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SQUARE ABSCISSION IN CALIFORNIA COTTON AND THE STAGE STRUCTURE OF WESTERN TARNISHED PLANT BUG POPULATIONS

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Abstract

There is often a large amount of unexplained variability between the number of *Lygus* observed in a cotton field and the amount of damage the crop sustains. This study attempts to bridge the gap in our understanding by examining relationships between the stage structure of *Lygus hesperus* populations and overall damage to cotton squares. We sampled 38 fields of upland cotton during June through August of 2001-2003 in the cotton growing region of the San Joaquin Valley, CA. In these fields *Lygus* were collected and counted in sweep samples and later identified to developmental stage. In addition, cotton plants were mapped for square retention, and squares were dissected to assess overall damage to anther sacs. A multivariate regression revealed that 4th and 5th instars are positively correlated with anther sac damage and negatively correlated with square retention. Adult *Lygus* are only marginally correlated with plant damage, and 1st through 3rd instars did not correlate with plant damage. Finally, subsampling at each of five sites within cotton fields in 2003 revealed that adult densities positively correlate with plant damage. This result opens up possibilities of managing *Lygus* on a site by site basis. Overall, our analyses suggest that late instars of *Lygus hesperus* are particularly damaging to cotton squares, having the largest impact on square abscission. Therefore it is important for field scouts and entomologists to pay close attention to these developmental stages when collecting *Lygus* in sweep nets.

Introduction

Lygus has been known as a key pest of cotton since early in the 20th century (reviewed by Leigh and Goodell 1996). Although *Lygus* bugs are present in relatively low densities in cotton, they have been thought to cause large reductions in yields (Leigh et al. 1988, Ellsworth 2000). *Lygus* adults and nymphs feed on developing cotton buds (squares), injecting pectin-digesting salivary enzymes that cause cotton plants to actively abscise buds (Strong and Kruitwagen 1968, Strong 1970). In California *Lygus hesperus* comprises over 97% of *Lygus* individuals, and is generally thought of as a major pest of cotton (Godfray 2000). However, California growers have repeatedly stressed difficulties in connecting *L. hesperus* densities in a field with damage to cotton buds. This disconnect is reflected in scientific studies that have found a large negative impact of *L. hesperus* on yields (e.g. Falcon et al. 1971, Leigh et al. 1988) as well as little effect of *L. hesperus* on yields (Falcon et al. 1968, 1971, Gutierrez et al. 1977). This has made *L. hesperus* a particularly feared pest, because it can cause large amounts of damage, in an unpredictable way, at seemingly very low densities.

One potential explanation for the disconnect between *Lygus* densities and cotton bud damage is that individual *Lygus* are behaving differently (i.e. imposing more or less damage) in different fields. Past work has suggested that *L. hesperus* nymphs inflict damage to buds that is equal to (or greater than) that of adults (Gutierrez et al. 1977, Ellsworth 2000). In addition, recent field-based behavioral observations have suggested that *L. hesperus* nymphs spend as much time as female adults on buds and that male adults spend less time on buds (Rosenheim et al. in review). However *Lygus* nymphs are very hard to sample, making them practically "invisible" from a management perspective (Byerly et al. 1978). If nymphs are generating much of the damage that occurs in cotton fields, it would be worthwhile overcoming these sampling limitations.

Recent work has documented that the absolute stage structure of *Lygus* populations is variable across fields, and that sweep nets are a reliable way of sampling each developmental stage (Zink and Rosenheim 2003). Following up on this study, we have used sweep samples to assess the stage structure of *Lygus* populations across 38 cotton fields. We combine these *Lygus* density and stage structure estimates with assessments of square damage and retention to evaluate the relative contribution of each *Lygus* stage to producing plant damage. In addition, subsampling of fields in 2003 allowed us to look for correlations between the relative density of *Lygus* adults at a site within a field and the relative amounts of plant damage at that same site.

Materials and Methods

In 2001-2003 we sampled 38 cotton fields spanning the San Joaquin Valley of California (Firebaugh to Bakersfield). We confined our sampling to the period of peak square set (June through August). We focused on Acala cotton fields (primarily cultivars Maxxa and Phytogen 72) for our sampling, and chose fields that had not been sprayed with insecticides in the previous three weeks. The *Lygus* adults in these fields appeared to be almost exclusively *L. hesperus* (versus *L. elisus*), matching estimates of 96-99% *L. hesperus* in other fields (Godfrey 2000). In 2001 and 2002, a total of 17 fields were sampled with 10 runs of 50 sweeps at a particular site in each field. Plants were randomly chosen within the site (20 in 2002 and 30 in 2003) for mapping and square dissection. In 2002, half of the plants collected (i.e. 15 out of 30) were searched in great detail for nymphs. All nymphs collected from plants and sweep samples were identified as 1st through 5th instar in the laboratory.

