NATIONAL PEANUT BOARD / SOUTHEAST PEANUT RESEARCH INITIATIVE

Final Report

REPORT for WORK DONE UNDER RESEARCH AGREEMENT #

INSTITUTION: University of Georgia

PROJECT TITLE: Biology, Ecology and Management of Insect Pests of Peanut in the Southeast US

RES. AGR. NO.: 

PROJECT LEADER: Dr. Mark R. Abney

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FINAL REPORT:

OBJECTIVE 1. Biology and management of three cornered alfalfa hopper in peanut:

Studies to evaluate the impact of S. festinus feeding on peanut were conducted in the field and greenhouse over two years at the Tifton and Athens Campuses of the University of Georgia. The activities reported in this objective were funded by both USDA NIFA and The National Peanut Board. USDA funds were primarily used to fund the graduate assistantship while NPB funds were used for supplies and to pay temporary hourly workers.

Field Trials

All experiments were conducted at the University of Georgia Tifton Campus Lang-Rigdon (31°31'17.8"N, 83°32'43.6"W) and Ponder (31°30'30.3"N, 83°38'14.9"W) research farms in Tift County, Georgia. The experiments were arranged in a randomized complete block design with 8 treatments (9 in 2015) and 6 replications. Treatments consisted of two infestation dates corresponding with the two generational population peaks observed by Rahman (2007), with four different rates of infestation (0, 3, 15, 30 nymphs per infestation period).

Seedbeds 1.8 m wide were prepared using a 1.83m tractor-mounted rototiller (KMC® Corp. Tifton, GA). A single row of peanut, Georgia-06G, was seeded down the middle of each bed to be used in the study with a single-row push planter (Earthway® Products Inc. Bristol, IN). A border bed was established between each research bed; two rows were seeded to peanut cultivar GA 06-G on each border bed with a tractor mounted vacuum planter (Monosem®, Edwardsville, KS). All plantings were treated with a same-day application of 0.033L/ha Valor® (Valent® © 2010), 0.017L/ha StrongArm® (DOW AgroSciences LLC © 2010), and 2.35L/ha Sonolan® (DOW AgroSciences LLC © 2014) herbicides. Trials received applications of land plaster (CaSO₄) at a rate of 1135kg/ha on 25 June 2014 and 16 June 2015. In 2014, fungicide
applications of Headline® (BASF Corporation © 2013) at a rate of 0.675L/ha were made on 9 and 24 July and Provost (Bayer CropScience © 2007) at a rate of 0.8L/ha on 7 August, 19 August, and 2 September. In 2015, fungicide applications of Headline (BASF Corporation © 2013) at a rate of 0.68L/ha were made on 8 July, 22 July, and 5 August and Convoy (Nichino America, Inc. © 2014) at a rate of 0.95L/ha on 19 August and 2 September.

At peanut emergence, cages (Fig 2.1) were centered over three peanut plants located within a 30-cm section of row; all other plants within a 60-cm radius were removed. Cages were constructed of pressure treated 5.1cm x 10.2cm lumber held together with 7.62cm deck screws to create a 91cm x 91cm square frame. Four 12.7mm holes were drilled into the top of each frame; two 1.52-meter lengths of 12.7mm schedule 80 CPVC pipe were bent into approximate half circles with the ends of each pipe placed into one of the parallel holes in the wood frame to create a hoop structure. 39.05 (7.1 x 5.5) holes per cm² mesh fiberglass window screen (PHIFER Inc., Tuscaloosa, AL) was placed over the structure and secured at the bottom with wood lattice strips (size) stapled into the wood frame. After placement over the plants, soil was mounded around the base of the cage.

Populations of 0, 3, 15, 30 nymphs per cage (NPC) placed using a soft-bristle paintbrush near the base of each plant’s main stem. There were two infestation periods. The first infestation (Gen 1) was terminated after 30 days, to eliminate all S. festinus and prevent Lepidopteran damage by treating the plants in each cage with Besiege® (Lambda-cyhalothrin 9.26% + Chlordantraniliprole 4.63%) at the rate of 5.16mL of per liter for ten seconds using a backpack sprayer with a single 8002XS nozzle at 40 psi. Cages were removed during application and replaced after treatment. The second generation (Gen 2) was infested as previously described; no insecticides were applied to Gen 2 treatments. In 2015, an additional infestation rate of 60 NPC was examined. This treatment was infested between the Gen 1 and Gen 2 infestation periods.

Peanuts were planted on 2 June 2014 at Lang-Rigdon farm. Cages were placed just after cracking on 9 June. On 7 July 2014, S. festinus nymphs were observed in adjacent, non-caged peanut plants, and on 9 July, first generation (Gen 1) cages were infested with first and second instar nymphs. All Gen 1 cages were treated with Besiege® on 5 August. On 5 September, second generation (Gen 2) cages were infested with the same infestation rates as Gen 1. All plants within cages were harvested on 6 October at 2,117 cumulative adjusted growing degree-days (aGDD) (calculated using UF PeanutFARM). The optimal cumulative aGDD for GA-06G peanuts is estimated to be 2500. Peanuts were harvested early due to logistical concerns regarding the seasonal timing.

