# MODIFYING A PLANT MAPPING PROGRAM TO MEASURE AND VISUALIZE PLANT BUG INJURY TO COTTON

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## Abstract

Agronomic plant mapping tools are effective in measuring/evaluating characteristics of the cotton plant under many conditions, including plant bug densities, but can lack the ability to include desired plant bug injury information. These plant bug injury measurements are abscission and an injury rating of the boll on a 0 (no injury) to 4 (alllocules injured) scale. A plant mapping program (PMAP) has been modified to manage information related to plant bug injury in cotton along with the current suite of agronomic measurements in the system. The current tool manages information in a numerical and visual format. This presentation introduces this tool and invites input from others in the cotton industry. An alpha version of the program we used is available for review and comment via email request to djanderson@ag.tamu.edu.

## Introduction

Computer programs for plant mapping cotton can serve as useful tools in evaluating research data both analytically (numerical) and visually (graphs). Plant mapping programs for use in cotton include BOLOCATE, BPMP, Box Mapping, CALEX, DIAGRAMMER, and PMAP. Another program, COTMAN, uses data from mapping the first fruiting position of each branch of the cotton plant to determine crop developmental status, detect stress, and assist with management decisions (www.cotman.org: Cotton Incorporated).

We have used the cotton plant mapping program PMAP (Brewer et al. 2013) in plant bug studies for cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter), verde plant bug, *Creontiades signatus* (Distant). This program was developed by Dr. Juan Landivar and first released in 1993 and ran in FORTRAN while recent releases run in Excel. The program manages agronomic data (plant height, number of vegetative nodes, types of fruit by branch and position, etc.) and the output includes visual information using a two-dimensional array to show the within-plant pattern of the data and descriptive statistics.

The primary use of PMAP for our entomological application has been to calculate detailed fruit abscission information of which it has performed extremely well. A shortfall is that we were unable to utilize the data recorded for open boll insect damage scores (0-4 scale, Lei et al. 2003) and insect induced rot. We were also investing a large time investment to generate only abscission data and we desired an alternative visual display of the results as we were limited to bar charts. As a result of these desires we began working on a concept to 1) incorporate our insect damage data into the PMAP methodology, 2) develop alternative visual interpretations of the data, and 3) reduce the time requirement needed to collect and enter the data into PMAP. To accomplish and evaluate these goals we placed the PMAP methodology into an Excel spreadsheet that would calculate our insect damage scores, produce color graphics, and provide descriptive statistics. We have tested this concept using data from field trials in 2013-14. The process and results from one trial serves as an example and are provided here. The next step was to analyze the data and evaluate methods to improve the efficiency of data collection and reduce the volume of data with minimum negative affects to the usefulness of the results. The process we used to reduce the large volume of data is also discussed here.

## Process and Results

We begin with brief description of the process that was used to modify PMAP. This information is helpful in understanding the modified version of PMAP and will assist the user of potential tailoring of the program for their individual needs.

PAMP utilizes the data from each fruiting site by using the letters "a, b, o, and s" to represent the presence or absence of fruit as follows:

s = square    b = green boll    o = open boll    a = abscised site

An example of how these four letters are placed into PMAP can be seen in figure 1. PMAP uses these four letters to calculate agronomic information by fruiting position, by branch, and entire plant, replication, and treatment.

