SETTING AN ACTION (BOLL PROTECTION) THRESHOLD FOR VERDE PLANT BUG, BASED ON INSECT DENSITY, GREEN BOLL INJURY, OR BOTH

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Abstract

The ability to monitor verde plant bug (scouting) and inspect green bolls for damage (cracking green bolls) provided opportunity to assess if either or both of these in-season measurements had value in evaluating at-harvest boll damage. One in-season verde plant bug density measurement, three in-season plant injury measurements, and two at-harvest boll damage measurements were taken in 15 cotton fields in South Texas in 2010. Two measurements were seen as potentially useful indicators of at-harvest damage: verde plant bug density and internal boll injury using multiple regression. A one variable model (verde plant bug density) (r^2 = 0.74, P = 0.0002) and a two variable model (verde plant bug density—internal boll injury) (r^2 = 0.76, P = 0.0007) were selected as potentially useful indicators of at-harvest damage. These models and a one variable internal boll injury model were validated using 2011 and 2012 data. The results showed that combining verde plant bug density measurement taken at mid-bloom (scouting with a beat bucket) and measurement of proportion of bolls with internal injury (cracking green bolls < 1 inch in diameter) provided the best indication of at-harvest boll damage.

We provide here a Beta-version of a decision-making chart built from this model. We invite consultants and others to test this Beta-version in the field as you scout for verde plant bug and crack green bolls for detecting boll injury in-season. Your in-season measurements can be used in the chart to estimate potential at-harvest damage. Based on our work, this chart is broken into three sections of risk (green for low chance of at-harvest damage, yellow for potential at-harvest damage, and red for high chance of at-harvest damage). If you decide not to spray based on your experience, the at-harvest open boll damage ratings in your field can be compared with the expected open boll damage ratings in the decision-making chart. It can be modified based on your preference and experience.

Introduction

Applied to cotton insect pest management, selection of an in-season measurement is based on its reliability as an indicator of at-harvest damage and operational factors such as sampling efficiency. The use of more than one in-season measurement as an indicator of at-harvest damage may improve the reliability of predicting subsequent at-harvest damage and this benefit may off-set any increased operational cost in taking multiple measurements. This concept is especially relevant when at-harvest damage is dependent upon a sequence of plant responses triggered by insect feeding, such as when either stink bugs or plant bugs feed on green bolls. The sequence of events initiated by sucking bug feeding on cotton bolls has been documented for the southern green stink bug, and is similar for verde plant bug, based on assessment of plant response to verde plant bug feeding and associated cotton boll rot (Fig. 1).

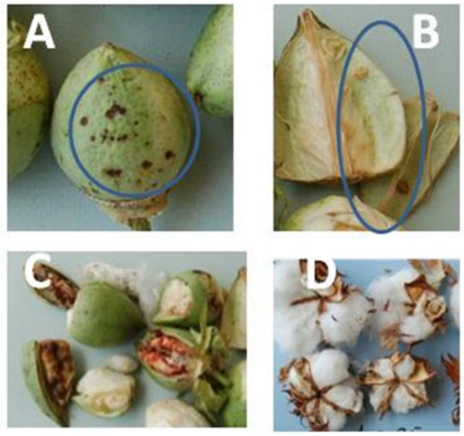

Fig. 1. Darkened lesions on the external boll wall result from initial probing with the piercing-sucking mouthparts (stylets) of boll-feeding sucking bugs like verde plant bug and stink bugs (A). If the mouthpart stylets penetrate the boll, the point of penetration may be visible when the boll is opened (cracking green bolls < 1 inch in diameter), callus tissue may occur around the penetration point (B), as well as the beginning of lint staining, boll rot, and seed injury within individual locules (C). Damage to the open boll varies at harvest, depending on the severity, intensity, and timing of events including the number of locules fed upon and the extent of pathogen introduction (D). Boll damage ranges from negligible with some indications of feeding on the carpel wall, internal locule-specific damage with no cotton boll rot, locule-specific damage with cotton boll rot, and more extensive damage and cotton boll rot in multiple locules (A through D).