Peanuts were planted on 26 and 27 May 2015 at UGA Ponder and Lang-Rigdon farms respectively. Cages were placed on 8 June. Gen 1 cages at Lang-Rigdon were infested on 1 July with first and second instar nymphs at identical rates as in 2014. On 31 July, Gen 1 cages were treated with Besiege®. On 31 August, Gen 2 cages were infested. All cages at Lang-Rigdon were harvested on 8 October at 2,117 cumulative aGDD.

Cages at the Ponder Farm location were infested with adults on 14 August. The treatments for this experiment consisted of infestation rates: 0, 10, 20 and 30 adults/cage (APC) with a sex ratio of 7:3 (male:female). This ratio was based on observation of the sex ratio of the extant S. festinus population at the Ponder farm at the time the cages were infested. Each treatment was replicated 12 times. Six reps were destructively sampled 30 days after infestation (DAI) on 16 September at 1935 cumulative aGDD. Plants in the cages were removed from the ground intact, placed in 50-gallon plastic bags, and transported to the lab, where each cage
sample was examined for the number of plants, total number of stem girdles (later differentiated into main and lateral stem girdles, where the main stem is that from which all other stems branch), leaf petiole girdles, and nymphs number and instar. Remaining cages were sampled on 30 September (44 DAI) at 2079 aGDD.

At harvest, plants from Lang-Rigdon and Ponder were exhumed from the ground intact, and all vegetative and reproductive parts were collected. Plants were examined for stem and leaf petiole girdles, number of pods, and number of plants. In 2015, main stem girdles and lateral stem girdles were recorded separately. Pods and plant material were separated and placed into a drying oven at 60°C until plants were dry; dry weight vegetative and pod biomass was recorded using a bench top laboratory balance (OHAUS CS5000g x 1g). Root biomass was measured separately from vegetative biomass for plants from Lang-Rigdon farm in 2015.

**Greenhouse Study**

In 2014 and 2015, peanuts were grown in the greenhouse in Athens (33°55'49.0"N, 83°21'45.3"W) and Tifton (31°28'24.6"N, 83°31'45.3"W), Georgia, respectively. Two seeds of cultivar ‘Georgia-06G’ peanut were planted in 12” plastic pots filled with propagation media (SunGro Propagation Mix). The pots were placed individually in separate BugDorm 2120F insect tents (160 x 160 mesh), and watered twice weekly. Plants were fertilized once with 20 grams of six-month Osmocote (13-13-13) 30 DAP. After emergence the plants were culled to one plant per pot. Cages were monitored once every 6-8 days in 2014 and every 3-5 days in 2015 for the number, instar, and location (stem or petiole) of nymphs, and presence of stem and leaf petiole girdles. Main stem girdles were differentiated in 2015.

In 2014, peanuts were planted on 9 October in a greenhouse located in Athens, Georgia. Temperature ranged from 22-32°C, and photoperiod was 14:10 day:night throughout the experiment. Gen 1 cages were infested on 15 November with 1st and 2nd instar nymphs. Nascent adults were removed when spotted during weekly observations; by December 16 all *S. festinus* had been removed. Gen 2 cages were infested on 12 January 2015. Cages with no visible nymphs on 17 January were reinfested with nymphs. On 12 Feb 2015 all *S. festinus* were removed from Gen 2 cages, and plants were harvested.

In 2015, peanuts were planted on 2 June in greenhouses in Tifton, Georgia. Temperature ranged from 26-32°C, and photoperiod was 14:10 day:night. Generation 1 cages were infested on 6 July. By 17 August, all nymphs had molted into adults, and the adults were removed. On 7 September, Gen 2 cages were infested. Generation 2 cages with no visible nymphs were reinfested on 14 September. Plants were harvested on 13 October.

Girdles were counted at harvest, and the number of plants and pods were recorded. Pods and plant material were separated and placed into a drying oven at 60°C until plants were completely dry. Dry weight pod and vegetative biomass were recorded using a bench top laboratory balance (OHAUS CS5000g x 1g). Root biomass was recorded separately in 2015.

