TIMING OF BOLLWORM INFESTATION ACROSS PLANTING DATES AND IMPACTS ON YIELD IN THE SOUTHEASTERN US

Dominic D. Reisig
Department of Entomology & Plant Pathology, North Carolina State University
Plymouth, NC
Jeremy Greene
Department of Plant and Environmental Sciences, Clemson University
Blackville, SC
Silvana V. Paula-Moraes
Department of Entomology and Nematology, University of Florida
Jay, FL
Phillip Roberts
Department of Entomology, University of Georgia
Tifton, GA
Sally Taylor
Department of Entomology, Virginia Tech
Suffolk, VA

Abstract

Bollworm, *Helicoverpa zea* Boddie, is an important pest of US cotton. Bt-resistance in bollworm has spurred renewed interest in investigating various IPM principles and tactics. Replicated small-plot trials were conducted in North Carolina during 2020 and 2021 to document the effect of planting date on *H. zea* infestation and damage in cotton. All planting dates were left untreated for bollworm during 2020, while during 2021, plots with and without insecticide to manage bollworm were included as a factor in a factorial design. Planting date influenced bollworm damage and, generally, bollworm damage was higher and more persistent in later-planted cotton. Population densities were so high in 2020 that yield could not be measured across planting dates. In 2021, yield was lowest in the latest planting date and in unsprayed plots. This was largely due to first position boll lint yields that decreased as planting was delayed or if plots were unsprayed. Our results align with previous studies indicating that later planted cotton is more at risk for bollworm infestation and damage.

Introduction

Few studies have documented the effect of planting date on *Helicoverpa spp.* in cotton. In other crops, such as soybeans, egg deposition by and larval survival of bollworm, *Helicoverpa zea* Boddie, is almost always greater in a later-planted crop (Terry et al. 1987). However, results with cotton have proved more variable, perhaps because plant growth characteristics, such as internode length, can vary widely across planting dates (Boquet and Clawson 2009) and despite bollworm populations usually increasing as the season progresses (Parajulee et al. 1998). A study in Zimbabwe found that larvae of *Helicoverpa armigera* (Hübner) were more prevalent in later-planted cotton (Karavina et al. 2012). In contrast, a North Carolina study did not find differences in egg deposition and damage in cotton among planting dates (Agi et al. 2001). Finally, another study found that early planted cotton had more larvae and more damage than later planted cotton, although egg deposition was similar among planting dates (Lambert et al. 1996).

Bt-resistance in bollworm has spurred renewed interest in investigating various IPM principles and tactics. Growers are unlikely to shift planting dates solely because they are concerned about damage from bollworm; however, if planting date consistently influences *H. zea* infestation and damage in cotton, then scouting or controlling bollworm could be prioritized into certain management zones across a farm. Furthermore, if studies show that cotton is an important crop for Bt-resistance management, then information concerning the effect of planting date on bollworm infestation will be important.

To approach this question, experimental small-plot trials were established in North Carolina for two years. The intention was to have at least one early, middle, and late planting date to compare differential levels of bollworm damage and impacts on yield. Our hypothesis was that bollworm infestation levels would be higher in later planting dates.

Materials and Methods

Non-Bt cotton (DP1822XF; Bayer Crop Science, St. Louis, MO, or FM2322GL; BASF, Research Triangle Park, NC) was planted during 2020 and 2021 on at least three planting dates (early, mid-, late) that were representative of cotton grown in North Carolina. In 2020 early conditions were poor and the early planting date was adjusted later. We used a randomized complete block design with four replications per planting date, with plots that were four or eight rows wide by forty feet long during 2020. During 2021, insecticide treatment- unsprayed or sprayed with chlorantraniliprole (Prevathon 0.43 SC at a rate of 0.053 kg ai ha^{-1}; FMC, Philadelphia, PA) every other week- was added as a factor in a factorial design. During 2020, plots were planted on 12 May (early), 26 May (middle), 1 June (middle-late), and 8 June (late). During 2021, plots were planted on 31 April (early), 17 May (middle), and 14 June (late). Standard agronomic practices were followed, except that a disruptive spray of acephate (Orthene 97, 1.05 kg ai ha^{-1}; AMVAC Chemical Corporation, Newport Beach, CA) was applied on 21 July 2020 and 16 July 2021 to eliminate natural enemies and to encourage bollworm establishment. Insecticide applications for bollworms were not made in any location.