In 2003, 21 fields were sampled for plant damage and *Lygus* densities, although in this year two sweep samples and four plant samples were taken at five different sites within each field. To obtain field-level estimates of *Lygus* densities and plant damage, averages were taken across all five sites in each field. These values were combined with values from 2001-2 for a multiple regression that controlled for year and *Lygus* stage. In addition, for each site within a field in 2003, we calculated the difference between *Lygus* adult densities at that site and the overall field average ('*Lygus* density residuals'). The same was done for plant damage and retention. We then examined the correlation between the *Lygus* density residuals and plant damage residuals, in order to assess the extent to which spatial heterogeneity in adult *Lygus* densities correlates with damage at a within-field scale. For the analyses we grouped developmental instars (1st-3rd and 4th-5th), which reflects the large disparity in the size of these two classes of nymphs.

Results

Multiple regression revealed that 4th-5th instar nymphs are positively correlated with anther sac damage and negatively correlated with square retention (Table 1). Adult *Lygus* followed the same pattern, but were only marginally significant (Table 1). In contrast, there was no relationship between the density of 1st-3rd instars and square damage or retention (Table 1).

The analysis of plant data for 2002 revealed a positive relationship between anther sac damage on a given plant and the presence of 4th-5th instar nymphs collected on the same plant (through a whole-plant search; Table 2). There was no relationship between densities of 1st-3rd instar nymphs and anther sac damage, or for any of the instars with square retention (Table 2).

For the 2003 data set we examined the relationship between adult densities at sites within a field and the plant damage and retention values at those sites. In particular, we calculated the deviation of these site-specific values from a field-level mean across all five sites within a field. There was an increase in the relative amount of anther sac damage (r=0.38, p=0.0001, N=105; Figure 1a) and square abscission (r=-0.27, p=0.005, N=1-5; Figure 1b) with an increase in the relative density of adult *Lygus*.

Discussion

The analyses in this study suggest that the late instars of *Lygus hesperus* are the most likely to have a large impact on square damage and abscission. Therefore it is important for field scouts and entomologists to pay close attention to these developmental stages when counting individual *Lygus* in sweep nets. Of course, even if nymphs are accurately counted in sweep nets, there is an inherent bias against collecting the smaller instars (Zink and Rosenheim 2003). Any true measure of nymphal densities will need to multiply each instar by a factor that is proportional to its overall sampling bias. In this case, the general rule of multiplying nymphs by a factor of 2 is appropriate for 4th and 5th instars (but grossly underestimates the density of 1st through 3rd instars). Despite the fact that 1st through 3rd instar nymphs did not correlate with square damage, it remains important to count these nymphs in sweep nets in order to predict the future presence of more damaging developmental stages such as the final instars.

It is likely that *Lygus* nymphs and adults are inflicting damage at different spatial scales due to the limited movement of nymphs relative to adults. At the level of the field, nymphs have been found to be more clustered in space relative to adults (Sevacherian and Stern 1972). Our results suggest that *Lygus* adults have enough of a limited dispersal (or consistent replacement rate) that particular sites within a cotton field show correlations between adult densities and plant damage. This would explain why damage and retention correlate with adult densities at sites within a field, and matches conventional wisdom that there are certain hotspots or problem areas within fields that do not disappear.

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Table 1: Field-level multiple regressions relating the density of *Lygus* in different developmental stages with plant damage.

	Percent damage to squares (anther sacs damaged)			
factor	**df**	**F**	**Prob**	**Direction**
Year	2	0.04	0.96	
Adults / sweep	1	2.6	0.07	positive
1st-3rd instars	1	0.9	0.60	
4th-5th instars	1	16.3	0.0002	positive

	Percent square retention (first position of top five nodes)			
factor	**df**	**F**	**Prob**	**Direction**
Year	2	0.6	0.56	
Adults / sweep	1	2.9	0.10	negative
1st-3rd instars	1	1.5	0.22	
4th-5th instars	1	15.9	0.0004	negative

Table 2: Plant-level multiple regressions relating stage of *Lygus* nymphs collected with damage on the plant on which they were collected (135 plants total).