**Statistical Analysis**

For all analyses, significance was measured with $\alpha = 0.05$, and SAS Studio 3.4 (SAS Institute Inc., Cary, NC, USA) was used for the following tests. Dry weight biomass data analyzed included total biomass of all plants per cage, peanut pod biomass of all plants per cage, and mean pod weight. Cages with plants possessing heavy incidence of disease (TSWV or white mold) were excluded from analyses.
Dry Weight Yield and Vegetative Biomass as Responses to Girdles

Statistical comparisons for analyzing stem girdles and dry weight yield and biomass readings as response variables were made with PROC GLIMMIX with infestation rate and infestation period as fixed effects, and block replicates as random effects. No data transformations were made, and all response variables were modeled with the negative binomial distribution, which provided the best fit for the data. All means using the negative binomial distribution were back-transformed using the ILINK function. When significant differences were observed (p<0.05), means were separated with the LSMEANS procedure and sliced by effect. PROC GLM was utilized for modeling dry weight yield and biomass readings as the response variables and total stem girdles, plant number per cage, infestation period as fixed effects. For comparisons of generation, the 20 nymphs per plant treatment data were excluded from analysis.

Greenhouse observations

PROC GLIMMIX was used to model the progression of stem girdles using week, total number of nymphs in each sample, and infestation period as fixed effects, with block replicate as a random effect. PROC LOGISTIC was used to measure the preference of feeding location of nymphs, with nymph instar as a fixed effect and block replicate as a random effect. When comparing infestation period, the 20 nymphs per plant treatment was excluded from analyses.

Results

Field trials

Girdle Damage

The presence of total stem girdles (Fig. 2.2-2.3) increased with increasing infestation rate (IR) across both infestation periods in both years of nymphal trials (2014: F=8.44; df=3.31; P=0.0003 and 2015: F=2.88; df=3.38; P=0.0487). There was no relationship between infestation rate and the number of leaf petiole girdles. When comparing the effect of individual treatment IR on total stem girdles, only the 3NPC and 15NPC treatments were significantly different (t=-2.89, df=31, P=0.0333). When comparing IR effects between generations, total stem girdles in Gen 2 controls were much higher than Gen 1 (Control: t=-3.21, df=31, P=0.0031) and Gen 1 30NPC girdle counts were higher than Gen 2 (t=2.69, df=31, P=0.0113).

In 2015, there was no effect of IR on main stem girdles (F=1.90, df=3, P=0.1446) or leaf girdles (F=0.55; df=3.43; P=0.6509), the following analyses are of total stem girdles. A significant correlation between total stem girdle formation and IR was only seen in Gen 1 in 2015 (F=3.82; df=3.38; P=0.0174). The 30NPC treatment of Gen 1 resulted in the highest number of total stem girdles between the two generations (x=10.66, s=9.07), but 60 NPC had the most of all treatments (x=14.5, s=1.5). There were no significant differences in the number of total stem girdles between individual infestation rates. Only 30NPC showed any significant difference in total stem girdles between Gen 1 and Gen 2 (t=2.86, df=40, P=0.0067). The additional treatment of 60NPC was not included in comparisons between generations.

At the Ponder farm, at 30 DAI, the total number of nymphs moderately correlated (F=11.18; df=1.20; P=0.0034) (R-Square=0.370444) with the number of total stem girdles found. The number of leaf petiole girdles was not affected by IR (F=0.04; df=1.15; P=0.8383) and few main stem girdles were observed. 30APC had the highest mean number of nymphs of all IR (F=8.66; df=3.15; P=0.0008) (Fig. 2.4). In the 44 DAI sample, stem girdle numbers positively correlated with IR (F=6.13; df=3.15; P=0.0062), but did not differ significantly between individual IRs (Fig. 2.5). There was no difference in stem girdle number between any of the IR
treatments and the control at 30 days after infestation. Direct comparisons between girdle counts at 30 DAI and 44 DAI showed no differences.

**Girdle Impact on Dry Weight Vegetative and Yield Biomass**

At the Lang-Rigdon farm in 2015 and at Ponder farm in 2015, number of total stem girdles did not affect dry weight vegetative biomass (Lang-Rigdon 2014: $F=0.58; \text{df}=1.43; \text{P}=0.4516$; and Ponder 2015: $F=1.12; \text{df}=1.23; \text{P}=0.3017$) (Fig. 2.6-7). At Lang-Rigdon farm in 2015 trials, a weak but significant negative correlation between total stem girdles and dry weight vegetative biomass was observed ($F=4.54; \text{df}=1; \text{P}=0.0385; \text{R-Square}=0.101288$).

At Lang-Rigdon farm in 2014 (Fig. 2.8) and Ponder farm in 2015 (Fig. 2.9), lateral stem girdles had no effect on total dry weight yield (Lang-Rigdon 2014, $F=0.50; \text{df}=1.43; \text{P}=0.4839$; Ponder 2015: $F=1.11; \text{df}=1.43; \text{P}=0.3026$). At Lang-Rigdon farm in 2015, yield was negatively impacted by lateral stem girdles ($F=4.41; \text{df}=1.48; \text{P}=0.0413$), but the correlation was weak (R-square=0.163439). At Lang-Rigdon farm in 2015, infestation period had an effect on total yield ($F=3.90; \text{df}=2.48; \text{P}=0.0480$); yields from Gen 2 were lower than Gen 1. Stem girdles from all fields and years had no effect on the mean dry mass of peanut pods (Lang-Rigdon 2014: $F=0.01; \text{df}=1.43; \text{P}=0.9170$; Lang-Rigdon 2015: $F=0.00; \text{df}=1.48; \text{P}=0.9820$; and Ponder 2015: $F=0.33; \text{df}=1.23; \text{P}=0.5714$). When the data from both years of trials from Lang-Rigdon farm were combined, there was a significant relationship between the total yield and the number of total stem girdles ($F=4.19; \text{df}=1.89; \text{P}=0.0434$) and infestation period ($F=4.64; \text{df}=1.89; \text{P}=0.0341$) (Fig. 2.10). In 2014, there were two cages with 4 plants, and in 2015, there were two cages with 2 plants and three cages with 4 plants. The cages with differing (n≠3) number of plants had no effect in the previous model ($F=2.01; \text{df}=2.89; \text{P}=0.1405$).