Once cotton began squaring, we checked weekly for the presence of bollworm or tobacco budworm, *Chloridea virescens* F. Once a larva was detected in any plot, we scouted 50 fruiting forms (squares or flowers prior to and during first or second week of bloom, but defaulted to bolls, when present) per plot in all planting dates weekly until no more larvae were detected (generally three to six weeks, depending on the location). We recorded fruiting form as damaged if there was a hole in the sepal wall, and we also recorded the number and larval instars found on the fruiting forms. We also collected 25 larvae for one week (or as many as possible) and reared them to adulthood to identify them as bollworm or tobacco budworm.

Plant mapping was done on 23 October 2020 and 4 November 2021 and box mapping was done after defoliation, but prior to harvest (2021 only). Plants were collected from the middle two rows of each plot by selecting 10 random plants. Yield was from the center two using a mechanical picker. Plant mapping variables collected included plant height, number of nodes, number of total bolls per plant, number of vegetative bolls per plant, position of the first fruiting node, and the percent retention at each position along fruiting branches at each node. Box mapping variables collected included the weight of seed cotton at each node and position on both reproductive and vegetative branches. Yield variables were not collected during 2020 because bollworms had caused nearly 100% boll abscission across the trial.

A generalized linear mixed models analysis of variance (PROC GLIMMIX; (SAS Institute 2011)) repeated measures approach was used for damaged boll data. The independent variables included planting date, sampling date, and their interaction which were fixed. Replication was included as a random factor. A mixed models analysis of variance approach (PROC MIXED; (SAS Institute 2011)) was used for yield component data, and separate models were constructed for each year because study design varied. The independent variables included planting date, which was fixed, and replication and the interaction of replication with planting date, which were random. Spray and its interactions were included as factors for the 2021 analysis. Dependent variables in separate analyses included averages per plot of: damaged squares or bolls (if present) at each sampling point, plant height, number of nodes, the height to node ratio (H:N), number of total bolls per plant, number of vegetative bolls per plant, position of the first fruiting node, and percent retention at each position along fruiting branches on nodes 1, 2, 3, and 4 (if present) averaged across nodes, and the weight of seed cotton at each position, averaged across nodes of both reproductive branches (positions 1, 2, and 3) and vegetative branches. Transformations were used, if needed, to satisfy model assumptions. Degrees of freedom were adjusted using Kenward-Roger's approach (Kenward and Roger 1997), and mean separations were analyzed using Tukey's honest significant differences test.

Results

In-Season Damaged Fruiting Forms.

In 2020, the percent of squares or bolls (if present) damaged by bollworms could only be statistically separated among planting dates on 17 August (Fig. 1; $F = 8.99$, d.f. = 3, 8.99, $P = 0.0017$).

