Today we’ll discuss a pest that has far reaching implications for the theory and practice of IPM, the boll weevil
The cotton boll weevil is one of several subspecies of *Anthonomous grandis*, but is the species responsible for essentially all of the economic damage to cotton in the US from this large family of weevils.
The family of insects to which the boll weevil belongs, Curculionidae, is one of the largest in the world.
As you can see from the images and the plastic embedded boll weevil (handed out in class), this insect is approximately 1/3” in total length
Under NC conditions, the boll weevil completes it’s life cycle in approximately 25 days. Because female boll weevils can deposit more than 200 eggs into squares and small bolls during their lifetimes and because this species typically undergoes 3-5 generations in the Southeast, this species has a high reproductive potential.
Boll weevils undergo a state of quiescence (whether they actually diapause is still a matter of some debate) in the fall in adjoining habitats where they overwinter. In areas of the deep south and TX, bolls weevils also overwinter within unharvested fruit (bolls).
A number of factors are responsible for both the boll weevil’s high damage potential and also for this species being a candidate for eradication. Once boll weevil eggs are deposited into squares or small bolls, the immature forms are safe from insecticides. The initial males that reach cotton squares in the spring following overwintering produce an aggregating pheromone after feeding on this tissue. The pheromone produced attracts subsequent males and females to fruiting cotton, thus enhancing this species establishment.
Few predators and parasitoids appear to limit boll weevil abundance.
Insecticides, targeted to the adult boll weevil stage, have been the primary means of “managing” this pest. Insecticides constitute the major initial first year strategy in eradication programs. Prior to the beginning of the Boll Weevil Eradication program in the late 70’s, managing insects on cotton has been cited as being responsible for up to 1/3 of the insecticides used of all crops in the US.
Three “egg punctures” are shown on the square to the left. With egg punctures, the female feeds into the square, turns around and inserts an egg into the opening, deposits a single egg, and fills the remaining void with frass. Note the “nipple-like” bulge on the right side of the left square. This is a characteristic indication of an egg puncture. The square in the right shows a “classic” feeding puncture. Both egg and feeding punctures result in the abscission (shed) of the square.
This is an image of a “flared square”, characterized by opening of the bracts and the square gradually turning yellowish (as opposed to the bracts being essentially “wrapping” undamaged green squares). Flared squares typically are shed from the cotton plant within 2-4 days; therefore bolls weevils complete most of their development within shed squares on the ground.
Third instar (last stage) boll weevil grub in cotton square.
This is an image of a small boll with 2-3 recent egg feeding punctures.
Left image: two last instar boll weevil grubs in cotton bolls. Right image: Boll weevil pupa in small cotton boll.
Left image showing normally-opened cotton boll; right image showing boll weevil-damaged boll.
This image demonstrates a high level damage to cotton resulting from boll weevil feeding (background) compared with cotton protected with multiple insecticide applications. Clayton, NC, 1972.
The boll weevil was introduced into the US in 1892 via a range expansion from Mexico, and had spread into North Carolina by 1919.
The range of the boll weevil had extended into most of Georgia by 1916 and by 1921 this species had resulted in a significant drop in cotton production (acreage x yield).