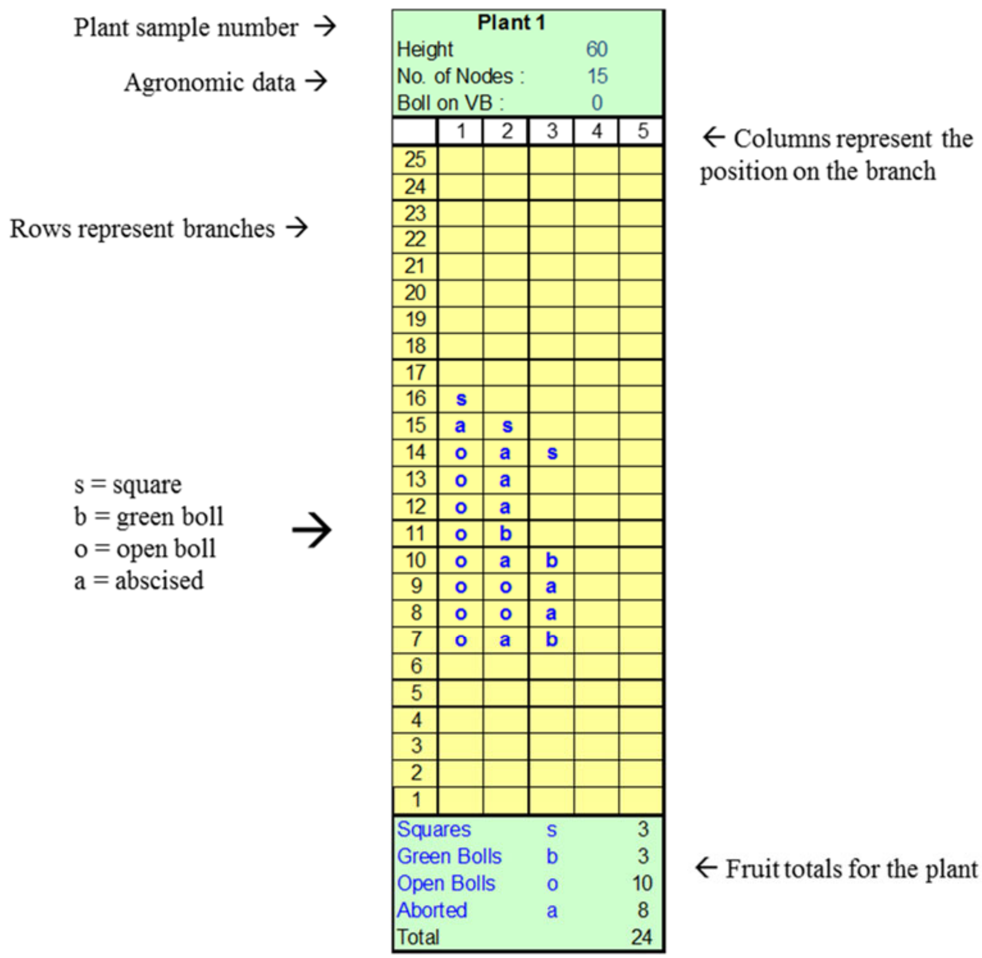


Figure 1. Example of how the data is entered into PMAP.

Our modified PMAP program drops the use of the letters "s and b" which eliminates the square and green boll data. (If the user desires square and green boll information then the user would use the current PMAP program.) The modified PMAP program continues the use of the letter "a" for abscised site and replaces the letter "o" with a "0, 1, 2, 3, or 4". The numbers 0-4 represent a) the presence of an open boll at that fruiting site and b) the amount of plant bug feeding is present on that boll. The 0-4 damage rating corresponds to the plant bug damage scale in figure 2 (Lei et al. 2003). The presence of insect induced boll rot is recorded in the modified PMAP by turning the color of the "cell" orange. The modified PMAP program does not have the programing to calculate rot, but the display clearly shows the pattern of rot within the plant in the visual display (Fig. 3).

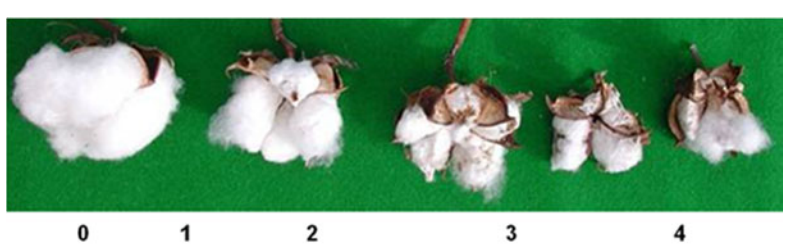


Figure 2. 0-4 insect damage rating scoring system

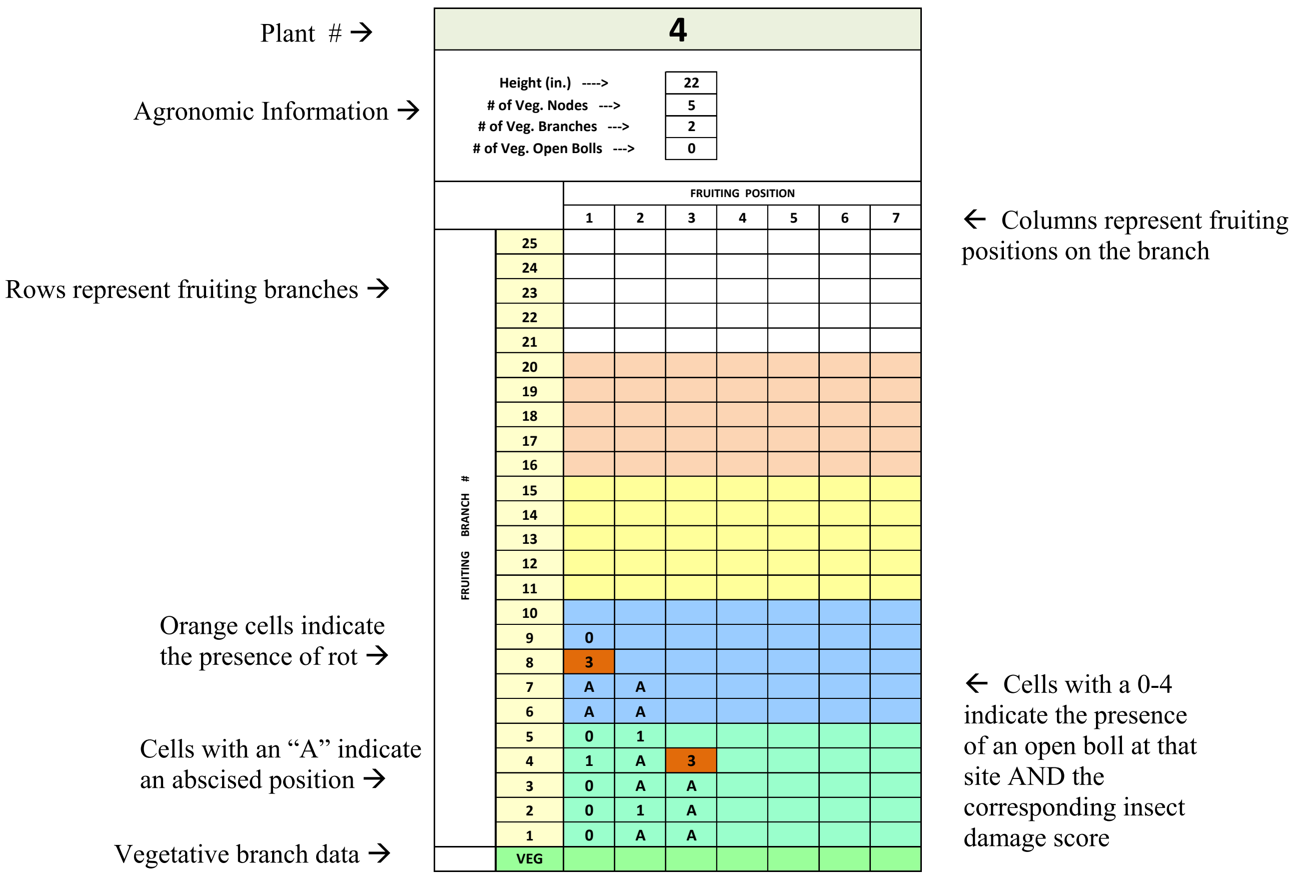


Figure 3. Example of how the data is entered into the modified version of PMAP.