For pest management purposes, boll protection guidelines for stink bugs have been based on frequency of green bolls with internal injury (cracking green bugs about 1 inch in diameter or quarter-sized bolls) because stink bugs are difficult to sample and internal damage provides a fair indicator of end-of-season damage to open bolls. For verde plant bug, bolls can also be inspected for damage, and the bug can be monitored with a beat bucket. Using these two measurements, we tested whether sampling for verde plant bug, internal green boll injury, or both provided the best indicator of end-of-season boll damage in South Texas where verde plant bug is important.

Methods

Verde plant bug scouting began early bloom in 15 cotton fields in the coastal cotton growing region of south Texas, 2010. Insect data were collected during mid-bloom for this work (about week three to four of bloom). Green boll data were taken two weeks later. Fields were randomly selected from a list provided by crop consultants: eight were selected within 8 km of the nearest coastline, inland bay, or coastal waterway (designated as coastal fields) and seven further inland (designated as inland fields). Locations by county were three in Calhoun County, one in Aransas County, six in Nueces County, three in Kleberg County, and two in Cameron County. Verde plant bug was the dominant boll-feeding sucking bug, and cotton boll rot was detected.

The in-season insect measurement was verde plant bug density at mid-bloom estimated using the beat bucket sampling method (n = 120-200 plants per field). The in-season plant measurement was taken from randomly selected green bolls about 1/3 to 1 inch diameter (n = 120 to 150 bolls per field). Bolls in this size range were known to be readily fed upon and damaged by verde plant bug. The bolls were opened and inspected for callous tissue, stylet penetration points, and lint and seed staining (Fig. 1BC). These in-season data were matched with subsequent open boll damage at harvest. Lint and seed was thoroughly inspected on randomly selected open bolls in the field (n = 120 to 150 bolls per field). Damage was scored using a five class locule damage scale (Fig. 2). The two in-season measurements were entered into stepwise multiple regression: verde plant bug per plant (x_1) and proportion of green bolls with internal injury of the carpel wall (x_2). Damage score (0—4 scale) at harvest was the dependent variable (y). Two other measures (external boll wall lesions and internal symptoms of cotton boll rot [Fig. 1AC]) were also considered but provided poor indication of damage and were not useful. These results were not included here.

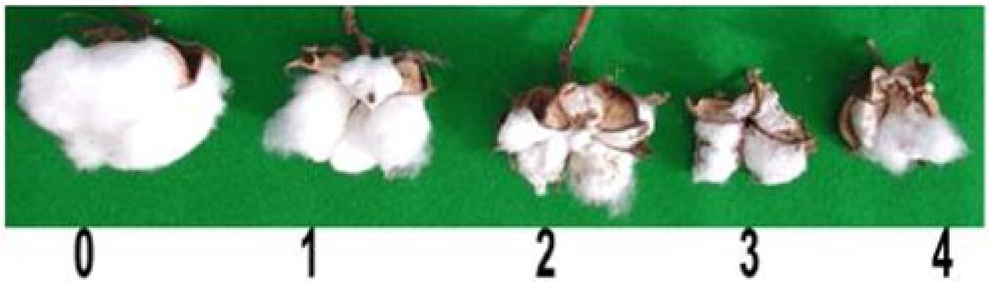

Fig. 2. At-harvest boll damage was scored using a five class locule damage scale. The scale was implemented for visual field assessment by equating the number of damaged locules directly to the scale: 0 = no locules damage, 1 = one locule damage, up to 4 damaged locules, and assuming damage affected at least a quarter of the locule.

Based on these initial results, a one variable verde plant bug density model (scouting for verde plant bug using a beat bucket), a one variable internal boll injury model (cracking green bolls), and a two variable verde plant bug density—internal boll injury model (using both in-season measurements) were compared in a validation exercise using additional data from 2011 and 2012 to help identify a general model applicable to a range of conditions in South Texas. Data for model validation came from a water regime—cultivar experiment conducted in 2011 and 2012, Corpus Christi, TX. Treatments were arranged in a split plot design with five replications. Three water regimes were set as the main plot and three (2011) or two (2012) cultivars were set as the split plot. Each subplot where data were taken measured 100 ft or more in length by four rows. The three water regimes were dryland, irrigation scheduled at 75% of evapotranspiration replacement, and irrigation scheduled at 90% of evapotranspiration replacement. The cultivars were Phytogen 367 WRF (PhytoGen Seed, Dow AgroSciences), Deltapine 1032 B2RF (Deltapine, Monsanto [used in 2011 only]), and Stoneville 5458 B2RF (Bayer CropScience). Agronomic practices were standard, and no insecticides were used.