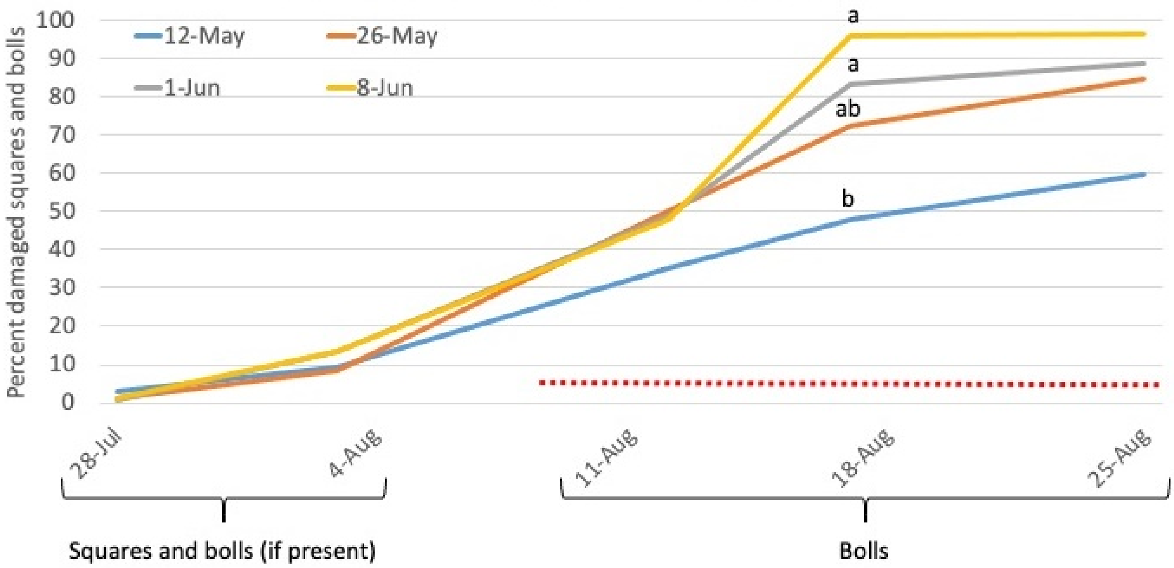

Figure 1. Percent squares and bolls damaged by bollworms across planting dates in 2020. 12 May = early planting date; 26 May = middle planting date; 1 June = middle-late planting date; 8 June = late planting date. Dashed red line denotes a threshold of 6% damaged fruiting structures (recommended threshold in some states, but not in North Carolina during 2020).

In 2021, the percent of squares or bolls (if present) was higher in the latest planting date on 5, 12, and 19 August (Fig. 2; F = 11.87, d.f. = 2, 33, P < 0.0001).

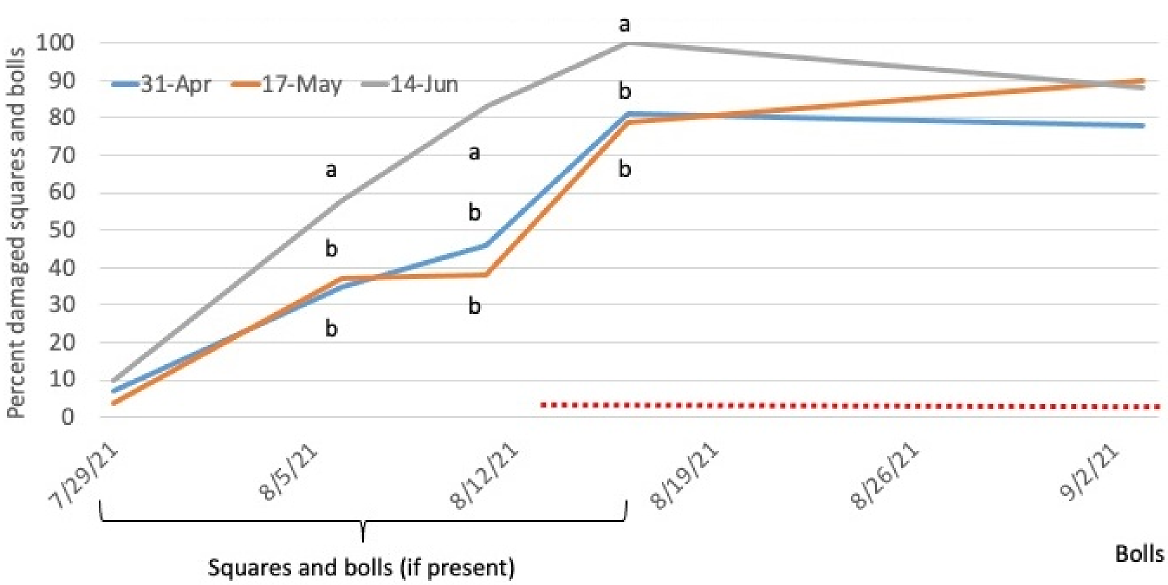

Figure 2. Percent squares and bolls damaged by bollworms across planting dates in 2021. 31 April = early planting date; 17 May = middle planting date; 14 June = late planting date. Dashed red line denotes a threshold of 4% damaged fruiting structures (threshold was added in North Carolina during 2021).