The mathematics and programing used to calculate abscission and damage score means was very similar to the programing used in PMAP. Visual application of the data is displayed in a format similar to the format of the data entry with the addition of color gradients.

We chose a caged trial of the leaf-footed plant bug, *Leptoglossus, phyllopus* (Coreidae: L.) as a case study, comparing the traditional approach to the modified PMAP approach in managing the data. Each cage enclosed four (4) cotton plants and the treatments were four (4) bugs per cage (1 bug/plant) and zero (0) bugs per cage (0 bugs/plant). The leaf-footed bugs were place in the cages at the plant stage 5 nodes above white flower (NAWF) and were allowed to feed for seven (7) days before ending the feeding period with an insecticide application of pyrethrin. Data was taken when the plants were 95% open. Green bolls were evaluated for insect damage after they were opened using a plant material dryer. Results from using PMAP (fig. 4, 5, & 6) and the modified PMAP (fig. 7, 8, & 9) are as follows:

Treatment: 0 bugs per cage from PMAP

**Percent Open Bolls by Pos.**

Internode Length : 4.3
Avg. No. of Open Bolls / Plant : ###

| 5 | 4 | 3 | 2 | 1 | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 25 | | | | | |
| | | | | | 24 | | | | | |
| | | | | | 23 | | | | | |
| | | | | | 22 | | | | | |
| | | | | | 21 | | | | | |
| | | | | | 20 | | | | | |
| | | | | | 19 | | | | | |
| | | | | | 18 | | | | | |
| | | | | | 17 | | | | | |
| | | | | | 16 | | | | | |
| | | | | 31 | 15 | | | | | |
| | | | | | 14 | 56 | | | | |
| | | | 38 | 56 | 13 | | | | | |
| | | | | | 12 | 69 | 38 | | | |
| | | 6.3 | 19 | 56 | 11 | | | | | |
| | | | | | 10 | 81 | 38 | 38 | | |
| | | 19 | 50 | 94 | 9 | | | | | |
| | | | | | 8 | 69 | 56 | 13 | 13 | |
| | 19 | 13 | 63 | 94 | 7 | | | | | |
| | | | | | 6 | 56 | 38 | 13 | | 6.3 |
| | | | 13 | 19 | 5 | | | | | |
| | | | | | 4 | | | | | |
| | | | | | 3 | | | | | |
| | | | | | 2 | | | | | |
| | | | | | 1 | | | | | |

**Summary / Position**

| | 1 | 2 | 3 | 4 | | |
|---|---|---|---|---|---|---|
| | 0 | | 0 | 0 | b+o | Ret |
| | | | | | | % |
| First | 0.0 | 0.0 | 6.8 | 3.7 | 6.8 | 65 |
| Second | 0.0 | 0.0 | 3.5 | 4.8 | 3.5 | 42 |
| Third | 0.0 | 0.0 | 1.0 | 3.6 | 1.0 | 22 |
| Four | 0.0 | 0.0 | 0.3 | 0.6 | 0.3 | 36 |
| Fifth | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 100 |
| Total | 0.0 | 0.0 | 11.7 | 12.6 | 11.7 | 48 |

**Summary / Branch**

| | 1 | 2 | 3 | 4 | | |
|---|---|---|---|---|---|---|
| | 0 | | 0 | 0 | b+o | Tot |
| Branch 01-05 | 0.0 | 0.0 | 0.3 | 0.3 | 0.3 | 56 |
| Branch 05-10 | 0.0 | 0.0 | 7.7 | 5.8 | 7.7 | 57 |
| Branch 11-15 | 0.0 | 0.0 | 3.7 | 5.7 | 3.7 | 39 |
| Branch 16-20 | 0.0 | 0.0 | 0.0 | 0.9 | 0.0 | 0 |
| Branch 20-25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 |
| Total | 0.0 | 0.0 | 11.7 | 12.6 | 11.7 | 48 |

Figures 4 & 5. Percent open bolls by fruiting site (on left) and Percent boll retention by position and branch (on right) for 0 bugs per cage.

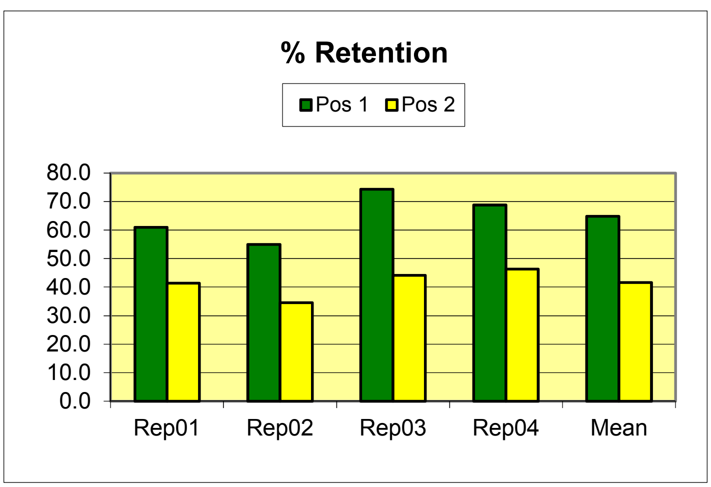


Figure 6. Percent boll retention of 1st and 2nd position bolls by rep and mean for 0 bugs per cage.

