EFFECTS OF PLANTING DATE AND VARIETY ON THRIPS POPULATIONS IN AND INJURY TO COTTON IN THE SOUTHEASTERN UNITED STATES

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Abstract

Thrips (Thysanoptera) are among the most important insect pests of cotton (*Gossypium hirstutum*) in the southeastern United States. In the southeastern United States, tobacco thrips is the predominant species in a complex of thrips species impacting seedling cotton. Resistance to neonicotinoid insecticides has been reported for tobacco thrips, resulting in a need for alternative control options for thrips. Data suggest that thrips population complexes in the southeastern United States have a distinct population peak that varies spatially and temporally within the normal planting window (about 8 weeks: late April, May, and early June) for cotton. This distinct and recurring variation indicates that risk from thrips injury to cotton can differ depending on the planting date of the crop. To investigate the suitability of planting date as a risk management tool to mitigate thrips injury in cotton, a study was conducted in 2016 and 2017. The study included cotton planted at ten different times from 15 April to 15 June in 2016 and 2017 in South Carolina. Cotton planted after mid-May in South Carolina in 2017 did not show significant benefits from insecticide for thrips, indicating that planting later in the planting window can help reduce injury from thrips. Another promising management technique to manage risk of thrips injury is the use of high yielding varieties of cotton that are less susceptible to thrips. To investigate the role of varietal susceptibility to thrips injury in cotton, ten different high yielding varieties of commercially available cotton were planted in five southeastern states in 2016 and 2017. Some varieties of cotton exhibited subtle reduced susceptibility to thrips injury but required insecticide under moderate to severe pressure from thrips.

Introduction

In recent years, thrips have been the number one pest of cotton (*Gossypium hirstutum*) in the southeastern United States (Williams 2015). Thrips are major pests in all cotton growing regions of the United States (Williams 2012, 2013, 2014, 2015, 2016, 2017). Certain populations of thrips in the southeastern United States are less susceptible to the neonicotinoid insecticides thiamethoxam and imidacloprid (Huseth et al. 2016), commonly used as seed treatments (Elbert et al. 2008). To investigate agricultural management techniques that reduce the risk of thrips injury to cotton (Elbert et al. 2008), two trials were conducted in 2016 and 2017 to investigate the effects of planting date and variety on thrips as cultural control methods in the southeastern United States.

Materials and Methods

Planting Date
Two varieties of commercially available upland cotton, including PHY 333 WRF (early maturation) and PHY 499 WRF (mid-full maturation), were planted across ten planting dates from mid-April to mid-June at the Edisto Research and Education Center in Blackville, South Carolina, in a completely randomized block design. Treatments included an at-plant insecticidal treatment of phorate applied as an in-furrow granule at 5 lb/acre with fungicide treated seed and an untreated fungicide only control (Table 1).

Table 1. Factors (planting date, insecticide treatment, and variety) influencing populations of thrips, injury from thrips, and cotton yield in 2017 in Blackville, SC.

Planting Date	Treatment (insecticide)	Variety	Factor
12 April 2017	Phorate IFS @ 5lbs/acre or UTC	PHY 333 WRF & PHY 499 WRF	Planting Date X Insecticide X Variety
21 April 2017	Phorate IFS @ 5lbs/acre or UTC	PHY 333 WRF & PHY 499 WRF	Planting Date X Insecticide X Variety
27 April 2017	Phorate IFS @ 5lbs/acre or UTC	PHY 333 WRF & PHY 499 WRF	Planting Date X Insecticide X Variety
4 May 2017	Phorate IFS @ 5lbs/acre or UTC	PHY 333 WRF & PHY 499 WRF	Planting Date X Insecticide X Variety
12 May 2017	Phorate IFS @ 5lbs/acre or UTC	PHY 333 WRF & PHY 499 WRF	Planting Date X Insecticide X Variety
17 May 2017	Phorate IFS @ 5lbs/acre or UTC	PHY 333 WRF & PHY 499 WRF	Planting Date X Insecticide X Variety
26 May 2017	Phorate IFS @ 5lbs/acre or UTC	PHY 333 WRF & PHY 499 WRF	Planting Date X Insecticide X Variety
31 May 2017	Phorate IFS @ 5lbs/acre or UTC	PHY 333 WRF & PHY 499 WRF	Planting Date X Insecticide X Variety
9 June 2017	Phorate IFS @ 5lbs/acre or UTC	PHY 333 WRF & PHY 499 WRF	Planting Date X Insecticide X Variety
24 June 2017	Phorate IFS @ 5lbs/acre or UTC	PHY 333 WRF & PHY 499 WRF	Planting Date X Insecticide X Variety