Verde plant bug arrived four weeks after first bloom. Data were taken on the inner two rows, with half the plot devoted to insect and boll sampling and half the plot left undisturbed for yield. Insect counts of nymphs and adults were based on a 10-plant beat bucket sample per plot. Counts were adjusted to a plant basis, and averaged across the five replications of each water regime—cultivar treatment combinations (n = 50 plants per treatment combination). Two weeks later, the internal boll injury measurement was taken by inspecting 15 green bolls in the same plots (n = 75 plants per treatment combination). Boll damage scores were taken at harvest on the same number of open bolls.
The in-season measurements of verde plant bug density and proportion of bolls with internal injury during mid-bloom taken from all the water regime—cultivar treatment combinations were used as input variables in the three selected models to obtain prediction of the at-harvest boll damage score for each treatment. The at-harvest boll damage scores observed in the field were regressed on the predicted scores for each of the models across the 2011 and 2012 experiments (n = 15 for each regression) to test the match of the model predictions to the observed boll damage scores.

Results

Verde plant bug averaged 0.42 bugs per plant using the beat bucket sampling method during 2010, and represented about 99% of the boll-feeding sucking bugs collected in the region. The range of verde plant bug activity and boll damage was representative of that experienced when verde plant bug became recognized as a threat to cotton in the region. Damage to open bolls was subsequently detected near harvest in coastal fields where verde plant bug was detected and yield losses were observed (up to 25% of open bolls with cotton boll rot and an open boll damage score of about 0.8 to 1.0 using the 0 to 4 scale) (Brewer et al. 2012b). This evaluation verified that we were working with a range of fields that were showing little damage to economic damage from the verde plant bug.

Based on these results, we set an economic injury level damage score of 0.8. Working with economic thresholds of about half of the economic injury level is common, so an economic threshold at-harvest boll damage score of 0.25 to 0.50 was used. But decisions need to be made in-season with insect scouting and/or boll injury measurements, so we report here results on whether these in-season measurements are good indicators of at-harvest boll damage. If one or both are, we can relate our in-season measurement to expected at-harvest damage scores and evaluate if we are in at risk to economic damage using a working economic threshold of 0.25 to 0.50 at-harvest boll damage score.

Mean damage score of open bolls at harvest was linearly related to mean verde plant bug density observed mid-bloom (r^2 = 0.68, P = 0.0004) (Fig. 3). Proportion of green bolls with internal injury was a good indicator of open boll damage (r^2 = 0.72, P = 0.004) (Fig. 4). The stepwise multiple regression selected a one variable model (verde plant bug density) (y = 2.06x1 + 0.27; r^2 = 0.74; P = 0.0002, where y is predicted at-harvest damage score and x_1 is verde plant bug density per plant at mid-bloom using a beat bucket) and a two variable model (verde plant bug density—internal boll injury) ($y = 1.58x_1 + 0.65x_2 + 0.11$; r^2 = 0.76; P = 0.0007, where y is predicted at-harvest damage score, x_1 is verde plant bug density, and x_2 is proportion of bolls with internal injury, both taken at mid-bloom) as potentially useful indicators of at-harvest boll damage. Operationally, it was much easier to only estimate verde plant bug density using the beat bucket method, in contrast to adding the process of cracking green bolls to estimate proportion of bolls with internal injury. Biologically, adding an internal boll injury evaluation provided information to confirm another step further along the sequence of plant responses initiated by insect feeding. Based on our findings, either of the models may be acceptable; therefore, the one variable verde plant bug density model and two variable verde plant bug density—internal boll injury model were entered into a validation exercise in 2011 and 2012 using new data taken from field test in Corpus Christi. A one variable internal boll injury model was included to compare the possible approaches a pest manager may consider using.