**Greenhouse Cages**

**Girdle Damage**

In 2014, IR had a significant effect on total stem girdles (2014: $F=3.34; \text{df}=3.64; \text{P}=0.0427$). In 2015, total stem girdles ($F=18.26; \text{df}=3.17; \text{P}<0.0001$), lateral stem girdles ($F=10.13; \text{df}=3.17; \text{P}=0.0005$), and main stem girdles ($F=7.68; \text{df}=3.17; \text{P}=0.0007$) (Fig. 2.11) were positively correlated with IR, as were leaf girdles ($F=9.17; \text{df}=3.17; \text{P}=0.0003$). Generation affected the number of leaf petiole girdles only in 2015; Gen 1 had fewer girdles than Gen 2 ($t=-2.11; \text{df}=17; \text{P}=0.0497$).

**Girdle Impact on Dry Weight Vegetative and Yield Biomass**

There was a significant negative correlation between total stem girdles ($F=5.54; \text{df}=1.26; \text{P}=0.0272$) (Fig 2.12) and dry weight vegetative biomass, as well as between main stem girdles ($F=13.33; \text{df}=1.26; \text{P}=0.0013$) (Fig 2.13) and dry weight vegetative biomass in 2015. Main stem girdles also negatively impacted root biomass ($F=6.50; \text{df}=1.26; \text{P}=0.0176$) (Fig 2.14). Leaf petiole girdles had no relationship with dry weight vegetative biomass (2014: $F=1.96; \text{df}=1.22; \text{P}=0.1767$; 2015: $F=3.81; \text{df}=1.26; \text{P}=0.0629$). There was no direct effect of IR itself on dry weight vegetative biomass for either year (2014: $F=1.56; \text{df}=3.16; \text{P}=0.2382$) (2015: $F=2.31; \text{df}=3.14; \text{P}=0.1209$). Plants infested at Gen 2 had lower dry weight mass than plants infested at Gen 1 regardless stem girdle number ($F=64.55; \text{df}=1.26; \text{P}=0.0433$) in 2015.

Total stem girdles (Fig. 2.15) and main stem girdles (Fig. 2.16) negatively influenced peanut pod biomass, but only in 2015 (total stem girdles: $F=5.39; \text{df}=1.26; \text{P}=0.0290$; main stem girdles: $F=7.61; \text{df}=1.26; \text{P}=0.0109$). However, counts of pods were very low in 2015 (x=1.88, s=2.11) compared to 2014 (x=11.00, s=8.00). Leaf girdles for both years had no effect on pod biomass (2014: $F=0.03; \text{df}=1.22; \text{P}=0.8737$; 2015: $F=2.21; \text{df}=1.26; \text{P}=0.1504$). Mean pod
weight did not correlate with any damage rating in either year: stem girdles, (2014: F=1.01; df=1.22; P=0.3273 and 2015: F=2.79; df=1.26; P=0.1171) leaf girdles, (2014: F=0.00; df=1.22; P=0.9662 and 2015: F=0.01; df=1.26; P=0.9262) and main stem girdles (2015: F=1.79; df=1.26; P=0.2021). Gen 2 plants had significantly lower mean pod biomass in 2015 regardless of IR (F=6.81; df=1.26; P=0.0154).

**Greenhouse Observations**

In 2014, there was an increase of stem girdles over time (F=3.99; df=3.90; P=0.0102) and number of nymphs observed (F=10.61; df=1.90; P=0.0016). Generation had no effect on stem girdle counts over time (F=0.00; df=1.90; P=0.9682). Location of nymphs varied by instar ($X^2 (3, N=93)=21.5018, P<0.0001$) and generation ($X^2 (1, N=93)=8.5645, P=0.0034$). Leaf girdle numbers did not change over time, but were greater in Gen 1 (F=5.40; df=1.22; P=0.0298).