All three factors (planting date, treatment, and variety) were organized into 40-foot plots with a 38-inch row spacing replicated four times in a randomized complete block design. For each planting date, thrips density was measured weekly or biweekly during times of rapid plant growth. Thrips sampling terminated when plants surpassed the four true leaf developmental stage or when four observations are taken, whichever occurred last. To sample thrips populations in cotton, ten cotton seedlings were removed from each plot and placed into containers filled with a mixture of 50% water and 50% alcohol. The containers were taken back to the laboratory and counted with a dissecting scope. Presence of genitalia, size, the presence of wings, and color were used to sort thrips specimens to life stage (adult or immature). Thrips injury ratings were taken at the time thrips samples were taken for all planting dates. Thrips injury ratings were estimated visually by inspecting cotton seedlings in a plot and rating the injury based on a 0-5 scale where '5' was the most severe injury (Figure 1). Yields were estimated from the middle four rows of each plot with a mechanical plot picker. All data were analyzed using the SAS 9.4 PROC Mixed function (SAS Institute 2015), and all letters of significance were calculated using Tukey's HSD. A thrips day calculation was used to take into account differing times between sampling dates. This calculation takes the number of adult and immature thrips at the first observation and the number of adult and immature thrips at the second observation and multiplies them by the number of days between the observations. The calculation appears:
$\left(\frac{(A_1+B_1)}{2}+\frac{(A_2+B_2)}{2}\right)*C$ where A is the number of adults, B is the number of immature thrips, and C is the number of days between observations.

Variety
To investigate the influence of varietal susceptibility as a role in the management of thrips populations infesting cotton in the southeastern United States, twelve varieties of commercially available upland cotton were planted at seven sites

across the southeastern United States. The seven sites spanned five states including Virginia, North Carolina, South Carolina, Georgia, and Alabama. The varieties included at all sites were PHY 312, PHY 333, PHY 444, PHY 499, DP 1410, DP 1518, DP 1538, DP 1646, ST 4747, ST 4946, ST 6182, and FM 1900 (Table 2). Cotton was planted during late April and through mid-May, when damaging populations of thrips are typically highest.

Table 2. Experimental arrangement for evaluating effects of variety on thrips populations in cotton in the southeastern United States in 2016 and 2017.

Location	Year	Date Planted	Factor
Suffolk, Virginia	2016	18 May	Variety
Plymouth, North Carolina	2016	5 May	Variety
Blackville, South Carolina	2016	4 May	Variety
Tifton, Georgia	2016	6 May	Variety
Tifton, Georgia	2016	9 May	Variety
Prattville, Alabama	2016	25 April	Variety
Belle Mina, Alabama	2016	16 May	Variety
Suffolk, Virginia	2017	4 May	Variety X Treatment (Acephate) @ 3oz/acre IFS
Plymouth, North Carolina	2017	9 May	Variety X Treatment (Acephate) @ 1lb/acre IFS
Blackville, South Carolina	2017	27 April	Variety X Treatment (Phorate) @ 5lbs/acre IFS
Prattville, Alabama	2017	14 April	Variety X Treatment (Acephate) @ 1lb/acre IFS
Tifton, Georgia	2017	20 April	Variety X Treatment (Phorate) @ 5lbs/acre IFS

All of the locations organized the treatment combinations into a randomized complete block design with four replications. At each location, thrips density was measured weekly until the plants surpassed the four true leaf developmental stage or when three observations were taken, whichever occurred last. To measure thrips population size at each location, 5-10 cotton seedlings were removed from each plot and placed into containers filled with a mixture of 50% water and 50% alcohol. The containers were taken back to the laboratory and counted with a dissecting scope. Presence of genitalia, size, the presence of wings, and color were used to sort the specimens to life stage (adult or immature). Thrips injury ratings were also taken at the time thrips samples are taken for all locations. Thrips injury ratings were estimated by visually inspecting cotton seedlings in a plot and rating the injury from thrips based on a 0-5 scale where '5' was the most severe injury (Figure 1). Yields were estimated with a mechanical plot picker. All data were analyzed using the SAS 9.4 PROC Mixed function (SAS Institute 2015), and all letters of significance are calculated using Tukey's HSD. A thrips day calculation was used to take into account differing times between sampling dates. This calculation takes the number of adult and immature thrips at the first observation and the number of adult and immature thrips at the second observation and multiplies them by the number of days between the observations. The calculation appears:

$\left(\frac{(A_1+B_1)}{2}+\frac{(A_2+B_2)}{2}\right)*C$ where A is the number of adults, B is the number of immatures, and C is the number of days between observations. All data for the variety results include data from all locations.

