TIMING OF COTTON FLEAHOPPER HERBIVORY AND COTTON'S COMPENSATORY RESPONSE

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Abstract

One defense strategy plants utilize against herbivory is tolerance. When plants tolerate herbivores, yield is unaffected because they alter their growth and development patterns to compensate for damage. In some cases, this response is exaggerated and plants "overcompensate" for herbivory. Thus, yield can be directly improved by herbivory. Overall, it is important to consider the factors that facilitate compensatory or overcompensatory responses of crops in order to improve the management of pests. In previous studies, Upland cotton has been found to tolerate early season herbivory by thrips and aphids. In this study we set out to determine if the timing of herbivory affects cotton's ability to tolerate feeding by a key pest, the cotton fleahopper, *Pseudatomoscelis seriatus* (Hemiptera: Miridae). We used cages to manipulate fleahopper presence on cotton terminals during early weeks of square production (weeks 1 through 4). We found evidence for compensation in overall lint yield in addition to a trend for fleahopper infestation to increase lint yield by 5-28% during the first three weeks of squaring. In contrast, lint yield was decreased by 20% following infestation in the 4th week of squaring. Lint yield from the 1st and 2nd fruiting positions was invariable. However, fleahopper infestation during the 1st -3rd weeks of squaring increased lint production by 9-34%, at the 3rd fruiting position, more lateral positions, as well as on the vegetative branches. Thus, cotton likely compensated for early season fleahopper herbivory by producing additional lint at the lateral and vegetative fruiting positions. Timing of fleahopper herbivory did not affect any fiber quality, but fleahopper herbivory increased micronaire. Overall, this study found that cotton can compensate for fleahopper herbivory during the early weeks of squaring and performance may be improved by fleahopper presence.

Introduction

To cope with herbivores, plants may utilize tolerance as a defense strategy and mitigate the potential effects of herbivory. Plants can compensate for damage by altering their growth, development, or metabolic processes so that performance is unaffected by damage (Tiffin 2000). In some cases this response can be exaggerated and plants can "overcompensate" for herbivory, resulting in improved plant performance after attack (Ring et al. 1993, Agrawal 2000). Understanding the compensatory or overcompensatory responses of crop plants is important because herbivores alter plant growth in ways that may have neutral or positive economic impacts. Thus, continued investigation into the conditions that facilitate compensation or overcompensation in cotton will improve pest management.

In previous studies, cotton has been found to tolerate early season herbivory by thrips (Sadras and Wilson 1998, Lei and Wilson 2004) and aphids (Rosenheim et al. 1997). Another early season pest, the cotton fleahopper, *Pseudatomoscelis seriatus* (Hemiptera: Miridae), has been of increased concern for producers since the integration of transgenic cotton to control Lepidopteron pests, and success of the boll weevil eradication program. In 2010 for example, fleahoppers infested 3,533,590 acres of cotton in Texas at a cost of $4.72 per acre for control (Williams 2011). This is the highest cost for control among all pests in Texas in 2010 (Williams 2011).

The cotton fleahopper preferentially feeds on cotton's terminal meristem and developing squares, and can cause a reduced square set (Chen et al. 2007). Regardless, cotton has been found to typically compensate for upwards of 30% square loss when no control measures are used against fleahoppers (Chen et al. 2007, Sansone et al. 2009). There has also been intermittent reports of overcompensation following fleahopper herbivory (Ring et al. 1993). However, how plants respond to herbivory during any given growing season depends on multiple variables including herbivore density, feeding duration, and infestation timing (Sadras and Felton 2010). In an effort to clarify the conditions that facilitate cotton compensation to fleahopper feeding, the primary objective of this study was to determine the effect of timing of fleahopper herbivory on cotton's ability to compensate or overcompensate for fleahopper feeding.

Materials and Methods

This experiment was conducted using Delta Pine 174 RR cotton grown under furrow irrigation at the Texas A&M Field Laboratory in Burleson County, TX in 2011. Planting was complete in late April and eighty experimental plots distributed among 15 rows were randomly assigned one treatment within a 4x2 factorial design. Factors included week of squaring (1st, 2nd, 3rd, or 4th) and fleahopper presence (present or absent). Experimental plots were 1.5m in length with 1.5m buffer zone between plots within a row. There were 10 replicates per treatment combination. After emergence, plants were monitored for the appearance of first squares and five plants per plot were treated within the first four days of the treatment week assigned. First week of squaring treatments began in early June, while fourth week of squaring treatments were complete by mid-July. Plants were caged at the terminal (Figure 1), enclosing one adult fleahopper for 48 hours. Cages on control plants were fleahopper free. Adult fleahoppers used for this experiment were collected from nearby feral fields of Silverleaf nightshade, *Solanum elaeagnifolium*, and maintained on a green bean diet until used in the experiment. In experimental plots which were assigned to be fleahopper infested, data were only collected from plants where the fleahopper was found alive in the cage following the treatment period.