In 2015, stem girdles increased as the number of nymphs increased (F=40.38; df=1.247; P<0.0001) and at each sample date over time (F=30.64; df=10.247; P<0.0001). Generation had no effect on stem girdles over time (F=0.71; df=1.247; P=0.4070). Main stem girdle counts were too low to be analyzed separately, and were combined with lateral stem girdles. Leaf petiole girdles increased as the number of nymphs increased (F=13.24; df=1.247; P=0.0003) and over time (F=7.73; df=10.247; P<0.0001).

Location of nymphs in 2014 differed as the nymphs matured ($X^2 (3, N=90)=21.5018, P<0.0001$). As nymphs matured, they transitioned from leaf petioles to stems (Fig. 2.17). From these observations, there was a 92% probability of first instar nymphs being located on a leaf petiole (8% on stems); the probability of fifth instars being on a leaf petiole was only 9%. Between the two infestation periods Gen 1 and Gen 2, the likelihood of nymphs being found on stem girdles was much higher in Gen 2.

Nymphs in 2015 are also more abundant on leaf petioles during early instars ($X^2 (8, N=457)=29.7560, P=0.0002$), and infestation period ($X^2 (2, N=457)=7.1140, P=0.0285$) influenced the observed location of nymphs (Fig 2.18). The probability of first instars feeding on the leaf petiole was 64%, with the remaining 36% found on the lateral stems and none on the main stem. Fifth instars were found 19% of the time on the leaf petiole, 18% on the main stem, and 63% on lateral branches. Gen 2 had a similar transition to lateral stems, though the proportion on the main stem remained the same throughout the instars. Between infestation periods, the probability of finding nymphs being located on leaf petioles was significantly lower in Gen 2 than in Gen 1 ($z=2.65, \text{SEM}=0.2698, P=0.0080$).

**Discussion**

**Damage and IR**

Increasing infestation rates of *Spissistilus festinus* on peanut resulted in a higher number of stem girdles, though this was only observed in Gen 1, which occurs in the early part of the season. Previous work on *S. festinus* on the peanut cultivar ‘Georgia Green’ documented up to six girdles per plant with no measurable pod yield response; however, the study did not report the location of the girdle (Rahman et al. 2007). The highest mean number of total stem girdles in either year of the field study was 18.5 in the cages with the 30APC treatment (about 5.33 stem girdles per plant), and IR did not affect yield of GA-06G peanuts in any field or greenhouse trial.

In the field, Gen 2 nymphs showed little capacity to create girdles. Observations made in the greenhouse experiments may offer an explanation for this result. The Gen 2 treatment in both years of the greenhouse experiment had to be reinfested with nymphs. In 2015, Gen 2 treatments had to be reinfested multiple times before ≥70% of the intended population would
survive. We hypothesize that the low survival of early instar nymphs in Gen 2 treatments is due to tougher stems and petioles found on older plants. Once the population in the greenhouse cages was established, similar girdle counts for each IR were found in generations 1 and 2.

The aforementioned observations may be used to explain the results from nymphal cages in the field, where infesting with Gen 2 nymphs alone resulted in weak counts of stem girdles in both years. For comparison, the adults used at Ponder farm trials were added to cages only 15 days prior to the Lang-Rigdon farm trials’ Gen 2 nymphs. Given that the average time of eclosion is 16.5 days after oviposition (Meisch & Randolph, 1965), nymphs from these cages would be on a similar timetable as those at Lang-Rigdon farm. Destructive sampling 30 days after infestation showed that up to 54 nymphs ($\bar{x}$=28.0) were present in the highest IR of 30 adults per cage, with up to 33 total stem girdles ($\bar{x}$=18.3). This indicates that it is possible for nymphs to survive (and most likely form girdles) in the later part of the season. The main difference between adding adults and adding nymphs alone is that the adults in the cage are likely girdling and feeding. Nymphs of all instars capitalize on girdles, feeding and aggregating above the nutrient dam (Moellenbeck & Quisenberry, 1991; Andersen et al. 2002), suggesting that younger instars later in the season may rely on older nymphs or adults for formation of girdles and the subsequent nutrient concentration.

Main stem girdles in the field were only found in Gen 1 nymph treatments. Results of the greenhouse experiment were similar, though there were more main stem girdles in total. This is likely a result of either tissue maturation, as the main stem is the most developed part of the peanut plant at the time of infestation, or lower nymph survival suggested previously. Numbers of main stem girdles were too few for a valid analysis of effect, which can be attributed to the timing of infestation and overall plant health. By the time Gen 2 infestations were made, the base of the main stem - where nymphs were often found in the field (Rahman et al. 2007) - was more developed and stouter than the relatively fresh and succulent lateral stems.

Mean numbers of leaf petiole girdles were largely inconsistent between IR and generations for all trials. This result may be explained through greenhouse observations. Petioles that were girdled often displayed necrotic tissue above and below the girdle, and these leaves were easily dislodged from the plant at the node. As nymphs developed, feeding sites changed from petioles to stems, and subsequent girdled petiole counts remained stable. Eventually, the number of petiole girdles decreased as the petiole tissue died around the girdle and through mechanical stimulation or plant-induced abscission. This is similar to what has been reported with girdled leaf petioles in soybean (Sparks & Newsom, 1984).