In 2011 and 2012, there was low damage detected in the field test across all treatment combinations (range of 0.04 to 0.54 for damage score means [Table 1] compared with a high score of 1.5 in 2010 [Fig. 3]). We were below our expected economic injury level of about 0.8 damage score using the 0--4 scale, and this was verified by no lint and seed weight differences due to verde plant bug feeding. Relatively low verde plant bug pressure was also seen (< 0.20 verde plant bug per plant, Table 1) compared with up to 0.79 verde plant bug per plant in 2010 (see range in Fig. 4). A persistent drought was also notable (i.e., < 3 in. of rainfall in 2011 and < 6 in. of rainfall in 2012 from April 1 through Aug. 30, compared with 18 in. in 2010 and a 14 in. average over 125 years [taken from the National Weather Service]).

Fortunately the observed damage score means varied considerably in the test, and this allowed comparison of the observed damage scores to those predicted from these three models we were testing (Table 1). The predicted damage scores of the one variable verde plant bug model deviated from the observed damage scores in the field as shown by poor linear fit (P = 0.12) (in Table 1 compare columns 'Damage score obs' with 'Damage pred verde'). In contrast, the predicted values from the one variable internal boll injury model were linearly related to observed values (P < 0.0001), but the model overestimated at-harvest damage (slope of 0.42 differed significantly from 1.0, P < 0.0001) (in Table 1 compare columns 'Damage score obs' with 'Damage pred boll), which may result in insecticide treatment during the growing season that does not result in decreased at-harvest damage. Performance improved considerably when using both in-season measurements in the two variable model, as judged by a significant linear regression of the observed values on the predicted values (P < 0.0001). There was no significant deviation of the estimated regression slope of 0.85 from 1.0 (P = 0.29), which indicated that at-harvest boll damage predictions were a close match to the observed damage in the field (in Table 1 compare columns 'Damage score obs' with 'Damage pred verde--boll').

The two year validation in our study was consistent with the viewpoint that use of in-season insect density (verde plant bug density) can be prone to error when used alone to indicate at-harvest boll damage. Also cracking green bolls alone tended to overestimate damage. The validation showed that combining use of verde plant bug density and internal boll injury estimation improved their usefulness as indicators of at-harvest damage and avoided both of these problems (Table 1). Operationally, field detection for verde plant bug and injury can start at early bloom, although it is more likely verde plant bug will begin to move into cotton mid-bloom or later.

We note that continuing validation would be helpful to consider model performance above the range of low verde plant bug pressure experienced in 2011 and 2012. For this reason, we present a Beta-version of a decision-making chart built based on these results that can be further tested (Fig. 5). We invite consultants and other pest management professionals to test this Beta-version in the field as you sample for verde plant bug and crack green bolls for detecting boll injury in-season. If you decide not to spray based on your experience, the end-of-season open boll damage ratings can be compared with the expected open boll damage ratings in the decision-making chart.

Table 1. Validation of a one variable verde plant bug density model, a one variable internal boll injury model, and a two variable verde plant bug density—internal boll injury model, as indicators of at-harvest cotton boll damage, Corpus Christi, TX, 2011 and 2012.

Cultivar/water[1]	Verde plant bug obs. [2]	Boll injury obs. [2]	Damage score obs. [2]	Damage pred. verde [3]	Damage pred. boll [3]	Damage pred. verde--boll [3]
		2011				
Phytogen/Dry	0.04 ± 0.02	0.31 ± 0.06	0.040 ± 0.016	0.351	0.472	0.372
Phytogen/Low	0.05 ± 0.03	0.33 ± 0.04	0.067 ± 0.021	0.372	0.507	0.406
Phytogen/High	0.14 ± 0.09	0.29 ± 0.05	0.120 ± 0.033	0.556	0.437	0.522
Deltapine/Dry	0.00 ± 0.00	0.41 ± 0.07	0.067 ± 0.030	0.269	0.648	0.377
Deltapine/Low	0.02 ± 0.02	0.30 ± 0.08	0.107 ± 0.021	0.303	0.454	0.333
Deltapine/High	0.04 ± 0.02	0.20 ± 0.02	0.067 ± 0.021	0.351	0.278	0.303
Stoneville/Dry	0.02 ± 0.02	0.25 ± 0.05	0.040 ± 0.027	0.310	0.366	0.305
Stoneville/Low	0.04 ± 0.02	0.37 ± 0.03	0.080 ± 0.013	0.351	0.578	0.416
Stoneville/High	0.02 ± 0.02	0.29 ± 0.08	0.067 ± 0.021	0.310	0.437	0.289
		2012				
Phytogen/Dry	0.01 ± 0.01	0.67 ± 0.06	0.314 ± 0.105	0.289	1.105	0.559
Phytogen/Low	0.04 ± 0.02	0.71 ± 0.08	0.510 ± 0.088	0.351	1.176	0.634
Phytogen/High	0.07 ± 0.03	0.72 ± 0.10	0.542 ± 0.084	0.413	1.193	0.689
Stoneville/Dry	0.10 ± 0.05	0.89 ± 0.05	0.350 ± 0.037	0.474	1.492	0.849
Stoneville/Low	0.19 ± 0.08	0.81 ± 0.04	0.500 ± 0.095	0.659	1.352	0.939
Stoneville/High	0.04 ± 0.03	0.79 ± 0.07	0.457 ± 0.124	0.351	1.316	0.685