Treatment: 4 bugs per cage from PMAP

**Percent Open Bolls by Pos.**

Internode Length : 4.2
Avg. No. of Open Bolls / Plant : ###

| 5 | 4 | 3 | 2 | 1 | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 25 | | | | | |
| | | | | | 24 | | | | | |
| | | | | | 23 | | | | | |
| | | | | | 22 | | | | | |
| | | | | | 21 | | | | | |
| | | | | | 20 | | | | | |
| | | | | | 19 | | | | | |
| | | | | | 18 | | | | | |
| | | | | | 17 | | | | | |
| | | | | | 16 | | | | | |
| | | | | 25 | 15 | | | | | |
| | | | | | 14 | 44 | | | | |
| | | | 6.3 | 44 | 13 | | | | | |
| | | | | | 12 | 44 | 19 | | | |
| | | | 13 | 81 | 11 | | | | | |
| | | | | | 10 | 81 | 44 | | | |
| | | 19 | 44 | 88 | 9 | | | | | |
| | | | | | 8 | 88 | 56 | | 6.3 | |
| | | 6.3 | 50 | 81 | 7 | | | | | |
| | | | | | 6 | 63 | 50 | 6.3 | | |
| | | | 13 | 31 | 5 | | | | | |
| | | | | | 4 | | | | | |
| | | | | | 3 | | | | | |
| | | | | | 2 | | | | | |
| | | | | | 1 | | | | | |

**Summary / Position**

| | 1 | 2 | 3 | 4 | | |
|---|---|---|---|---|---|---|
| | 0 | | 0 | 0 | b+o | Ret |
| | | | | | | % |
| First | 0.0 | 0.0 | 6.7 | 3.1 | 6.7 | 68 |
| Second | 0.0 | 0.0 | 2.9 | 4.6 | 2.9 | 39 |
| Third | 0.0 | 0.0 | 0.3 | 2.4 | 0.3 | 11 |
| Four | 0.0 | 0.0 | 0.1 | 0.6 | 0.1 | 9 |
| Fifth | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0 |
| Total | 0.0 | 0.0 | 10.0 | 10.9 | 10.0 | 48 |

**Summary / Branch**

| | 1 | 2 | 3 | 4 | | |
|---|---|---|---|---|---|---|
| | 0 | | 0 | 0 | b+o | Tot |
| Branch 01-05 | 0.0 | 0.0 | 0.4 | 0.3 | 0.4 | 64 |
| Branch 05-10 | 0.0 | 0.0 | 6.8 | 5.6 | 6.8 | 55 |
| Branch 11-15 | 0.0 | 0.0 | 2.8 | 4.8 | 2.8 | 36 |
| Branch 16-20 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0 |
| Branch 20-25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 |
| Total | 0.0 | 0.0 | 10.0 | 10.9 | 10.0 | 48 |

Figures 7 & 8. Percent open bolls by fruiting site (on left) and
Percent boll retention by position and branch (on right) for 4 bugs per cage.

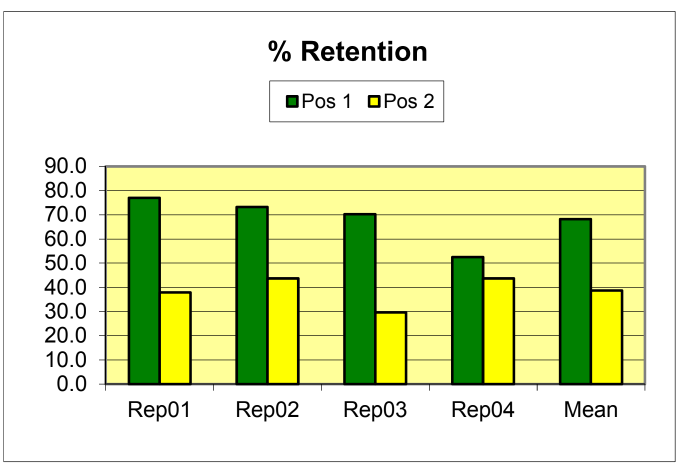


Figure 9. Percent boll retention of 1st and 2nd position bolls by rep and mean for 4 bugs per cage.

