
- Washington County: 0/100 Sweeps
- Bolivar County: 0/100 Sweeps

***Nymphs Present**

RBSB ditch bank survey results from the week of April 26, 2021:

- Covington County: 3/500 Sweeps
- Rankin County: 0/200 Sweeps
- Montgomery County: 0/100 Sweeps
- Leflore County: 0/100 Sweeps
- Webster County: 0/100 Sweeps
- Choctaw County: 1/100 Sweeps
- Oktibbeha County: 0/100 Sweeps
- Winston County 1: 1/100 Sweeps
- Winston County 2: 1/100 Sweeps
- Noxubee County: 0/100 Sweeps
- Leake County: 0/100 Sweeps

*At this time all finds were adults

RBSB ditch bank survey results from the week of April 19, 2021:

- Adams County 1: 1/500 Sweeps
- Adams County 2: 0/300 Sweeps
- Jefferson County 1: 0/200 Sweeps
- Jefferson County 2: 0/200 Sweeps
- Lowndes County 1: 0/100 Sweeps
- Lowndes County 2: 0/100 Sweeps
- Copiah County: 0/100 Sweeps

*At this time all finds were adults