	Percent damage to squares (anther sacs damaged)			
factor	**df**	**F**	**Prob**	**Direction**
Field		8	2.7	0.009
1st-3rd instars	1	0.9	0.35	
4th-5th instars	1	16.3	0.0003	positive

	Percent square retention (first position of top five nodes)			
factor	**df**	**F**	**Prob**	**Direction**
Field	8	23.1	0.0001	
1st-3rd instars	1	0.3	0.56	
4th-5th instars	1	2.4	0.13	

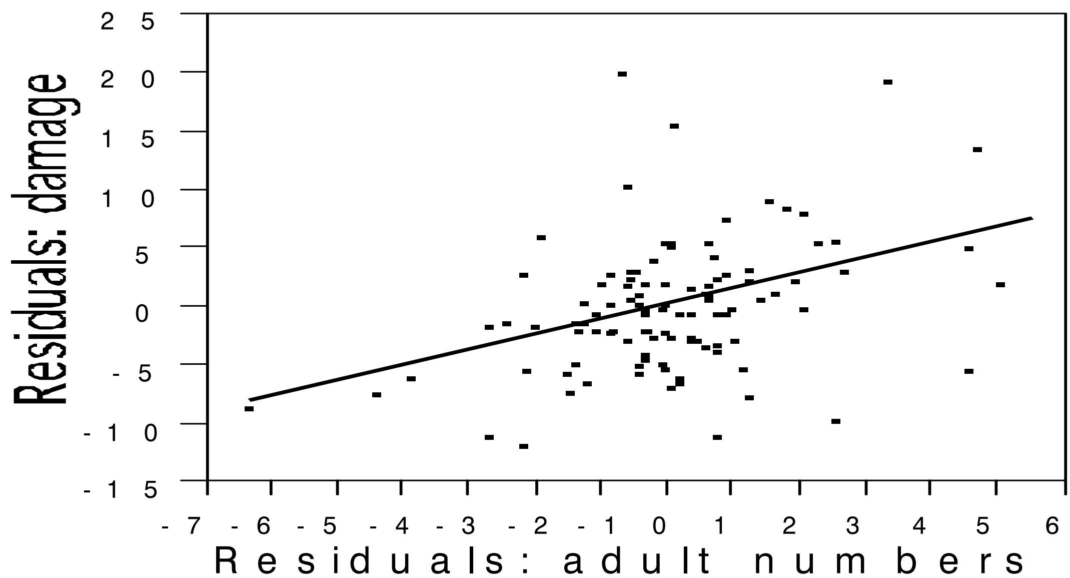

Figure 1A: Relationship between the number of *Lygus* adults at a site within a field (relative to the field mean) and the percent damage to anther sacs at the same site (relative to the field mean).

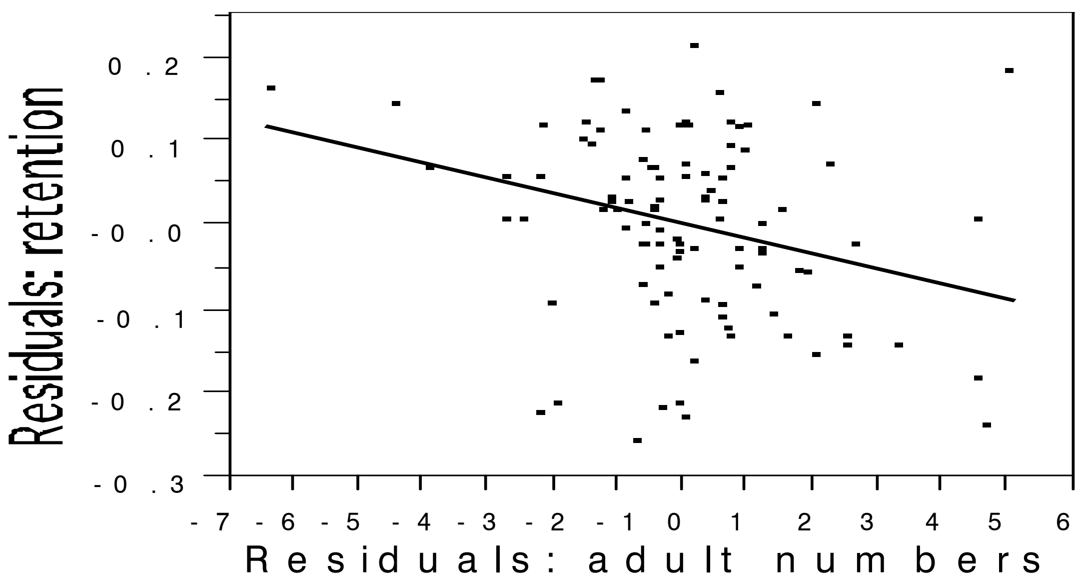

Figure 1B: Relationship between the number of *Lygus* adults at a site within a field (relative to the field mean) and levels of square retention at the same site (relative to the field mean).