Treatment: 0 bugs per cage form the modified PAMP

**TOTAL of Abscissions per Site, Branch, Position**

| FRUITING BRANCH | FRUITING POSITION 1 | 2 | 3 | 4 | 5 | 6 | 7 | TOTAL per BRANCH | % of TOTAL ABSCISSION per BRANCH |
|---|---|---|---|---|---|---|---|---|---|
| 25 | | | | | | | | 0 | 0.0 |
| 24 | | | | | | | | 0 | 0.0 |
| 23 | | | | | | | | 0 | 0.0 |
| 22 | | | | | | | | 0 | 0.0 |
| 21 | | | | | | | | 0 | 0.0 |
| 20 | | | | | | | | 0 | 0.0 |
| 19 | | | | | | | | 0 | 0.0 |
| 18 | | | | | | | | 0 | 0.0 |
| 17 | | | | | | | | 0 | 0.0 |
| 16 | | | | | | | | 0 | 0.0 |
| 15 | | | | | | | | 0 | 0.0 |
| 14 | | | | | | | | 0 | 0.0 |
| 13 | 1 | | | | | | | 1 | 0.4 |
| 12 | 5 | | | | | | | 5 | 2.0 |
| 11 | 9 | 1 | | | | | | 10 | 4.0 |
| 10 | 10 | 5 | | | | | | 15 | 6.0 |
| 9 | 9 | 11 | | | | | | 20 | 8.0 |
| 8 | 8 | 8 | 3 | | | | | 19 | 7.6 |
| 7 | 9 | 14 | 5 | | | | | 28 | 11.2 |
| 6 | 6 | 15 | 8 | | | | | 29 | 11.6 |
| 5 | 4 | 14 | 12 | 1 | | | | 31 | 12.4 |
| 4 | 2 | 11 | 9 | 1 | | | | 23 | 9.2 |
| 3 | 3 | 8 | 15 | 5 | | | | 31 | 12.4 |
| 2 | 5 | 8 | 10 | 2 | | | | 25 | 10.0 |
| 1 | 2 | 4 | 8 | | | | | 14 | 5.6 |
| Veg | n/a | n/a | n/a | n/a | n/a | n/a | n/a | | |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | CHECKS | | |
|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL FRUIT per Position | 138 | 65 | 18 | 5 | 1 | 0 | 0 | 227 | 251 | 100 |
| TOTAL A's per Position | 73 | 99 | 70 | 9 | 0 | 0 | 0 | 251 | | |
| % Abscission of the BRANCH | 34.6 | 60.4 | 79.5 | 64.3 | 0.0 | #DIV/0! | #DIV/0! | 478 | 52.5 | <-- TOTAL ABSCIOSSION |
| % of TOTAL Abscission | 29.1 | 39.4 | 27.9 | 3.6 | 0.0 | 0.0 | 0.0 | 100.0 | | |
| Average # of Abscissions per position | 3.7 | 5.0 | 3.5 | 0.5 | 0.0 | 0.0 | 0.0 | | | |

Figure 10. Total abscissions per site, branch, and position. Data taken from modified PMAP program, Leaf-footed bug trial, 0 bugs per cage.

**PERCENT ABSCISSION per SITE**

| FRUITING BRANCH | FRUITING POSITION 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 25 | | | | | | | |
| 24 | | | | | | | |
| 23 | | | | | | | |
| 22 | | | | | | | |
| 21 | | | | | | | |
| 20 | | | | | | | |
| 19 | | | | | | | |
| 18 | | | | | | | |
| 17 | | | | | | | |
| 16 | | | | | | | |
| 15 | | | | | | | |
| 14 | | | | | | | |
| 13 | 100 | | | | | | |
| 12 | 100 | | | | | | |
| 11 | 82 | 100 | | | | | |
| 10 | 63 | 83 | | | | | |
| 9 | 47 | 100 | | | | | |
| 8 | 42 | 57 | 100 | | | | |
| 7 | 45 | 74 | 83 | | | | |
| 6 | 30 | 75 | 73 | | | | |
| 5 | 20 | 70 | 86 | 100 | | | |
| 4 | 10 | 58 | 60 | 100 | | | |
| 3 | 15 | 42 | 88 | 63 | | | |
| 2 | 25 | 42 | 83 | 67 | | | |
| 1 | 10 | 25 | 80 | | | | |
| Veg | n/a | n/a | n/a | n/a | n/a | n/a | n/a |

Figure 11. Percent abscission per site. Data taken from modified PMAP program, Leaf-footed bug trial, 0 bugs per cage.

**AVERAGE DAMAGE SCORE**

TOTAL Damage Score per site / TOTAL Fruit per site

| FRUITING BRANCH | FRUITING POSITION 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 25 | | | | | | | |
| 24 | | | | | | | |
| 23 | | | | | | | |
| 22 | | | | | | | |
| 21 | | | | | | | |
| 20 | | | | | | | |
| 19 | | | | | | | |
| 18 | | | | | | | |
| 17 | | | | | | | |
| 16 | | | | | | | |
| 15 | | | | | | | |
| 14 | | | | | | | |
| 13 | | | | | | | |
| 12 | | | | | | | |
| 11 | 0.00 | | | | | | |
| 10 | 0.00 | 0.00 | | | | | |
| 9 | 0.00 | | | | | | |
| 8 | 0.18 | 0.33 | | | | | |
| 7 | 0.00 | 0.00 | 0.00 | | | | |
| 6 | 0.43 | 0.00 | 0.00 | | | | |
| 5 | 0.13 | 0.00 | 1.00 | | | | |
| 4 | 0.44 | 0.13 | 0.00 | | | | |
| 3 | 0.12 | 0.09 | 0.00 | 0.00 | | | |
| 2 | 0.40 | 0.27 | 0.00 | 0.00 | 0.00 | | |
| 1 | 0.00 | 0.08 | 0.00 | 0.00 | | | |
| Veg | 0.04 | | | | | | |

Figure 12. Average damage score using a 0-4 scoring system. Data taken from modified PMAP program, Leaf-footed bug trial, 0 bugs per cage.