Girdle counts in the greenhouse in 2015 were much higher than those in 2014. Location effects could be responsible for this difference; greenhouse facilities used in 2014 had better lighting conditions, leading to apparently healthier and stronger plants. It is well established that *S. festinus*, prefers softer tissues (Mitchell & Newsom, 1984b; Rice & Drees, 1985; Andersen et al. 2002; Rahman et al. 2007), and plants grown in less than optimal lighting can have reduced health, stem thickness, and strength (Shirley, 1929). If the plants were weaker due to poor lighting conditions, it is likely that more girdles would be made not only because it is easier, but also because with a less substantive food source, more girdles would needed to compensate for low nutritional content. Girdles on healthy plants will become callused after about 7 days (Moellenbeck & Quisenberry, 1991; Andersen et al. 2002), but is unknown whether a girdle on an unhealthy plant will callus faster or slower. The possibility exists that *S. festinus* may have more impact on plants under less-than-optimal growth conditions.
Girdle Effects on Vegetative Biomass and Pod Biomass
Field Trials

Based on the results presented here indicate that *S. festinus* has the capability of reducing peanut pod yield and thus should be considered a potential pest. In 2015, there was a high amount of variation in girdles and vegetative and pod biomass, but stem girdles resulting from nymphal infestations had a negative impact on both vegetative biomass and pod biomass. However, biomass did not differ by IR. IR only reflects the number of nymphs initially added, and it was shown in the greenhouse trials that nymph mortality could be high. Counting nymphs in field cages was not feasible. Quantifying nymph densities within the cages would have been impractical without destructively sampling the cages. For this reason, stem girdles were best suited to evaluate the impact of nymphs on yield.

The $R^2$ values of the regression of stem girdles on dry weight vegetative and pod biomasses were low, indicating that other factors contribute more significantly to variation in yield. The cages were not designed to be insect (specifically thrips) proof; the main purpose of the cage was to contain *S. festinus* nymphs and prevent infestation by extant adults. Some feeding girdles were found in insect-free control cages; this likely occurred as a result of rodent damage that allowed *S. festinus* adults access to the cages. The only other observable effect of this permeability was Tomato Spotted Wilt in less than five cages; these cages with diseased plants were excluded from analysis.

Monitoring nymph populations within cages during the season would provide a better measure of impact of a specific population density on damage and yield. Greenhouse observations and the destructive sampling at Ponder were conducted in an attempt to quantify number of nymphs within cages. Nevertheless, the relationship between nymph number and girdles cannot be examined based on the data collected. The number of girdles formed by *Spissistilus festinus* can be quite variable, as the 30 DAI samples had marginally higher counts of girdles than the 44 DAI samples.

*Greenhouse Trials*

We found a significant effect in 2015 of total stem girdles and main stem girdles on dry weight vegetative biomass and pod yield. The effect on yield was muted somewhat by the low number of pods found in all cages, most likely a result of lighting concerns mentioned previously. It was impossible to differentiate the effect of main stem girdles or lateral stem girdles. A reduction in biomass and pod yield was only seen with a very high number of stem girdles. Levels of damage in the field trials never exceeded 37 stem girdles in a cage, or 12.33 stem girdles per plant.

Leaf petiole girdles did not affect yield, though accumulation of leaf petiole girdles could not be accurately measured due to abscission of leaves from girdled petioles. It is possible that *S. festinus* can cause enough defoliation to affect yield as has been reported in soybean (Sparks & Boethel, 1987). However, our greenhouse observations suggest that older nymphs move away from leaf petioles as the season progresses; this is different than what is observed in soybean (Mitchell & Newsom, 1984b; Spurgeon & Mueller, 1993). Nevertheless, peanut can sustain a great deal of defoliation with no measurable impact.

*Generational Effect on Biomass and Yield*

All treatments with nymphs assessed the effect of only one generation at any time, and the cumulative effect of damage caused by multiple generations is yet to be determined. Experiments from the field and greenhouse demonstrated that damage or feeding occurring later
in the season has more impact on dry weight vegetative biomass and yield than early season damage. This effect is possibly a result of the plant focus shifting from vegetative growth to fruit production later in the season, as flowering begins about 40 days into the season. Even though more girdles were formed by the first generation of nymphs, damage occurring later may impact pod production. This may be explained by the fact that the girdle’s effects on translocation are not permanent. Phloem activity resumes 7-11 days after girdle formation (Andersen et al. 2002). So that plants damaged only in the early season may not suffer yield loss.