<u>Plant Mapping</u>.
Average total nodes per plant were the fewest on the latest planting date compared with all others in 2020 (Fig. 3; F = 14.10, d.f. = 3, 9, P = 0.0009) and different across all planting dates in 2021 (Fig. 3; F = 35.59, d.f. = 2, 15, P < 0.0001). Average total nodes per plant were fewer in the sprayed plots compared to the unsprayed plots (Fig. 3; F = 26.64, d.f. = 1, 15, P < 0.0001).

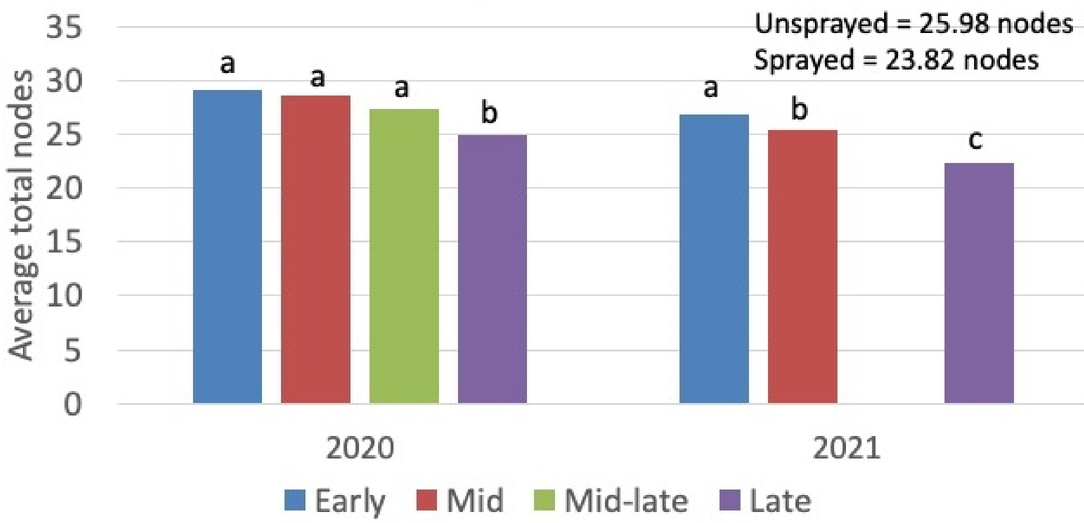

Figure 3. Average total nodes per plant in 2020 and 2021. Early = early planting date; Mid = middle planting date; Mid-late = middle-late planting date; Late = late planting date.

In 2020, average bolls per plant were lowest in the middle-late and late planting dates compared with the middle and early planting date (Fig. 4; $F = 19.10$, d.f. = 3, 9, $P = 0.0003$). In 2021, average bolls per plant were highest in the early planting date, intermediate in the middle planting date, and lowest in the late planting date (Fig. 4; $F = 26.52$, d.f. = 2, 15, $P < 0.0001$). Average bolls per plant were more in the sprayed plots compared to the unsprayed plots (Fig. 4; $F = 118.46$, d.f. = 1, 15, $P < 0.0001$).