Treatment: 4 bugs per cage from the modified PMAP

**TOTAL of Abscissions per Site, Branch, Position**

| FRUITING BRANCH | FRUITING POSITION 1 | 2 | 3 | 4 | 5 | 6 | 7 | | TOTAL per BRANCH | % of TOTAL ABSCISSION per BRANCH |
|---|---|---|---|---|---|---|---|---|---|---|
| 18 | | | | | | | | | 0 | 0.0 |
| 17 | | | | | | | | | 0 | 0.0 |
| 16 | | | | | | | | | 0 | 0.0 |
| 15 | | | | | | | | | 0 | 0.0 |
| 14 | | | | | | | | | 0 | 0.0 |
| 13 | | | | | | | | | 0 | 0.0 |
| 12 | 2 | | | | | | | | 2 | 1.1 |
| 11 | 3 | | | | | | | | 3 | 1.7 |
| 10 | 6 | 2 | | | | | | | 8 | 4.6 |
| 9 | 10 | 5 | | | | | | | 15 | 8.6 |
| 8 | 5 | 10 | 1 | | | | | | 16 | 9.2 |
| 7 | 7 | 12 | 2 | | | | | | 21 | 12.1 |
| 6 | 7 | 11 | 4 | | | | | | 22 | 12.6 |
| 5 | 2 | 5 | 7 | 1 | | | | | 15 | 8.6 |
| 4 | 1 | 11 | 5 | 1 | | | | | 18 | 10.3 |
| 3 | 3 | 7 | 7 | 4 | 1 | | | | 22 | 12.6 |
| 2 | 2 | 4 | 8 | 3 | | | | | 17 | 9.8 |
| 1 | 2 | 6 | 5 | 1 | 1 | | | | 15 | 8.6 |
| Veg | n/a | n/a | n/a | n/a | n/a | n/a | n/a | | | |
| | | | | | | | | CHECKS | | |
| TOTAL FRUIT per Position | 107 | 48 | 5 | 1 | 0 | 0 | 0 | 161 | 174 | 100 |
| TOTAL A's per Position | 50 | 73 | 39 | 10 | 2 | 0 | 0 | 174 | | |
| % Abscission of the BRANCH | 31.8 | 60.3 | 88.6 | 90.9 | 100.0 | #DIV/0! | #DIV/0! | 335 | 51.9 | <-- TOTAL ABSCIOSSION |
| % of TOTAL Abscission | 28.7 | 42.0 | 22.4 | 5.7 | 1.1 | 0.0 | 0.0 | 100.0 | | |
| Average # of Abscissions per position | 3.1 | 4.6 | 2.4 | 0.6 | 0.1 | 0.0 | 0.0 | | | |

Figure 13 Total abscissions per site, branch, and position. Data taken from modified PMAP program, Leaf-footed bug trial, 4 bugs per cage.

**PERCENT ABSCISSION per SITE**

| FRUITING BRANCH | FRUITING POSITION 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 18 | | | | | | | |
| 17 | | | | | | | |
| 16 | | | | | | | |
| 15 | | | | | | | |
| 14 | | | | | | | |
| 13 | | | | | | | |
| 12 | 100 | | | | | | |
| 11 | 75 | | | | | | |
| 10 | 75 | 100 | | | | | |
| 9 | 67 | 83 | | | | | |
| 8 | 31 | 91 | 100 | | | | |
| 7 | 44 | 80 | 100 | | | | |
| 6 | 44 | 73 | 100 | | | | |
| 5 | 13 | 38 | 88 | 100 | | | |
| 4 | | 69 | 83 | 50 | | | |
| 3 | 19 | 47 | 78 | 100 | 100 | | |
| 2 | 13 | 27 | 89 | 100 | | | |
| 1 | 13 | 46 | 100 | 100 | 100 | | |
| Veg | n/a | n/a | n/a | n/a | n/a | n/a | n/a |

Figure 14. Percent abscission per site. Data taken from modified PMAP program, Leaf-footed bug trial, 4 bugs per cage.

**AVERAGE DAMAGE SCORE**

**TOTAL Damage Score per site / TOTAL Fruit per site**

| FRUITING BRANCH | FRUITING POSITION 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 18 | | | | | | | |
| 17 | | | | | | | |
| 16 | | | | | | | |
| 15 | | | | | | | |
| 14 | | | | | | | |
| 13 | | | | | | | |
| 12 | | | | | | | |
| 11 | 2.00 | | | | | | |
| 10 | 0.50 | | | | | | |
| 9 | 1.60 | 1.00 | | | | | |
| 8 | 1.18 | 0.00 | | | | | |
| 7 | 1.33 | 2.33 | | | | | |
| 6 | 1.67 | 0.00 | | | | | |
| 5 | 1.14 | 1.13 | 0.00 | | | | |
| 4 | 0.33 | 1.20 | 3.00 | 0.00 | | | |
| 3 | 0.23 | 0.63 | 0.00 | | | | |
| 2 | 0.00 | 0.36 | 0.00 | | | | |
| 1 | 0.00 | 0.29 | | | | | |
| Veg | 0.54 | | | | | | |

Figure 15. Average damage score using a 0-4 scoring system. Data taken from modified PMAP program, Leaf-footed bug trial, 4 bugs per cage.

The test of the modified PMAP was successful as we were able to map insect damage scores using a PMAP format and generate comprehensive numerical results and visually display the results. With this success we were now faced with two feasibility issues. First, the data set was extremely large making the process of running all of the data through SAS cumbersome and difficult (Brewer et al. 2013). Second, a large time investment was required to collect and process the data.