Impact of the Boll Weevil on Georgia’s cotton production: 1919-1922

<table>
<thead>
<tr>
<th>Year</th>
<th>Bales of Cotton</th>
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<tbody>
<tr>
<td>1919</td>
<td>19,789</td>
</tr>
<tr>
<td>1920</td>
<td>11,685</td>
</tr>
<tr>
<td>1921</td>
<td>1,509</td>
</tr>
<tr>
<td>1922</td>
<td>710</td>
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Even though the introduction and subsequent establishment of the boll weevil resulted significant damage to cotton in most states and a substantial loss of cotton acreage in many, in several states this dilemma was responsible for an increase in crop diversification. The citizens of Enterprise, AL in Coffee County dedicated a statue to crop diversification (primarily peanut) in 1919. Coffee County later became the largest peanut-producing county in the US. In 1949, a boll weevil was added to the top of the statue.
With the development and widespread use of synthetic insecticides following WWII, cotton pests such as the boll weevil were effectively controlled.
However, a number of agricultural pests, such as the boll weevil had developed resistance to these insecticides.
With the advent of resistance, a number of cultural tactics were promoted and used by US cotton producers with varying degrees of adherence and success.
Along with cultural methods of limiting boll weevil damage to cotton, the monitoring of boll weevil adults and fruit damage and the use of thresholds became the basis for early “scouting” efforts on cotton, largely begun in the 1960’s.
One relatively successful method of timing insecticide applications for boll weevil control was the use of early “pinhead” (so named for the small size of squares before boll weevils could be come established on cotton fruit in the spring following overwintering) applications. One or two well-timed sprays at this time could often greatly limit the development of later season boll weevil build-ups. With “diapause control” 1-3 late season insecticide applications were targeted to potentially-overwintering boll weevils. This strategy, along with winter mortality, often significantly limited boll weevil levels in the following year. However this strategy was most successful when conducted over a wide area that included a high proportion of the cotton acreage.
ERADICATION of the boll weevil has been the impossible dream of the cotton industry since the pest invaded Texas in the late 1800’s.

As early as the introduction of the boll weevil into the US just prior to the 1900’s, cotton producers and scientists have pondered the possibility of eradicating the boll weevil from the US.
Depending on vantage point and politics, the term “eradication” was defined differently by various scientists and groups.
Most eradication programs have resulted in costly failures. Successes have been limited to recent invader species (fruit flies) or to portions of a species range (screwworm).

To put eradication into its proper context, we should be reminded that most eradication efforts (however defined) have not been successful. However, even though some of these programs have fell well short of eradication, many have been of economic benefit.
A Pilot Boll Weevil Eradication Experiment envisioned by a committee selected by grower representatives of the National Cotton Council in 1969, the organizational and lobbying group for North America’s cotton producers.
This program was designed to determine the feasibility of eradicating the boll weevil from the US and adjoining cotton production areas of Mexico.
A number of new developments appeared to increase the odds that eradication of the boll weevil was more than a pipe dream.
Some of the approaches used in the Pilot Boll Weevil Eradication Experiment in Mississippi (and a small adjacent area in Louisiana and Alabama) included a number of the tactics previously mentioned. Headway had also been made in the use of irradiation to sterilize males for subsequent release.
E. F. Knipling, a USDA scientist who was largely regarded as the individual responsible for the development and deployment of the “sterile male technique” of total population suppression or elimination, was a strong advocate of boll weevil eradication. His published definition of successful eradication allowed that insects could be found in the “eradicated” area if this occurrence were due to reinvasion. This raised a significant issue of determining the difference between reinvaders and a low level population that had not been eradicated.
L. D. Newsom, an equally well know research entomologist from LSU, had a more restrictive definition of eradication. In his view, a natural reinvasion would not qualify as successful eradication. These two differing definitions would shape the upcoming debate about the success or failure of the Pilot Boll Weevil Eradication Experiment.

L. D. Newsom (1978)

“Eradication is the destruction of every individual of a species from an area surrounded by naturally occurring or man-made barriers sufficiently effective to prevent reinvasion of the area except through the intervention of man.”
Two separate committees were enlisted to determine the success of the PBWEE.