1. The cultivars were Phytogen 367 WRF, Deltapine 1032 B2RF (used in 2011 only), and Stoneville 5458 B2RF. The three water regimes were dryland (dry), irrigation scheduled at 75% of evapotranspiration replacement (low), and irrigation scheduled at 90% of evapotranspiration replacement (high).
2. Observed measurements (± SEM) were verde plant bug per plant at mid-bloom (verde plant bug obs.), proportion of green bolls with internal injury two weeks later (boll injury obs.), and at-harvest open boll damage (0--4 scale) (damage score obs).
3. Predicted damage scores from the one variable verde plant bug density model (damage pred. verde), one variable internal boll injury model (damage pred. boll), and two variable verde plant bug density--internal boll damage model (damage pred. verde—boll). See text for results of linear regression of observed and predicted values.

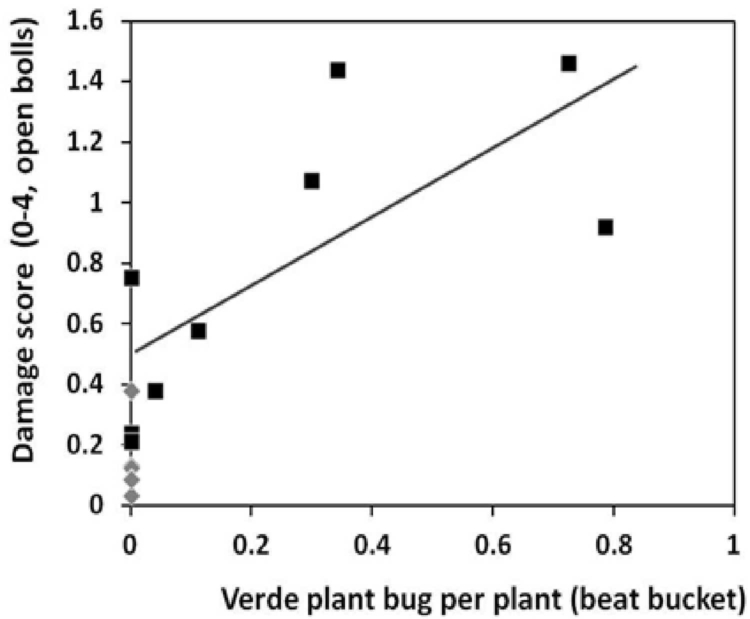

Fig. 3. Regression of mean damage score of open bolls at harvest on mean number of verde plant bug per plant detected mid-bloom with a beat bucket. Symbols indicate coastal fields within 8 km of the coastline and inland bays (squares) and inland fields (diamonds), South Texas, 2010.