The next step was to analyze the data and evaluate methods to improve the efficiency of data collection and reduce the volume of data with minimum negative affects to the usefulness of the results. Our first decision was to evaluate where on the cotton plant was the most valuable plant bug damage data by volume and intensity. For our data set there was no fruit above the 12th branch and the data from branches 10-12 primarily came from the 1st position fruit. Also for our data set there was a dramatic drop in the number of fruit after position number 3. We now concentrated our efforts in evaluating positions 1-3 on fruiting branches 1-9 and position 1 on branches 10-12. After considerable discussion we chose a second strategy of combining, joining, or merging the data from two or more sites into what we called zones. We based this decision on the premise that we really were not interested in the damage to a specific individual fruiting site on each and every plant but rather our interests lied in specific regions of the plant, i.e. top, middle, or bottom or the plant or the interior versus the periphery or the plant.

Thus we chose to combine 1st, 2nd, and 3rd position fruiting sites that were above and below their neighboring 1st, 2nd, and 3rd position fruiting sites in groups of 2, 3, and 4 sites and evaluate how these combinations affected our data. For our data set, merging 3 sites into a zone provided advantages over the 2 and 4 site combinations. We were also able to omit the data from positions 2 and 3 for branches 10, 11, and 12 with minimal effect on the dataset as a whole. The final decision on combining fruiting sites was how to manage the data on the vegetative branches. The decision was to combine all of the data from the vegetative sites into one zone. The end result was to combine 30 fruiting sites plus the vegetative fruiting sites into 11 zones (figure 16) reducing the data load by two 66% and reducing collection of data by approximately 20%.

The zone format serves as a visual tool to evaluate the data plus serves as the link to cells immediately below the zones that provide labels and data for use in SAS.

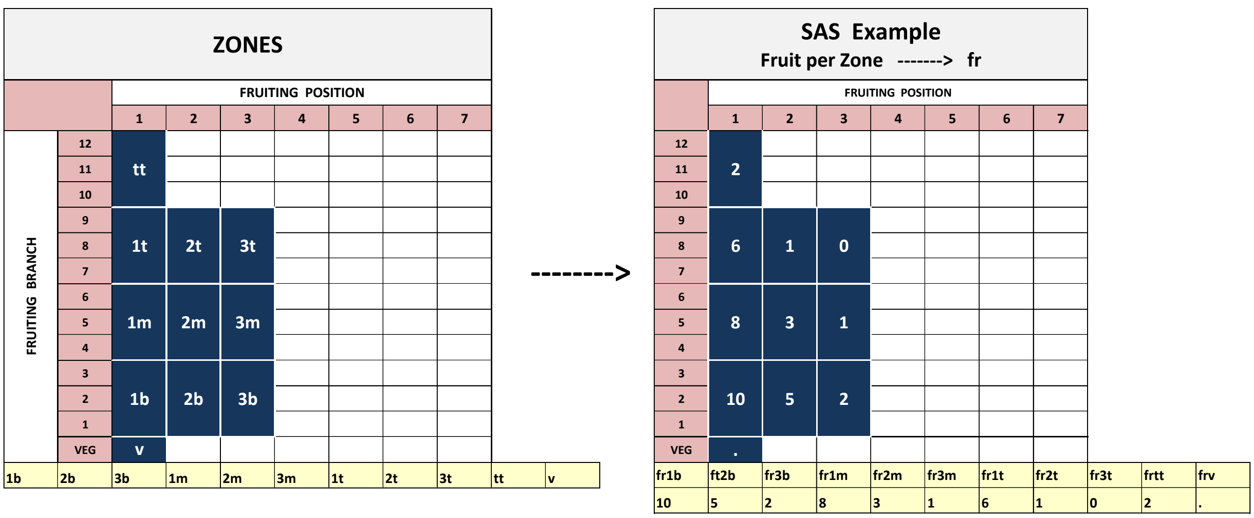


Figure 16. Diagram of the 11 designated fruiting zones (left) and an example of data (fruit per zone = fr) with labeling for use in SAS (yellow cells). The numeral designates the fruiting position, b = bottom, m = middle, t = top, tt = tip top, and v = vegetative. For example: fr2m = average number of fruit, position 2, middle zone

The final analysis of the insect damage data using the modified PMAP program can be viewed in figure 17. The insect data is reported by zone numerically and visually for five measurements; total abscised sites, percent abscission, average damage, total damage, and rot. The color choice is gradients from red to green representing high to low damage from insects.

0 bugs per cage → to → 4 bugs per cage

## 0 bugs per cage

TOTAL ABSCISSED SITES per ZONE

| | FRUITING POSITION | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 12 | | | | | | | |
| 11 | 24 | | | | | | |
| 10 | | | | | | | |
| 9 | | | | | | | |
| 8 | 26 | 33 | 8 | | | | |
| 7 | | | | | | | |
| 6 | | | | | | | |
| 5 | 12 | 40 | 29 | | | | |
| 4 | | | | | | | |
| 3 | | | | | | | |
| 2 | 10 | 20 | 33 | | | | |
| 1 | | | | | | | |
| VEG | | | | | | | |

% ABSCISSION per SITE

| | FRUITING POSITION | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 12 | | | | | | | |
| 11 | 75.0 | | | | | | |
| 10 | | | | | | | |
| 9 | | | | | | | |
| 8 | 44.8 | 75.0 | 88.9 | | | | |
| 7 | | | | | | | |
| 6 | | | | | | | |
| 5 | 20.0 | 67.8 | 72.5 | | | | |
| 4 | | | | | | | |
| 3 | | | | | | | |
| 2 | 16.7 | 37.0 | 84.6 | | | | |
| 1 | | | | | | | |
| VEG | | | | | | | |

