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Recording within-cotton distribution of plant bug injury using plant mapping computer-based tools

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ABSTRACT

Plant mapping has been included and evolving in cotton (*Gossypium hirsutum* L. [Malvales: Malvaceae]) research and management for over 100 years. Here we describe the structure and use of a plant mapping program (PMAPplus) that includes capabilities to record and manage insect injury to fruiting bodies by position and branch, compare it to existing programs (COTMAN and PMAP), and illustrate its use in cotton research that includes an assessment of insect injury. PMAPplus was modified from PMAP to allow entry of additional data on insect injury to squares and bolls and cotton boll rot and to produce output in a numerical and graphical format that can be customized to user specifications. Comparing use side-by-side, protocols of PMAPplus required more mapping time per plant than PMAP and COTMAN due to observing the additional insect injury data. But the added data were found useful in a planting date experiment that included evaluation of verde plant bug (*Creontiades signatus* Distant [Hemiptera: Miridae]) feeding on cotton that results in injury to bolls and is associated with cotton boll rot. PMAPplus graphical displays and output that was further analyzed statistically indicated that first position bolls in the middle branches of later planted cotton had the higher insect injury scores and incidence of boll rot, despite similar verde plant bug densities occurring on both plantings. The within-cotton distribution of verde plant bug insect injury helped explain the significantly higher yield from the earlier planting than from the later planting that was incongruent with the weekly insect monitoring data alone.

1. Introduction

Plant mapping in cotton (*Gossypium hirsutum* L. [Malvales: Malvaceae]) refers to the recording and evaluation of plant structure and the distribution and retention of fruit on plants (Oosterhuis et al., 1996). In cotton, plant mapping began in the early 1900s and improvements based on the understanding of cotton physiology and needs of cotton management continue (Kerby et al., 2010). Data management of cotton plant mapping today is facilitated by computer programs. Two representative cotton plant mapping computer programs are COTMAN (COTton MANagement software) (Oosterhuis and Bourland, 2008) and PMAP (Plant Map Analysis Program) (Landivar, 1993). Both programs emphasize recording and displaying within-cotton distribution of plant growth and fruit retention data. COTMAN manages data taken on the first fruiting position for each fruiting branch (i.e., a first position by '*n*' fruiting branch matrix of data). PMAP manages data from all fruiting positions for each fruiting branch (i.e., a '*m*' position by '*n*' fruiting branch matrix of data). The programs are used for estimating fruit retention and plant development stage, such as the point of physiological maturity (Oosterhuis and Bourland, 2008). For insect management applications, the programs have been used to determine when cotton maturity reaches a point at which insect control is no longer economical (i.e., spray termination rules) (Oosterhuis and Bourland, 2008; Leonard et al., 2008).

Plant bugs and stink bugs injure fruiting structures of cotton and knowledge of the within-cotton distribution of the fruit injury is useful for study of fruit-age sensitivity to injury and insect feeding preferences (Greene et al., 2001, Brewer et al., 2012a, 2013). Recording plant bug or stink bug injury data that occur on each fruiting position and branch is a natural extension of COTMAN and PMAP mapping concepts. We modified PMAP to facilitate plant mapping fruit retention influenced by insects and boll injury caused by insects, referred to as PMAPplus. Here we use cotton fleahopper (*Pseudatomoscelis seriatus* Reuter [Hemiptera: Miridae]) and verde plant bug (*Creontiades signatus* Distant [Hemiptera: Miridae]) to serve as model sucking bugs of cotton to exhibit the applicability of changes found in PMAPplus in cotton entomology

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research. The application is also relevant to stink bugs (Hemiptera: Pentatomidae), that cause similar injury to bolls as caused by verde plant bug (Greene et al., 2001; Armstrong et al., 2013) and selected other plant bugs that also injure squares and bolls (Parajulee et al., 2006).

There has been an increase in the relative importance of plant bugs and stink bugs as cotton pests because of the success of the boll weevil eradication program and adoption of Bt transgenic cotton which controls selected boll-feeding lepidopteran larvae (Lu et al., 2010). Insecticide applications for control of these pests have declined (Luttrell et al., 2015), but foliar applied insecticides must still be applied to control plant bugs and stink bugs (Vyavhare et al., 2018). Consequently, the cotton fleahopper is an important insect pest of cotton in Texas and neighboring growing regions where it benefits from favorable off-crop habitat (Parajulee et al., 2006; Vyavhare et al., 2018). In 2011, the cotton fleahopper was the third most damaging insect pest of cotton in Texas, and up to four insecticide applications were applied annually for its control (Williams, 2011). Cotton fleahopper feeds on young cotton squares, which can result in fruit abscission, delay of crop maturity, and yield reduction (Parajulee et al., 2006). The cotton fleahopper is considered primarily an early season (pre-bloom) pest in cotton in south Texas (Brewer et al., 2016). The verde plant bug is a post-bloom pest of cotton along the Texas Gulf Coast. Feeding by this insect causes square abscission and injures young bolls (Armstrong et al., 2013), and its feeding also has been associated with cotton boll rot (Brewer et al., 2012b). Along the Texas Gulf Coast, it normally migrates into cotton from neighboring vegetation associated with coastal riparian areas (Armstrong et al., 2013).

The objectives of this study were first to describe the structure and use of PMAPplus and compare its structure to the existing COTMAN and PMAP programs. Next, recording and display of data managed in the three programs were compared side-by-side when mapping field-collected cotton plants exposed to cotton fleahopper and verde plant bug. Third, an example of the value of recording and managing within-cotton distribution of insect injury was illustrated by an examination of data from a planting date experiment in which plant bugs were also present.