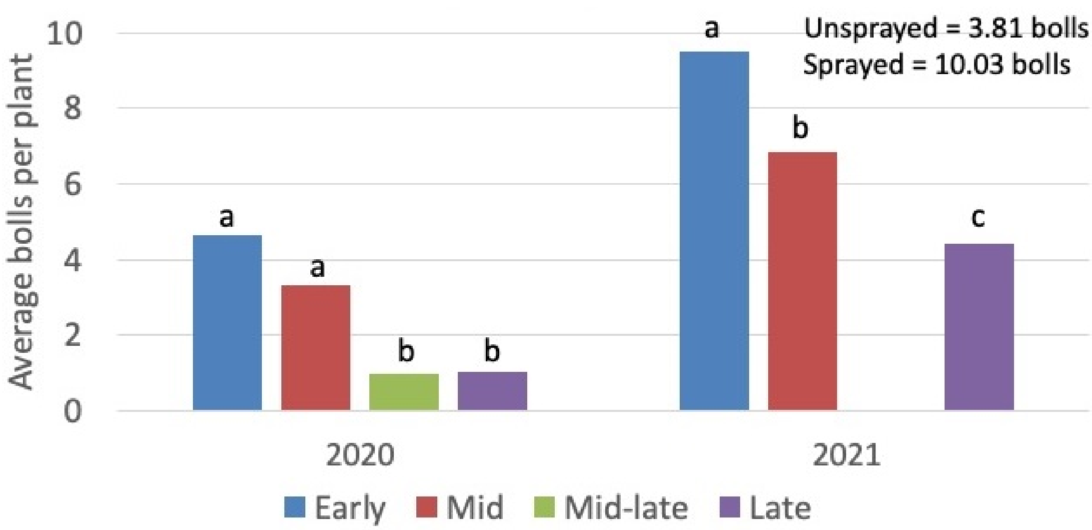

Figure 4. Average bolls per plant in 2020 and 2021. Early = early planting date; Mid = middle planting date; Mid-late = middle-late planting date; Late = late planting date.

In 2020, first position boll retention was lower in mid-late and late-planted cotton than early planted cotton (Fig. 5; $F = 9.82$, d.f. = 3, 9, $P = 0.0034$). In 2021, first position boll retention was lower in late-planted cotton than early-planted cotton (Fig. 5 $F = 6.64$, d.f. = 2, 15, $P = 0.0086$). First position boll retention was higher in the sprayed plots compared to the unsprayed plots (Fig. 5; $F = 558.85$, d.f. = 1, 15, $P < 0.0001$).

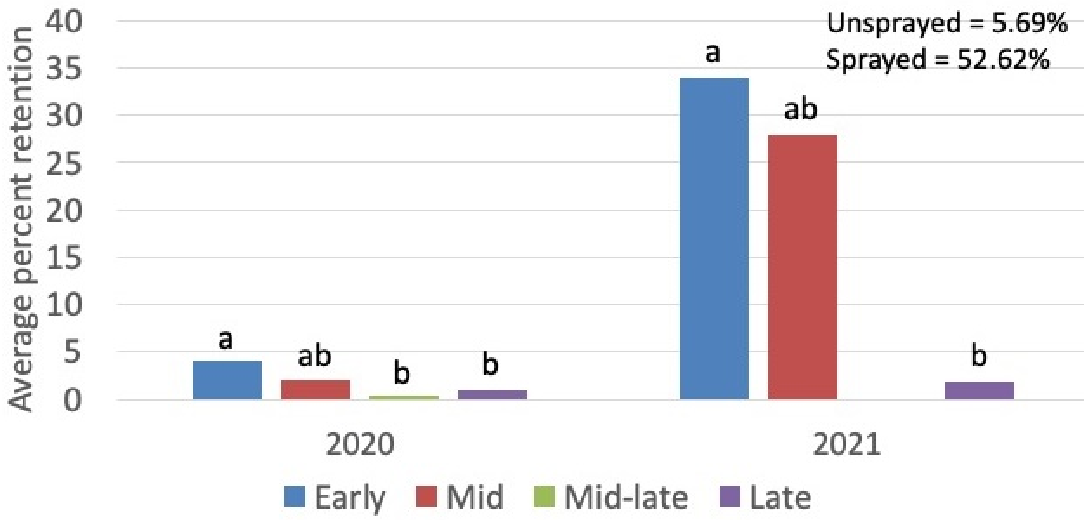

Figure 5. Average percent retention of the first position boll across all nodes in 2020 and 2021. Early = early planting date; Mid = middle planting date; Mid-late = middle-late planting date; Late = late planting date.