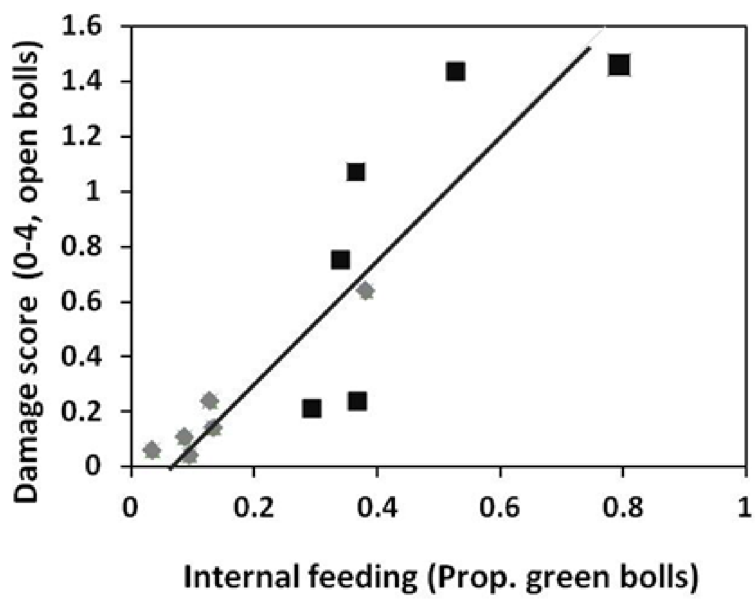

Fig. 4. Regression of mean damage score of open bolls at harvest on mean proportion of green bolls with internal injury to the carpel wall. Symbols indicate coastal fields within 8 km of the coastline and inland bays (squares) and fields further inland (diamonds), South Texas, 2010.

Open boll damage (100 bolls, 0-4 scale)

% Internal boll injury (40 bolls)											
80	0.63	0.71	0.79	0.87	0.95	1.03	1.11	1.18	1.26	1.34	1.42
70	0.56	0.64	0.72	0.80	0.88	0.96	1.04	1.12	1.20	1.28	1.36
60	0.50	0.58	0.66	0.74	0.82	0.90	0.97	1.05	1.13	1.21	1.29
50	0.43	0.51	0.59	0.67	0.75	0.83	0.91	0.99	1.07	1.15	1.23
40	0.37	0.45	0.53	0.61	0.69	0.77	0.84	0.92	1.00	1.08	1.16
30	0.30	0.38	0.46	0.54	0.62	0.70	0.78	0.86	0.94	1.02	1.10
20	0.24	0.32	0.40	0.48	0.56	0.64	0.71	0.79	0.87	0.95	1.03
15	0.21	0.29	0.37	0.44	0.52	0.60	0.68	0.76	0.84	0.92	1.00
10	0.17	0.25	0.33	0.41	0.49	0.57	0.65	0.73	0.81	0.89	0.97
5	0.14	0.22	0.30	0.38	0.46	0.54	0.62	0.70	0.78	0.85	0.93
0	0.11	0.19	0.27	0.35	0.43	0.51	0.58	0.66	0.74	0.82	0.90
	0	5	10	15	20	25	30	35	40	45	50

 # Verde plant bug per 100 plant

Fig. 5. We provide here a Beta-version of a decision-making chart built from the two variable verde plant bug density—internal boll injury model built from 2010 data and validated with 2011 and 2012 data. The expected at-harvest boll damage scores (0—4 scale) in the cells are calculated from the two variable model (verde plant bug density—internal boll injury) ($y = 1.58x_1 + 0.65x_2 + 0.11$; $r^2 = 0.76$; $P = 0.0007$, where y is predicted at-harvest damage score, x_1 is verde plant bug density, and x_2 is proportion of bolls with internal injury, both taken at mid-bloom). We invite consultants and others to test this Beta-version in the field as you sample for verde plant bug and crack green bolls for detecting boll injury in-season. Field detection for verde plant bug and injury can start early bloom, although it is more likely verde plant bug will begin to move into cotton mid-bloom and later. Verde plant bug density is estimated using a beat bucket shaking 100 plants, counting verde plant bugs after 10 plants are shaken and continuing in 10 spots in the field. Proportion of bolls with internal injury is estimated by cracking green bolls between 1/3 and 1 inch in diameter and inspecting the inside for penetration and callus tissue around the penetration point, as well as the beginning of lint staining, boll rot, and seed injury within individual locules. Based on our work, this chart is broken into three sections of risk based on our work (green for low chance of at-harvest damage, yellow for potential at-harvest damage, and red for high chance of at-harvest damage, using a working economic threshold of 0.25 to 0.50 at-harvest boll damage score). If you decide not to spray based on your experience, the at-harvest open boll damage ratings in your field can be compared with the expected open boll damage ratings in the decision-making chart. It can be modified based on your preference and experience.

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