- Technical Guidance Committee (TGC) for PBWEE
- ESA Review Committee
As might be guessed from the previous different opinions, the Technical Guidance Committee stated that eradication was technically and operationally feasible, while the Entomological Society of America Committee stated that eradication of the boll weevil was not achieved. Who was correct?
With help from cotton entomologists from North Carolina State University, plans were made for a “final” boll weevil eradication trial to be held in NE NC beginning in 1978. Why was this area selected? Some points are listed above. An “Optimum Pest Management Trial” was concurrently conducted in MS.
As you can see from this picture compared with what’s before you, this ongoing program has been underway for more 36 years!
Schematic of original trial area
Much to the benefit of the trial program, the harsh winters of 1976/77 and of 1977/78 resulted in extremely low populations of boll weevils during the growing season of 1978. Late season applications for boll weevil (actually just preceding the fall diapause applications) averaged just over 2 application/acre, while the fall diapause applications averaged 5 apps./acre in those areas with positive trap captures.
Early boll weevil trappers in 1978, L to R (John Parker, Jim Wilkins and Jack Bacheler)
In the crop year 1979, only 7 total boll weevils were found during the massive spring and fall pheromone trapping program. With the low density of boll weevils and the high trapping rate, the odds of a scarce boll weevil finding a mate was essentially zero. Thus, the major thrust of the program was to initially get the weevil population down to very low levels via extensive fall diapause insecticide applications followed by both spring and fall “saturation” pheromone trapping. Ongoing research into the utility of the sterile male technique showed that this approach did not help reduce boll weevil levels (the irradiated weevils were not competitive); therefore the use of sterile males was eliminated in 1979.
Although boll weevils were undetectable in most of the core area of NC, an additional year of high density trapping was conducted. Insecticide treatments triggered by a trap catch were extremely rare.
Boll weevil eradication cost to NC cotton producers is show above. The total cost was 2-fold these amounts: the USDA APHIS and the state of North Carolina shared the remaining 50% balance of the total program cost.
At the end of the 3-year NC/VA Boll Weevil Trial program in 1980, a 2-year economic, biological and environmental evaluation was to be undertaken. National Cotton Council representatives and several influential cotton producers wanted to expand boll weevil eradication into the remainder of NC and into SC, either without these evaluations or concurrently with the evaluations. Because these evaluations were designed to determine whether to proceed with the eradication program following the “Trial”, J.R. Bradley, Jack Bacherler and a number of university cotton entomologists were against what they felt was a premature expansion. The above sentence was part of a NC state report given at the Beltwide Cotton Conferences in St. Louis in 1980 as part of a section on the progress of the BWET.
This figure shows the benefits of boll weevil eradication of North Carolina and South Carolina cotton producers, according to Gerald Carlson, Glen Sappy and others for the period of 1980 to 1985.
Total economic advantage of eradication in North Carolina-Virginia area:

$68.34/acre/year

Boll weevil eradication Benefits to NC and NC cotton producers for the early 1980’s
The Boll Weevil Containment Program presently costs NC cotton producers $.80 per acre.
Eradication of the boll weevil is thought to have led to significant cotton acreage increases in the Southeast and in the Mid-South. Note also that Bt cotton was introduced in NC in 1996.
Eradication of the boll weevil is thought to have led to significant cotton acreage increases in the Southeast and in the Mid-South. This pattern is less apparent in the North Carolina. Note also that Bt cotton was introduced in NC in 1996.
As you can see from this figure, the number late season applications for insects has declined dramatically.
Some consumer surveys show that concern about pesticide exposure (primarily insecticides) is greater now than 30 or 40 years ago. As you can see from this table, in the case of cotton, the number of applications, the pounds of active ingredient per application and the mammalian toxicity to standard test animals (the lower the LD$_{50}$, the more toxic the substance) is several thousand-fold lower than in the early 70’s. This huge drop (actually a trend) in potential human exposure to pesticides has been underway across essentially all southern field crops crops.
The above points shows the triggers for responding to “post-eradication” responses to boll weevil captures.
As one can see from the table, numerous boll weevils have been found in the Southeast since the end of the active phase of the Eradication Program in GA in 1990. No boll weevils have been found in the Southeast since 2005. However, the trapping density is presently approaching 1 trap per square mile. When approximately 2,300 boll weevils were caught in Edgecombe County in the fall of 1998, the intense trapping program to eliminate the reproductive populations in that area cost just over $750,000. At this time the trapping density was 5-10-fold greater than the present level of trapping, and the cost to the producer is only about 30% less per acre. One concern that was been expressed by members of the NC Boll Weevil Technical Advisory Committee in 2008 was that if one or more gravid boll weevils found their way into North Carolina, with the present trapping density detection might not locate the resulting offspring until several generations later in the second year of infestation, resulting in an extremely costly “re-eradication” effort. The 17,000 boll weevils found in SC pheromone trap in 1995 cost more than 1 million dollars to clean up. If North Carolina cotton producers plant 600,000 acres of cotton in 2011, collections would total the $750,000 spend in Edgecombe County in 1998. Our concern is the possibility of an undetected initial population with associated 20-30 mile “diapause flights” that then go undetected until the following year when the traps are put out in the late summer and boll weevils have undergone 2-3 generations. The cost of this re-eradication effort and the concern of citizens about the heavy use of organophosphate insecticides could well threaten the success of the program.
As we have learned, the boll weevil is a classic example of a key pest that has had a major impact on insect management in general, cotton insect management in particular, and has had a significant influence on the southern economy, both good and bad.
The Lower Rio Grande Valley has presented some challenges in achieving boll weevil eradication in the US, as can be seen from the above points. What do you think has been a huge issue in the past couple of years? Violence! Some of the pheromone traps on the US side of the Mexican/US border and many traps on the Mexican side of the border and lower into Mexico have not been checked due to legitimate concerns about human safety and the recent reluctance of some producers to permit entrance to their farms.
Lower Rio Grande area challenging
Substantial numbers of boll weevils still being caught through. No population limiting progress being made from 2012 through 2014.
Cotton plants (perennial) continue to grow in the absence of freezing temps.
Full reproductive cycle “easy” in these situations
Cotton plant with 5 growth rings