In 2020, boll retention was similar for all other positions across planting dates. In 2021, second position boll retention was higher in the sprayed plots compared to the unsprayed plots (Fig. 6; F = 46.04, d.f. = 1, 18, P < 0.0001). In 2021, third position boll retention was highest in the middle planting sprayed plots compared to all plots, except those planted early and sprayed (Fig. 6; F = 8.11, d.f. = 2, 15, P = 0.0041). Furthermore, third position boll retention was higher in plots planted early and sprayed compared to the early and middle-planted unsprayed plots.

Position	Unsprayed	Sprayed
2nd	5.3%	23.16%

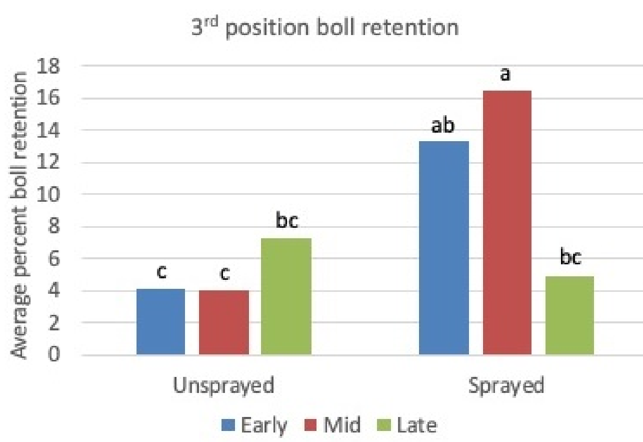

Figure 6. Average percent retention of the second and third position boll across all nodes in 2021. Early = early planting date; Mid = middle planting date; Late = late planting date.

<u>Yield Components.</u>

Yield components were only measured during 2021. First position grams of lint were highest in early planted sprayed plots (Fig. 7; F = 6.26, d.f. = 2, 15, P = 0.0105). They were less in middle-planted sprayed plots and less in late-planted sprayed plots. First position grams of lint were less in early-planted unsprayed plots than late-planted sprayed plots, but similar to middle-planted unsprayed plots. First position grams of lint in plots planted early and middle and unsprayed were more than plots planted late and unsprayed.

Second position grams of lint were highest in early and middle planted sprayed plots (Fig. 7; F = 6.26, d.f. = 2, 15, P = 0.0105). Second position grams of lint were similar in early-planted and mid-planted sprayed plots. Second position grams of lint were similar in late-planted sprayed plots and all unsprayed plots.

Figure 7. Average grams of lint from the first and second position boll across all nodes in 2021. Early = early planting date; Mid = middle planting date; Late = late planting date.

Third position (Fig. 8; $F = 6.16$, d.f. = 2, 18, $P = 0.0092$) and vegetative (Fig. 7; $F = 6.73$, d.f. = 2, 15, $P = 0.0082$) grams of lint were highest in early and middle-planted plots. Fourth position grams of lint were highest in early and middle-planted cotton compared to late-planted cotton (Fig. 8 $F = 3.58$, d.f. = 2, 18, $P = 0.049$). Vegetative lint was higher in sprayed plots compared to unsprayed plots (Fig. 8; $F = 23.63$, d.f. = 1, 15, $P = 0.0002$).