**Economic Injury Level**

A preliminary EIL was established using stem girdles and yield from Lang-Rigdon trials of both years combined using the following formula as per Higley and Pedigo (1996):

\[
\text{Insecticide cost} = \frac{\text{crop value} \times \text{Yield loss per girdle} \times \text{expected control}}{}
\]

Where the cost of the insecticide (calculated from an average treatment cost/acre of a typical pyrethroid) and application costs are totaled in the numerator (Smith & Smith, 2015). Crop value was obtained from 28 October 2015 report from USDA (Soto, 2015). Girdle counts were used in the equation instead of nymph numbers because nymph numbers (IR) could not be related to yield. Expected control was calculated by using treatment effects of lambda-cyhalothrin on girdle counts (Rahman et al. 2007) in Georgia Green, a peanut variety that had similar girdle damage to what was observed in Georgia-06G in the current study. The preliminary EIL is not given here as additional research is needed for validation. Nevertheless, our work showed that yield loss may occur due to insect damage and potential interactions of *S. festinus* with disease. It is known that *S. festinus* damage can influence *S. rolfsii* severity in soybean (Herzog et al. 1975; Russin et al. 1986). Plants infected with white mold in one cage had the one of the highest numbers of girdles of all trials. Additional studies are needed to evaluate this potential interaction.

**Conclusions**

These data suggest that stem girdles formed by *S. festinus* are capable of lowering yield, but more data are needed to create a robust EIL. Because this study was conducted entirely with caged plants, the results cannot be fully extrapolated to field situations. Sample sizes were relatively small, and variation in yield between cages with similar numbers of girdles was high.

The single most important limitation to this study was the inability to quantify the number of nymphs and damage in real-time. Future experiments involving *S. festinus* should examine the cumulative effect of girdling over multiple generations.
Figure 2.1: The cage used in the field trials at Lang-Rigdon and Ponder farms.
Figure 2.2: Mean ± Standard error of the mean (SEM) for *Spissistilus festinus* stem girdles in each treatment of NPC (nymphs per cage) ordered by infestation period for Lang-Rigdon farm in 2014. Different letters above bars indicates significant differences in girdle counts among treatments and generations (LSMEANS, P<0.05).
Figure 2.3: Mean ± SEM for *Spissistilus festinus* stem girdles in each treatment of NPC (nymphs per cage) ordered by infestation period for Lang-Rigdon farm in 2015. 20 NPC has no generation as the infestation was made in between Gen 1 and Gen 2. Different letters above bars of the same girdle type indicates significant differences between IR (LSMEANS, P<0.05).
**Figure 2.4:** Mean ± SEM for *Spissistilus festinus* stem girdles in each treatment of APC (adults per cage) from different DAI (days after infestation) for Ponder farm in 2015. Different letters above bars indicates significant differences of girdle counts among treatments and generations (LSMEANS, P<0.05).
Figure 2.5: Mean ± SEM for 30 DAI (days after infestation) total nymph counts ordered by APC (adults per cage) for field cages at Ponder farm 2015. Different letters above bars indicates significant differences of nymph counts (LSMEANS, P<0.05).
Figure 2.6: Relationship between total numbers of stem girdles per cage and the dry weight vegetative biomass of peanut for each year of Lang Ridgon farm cage trials.
Figure 2.7 Relationship between total numbers of stem girdles per cage and the dry weight vegetative biomass of peanut for Ponder farm cage trials.
Figure 2.8: Relationship between total numbers of stem girdles per cage and the dry weight yield biomass of peanut for each year of Lang-Ridgon farm cage trials.
Figure 2.9: Relationship between total numbers of stem girdles per cage and the dry weight yield biomass of peanut for Ponder farm cage trials.
Figure 2.10: Relationship between total numbers of stem girdles per cage and the dry weight yield biomass of peanut for both years of Lang-Ridgon farm cage trials combined.
**Figure 2.11:** Mean ± SEM for Greenhouse 2015 stem girdles in each treatment ordered by generation. 20 NPC was included only in Gen 1. Different letters above bars of the same girdle type indicate significant differences between IR across infestation period (LSMEANS, P<0.05).
Figure 2.12: Relationship between total numbers of stem girdles per cage on the dry weight vegetative biomass of peanut for each year of Greenhouse cage trials.
Figure 2.13: Relationship between main stem girdles per cage on the dry weight vegetative biomass of peanut for the 2015 Greenhouse cage trials.
Figure 2.14: Relationship between total numbers of stem girdles per cage on the dry weight root biomass of peanut for each year of Greenhouse cage trials.
Figure 2.15: Relationship between total numbers of stem girdles per cage on the dry weight yield biomass of peanut for each year of Greenhouse cage trials.
Figure 2.16: Relationship between main stem girdles per cage on the dry weight yield biomass of peanut for each year of Greenhouse cage trials.
**Figure 2.17**: Mosaic plot showing the progression of location preference as instar increases, separated by generations for 2014 Greenhouse trials. Wider boxes indicate higher $N$ observed. Instars 2 and 3 were more likely to be found on leaf petioles in Gen 1, and in Gen 2, only the 2nd instar was more likely to be found on leaf petioles than on stem girdles.
Figure 2.18: Mosaic plot showing the progression of location preference as instar increases, separated by generations for 2014 Greenhouse trials. Wider boxes indicate higher N observed. The location preference of nymphs transitions from leaf petioles to total stems in Gens 1 and 2. Nymphs prefer the main stem more as instar progresses in Gen 1, but no changes occur in main stem preference for Gen 2.
OBJECTIVE 2. Establishment of a burrower bug monitoring network in Georgia:

A light trapping network was established in peanut growing counties in South Georgia in 2015 to monitor the presence, abundance, and flight activity of peanut burrower bug, *Pangea bilineatus*. Monitoring stations consisted of commercial light traps modified with aftermarket components to facilitate remote field use and specific run times (Fig. 1). Work was completed in cooperation with county Extension agents who were responsible for maintaining traps during the growing season. Fifteen traps were placed in thirteen counties beginning in June, and collections were made twice a week each week until peanut harvest. Traps were located in Brooks (2), Bullock (1), Coffee (1), Dooly (1), Lowndes (1), Miller (1), Mitchell (1), Pulaski (1), Randolph (1), Thomas (1), Tift (1), Ware (1), and Emanuel (2) Counties (Fig. 2). Traps were programmed to run Sunday and Monday nights and Wednesday and Thursday nights from dusk until dawn. Insects were removed from each trap on Tuesday and Friday mornings and transported to the county office where samples were labeled with the location and date and stored in a freezer until they were processed. Samples were processed by personnel at the UGA Peanut Entomology lab at the end of the growing season. All cynid species (burrower bugs) were counted and placed in 70% ethanol in vials labeled with the location and date of sample collection.

The number of peanut burrower bugs collected in light traps varied significantly by location, but specimens were collected from traps at every sample site (Fig. 3). This result is not surprising given the fact that the insect is native to Georgia, feeds on a wide range of host plants, and has been reported as a pest of peanut in many counties. Flight activity peaked in June, but insects were collected in July, August and September (Fig 4). Plans for future research include deploying traps earlier in the spring to better understand the seasonal dynamics of the pest. Burrower bug presence in traps was not a good predictor of peanut grade based on damage. Some locations with relative high burrower bug trap captures reported no loss of grade due to insect feeding. This result does not preclude the possibility that insect damage could have been present in some areas of the field.

The data gathered in this study will assist in future research to develop management strategies for burrower bug. Future field trials will evaluate the efficacy of foliar insecticide sprays made at night during periods of peak flight activity. If effective, this tactic would be the first new management tool available for growers to combat this destructive pest. County agents that cooperated in the study are in the process of completing a survey related to the environment around the trap in his/her county. Information to be collected include crop rotation history, insecticide use, tillage practices, irrigation, soil type, etc.
Total BB in Light Traps by Location

Figure 3

Total BB in All Traps by Sample Week

Figure 4
OBJECTIVE 3. Peanut cultivar response to insect damage:

Experiments were conducted in Georgia and Alabama in 2014 to evaluate insect feeding and resulting crop damage on commercially available runner type peanut cultivars. In addition, treatments were imposed on each cultivar to compare the outcome of an IPM (monitoring and threshold based pest management) approach to insect management with a calendar based spray program. Research plots were established at the UGA Bowen Farm.

Peanuts were grown according to UGA Extension recommendations. Cultivars tested included: GA-06G, GA-12Y, GA-13M, and Tifguard. Insect management program treatments include: untreated control, IPM based insecticide application, and a calendar based spray program consisting of one automatic spray for thrips, two pyrethroid applications in mid-season, and one caterpillar specific application in late summer. Insect populations were monitored weekly throughout the season with 15” sweepnets and beat sheet sampling in each plot. At harvest, the middle two rows of each plot were inverted and harvested. Yield and grade data were collected from each plot at each location.

Data analysis revealed few significant effects of cultivar or insect management regime on pest populations or yield. Higher numbers of potato leaf hopper adults were observed in the cultivar Tifguard compared to GA-12Y, but overall populations were low. Garden fleahopper adults were more abundant in the calendar/high-spray program than in the non-treated control suggesting that disruption of natural enemies could play a role in flaring garden fleahopper infestations. Yield was not found to be affected by insecticide regime in initial analyses. These results suggest that calendar based insecticide applications are not economically justifiable, though more data are needed.

This report covers work completed in 2014, but this research continued in 2015 and 2016. The results of these studies should provide growers with information they need to make informed decisions regarding pest management in peanut. Regular systematic peanut scouting occurs on only a small fraction of the total acreage in GA, and monitoring pest populations is one way growers can save money and become more efficient. Optimizing insecticide applications by making them only when pests are present and before damage is severe reduces cost of production and preserves yield and quality. For growers who choose not to scout their peanuts, the timing and economic data developed in this study should help in the process of deciding which insecticides to use and when they are most likely to result in greatest return on investment.