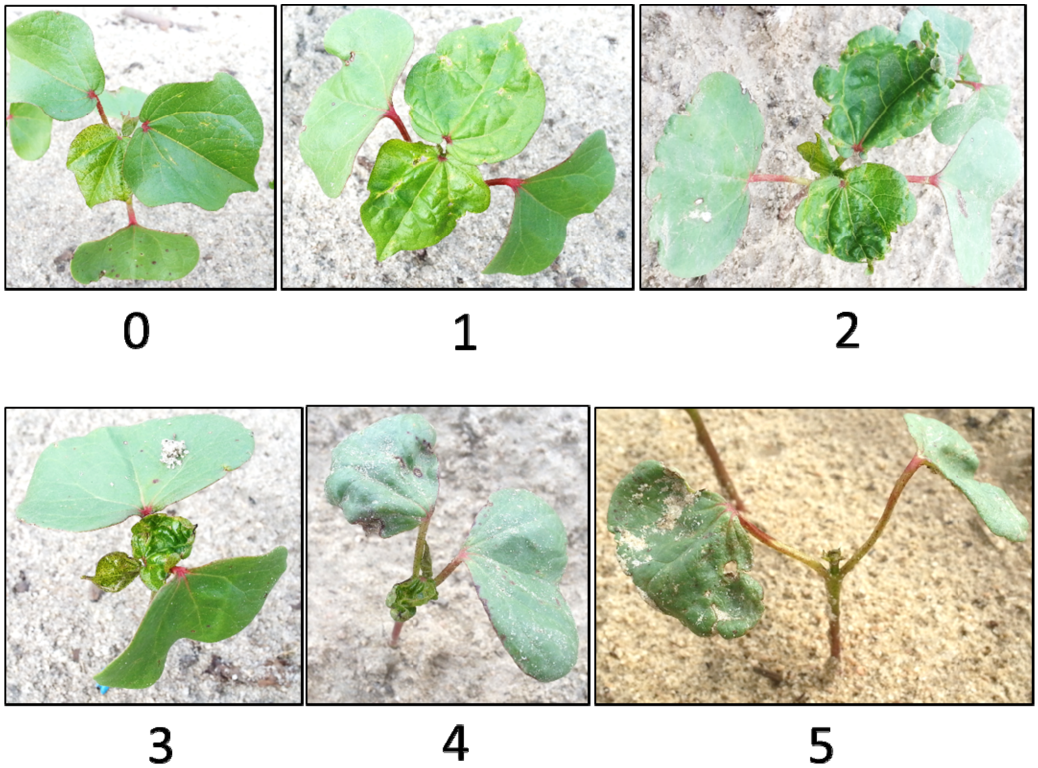

Figure 1. Levels of injury to cotton seedlings rated from '0' (no damage) to '5' (dead terminal or plant) from thrips. Injury at '3' or above approximates a threshold for intervention with an insecticide application.

Results and Discussion

Planting Date

Planting date had a significant effect on populations of thrips (Figure 2.) The later in the calendar year that cotton was planted, the lower the density of thrips sampled, reducing calculated average thrips days.

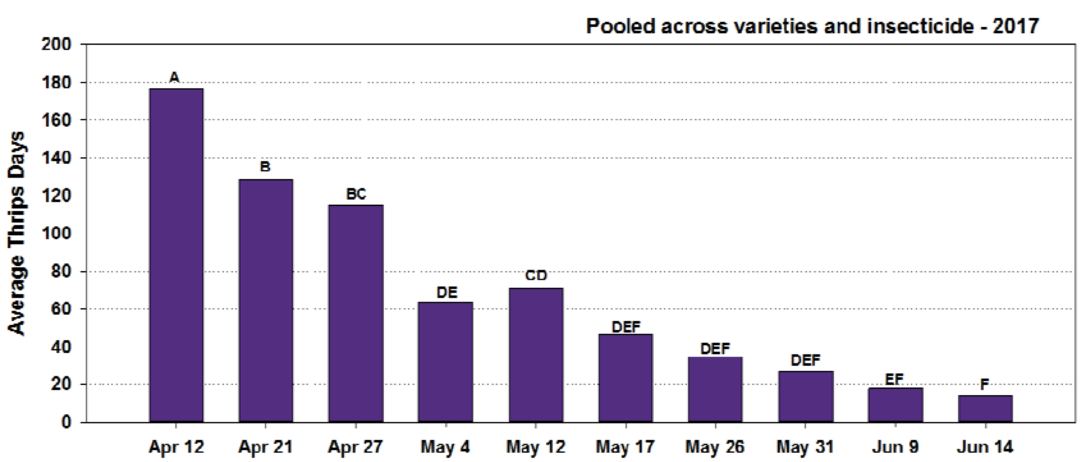

Figure 2. Accumulation of thrips days by planting date in cotton during 2017 (Blackville, SC). Bars indicate estimates of thrips days from plots including both varieties and treatments.