AVERAGE DAMAGE per ZONE

| | FRUITING POSITION | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 12 | | | | | | | |
| 11 | 0 | | | | | | |
| 10 | | | | | | | |
| 9 | | | | | | | |
| 8 | 0.06 | 0.18 | 0 | | | | |
| 7 | | | | | | | |
| 6 | | | | | | | |
| 5 | 0.33 | 0.05 | 0.18 | | | | |
| 4 | | | | | | | |
| 3 | | | | | | | |
| 2 | 0.16 | 0.15 | 0 | | | | |
| 1 | | | | | | | |
| VEG | 0.17 | | | | | | |

TOTAL DAMAGE per ZONE

| | FRUITING POSITION | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 12 | | | | | | | |
| 11 | 0 | | | | | | |
| 10 | | | | | | | |
| 9 | | | | | | | |
| 8 | 2 | 2 | 0 | | | | |
| 7 | | | | | | | |
| 6 | | | | | | | |
| 5 | 16 | 1 | 2 | | | | |
| 4 | | | | | | | |
| 3 | | | | | | | |
| 2 | 8 | 5 | 0 | | | | |
| 1 | | | | | | | |
| VEG | 0 | | | | | | |

ROT per ZONE

| | FRUITING POSITION | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 12 | | | | | | | |
| 11 | 0 | | | | | | |
| 10 | | | | | | | |
| 9 | | | | | | | |
| 8 | 1 | 1 | . | | | | |
| 7 | | | | | | | |
| 6 | | | | | | | |
| 5 | 0 | 0 | 0 | | | | |
| 4 | | | | | | | |
| 3 | | | | | | | |
| 2 | 2 | 1 | 0 | | | | |
| 1 | | | | | | | |
| VEG | 0 | | | | | | |

## 4 bugs per cage

TOTAL ABSCISSED SITES per ZONE

| | FRUITING POSITION | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 12 | | | | | | | |
| 11 | 11 | | | | | | |
| 10 | | | | | | | |
| 9 | | | | | | | |
| 8 | 22 | 27 | 3 | | | | |
| 7 | | | | | | | |
| 6 | | | | | | | |
| 5 | 10 | 27 | 16 | | | | |
| 4 | | | | | | | |
| 3 | | | | | | | |
| 2 | 7 | 17 | 20 | | | | |
| 1 | | | | | | | |
| VEG | | | | | | | |

% ABSCISSION per ZONE

| | FRUITING POSITION | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 12 | | | | | | | |
| 11 | 78.6 | | | | | | |
| 10 | | | | | | | |
| 9 | | | | | | | |
| 8 | 46.8 | 84.4 | 100.0 | | | | |
| 7 | | | | | | | |
| 6 | | | | | | | |
| 5 | 20.8 | 61.4 | 88.9 | | | | |
| 4 | | | | | | | |
| 3 | | | | | | | |
| 2 | 14.6 | 39.5 | 87.0 | | | | |
| 1 | | | | | | | |
| VEG | | | | | | | |

AVERAGE DAMAGE per ZONE

| | FRUITING POSITION | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 12 | | | | | | | |
| 11 | 1.00 | | | | | | |
| 10 | | | | | | | |
| 9 | | | | | | | |
| 8 | 1.32 | 1.60 | - | | | | |
| 7 | | | | | | | |
| 6 | | | | | | | |
| 5 | 0.95 | 0.88 | 1.50 | | | | |
| 4 | | | | | | | |
| 3 | | | | | | | |
| 2 | 0.07 | 0.42 | 0.00 | | | | |
| 1 | | | | | | | |
| VEG | 0.54 | | | | | | |

TOTAL DAMAGE per ZONE

| | FRUITING POSITION | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 12 | | | | | | | |
| 11 | 3 | | | | | | |
| 10 | | | | | | | |
| 9 | | | | | | | |
| 8 | 33 | 8 | - | | | | |
| 7 | | | | | | | |
| 6 | | | | | | | |
| 5 | 36 | 15 | 3 | | | | |
| 4 | | | | | | | |
| 3 | | | | | | | |
| 2 | 3 | 11 | 0 | | | | |
| 1 | | | | | | | |
| VEG | 7 | | | | | | |

ROT per ZONE

| | FRUITING POSITION | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 12 | | | | | | | |
| 11 | 0 | | | | | | |
| 10 | | | | | | | |
| 9 | | | | | | | |
| 8 | 5 | 2 | - | | | | |
| 7 | | | | | | | |
| 6 | | | | | | | |
| 5 | 6 | 2 | 1 | | | | |
| 4 | | | | | | | |
| 3 | | | | | | | |
| 2 | 1 | 2 | 0 | | | | |
| 1 | | | | | | | |
| VEG | 1 | | | | | | |

Figure 17. Leaf-footed bug trail. Comparison of zone data results of 0 bugs per cage and 4 bugs per cage calculated using the modified PMAP program. Measurements compared are; total abscised sites, percent abscission, average damage, total damage, and rot per zone.

## Conclusions

The modified PMAP program we developed in Excel uses the PMAP concept developed and released by Dr. Juan Landivar in 1993 (Landivar, 1993 and personal communication) can use insect damage data as well as other forms of cotton fruiting site specific data to calculate numerical means as well as color visual interpretations of the data. By using the modified PMAP program to analyze the data by fruiting zones instead of by fruiting sites the time required to collect and record data can be shorten by 20% and the volume of data use in SAS can be reduced by 66%. Currently all calculations by the modified PMAP can be handled by Excel except for the calculations for rot. Readers interested in evaluating an alpha version of the modified PMAP may receive an electronic copy by contacting the primary author, Darwin J. Anderson at Texas A&M AgriLife Research, Corpus Christi, Texas by email djanderson@ag.tamu.edu.

## References

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