2. Methods and process

2.1. Cotton mapping program use

COTMAN and PMAP have been fully documented along with current applications of the programs including entomological applications (Kerby et al., 2010; Landivar, 1993). Briefly, describing their end of season use in an entomology field research application, data for COTMAN and PMAP are taken from representative plants, typically ten plants or less per plot for COTMAN and up to six plants per plot for PMAP. The plants are cut in the field (1–3 days prior to harvest) just below the cotyledonary node and can be mapped in the field or at another location. Each plant is measured for plant height from the cotyledonary node to the terminal, and the number of vegetative nodes from the cotyledonary node to the first fruiting branch are counted. Branches growing from the vegetative nodes are counted as well as the open bolls on these branches. In COTMAN, tabulations are a ‘1’ for squares (pre-bloom fruiting body), a ‘2’ for bolls, and a ‘0’ for an abscised fruiting site. In PMAP, open bolls are tabulated using the letter ‘O’, green bolls are tabulated as ‘G’, squares are tabulated as ‘S’, and abscised sites are tabulated as ‘A’ (Fig. 1). The spatial positions of the fruiting measurements are recorded using the row (branches) and column (position) layout of a Microsoft Excel spreadsheet (Microsoft Corporation, Redman, WA, USA). Excel's row by column configuration and graphics capabilities drive the features of PMAP as modified from the original version which ran in VisiCalc (Landivar, 1993). The same process is used for COTMAN except data collection is limited to the first fruiting position along each branch. For COTMAN, the software runs on

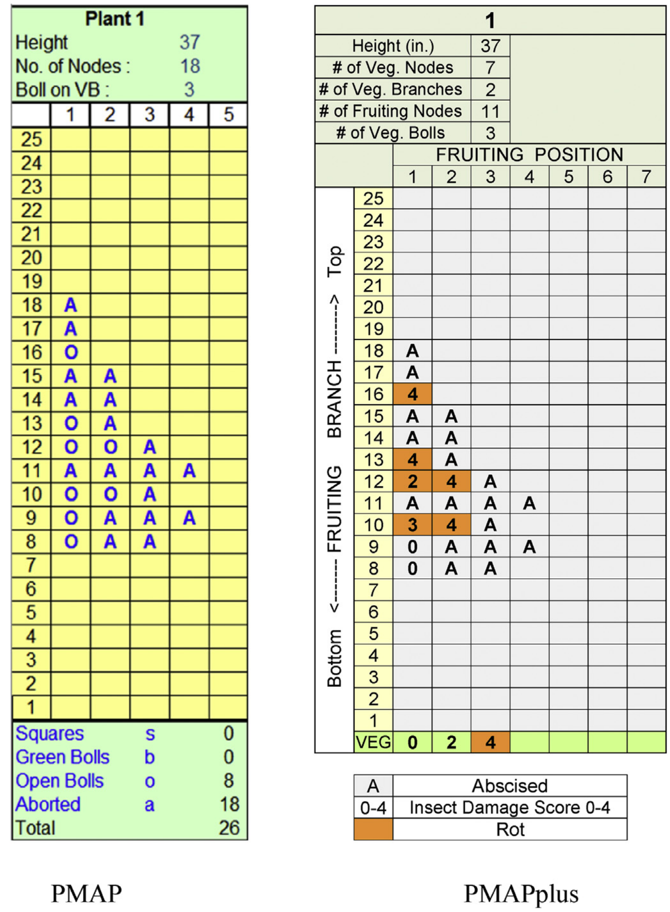

Fig. 1. Comparison of data entry screen for PMAP (left) and PMAPplus (right). Abscised sites are indicated by an ‘A’ (both programs), open bolls are indicated by an ‘O’ (PMAP), insect injury of bolls are scored from 0 to 4, and orange highlighted cells indicate cotton boll rot presence (PMAPplus). A second screen for PMAPplus for entering ‘R’ for cotton boll rot (for calculation purposes) is not shown. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

a Windows (XP or more recent) operating system (O'Leary, 2017).

The process used for PMAPplus is structured the same as PMAP except bolls are also examined for insect injury and cotton boll rot. In the application shown here using the programs near harvest, open bolls are scored and mapped using a five class locule scale for insect injury to the bolls. The scale ranges from 0 to 4, with 0 representing no boll injury observed, 1–3 representing a progression from localized injury in one locule to injury in three locules, and 4 representing severe injury in all locules (Lei et al., 2003; Brewer et al., 2013). Abscised sites are indicated by an ‘A’. Open bolls exhibiting cotton boll rot are indicated using an ‘R’ on printed tabulation sheets, combined with the insect injury rating from 0 to 4. Transferring data to Excel spreadsheets, the cells with a ‘R’ are manually highlighted orange to signify rot upon entering the data on the primary spreadsheet, which is useful for visualization (Fig. 1). A second spreadsheet is used to enter the ‘R’ coding needed for calculating cotton boll rot descriptive statistics. The program automatically sums and averages abscised fruiting sites, bolls, total fruiting sites, insect injury scores and cotton boll rot presence by site, position, and branch within a replication (or plants examined in a plot in our application). A PMAPplus spreadsheet can except data from one to 20 plants per replication or plot. The structure of the program in Excel provides sums and means per plant graphically and numerically for display. The raw data are also available for export in a separate Excel spreadsheet that is simplified to facilitate importing the data into other programs, such as statistical programs.