Variety did not affect populations of thrips, but plots treated with phorate exhibited significantly reduced populations of thrips (Table 3, Figure 3). In-furrow application of granular phorate has been shown to be an effective chemical management tool of thrips populations (Reisig et al. 2015). No significant interactions effecting populations of thrips were found between planting date, treatment, or variety. Populations of thrips in South Carolina generally declined as the growing season progressed. Cotton planted in April was infested with the highest populations of thrips. Cotton planted early (April to early May) observed the most benefit from insecticide treatments, as thrips populations were highest during that period.

Table 3. Significance of factors influencing Thrips Days.

Effect	Num DF	Den DF	F Value	Pr > F
Planting Date	9	52.3	25.66	<.0001
Treatment	1	92.34	38.20	<.0001
Variety	1	92.47	0.57	0.4540
Treatment*Variety	1	100.1	1.16	0.2843
Treatment*Planting Date	9	91.52	1.42	0.1924
Planting Date*Variety	9	90.98	0.73	0.6841
Treatment*Planting Date*Variety	9	99.09	0.23	0.9889

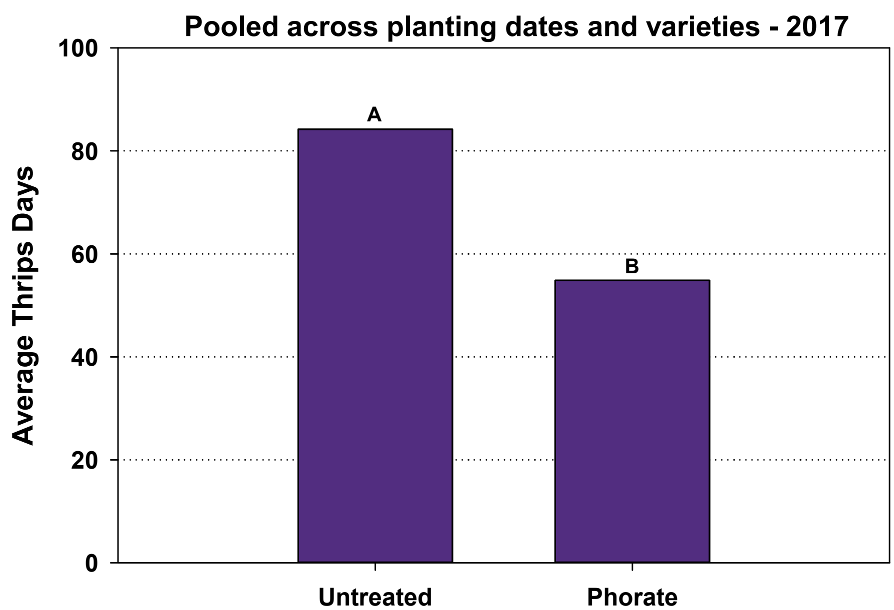

Figure 3. Average thrips days found in each insecticidal treatment of cotton pooled for all planting dates and varieties during 2017 (Blackville, SC). Phorate applied as an in-furrow granule at 5 lb/acre.

Injury ratings positively correlate with higher sample sizes of thrips. Planting date, variety, and insecticide treatment were significant factors effecting observed injury ratings (Table 4). The only significant interaction between effects was between planting date and variety. Average injury ratings for levels of both variety and treatment together and treatment and planting date together were not significantly different. Both varieties experience similar levels of infestation of and injury from thrips. The only planting date with a significant interaction of variety and planting date was 31 May (Figure 4); however, there was no biological basis for this difference. Most planting dates in the trial did not become infested with economically damaging levels of thrips. Plots treated with phorate observed less injury than plots that were untreated (Figure 5). Some individual plots reached economic levels of injury, but the overall level of damage was not economically (defined as '3' on injury scale) significant (Figure 5).

Table 4. Significance of factors influencing cotton injury from thrips.

Effect	Num DF	Den DF	F Value	Pr > F
Planting Date	9	27	14.94	<.0001
Treatment	1	90	37.80	<.0001
Variety	1	90	31.95	<.0001
Treatment*Variety	1	90	2.86	0.0942
Treatment*Planting Date	9	90	1.91	0.0601
Planting Date*Variety	9	90	2.52	0.0126
Treatment*Planting Date*Variety	9	90	0.78	0.6385