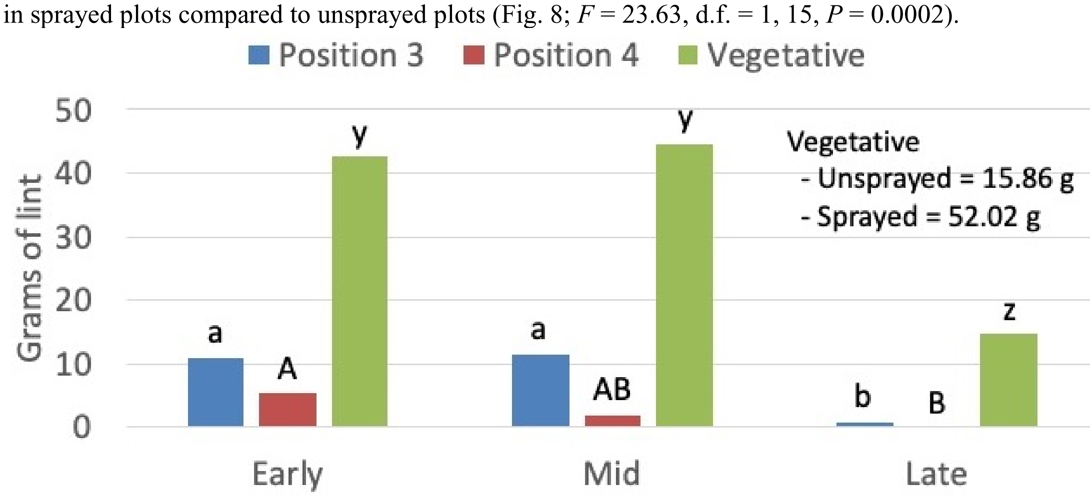

Figure 8. Average grams of lint from the third and fourth position boll, as well as vegetative bolls, across all nodes in 2021. Early = early planting date; Mid = middle planting date; Late = late planting date.

Average cotton yields were highest in early and middle-planting dates (Fig. 8; $F = 137.17$, d.f. = 2, 13, $P < 0.0001$), and in sprayed plots (Fig. 9; $F = 439.55$, d.f. = 1, 13, $P < 0.0001$).

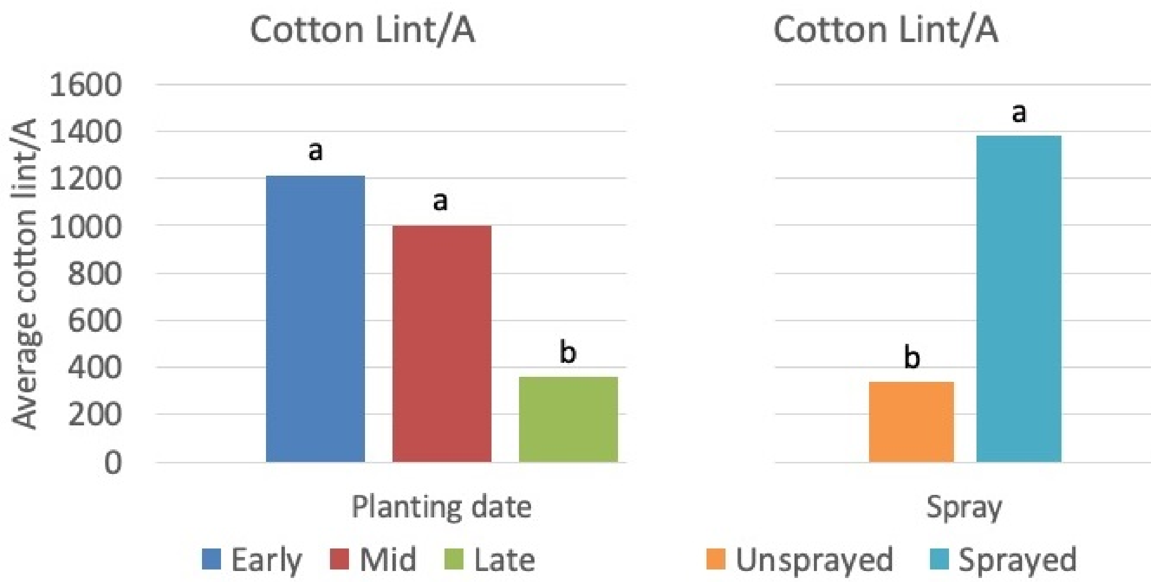

Figure 9. Average cotton lint per acre in 2021. Early = early planting date; Mid = middle planting date; Late = late planting date.