Figure 1. Fleahopper cage at cotton plant terminal

Harvest and plant mapping were completed in mid-September over two consecutive weekends. Thus, lint yields are blocked by harvest date, and each harvest date included randomly selected plots to represent each treatment combination. All open bolls were hand harvested by fruiting position (1st, 2nd, and "3+") and ginned using 8 or 10 saw gins depending on sample size. "3+" position bolls included bolls collected from lateral fruiting positions 3 and higher, as well as bolls collected from the vegetative branches. Three samples of harvested first position lint were analyzed for quality parameters by the Texas Tech Fiber and Biopolymer Research Institute in Lubbuck, TX.

Results and Discussion

Lint Yield

Total lint yield per acre for each treatment combination are shown in Table 1. Lint yield (lbs. per acre) did not differ statistically, regardless of treatment combination of fleahopper infestation at the various weeks of squaring ($F_{3,65}$=1.805 p= 0.164). There was, however, a trend for an overall increased yield following fleahopper infestations at the 1st, 2nd and 3rd week of squaring by 18%, 28% and 4% respectively. In contrast, following infestation at the 4th week of squaring yield was decreased by 20%. Harvest date did affect lint yield (Table 1, $F_{3,65}$=3.377 p= 0.029); larger amounts of lint were harvested from plants during the later harvest dates (data unpublished). Fleahopper infestations tended to increase lint yield in the later harvested plots ($F_{3,65}$= 2.971, p= 0.054, data unpublished). These date interactions may be due to the additional week for bolls to mature.

Table 1. Mean values of lint yield (lbs./acre) ± SE from each treatment combination of fleahopper herbivory at the different weeks of squaring (Treatment*Week). Effects shown below of harvest date (Date), the interaction of harvest date and fleahopper infestation treatments (Date*Treatment), the interaction of harvest date, fleahopper infestation treatment and week of squaring (Date*Treatment*Week).

	Lint Yield (lbs./acre) by Week of Squaring			
Treatment	1st	2nd	3rd	4th
Fleahopper	4460 ± 693	6545 ± 741	4436 ± 478	3885 ± 502
Control	3781 ± 478	5108 ± 478	4226 ± 478	4913 ± 478
Effects				
Date	p= 0.029			
Date*Treatment	p= 0.054			
Treatment*Week	p= 0.164			
Date*Treatment*Week	p= 0.080			

Lint Yield by Fruiting Position

Lint yield per acre at the different fruiting positions harvested from plots of each treatment combination are shown in Table 2. Timing of fleahopper infestation had no effect on lint yield from first, second and “3+” position bolls ($F_{3,65}$=0.464 p=0.709, and $F_{3,65}$=0.653 p=0.586, $F_{3,65}$=1.484 p=0.235 respectively). Harvest date had a marginal positive effect on lint yield from “3+” positions ($F_{3,\ 65}$=2.544 p=0.071), including a positive interaction with fleahopper infestation at the different weeks of squaring ($F_{3,65}$=2.022, p=0.065).

Table 2. Mean values of lint yield (lbs/acre) ± SE harvested from different fruiting positions from each treatment combination of fleahopper herbivory at the different weeks of squaring (Treatment*Week). Effects shown below of the effect of fleahopper infestation alone on lint yield (Treatment), the interaction of harvest date and fleahopper infestation treatments (Date*Treatment), the interaction of harvest date, fleahopper infestation treatment and week of squaring (Date*Treatment*Week) as well as the fleahopper infestation interaction with week of squaring (Treatment*Week).