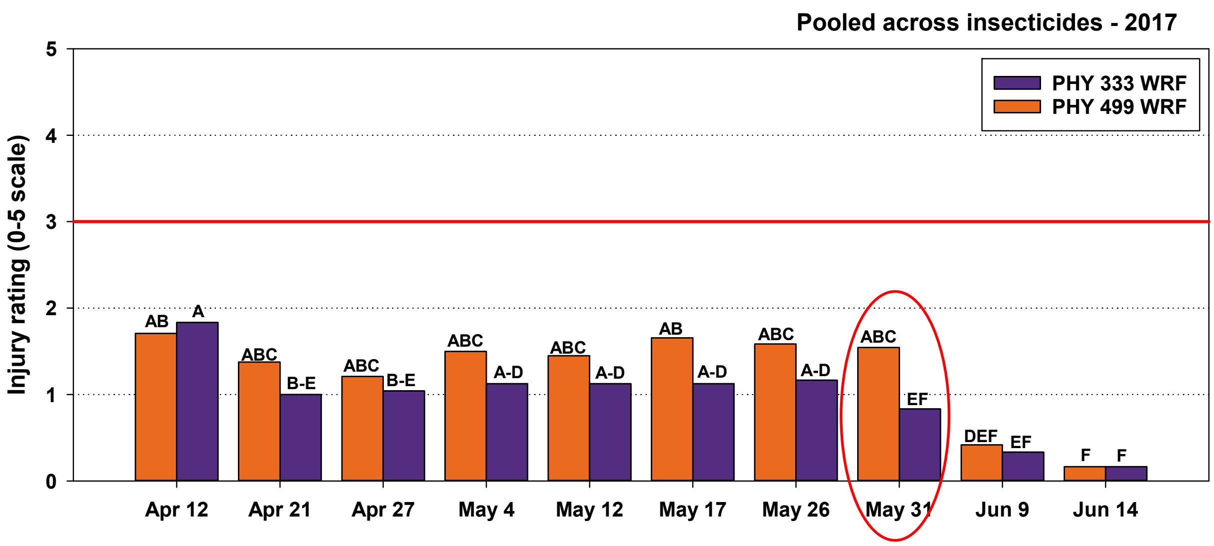

Figure 4. Average cotton injury from thrips by planting date and variety in 2017 (Blackville, SC)

Population density and injury from thrips in the trial did reach not high enough sizes to cause detectable yield loss from differences in variety or treatments (Table 5). Both varieties experience highest yields when planted in May (Figure 6).

Variety

When unaided by insecticide treatment, variety did not influence populations of thrips and calculated thrips days statistically (Table 6). Use of insecticide (phorate or acephate) at planting did have a significant impact on calculated thrips days (Table 6, Figure 6). Varieties treated with at-plant insecticide were infested with significantly fewer thrips than untreated varieties (Figure 6).

While the effect of insecticide treatment on thrips was significant, no difference between treatment with phorate or acephate was measured (Figure 6). The interaction between treatment with insecticide and variety was significant (Table 6), indicating that treated varieties had more influence on thrips and calculated thrips days than untreated varieties (Figure 7).

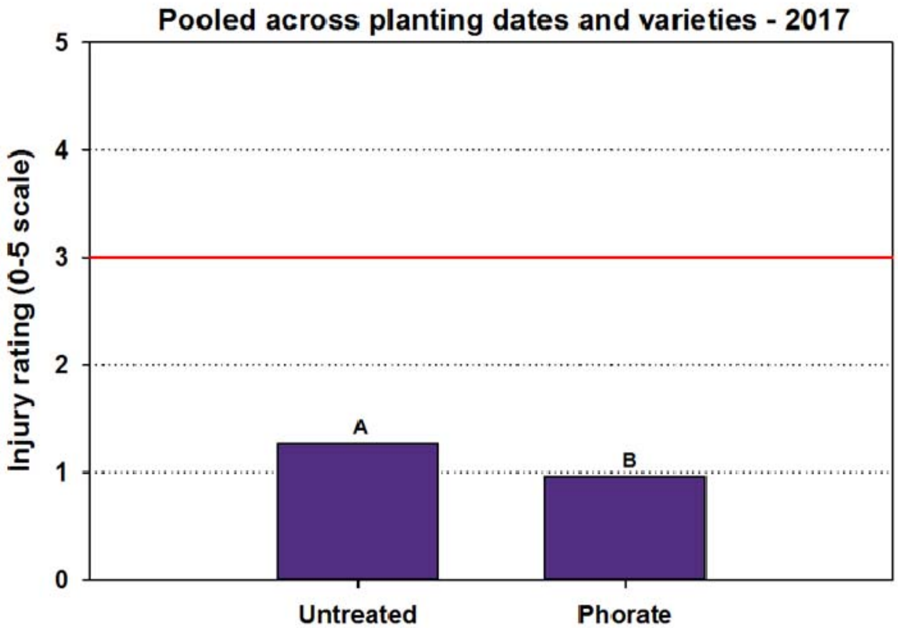

Figure 5. Average cotton injury by treatment in Blackville, SC, 2017. Phorate applied as in-furrow granule at 5 lb/acre.

Table 5. Significance of factors influencing seed cotton yield.