Front yard landscape plant
Roadside harvested cotton in the way to gin
Cotton plants along roadside ditch.
Mature cotton plants in fallow field
Cotton plants in sugar cane field
Emergence of almost 250 weevils produced by only 2 cotton plants

<table>
<thead>
<tr>
<th>Plant</th>
<th>Egg Puncture</th>
<th>Feeding injury</th>
<th>No injury</th>
<th>Weevil emergence</th>
<th>Total fruit</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>132</td>
<td>46</td>
<td>128</td>
<td>6</td>
<td>312</td>
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<td>2</td>
<td>58</td>
<td>29</td>
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<tr>
<td>Shed</td>
<td>68</td>
<td>34</td>
<td>173</td>
<td>83</td>
<td>358</td>
</tr>
<tr>
<td>Total</td>
<td>258</td>
<td>109</td>
<td>437</td>
<td>96</td>
<td>900</td>
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- Total of 249 weevils produced from two plants (153 emerged in the lab + 96 emerged in the field)
- Potential of 12,500 to 37,500 eggs
This has been subject to several tropical storms making access to pheromone traps difficult.
Drug cartels active in much of Mexico, in some cases denying access to cotton fields.
Failed innovative attempt to cross into the US
Red line is the US/Mexican border fence; yellow is the Rio Grand. Note proximity of Mexican and US cotton.
Human and biological factors in Southeast TX suggest that the boll weevil has not been eradicated. However, for cotton producers in the Southeast the definition of eradication is of little interest. For them, the Boll Weevil Eradication Program has been a geographically-widespread economic and environmentally unqualified success. Of interest to cotton entomologists in North Carolina is whether our present containment program of widely scattered pheromone traps could detect a population of boll weevils in time to avoid an expensive, protracted, potentially unsuccessful re-eradication program.
Although the Boll Weevil Eradication Program has probably been the largest, most economically successful entomological program ever initiated in the US, the resulting lower insecticide use has released a number of secondary pests once controlled by boll weevil- or bollworm-active insecticides, particularly Hemipterans or bug pests. Most notable are *Lygus lineolaris* (plant bugs) in the Mid-South and a complex of stink bugs in the Southeast. This dilemma will be discussed in Thursday’s lecture.
J.R. Bradley and first graduate student picking cotton at the Central Crops Research Station in Clayton, NC.