	Lint Yield (lbs./acre) by Fruiting Position		
Week of Squaring	1st	2nd	"3+"
1st			
Fleahopper	1354± 216	728.93 ± 166	2326 ± 587
Control	1207 ± 152	718.41 ± 114	2132 ± 405
2nd			
Fleahopper	1583 ± 238	1075 ±177	3916 ± 628
Control	1403 ± 152	808 ± 114	2917 ± 405
3rd			
Fleahopper	1300 ± 152	778 ±114	2512 ± 405
Control	1380 ± 152	866 ± 114	2039 ± 405
4th			
Fleahopper	1214 ± 160	640 ± 120	2060 ± 425
Control	1256 ± 152	747 ± 114	2901 ± 405
Effect			
Treatment	p= 0.863	p= 0.890	p= 0.537
Treatment*Week	p= 0.709	p= 0.586	p= 0.235
Date*Treatment	p= 0.040	p= 0.976	p= 0.071
Date*Treatment*Week	p= 0.292	p= 0.436	p= 0.065

Fiber Quality

Fiber qualities from samples of each treatment combination are shown in Table 3. There was no effect of timing of infestation on fiber micronaire, length, uniformity, and strength. Micronaire was increased by fleahopper herbivory, regardless of the timing of infestation (Table 3; $F_{1,65}$=7.807 p=0.023).

Table 3. Mean values of fiber qualities from each treatment combination: cotton terminals caged with and without (control) at different weeks of squaring (1st-4th). Effects shown below of fleahopper infestation interaction with week of squaring (Treatment*Week), and fleahopper infestation (Treatment) effect alone.

	Fiber Quality			
Week of Squaring	Micronaire	Length	Uniformity	Strength
1st				
Fleahopper	5.13	1.10	82.97	29.83
Control	4.97	1.09	82.00	30.90
2nd				
Fleahopper	5.23	1.08	82.57	30.53
Control	4.93	1.11	82.77	29.90
3rd				
Fleahopper	4.93	1.09	82.47	29.63
Control	4.97	1.08	82.97	30.77
4th				
Fleahopper	5.17	1.09	81.53	29.40
Control	5.00	1.08	82.93	31.13
Effect				
Treatment	p= 0.023	p= 0.800	p= 0.539	p= 0.105
Treatment*Week	p= 0.256	p= 0.144	p= 0.363	p= 0.348

Summary

It is important to consider the conditions that facilitate compensation and overcompensation of plants to their herbivorous pests in order to employ efficient pest management. The cotton fleahopper is an early season pest of cotton terminal nodes and early season squares. The objective of this study was to determine the effect of timing of fleahopper herbivory on the compensatory response of cotton to fleahopper feeding. This study found that not only did cotton tend to fully compensated for fleahopper herbivory, but it tended to overcompensate and produce a higher lint yield following infestation. This result was regardless of timing of infestation. Other studies have reported cotton's compensatory response (Parker and Buehring 2006, Sansone et al. 2009), or trend for overcompensation (Chen et al. 2007, Ring et al. 1993). Specifically, in this study fleahoppers tended to increase lint yield by 5-28% if infested during the first three weeks of squaring. However, lint yield decreased by 20% following infestation in the 4th week of squaring suggesting that cotton has decreased tolerance for loss of later season squares. This may be due to inadequate time left in the growing season to produce compensatory regrowth (Sadras and Felton 2010).

This study also supports previous research demonstrating that cotton mechanistically compensates for fleahopper herbivory is by altering resource allocation and producing more lint at lateral fruiting positions (Chen et al. 2007). This response has also been found following herbivory by the western tarnished plant bug, *Lygus hesperus* (Hemiptera:Miridiae) which is of the same feeding guild as fleahoppers (Parajulee et al. 2009). In this study the largest difference in lint yield among fruiting positions between fleahopper infested plants and control plants occurred at the "3+" fruiting position. The "3+" fruiting position included bolls harvested from the 3rd fruiting position and higher, as well as bolls from the vegetative branches. At these positions, fleahopper infestation resulted in a 9-34% increase in lint yield depending on the timing of infestation during the first 3 weeks of squaring. Further research is needed to quantify the relative contributions of these fruiting positions to this compensatory response of cotton to fleahopper herbivory. Nevertheless, in manual removal studies, early season removal of squares results in increased production of seed cotton in fruiting position other than the first. In this way, cotton completely compensates for even 100% fruit removal during three weeks of squaring (Bednarz and Roberts 2001).

In conclusion, continued research into the conditions that facilitate compensatory and overcompensatory responses of cotton is important to ensure that pest thresholds accurately reflect a need for insecticide application. This study found that not only can cotton compensate for fleahopper herbivory but that fleahoppers can induce an overcompensatory response in cotton to produce more lint yield. This evidence weakens the fleahopper's pest status and suggests that less extensive control may be warranted.

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