Effect	Num DF	Den DF	F Value	Pr > F
Planting Date	9	42.05	10.12	<.0001
Treatment	1	88.54	0.01	0.9252
Variety	1	87.25	2.39	0.1254
Treatment*Variety	1	98.86	0.02	0.8851
Treatment*Planting Date	9	87.43	0.66	0.7452
Planting Date*Variety	9	86.89	2.70	0.0080
Treatment*Planting Date*Variety	9	95.54	1.38	0.2094

Table 6. Significance of factors influencing Thrips Days

Effect	Num DF	Den DF	F Value	Pr > F
Variety	11	175.1	0.95	0.4964
Treatment	2	1327	520.70	<.0001
Variety*Treatment	22	1413	5.87	<.0001

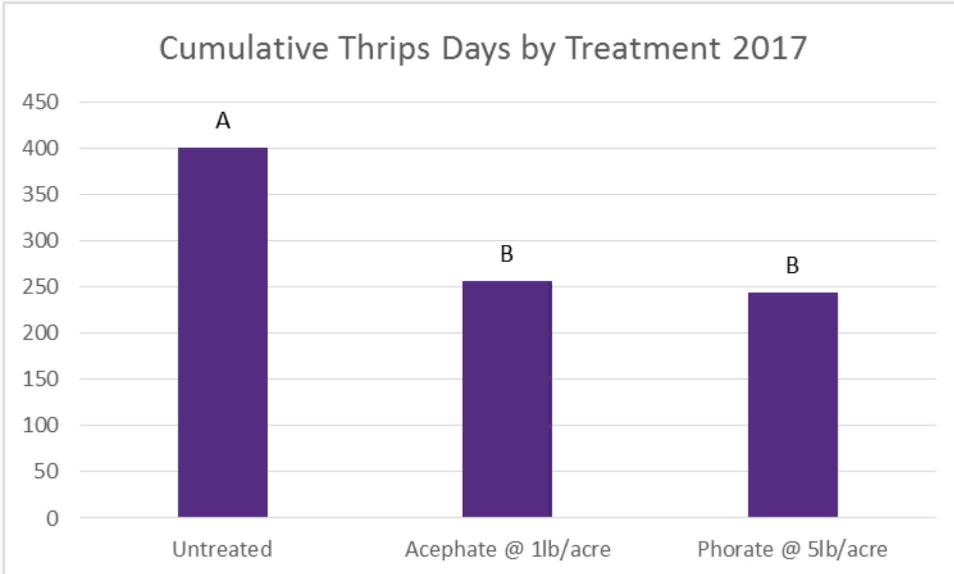

Figure 6. Effect of insecticide treatments on thrips days in 2017 (Blackville, SC).