Summary

Planting date influenced bollworm damage in both years. Generally, bollworm damage was higher and more persistent in later-planted cotton and these differences were more apparent later in the season in 2020, but during the middle of the season in 2021.

Planting date also influenced plant response. For example, the number of average total nodes, average bolls per plant, and first position boll retention tended to decrease as planting date was delayed. The insecticide spray also influenced plant response, with the number of average total nodes lower in sprayed plots compared to unsprayed plots, and the average bolls per plant, first, second and third position boll retention generally being higher. Likely plants in unsprayed plots increased growth in an attempt to compensate for missing squares and bolls due to bollworm.

In 2021, when yield could be measured, most of the lint was produced by the fist position bolls in sprayed plots. Grams of lint tended to decrease as planting date became later in this position regardless of spray. There were not major differences in other positions across planting dates, although the least lint tended to be in the latest planting date in the other bolls' positions. Sprayed plots tended to have more lint than unsprayed plots. This was reflected in the final yield results, with the latest planting date having the lowest yield and unsprayed plots yielding less than sprayed plots.

These experiments represent a range of responses to cotton planting date by bollworm. Both experiments had population levels much higher than recently recommended damaged-boll thresholds (Del Pozo-Valdivia et al. 2021). Our results align with the results of previous studies indicating that later planted cotton is more at risk for bollworm infestation and damage.

Acknowledgements

Partial support of these studies was provided by Cotton Inc. and NIFA Hatch Project # NC02778. This project represents a collaborative effort of the Southeast Row-Crop Entomology Working Group (SERCEWG).

References

Agi, A. L., A. Burd, J. R. Bradley, Jr., and J. W. Van Duyn. 2001. Planting date effects on Heliothine larval numbers, fruit damage, and yield of transgenic B.t. cotton in North Carolina. J. Entomol. Sci. 36: 402-410.

Boquet, D. J., and E. L. Clawson. 2009. Cotton planting date: yield, seedling survival, and plant growth. Agron. J. 101: 1123-1130.

Del Pozo-Valdivia, A. I., D. D. Reisig, L. Braswell, J. K. Greene, P. Roberts, and S. V. Taylor. 2021. Economic injury levels for Bt-resistant *Helicoverpa zea* (Lepidoptera: Noctuidae) in cotton. J. Econ. Entomol. 114: 747-756. doi: 10.1093/jee/toab012.

Karavina, C., R. Mandumbu, C. Parwada, and T. Mungunyara. 2012. Variety and planting date effects of the incidence of bollworms and insect sucking pests of cotton (*Gossypium hirsutum* L.). Research Journal of Agricultural Sciences. 3: 607-610.

Kenward, M. G., and J. H. Roger. 1997. Small sample interference for fixed effects from restricted maximum likelihood. Biometrics. 53: 983-997.

Lambert, A. L., J. R. Bradley, Jr., and J. W. Van Duyn. 1996. Effects of natural enemy conservation and planting date on the susceptibility of Bt cotton to *Helicoverpa zea* in North Carolina. *In* C. P. Dugger and D. A. Richter (eds.), Beltwide Cotton Conferences, Jan. 9-12 1996, Nashville, TN. National Cotton Council of America, Memphis, TN.

Parajulee, M. N., J. E. Slosser, and E. P. Boring, III. 1998. Seasonal activity of *Helicoverpa zea* and *Heliothis virescens* (Lepidoptera: Noctuidae) detected by pheromone traps in the Rolling Plains of Texas. Environ. Entomol. 27: 1203-1219.

SAS Institute. 2011. User manual, version 9.3. SAS Institute, Cary, NC.

Terry, I. L., J. R. Bradley, Jr., and J. W. Van Duyn. 1987. Population dynamics of *Heliothis zea* (Lepidoptera: Noctuidae) as influenced by selected soybean cultural practices. Environ. Entomol. 16: 237-245.