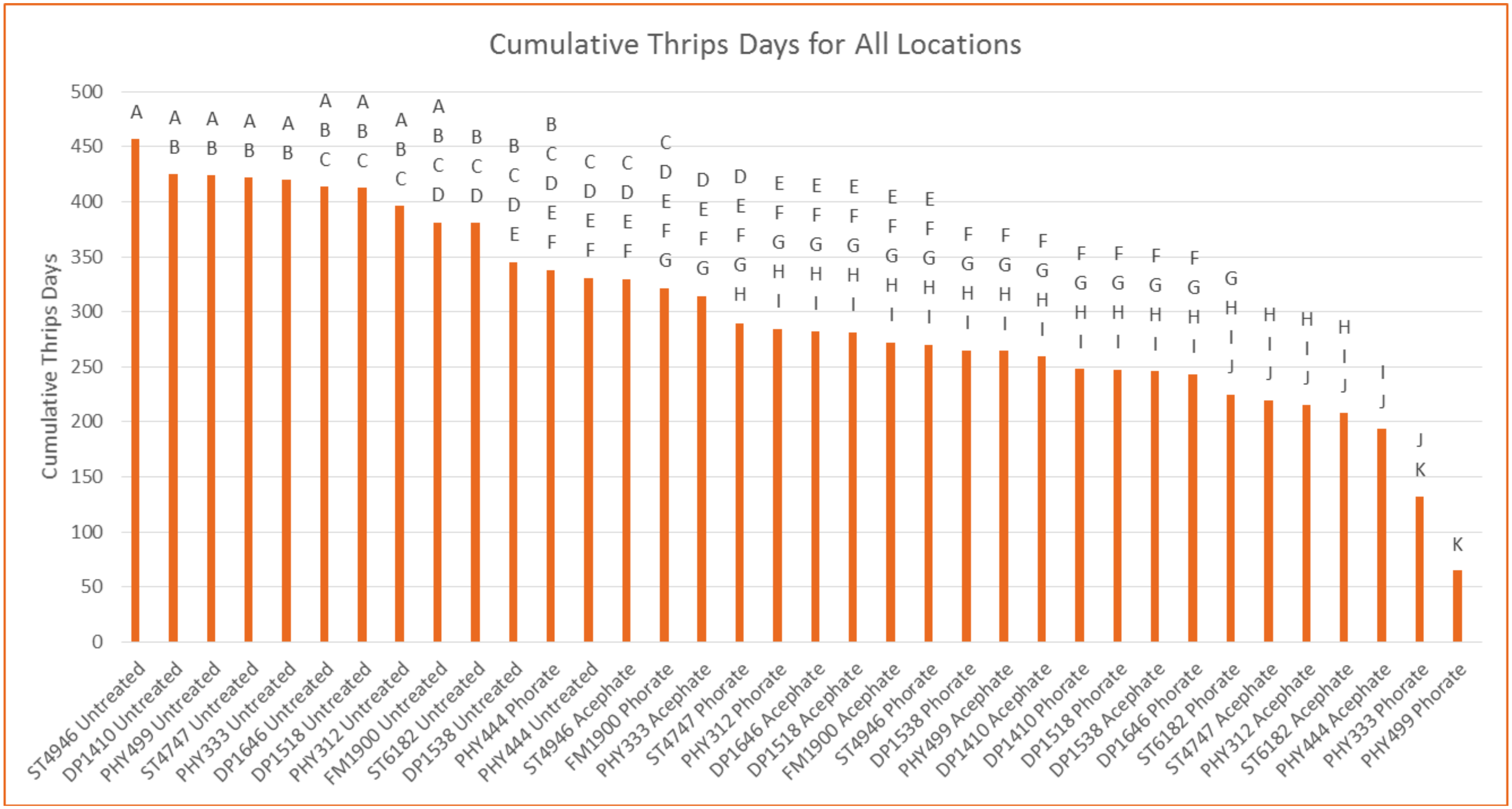

Figure 7. Effect of variety and treatment on thrips days in 2017 across all sites. Phorate treatment applied as in-furrow granule at 5 lb/acre. Acephate applied as in-furrow spray at 1 lb/acre.

Plots left untreated were generally infested with more thrips than plots with an at-plant insecticide treatment, and most varieties treated with insecticide were infested with thrips at similar densities despite choice of insecticide (Figure 7). FM 1900 displayed statistically lower injury than DP 1538. The biological basis of differing injury from thrips is unknown, but is most likely from antibiosis or antixenosis resulting from differing chemical properties of the cotton plants (Leigh 1995). Injury ratings were generally higher in plots with larger populations of thrips. Both variety and treatment were each significant in their effects on estimated injury ratings in the field, but they were not significant as an interaction (Table 7).

Table 7. Significance of factors influencing cotton injury from thrips.

Effect	Num DF	Den DF	F Value	Pr > F
Variety	11	813.7	2.09	0.0187
Treatment	2	814.5	296.00	<.0001
Variety*Treatment	22	814.1	0.65	0.8847

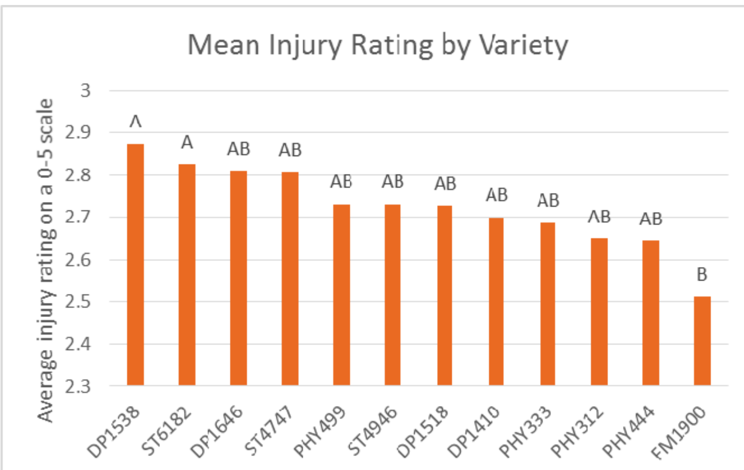

Figure 8. Effect of variety in 2017 across all sites.

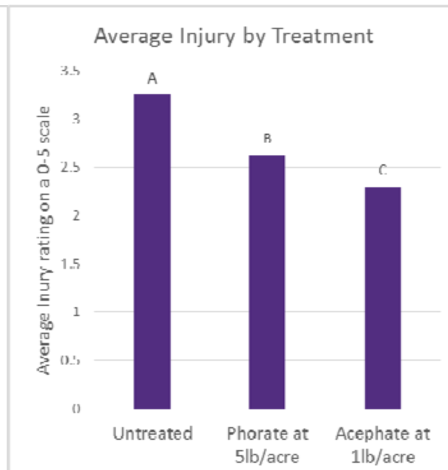

Figure 9. Effect of treatment in 2017 across all sites.

Injury ratings, on average, did not reach a level at which a foliar application of insecticide would be applied ('3') for any variety (Figure 8). There was no interaction between insecticide treatment and variety for injury ratings (Table 7). Injury from thrips was lowest in plots treated with acephate, but injury in plots treated with phorate was also lower than the untreated control (Figure 9).

Table 8. Significance of factors influencing seed cotton yield.

Effect	Num DF	Den DF	F Value	Pr > F
Variety	11	207	2.57	0.0045
Treatment	2	1829	28.56	<.0001
Variety*Treatment	22	1930	4.29	<.0001

All interactions and variables tested were significant for yield (Table 8). Overall, yields were highest in plots treated with in-furrow application of acephate, and the use of phorate as an in-furrow granule also resulted in significantly more seed cotton than untreated control plots (Figure 10). PHY 444 showed statistically better yield than DP 1410, ST 6182, and FM 1900 (Figure 10). Two of the three varieties with significantly lower yields (Figure 11) also displayed the highest levels of estimated injury (Figure 8). The only exception was FM 1900, which had a low injury (Figure 8) and low yield (Figure 11) compared with other varieties.

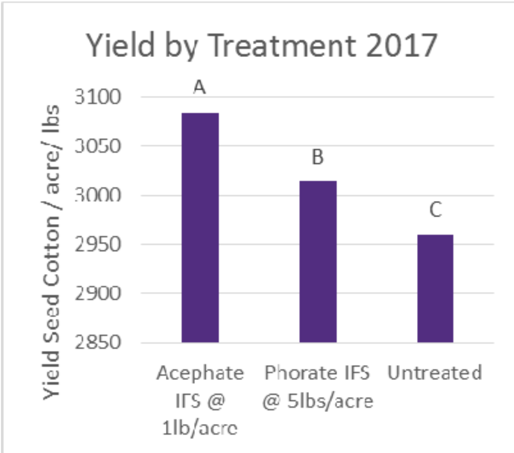

Figure 10. Effects of treatment on seed cotton yield across all sites in 2017.

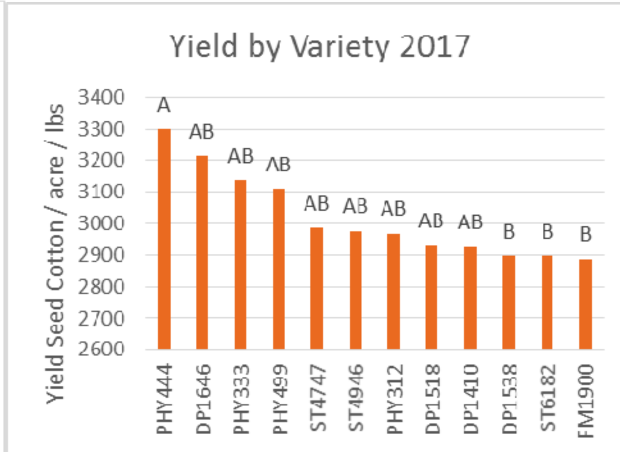

Figure 11. Effects of variety on seed cotton yield across all sites in 2017.

Summary

Thrips populations in South Carolina were highest in early planted cotton. Cotton planted before mid-May received the most benefit from at-plant insecticide. Cotton planted mid-May or later experienced decreased pressure from thrips, and reduced benefits from insecticide use were observed. Cotton planted after mid-May experienced reduced benefits from both acephate and phorate insecticide applications applied at-plant. At-plant treatments are a useful tool for managing risk from thrips in cotton when thrips populations are high enough to cause economic damage. Results demonstrate the importance of planting date for risk due to thrips and suggest that planting date could be used to mitigate risk of thrips injury in cotton and reduce costs of controlling thrips in cotton. A model developed and refined using data from these experiments is available to help predict risk from thrips due to planting date (http://climate.ncsu.edu/CottonTIP). Differences in varietal susceptibility to thrips were subtle but measurable with some varieties, particularly if used with an at-plant insecticide. The significant interaction of insecticide and variety will require additional analyses to determine if there were antagonistic or synergistic impacts that affected density of and injury from thrips. Selecting high yielding varieties that are less susceptible to thrips should be a goal, but determining what makes varieties less susceptible to thrips remains a topic for further research. Varietal susceptibility should be complemented with use of insecticides at planting to avoid yield loss under moderate to high pressure from thrips. At-plant applications of insecticide, such as phorate or acephate, remain effective at managing infestations of thrips in seedling cotton, particularly if used in combination with high yielding varieties with putative reduced susceptibility to thrips. Further research and investigation into varietal susceptibility to thrips in cotton is warranted.

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